

# Oxford Research Encyclopedia of African History

## **The History and Historiography of Science**

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## **Summary and Keywords**

There is no escaping the fact that the history of science took European places and people, broadly construed, as its original object of study. There is also no escaping that in African history, scholars interested in science, technology, and to a lesser extent environmental knowledge have concentrated the bulk of their investigative energies on developments since European (and North African) conquest. This focus on the period since the 1870s has tended to foreground dynamics relating to colonial rule and state-building, extractive economies and development, and decolonization and geopolitics. A handful of Africanists in the history of science have explicitly worked to cross the colonial divide, often taking single topics deeper back in time. The field as a whole, however, still needs to debate more systematically what the overarching narratives and benchmark phenomena should be for the precolonial periods. It also needs to grapple more explicitly with methodological tensions that arise from a focus on human agency and specific places (and the languages this requires) versus a focus on ideas, tools, and phenomena that transcend local or state containers (and the trade-offs this produces). As historians of science extend their reach into Africa's pasts and bridge the colonial and post-colonial divides, it raises thorny questions about different approaches. Among others this includes *how* we produce histories of science, *why* they matter, and *what* we ought to bear in mind as we do. To this end, four goals are advanced here simultaneously: First, is the aim to open a dialogue with historians of science working outside Africa about ways Africanist scholarship speaks to and could be incorporated into the field as a whole (encouraging non-Africanists to consider the blind spots of "global" histories). Second, is the objective to draw attention to the pitfalls and benefits of different research methods and theoretical assumptions, especially as they relate to expert knowledge (an analysis that may be most useful for students entering the field). Third, is the ambition to explore a set of topics that connect deeper time periods to more recent developments (topics that invite critical scrutiny from specialists and generalists alike). Finally, is the desire to foreground the many different ways people across sub-Saharan Africa have initiated, responded to, and been incorporated into the production of knowledge. Africa has been a site of rich and varied epistemological and material experiments for millennia—some deleterious, some beneficial, and all imbued with different kinds of power. Acknowledging this long-standing history can serve to correct stereotypes that suggest otherwise. It can also contribute to debates within the history of science as the field continues to move away from its original focus on Europe and Europeans.

Keywords: science, epistemology, knowledge, colonialism, practice, postcolonial, precolonial, embodied knowledge, tacit knowledge, indigenous, vernacular, technology, environment, medicine, healing

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## Where Does Africa Fit in the History of Science?

If historians have learned anything from research on the intersections between knowledge and politics around the world, it is that words and ideas, tools and techniques, plants and parasites, and models and materials rarely remain fixed in any one place.<sup>1</sup> Just as people have circulated within and beyond the African continent, so too have concepts, objects, and biota, both through deliberate and accidental exchanges. Tracing these flows and pinning down approximate paths have in fact helped scholars correct misleading and inaccurate assumptions about all kinds of innovations within Africa: architectural, artistic, environmental, therapeutic, mathematical, material, and symbolic. This scholarship tends to cover (or at least invoke) long sweeps of time and identifies forms of ingenuity and improvisation—“millennial stores of learning” as Paulin Hountondji puts it—that surely qualify as relevant to the history of science.<sup>2</sup> Such repositories of knowledge seem to have been taught and transmitted through different modes of practice, highlighting the significance of tacit and embodied knowledge and their connections to memory, performance, and forgetting that ought to be included when writing their histories.<sup>3</sup>

These points are not new for scholars and students of African history, but as Jane Guyer noted with some dismay more than two decades ago, there are still “surprisingly few cross-references from one discipline or domain of inquiry to another and no synthesis . . . Without a concerted approach to the social organization of knowledge in Africa in the centuries before the conquest, we tacitly allow a continued highly selective mobilization of individual studies of African societies to illustrate general points of Western social theory.”<sup>4</sup> Without such syntheses, scholars inhibit possibilities for training new generations and for richer debates about cross-cultural epistemologies. In Africa, no less than in other parts of the world, forms of vernacular and endogenous expertise have connected directly to collective survival, but also to so much more.<sup>5</sup> This includes types of proficiency having to do with nourishment, health, travel and communication, governance, non-human nature, economic exchange, and reproduction. These kinds of know-how have intersected in fascinating ways with cosmological orders, so that art, sustenance, literary productions, longevity, philosophy, and built environments were intimately connected. Indeed, to imagine that necessity drives invention is misleading, as so many African historians interested in aesthetics, knowledge, and artistry have demonstrated. Although there are many domains for which scholars still “don’t know exactly how knowledge functioned . . . nor how judgments of effectivity were made, either socially or epistemologically,” bodies of scholarship do exist considering the expertise required, for instance, to mine metals and craft tools (as well as artwork); grow and store food; build and maintain communities and places of worship; communicate across distances; and handle individual and collective misfortunes, including enslavement, colonialism, and the encroachment of capitalism.<sup>6</sup> There are also studies that shed light on people’s techniques to understand and master environments and explain the nature of the world. Analyses of these developments, and many others, deserve to be incorporated into a new canon for African history and its interplay with science and expertise.

As historians of science extend their reach into Africa's pasts and bridge the colonial and post-colonial divides, it raises thorny questions about different approaches. Among others, this includes *how* to produce histories of science, *why* they matter, and *what* we ought to bear in mind as we do? To this end, four goals are advanced here simultaneously: First, is the aim to open a dialogue with historians of science working outside Africa about ways Africanist scholarship speaks to and could be incorporated into the field as a whole (encouraging non-Africanists to consider the blind spots of "global" histories). Second, is the objective to draw attention to the pitfalls and benefits of different research methods and theoretical assumptions, especially as they relate to expert knowledge (an analysis that may be most useful for students entering the field). Third, is the ambition to explore a set of topics that connect deeper time periods to more recent developments (topics that invite critical scrutiny from specialists and generalists alike). Finally, is the desire to foreground the many different ways people across sub-Saharan Africa have initiated, responded to, and been incorporated into the production of knowledge.

Throughout, readers are introduced, selectively and thematically, to an array of issues scholars tend to confront, focusing as much on conceptual framing as on narratives themselves. This includes several theoretical issues that haunt and underpin many studies that explore the history of knowledge and expertise in parts of the world now loosely, if often inaccurately, labeled the "Global South."<sup>7</sup> It also involves a set of topics that connect longue durée African history to material cultures and epistemologies. And, finally, it takes account of exogenous European influences, which introduced new kinds of institutions, instruments, and methods. These changes achieved a concentrated wave of effects during the European and North African Scramble for Africa (c. 1870–1910) and the ensuing process of empire and state-building (1910–1950). During this period, the African continent in all its complexity was subjected to more intense (outside) scientific scrutiny than ever before, making it an object of study in its own right. An even more forceful wave of changes occurred in the decades surrounding political decolonization and the Cold War (1950–1990). This era has yet to receive the systematic attention it is due, though a growing number of scholars have begun to analyze key components.<sup>8</sup>

Perspective is everything. The point at which scholars begin a study of the history of science in Africa—that abstraction par excellence—determines the arc of the stories they tell and the topics they highlight or abandon.<sup>9</sup> What if histories of science for Africa paralleled those for that other mythical entity, Western Europe, for which historians have often adopted a "Plato to NATO" timescale?<sup>10</sup> How, if at all, would this exercise affect narratives in both realms? Although the history of science has considerably broadened and deepened its coverage of other parts of the world over the last three decades, this geographical inclusivity has not always dislodged some of the unquestioned assumptions about place and epistemology on which the field was originally grounded.<sup>11</sup> Even now, for instance, introductory surveys in the "history of science" often use the labels "Western" or "modern" as a way to flag geographical partiality. This approach rightly acknowledges regional limits, and yet it can also suggest that other parts of the world matter only when they intersect in some way with "the West." What this often means in practice is that few

survey texts in the history of science include any material at all on Africa. Indeed, the narrative arc of the history of science still tends to be built—sometimes implicitly and other times explicitly—around a “great divergence” of epistemologies and material cultures, so that non-Western regions and the people in them can often be relegated to the margins because the very story being told is about the West’s atypical and globalizing trajectory.<sup>12</sup> Granted, scholars no longer speak of this divergence in terms of unadulterated triumphs, choosing to explore “the dark side of progress” and inject declensionist notes about adverse consequences. Yet the center of gravity still hovers around an amorphous West. Although many historians of science see the need for multi-centered and polyvalent approaches, tensions endure between those who work on the West and those who work on the rest, partly for the mundane reason that so many scholars struggle to read deeply in regions (and time periods) other than their own.

If historians embrace approaches for Africa that cross centuries—and even millennia—they are forced to take continuities and resilience seriously. What epistemic cultures persisted over time and why?<sup>13</sup> Which places and sites mattered to the production of knowledge? How, if at all, were these replicated or modified? Did networks of specialists rise and fall, or come and go? What norms, rules, and institutions supported their work? How was expertise transmitted across generations, and what kinds of effects did oral versus print cultures have on these methods? (These questions can be asked of any region of the world and embrace a vocabulary—in accordance with insights from science studies—that recognizes the social and institutional foundations of expert knowledge.) As Ali Mazrui has reminded us, “In Arab Africa, universities go further back than not only universities in the United States but those in Europe,” pointing to Al-Azhar University in Cairo, Qarawiyyin in Morocco, and the consortium of schools in Timbuktu in Mali.<sup>14</sup> Such sites of learning offer scholars important precedents that can be compared to other institutions (and places) over time. Yet they deserve to be situated alongside sites of expertise that have shifted as people moved and that relied on modes of transmission outside manuscripts and bureaucracies.<sup>15</sup> This approach forces scholars to analyze groups of experts in African history who were not only mobile but also relied on complex techniques to transmit, verify, authorize, and test different sorts of truth claims and beliefs. It also insists on sustaining broad definitions of what counts as a site of “scientific” learning.<sup>16</sup> Such centers and modes of expertise across sub-Saharan Africa are rarely included in grand narratives about the history of science, yet they should be. It would hardly be a stretch for a field at home with alchemists, artisans, and invisible technicians to learn more about the history of African blacksmiths, masons, ritual healers, and even deities and diviners, and still this dialogue has yet to happen in any concerted way.<sup>17</sup> By focusing on historical continuities among epistemic cultures across Africa, it puts trends in other parts of the world in sharper relief while also leading us to see with fresh eyes the disruptive effects of the trans-Atlantic slave trade, different forms of colonialism, and economic and industrial development. These radical ruptures indisputably transformed expert communities across Africa, yet they also created new conditions of possibility.

Just this preoccupation with rupture underpinned Alexander Koyré's and Herbert Butterfield's original desire to label the changes they observed in European scholarship, between the 16th and 18th centuries, a "scientific revolution."<sup>18</sup> For most of the 20th century, in fact, you could not train as a historian of science—or have an eminent role within its different societies—without mastering this crucial period or the subjects defined at its core: astronomy, physics, mathematics, and mechanics. Even scholars who focused on the life, medical, or environmental sciences still often had to pay homage to the precedents set in other fields and consider whether their "revolutions" were "delayed." Naturally, scholars then had to debate the extent to which different ideas, tools, and methods were crucial or tangential to these alleged ruptures. Was it the desire to control and manipulate nature writ large; did it stem from a rejection of the knowledge of the Ancients; was it the turn to quantification and experimentation; should it be explained in terms of new institutions and instruments (e.g., professional societies, coffeehouses, microscopes, telescopes, laboratories); did it result from voyages and cross-cultural translations; was it because or in spite of specific religions; should it be traced to new concepts of truth, rationality, and law (as in "laws of nature"); did it result from the proliferation of print technologies and a burgeoning "Republic of Letters"; should it be seen as driven by elite savants (philosophers, professors, courtly advisors), or did it bubble up from below (through the actions of artisans, craftsmen, workers, and lay experts)? Was it all, most, some, or none of the above? Indeed, was it a revolution at all?<sup>19</sup>

For scholars in African history, even this quick foray into Europe-centered debates may seem distracting or even disconcerting: distracting because so many people have tried for so long to decenter the stories we tell about knowledge and expertise around the world, and disconcerting because it potentially establishes early modern European developments as the norm or yardstick. Yet this foray is meant to remind readers of an inescapable conundrum: the concept of "science," including its historical study, was slowly codified through centuries of intercontinental and transoceanic dynamics, both real and imagined. This process, in turn, tended to erase or render invisible experts' active engagement with different parts of the world.<sup>20</sup> The term "scientist" entered the English lexicon only in 1834, and although the concept of "science" had a longer currency among specialists, it achieved popular and widespread use only during the long 19th century, when the qualifier "Western" also gained greater purchase.<sup>21</sup> That these terms have come to be associated with certain kinds of institutions, professional associations, educational and publishing practices, standards of evidence and argument, and experimental and field methods, makes it necessary—no matter what part of the African continent scholars study—to recognize their roots and effects. In other words, the historicity of these categories matters.<sup>22</sup>

Ironically, certain historians' tendency to seal regions of the world off from one another has been especially pronounced within some "global" histories of science, as different surveys fail to notice, much less account for, the fact that many parts of the world (and the people in them) have contributed to processes of knowledge production and innovation. These moves reinforce ill-informed judgments that people's intellectual labors across Africa, as well as the continent's significance as a site of experimentation and

innovation, have been negligible.<sup>23</sup> If scholars wish to argue that African studies ought to include stories about science, which seems an uncontroversial point, then does the converse also apply: Should global histories of science include material from African studies? Or will global narratives about the history of science—conforming to certain global narratives relating to economics, religion, cities, technology, and even globalization itself—always require an asterisk noting either that most of the African continent has been left out or that the conceptual framing does not fit?<sup>24</sup>

Critics' and scholars' calls to decolonize knowledge stem from well-founded concerns that colonial rule, in particular, misconstrued and distorted Africans' epistemological and material achievements. That said, not all critiques have rested on firm empirical grounds, and some have even had distorting effects of their own, which scholars in African studies also ought to guard against. These distortions creep in when authors assume rather than investigate the vast array of ideas Europeans espoused and the heterogeneous activities different institutions pursued, across many scales. They also arise when authors avoid teasing out causes and effects precisely. To decolonize knowledge, even in aspirational rather than practical terms, requires patient and systematic exploration of different actors' thought worlds and actual effects. Ideas, colonial or otherwise, are slippery and multifaceted; so too are people and modes of power. If scholars assume greater homogeneity or internal coherence in imperial projects, this can lead to flawed analyses and can even misidentify the roots or sources of the problems authors wish to move beyond (i.e., the "post" in postcolonial). When reconstructing social, political, or imperial worlds, or the mixtures among them, there are no shortcuts. Every project deserves the methods of the scalpel rather than the sledgehammer. As tempting as it may be to label historical analyses of science "postcolonial" or "decolonial," unless these rest on accurate foundations, such labels serve illusory purposes.

Finally, as scholars consider Africa's place in the wider field and possibilities for dialogue across regions, it seems important to consider whether there is a danger of turning the conversation into a glorified "impact assessment exercise" so that regions are included or excluded depending on their relative "global" effects. Although the debates over *The African Origin of Civilization* and *Black Athena* (and the influence of Egyptian and Phoenician cultures on ancient Greece) live on, the more general points that Chiekh Anta Diop and Martin Bernal wished to make have become commonplace: no one should assume a pure lineage to any intellectual genealogy because entanglements, appropriations, mutations, and dislocations have been the norm, not the exception.<sup>25</sup> Even so, debates about the history of different kinds of human ingenuity remain charged. It may still be easier for many historians of science to minimize or ignore African (and other regions') historiographies than it is to consider how this scholarship might reorient at least some of the field's questions, preoccupations, and arguments.<sup>26</sup>

## Methods and Insights—Asymmetries, Endogeneity, Commensurability, and Not-Knowing

African historians stand to gain a lot by deconstructing categories of science and engaging critically with their histories, just as they also stand to benefit by confronting the diverse effects of different scientific activities head-on.<sup>27</sup> This dual approach toggles between ideas and reality in ways that are necessary not just because people across much of Africa have wrestled increasingly with definitions and effects of this thing called “science,” but also because geographies of knowledge are typically imbricated in radically uneven geographies of power.<sup>28</sup> (This insight applies just as much to African politics as to those anywhere else.)<sup>29</sup> Indeed, no attempt to explode categories or define them out of existence will do away with the nodes of epistemological and technical influence—often situated outside Africa—that built these very inequalities in the first place or continue to sustain them. Scholars tend to refer to this as a problem of *asymmetric epistemologies* because the phrase captures the extent to which knowledge systems (and the professionals who master them) often interact around the world on a lopsided playing field. Asymmetries of power produce additional problems related to *demarcations* and *boundaries*, whether in terms of science and non-science or effective versus ineffective interventions.<sup>30</sup> Because there have never existed absolute dividing lines between what is and is not science or what is and is not (considered) efficacious, examining how people have adjudicated these boundaries in the past helps scholars and students alike understand what’s at stake over such definitions and how borders themselves have shifted over time. These patterns and the work involved in drawing such distinctions are easily demonstrated in African colonial history by examining the work of research officers trained in any number of scientific professions, such as agronomy, entomology, limnology, botany, geology, pedology, anthropology, epidemiology, and even engineering. When fieldworkers enlisted assistants and informants in order to understand aspects of their work, the balance of power was typically tilted in their favor. Because fieldworkers usually had official credentials (whereas informants did not) and because they availed themselves of publishing practices that their informants also did not, they became possessors and producers of new knowledge even when they had been dependent on assistants for some of their insights. Nancy Jacobs’ *Birders of Africa: A History of a Network* illustrates these points beautifully—crossing colonial divides in the process—by using birding and ornithology as a way to explore how knowledge of birds (and so much more) in southern Africa was exchanged and generated in such intimate relationships. Lyn Schumaker explores similar patterns in ethnographic research in Zambia in her revealing history of the “work culture” of the Rhodes Livingstone Institute, including the contributions of successive generations of research assistants.<sup>31</sup>

Global comparisons and contexts, in turn, help scholars deal more thoughtfully with a second problem relating to *endogenous* and *exogenous* influences. Africanists understandably seek to recover and feature continuities over time, whether in terms of ideas, practices, or tools. This helps to push back against so many of the misleading assertions that have stripped people and polities of their agency and originality. Just as significant, it helps paint a more accurate picture of people's life worlds and creative initiatives. Occasionally, however, an emphasis on endogeneity runs the risk of characterizing anything that arose from "outside" the continent as somehow inauthentic, invalid, or even insidious. It can also pit forms of vernacular knowledge against knowledge emanating from expert professions (otherwise referred to as sciences). Given that African intellectuals have embraced scientific disciplines for more than a century and a half, it seems vital to consider these realms of practice no less "African" than those of any other expert domain.<sup>32</sup> Although some groups have longer or shorter histories in different places, that does not automatically make them more or less legitimate. More than this, because so many borders and frontiers are porous—especially at the scale of continents—scholars should resist the temptation to imagine any place as epistemologically pristine, prototypical, or isolated. Put differently, although all knowledge has a politics—which scholars can unearth, examine, and critique—suggesting that exogenous origins make some forms of knowledge insufficiently *African* or inherently dubious can also lead into interpretive and even political traps.<sup>33</sup>

The layered complexity of these orthodox-heterodox, insider-outsider, dominant-subaltern, and ancestral versus modern dichotomies come alive in Didier Fassin's historical anthropology of the real-world controversies surrounding the causes and treatments of AIDS in South Africa at the turn of the 21st century. Resisting easy moralizing and reminding readers when necessary of the "unstable state of knowledge" of the period, Fassin reveals the different logics that produced the Mbeki's government's "heretical" stance challenging the viral theory of immune deficiency and objecting to its "toxic" cures for AIDS. The government's position, Fassin shows, rested equally on leaders' understanding of the state's objectionable past (with colonialism, apartheid, and even foreign pharmaceutical and medical abuse) *and* on a decidedly modern politics of paranoia that allowed "dissident" science to seep into a nascent democracy. That the dissidents explained the rise in autoimmune diseases within South Africa, and the continent more broadly, in terms of people's poverty and malnourishment gave them greater traction because it mapped onto lived realities.<sup>34</sup> As Karen Flint has discussed, that some political leaders then chose to encourage "traditional" cures in the spirit of an "African renaissance" doubled down on a dichotomy that preferred "African" to (dominant) biomedical knowledge.<sup>35</sup> Although the real-world stakes are lower for scholars in African studies, Fassin's and Flint's analyses highlight some of the dangers of following theoretical positions to their logical extremes.

This example leads into a third set of problems relating to knowledge that center on *commensurability* and *alterity*. If patterns of thought and structures of power appear to be too close to European systems, then it can prompt non-Africanists to ask, "What is African about this?"<sup>36</sup> Such a perspective suggests that difference not similitude, usually

with respect to North American or European norms, makes something recognizably African. By this logic, a discussion of subaltern knowledge makes sense, whereas a discussion of physics (or even democratic states) does not. In contrast, if concepts or practices (or both) are alleged to have too few touchstones to link them to other peoples, places, and times, it suggests forms of radical incommensurability (or exoticism) that also may not be warranted. In such instances the danger for historians is to suggest that conceptual differences are socially and even epistemologically unbridgeable. Are electrons and photons really so incompatible with spirits and deities when it comes to explaining how they act in the world? (The answer to this question is beyond the scope of this chapter, but it can be made more manageable by observing that electrons and spirits operate in different epistemological and ontological terrain.) At the heart of this admittedly provocative question lies a more basic one: Where does methodological relativism stop and epistemological relativism (and ontological pluralism) begin? These questions hum in the background for many scholars in science studies and are often evident in primary sources as well.

Given that matters of commensurability arose frequently in colonial contexts, it should come as little surprise that critics and scholars alike began to seek what could be called *instrumental commensurabilities*, that is, those points of epistemic comparison that showed some similarity to dominant forms of thought originating elsewhere. Thinking of these dynamics in scripted terms, it tended to be a dialogue about shared definitions (of reality) and practical or real-world effects. To take an example from the early 20th century, an unnamed writer for the *Lagos Standard* commented on “the wonderful discovery” reported out of Britain “that nearly every disease to which human flesh is heir is traceable to germs or parasites in the system,” an insight “comparatively new to the civilised medical world.” “Will it be believed,” the writer continued with honest surprise, “that this theory has been known to the Natives of Yorubaland for a long, long time past. A great many diseases native doctors will tell you are caused by *aràn*, (worms) or *korkoro* (insects)—by which they mean parasites—in the system. After all, there is nothing new under the sun.”<sup>37</sup> People’s search for partial commensurability has sometimes come at the expense of analyzing epistemologies and practices on their own terms or in their entirety. That said, it is not an inherently wrong approach: much depends on the purpose of such comparisons. If the point is to illustrate how people have operated in different conceptual “trading zones” or how they have tried to achieve epistemological rapprochement, even in situations where there really were considerable differences in power (as the Lagosian writer was doing), then the exercise can be especially productive.<sup>38</sup> But if the point begins and ends by seeking only those patterns that look like those produced elsewhere, then it runs the risk of generating incomplete and potentially misleading pictures.

Yet, there can be another dynamic at work in such comparisons: people’s search for (or efforts to uncover) instrumental commensurabilities can produce new and distinct bodies of knowledge in their own right, following a kind of feedback loop.<sup>39</sup> These genres of knowledge have sometimes taken on a life of their own—usually within state and international bureaucracies—even when scholars of African history might perceive them

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to be somehow less real, complete, or accurate than other forms of knowledge. One dimension of this dynamic produces epistemological packages increasingly labeled “traditional” knowledge, where “traditional” modifies a realm of expertise such as medicine, botany, pharmacopeia, animal husbandry, or even astronomy. Especially when circulating within and between states, these tend to be stripped down and cleaned up epistemic bundles with operating principles that have gone through a series of sieves relating to dominant scientific and legal frameworks.<sup>40</sup> A flip side to this is a pattern I describe in my book *Africa as a Living Laboratory* and have labeled *vernacular science* to distinguish it from vernacular knowledge. Vernacular science signals the extent to which field scientists and intellectuals worked to understand, translate, and even incorporate ethnographic findings into their own scientific research and policy recommendations.<sup>41</sup> Paradoxically, it tends to be integral to people’s efforts to support claims that “traditional” or “indigenous” knowledge works. That there exists such a symbiotic relationship between the two realms serves as a vexing methodological insight, revealing the different kinds of scientific labor necessary to make “traditional knowledge” visible. How do we know “traditional knowledge” deserves the status of knowledge and has an effect in the world? Because our techno-scientific tools—including ethnographic fieldwork and other instruments of translation and comparison—help us see that it does. To invoke a phrase developed to analyze the early modern period, vernacular science and traditional knowledge are themselves “go-between” epistemologies because they try to bridge worlds and worldviews, albeit still in incomplete ways.

A fourth set of challenges arise from studies of the *longue durée* that attempt to show how patterns and practices persisted across time and space. Above all, there is the danger of projecting backwards developments that were of more recent origin. This problem tends to stem from a lack of sources and the difficulties inherent in piecing together fragmentary evidence and pinpointing precise time periods. Then there is the risk of portraying dynamics as more coherent epistemologically than they really were in order, perhaps, to drive home collective and intergenerational agency over long periods. And finally is the failure to account for or flatten out the braided and entangled forms of expertise that intersect in different places at any one time.<sup>42</sup> This last difficulty tends to occur when scholars are more invested in one entry point or group than in a comprehensive overview, attempting to make sense of natural or medical knowledge, for instance, rather than reconstructing a full picture. It can also emerge from the fact that disentangling and contextualizing knotty forms of knowledge tends to require sophisticated skill sets that take years if not decades to achieve.

In all these instances, historians need to triangulate evidence and focus at least a little attention on what they do not or cannot know, which serves as a fifth conceptual and methodological challenge. Murray Last made this point decades ago, but it bears repeating: *not-knowing* ought to be an integral part of our theoretical toolkit.<sup>43</sup> This kind of conceptual apparatus helps us explain how people can do effective things without knowing or even having a full “system.” (This point applies as much to users of computers and global positioning systems as it does to users of tools and practices relating to other realms of knowledge. A first-year medical student and a retired general practitioner are

not equally knowledgeable. All epistemic cultures tend to be black boxed at some point or another so that those who deploy their parts may not always be fully aware of their inner workings.) More than this, knowing about not-knowing also helps us account for the fact that people have not always been willing to divulge what they know, so techniques to conceal, erase, and withhold sit alongside techniques to transmit, convey, and reveal. These maneuverings can operate on many levels simultaneously, making it all the more important for scholars to consider how and why different things become or remain visible and just what eludes our grasp or gets constructed as invisible.<sup>44</sup> Obfuscating, hiding, ignoring, and dissembling about types of knowledge also require their own skill sets, reminding us that experts have produced cultures of secrecy and ignorance too.<sup>45</sup> Going further, not-knowing takes us into realms of uncertainty and impossibility. What exactly can we explain about the world, what remains inexplicable, and what do these gaps tell us? It is precisely at points of epistemological and ontological uncertainty that scholars in area studies and scholars in science studies have a lot to say to one another. It is also at these points where scientists and other kinds of experts occupy common ground: however much they might have different default assumptions about physical reality, they are united in a search for answers that explain the world and its animating forces.

## Vernacular Trajectories and Endogenous Trends—Bridging Colonial Divides

Longitudinal studies in African history have given the field a rich array of information about forms of mining and metallurgy, textiles and pottery, architecture and built environments, mathematical and spatial knowledge, and even techniques for long-distance communication.<sup>46</sup> Scholars have also amassed considerable evidence of epistemological systems and everyday practices relating to the natural world and public healing, knowledge that often went hand in glove. There also exists a growing body of work on African diasporas across the Americas, which takes advantage of evidentiary trails left in court, scholarly, church, and government records from the 16th century onward. These studies offer Africanists fascinating points of comparison to consider the ways botanical knowledge, animal husbandry, medicine, and ritual expertise intersected with political and social movements.<sup>47</sup> Because this latter literature builds upon printed records, it provides more fine-grained evidence of how individual experts (as distinct from groups) struggled and even thrived under adverse and adversarial conditions. More than this, it shows that people of many different backgrounds who lived in Atlantic worlds deployed and judged experiential and bodily knowledge in ways that were not so radically different after all, even when some people's expertise was criminalized while others' was promoted.<sup>48</sup> In the paragraphs that follow, just a few of these topics receive attention in order to explore what they have to offer to, as well as how they intersect with, debates in the history of science. Some of these topics have been (and remain) flashpoints in larger colonial and national controversies over credit and meaning; others are integral to histories of ingenuity and creativity that African specialists have debated for decades. The point is not for historians of science to remake these wheels, but to be aware of these conversations and even offer fresh perspectives. On all of these subjects, Africanists have already brought creative and flexible approaches to language and data in their attempts to reconstruct life worlds of the past.

One of the subjects that can be traced deepest back in time in African history is metallurgy. Given the abundant evidence of mining across Africa, for instance, scholars have pointed to the absence of "foreign" words and terms as a way to counteract theories, proffered periodically during the colonial era, that sophisticated extracting and smelting techniques with iron, gold, and to a lesser extent copper, had to have been imported from the outside. As Eugenia Herbert explains, "The main centers of metalworking have failed to show evidence of either foreign technology or the foreign goods, settlement patterns, or language borrowings, that could have been expected to accompany colonies of foreigners producing for an outside market."<sup>49</sup> In a more recent exploration of the linguistic evidence, Jan Vansina admitted that such genealogies were sometimes indeterminate when it came to questions of origin, but he still concluded that ironworking was introduced "very early . . . into northern and central Nigeria and some adjacent sites in Cameroon and the Central African Republic" and then "spread

southward along several pathways into Bantu-speaking lands, a spread that started long before 420 BCE.” Reinforcing Herbert’s point, Vansina noted, perhaps more definitively than was warranted given ongoing debates, that “there is no evidence at all for any other introduction of [iron-working and smelting] technology into the subcontinent from anywhere else.”<sup>50</sup> Interestingly, smith workers operated as a class of specialists akin to healers, with Herbert applying the very term *nganga* that is more often associated with the latter group.<sup>51</sup> This labeling stems partly from the ritual power blacksmiths brought to social groups, partly from the role they played transmitting closely guarded expertise between generations, and partly from the practical and spiritual services they provided, services that depended upon their “arcane” knowledge. Here we begin to see a recurring pattern that appears in many different African sites (and studies): knowledge segues into technology, which segues into art and politics, which segues into real-world and otherworldly *work*. To look at these patterns from a different vantage point, people have acted and created things in the world to achieve a variety of effects that we can reasonably label scientific given their focus on mastery, experimentation, and problem-solving.<sup>52</sup> These different kinds of work—intended, incidental, and accidental—should all remain within the analytical purview of scholars interested in African histories of science. Indeed, these expert groups were custodians of more than knowledge, passing on to new generations ethical norms and specific histories relating to their practice.<sup>53</sup>

Moving into other realms that have also covered vast sweeps of time, a range of studies have examined vernacular architectural achievements, revealing shared patterns of mathematical and geometric design across different parts of Africa.<sup>54</sup> Such studies underscore how expert communities have developed distinct “ways of knowing” about specific locales and materials, while also bringing to bear abstract forms of reasoning and metaphysical priorities to their designs, which they then transmit to new generations. These different built environments can be interpreted almost as texts in themselves, as their significance and meaning have been on full display for those with the tools to decipher them.<sup>55</sup> Trevor Marchand, for instance, in his study of communities of masons in Mali, notes that teaching and training have long been embodied acts for the men designing and maintaining the many hundreds of adobe houses and mosques of Djenné, a cosmopolitan crossroads in which Songhay and Mande cultures meet and mix.<sup>56</sup> Since at least the 14th century, Djenné has served as a hub of trans-Saharan trade and has long been considered the “mother” of that other cosmopolitan center of learning, Timbuktu.<sup>57</sup> As Marchand explains, in order to become legitimate masons, men within the guild had to achieve not only a high level of “technical skill” but also “design ability, propositional knowledge, and mastery of secrets.” Knowing and doing, in other words, were inextricably linked so that masons simultaneously refined their abilities to “formulate statements about the world” and deployed “words, objects and physical rituals that connect[ed] people to the forces that animate the world.” These elements have combined among masons to produce a repertoire of knowledge that was—and remains—dynamic.<sup>58</sup> Just in terms of technical skill alone, Marchand elaborates, masons possessed “an experiential knowledge of the compressive strength of mud bricks . . . the tensile capacity of palm wood timbers . . . the durability of plasters made from fermented laterite soil . . .

the compatibility (or incompatibility) of materials such as mud, cement, and clay tiles, each with their own physical properties and rates of thermal expansion and contraction.”<sup>59</sup> Although Marchand’s focus has been on Mali’s recent past, his claims about how Djenné’s masons have learned and passed on their expertise over time are robust enough to project backwards, certainly to the early 19th century and perhaps even to the building of the first mosque in the 13th or 14th century.<sup>60</sup> Indeed tacit and embodied expertise of this sort has not only shown remarkable durability in many places within Africa but has also been linked to systems of thought that are equally resilient and intentional.

Similar insights can be gleaned from the way scholars and laypeople alike have interpreted large-scale architectural remains that were built several centuries ago. Take the historical controversies over Great Zimbabwe, constructed between the 12th and 16th centuries and serving as a hub of one among several bustling polities in the region.<sup>61</sup> The site included, conservatively, between 16,000 and 20,000 people, probably ancestors of Shona speakers, complete with its own mining infrastructure in which copper, more than gold, was a commodity and ornament of choice.<sup>62</sup> The massive stone walls, reaching 30 feet high and 15 feet thick, are thought by at least some archaeologists to have stood as emblems of royal authority, constructed less for defense, as “few walls achieve complete closure; [and] many are short, interrupted arcs, easily circumvented,” and more to invoke rulers’ relationships to ancestral lands and to celebrate “human ingenuity” itself.<sup>63</sup> Indeed, scholars interested in promoting forms of “African knowledge systems” invoke Great Zimbabwe as a prime example of sophisticated technical expertise.<sup>64</sup> As with linguistic evidence, however, archeological sources can be inconclusive, especially when it comes to “cognitive archaeology” or the attempt to use material culture to understand “the ideals, values, and beliefs that constitute a society’s world-view.”<sup>65</sup> David Beach points out that it was not just colonial researchers who surmised that Europeans built the *zimbabwes*, or “houses of stone,” but also oral informants at the end of the 19th century.<sup>66</sup> Several centuries of Shona migration and conquest, he argues, would have interrupted oral transmissions of knowledge, making it difficult for people to reconstruct who built what and even more challenging for them to say with certainty what such constructs meant. Although scholars have in fact achieved considerable consensus on many of Great Zimbabwe’s features, a small example of an ongoing dispute over eight soapstone carvings of mythic birds of prey, found in the site, reveals the way debates over past innovations come to be nestled within wider contests over patriotic expertise.<sup>67</sup> Pushing back against the idea that the soapstone carvings necessarily represented some kind of collective meaning in Shona cosmologies, Beach takes a pragmatic approach, noting that if the carvings were the product of one person’s imagination, they need not be seen as representative of anything more: “We simply do not know what the soapstone birds meant, but in fact they would not have strained the capacity of a single carver working over a few years . . . The birds were beautiful, but they may not have been as crucial to the thinking of the Great Zimbabwe people as they are to that of archaeologists.”<sup>68</sup> Such artifacts can still be prone to misinterpretation and other methodological difficulties. To shoehorn them into a coherent worldview or stable

narrative about innovation may not always do justice to competing interpretations. As Terence Ranger and others have more recently emphasized, not only do the material artifacts of Great Zimbabwe still invite people to conjecture about their meaning and possible relationship to royal lineage, ancestors, the spirit world, landscapes, gender relations, and epistemic cultures, but they also continue to serve as a source of nationalist and ethnic tensions.<sup>69</sup> In an increasingly familiar twist, the site's totemic birds, which were carved at least 500 years ago, also now stand at the heart of debates within contemporary Zimbabwe about cultural and intellectual property.<sup>70</sup>

Moving from architecture to artifacts and categories of knowledge foregrounds the very languages experts use to learn and work in different scientific disciplines, languages that have diminished rather than increased over the last several centuries. This phenomenon arose in tandem with “global English” and the gradual consolidation of hegemonic languages of science.<sup>71</sup> Colonial occupation in many parts of the world facilitated these processes, as did the founding of transnational organizations that prized efficient and standardized communication, even as advocates for other languages of science—Arabic, Urdu, Hindi, Mandarin, and even Spanish and Russian—resisted these changes.<sup>72</sup> This more recent global history invites scholars to consider cognates for science and knowledge in different African languages and to reflect upon the ways of ordering the world that they encompass.<sup>73</sup> Although concepts can and do change over time, certain constructs have been stable enough that they warrant closer inspection, especially for anyone interested in polycentric histories of science before the professions proliferated toward the end of the 19th century. In Yórùba, for instance, cognates for both “science” and “knowledge” around the turn of the 20th century invoked old age (*ogbón*), clarity (*imo*), and teaching/educating (*èkó*); for “science” in particular there was also wisdom (*oye*) and variations on profound, mysterious, and deep (insight) (*ijinlè*).<sup>74</sup> (It is worth remembering that Yórùba shares lexical roots with other language families and that certain terms, not unlike Greek or Latin roots, have a wider geographical reach.) From intellectual histories of Yórùba cosmologies that go deeper back in time, scholars have shown that energy and power (*ase*), rather than matter, are considered the basis of “the true nature of things . . . [and] permeate all things.”<sup>75</sup> In people, *ase* resides in the head, an understanding that has helped art historians interpret the epistemological significance of the Ife bronzes dated to the 14th century.<sup>76</sup> Scholars have also shown how concepts of energy and power morph into ideas of visible and spiritual realms (*ayé* and *òrun*), which are characterized as porous and interdependent. More than this, these realms display malleable and multifaceted qualities that change with the times.<sup>77</sup>

So although what is true (*otito*) and trustworthy (*nitoto*) matters to people, these concerns exist alongside values about what is just (*olododo*) and good (*rere*). In other words, moral and spiritual reasoning—and the sociopolitical and metaphysical orders within which they are nestled—cannot be disaggregated easily from what we might call scientific reasoning, as both deal with the nature of the world and reality. Many of these topics—matter, energy, mind, trust, and truth—are central to early modern European histories of science and lend themselves to interesting comparisons. Thus even a cursory exercise in semantics and translation leads us quickly from epistemology into matters of

ontology. Anthropologists have recently pushed scholars to acknowledge that reality is not the same everywhere for everyone, that we need to think in terms of people (and things) occupying multiple ontologies.<sup>78</sup> This insight can help historians of science tease out and understand people's different creative worlds and the products of their intellectual labors.

These framing concepts help to explain why various deities or invisible agents come to be associated in adherents' minds with decidedly new trends—skyscrapers, electricity, and highways to name a few examples—accreting and shedding meanings as the situation demands. Such shape-shifting, however, has not been limitless, but has usually been tied to and constrained by existing conditions.<sup>79</sup> Take *Ògún*, a deity of war, iron, and hunting, which forms the subject of Sandra Barnes' groundbreaking edited collection, exploring its diverse pasts and persistence across the wider Atlantic world.<sup>80</sup> The “power in the Ogun philosophy of life,” Barnes points out, “resides in its plasticity and transportability.”<sup>81</sup> This helps to explain its presence and endurance in Cuba and Brazil, as a result of forced migrations of enslaved people, as much as in Nigeria and Benin. It remains the deity most associated with innovations and revolutionary change: *Ògún* first introduced fire and iron, cleared fields and forests, built roads, and founded kingdoms.<sup>82</sup> Its power, when focused, was thought to produce great good, but when unleashed irresponsibly or inadvertently, could generate “mayhem.”<sup>83</sup> Not coincidentally, it was and is most associated with professional blacksmiths whose expertise in ironworking connected them to forms of vital power that fused invisible and visible realms.<sup>84</sup> Indeed, because *Ògún* functions as the clearer of roads, it also “allow[ed] both men and deities to travel from one level of reality to the next.”<sup>85</sup> As with so many other subjects in African history, analyses of this deity—including its adherents, their productive lives, and geographical reach—help historians appreciate precisely the kinds of knotty epistemologies and ontologies that take a lifetime to master.

Even more provocative, perhaps, the science studies scholar Ron Eglash, in examining a vast array of African design systems, including settlement patterns, hairstyles, textile weaving, adornments, sculpture and painting, and even divination techniques, has concluded that many of them display the nonlinear, recursive, and self-organizing principles of fractal geometry.<sup>86</sup> More than this, at least some have been constructed using rules of calculation and logic (i.e., algorithms) that are both precise and robust. This explains how and why these designs have endured, both in terms of their aesthetic principles and their underlying logic (because aesthetics could be reproduced even in the absence of knowledge of the rules). It also highlights the extent to which mathematical and spatial reasoning have mattered to different African polities, something Eglash underscores when he points out the ubiquity of base-2 (as distinct from base-10) calculations, especially in divination practices.<sup>87</sup> Eglash believes historians of mathematics have failed to appreciate how African numeracy systems circulated within and beyond the continent, influencing indirectly even Leibniz's binary system of mathematics in the 17th century.<sup>88</sup> Whether the causal connections can be traced with certainty remains an open question, but Leibniz for one took the cosmological implications of binary code to heart, seeing it as reflecting “the all-power of god”: “For

while in the ordinary mode of writing numbers there can be recognized no order or sequence of characters or relations, there appears now, since one can see the innermost recesses and the primitive states, a wonderfully beautiful order and harmony which cannot be improved upon.”<sup>89</sup>

Whatever their differences, Leibniz likely shared with many intellectuals in sub-Saharan Africa in the 17th century a desire to connect numbers and nature to a divine order. A leading figure in the U.S. Pharmaceutical Association from the 1850s noted a different kind of benefit to binary arithmetic: it allowed people to dispense with tables and written materials of all kinds, so that “the labor of the brain [was] transferred to the eye and the hand.”<sup>90</sup> A better description of and rationale for embodied knowledge could hardly be found. In fact, it resonates with a story I recount in *Africa as a Living Laboratory* about the introduction of intelligence tests to colonial Kenya in the early 1930s and the reported puzzle on Porteus maze tests that groups of Gikuyu teenagers and young adults (between 14 and 20 years old) performed better than did their British counterparts from missionary and settler families. As the test’s architect, R. C. Oliver, reported, “A European child, when he reaches a maze beyond his mental age, tends to enter a blind alley and explore it to the end, and then to retrace his path to the entrance of the blind alley and go on again. He penetrates to the center of the maze quickly enough, but with many errors. The typical procedure of the Africans tested was different. The subject would study the maze for many minutes without making a move: then he would trace his path to the center without hesitation or error.”<sup>91</sup> Because so many of Kenyans were so successful, Oliver discarded the maze as an accurate measure of intelligence, “for even the most difficult mazes in the series were solved in this way by too many of the subjects.” (By contrast, when Europeans performed better with other parts of the test, he kept the tool as an effective measure of “intelligence.”) No one at the time seemed to wonder about the differences between the test subjects’ eyes and hands or why such precision came more easily to one group than another, regardless of age. What kinds of educational experiences were these young Gikuyu students having that refined their visual acuity, and why could the test result be so easily brushed aside?<sup>92</sup> We know the answer to the latter question lies, in part, in the racial economies of knowledge in the colonial era, but it also had to do with a literal blindness to certain pedagogical methods and skills that were simultaneously signs of “intelligence” and means to innovation.<sup>93</sup>

So, whether genealogies of binary code (and algorithmic computing) should be sought in African sources or not, certain forms of geometric and spatial reasoning—and their persistence—do seem to provide further evidence of the extent to which precolonial polities existed as “information societies,” forged through a complex assemblage of tacit and embodied knowledge, mnemonic devices, symbolic practices, and even animated things.<sup>94</sup> If scholars accept that divination systems are structured forms of knowledge that toggle between social, juridical, and epistemological truths (and falsehoods), then it stands to reason that they too ought to be a core part of African histories of science (and medicine).<sup>95</sup> In fact, Edward Evans Pritchard’s study of Azande methods of divination and so-called magic and witchcraft in the Sudan in the 1930s had profound ripple effects not just on scholars of Africa but also on philosophers of science interested in rationality,

reason, and tacit knowledge.<sup>96</sup> Divination systems have both social and truth value because of the work they do in the world for the people who use them, making their persistence a matter less of accident or recalcitrance than of creative choice. Little wonder then that Sierra Leone and Nigerian intellectual John Augustus Abayomi Cole insisted in 1898 on referring to ifá divination techniques, or “geomancy,” as a form of “African science.”<sup>97</sup> It was not just the mathematical sophistication of the system that made the label seem warranted to him, but also its focus on explanation, prognostication, and even therapeutics. Cole was one among several intellectuals at the turn of the 20th century who took part in transnational conversations about science (and its uncertainties) and who wanted to be sure that epistemologies and practices with which he was familiar were included. He was also an ardent student of electromagnetism and physics, traveling to different parts of Britain to study the topics further, as he felt those fields provided an entryway to understanding the invisible realms ifá addressed.

Finally, scholars have developed a vast body of scholarship that links environmental history with the history of knowledge and medicine over a *longue durée*.<sup>98</sup> Take Jan Vansina’s *Paths in the Rainforest* (1990), which is replete with references to Equatorial Africans’ tools, techniques, and styles of innovation, and the way these were connected over the centuries to “political tradition.”<sup>99</sup> Vansina uncovered, during his own fieldwork and by mining ethnographic studies from the colonial era, abundant evidence of the “encyclopedic knowledge about the natural environment” that Equatorial people possessed, noting its “depth and systematic nature.” He saw this as more than a utilitarian project because it clearly transcended basic needs and branched out into cultural arenas. Indeed, while Equatorial environments shaped how people lived, their knowledge of these environments helped them tap into new possibilities too.<sup>100</sup> “Such scientific knowledge for knowledge’s sake,” Vansina stressed, “provided them with a wide range of choices according to social and cultural goals.” It also allowed different specialists, whether women agriculturalists, male hunters, or “physicians” of both sexes, to move between “physical and cognitive realities” by using explicit and ongoing experimental methods. “This constant striving to match both realities is the essence of science, and in that sense science was practiced.”<sup>101</sup> Vansina viewed the decentralized political institutions as anchors for this knowledge, so that innovations in both spheres, politics and knowledge, had direct bearing on territorial control and even expansion over time.<sup>102</sup> Although geographical borders were clearly permeable, as so many different things crossed in and out of the Equatorial region during the centuries he covers, it was people who decided, on the one hand, what to embrace and incorporate, and on the other, to resist and reject. “In the final analysis, the [western Bantu] tradition retained its ability to determine the future, to reject unwanted innovations, and to invent institutions, ideologies, values, and concepts to cope with its new environment.”<sup>103</sup> This kind of “self-regulating” process remained robust for so long—“a moving continuity” as Vansina calls it—because its cognitive and institutional scaffolding were widely distributed and included flexible procedures.<sup>104</sup> The greatest challenges to such systems, he concluded, were periods of violence, disease, and famines, developments that hit the region with

increasing force from the 1870s onward through multinational encroachments under the dual banners of (European) trade and territoriality.

As Vansina saw things, the political tradition in the Congo fell apart over the course of four decades (1880s to 1920s), producing conditions not unlike those in northern Nigeria that led Murray Last to point out the “importance of knowing about not-knowing.” Certainly violent assaults combined with random and deliberate state interventions could cause even resilient networks to fragment, and yet not all intellectual communities experienced disruptions in the same way.<sup>105</sup> There is still a great deal African historians do not understand about how colonialism and conquest transformed epistemic cultures. There are also other subjects that this section has not even touched upon. The point has been to get a more concerted conversation started about threads that scholars can pursue across various temporal (and political and intellectual) divides. The good news for scholars is just how much literature is already out there on which to build this dialogue.

## Epistemologies and Realities of European Conquest and State-Building

A central challenge of crossing the “precolonial” and “colonial” divides has to do with the different ways we use or problematize evidence from the sciences themselves. To overstate the difference (as there are important exceptions and blended studies), scholars focused on the precolonial past, much like certain environmental and medical historians often make direct or indirect use of scientific evidence to tell their stories and build up a coherent analysis, drawing on research in the natural, medical, and human sciences in particular. (The last category includes ethnographic and travel monographs, texts that scholars often scour for sociological and empirical details.) By contrast, scholars interested in science in the colonial or postcolonial periods often take this knowledge as an object of study in its own right, historicizing not just concepts or theories but also the scaffolding and labor necessary to produce them. For deeper time scales, then, scientific expertise becomes part and parcel of authors’ multifaceted methods, allowing them to reconstruct worlds for which there may be limited printed records. The sciences underpinning these historical arguments tend to be rendered invisible and operate more off-stage than on, that is, in footnotes. For more recent time scales, going back between 100 and 200 years, with the earlier points of departure often reserved for Northern and Southern Africa, scholars presume that a key point of their studies is to unpack the black box of different sciences (including their instruments, institutions, and artifacts), opening and interrogating epistemological processes and products as well as their political economies. Because dissection and analysis are the very purpose of such studies, the sciences themselves and all their trappings occupy center stage.

This dynamic helps to explain why no Africanist who self-identifies as a historian of science, an admittedly small group, has yet to write a book focused solely on the precolonial period. So although the early modern period has anchored European histories of science for so long, it is the colonial and postcolonial periods that currently anchor African histories of science. Part of this temporal gap stems from the fact that languages and forms of evidence constrain historians' spatial and social analyses, making the very skill sets scholars need, to understand different places and peoples over long sweeps of time, daunting to acquire. The academic model of a single author focused on a single object of analysis, even if multisited and transdisciplinary, inhibits the field's ability to craft the kinds of comprehensive narratives—about epistemic and material changes—that the field so sorely needs.

European conquest tended to scramble geographies of knowledge and recalibrate power relations among their possessors in myriad ways, a process that both shut down and created many (new) possibilities. This raises an important paradox of imperial legacies: it is now exceedingly difficult for scholars in any field to step outside scientific worldviews in their entirety. How do we know so much about Africa's features, its non-human nature, and its peoples, including their initiatives and experiences? the continent has served as an object of study for many different kinds of experts, a phenomenon that cannot be divorced from the territorial and administrative projects of empires and (colonial) states. Forests and soils, rivers and lakes, insects and parasites, mountains and deserts, minerals and metals, diseases and pathologies, flora and fauna, "races" and languages, climates and cultures, even gravity and stellar phenomena all underwent scientific scrutiny. Although historians can certainly label the results of these studies "inventions," it also seems important to acknowledge how many scholars now rely on scientific evidence for their work, whether they are writing about changing landscapes, economies, or even bodies and minds. It was state-building dynamics that both stabilized and naturalized certain forms of knowledge (more than others) in sub-Saharan Africa. Indeed, colonial states' legal and institutional scaffolding gradually defined and adjudicated what would count as legitimate knowledge within and across different jurisdictions. Social practices in these states could still run the gamut, because infrastructures could be sparse and laws difficult to enforce, but the legal apparatus itself still established fence posts marking out the epistemological terrain.<sup>106</sup> Yet none of this happened in a vacuum. Even with steep gradients of power (and sometimes because of them), endogenous cultures and natures were an unavoidable factor in colonial calculations, legal and otherwise.

Given all the attention imperial historians have devoted to the Scramble for Africa, it remains striking how little causal weight they still give to scientists and their learned societies across Europe, the United States, and Northern Africa. Before there was a "legal" partition of the continent there was a kind of *scientific partition*, because these societies—and the newspapers and journals that amplified their work—generated considerable debate about territorial resources and control.<sup>107</sup> As field expeditions crisscrossed different regions between the 1860s and 1880s, maps of all scales began to multiply, as did proposals to irrigate deserts, deepen ports, build telegraph and railway lines, study environments, and extract commodities of all kinds.<sup>108</sup> Publicity surrounding

the opening of the Suez Canal in 1869 served as another kind of catalyst, heightening attention to the interior, reinforcing people's confidence in engineering and steam power while also introducing a new motif of Africa as "a large island separated from the rest of the globe" because the canal had literally severed "the sandy ligaments [that had] hitherto united Asia and Africa."<sup>109</sup> Islands had, of course, been central sites for Europeans to work out key principles not only of natural history, conservation, and evolution, but also of jurisprudence and political philosophy.<sup>110</sup> Viewing Africa as an island underscored the extent to which scientific imaginations were scaling up and bolstered the idea that it too might become a site of experimentation and development. Geographers were often willing to state these dynamics explicitly, as Norbert Dournaux-Dupéré did in 1873 when reporting on France's expeditions across northern Africa: "To each century belongs its task: to the nineteenth century, the scientific conquest of Africa, to the twentieth, its transformation."<sup>111</sup>

The collective labor and knowledge that went into various expeditions and cartographic projects cannot be overstressed. To put this process in perspective, almost twice as many maps of Africa (408) were published between 1860 and 1880 as appeared during the first six decades of the 19th century (257). And more than 1,100 maps were published in the 1880s and 1890s, or nearly three times what had been produced in the prior two decades.<sup>112</sup> In the midst of this process, a writer for the journal *Nature* pointed out that knowledge of the interior had once been more robust and that "recent investigation seem[ed] to show . . . that, in fact, it [was] only within two or three centuries that a knowledge of Central Africa ha[d] been allowed to lapse."<sup>113</sup> At least some mapmakers also acknowledged that the blank spaces placed on their African maps were used not because the regions were entirely unknown to them, but because the evidence was less precise than that used for other parts of the world.<sup>114</sup> Their efforts to create higher standards for maps as a whole paradoxically left literal gaps in African maps and paved the way for cartographers and field researchers to serve as gatekeepers in deciding what was and was not legitimate and credible knowledge.<sup>115</sup>

As social artifacts, maps, like so much else relating to the production of knowledge, can be interrogated for what they reveal about authorship, credit, control, and even lived experience. Scholars know, for instance, that many European expeditions were undertaken in the company of porters, guides, and interpreters who often possessed and passed on strategic knowledge without which expeditions would have produced very different results. One such man, of Yao descent and known as Bombay (*ca.* 1820–1885) for the time he spent as a slave in India, worked on four different multiyear expeditions in eastern Africa between 1857 and 1876, eventually being awarded a pension from Britain's Royal Geographical Society for his labors. In the nominating letter, James Grant, one of the expedition leaders, bluntly reported that "'Bombay' in making the four . . . journeys has walked some twelve thousand miles, seeing and doing as much as all these travellers put together."<sup>116</sup> This kind of credit, of course, extended no further than a pension and a medal: others were celebrated for their geographical "discoveries," a

pattern not unlike the erasure of collective contributions to scientific “genius” or to patent authorship.<sup>117</sup>

The thousands of lesser-known assistants on these expeditions—and the paths they pursued—have recently been resurrected through a two-part analysis of French geographer Regnaud de Lannoy de Bissy’s 16-year project (1874–1888), to create a 1:2,000,000 scale map of Africa based on details from 1,800 journeys of 600 different expedition leaders. The final set of 63 sheets—measuring approximately 12.5 feet wide by 16 feet tall—listed not just explorers’ routes but also “supplementary information on ethnic groups, the territorial organization of African states and kingdoms, and the fauna and flora.”<sup>118</sup> Mapmaking did much more than standardize spaces and places; it also helped to reify identity categories and inventory different landscapes. (It is worth noting that not until the end of the First World War did the British government attempt to produce a map of Africa on this same scale. And, as Jeffrey Stone has pointed out, it took another 35 years before the 30th arc of the meridian—a set of triangulation points that runs from Cairo to Port Elizabeth in South Africa and helps geographers determine the shape of the Earth—was completed.)<sup>119</sup> What Lannoy de Bissy’s set of maps illustrates, according to Aharon de Grassi, is a vast network of “precolonial” paths, trails, and itineraries that reflected endogenous labor, knowledge, and circuits of communication.<sup>120</sup> Seeing expedition routes as literally path dependent, de Grassi reminds us whose agency is also visible on Lannoy de Bissy’s maps. Building upon these kinds of insights, Julie MacArthur has shown how cartographic imaginations could serve different kinds of functions *within* colonial states, helping subjects chart a course as “ethnic patriots” in ways that oscillated between “nativism and cosmopolitan pluralism.” Focusing on Luyia men and women in western Kenya, MacArthur shows how they developed their own “cartographic literacy” and “countermapping” strategies to control spatial depictions, including over land rights and property itself.<sup>121</sup>

In a fascinating twist on these cartographic stories, Robyn d’Avignon has taken mapping pursuits underground, tracing how geological prospecting in French West Africa during the colonial era literally mapped onto endogenous miners’ hard-won insights about rock formations, soil types, and even extraction techniques. These burgeoning efforts in Senegal only flourished, however, in the period following independence, when Léopold Senghor’s administration joined forces with UN development agencies and Soviet, Swiss, and French geologists. These experts had guides of their own, known as *orpailleurs*, or artisanal miners, who performed a function similar to the guides during the Scramble for Africa, identifying for outsiders the salient features of the landscape being sought, in this case gold and diamonds.<sup>122</sup> As one such guide, Dembélé Danfakha, put it to d’Avignon when describing one of the largest open-pit gold mines in Senegal, “The first thing you need to know, they did not discover Sabodala. We did.” Although prospectors rarely cared about the long history of ritual and technical experts across the Sahel, d’Avignon brings these vividly back to life, reminding readers that “the ritual logic of artisanal mines is

crucial to understanding what West Africans lost—and fought to regain—after goldfields became imperial property.”<sup>123</sup>

Moving from geography (or landscapes) to anthropology (or social-scapes), Johannes Fabian has eloquently helped us see the extent to which field ethnographers during the Scramble for Africa did their work while “out of their minds,” disoriented by conditions and bodily states—illness, fear, intoxication, anger, and even attraction—that fed back into their understandings and analyses.<sup>124</sup> This critique was one that Edward Blyden had actually expressed in the 1870s when he read Herbert Spencer’s compilation on the “facts” of *African Races*. According to Blyden, Spencer’s book could hardly be a “trustworthy guide” because so many of the selections were drawn “from the writings of travellers whose observations were confined to very small localities and made under the disturbing influence of disease.”<sup>125</sup> Fabian takes concerns about facts and trust further, noting that human rationality itself can never be scrubbed clean of “disturbing” influences, particularly when the object of study is other people.<sup>126</sup> By tracing African anthropology’s roots to these extensive expeditions, Fabian not only joins a lineage of people engaged in a “critique of reason,” but also reminds us of the need to include human subjects within the remit of the history of science. And as Patrick Harries has so carefully explored for Southern Africa, such ethnographic investigations tended to be tied closely to religious, linguistic, racial, and biotic concerns as well.<sup>127</sup> Histories of the human sciences, anchored in anthropology but including sociology, demography, economics, and psychology and psychiatry, have begun to flourish over the last two decades, helping us appreciate their varied assumptions, institutional sponsors, and lasting effects.<sup>128</sup>

The work to build states in colonial Africa entailed an abundance of environmental, medical, and human research, though the funds and staff allocated were unevenly distributed and often paled in comparison to states in other parts of the world. It also involved patterns of coordination and circulation that crossed borders and operated on many scales simultaneously. Professionals were put to work to inventory lands, demarcate territories, build new infrastructures, craft identities, steward life paths, generate energy (and revenue streams), and construct systems of governance. This process produced mosaics of knowledge whose parts changed over time, generating decidedly new and uneven composite pictures by the decade. This dynamism makes it challenging for Africanists because few scholars know enough languages to place these new epistemic cultures in the fullest context given their broad spatial parameters. The sheer scope and scale of scientific investigations also meant that their effects transformed European intellectual priorities, including the very fields constitutive of African Studies. Indeed conflicts, contradictions, and fault lines abounded during the colonial era. Although certain kinds of category errors and misinterpretations went uncorrected, many scientists and fieldworkers continued to revisit and revise their theories as they accumulated more and different kinds of concrete knowledge. This meant that benchmark ideas pervasive during the “Scramble for Africa” had morphed, sometimes dramatically, by the decades surrounding political decolonization. In other words, what communities of experts deemed tenable and true in 1890 could seem untrue and even untenable by 1960, even

before efforts to “decolonize” states, much less knowledge, were fully underway.<sup>129</sup> To be provocative, there was arguably a greater sea change in scientific thinking about Africa between 1890 and 1960 than there has been between 1960 and 2018. This is not to downplay the significance of studies focused on analyzing errors, mistakes, and even what we might call “spurious” science, because such analyses are essential to helping us appreciate the uphill battles that different people endure when they encounter powerfully wrong theories. Instead, it draws attention to the fact that new or different scientific evidence is *always* used to call these theories into question.

Beyond the archeological and architectural examples already explored here, it may be helpful to consider the expert evidence underpinning theories in different parts of Africa about deforestation and desertification.<sup>130</sup> Scholars who undertake this work are not saying that truth claims themselves are invalid or even relative, but that false or misleading claims, dressed up as true, have achieved an orthodox status.<sup>131</sup> As James Fairhead, Melissa Leach, and Diana Davis have persuasively demonstrated, “bad” environmental facts—whether in Guinea (around forest mosaics) or in French North Africa (around pastures and forests)—tended to be rooted in forms of property and profitability that simultaneously rendered subaltern ways of knowing (and managing) landscapes less relevant and also ensured that solutions to these alleged problems reproduced state and economic logics at the expense of people’s livelihoods and autonomy. These dynamics help to explain why certain kinds of vernacular praxis have failed to attract consistent policy attention. It also puts in perspective why Paul Richards, one of the early advocates in African studies of “folk ecology” and “people’s science” invoked the latter phrase to explain how and why so many people in Guinea, Sierra Leone, and Liberia avoided the staggering death tolls that global health “experts” predicted during the Ebola outbreak between 2013 and 2015.<sup>132</sup> Richards’ analysis drives home the high stakes of misunderstanding social practices and also of discounting how people can adapt creatively and even quickly when confronted with life-threatening conditions.

## Conclusion: Where to Go from Here?

To conclude this essay, it may be helpful to say just a few words about the end of empires, problems endemic to resource poor areas, and people’s ongoing efforts to experiment and improvise. This also provides an opportunity to acknowledge others who are thinking through related dynamics. First, to tackle decolonization: African historians simply need many more fine-grained analyses of these decades and of the myriad dynamics relating to scientific training, funding, research priorities, and practices across an array of subjects. Scholars at the forefront of this effort have focused on the human sciences and have brought sophisticated theories of empire and social scientific knowledge to their analyses.<sup>133</sup> There is a need for many more such studies, and they should try to unpack state, elite, and popular dynamics simultaneously. It is difficult to discuss decolonization

without analyzing Cold War geopolitics and the role of pan-African and “Third World” collaborations and tensions. Transnational phenomena of this period also cry out for analysis and need to be linked back to concrete developments within the continent.<sup>134</sup> Having more comprehensive studies of key shifts between 1950 and 1990 will help Africanists place in a wider context much of the exciting work coming from STS (science and technology studies) scholars on such subjects as race and genetics, patents and priority claims, demographic and development data, and toxics and environmental knowledge.<sup>135</sup>

Turning to questions of resources and African states in the 21st century, it seems important to acknowledge the push-pull dynamic of historical research. On the one hand, so much scholarship in African studies pushes back against ideas of absence (of intellectual accomplishments) and lack (of innovation and knowledge). This research continues to counter the kind of ahistorical and oversimplified assessments offered in policy circles and captured succinctly in the title of a 2008 book in political science about African agriculture, *Starved for Science*.<sup>136</sup> On the other hand, stark disparities in state-funded and university-funded science infrastructures undeniably affect many African countries, especially in the wake of structural adjustment projects over the last three decades. These disparities and the needs they create pose real problems for people, especially given how interlinked knowledge economies and actual economies have become. This conundrum is captured in the subtitle of Iruke Okeke’s 2011 book, *Divining without Seeds: The Case for Strengthening Laboratory Medicine in Africa*. One could in fact make a case for strengthening all kinds of disciplinary infrastructures, while still avoiding blind faith in technocratic knowledge or the suggestion that the best ideas and tools must be imported. As Okeke makes clear, it is not just too little money that is a problem in resource-poor areas, but the inadequate models put in place (in her case to deal with infectious diseases) and the myths (at the municipal, state, and international levels) that prevent them from changing. These resource realities are ever-present, even in wealthier countries, and should serve as a further reminder (should anyone need one) that economic and social inequalities need not be romanticized in order to draw attention to people’s creativity, resilience, and improvisational problem-solving.<sup>137</sup> Indeed, they allow us to see that epistemological and technical norms taken for granted in other parts of the world (Europe or North America) are *not* the norms that have developed within different parts of Africa. These very differences call for polycentric narratives and a willingness to read across regions within the history of science.<sup>138</sup>

## Further Reading

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Gieryn, Thomas. "Boundary-Work and the Demarcation of Science from Non-Science: Strains and Interests in Professional Ideologies of Scientists." *American Sociological Review* 48 (1983): 781-795.

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Hacking, Ian. "The Looping Effects of Human Kinds." In *Causal Cognition: A Multidisciplinary Debate*. Edited by Dan Sperber et al., 351-394. Oxford: Clarendon Press, 1996.

Harries, Patrick. *Butterflies and Barbarians: Swiss Missionaries and Systems of Knowledge in South-East Africa*. Oxford: James Currey Press, 2007.

Hecht, Gabrielle. *Being Nuclear: Africans and the Global Uranium Trade*. Cambridge, MA: MIT Press, 2012.

Hountondji, Paulin, ed. *Endogenous Knowledge-Research Trails*. Oxford: CODESRIA and Anthony Rowe, 1997.

Jacobs, Nancy. *Birders of Africa: History of a Network*. New Haven, CT: Yale University Press, 2016.

Knorr Cetina, Karin. *Epistemic Cultures: How the Sciences Make Knowledge*. Cambridge, MA: Harvard University Press, 1999.

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Last, Murray. "The Importance of Knowing about Not-Knowing: Observations from Hausaland." In *The Social Basis of Health and Healing in Africa*. Edited by Steven Feierman and John Janzen, 393-408. Berkeley: University of California Press, 1992.

Marchand, Trevor. *The Masons of Djenné*. Bloomington: Indiana University Press, 2009.

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Osborn, Emily. "From Bauxite to Cooking Pots: Aluminum, Chemistry, and West African Artisanal Production." *History of Science* 54 (2016): 425–442.

Peek, Philip, ed. *African Divination Systems: Ways of Knowing*. Bloomington: University of Indiana, 1991.

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Schumaker, Lyn. *Africanizing Anthropology: Fieldwork, Networks, and the Making of Cultural Knowledge in Central Africa*. Durham, NC: Duke University Press, 2001.

Sibeud, Emmanuelle, ed. "Décolonisation et sciences humaines." *Revue d'Histoire des Sciences Humaines* 24 (2011): 3–187.

Tilley, Helen. *Africa as a Living Laboratory: Empire, Development, and the Problem of Scientific Knowledge*. Chicago: University of Chicago Press, 2011.

### Notes:

(1.) Much of this essay focuses on trends and scholarship south of the Sahara and leaves largely to one side historiographies relating to medicine and technology, as other authors address these subjects in their chapters. It also relies predominantly on secondary literature in English. My heartfelt thanks to Tom Spear for inviting me to write it in the first place, and to several colleagues and students—David Schoenbrun, Michael Gordin, Jonathon Glassman, Andrea Rosengarten, Jessica Biddlestone, and an anonymous reviewer—for their astute feedback. Time and my own limits have prevented me from addressing all their excellent points; the flaws remain mine.

(2.) Paulin Hountondji, ed., *Endogenous Knowledge-Research Trails* (Oxford: CODESRIA and Anthony Rowe, 1997), 14; and Goudjinou Metinhouse, "Methodological Issues in the Study of 'Traditional Techniques' and Know-How," in *Endogenous Knowledge*, ed. Hountondji, 43–62.

(3.) Michael Polanyi is credited with introducing the concept of tacit knowledge to refer to forms of know-how that are often passed along as they are practiced: Michael Polanyi, *Personal Knowledge: Towards a Post-Critical Philosophy* (Chicago: University of Chicago Press, 1958). For a discussion of Edward Evans Pritchard's influence on Polanyi's theories of doubt and "objectivism," see John Mack, "Telling and Foretelling: African Divination and Art in Wider Perspective," in *Insight and Artistry in African Divination*, ed. John

Pemberton III (Washington, DC: Smithsonian Institution, 2000), 34–44. For a range of studies dealing with embodiment and environments, see Trevor Marchand, ed., *Making Knowledge: Explorations of the Indissoluble Relation Between Mind, Body, and Environment* (London: Royal Anthropological Institute, 2010). Also see Karen McCarthy Brown, “Systematic Remembering, Systematic Forgetting—Ogou in Haiti,” in *Africa’s Ogun: Old World and New—Second Expanded Edition*, ed. Sandra Barnes (Bloomington: Indiana University Press, 1997), 65–89.

(4.) Her leading example of this danger is the social theory of Anthony Giddens: Jane Guyer, “Traditions of Invention in Equatorial Africa,” *African Studies Review* 39 (1996): 1–28, p. 3.

(5.) I explore these concepts in more detail in section two.

(6.) Guyer, “Traditions of Invention,” 3. See, for instance, Patrick McNaughton, *The Mande Blacksmiths: Knowledge, Power, and Art in West Africa* (Bloomington: Indiana University Press, 1988); Amanda Logan and M. Dores Cruz, “Gendered Taskscapes: Food, Farming, and Craft Production in Banda, Ghana in the Eighteenth to Twenty-First Centuries,” *African Archaeological Review* 31 (2014): 203–231; Judith Carney and Richard Nicholas Rosomoff, *In the Shadow of Slavery: Africa’s Botanical Legacy in the Atlantic World* (Berkeley: University of California Press, 2009); James D. La Fleur, *Fusion Foodways of Africa’s Gold Coast in the Atlantic Era* (Leiden: Brill, 2012); and John Janzen, *Ngoma: Discourses of Healing in Central and Southern Africa* (Berkeley: University of California Press, 1992).

(7.) Most scholars who use this label seem to mean those regions of the world once called the “Third World,” but they also include all groups of people who have suffered or failed to benefit from “globalization.” See Alfred Lopez, “Introduction: the (Post) Global South,” *The Global South* 1 (2007): 1–11; and Vijay Prashad, *The Poorer Nations: A Possible History of the Global South* (London: Verso Books, 2012).

(8.) Because I do not discuss the history of 20th-century technology explicitly, this is a good place to mention the terrific work of Gabrielle Hecht, *Being Nuclear: Africans and the Global Uranium Trade* (Cambridge, MA: MIT Press, 2012).

(9.) For a variety of perspectives on the invention of Africa, see Valentin Mudimbe, *The Invention of Africa: Gnosis, Philosophy, and the Order of Knowledge* (Bloomington: Indiana University Press, 1988); Annie Coombs, *Reinventing Africa: Museums, Material Culture, and Popular Imagination* (New Haven, CT: Yale University Press, 1994); and Philip Curtin, *The Image of Africa: British Ideas and Action, 1780–1850* (Madison: University of Wisconsin Press, 1973). For an earlier contribution on history and philosophy of science since 1935, see Ali Mazrui and Jacob F. Ade Ajayi, “Trends in Philosophy and Science in Africa,” in *Africa Since 1935*, vol. 8: *UNESCO General History of Africa*, Ali A. Mazrui, ed.; C. Wondji, asst. ed. (Berkeley: University of California Press, 1993), 633–677; and on the way research in African Studies has affected disciplines, see

Robert Bates, Valentin-Yves Mudimbe, and Jean O’Barr, eds., *Africa and the Disciplines: The Contributions of Research in Africa to the Social Sciences and Humanities* (Chicago: University of Chicago Press, 1993).

(10.) A review of companion volumes to the history of science reveals the magnetism Europe and Europeanists still hold over the field, even as more recent surveys emphasize “global” sites and circulations and explore the outsized influence of U.S. actors and institutions for the 20th century onward. Medical histories tend to be more cosmopolitan and regionally balanced, but even surveys in medical history often omit topics relating to public healing and popular therapeutics that are central to African and diasporic pasts (and presents). See, for instance, Robert C. Olby et al., eds., *Companion to the History of Modern Science* (New York: Routledge, 1990); John L. Heilbron, ed., *The Oxford Companion to the History of Modern Science* (Oxford: Oxford University Press, 2003); and Bernard Lightman, ed., *A Companion to the History of Science* (Oxford: Wiley Blackwell, 2016).

(11.) David Livingstone, *Putting Science in Its Place: Geographies of Scientific Knowledge* (Chicago: University of Chicago Press, 2003). As Livingstone notes (p. 13), his book focuses primarily on “science as we think of it in the West,” but adds “that should not be taken to imply that these are the only practices that warrant the name science.” It’s the step of integrating spheres and synthesizing narratives that remains a sticking point of the field. Also see, Peter Burke, *A Social History of Knowledge II From the Encyclopedie to Wikipedia* (Cambridge, UK: Polity Press, 2012).

(12.) Helen Tilley, “A Great (Scientific) Divergence: Fault Lines in the History of Science,” *Isis* (forthcoming 2019).

(13.) Karin Knorr Cetina, *Epistemic Cultures: How the Sciences Make Knowledge* (Cambridge, MA: Harvard University Press, 1999); and Karine Chemla and Evelyn Fox Keller, eds., *Culture Without Culturalism: The Making of Scientific Knowledge* (Durham, NC: Duke University Press, 2017).

(14.) Ali Mazrui, “The Re-Invention of Africa: Edward Said, V. Y. Mudimbe, and Beyond,” *Research in African Literatures* 36 (2005): 68–82, on p. 73. I largely omit from this essay Islamicate scientific traditions within Africa, but see Daniel Stolz, *The Lighthouse and the Observatory: Islam, Science, and Empire in Late Ottoman Egypt* (Cambridge, UK: Cambridge University Press, 2018); Ousmane Oumar Kane, *Beyond Timbuktu: An Intellectual History of Muslim West Africa* (Cambridge, MA: Harvard University Press, 2016); Rudolph Ware, *The Walking Qur’an: Islamic Education, Embodied Knowledge, and History in West Africa* (Chapel Hill: University of North Carolina Press, 2014); and Jane Murphy, “Islamicate Knowledge Systems: Circulation, Rationality, and Politics,” in *The Wiley Blackwell History of Islam*, ed. Armando Salvatore (London: Blackwell, 2018), 479–498.

(15.) Scholarship exploring circulating knowledge in the history of science could be put profitably in dialogue with anthropological and archaeological work on knowledge in motion; for example, James Secord, "Knowledge in Transit," *Isis* 95 (2004): 654–672; and Marwa Elshakry, "Knowledge in Motion: The Cultural Politics of Modern Science Translations in Arabic," *Isis* 99 (2008): 701–730, compared to Andrew Roddick and Ann Stahl, eds., *Knowledge in Motion: Constellations of Learning Across Time and Place* (Tucson: University of Arizona Press, 2016).

(16.) The "places and spaces" of science included in Lightman's companion volume are the university, the observatory, the court, academies and societies, museums and botanical gardens, domestic space, commercial science, the field, and the laboratory: Lightman, ed., *A Companion to the History of Science*. Good models for considering mobile spaces come from studies of sciences of "the field" and of those vectors that allow ideas, things, and people to circulate, such as ships, railways, cars, caravans, airplanes, telegraphs, satellites, phones, and so on.

(17.) These professional categories are admittedly inadequate since they are English equivalents, but in the spirit of dialogue across continents and regions they will do for now. For citations dealing with alchemy, artisans (and other craftspeople), and invisible technicians in early modern Europe, see below.

(18.) In his 1925 book, Edwin A. Burttt wrote of a metaphysical and intellectual revolution in science and is sometimes credited with originating the term "scientific revolution," but that distinction goes to Koyré who used it in his 1939 book *Études Galiléennes* and then more widely in the 1940s, and to Herbert Butterfield who popularized it in his 1949 survey: see Edwin A. Burttt, *The Metaphysical Foundations of Modern Science* (London: Kegan Paul, 1925); Alexander Koyré, *Études Galiléennes* (Paris: Hermann, 1939); Alexander Koyré, "Galileo and the Scientific Revolution of the Seventeenth Century," *Philosophical Review* 52 (1943): 333–348; Alexander Koyré, *From the Closed World to the Infinite Universe* (Baltimore: Johns Hopkins Press, 1957); Alexander Koyré, *Metaphysics and Measurement: Essays in Scientific Revolution* (Cambridge, MA: Harvard University Press, 1968); and Herbert Butterfield, *The Origins of Modern Science, 1300–1800* (London: Bell, 1949). Also see Edgar Zilsel, *The Social Origins of Modern Science* (Boston: Kluwer Academic Publishers, 2000), a compilation of his essays; A. Rupert Hall, *The Scientific Revolution, 1500–1800* (London: Longmans Green, 1954); and Thomas Kuhn, *The Copernican Revolution* (Cambridge, MA: Harvard University Press, 1957).

(19.) The literature on these subjects is vast; in addition to texts already cited, see Steven Shapin and Simon Schaffer, *The Leviathan and the Air-Pump: Hobbes, Boyle, and the Experimental Life* (Princeton, NJ: Princeton University Press, 1986); Roy S. Porter, "The Scientific Revolution—A Spoke in the Wheel," in *Revolution in History*, ed. Roy S. Porter and Mikuláš Teich (Cambridge, UK: Cambridge University Press, 1986), 290–316; David Linberg and Robert Westman, eds., *Reappraisals of the Scientific Revolution* (Cambridge, UK: Cambridge University Press, 1990); I. Bernard Cohen, ed., *Puritanism and the Rise of Modern Science: The Merton Thesis* (New Brunswick, NJ: Rutgers University Press,

1990); Mario Biagioli, *Galileo, Courtier* (Chicago: University of Chicago Press, 1993); H. Floris Cohen, *The Scientific Revolution: A Historiographical Guide* (Chicago: University of Chicago Press, 1994); Steven Shapin, *A Social History of Truth: Civility and Science in Seventeenth Century England* (Chicago: University of Chicago Press, 1994); Steven Shapin, *The Scientific Revolution* (Chicago: University of Chicago, 1996); Peter Dear, *Revolutionizing the Sciences: European Knowledge and Its Ambitions* (Princeton, NJ: Princeton University Press, 2001). Pamela Smith, *The Body of the Artisan: Art and Experience in the Scientific Revolution* (Chicago: University of Chicago Press, 2004); Deborah Harkness, *The Jewel House: Elizabethan London and the Scientific Revolution* (New Haven, CT: Yale University Press, 2008); and Lawrence Principe, *The Scientific Revolution: A Very Short Introduction* (Oxford: Oxford University Press, 2011).

(20.) Anthony Grafton with April Shelford and Nancy Siraisi, *New Worlds, Ancient Texts: The Power of Tradition and the Shock of Discovery* (Cambridge, MA: Belknap Press, 1992); Richard Grove, *Green Imperialism: Colonial Expansion, Tropical Island Edens, and the Origins of Environmentalism, 1600–1860* (Cambridge, UK: Cambridge University Press, 1996); Richard Drayton, *Nature's Government: Science, Imperial Britain, and the "Improvement" of the World* (New Haven, CT: Yale University Press, 2000); Jorge Cañizares-Esguerra, *Nature, Empire, and Nation: Explorations in the History of Science in the Iberian World* (Palo Alto, CA: Stanford University Press, 2006); Neil Safier, *Measuring the New World: Enlightenment Science and South America* (Chicago: University of Chicago Press, 2008); Hal Cook, *Matters of Exchange: Commerce, Medicine, and Science in the Dutch Golden Age* (New Haven, CT: Yale University Press, 2007); Kapil Raj, *Relocating Modern Science: Circulation and Construction of Knowledge in South Asia and Europe, 1650–1900* (London: Palgrave Macmillan, 2007); James Delbourgo and Nicholas Dew, eds., *Science and Empire in the Atlantic World* (New York: Routledge, 2009); Simon Schaffer et al., *The Brokered World: Go-Betweens and Global Intelligence* (Sagamore Beach, MA: Science History Publications, 2009); Antonio Barrera-Osorio, *Experiencing Nature: The Spanish American Empire and the Early Scientific Revolution* (Austin: University of Texas, 2010); and Daniel Margócsy, *Commercial Visions: Science, Trade, and Visual Culture in the Dutch Golden Age* (Chicago: University of Chicago Press, 2014).

(21.) William Whewell coined the term "scientist" in 1834 in an anonymous review of Mary Somerville's *On the Connexion of the Physical Sciences*; it gained a wider audience only after he used it in his history of the inductive sciences in 1837. For an explication of the terms science, scientific knowledge, and scientist, see Sydney Ross, "Scientist: The Story of a Word," *Annals of Science* 18 (1962): 65–85; for a broader analysis see Richard Yeo, *Defining Science: William Whewell, Natural Knowledge, and Public Debate in Early Victorian Britain* (Cambridge, UK: Cambridge University Press, 1993). On the concept of "Western science" see, Marwa Elshakry, "When Science Became Western: Historiographical Reflections," *Isis* 101 (2010): 98–109. On popularization of science, see Bernard Lightman, *Victorian Popularizers of Science: Designing Nature for New*

*Audiences* (Chicago: University of Chicago Press, 2007); and on the enduring boundary work that went into policing who counts as a “scientist” and what constituted science, see Melinda Baldwin, *Making “Nature”: The History of a Scientific Journal* (Chicago: University of Chicago Press, 2015).

(22.) On historicity from a variety of relevant vantage points, see Dipesh Chakrabarty, *Provincializing Europe: Post-Colonial Thought and Historical Difference* (Princeton, NJ: Princeton University Press, 2000); Neil Whitehead, ed., *Histories and Historicities in Amazonia* (Lincoln: University of Nebraska Press, 2003); and Tom Rockmore and Joseph Margolis, eds., *History, Historicity, and Science* (New York: Routledge, 2016).

(23.) You would hardly guess from consulting recent origin stories and “global” surveys that there existed rich literatures on science, technology, and medicine in Latin America, the Caribbean, Africa, the Middle East, Asia, and the Indian and Pacific oceans. This scholarship has helped explain how these regions mattered to key developments in the history of science. When ignored, it tends to lead historians to generalize about “global” dynamics in misleading and distorting ways. I have already cited companion volumes for the history of science in endnote 2; for the sparse or uneven treatments of these parts of the world, see David Wooton, *The Invention of Science: A New History of the Scientific Revolution* (New York: Harper Collins, 2015); James McClennan and Harold Dorn, *Science and Technology in World History*, 3rd ed. (Baltimore: Johns Hopkins University, 2015); and Jon Agar, *Science in the Twentieth Century and Beyond* (Cambridge, UK: Polity Press, 2012).

(24.) Steven Feierman, “African Histories and the Dissolution of World History,” in *Africa and the Disciplines*, ed. Robert Bates, Valentin-Yves Mudimbe, and Jean O’Barr (Chicago: University of Chicago Press, 1993), 167–212; Frederick Cooper, “What Is the Concept of Globalization Good For? An African Historian’s Perspective,” *African Affairs* 100 (2001): 189–213; Achille Mbembe and Sarah Nuttall, “Writing the World from an African Metropolis,” *Public Culture* 16 (2004): 347–372; Megan Vaughan, “Africa and the Birth of the Modern World,” *Transactions of the Royal Historical Society* 16 (2006): 143–162; James Ferguson, *Global Shadows: Africa and the Neoliberal World* (Durham, NC: Duke University Press, 2006), especially chapter 2 on globalization; Gareth Austin, “Reciprocal Comparison and African History: Tackling Conceptual Euro-Centrism in the Study of Africa’s Economic Past,” *African Studies Review* 50 (2007): 1–28; and David Serlin, “Confronting African Histories of Technology: A Conversation with Keith Breckinridge and Gabrielle Hecht,” *Radical History Review* 127 (2017): 87–102. For an additional discussion of these trends and how they are being inverted, see Jean Comaroff and John Comaroff, *Theory From the South: Or How Euro-America is Evolving Toward Africa* (London: Routledge, 2016 [2012]).

(25.) Cheikh Anta Diop, *The African Origin of Civilization: Myth or Reality* (Chicago: Lawrence Hill, 1974); and Martin Bernal, *Black Athena: The Afroasiatic Roots of Classical Civilization*, vol. 1: *The Fabrication of Ancient Greece* (New Brunswick, NJ: Rutgers

University Press, 1987). Cheikh Anta Diop, Senegalese philosopher, physical scientist, and historian, worked out these ideas before Bernal's *Black Athena* appeared in two books in French that Diop published with *Présence Africaine* in 1955 and 1967.

(26.) My invocation of reorient is indebted to Andre Gunder Frank, *ReOrient: Global Economy in the Asian Age* (Berkeley: University of California Press, 1998), who is making a strong case that European preeminence in economic history has been exaggerated.

(27.) Readers who wish to get more quickly to the thematic discussion of topics that cover a longue durée can move to the next section; this section offers food for thought, especially for those just beginning to think about the history of science.

(28.) Livingstone, *Putting Science in Its Place*; Crosbie Smith and Jon Agar, *Making Space for Science: Territorial Themes in the Shaping of Knowledge* (Basingstoke: Macmillan, 1998); Adi Ophir and Steven Shapin, "The Place of Knowledge: A Methodological Survey," *Science in Context* 4 (1991): 3–21; Clifford Geertz, *Local Knowledge: Further Essays in Interpretive Anthropology* (New York: Basic Books, 1983); and Donna Haraway, "Situated Knowledges: the Science Question in Feminism and the Privilege of the Partial Perspective," *Feminist Studies* 14 (1988): 575–599.

(29.) Among others see, Neil Kodesh, *Beyond the Royal Gaze: Clanship and Public Healing in Buganda* (Charlottesville: University of Virginia Press, 2010), especially chapters 1 and 5; also Jane Guyer and Samuel Eno Belinga, "Wealth in People as Wealth in Knowledge: Accumulation and Composition in Equatorial Africa," *Journal of African History* 36 (1995): 91–120.

(30.) Historians and sociologists of science have long been preoccupied with how professional, institutional, and disciplinary borders (and objects) are policed and regulated, for example, Thomas Gieryn, "Boundary-Work and the Demarcation of Science from Non-Science: Strains and Interests in Professional Ideologies of Scientists," *American Sociological Review* 48(1983): 781–795; Thomas Gieryn, *Cultural Boundaries of Science: Credibility on the Line* (Chicago: University of Chicago Press, 1999); and Susan Leigh Star and James Griesemer, "Institutional Ecology, 'Translations,' and Boundary Objects," *Social Studies of Science* 19 (1989): 387–420.

(31.) Nancy Jacobs, *Birders of Africa: History of a Network* (New Haven, CT: Yale University Press, 2016); and Lyn Schumaker, *Africanizing Anthropology: Fieldwork, Networks, and the Making of Cultural Knowledge in Central Africa* (Durham, NC: Duke University Press, 2001).

(32.) I am here paraphrasing and extending a point Megan Vaughan made about medical professionals: Megan Vaughan, *Curing Their Ills: Colonial Power and African Illness* (Cambridge, UK: Polity Press, 1991), 25.

(33.) For an extended rumination on matters of mixture, impurity, and contamination, see Anthony Appiah, *Cosmopolitanism: Ethics in a World of Strangers* (New York: Norton and Company, 2006).

(34.) Fassin's analysis of the moving parts of the controversy—historical, political, economic, epistemological, and professional—and his insistence on avoiding theoretical traps serve as a useful model: Didier Fassin, *When Bodies Remember: Experiences and Politics of AIDS in South Africa* (Berkeley: University of California, 2007), especially chapters 2 and 3.

(35.) Fassin only touches on this point, which is more fully developed in Karen Flint, *Healing Traditions: African Medicine, Cultural Exchange, and Competition in South Africa, 1820–1948* (Athens: Ohio University Press, 2008), 187–191.

(36.) I have myself received this question periodically in the United States, and such questioners tend to suggest that African history must be sufficiently different from, say, European or U.S. history to justify its existence as an object of study. For a recent exploration, see Valentin Mudimbe, *On African Fault Lines: Meditations on Alterity Politics* (Durban: University of Kwazulu-Natal Press, 2013).

(37.) Janus, *Lagos Standard* (June 19, 1907), 4. The search for commensurable concepts around disease can be seen in Edward Green, *Indigenous Theories of Infectious Disease* (London: AltaMira Press, 1999).

(38.) For trading zones, see Peter Galison, *Image and Logic: A Material Culture of Microphysics* (Chicago: University of Chicago Press, 1997). Galison is building upon literature from anthropology about trade and exchange.

(39.) We should hardly be surprised that as disciplines, experts, and institutions proliferate, it generates new kinds of professionals and new classes or categories of knowledge; my thinking here has been influenced by Ian Hacking, "The Looping Effects of Human Kinds," in *Causal Cognition: A Multidisciplinary Debate*, ed. Dan Sperber et al. (Oxford: Clarendon Press, 1996), 351–383; and Ian Hacking, *Representing and Intervening: Introductory Topics in the Philosophy of Natural Science* (Cambridge, UK: University of Cambridge Press, 1983). Hacking taught philosophy for three years, between 1967 and 1969, in Uganda at Makerere.

(40.) My language here is indebted to David Schoenbrun, "Conjuring the Modern in Africa: Durability and Rupture in Histories of Public Healing between the Great Lakes of Africa," *American Historical Review* 111 (2006): 1403–1439. These issues form the subject of my current book manuscript, with the working title *The Wisdom of the Peoples: African Decolonization, Global Governance, and Cold War Constructions of Traditional Medicine*.

(41.) Helen Tilley, "Global Histories, Vernacular Science, and African Genealogies," *Isis* 101 (2010): 110–119; and Helen Tilley, *Africa as a Living Laboratory: Empire, Development, and the Problem of Scientific Knowledge* (Chicago: University of Chicago Press, 2011).

(42.) Scholarship on entanglements in material cultures, therapeutics, and science is vast. I take the idea of braiding from Projit Mukharji, *Doctoring Traditions: Ayurveda, Small Technologies, and Braided Sciences* (Chicago: University of Chicago Press, 2016).

(43.) Murray Last, "The Importance of Knowing about Not-Knowing: Observations from Hausaland," in *The Social Basis of Health and Healing in Africa*, ed. Steven Feierman and John Janzen (Berkeley: University of California Press, 1992), 393–408.

(44.) Steven Feierman has raised these issues persistently in African history: Steven Feierman, "Healing as Social Criticism in the Time of Colonial Conquest," *African Studies Review* 54 (1995): 73–88; Steven Feierman, "Colonizers, Scholars, and the Creation of Invisible Histories," in *Beyond the Cultural Turn*, ed. Victoria Bonnell and Lynn Hunt (Berkeley: University of California Press, 1999), 182–216; and Steven Feierman, "Marginality and Invisibility in African Medical Practice," unpublished paper for "Knowledge, Domination, and the Public in Africa," March 2011, Dahlem Conference, Berlin, Germany.

(45.) It is worth pointing out that scholars in African studies and science studies have developed literatures on these subjects often without much dialogue; for additional references in the history of science, see contributions to Robert Proctor and Londa Schiebinger, eds., *Agnology: the Making and Unmaking of Ignorance* (Palo Alto, CA: Stanford University Press, 2008); and Koen Vermier and Daniel Margocsy, eds., "Special Issue: States of Secrecy," *British Journal for the History of Science* 45 (2012): 153–280.

(46.) This section covers a modest number of works by historians and anthropologists to illustrate a set of wider points about enduring patterns. I have elected to include certain material—on fractals—that has not yet become integral to African history because I think it is a conversation worth having. For further background on some of these issues, see the special issue by Kai Kresse and Trevor Marchand, eds., "Knowledge in Practice: Expertise and the Transmission of Knowledge," *Africa* 79, no. 1 (2009): 1–167; Ron Eglash and Audrey Bennett, eds., "Special Issue: Fractals in Global Africa," *Critical Interventions: Journal of African Art History and Visual Culture* 6 (2012): 4–172; Jane Guyer, "Traditions of Invention in Equatorial Africa," *African Studies Review* 39 (1996): 1–28; and Jane Guyer, "Africa Has Never Been 'Traditional': So Can We Make a General Case?" *African Studies Review* 50 (2007): 183–202.

(47.) In addition to sources already cited, see James Sweet, *Domingos Álvares, African Healing, and the Intellectual History of the Atlantic World* (Chapel Hill: University of North Carolina, 2011); Judith Carney, *Black Rice: the African Origins of Rice Cultivation in the Americas* (Cambridge, MA: Harvard University Press, 2002); Londa Schiebinger, *The Secret Cures of Slaves: People, Plants, and Medicine in the Eighteenth Century Atlantic World* (Palo Alto, CA: Stanford University Press, 2017); and Andrew Sluyter, *Black Ranching Frontiers: African Cattle Herders in the Atlantic World, 1500–1900* (New Haven, CT: Yale University Press, 2012). For an Indian Ocean example, see Megan Vaughan, *Creating the Creole Island: Slavery in Eighteenth Century Mauritius* (Durham, NC: Duke University Press, 2005).

(48.) Pablo Gomez, *The Experiential Caribbean: Creating Knowledge and Healing in the Early Modern Atlantic World* (Chapel Hill: University of North Carolina Press, 2017).

(49.) Eugenia Herbert, *Red Gold of Africa: Copper in Precolonial History and Culture* (Madison: University of Wisconsin Press, 1984), 32.

(50.) Jan Vansina, “Linguistic Evidence for the Introduction of Ironworking into Bantu-Speaking Africa,” *History in Africa* 33 (2006): 321–361, quotations on p. 354; also see pp. 335–336.

(51.) Mathew Schoffeleers, “Folk Christology in Africa: The Dialectics of the *Nganga* Paradigm,” *Journal of Religion in Africa* 19 (1989): 157–183; and Stephan Palmié, “Thinking with Ngangas: Reflections on Embodiment and the Limits of ‘Objectively Necessary Appearances,’” *Comparative Studies in Society and History* 48 (2006): 852–886.

(52.) Peter Schmidt, “Science in Africa: A History of Ingenuity and Invention in African Iron Technology,” in *A Companion to African History*, ed. William Worger (New York: Wiley-Blackwell, 2018), 267–288; and Peter Schmidt, *Iron Technology in East Africa: Symbolism, Science, and Archaeology* (Bloomington: Indiana University Press, 1997).

(53.) I am indebted to David Schoenbrun for this point, which deserves more attention than I can give it here.

(54.) On the historical use, including strengths and limitations, of the qualifier “vernacular” see Suzanne Preston Blier, “Vernacular Architecture,” in *Handbook of Material Culture*, ed. Christopher Tilley et al. (London: SAGE, 2006), 230–253. As she points out (p. 231), “Those who study these architectural exemplars . . . must seek to understand an array of factors—local theories concerning the natural world, taxonomies of thought, ancillary arts and ritual—among other factors.”

(55.) Steven Nelson, *From Cameroon to Paris: Mousgoum Architecture In and Out of Africa* (Chicago: University of Chicago Press, 2007). To extend the metaphor of texts, it bears noting that scholars’ different tools yield different interpretations.

(56.) Trevor Marchand, *The Masons of Djenné* (Bloomington: Indiana University Press, 2009). Also see James Morris (photographs) and Suzanne Preston Blier (text), *Butabu: Adobe Architecture of West Africa* (Princeton, NJ: Princeton University Press, 2004).

(57.) Jean-Louis Bourgeois, "The History of the Great Mosques of Djenné," *African Arts* 20 (1987): 54–63 and 90–92. Bourgeois explains how Malians became convinced that the mosques' designs were inspired by French engineers rather than indigenous experts, a view that had its roots in an effort led by Sekou Amadou in the 1820s and 1830s to conceal its true history, which allowed French rulers in the 1890s to build upon misinformation: "As time went on, history rewritten probably shifted from conscious deception to unconscious self-deception—from Africans' saying that the French built the mosque to their believing that they did" (p. 62).

(58.) For an analogous example dealing with pottery and the women who produce it, see Olivier Gosselein, "The World Is Like a Beanstalk: Historicizing Potting Practice and Social Relations in the Niger River Area," in *Knowledge in Motion: Constellations of Learning Across Time and Place*, ed. Andrew Roddick and Ann Stahl (Tucson: University of Arizona Press, 2016), 36–66. My thanks to David Schoenbrun for this reference.

(59.) Trevor Marchand, "Negotiating License and Limits: Expertise and Innovation in Djenné's Building Trade," *Africa* 79 (2009): 71–91, quotations on pp. 74, 76–78. Labelle Prussin, one of the forerunners of African architectural studies, made similar points following her fieldwork in the West African savannah about designers' technical precision; Labelle Prussin, "An Introduction to Indigenous African Architecture," *Journal of the Society of Architectural Historians* 33 (1974): 182–205.

(60.) I choose these dates based on Bourgeois' judicious historical reconstruction; he lists 1818 as a point when the main mosque was known to have been refinished: Bourgeois, "The History of the Great Mosques," 54.

(61.) Shadrek Chirikure, "Motion with Caution: Jan Vansina and the Last Two Thousand Years of the Southern African Past," *History in Africa* 45 (2018): 113–129, esp. 123–125.

(62.) The literature on Great Zimbabwe is vast and still growing; I am using "Shona" here advisedly, as the label for one of the three broad linguistic groups in the region did not consolidate until the 18th century. These details come from Peter Garlake, *Early Art and Architecture of Africa* (Oxford: Oxford University Press, 2002), chapter 7, "Great Zimbabwe and the Southern African Interior"; and Herbert, *Red Gold of Africa*, 107.

(63.) Garlake, *Early Art and Architecture of Africa*, 151 and 153–154.

(64.) Gloria Emeagwali and Edward Shizha, eds., *African Indigenous Knowledge and the Sciences: Journeys into the Past and Present* (Rotterdam: Sense Publishers, 2016), x.

(65.) Thomas Huffman quoted in David Beach, "Cognitive Archaeology and Imaginative History at Great Zimbabwe," *Current Anthropology* 39 (2009): 47–72, on p. 49.

(66.) For a history of colonial misinterpretations, see Henrika Kuklick, "Contested Monuments: The Politics of Archaeology in Southern Africa," in *Colonial Situations: Essays on the Contextualization of Ethnographic Knowledge*, ed. George Stocking (Madison: University of Wisconsin Press, 1991), 135–170.

(67.) Thomas Huffman, "The Soapstone Birds of Great Zimbabwe," *African Arts* 18 (1985): 68–100; Thomas Huffman, *Snakes and Crocodiles: Power and Symbolism in Ancient Zimbabwe* (Johannesburg: Witswatersrand University Press, 1996). There is a long-standing interest in forms of patriotic science, and I am just extending this point here; for an influential example, see Jorge Cañizares-Esguerra, *Nature, Empire, and Nation: Explorations of the History of Science in the Iberian World* (Palo Alto, CA: Stanford University Press, 2006), especially chapter 4.

(68.) Beach, "Cognitive Archaeology," 60.

(69.) Terence Ranger, "Nationalist Historiography, Patriotic History and the History of the Nation: The Struggle over the Past in Zimbabwe," *Journal of Southern African Studies* 30 (2004): 215–234; and Edward Matenga, *The Soapstone Birds of Great Zimbabwe: Symbols of a Nation* (Harare, Zimbabwe: African Publishing Group, 1998).

(70.) Joost Fontein, *The Silence of Great Zimbabwe: Contested Landscapes and the Power of Heritage* (London: University College London Institute of Archaeology, 2006); for an overview of relationships between cultural and intellectual property, see Rosemary Coombe, "Frontiers of Cultural Property in the Global South," in *The Routledge Companion to Cultural Property*, ed. Jane Anderson and Haidy Geismar (New York: Routledge, 2017), chapter 19.

(71.) Michael Gordin, *Scientific Babel: How Science Was Done Before and After Global English* (Chicago: University of Chicago Press, 2015); and Michael Gordin, ed., "Focus Section: Linguistic Hegemony and the History of Science," *Isis* 108 (2017): 606–650.

(72.) In *Scientific Babel* (p. 295), Gordin plays down the role of British and U.S. empire-building to the rise of “global English,” pointing out that English’s spread largely took off following the Second World War and that non-native speakers’ choices to publish in English also played a crucial role. I take his points but see imperial structures (including those that fed into international organizations and scientific congresses) as necessary and formative. English-speaking empires seeded a language for science in the very laws and institutional infrastructures of colonial states. The British Commonwealth today—excluding the United States and its former imperial holdings—comprises 53 member states and totals close to a third of the world’s population. Political independence led people to challenge linguistic dynamics, but few states reverted to a different language for science, no matter how hard advocates pressed them to. For a significant case study on languages of science in South Asia, see Andrew Amstutz, “The Language of Science: Urdu and the Making of Muslim Politics in Modern South Asia” (PhD diss., Cornell University, 2017); on colonialism and African languages, Johannes Fabian, *Language and Colonial Power: The Appropriation of Swahili in the Former Belgian Congo, 1880–1938* (Berkeley: University of California Press, 1991); and Sara Pugach, *Africa in Translation: A History of Colonial Linguistics in Germany and Beyond, 1814–1945* (Ann Arbor: University of Michigan Press, 2012). And on the question of “national” languages, see Andrew Simpson, ed., *Language and National Identity in Africa* (Oxford: Oxford University Press, 2008).

(73.) A search for cognates takes us quickly into other ordering concepts, so that knowledge slots into a wider framework. Another dimension of this has to do with languages of science instruction, which has experienced both winnowing and expansion over the last century.

(74.) I base these translations on Church Missionary Society, *Dictionary of Yoruba Language* (Lagos, Nigeria: CMS Library, 1913); and Roy C. Abraham, *Dictionary of Modern Yoruba* (London: University of London, 1958). On systems of ethics among *onísègun* (a set of healers), including the way they distinguish between knowledge (*imo*) and belief (*igbagbo*), see Barry Hallen, *The Good, the Bad, and the Beautiful: Discourses about Values in Yoruba Culture* (Bloomington: University of Indiana, 2000).

(75.) Garlake, *Early Art and Architecture of Africa*, 135–136.

(76.) Suzanne Blier, *Art and Risk in Ancient Yoruba: Ife History, Power, and Identity c. 1300* (Cambridge, UK: Cambridge University Press, 2015).

(77.) Henry John Drewel, John Pemberton III, and Rowland Abiodun, “The Yoruba World,” in *Yoruba: Nine Centuries of African Art and Thought*, ed. Allen Wardwell (New York: Center for African Art and Harry Abrams, 1989), 13–44, diagram on p. 14.

(78.) For an example in medical anthropology, see Annemarie Mol, *The Body Multiple: Ontology in Medical Practice* (Durham, NC: Duke University Press, 2003); for a recent review that exempts medicine, but includes STS, see Martin Holbraad and Morten Axel Pedersen, *The Ontological Turn: An Anthropological Exposition* (Cambridge, UK: Cambridge University Press, 2017); and for a study of ontology and African healing, see Stacey Langwick, *Bodies, Politics, and African Healing: the Matter of Maladies in Tanzania* (Bloomington: Indiana University Press, 2011).

(79.) Different kinds of shape-shifting, with deities and spirits, respectively, are on display in Jean Allman and John Parker, *Tongnaab: The History of a West African God* (Bloomington: Indiana University Press, 2005); and David Gordon, *Invisible Agents: Spirits in a Central African History* (Athens: Ohio University Press, 2012).

(80.) Sandra Barnes, ed., *Africa's Ogun: Old World and New; Second, Expanded Edition* (Bloomington: Indiana University Press, 1997).

(81.) Sandra Barnes, "The Many Faces of Ogun: Introduction to the First Edition," in *Africa's Ogun*, ed. Barnes, 18.

(82.) Sandra Barnes and Paula Girshick Ben-Amos, "Ogun, the Empire Builder," in *Africa's Ogun*, ed. Barnes, 57.

(83.) Henry John Drewel, "Art or Accident: Yoruba Body Artists and Their Deity Ogun," in *Africa's Ogun*, ed. Barnes, 238.

(84.) Robert Armstrong, "The Etymology of the Word 'Ògún,'" in *Africa's Ogun*, ed. Barnes, 29–38.

(85.) John Mason, "Ògún: Builder of the Lùkùmí's House," in *Africa's Ogun*, ed. Barnes, 353.

(86.) Ron Eglash, *African Fractals: Modern Computing and Indigenous Design* (New Brunswick, NJ: University of Rutgers Press, 1999).

(87.) The operative word here is "calculations," as Eglash's most significant example rests in binary divination practices; as he and other specialists in mathematics are aware, many other base systems (3, 4, 5, 10, 12, 20) also exist across Africa. See Claudia Zaslavsky, *Africa Counts: Number and Pattern in African Cultures*, 3rd ed. (Chicago: Lawrence Hill Books, 1999); George Joseph, *The Crest of the Peacock: Non-European Roots of Mathematics*, 3rd ed. (Princeton, NJ: Princeton University Press, 2011); Helen Verran, *Science and an African Logic* (Chicago: University of Chicago Press, 2001), chapter 3 (on base-20 systems among Yoruba); and William Bascom, *Ifa Divination: Communication Between Gods and Men in West Africa* (Bloomington: Indiana University Press, 1969), on the way Ifá divination techniques rest on interpreting patterns based on a binary system (marks of I and II) to generate 16 figures and 256 verses (2 to the power of 8, or 16 to the power of 2).

(88.) Eglash, *African Fractals*, 99–101. Eglash, and others, trace Leibniz’s interest in binary systems to Ramon Llull (*ca.* 1232–1316), whom Leibniz acknowledged in his 1666 dissertation. Llull’s base-2 system derived from geomancy that had roots in the African continent, given his multiple visits. On Leibniz’s binary mathematics, see Florian Cajori, “Leibniz’s ‘Image of Creation,’” *The Monist* 26 (1916): 557–565.

(89.) Leibniz to Duke Rudolph, January 2, 1697, quoted in Cajori, “Leibniz’s ‘Image of Creation,’” 561–562. Leibniz saw “primitive states” or concepts as being like prime numbers, indissoluble and therefore closer to God; for an explication, see Dennis Plaisted, “Leibniz’s Argument for Primitive Concepts,” *Journal of the History of Philosophy* 41 (2003): 329–341. On Leibniz’s ethnographic interests, see Han Vermeulen, *Before Boas: The Genesis of Ethnography and Ethnology in the German Enlightenment* (Lincoln: University of Nebraska Press, 2015), chapter 2. On Leibniz and China, see Franklin Perkins, *Leibniz and China: A Commerce of Light* (Cambridge, UK: Cambridge University Press, 2004). By the late 17th century, Leibniz described God as unity and everything beyond God as “nothing or privation,” which he later described as “unity with zero, that is the positive with the privative.” See Maria Rosa Antognazza, *Leibniz: An Intellectual Biography* (Cambridge, UK: Cambridge University Press, 2009), 359 and 435.

(90.) Alfred Bower Taylor, *Report on Weights and Measures* (Boston: Rand and Avery, 1859), 34–35.

(91.) R. C. Oliver quoted in Helen Tilley, *Africa as a Living Laboratory*, 247, and chapter 5, “A Racial Laboratory.”

(92.) There is a vast literature on colonial rule and education in Kenya as well as Gikuyu/Kikuyu groups; for one intervention that highlights the fight over pedagogy, see Theodore Natsoulas, “The Kenyan Government and the Kikuyu Independent Schools: From Attempted Control to Suppression, 1929–1952,” *The Historian* 60 (1998): 289–305; and for a study of literacy and cultural knowledge production, see Derek Petersen, *Creative Writing: Translation, Bookkeeping, and the Work of Imagination in Colonial Kenya* (Portsmouth, NH: Heinemann, 2004).

(93.) Saul Dubow’s studies of southern Africa offer a wonderful point of departure for understanding histories of racial science, on the one hand, and how cultures of science helped craft racial identities of belonging (and exclusion), on the other: Saul Dubow, *A Commonwealth of Knowledge: Science, Sensibility, and White South Africa, 1820–2000* (Oxford: Oxford University Press, 2006); and Saul Dubow, *Scientific Racism in Modern South Africa* (Cambridge, UK: Cambridge University Press, 1995). On “racial” thinking (as distinct from “science”), see Jonathon Glassman, “Ethnicity and Race in African Thought,” in *A Companion to African History*, ed. William Worger et al. (New York: Wiley-Blackwell, 2018), 199–224.

(94.) Interestingly, both Jane Guyer and Ron Eglash write about “information societies,” but for different reasons and in different contexts. Guyer, “Traditions of Invention,” 2; and Eglash, *African Fractals*, passim. Although it might seem anachronistic to use such a phrase, there is a need to capture how people transmitted complex information relating to political and social genealogies, details about the natural world and health, and literary corpuses across generations.

(95.) Philip Peek, ed., *African Divination Systems: Ways of Knowing* (Bloomington: University of Indiana, 1991); it is worth pointing out that this book preceded by a decade John Pickstone’s wonderful synthesis of “Western” scholarship, *Ways of Knowing: A New History of Science, Technology, and Medicine* (Chicago: University of Chicago Press, 2001).

(96.) Martin Hollis and Steven Lukes, eds., *Rationality and Relativism* (Cambridge, MA: MIT Press, 1982).

(97.) My analysis here is indebted to the ongoing research of Colin Bos, “John Augustus Abayomi Cole and the Search for an African Science, 1886-1898” (unpublished research paper, Northwestern University, May 2017). The dialogic nature of these arguments deserves much closer scrutiny; Cole, for instance, may have explored mathematical subjects while working with his instructor, Adolphus Mann (who first drew attention to Yoruba “numeral systems”); Cole also played a role in heated debates within Freetown in the 1880s and early 1890s about his (and others’) role as local healers and agriculturalists.

(98.) See, for instance, David Schoenbrun, *A Green Place, A Good Place: Agrarian Change and Social Identity in the Great Lakes Region to the Fifteenth Century* (Portsmouth, NH: Heinemann, 1998); and for a fascinating study focused on more recent environmental changes, but which gestures to deeper pasts using an endogenous category, *doli* (a way of seeing and a body of knowledge) to anchor the story, see Tamara Giles-Vernick, *Cutting the Vines of the Past: Environmental Histories of the Central African Rain Forest* (Charlottesville: University of Virginia Press, 2002). Giles-Vernick rightly questions the label “indigenous knowledge” for her analysis, as *doli* captures a much broader set of phenomena and is far less instrumental.

(99.) Jan Vansina, *Paths in the Rainforest: Toward a History of Political Tradition in Equatorial Africa* (Madison: University of Wisconsin Press, 1990).

(100.) For a complementary analysis of a smaller subset of groups in Equatorial Africa, which uses game theory heuristically to unpack collective priorities and innovations, see Robert Harms, *Games Against Nature: An Eco-Cultural History of the Nunu of Equatorial Africa* (Cambridge, UK: Cambridge University Press, 1987). Harms explains his conceptual framing: “The game metaphor . . . allowed me to distinguish, in a systematic way, between different forms and different rates of change. Tactics can change rapidly. Strategies, which involve sequences of tactics, change more slowly. Rules change more slowly still. Slowest of all to change are the objective and goal of the game itself. Distinguishing among tactics, strategies, rules, and goals gave me a way of discussing complex changes in a series of related, yet distinct, societies in a systematic manner” (p. xvii).

(101.) Vansina, *Paths in the Rainforest*, 255–256, and 88–92. Vansina’s understanding of vernacular knowledge as science conforms to anthropologists’ assertions in the early 20th century that all people possess science; see Tilley, “Global Histories, Vernacular Science, and African Genealogies.”

(102.) Vansina, *Paths in the Rainforest*, 251 and passim.

(103.) Vansina, *Paths in the Rainforest*, 237.

(104.) Vansina, *Paths in the Rainforest*, 258–259.

(105.) In medical history, Nancy Hunt’s work explores some of these questions for the Congo in the 20th century: Nancy Hunt, *A Nervous State: Violence, Remedies, and Reverie in Colonial Congo* (Durham, NC: Duke University Press, 2016); and Nancy Hunt, *A Colonial Lexicon: Of Birth Ritual, Medicalization, and Mobility in the Congo* (Durham, NC: Duke University Press, 1999). On fragmentation and debris, see Ann Stoler, ed., *Imperial Debris: On Ruins and Ruination* (Durham, NC: Duke University Press, 2013).

(106.) Many African historians explore the shaping influences of colonial/state laws, including the codification of customary law, but few have yet explored the macro patterns I am invoking here; see Diana Jeater, *Law, Language, and Science: The Invention of the “Native Mind” in Southern Rhodesia, 1890–1930* (Portsmouth, NH: Heinemann, 2007); Dubow, *A Commonwealth of Science*, chapter 3; and Langwick, *Bodies, Politics, and African Healing*, chapter 2.

(107.) Even recent syntheses fail to appreciate the role of learned societies and the part they played in legal dynamics; see Steven Press, *Rogue Empires: Contracts and Conmen in Europe’s Scramble for Africa* (Cambridge, MA: Harvard University Press, 2017) and compare to chapter 2 of *Africa as a Living Laboratory*. More work on this front still needs to be done because it is clear that laws and procedures of partition were deeply tied to geographical expeditions and the findings of naturalists.

(108.) Bruno Carrière, "Le Transsaharien: histoire et géographie d'une entreprise inachevée," *Acta Geographica* 74 (1988): 23–38; and N. Broc, "Les Français face à l'inconnue saharienne: géographes, explorateurs, ingénieurs (1830–1881)," *Annales de Géographie* 535 (1987): 302–338; David Sunderland, ed., *Communication in Africa, 1880–1939*, 5 vols. (London: Pickering and Chatto, 2012); and Casper Anderson, *British Engineers and Africa, 1875–1914* (New York: Routledge, 2011).

(109.) Casual references to the Suez canal turning Africa into an island appeared periodically between 1869 and 1890; J. Clerk, "Suez Canal," *Fortnightly Review* 5, n.s. (1869): 80–100 and 206–225, 80; John F. Bateman, "Some Account of the Suez Canal," *Proceedings of the Royal Society* 18 (1869–70): 132–144, 142; Paul Soleillet, *Avenir de la France en Afrique* (Paris: Challamel Ainé, 1876), 57; and Arthur Silva White, *The Development of Africa*, 4.

(110.) Richard Grove, "The Island and the History of Environmentalism," in *Nature and Society in Historical Context*, ed. Mikulas Teich, Roy Porter, and Bo Gustafsson (Cambridge, UK: Cambridge University Press, 1997), 148–162; Gillian Beer, "Writing Darwin's Islands: England and the Insular Condition," in *Inscribing Science: Scientific Texts and the Materiality of Communication*, ed. Timothy Lenoir (Stanford, CA: Stanford University Press, 1998), 119–139; Rod Edmond and Vanessa Smith, eds., *Islands in History and Representation* (New York: Routledge, 2003); and John Gillis, *Islands of the Mind: How the Human Imagination Created the Atlantic World* (New York: Palgrave Macmillan, 2004).

(111.) Norbert Dournaux-Dupéré, "Le rôle de la France dans l'Afrique septentrionale," *Bulletin de la Société de Géographie* 6 (1873): 607–650, on p. 650; Dournaux-Dupéré was killed the following year on an expedition.

(112.) These figures are illustrative (rather than definitive) as they are from one library's collection; the countries surveyed include Britain, Germany, France, Italy, the Netherlands, Switzerland, and the United States, and the maps include those that were freely circulating as well as those published in geographical journals; 257 maps appeared between 1800 and 1859; 172 appeared in the 1860s; 236 appeared in the 1870s; 535 appeared in the 1880s; and 628 appeared in the 1890s. See Thomas Bassett and Yvette Scheven, eds., *Maps of Africa to 1900: A Checklist of Maps in Atlases and Geographical Journals in the Collections of the University of Illinois* (Urbana: University of Illinois, 2000).

(113.) "Old Maps of Africa," *Nature* (June 6, 1878): 149–151, on p. 149; for this earlier period, see Richard Betz, *The Mapping of Africa: a Cartobibliography of Printed Maps of the African Continent to 1700* (Brill: Hes and De Graf, 2007).

(114.) Oscar Norwich, *Maps of Africa: An Illustrated and Annotated Carto-Bibliography* (Cape Town: Donker, 1983); see 19th-century maps on pp. 176–208; the precedent for

leaving blanks on maps was set by the French cartographer J. B. B. d'Anville (1697–1782), p. 163.

(115.) Thomas Bassett, "Cartography and Empire Building in Nineteenth Century West Africa," *Geographical Journal* 84 (1994): 316–335.

(116.) James Grant to Sir Henry Rawlinson, April 13, 1876, in James A. Grant, RGS Correspondence Block 1871–80, Royal Geographical Society Archives, London. For a now dated, but empirically rich study, see Donald Simpson, *Dark Companions: The African Contribution to the European Exploration of East Africa* (New York: Harper and Row, 1975).

(117.) On patent controversies and their wider contexts, see Abena Osseo-Asare, *Bitter Roots: The Search for Healing Plants in Africa* (Chicago: University of Chicago Press, 2014); and Laura Foster, *Reinventing Hoodia: Peoples, Plants, and Patents in South Africa* (Seattle: University of Washington Press, 2017). A focus on controversies over profits and priority needs to be complemented with studies of patent claims that did not become controversial and that were not necessarily about profits.

(118.) Quotations and details from Olivier Loiseaux, "Regnauld de Lannoy de Bissy's Nineteenth Century Map of Africa at a Scale of 1: 2,000,000," *Cartographic Journal* 53 (2016): 282–293.

(119.) J. C. Stone, "Pioneer Geodesy: The Arc of the 30th Meridian in Former Northern Rhodesia," *Cartographic Journal* 13 (1976): 122–128; and J. C. Stone, *A Short History of the Cartography of Africa* (Lewiston, NY: Edwin Mellon Press, 1995).

(120.) Also relevant here are Thomas Bassett, "Indigenous Mapmaking in Inter-Tropical Africa," in *The History of Cartography*, ed. D. Woodward and M. Lewis (Chicago: University of Chicago Press, 1998), 24–48; and Thomas Bassett, "African Maps and Map-Making," in *Encyclopedia of the History of Science, Technology, and Medicine in Non-Western Cultures*, ed. H. Selin (Dordrecht: Kluwer, 1997), 554–558.

(121.) Julie MacArthur, *Cartography and the Political Imagination: Mapping Community in Colonial Kenya* (Athens: Ohio University Press, 2016). In spite of her focus, MacArthur engages surprisingly little with African historiographies of science and cartography, which seems a missed opportunity given the strength of her evidence.

(122.) Robyn d'Avignon, "Subterranean Histories: Making 'Artisanal' Miners on the West African Sahel," (PhD diss., University of Michigan, 2016); and Robyn d'Avignon, "Shelf Projects: The Political Life of Exploration Geology in Senegal," *Engaging Science, Technology and Society* 4 (2018): 111–130, quote on p. 112.

(123.) D'Avignon, "Subterranean Histories," 21.

(124.) Johannes Fabian, *Out of Our Minds: Reason and Madness in the Exploration of Central Africa* (Berkeley: University of California Press, 2000).

(125.) Edward Blyden, "Africa and the Africans," *Fraser's Magazine* 18 (1878): 178–196, on pp. 181–182; Herbert Spencer, ed., *Descriptive Sociology or Groups of Facts, African Races*, compiled by David Duncan (New York: Appleton, 1875).

(126.) Relevant here is also Johannes Fabian, *Time and the Other: How Anthropology Makes Its Object* (New York: Columbia University Press, 1983).

(127.) Fabian, *Out of Our Minds*, 275. Patrick Harries, *Butterflies and Barbarians: Swiss Missionaries and Systems of Knowledge in South-East Africa* (Oxford: James Currey Press, 2007).

(128.) This literature is burgeoning; see, for instance, Schumaker, *Africanizing Anthropology*; Helen Tilley with Robert Gordon, eds., *Ordering Africa: Anthropology, European Imperialism, and the Politics of Knowledge* (Manchester: Manchester University Press, 2007); Andrew Bank and Leslie Bank, eds., *Inside African Anthropology: Monica Wilson and Her Interpreters* (Cambridge, UK: Cambridge University Press, 2013). On economic knowledge, see (for newly independent Nigeria) Mary Morgan, "'On a Mission' with Mutable Mobiles," Working Paper on the Nature of Evidence: How Well Do Facts Travel?, no. 34/08, London School of Economics and University of Amsterdam (2008); Morten Jerven, *Poor Numbers: How We Are Misled by African Development Statistics and What We Can Do About It* (Ithaca, NY: Cornell University Press, 2013); Grace Davie, *A History of Poverty Knowledge in South Africa: A Social History of Human Science* (Cambridge, UK: Cambridge University Press, 2015); and Alden Young, *Transforming Sudan: Decolonization, Development, and State Formation* (Cambridge, UK: Cambridge University Press, 2018). For a recent contribution on psychiatry, see Matthew Heaton, *Black Skin, White Coats: Nigerian Psychiatrists, Decolonization, and the Globalization of Psychiatry* (Athens: Ohio University Press, 2013).

(129.) I discuss this as a pattern of "epistemic decolonization" in my book *Africa as a Living Laboratory*, but I hasten to add that this point should not be overdrawn both because different instruments of power—economic, political, and military—have a way of resurrecting stereotypes, myths, and inaccuracies, and also because changing theories can produce inaccuracies of their own.

(130.) Some of the leading examples are James Fairhead and Melissa Leach (with research collaboration with Dominique Millimouno and Marie Kamano), *Misreading the African Landscape: Society and Ecology in a Forest-Savanna Mosaic* (Cambridge, UK: Cambridge University Press, 1996); James Fairhead and Melissa Leach, *Reframing Deforestation—Global Analysis and Local Realities: Studies in West Africa* (London: Routledge, 1998); and Melissa Leach and Robin Mearns, eds., *The Lie of the Land: Challenging Received Wisdom on the African Environment* (London: James Currey, 1996). For a recent study of Northern Africa, see Diana Davis, *Resurrecting the Granary of Rome: Environmental History and French Colonial Expansion in North Africa* (Athens: Ohio University Press, 2007).

(131.) On this latter point, see Peter Howlett and Mary Morgan, eds., *How Well Do Facts Travel: The Dissemination of Reliable Information* (Cambridge, UK: Cambridge University Press, 2011); especially relevant in this context is Naomi Oreskes' chapter, "My Facts Are Better Than Your Facts."

(132.) Paul Richards, "'Alternative' Strategies for the African Environment: 'Folk Ecology' as a Basis for Community Oriented Agricultural Development," in *African Environment: Problems and Perspectives*, ed. Paul Richards (London: International African Institute, 1975), 102-117; and Paul Richards, *Ebola: How a People's Science Helped End an Epidemic* (London: Zed Books, 2016).

(133.) See, for instance, Frederick Cooper, "Development, Modernization, and the Social Sciences in the Era of Decolonization: The Examples of British and French Africa," *Revue d'Histoire de Sciences Humaines* 10 (2004): 9-38; Emmanuelle Sibeud, ed., "Décolonisation et sciences humaines," *Revue d'Histoire des Sciences Humaines* 24 (2011): 3-187; Gregory Mann, "Knowing the Postcolony: Sociology and Socialist Government in 1960s Mali," *La Fabrique des Savoirs en Afrique subsaharienne*, ed. Didier Nativel and Daouda Gary-Tounakara (Paris: Karthala, 2012), 91-108; and Gregory Mann, "Anti-Colonialism and Social Science: Georges Balandier, Madeira Keita, and 'the Colonial Situation' in French Africa," *Comparative Studies in Society and History* 55 (2013): 92-119.

(134.) Here the already cited work of Gabrielle Hecht and Robyn d'Avignon stands out for its rich evidence base and links to environmental politics; for a creative piece pointing to Cold War legacies, see Stacey Langwick, "From Non-Aligned Medicines to Market-Based Herbs: China's Shifting Relationship to Traditional Medicine in Tanzania," *Medical Anthropology* 29 (2010): 15-53.

(135.) Beyond works already cited by Laura Foster, Abena Osseo-Asare, and Morten Jerven, I would include Duana Fullwiley, *The Enculturated Gene: Sickle Cell Health Politics and Biological Difference in West Africa* (Princeton, NJ: Princeton University Press, 2011); Crystal Biruk, *Cooking Data: Culture and Politics in an African Research World* (Durham, NC: Duke University Press, 2018); and Noémi Tousignant, *Edges of Exposure: Toxicology and the Problem of Capacity in Postcolonial Senegal* (Durham, NC: Duke University Press, 2018). For a fictional account that brings an STS perspective on development into play, see Richard Rottenburg, *Far Fetched Facts: A Parable of Development Aid* (Cambridge, MA: MIT Press, 2009).

(136.) Robert Paarlberg, *Starved for Science: How Biotechnology Is Being Kept Out of Africa* (Cambridge, MA: Harvard University Press, 2008).

(137.) On improvisation and the limits of biomedicine, see Julie Livingston, *Improvising Medicine: An African Oncology Ward in an Emerging Epidemic* (Durham, NC: Duke University Press, 2012).

(138.) On polycentrism in the history of chemistry, see Emily Osborn, "From Bauxite to Cooking Pots: Aluminum, Chemistry, and West African Artisanal Production," *History of Science* 54 (2016): 425–442; and for an example that explores mobile technologies, see Francis Nyamnjoh, *Mobile Phones: The New Talking Drums of Everyday Africa* (Leiden: Langaa/African Studies Center Leiden, 2009).

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