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THEMATIC COLLECTION: STANDARDS & THEIR CONTAINERS ORIGINAL RESEARCH ARTICLE

Standards and Their Containers: Introduction to the Thematic Issue on Histories of Microbial Pathogens from the Colonial to the Postcolonial Eras

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Abstract

Standards and infrastructures have become ubiquitous objects of study in STS. They are critical to the global work of microbiology. However, the role of early twentieth-century colonial, military, and capitalist expansion in the production of these infrastructures is underappreciated. Further, the role of microbial "resistance" in shaping and changing the global microbiological order needs better elucidation. This requires connecting the technical work done in laboratories across the world with the global processes that have shaped much of the twentieth century. The articles in this thematic collection cast light on neglected temporal and geographic areas of human-microbial interactions, explore new ways of (re)reading historical sources to reveal (post)colonial distortions of scientific practice and acts of resistance, and underline the need to trace microbes and associated biomedical interventions not only within laboratories, but also within wider human and non-human environments.

Keywords

standardization; microbiology; vaccination; empire; colonialism

Introduction

The microbial cosmos is vast and unruly. On a daily basis, we encounter, play host to, and are shaped by billions of microbes – tiny entities including bacteria, fungi, and viruses – alongside their genes. The microbiota around and in us are subject to constant flux and their inhabitants are continuously evolving and exchanging new mechanisms to cope with, adapt to, and thrive in numerous environments (Kirchhelle, 2023a). Studying this profusion of life and information is challenging. Since the 1970s, a growing number of scholars from the fields of science and technology studies (STS), sociology, philosophy, anthropology, and history have developed sophisticated explanatory frameworks for how humans research, preserve, and manipulate individual microorganisms or wider microbial environments. Resulting insights have revolutionized humanities and social sciences research on the life sciences with the laboratory emerging as

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one of the most intensively studied sites of modern knowledge production. Iconic lab studies such as Bruno Latour's *The Pasteurization of France* (1988) and numerous historians of science, medicine, and technology have shed light on early microbiology and biotechnology around 1900 (Cunningham and Williams 1992; Hardy 2015; Pickstone 2000; Löwy 2011; Gradmann 2009; Chakrabarti 2012; Velmet 2020). Meanwhile, since the late 1990s, a substantial amount of ethnographic and STS enquiries have highlighted the complexities of studying and manipulating the microbial world from high-tech laboratories to artisanal cheese-making enterprises (Rabinow 2002; Helmreich 2003; Paxson 2008; Crane 2011; Brives and Froissart 2021).

This thematic collection aims to connect the "golden age" of microbiology in the early-twentieth century to the current age of global health, by making explicit the colonial, military, and capitalist provenance of much of the standards and infrastructures that have made possible the universalization of microbiological knowledge today. Scholars of public health and laboratory medicine have long underscored the role European colonial expansion has played in the construction of knowledge about the microbial world (Anderson 1998; Velmet 2020; Rogaski 2004; Bhattacharya et al. 2005). By contrast, research on the global spaces of microbiological research in the postcolonial era is less thorough (Gradmann 2016; Beaudevin et al. 2020). Though the capacity to examine microbes and compare notes across continents is now taken for granted and ethnographic historical research is shedding light on the recent history of laboratory systems (Vernooij 2021; Street and Kelly 2021; Koster et al. 2021; Kirchhelle 2022, 2023b), much of that research has concentrated on Western laboratories. We know relatively little about the infrastructures that have made such comparisons possible – but it should hardly be a surprise that these tend to be built on a colonial legacy (Geissler 2015; Stoler 2013).

Similarly, the inevitable bias of archives and publications towards capturing "success" means that we know less about the manifold instances of non-human and human resistance against microbiological, biomedical, and biotechnological attempts to impose order or reorder biosocial environments, particularly on a transnational scale. With some notable exceptions, which have largely dealt with (post)colonial settings (Lachenal 2017; Anderson 2008; Geissler 2015), histories of human-microbial relations tend to focus on the emergence of successful manipulations, treatment regimens or pharmaceuticals, rather than instances when microbes have proven to be unruly.

The articles assembled in this thematic collection address some of these gaps by bringing together a range of historical case-studies on the production of infrastructures that have allowed for the proliferation of seemingly universal, standardized knowledge about pathogenic microorganisms (including bacteria, viruses, protozoa, and nematodes). We are particularly interested in the productive tension between the challenge of coordinating frameworks of biomedical knowledge and interventions across the globe on the one hand, and the resistance posed by the unruly, ever-evolving, and highly variable organisms themselves on the other hand. Thus, the following articles trace the emergence of standard procedures, such as protocols for typing bacteria strains or running randomized controlled trials, or developing vaccine schedules and approved lists of vaccines used in mass campaigns. At the same time, they reveal not only how these standards were themselves products of colonial and postcolonial politics, but, critically, how, by connecting the macrocosm of global politics to the microcosms of pathogenic organisms, the unpredictability of the organisms themselves helped reconstitute spaces of political action. The following case studies cast light on neglected temporal and geographic areas of human-microbial interactions, explore new ways of (re)reading

historical sources to reveal (post)colonial distortions of scientific practice and acts of resistance, and underline the need to trace microbes and associated biomedical interventions not only within laboratories, but also within wider human and non-human environments. The selection of microorganisms under study has been driven not by a fidelity to any abstract definition of microbiology, but by the attention our historical actors – the community of bacteriologists and public health experts – have accorded to them.

Connecting our historical explorations of microbial ordering is the act of standardization, which has the formidable task of making a diverse and unruly "pluribiosis" (Brives 2021) of organisms and genes appear essentially similar, and therefore comparable and manipulable. Underlying the apparently stable forms of order produced through standardization, a staggeringly diverse microbial world undergoes constant change. The current usage of the word "standard" as an object or quality that serves as the authorized basis or principle to which others conform or are judged by dates to fifteenth-century debates over weights and measures. From the eighteenth century onwards, the spread of new allegedly universal metrics and standards was intimately bound to the rise of a new era of professionalized science, industrialized knowledge, managed risks, and global imperialism (Agar 2012; Jasanoff 2004; Zwierlein 2011; Pickstone 2011). Standards were always more than the objects or qualities they were supposed to embody. Reflecting wider belief systems, power relations, and socio-cultural norms, the ultimate success and impact of any standard was tied to its acceptance and usage by humans. In the words of Robert Kohler, standards are "the things that everyone uses" (Kohler 1994, 14).

Our own analytic definition of "standardization" centers three processes: the politics of inclusion and omission; the labor of making and maintaining the infrastructures of standardization, and the biology of the organisms at the heart of standardization. We draw on overlapping traditions from the sociology of work, the study of knowledge infrastructures, and STS to showcase a variety of underexplored standardization processes of microbes and microfauna (i.e. protists and nematodes; see Kollmer (2024); Vanderslott (2024) in this volume), laboratory processes, and public health routines. Finally, we integrate the literature on standards and infrastructures with recent research on imperial history in order to fully flesh out how imperial formations both enabled and limited global research on pathogenic microorganisms. When we discuss infrastructure, the term should be understood as *sociotechnical* in nature, encompassing both material "hardware" (and in our case, also "wetware") as well as institutions, cultural and legal norms, social relations, rituals and so on (Edwards 2002; Edwards 2009; Star and Ruhleder 1996) that make up the substratum on which the standardized procedures we investigate could emerge. Standards, of course, are essential to the invisible operation of various infrastructures.

Whether "in the laboratory" or "in the field" (we fully acknowledge the artificiality of this distinction), standards as well as the infrastructures that maintain them stabilize human-microbial interactions, enable coordinated action and mutual intelligibility, and impose often invisible hierarchies of selection and omission (Bowker and Star 1999). Since the late 1970s, STS scholars, historians, sociologists, and anthropologists have focused on the microbiological laboratory as a standardized space, where experimental conditions could be replicated irrespective of local contingencies and microbes were transformed into ideal-type laboratory projects (Latour and Woolgar 1987; Latour 1988; Mendelsohn 2002; Fleck [1935] 1979). Focusing on the role of standards in facilitating biological research, other researchers have drawn attention to the construction of "model organisms," such as the *Drosophila* fly (Kohler 1994), a

process that required not simply the manipulation of nonhumans but the creation of new technical infrastructures and ecosystems, the negotiation of routinized working practices, and novel tools such as radioisotope tracing (ibid.; Nelson 2018; Lederer 1992; Creager 2009). By paying close attention to the material culture of a workplace, scholars have also emphasized how the construction, manipulation, and maintenance of biological standards and their environmental containers spread specific tools, from petri dishes and test tubes to high-throughput sequencing machines. This proliferation of practices and tools was far from uniform and was shaped as much by moral economies and social hierarchies as it was by access to stable funding and complex international supply chains for reagents, reference strains, and spare parts (Gossel in Clarke and Fujimura 1992; Vernooij 2021; Okeke 2011). Questions of manipulation and standardization were interrelated with questions of representation as evidenced by the emergence of rigidly defined rules for the depiction of bacterial and cell cultures in the era of bacteriology, or of chromosomes and the double helix in the era of molecular biology (Galison and Daston 2007; de Chadarevian 2002, 2020). Ultimately, the standardized scientific object emerges not as a discrete entity, but as "an assemblage of material instruments, standard recipes and procedures, and working relationships" (Kohler 1994, 8) that also sustained cultures of seeing.

Laboratory processes of stabilization and uniformity often existed in tension with workplace practices that called for improvisation, tinkering, and ad hoc arrangements (Gosell 1992; Bowker and Star 1999). Indeed, standardization relies on both protocol and improvisation, as no standard can fully anticipate all real-world contingencies – infrastructures can break down, microbes can resist, humans can make mistakes, unexpected events may require swift action, and standardized objects may be used fruitfully for novel purposes. In all such situations, the ongoing validity of a standard and the technical infrastructure supporting it rely on the creativity of their operators for continuous functioning. Finally, as Geoffrey Bowker and Susan Leigh Star have pointed out, standardizing infrastructures are most effective, when they remain invisible. This, in turns, makes standards appear natural and conceals this sort of intense labor and maintenance required for their smooth operation (Bowker and Star 1999).

Outside of the laboratory, microbial standards have shaped and been shaped by broader public health policies, inequalities, global health cooperation, and the emergence of scientific infrastructures and international regulatory institutions. With regards to the interrelation of microbes and human health, this history is usually traced back to the International Sanitary Conferences (ISC), first convened in 1851 to exchange knowledge about the etiology and epidemiology of cholera, and to harmonize public health measures (Huber 2006). Historians have highlighted how these conferences, which later expanded to include the Third Plague Pandemic, created new standards for the collection and dissemination of epidemiological and increasingly microbiological data – as well as preventive measures (Engelmann and Lynteris 2020; Harrison 2004; McVety 2018). They also led to the creation of new permanent regulatory institutions, which in turn engaged in standard-setting activities including norms for the design of diagnostics, vaccines, and antimicrobials and mapping of microbial prevalence (Weindling 1995; Mazumdar 2003; Gradmann and Simon 2010; von Schwerin et al. 2015). We should recall, of course, that behind this process of international legal and scientific standardization lay relations of empire and of global trade: how to move ships with valuable cargo without contributing to the spread of epidemic disease, how to guarantee the integrity of the "civilizing mission" and the safety of European troops and administrators in the tropics,

and how to contain the movement of people deemed uncivilized and therefore unhygienic (Huber 2006; Engelmann and Lynteris 2020; Rogaski 2004). Both the laboratory and the institutions that surrounded it were produced by the demands of colonial rule.

To be useful in the field, these standardized biomedical technologies in turn depended on the creation of separate physical infrastructures to calibrate and guarantee the replicability of biomedical interventions across space. The global circuits of scientific production, prestige, exchange, and prospecting that were embedded in these infrastructures thus often ended up mirroring the structural inequalities produced by imperial and postcolonial regimes and the "contestation, adaptation, compromise, and hybridity" found therein (Anderson 2020, 372).[1] The same was true for resulting microbial data and standards. Following the First World War, biological reference material, written – and increasingly electronic – information, and compendia of genetic codes were deposited in a select number of carefully curated physical collections and digital databanks (Radin 2017; Bangham 2014; Gallay-Keller 2021; Strasser 2019; McGovern 2021; Kollmer 2022) However, the composition of and geographic location of these depositories of microbial knowledge reflected and reinforced global inequalities – although, until recently, this fact was rarely reflected on by most researchers using them (Abimbola and Madhukar 2020; Büyüm et al. 2020).

Finally, the technical achievements of standardization where never hegemonic acts of human will but complex and precarious processes of negotiation. Microbes frequently resisted imposed standards by changing their behavior or dying once they were isolated from their original environment, dropping or acquiring new genetic traits while in storage, or evolving ways to overcome antimicrobial constraints (Greenhough 2012; Kirchhelle 2020). The described encounters and negotiations happen at different scales ranging from the laboratory to mass campaigns against microbial diseases while the standards and the containers in which they traveled – be they manuals, culture media, or reference strains – spread unevenly across the globe. As the historian of biotechnology, Hannah Landecker observes, the result has been a twofold process of adaptation: human culture and politics have become inscribed in microbial biology and were in turn shaped by the biological agency of the microbial cultures they were trying to order (Landecker 2016).

Historians of colonialism have emphasized the thinness of bourgeois empires, their reliance on "rule through intermediaries," and the many ways imperial power was contested and shaped by conflicts and contingent alliances that did not neatly map onto a binary opposition between colonizers and colonized (Cooper and Stoler 1997; Burbank and Cooper 2011). This is a dynamic that historians of medicine have explored in depth in public hygiene (Rogaski 2004), bacteriology (Velmet 2020; Chakrabarti 2012), management of epidemic disease (Engelmann and Lynteris 2020), and elsewhere. These studies have provided us with more nuanced analyses of colonial bacteriology, showing how projects of public health worked both to circumscribe colonial power and to expand it, and highlighting how biomedical

[1] See also: Raj 2007; Tilley 2011; Huber 2006; Monnais and Tousignant 2016.

epistemologies could be rallied to subvert empire as well as to bolster it. This collection fleshes out the tug-and-pull of imperial formations and microbial ecologies in a variety of underexplored contexts, while also taking heed of the call to explore the influence of "imperial debris" (Stoler 2013) on postcolonial spaces in the Global South, the Global North, and in the supposedly abstract spaces of global health organizations – as well as initiatives to move beyond them.

Ranging from the typing of microbial strains to the use of blood parasites as model organisms to vaccine scheduling, our case studies showcase both the labor and infrastructures that are necessary to create, calibrate, and maintain standards as well as the vessels, instructions, and networks that connect the microbial standard to the world and politics of global public health. Reconstructing the lifecycles and impacts of standards at different scales not only allows us to illuminate the precarious stabilization of human-non-human relations inherent in any standard, but also to highlight how standards frequently reflect and reinforce existing power relations – both at the level of the laboratory and within Global Health. We also show how it is often in moments of crisis and failure that both the *invisible* work that standards routinely perform as well as embedded power relations are best understood.

Although the collection is primarily focused on standards and infrastructures underlying *pathogenic* microorganisms, this is, of course, but a small slice of how microbes are embedded into the foundations of industrial societies. Take, for instance, fermentation, a central process in industrial agriculture that is used in the production of commodities ranging from wine to soy sauce, (Sasges 2021; Lee 2021) or the meticulous acts of standardization underlying the production, use, and patenting of recombinant organisms producing substances ranging from monoclonal antibodies to acetone (Rasmussen 2014; Yi 2015; Bud 1994). While scholars working on the history of food, history of biotechnologies and the history of scientific globalization have touched on the role standardization has played in these processes, a more thorough investigation of these fields is beyond the scope of this collection.

The ordering of the six following papers reflects the different scales and networks through which microbial standards work and travel as well as the hierarchical relationships they illuminate. The first two papers trace the networks, material conditions, and human labor that are necessary to source, stabilize, and sort microorganisms into scientifically viable standards. Following this, we reconstruct the tensions inherent in creating standards at the juncture of laboratory research and public health by tracing the (post-)colonial politics of aligning microbial laboratory strains, human bodies, and pathogenic environments via vaccine design, trials, and routine vaccination schedules. And finally, we reflect on situations in which processes of standardization break down amidst non-alignment of microbiological theories with pathogen biology and competing disciplinary interpretations of what counts as a standard.

Focusing on the interplay between the human and biological cultures of the laboratory, Charles Kollmer (2024) traces the painstaking work involved in the construction of a complex *in-vitro* ecology, which made it possible to keep alive blood parasites without the presence of the host organism and study their behavior and physiology independently. This complex infrastructure, which encompassed scientific laboratories in multiple countries, extractive sampling networks, and high-grade nutrients supplied by industry, in turn, permitted the use of blood parasites, seemingly paradoxically, as models to metabolic components of broader physiological processes.

But how did organisms arrive in the laboratory in the first place? In the case of microbiology, imperial geopolitics often loom large as many prominent institutions that have become international standard setters have often been conceived by (quasi-)colonial powers to further develop direct or indirect governance of other territories (Huber 2006; Velmet 2020). The legacies of these institutions have persisted well into the postcolonial era and affect all areas of microbiology – from extractive modes of sampling, geographically skewed collections, and biased taxonomies. As (2024) Class Kirchhelle and Charlotte Kirchelle show in their article, Cold War surveys of microbial diversity were largely conducted in laboratories in the Global North. Focusing specifically on typhoid, they show that the biological biases, biosecurity concerns, and extractive sampling practices of Northern microbiologists and their viral bacteriophage-typing sets became embedded in authoritative international taxonomies. Even though a vast majority of cases of typhoid occurred in the Global South, taxonomic distinctions between "universal" Northern and "exotic" Southern typhoid types provided scientific justification for intensified surveillance of migrants and travelers to North America and Europe and biased vaccine trials.

The occlusion of (post-)colonial geo- and biosecurity politics in authoritative laboratory standards and taxonomies was mirrored in international vaccine campaigns. In his paper, Aro Velmet (2024) looks at how the routines of vaccinators in French West Africa during World War II achieved the vaccination of over 14 million Africans against yellow fever, allowed the French Pasteur Institute to claim success in their vaccine development, and yet simultaneously occluded the danger of potentially fatal adverse effects the yellow fever vaccine could have on small children. Here, too, examining the actual work routines of vaccinators helps shed light on wider issues, this time in colonial public health, that standard procedures and later reports produced at the Institute rendered invisible. The article also illustrates the role of moments of acute crisis in rendering visible previous assumptions about material and bureaucratic capacity in diverse and unequal societies and driving the modification or rejection of existing standards (Lakoff 2017; Redfield 2013). Thus, WHO vaccination guidelines could recommend the deployment of a particular kind of yellow fever vaccine. However, if the existing infrastructure in a region struggling under an epidemic outbreak did not accommodate the biological properties of that vaccine, then these standards ended up being ignored.

A particular problem with regards to microbial standards is not only that microorganisms need to be stabilized and made cooperative for public health programs, but also that the behavior of microbes needs to be *coordinated* to align with a variety of other goals, as Noémi Tousignant (2024) shows in her paper on the politics of vaccine scheduling in West Africa. Vaccine schedules are designed to synchronize the immune-stimulating act with the responsiveness of the body's immune system as well as with potential exposure to the relevant pathogen. In other words, a vaccine should be injected at a time when the body will tolerate vaccine components, when maternal antibodies no longer interfere with the immune response, but before the child is likely to have been exposed to the pathogen. Yet, as Tousignant shows, vaccine schedules also synchronize other goals – including business plans, kinship relations, government budgets, and much more.

But what happens if no synchronization of microbes, microbiological knowledge production, and broader medical and political systems takes place and no interoperable standards emerge? The final two papers of the collection analyze events in which the microbial world refuses to bend to existing norms of intervention and measurement. Both contributions highlight the need to not only pay close attention to the

institutional and political contexts that allow certain organisms or standards to be selected (Gaudillière 2001; Rader 2004), but also to the centrifugal forces that are unleashed in situations of incommensurability.

In his article, Benoit Pouget (2024) shows how attempts to manage outbreaks of the flu in the French military after the 1918 pandemic were hampered by the inability of microbiologists to actually isolate the virus responsible for causing the disease. The perceived failure of classic bacteriology to impose its standardized mode of rendering microorganisms visible and controllable posed a threat to the public health programs that had formed around it. Though French microbiologists pursued a variety of avenues throughout the 1920s and '30s, from developing vaccination programs, to surveillance and containment, as well as non-pharmaceutical interventions, such as the adoption of face masks, no coherent program of prophylaxis emerged in this period. Here, Pouget points to a confluence of biological and social factors that prevented standards from emerging: there was no scientific consensus on what actually *caused* the flu; and the institutions responsible for implementing preventive measures, most notably the French military, were themselves undergoing reorganization at the time.

Fragmentation and ongoing conflicts over standards are also at the heart of Samantha Vanderslott's paper on the 'worm wars' (2024). Focusing on controversies over deworming programs and their connection to student attainment and economic development, Vanderslott traces how the rise of the randomized controlled trial (RCT) – the gold standard of evidence adjudication – led to new hierarchies of evidence. These hierarchies reflected institutional preferences for quantifiable single solution approaches like mass drug administration over more complex multi-causal explanations. Over time, they also reshaped how disciplines like developmental economics approached questions of measurement (Adams 2016). This did not mean that generated data necessarily pointed towards the same interventions. In this situation, RCTs' focus on comparing data rather than measurement rationales meant that they proved powerless to produce standards that were interoperable at the disciplinary level or capable of accounting for multicausal phenomena in the field.

Even after two centuries of ongoing standard-setting, it seems that the way we try to order the unruly microcosm in and around us reveals at least as much about the values of and relations between the humans trying to impose standards as it does about the microbes themselves.

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