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RESEARCH ARTICLE

The history of science through the prism of race

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Abstract

One methodological approach to grasping a 'big-picture' history of modern science involves tracing the complex entanglements between scientific knowledge and the development of racism and racialized economic systems. Indeed, no historical account of any scientific field can be complete without acknowledging the role of race as an intellectual, social or economic factor. We substantiate this argument through a synthetic review of three overlapping threads in the historiography of science. First, historical research on 'race science' has analysed the formation of disciplines directly involved in constructing scientific concepts of race, including medicine, anthropology, linguistics, phrenology, psychology, archaeology and genetics. Second, historians have demonstrated that connections between race and science are not limited to the domain of race science. Rather, European imperial expansion, colonialism and capitalism created the foundational infrastructures undergirding the emergence of modern professional science. Finally, new research shows how race remains covertly embedded in theoretical frameworks, statistical formulae and technological devices still used by scientists today. Through these examples, we perceive a big-picture history of science in which its co-constitution with race links localized case studies and imperial narratives across space and time.

This paper responds to an invitation to re-evaluate the role of the human social category of race in the historical development of science, as well as the significance of race to writing 'big-picture' narratives of science. Is race a niche topic within the history of science, relevant only to the specific domains of knowledge that happen to be concerned with human beings? Or do processes of racialization permeate the entire history of modern science? Our answer to these questions draws inspiration from Ludmilla Jordanova's 1993 observation that race, like gender, is an evolving concept that 'the history of science is uniquely well-suited to uncover'. At the same time, the concept of race has 'analytical value' for historians who aim to understand science in its social contexts and 'the associated ways of ordering the world'.[1] Accordingly, we argue that race must be a core analytic for the history of all scientific disciplines, as well as for histories of medicine and technology. We substantiate this argument through a synthetic review of three distinct, yet overlapping, threads in recent historiography of science.

First, historical research on race science has shown the myriad of disciplines involved in constructing scientific concepts of race and reinforcing or challenging evidence of racial differences. These disciplines include, but are not limited to, anthropology,

1 Ludmilla Jordanova, 'Gender and the historiography of science', *BJHS* (1993) 26, pp. 469–83, 475.

linguistics, archaeology, medicine, phrenology, psychology, evolutionary biology, eugenics and genetics. While modern practitioners of these sciences largely disavow the race science of the past, their work nevertheless remains co-constitutive with social processes of racialization worldwide. Second, historians have more recently demonstrated that connections between race and science are not at all limited to the domain of race science. Rather, European imperial expansion, the formation of racial capitalism and multiple forms of colonialism created and sustained foundational infrastructures that made possible many of the achievements credited to European scientists: modern science is the product of racialized economies and social hierarchies. Finally, new research shows how race remains covertly embedded in theoretical frameworks, statistical formulae and technological devices that continue to be used by scientists, medical practitioners and the lay public for purposes that ostensibly have nothing to do with race. The peculiarities and problems that these scientific tools manifest cannot be fully understood and remedied without reflecting on their original racializing functions. By synthesizing these historiographical trends, we perceive a big-picture history of science in which its co-constitution with race enables localized case studies and imperial narratives to be linked across space and time. The 'prism' of race invoked in our title is only partly metaphorical – as we describe below, Isaac Newton's optical experiments using actual prisms were incorporated into scientific debates about variation in human skin colour. More significantly, we contend that viewing the history of science through the prism of race has supported major scholarly innovations in our field.

One of these is the effort to challenge the Eurocentric underpinnings of 'diffusionist' historiography that characterizes most of the world as merely the source of raw data to be converted by Europeans into 'Western science', which then spread back out to other regions to become the dominant international paradigm of natural knowledge. Counternarratives to diffusionism first appeared in the form of an 'imperial' or 'colonial turn' in the history of science, but nevertheless remained Eurocentric in their focus on Europe's imperial institutions, overseas colonies and scientific actors. More recent historiographical moves, using 'circulation of knowledge' as an analytical framework toward writing 'global' and 'transnational' histories of science, have revealed the extent to which racialization (and gender discrimination) caused vast numbers of individuals to be written out of the historical record as producers of scientific knowledge.[2] Although enslaved and colonized peoples directly contributed information and experimental labour to the corpus of 'Western' science and medicine, European logics of racialization meant that they were frequently denied both epistemic credibility and personal credit for these contributions.

Increasing awareness of these racialized erasures motivated historians of science to augment their methodologies by moving beyond conventional European intellectual history. These new strategies included reading more sources in non-European vernaculars, revisiting European sources in order to read against the grain, and incorporating new analyses of material, visual and oral culture. These approaches have enabled historians to deconstruct the notion of distinct, bounded analytical categories such as 'Western science' contrasted with 'indigenous knowledge' and 'vernacular science', turning instead to such concepts as 'braided science'.[3] Attention to race and the search for new sources has also helped to shift historians' understanding of who counts as a scientific actor. Histories of

2 James A. Secord, 'Knowledge in transit', *Isis* (2004) 95, pp. 654–72; Londa Schiebinger, 'Forum introduction: the European colonial science complex', *Isis* (2005) 96, pp. 52–5; Kapil Raj, *Relocating Modern Science: Circulation and the Construction of Knowledge in South Asia and Europe, 1650–1900*, Basingstoke: Palgrave Macmillan, 2010; Marwa S. Elshakry, 'Knowledge in motion: the cultural politics of modern science translations in Arabic', *Isis* (2008) 99, pp. 701–30.

3 Helen Tilley, 'Global histories, vernacular science, and African genealogies; or, is the history of science ready for the world?', *Isis* (2010) 101, pp. 110–19; Projit Bihari Mukharji, *Doctoring Traditions: Ayurveda, Small Technologies, and Braided Sciences*, Chicago: The University of Chicago Press, 2016.

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science became increasingly populated with 'go-betweens', 'knowledge brokers' and 'human instruments', many of whom navigated between racialized social groups and/or personally embodied racial marginalization.[4] By centring such figures (or the technologies or specimens they interacted with), historical narratives of science went beyond actor-network theory's exhortation to 'follow' people and things from one place to another; they also brought to the fore the contingencies of social and scientific identities for these mobile actors, and, as a corollary, the contingent nature of race itself.[5]

These approaches have not only impacted understandings of racialization as an important factor affecting the global circulation of scientific knowledge; they have also influenced the historiography of race itself as a construct of globally circulating scientific ideas and practices. As a result, there are now a burgeoning number of regional and global histories of race sciences, including phrenology, physical anthropology, archaeology, eugenics and human genetics, and medicine. These studies have emphasized that the category of 'race' has been constructed and reconstructed many times in different geographical, political and intellectual contexts. Different classification systems incorporated varying combinations of social factors (e.g. religious, tribal or caste identities) and cultural stereotypes (e.g. of temperament, personality or intelligence), as well as biological traits (e.g. physical appearance or susceptibility to diseases), to define racial groups. This scholarship demonstrates that racialized categories never solely derived from biological observations but also drew upon notions of religious genealogies and civilizational hierarchies. Furthermore, while often rooted in a specific region or empire, these works provide compelling analytical models for big-picture histories of science in their navigation of different source types and languages and attention toward ideas of the 'global', 'international' or 'collaborative' nature of science as actors' categories. Many of these globally oriented accounts of race science have exposed the previously underappreciated extent to which non-European actors and ideas contributed to historical debates about racial categories and origins, up to the point of appropriating European race science methodologies for anti-colonial and nationalist aims.[6] In other words, race science – like

4 Simon Schaffer, Lissa Roberts, Kapil Raj and James Delbourgo (eds.), *The Brokered World: Go-Betweens and Global Intelligence, 1770–1820*, Sagamore Beach, MA: Science History Publications, 2009; Raj, op. cit. (2); Londa L. Schiebinger, *Secret Cures of Slaves: People, Plants, and Medicine in the Eighteenth-Century Atlantic World*, Stanford, CA: Stanford University Press, 2017.

5 Bruno Latour, *Science in Action: How to Follow Scientists and Engineers through Society*, Cambridge, MA: Harvard University Press, 1987.

6 A sampling of this literature from the last decade would include Susan Lindee and Ricardo Ventura Santos, 'The biological anthropology of living human populations: world histories, national styles, and international networks. An introduction to Supplement 5', *Current Anthropology* (2012) 53(S5), pp. S3–S16; Helen Tilley, 'Racial science, geopolitics, and empires: paradoxes of power', *Isis* (2014) 105, pp. 773–81; Warwick Anderson, 'Racial conceptions in the global South', *Isis* (2014) 105, pp. 782–92; Peter Wade, Carlos López Beltrán, Eduardo Restrepo and Ricardo Ventura Santos, eds., *Mestizo Genomics: Race Mixture, Nation, and Science in Latin America*, Durham, NC: Duke University Press, 2014; Hsiao-pei Yen, 'From palaeoanthropology in China to Chinese palaeoanthropology: science, imperialism and nationalism in north China, 1920–1939', *History of Science* (2015) 53, pp. 21–56; Hidefumi Nishiyama, 'Towards a global genealogy of biopolitics: race, colonialism, and biometrics beyond Europe', *Environment and Planning D: Society and Space* (2015) 33, pp. 331–46; Edna Suárez-Díaz, 'Blood diseases in the backyard: Mexican "indígenas" as a population of cognition in the mid-1960s', *Perspectives on Science* (2017) 25, pp. 606–30; Jaehwan Hyun, 'Making postcolonial connections: the role of a Japanese research network in the emergence of human genetics in South Korea, 1941–1968', *Korean Journal for the History of Science* (2017) 39, pp. 293–324; Joanna Radin, *Life on Ice: A History of New Uses for Cold Blood*, Chicago: The University of Chicago Press, 2017; James Poskett, *Materials of the Mind: Phrenology, Race, and the Global History of Science, 1815–1920*, Chicago: The University of Chicago Press, 2019; Miriam Kingsberg Kadia, *Into the Field: Human Scientists of Transwar Japan*, Stanford, CA: Stanford University Press, 2019; William Carruthers, 'Archaeological (non?)alignments: Egypt, India, and global geographies of the post-war past', *South Asian Studies* (2020) 36, pp. 45–60; Jenny Bangham, *Blood Relations: Transfusion and the Making of Human Genetics*, Chicago: The University of Chicago Press, 2020; Elise

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all other modern sciences – evolved as a braided science, drawing together European and non-European knowledge systems about human variation, within a political context of European imperial domination over much of the rest of the world.

We briefly sketch this evolving historiography of race science within the first section of this paper. In the second and third sections, we examine other fields of science as refracted through the prism of race. The second section synthesizes scholarship demonstrating how racialized regimes of unfree labour established in the early modern period created the political, economic and intellectual scaffolding for the development of scientific institutions, practices and theoretical debates, with a focus on early modern physics, chemistry, botany and geology. The third section shows how race as a social and scientific concept also shaped the emergence of new quantitative disciplines, specifically 'data science'. The history behind contemporary data science leads us from statistics to data-gathering tools like the spirometer and the camera, demonstrating the racializing functions of these technologies through ongoing practices of medical 'race correction' and racial profiling aided by computerized facial-recognition algorithms.

The goal in orienting the bulk of this paper away from those disciplines that are conventionally understood as race science is not to downplay the historical prominence and influence of those fields, but rather to contest the frequent temptation to bracket off medicine and the human sciences as uniquely implicated in, and burdened with disavowing, the injustices committed in the name of human biological variation. Our approach exposes how all of the endeavours that we attribute to the history of science from the sixteenth century onward are significantly indebted to the racialization processes that structured the political, economic, social and epistemological conditions of knowledge production. As such, historians and practitioners of all scientific and technological fields have a stake in acknowledging and resisting discriminatory modes of professional thought, practice and communication about the role of science in society.

The sciences of racialization

The historical phenomenon we refer to as 'race science' was not a single institutionalized discipline, but rather the convergence of concepts and methodologies around the shared problematic of human biological variation. It emerged from older ideas in medicine and natural history that eventually fragmented into more specialized disciplines during the nineteenth century: anatomy and physiology, anthropology and ethnology, archaeology, philology and linguistics, psychology and phrenology: a set of fields now sometimes lumped back together under the label 'human sciences'. Although 'race science' did exist as a historical actors' category, it seems to be more frequently used now by historians than in the past by its practitioners (at least in English – the reverse may be true for German *Rassenkunde* and French *raciologie*). For the most part, 'race science' was not something one could directly earn a degree in; the majority of race science experts were formally trained in medicine, philosophy or anthropology. However, race science 'had a history and coherence of its own to its practitioners' and an 'internal logic of scientific arguments' forming the basis of local and transregional intellectual communities.[7]

K. Burton, *Genetic Crossroads: The Middle East and the Science of Human Heredity*, Stanford, CA: Stanford University Press, 2021; Burton, 'Rethinking collaboration: medical research and working relationships at the Iranian Pasteur Institute', *Isis* (2021) 112, pp. 461–83; Projit Bihari Mukharji, *Brown Skins, White Coats: Race Science in India, 1920–66*, Chicago: The University of Chicago Press, 2022; Thiago P. Barbosa, 'Racializing a new nation: German coloniality and anthropology in Maharashtra, India', *Perspectives on Science* (2022) 30, pp. 137–66; Ricardo Roque, 'Transnational isolates: Portuguese colonial race science and the foreign world', *Perspectives on Science* (2022) 30, pp. 108–36.

7 Nancy Stepan, *The Idea of Race in Science: Great Britain, 1800–1960*, Hamden, CT: Archon Books, 1982, xvi.

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Historians' efforts to understand these scientific communities under the rubric of 'race science' have been deeply influenced by the work of Nancy Stepan, whose 1982 book *The Idea of Race in Science* popularized 'race science' as a historiographical phrase. She described her book as an 'introduction to the history of scientific racism in Britain', which has contributed to a lingering tendency among both historians and the general public to treat the terms 'race science' and 'scientific racism' as interchangeable.[8] Nevertheless, 'scientific racism' has a distinct historiographical genealogy rooted in post-war twentieth-century efforts to delegitimize lingering vestiges of race science as pseudoscience and relegate it once and for all to the fringes of professional science.[9] The particular formulation of 'scientific' racism (with only the word 'scientific' in quotation marks), popularized in the early 1960s, was simultaneously used by the American historian of Africa Philip D. Curtin to critique nineteenth-century British imperial ideology, and by the Spanish anthropologist Juan Comas in his scathing rebuke of the first publication of the journal *Mankind Quarterly*.[10] While 'scientific racism' is a meaningful term, for our purposes, it is important to set aside this term's connotations of pseudoscience and speak instead of 'race science' to accurately depict a series of inquiries and debates that, in their time, were based upon widely accepted scientific methodologies and theoretical frameworks and expressed in recognized scientific venues.

The origins of race science proper are conventionally dated to the late eighteenth century, when European naturalists constructed taxonomic systems of organisms that included divisions of the human species into 'varieties' or 'races'.[11] However, the social and intellectual processes of racializing human groups long pre-date formal race science. Ideas of human group differences already existed in all parts of the world during the pre-modern period; in Europe, West Asia and North Africa these ideas were rooted in humoural medicine, the Graeco-Roman geographic theory of climes, religious genealogies of human origins, cultural practices of recording ancestral lineages, and prejudicial hierarchies of civilizational greatness. Historians still debate the intellectual, social and political processes through which these various forms of pre-racial thinking were gradually transformed into the notion of distinct human races defined by physiological differences detectable in the skin, bones and brain.

Researchers largely agree that early modern medical practice, especially in the context of the African slave trade, played a significant role, leading to Suman Seth's suggestion that race medicine was the immediate predecessor of modern race science.[12] Christian theology also fundamentally shaped how physicians and naturalists thought about the possibility of human races having shared or distinct origins.[13] What is indisputable is

8 Stepan, op. cit. (7), xvii.

9 Our usage of fringe science and pseudoscience is inspired by Michael D. Gordin, *On the Fringe: Where Science Meets Pseudoscience*, New York: Oxford University Press, 2021.

10 P.D. Curtin, '"Scientific" racism and the British theory of empire', *Journal of the Historical Society of Nigeria* (1960) 2, pp. 40–51; Juan Comas, '"Scientific" racism again?', *Current Anthropology* (1961) 2, pp. 303–40; Comas, 'More on "scientific" racism', *Current Anthropology* (1962) 3, pp. 284–302.

11 Bruce David Baum, *The Rise and Fall of the Caucasian Race: A Political History of Racial Identity*, New York: New York University Press, 2006; Claude-Olivier Doron, 'Race and genealogy: Buffon and the formation of the concept of "race"', *Humana.Mente: Journal of Philosophical Studies* (2012) 22, pp. 75–109.

12 Suman Seth, *Difference and Disease: Medicine, Race and the Eighteenth-Century British Empire*, New York: Cambridge University Press, 2018, p. 170; Pablo F. Gómez, *The Experiential Caribbean: Creating Knowledge and Healing in the Early Modern Atlantic*, Chapel Hill: University of North Carolina Press, 2017; Rana A. Hogarth, 'Race, place, and power in the production of medical knowledge: perspectives from the Greater Caribbean', *History Compass* (2021) 19(11), https://doi.org/10.1111/hic3.12694; Hannah Murphy, 'Re-writing race in early modern European medicine', *History Compass* (2021) 19(11), https://doi.org/10.1111/hic3.12692.

13 Terence Keel, *Divine Variations: How Christian Thought Became Racial Science*, Stanford, CA: Stanford University Press, 2019.

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that race science reached its height in the mid-nineteenth century, as European empires reached the height of their power and scientific methodologies for constructing racial classifications rapidly proliferated. Generalized fields of study like anatomy and philology produced specialized techniques and instruments that lent themselves well to identifying racialized differences: anthropometry, craniometry, phrenology and linguistics all found their way into the emergent disciplines of ethnology and anthropology.[14] However, widespread scholarly and public interest around race as a scientific category did not lead to consensus about the definition of race. Every aspect of race science, from the number of human races to the relative value of classifying methodologies, was vigorously contested. Regardless, these intellectual debates were unified by their links to colonial socioeconomic structures. Colonial spaces, including settler colonies, became sources of empirical data for the study of racial difference; the resulting theoretical products of race science, in turn, provided the justification for practising racial discrimination in the colonies. In other words, race science as an epistemological domain was co-constituted with the racial discrimination inherent to colonial governance.[15] Colonies became 'laboratories'; that is, sites for experimental practices ranging from medical concentration camps to new educational curricula.[16] The different legal status and racial classification of colonized peoples enabled Europeans to conduct research that was unfeasible, unpopular or even banned in the metropole.[17]

However, by the early twentieth century, contestations regarding race science methodologies and categories reached a critical point. The reliability of key craniometric measures like the cephalic index came under attack by American anthropologist Franz Boas at the same time as emerging methods like serology, undergirded by Mendelian theories of heredity, seemed to contradict earlier systems of racial classification.[18] Elazar Barkan links together these scientific developments with the activism of American and European scientists and physicians against Nazi racial hygiene as evidence of the 'retreat of scientific racism' by the 1930s.[19] This chronology, with its implication that race science was already and everywhere in decline by the outbreak of the Second World War, has been challenged on multiple fronts. For example, new histories of race science centring Asia and Africa have revealed that race science continued to flourish in these regions well after the 1930s, practised not only by European colonial administrators but also by indigenous elite intellectuals for their own anti-colonial and elite nationalist purposes.

14 On the relation of these methodologies to ethnology and anthropology see Richard McMahon, 'Anthropological race psychology 1820–1945: a common European system of ethnic identity narratives', *Nations and Nationalism* (2009) 15, pp. 575–96; Sadiah Qureshi, *Peoples on Parade: Exhibitions, Empire, and Anthropology in Nineteenth Century Britain*, Chicago: The University of Chicago Press, 2011; Stefani Engelstein, *Sibling Action: The Genealogical Structure of Modernity*, New York: Columbia University Press, 2017; Poskett, op. cit. (6).

15 Partha Chatterjee, *The Nation and Its Fragments: Colonial and Postcolonial Histories*, Princeton, NJ: Princeton University Press, 1993.

16 Wolfgang U. Eckart, 'The colony as laboratory: German sleeping sickness campaigns in German East Africa and in Togo, 1900–1914', *History and Philosophy of the Life Sciences* (2002) 24, pp. 69–89; Helen Tilley, *Africa as a Living Laboratory: Empire, Development, and the Problem of Scientific Knowledge, 1870–1950*, Chicago: The University of Chicago Press, 2011; Gauri Viswanathan, *Masks of Conquest: Literary Study and British rule in India*, London: Faber and Faber, 1990; Gyan Prakash, *Another Reason: Science and the Imagination of Modern India*, Princeton, NJ: Princeton University Press, 1999.

17 Roy M. MacLeod, 'Scientific advice for British India: imperial perceptions and administrative goals, 1898–1923', *Modern Asian Studies* (1975) 9, pp. 343–84; Pratik Chakrabarti, 'Beasts of burden: animals and laboratory research in Colonial India', *History of Science* (2010) 48, pp. 125–51.

18 Jonathan Marks, 'The origins of anthropological genetics', *Current Anthropology* (2012) 53(S5), pp. S161–S172.

19 Elazar Barkan, *Retreat of Scientific Racism: Changing Concepts of Race in Britain and the United States between the World Wars*, Cambridge: Cambridge University Press, 1992.

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A narrative of decline rooted in the North Atlantic thus overlooks the ongoing role of race science in decolonizing movements, from Egypt to India to Indonesia, during the early to mid-twentieth century.

On the one hand, Asian and African nationalist practitioners of sciences such as anthropology, archaeology and statistics rejected European claims about the racial inferiority of non-Europeans, attacking the methodological and analytical inconsistencies of race science to undermine the racial hierarchies proposed by European scientists. On the other hand, elite nationalists used methods and discourses similar to those of race science to demonstrate the existence of a coherent national unit capable of self-government. Measurements from racial anthropology and serology were leveraged in international decisions about the territorial boundaries of new nation states, and were used to arbitrate communal claims of national belonging. In the process, anti-colonial race scientists tended to reinforce and naturalize the social and religious hierarchies of dominant communities, contributing to forms of systematic exclusion and even ethnic cleansing. Thus race science functioned as a double-edged sword in the hands of nationalist movements, and continues to sustain ongoing racialized discrimination within post-colonial nation states.[20]

Equally significant to this history are non-European regimes of imperial expansion and colonial occupation, such as those of China and Japan. Han Chinese anthropologists conducted anthropological research on non-Han ethnic groups to argue that they comprised a racial unity, supporting Han settler colonialism in other regions under Chinese rule.[21] Japanese scientists were pioneers in race science methods like serology and dermatoglyphics, deployed on the inhabitants of their colonial territories stretching from Taiwan to Korea and Manchuria.[22] Japanese racial taxonomies of aboriginal peoples in Taiwan have had an enduring afterlife, shaping recent nationalist genetic research aiming to distinguish Chinese people in Taiwan from those living in the mainland People's Republic of China.[23] Furthermore, post-war Japanese scientists involved in the International Biological Programme pursued personal collaborations with Carleton Coon and Reginald Ruggles Gates in their research on 'hybrid' Japanese American children, despite American anthropologists' ostracization of Coon and Gates as figureheads of outdated scientific racism.[24]

Interdisciplinary scholarship demonstrates that North Atlantic race science endures in contemporary forms of biological and medical theories, methods and practices. The malleability of what constitutes the marker of race – that is, the physiological site in which

20 Omnia S. El Shakry, *The Great Social Laboratory: Subjects of Knowledge in Colonial and Postcolonial Egypt*, Stanford, CA: Stanford University Press, 2007; Murat Ergin, *Is the Turk a White Man? Race and Modernity in the Making of Turkish Identity*, Leiden: Brill, 2017; Warwick Anderson and Ricardo Roque, 'Introduction. Imagined laboratories: colonial and national racialisations in island Southeast Asia', *Journal of Southeast Asian Studies* (2018) 49, pp. 358–71; Fenneke Sysling, 'The human Wallace Line: racial science and political afterlife', *Medical History* (2019) 63, pp. 314–29; Sayori Ghoshal, 'Experts of identity: race, ethnicity, and science in India, 1910s–1940s', *Isis* (2024) 115, pp. 84–104; Burton, *Genetic Crossroads*, op. cit. (6); Mukharji, op. cit. (6).

21 Hsiao-pei Yen, 'Frontier anthropology and Chinese colonialism in the southwestern frontier during the Second Sino-Japanese War', *boundary 2* (2017) 44, pp. 157–86; Jing Zhu, 'Measuring non-Han bodies: anthropometry, colonialism, and biopower in China's south-western borderland in the 1930s and 1940s', *History of the Human Sciences* (2022) 35, pp. 84–112.

22 Daniel Asen, '"Dermatoglyphics" and race after the Second World War: the view from East Asia', in Patrick Manning and Mat Savelli (eds.), *Global Transformations in the Life Sciences, 1945–1980*, Pittsburgh: University of Pittsburgh, 2018, pp. 61–77; Nishiyama, op. cit. (6); Kadia, op. cit. (6); Hyun, op. cit. (6).

23 Yu-yueh Tsai, 'Geneticizing ethnicity: a study on the "Taiwan Bio-bank"', *East Asian Science, Technology and Society* (2010) 4, pp. 433–55.

24 Jaehwan Hyun, 'In the name of human adaptation: Japanese American "hybrid children" and racial anthropology in postwar Japan', *Perspectives on Science* (2022) 30, pp. 167–93.

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ancestry can be seen and measured – has enabled the persistence of racial research through population genetics, biomedicine, pharmacogenomics and forensics. Notwithstanding scientists' terminological shifts from racial type to ethnic group, population, and biogeographical ancestry, the notion that racial categories capture something biologically meaningful continues to persist. While individuals are no longer considered to belong to pure racial types, specific groups have been targeted as especially desirable for the study of human genomic diversity: namely geographically and socially 'isolated' groups whose histories of marginalization make them vulnerable to extinction as distinct communities.[25] Meanwhile, individuals considered to belong to 'admixed' populations may have their DNA analysed into a precisely calculable mixture of African, Asian or European ancestry, thus entrenching these categories as distinct typological populations rather than gradients of genetic variation.[26] Social scientists like Dorothy Roberts and Nadia Abu El Haj, among others, show how the biological reductionism of nineteenth-century race science has successfully adapted itself to the profit logics of neoliberal capitalism and its allied imagination of biological citizenship. Thus, even while neoliberal states recognize the claims and possibilities of multiracial identities, the biological reality of race is reinscribed through the recognition of medical interventions into racially specific diseases and drugs.[27]

Racial economies of science

The imperial turn in historiography has shown the extent to which science is part and parcel of global histories of slave labour, colonialism and other dimensions of economic exploitation. In this regard, modern science is irrevocably embedded in the rise of racial capitalism. Drawing on the work of Destin Jenkins, Justin Leroy and other scholars of the Black Marxist tradition, we consider all capitalism, 'from the beginnings of the Atlantic slave trade and the colonization of the Americas onward', to constitute racial capitalism 'in material profitability and ideological coherence'.[28] We therefore use this term not to imply the existence or possibility of a non-racial capitalism, but rather to highlight that 'domination based on difference [is an] inciting incident' for the history of capitalism.[29] The expansion of European empires' racialized domination of the global economy simultaneously generated both the funds and the motivation to carry out extensive new investigations of the natural world. With this in mind, we embrace James Poskett's

25 Jenny Reardon, *Race to the Finish: Identity and Governance in an Age of Genomics*, Princeton, NJ: Princeton University Press, 2005; Veronika Lipphardt, 'The Jewish community of Rome: an isolated population? Sampling procedures and bio-historical narratives in genetic analysis in the 1950s', *BioSocieties* (2010) 5, pp. 306–29; Marianne Sommer, *History Within: The Science, Culture, and Politics of Bones, Organisms, and Molecules*, Chicago: The University of Chicago Press, 2016; Radin, op. cit. (6).

26 Duana Fullwiley, 'The biologistical construction of race: "admixture" technology and the new genetic medicine', *Social Studies of Science* (2008) 38, pp. 695–735; Fullwiley, 'The "contemporary synthesis": when politically inclusive genomic science relies on biological notions of race', *Isis* (2014) 105, pp. 803–14; Lisa Gannett, 'Projectibility and group concepts in population genetics and genomics', *Biological Theory* (2013) 7, pp. 130–43; Gannett, 'Biogeographical ancestry and race', *Studies in History and Philosophy of Science Part C: Studies in History and Philosophy of Biological and Biomedical Sciences* (2014) 47, pp. 173–84.

27 Dorothy Roberts, *Fatal Invention: How Science, Politics, and Big Business Re-create Race in the Twenty-First Century*, New York: New Press, 2011; Nadia Abu El-Haj, 'The genetic reinscription of race', *Annual Review of Anthropology* (2007) 36, pp. 283–300.

28 Destin Jenkins and Justin Leroy (eds.), *Histories of Racial Capitalism*, New York: Columbia University Press, 2021, p. 1.

29 Jenkins and Leroy, op. cit. (28), p. 6.

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suggestion that 'rather than thinking of some sciences as racial, and others as not, we should therefore think of modern science as racial from the start'.[30]

Some Anglocentric examples can illustrate this phenomenon. Several eminent members of the Royal Society of London, including but not limited to Robert Boyle, Hans Sloane and Isaac Newton, had significant ties to slave-trading companies and slave-worked plantations until the abolition of slavery in the British Empire in 1833. They financed their scientific activities using stock dividends and other forms of profit from slavery. Furthermore, the role of slavery in the work of these British natural philosophers was not merely financial: the logistics of slave-based economies were inextricable from their intellectual interests and output.[31] For example, Boyle, Newton, Robert Hooke and their contemporaries were preoccupied with optics and the relation of light to colour. As such, they were interested in determining the underlying basis of different human skin colours, and the Royal Society avidly solicited observations on skin colour from travellers to Africa and the Americas throughout the seventeenth century.[32] The scientific stakes of this debate over skin colour were not solely about racialized anatomical differences, but also about physics, for which experiments with skin could test theories about the nature of colour perception more broadly.

European colonies in the Americas, sustained by slave-holding plantation economies, became sites for experimental research into this question. Eighteenth-century Creole scholars like physician–naturalist John Mitchell and physician–chemist Edward Bancroft took advantage of their access to enslaved Africans and indigenous peoples in Virginia and Dutch Guiana, respectively, to debate the physical and chemical underpinnings of colour. Both Mitchell and Bancroft engaged deeply with Newton's work on optics, derived from the latter's experiments refracting light through prisms. Mitchell's gruesome experiments on the skin of enslaved Africans led him to declare that there was no pigment or other substance within human skin producing colour variations. Rather, hailing Newton's theories of colour, Mitchell argued that the skin of Europeans, Africans and Native Americans had distinct variations in physical structure that produced different degrees of light reflectance and thus created the optical effect of skin colour variation.[33]

Bancroft did not work directly on the question of skin colour, but nonetheless his contributions to chemistry repeatedly invoked racial differences. Bancroft, who made his fortunes directly from colour in the form of dyes, rejected Newton's proposition that colour was solely a visual effect of light and not an inherent property of matter. According to Bancroft, different kinds of matter possessed colour according to 'chemical affinities' through which they reacted to light rays and to oxygen. Bancroft's perspective was partly influenced by his observations of the effects of certain plant dyes upon the skin of indigenous peoples and European colonists in Guiana, which had dramatic but always temporary darkening effects. Furthermore, Bancroft's account of the history of dyeing reinforced a racial hierarchy of chemical knowledge: while he acknowledged that even 'savages' were capable of manipulating colour and Indians of producing calico prints, only Europeans,

30 James Poskett, 'Racial science', in Andrew Goss (ed.), *The Routledge Handbook of Science and Empire*, London and New York: Routledge, 2021, pp. 35–46, 35. This section of the paper is heavily indebted to Chapter 3 in Poskett, *Horizons: A Global History of Science*, London: Viking, 2022.

31 Mark Govier, 'The Royal Society, slavery and the island of Jamaica: 1660–1700', *Notes and Records of the Royal Society of London* (1999) 53, pp. 203–17; James Delbourgo, *Collecting the World: The Life and Curiosity of Hans Sloane*, London: Penguin, 2017.

32 Cristina Malcolmson, *Studies of Skin Color in the Early Royal Society: Boyle, Cavendish, Swift*, Burlington, VT: Ashgate, 2013, pp. 29–64.

33 James Delbourgo, 'The Newtonian slave body: racial enlightenment in the Atlantic World', *Atlantic Studies* (2012) 9, pp. 185–207.

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through their understanding of philosophical chemistry, had been able to rationalize and perfect the technical art of dyeing.[34]

Much of Newton's own work did not concern humans at all, yet he nevertheless benefited from an early modern 'information order' that was strongly shaped by the colonial networks of racialized plantation economies.[35] Newton never travelled outside Britain, so the insights of his vaunted *Principia Mathematica* depended on astronomical data and experimental observations of gravitational force collected by others travelling across the world. One significant example is Newton's use of the observations of Jean Richer and Jean Deshayes, French astronomers who experimented with pendulums in Gorée, Cayenne and Guadeloupe, major end points of the French trade in enslaved Africans in Senegal, Guiana and the Caribbean respectively. Their lengthy voyages to collect data were directly enabled by the slave-trading companies, who carried them aboard ships with human cargo. Newton's groundbreaking conclusions about geographical variations in gravitational force, based on the data of Richer and Deshayes, are thus inextricably linked to European enslavement of Africans.[36]

The racialized coercive regimes of manual and intellectual labour hidden within Newton's physics are rather easier to detect in the history of botanical sciences, where the importance of non-European agricultural and pharmaceutical knowledge was more readily acknowledged for its potential economic and medicinal value. Indeed, Europeans highly valued the botanical knowledge of Asian peoples, to the point of staking major economic ventures upon their racialized understanding of plant–cultivator relationships. In 1621 the Dutch East India Company, seeking to create a monopoly over nutmeg in the Maluku archipelago's Banda islands, massacred or exiled almost the entire indigenous population of 15,000 people and divided the islands into Dutch-controlled plantations to be worked by people enslaved and imported from other parts of South and South East Asia. The small number of Bandanese allowed to remain were also enslaved and 'deliberately distributed about the islands to make use of their expertise in cultivation and spice production, with several hundred individuals initially exiled to Batavia being returned to the Bandas for this very purpose'.[37]

Attempts by other European empires to break the Dutch monopoly and cultivate smuggled nutmeg elsewhere, such as the French colony of Mauritius, were often foiled by Europeans' lack of knowledge about the plant and its peculiar botanical features and ecological needs. Assuming that this knowledge was racially embodied, French officers brought two Maluku men to Mauritius in the 1770s, expecting that the nutmeg plants would thrive under their care; however, they were disappointed when the men (who had not previously worked in nutmeg cultivation) were unsuccessful. The French had to accumulate botanical knowledge of nutmeg through experimental acclimatization, translation of Dutch texts and spying missions to the Banda islands.[38] A similar phenomenon occurred in the early nineteenth century, when the British East India Company (EIC) began to set up tea plantations in Assam. The EIC initially aspired to recruit Chinese tea cultivators, whom they believed to have leaf-processing skills, botanical expertise and a

34 James Delbourgo, 'Fugitive colours: shamans' knowledge, chemical empire and Atlantic revolutions', in Schaffer *et al.*, op. cit. (4), pp. 271–320.

35 Simon Schaffer, 'Newton on the beach: the information order of *Principia Mathematica*', *History of Science* (2009) 47, pp. 243–76.

36 Schaffer, op. cit. (35), pp. 247–8; Isaac Newton, *The Mathematical Principles of Natural Philosophy* (tr. Andrew Motte), London: Benjamin Motte, 1729, vol. 2, pp. 248–51; Poskett, *Horizons*, op. cit. (30), pp. 101–5.

37 Phillip Winn, 'Slavery and cultural creativity in the Banda islands', *Journal of Southeast Asian Studies* (2010) 41, pp. 365–89, 369.

38 Dorit Brixius, 'A hard nut to crack: nutmeg cultivation and the application of natural history between the Maluku islands and Isle de France (1750s–1780s)', *BJHS* (2018) 51, pp. 585–606, 594–5.

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racial disposition toward industry that neither Europeans nor the region's 'primitive' natives possessed. Like the French in Mauritius, the British were disappointed that the Chinese workers they recruited from South East Asian trade ports did not live up to these racialized expectations, and soon turned to migrant labour from central India to harvest Assamese tea.[39]

Historians of botany in colonial Latin America and the Caribbean have highlighted European 'bioprospecting', the search for new plants with medicinal and agricultural value. Such bioprospecting similarly hinged on the racialization of knowledge, with European physicians and naturalists seeking to extract everything that indigenous or African diasporic communities knew about the local plant life.[40] These communities were not always willing to share their knowledge of herbal remedies, which were often administered within the rituals of healing systems that Europeans openly ridiculed and rejected. European physicians therefore coerced indigenous and African-descent healers to give up their botanical secrets through means ranging from cash bribes and spying on their activities to physical force and threats to their lives.[41] In early colonial Mexico, Iberian physicians valued direct observation of indigenous informants in the preparation of medicinal and food plants.[42] This fetishization of 'untainted' indigenous knowledge only increased in the following centuries as indigenous peoples themselves were 'lost' to the ravages of disease or amalgamated into Mexico's culture of *mestizaje*. By the late eighteenth century, colonial botanists of the Royal Botanical Expedition to New Spain lamented their difficulty in finding indigenous people 'uncorrupted enough to still have the old wisdom'.[43] Lance Thurner shows that the expedition's objectives and epistemology centred on 'careful attention to race', their task being 'to discern truths and medical discoveries' achievable only through identifying racialized indigeneity, through which they would access 'secrets of nature'.[44]

The process of racializing Mexico's knowledge resources was not limited to humans, as Helen Anne Curry shows through her analysis of twentieth-century botanical taxonomic research into Mexican 'races of corn'. The term 'race', of course, can be applied to plants and animals just as well as to humans, and historically this was a common usage (recall the subtitle of Darwin's *On the Origin of Species by Means of Natural Selection, or the Preservation of Favoured Races in the Struggle for Life*, which refers more often to races of cabbages, dogs and pigeons than to humans). Yet even as human race science was allegedly declining in the mid-twentieth century, botanists documented and classified Mexico's diverse maize varieties through explicit analogies to physical anthropology and the racialization of indigenous peoples in Mexico.[45]

More recently, historians have exposed how the development of geological sciences is likewise indebted to the racialized economies of European empires. The forms of environmental and chemical knowledge that underlie the modern science of geology, such as

39 Jayeeta Sharma, *Empire's Garden: Assam and the Making of India*, Durham, NC: Duke University Press, 2011, pp. 35–40.

40 Tomomi Kinukawa, 'Science and whiteness as property in the Dutch Atlantic world: Maria Sibylla Merian's *Metamorphosis Insectorum Surinamensium* (1705)', *Journal of Women's History* (2012) 24, pp. 91–116.

41 Londa L. Schiebinger, *Plants and Empire: Colonial Bioprospecting in the Atlantic World*, Cambridge, MA: Harvard University Press, 2004.

42 Ran Segev, '"For the sciences migrate, just like people": the case of botanical knowledge in the early modern Iberian empires', *Perspectives on Science* (2022) 30, pp. 732–56.

43 Lance C. Thurner, 'Botanizing in the borderlands: the limits of scientific indigeneity in late colonial New Spain', *Colonial Latin American Review* (2021) 30, pp. 109–36, 113.

44 Thurner, op. cit. (43), p. 127.

45 Helen Anne Curry, 'Taxonomy, race science, and Mexican maize', *Isis* (2021) 112, pp. 1–21.

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mining and metallurgy, underwent significant shifts following Iberian imperial expansion in the sixteenth century. As Allison Bigelow writes, 'the collision of African, Indigenous, and Spanish knowledge in the Americas' enabled the conceptual emergence of a technical expert with 'skilled knowledge of mineral extraction' distinct from general manual labour or artisanal techniques.[46] This skilled knowledge incorporated notions of human difference into its technical language and practices. Not only did Spanish colonial mining and metallurgy operate through highly racialized divisions of labour, just like agricultural plantations; Spanish colonial scholars also used racialized language, including colour-based terminology and categorical terms like *casta* and *mulato*, to classify different grades of metals and ores.

Robyn d'Avignon traces similar patterns through the history of West African gold mining and French colonial 'exploration geology'. West African peoples possessed a dynamic tradition of geological knowledge and mining practices that often outperformed European colonial excavation technologies. In the early decades of the twentieth century, d'Avignon writes, 'French prospectors benefited from the labor and mineral expertise of generations of African miners, [who, in turn,] acquired new techniques from expatriate geologists', creating an 'economy of subterranean knowledge that blurred any facile distinction between African and European mining practice'.[47] Yet for decades, French racism denied the importance of this 'fluid' knowledge exchange, casting African gold prospecting and mining techniques as primitive and static, and legally restricting African miners to work only in designated areas.

In between these historical examples, geology's systematization as a distinct scientific discipline in the nineteenth century was firmly intertwined with racial ideas. Studying the physical properties of the Earth meant constant confrontations with evidence of past worlds and lives in the form of sedimentary deposits and the fossils they contained. By the 1830s, British scientist Charles Lyell offered an expansive definition of geology as the study of changes in both 'organic and inorganic kingdoms of nature', requiring knowledge not only of mineralogy and chemistry but also of zoology, botany and anatomy. Lyell drew direct analogies between the proper methodologies of geologists to understand the past changes leading to the Earth's present state, and of historians to understand the 'present condition of nations' on the basis of 'various peculiarities of national character' and 'different degrees of moral and intellectual refinement'.[48]

Indeed, the linkage of geology to human history went beyond mere analogy. Questions about the age of the Earth and the speed and timing of geological events were addressed through the accumulation of human and primate fossils and the archaeological remains of past human activity. For example, archaeologists working in Egypt began applying the geological method of stratigraphy to their excavation practices, while geologists used their new relative dating of human habitation in Egypt to dispute biblical chronologies of the Earth.[49] The framework of 'deep time' that coalesced during the nineteenth century, based on intensive analysis of geological formations, fossils and prehistoric human remains was not simply contemporaneous with European colonization of other

46 Allison Margaret Bigelow, *Mining Language: Racial Thinking, Indigenous Knowledge, and Colonial Metallurgy in the Early Modern Iberian world*, Chapel Hill: University of North Carolina Press, 2020, pp. 14–16.

47 Robyn D'Avignon, *A Ritual Geology: Gold and Subterranean Knowledge in Savanna West Africa*, Durham, NC: Duke University Press, 2022, pp. 110–11.

48 Charles Lyell, *Principles of Geology, Being an Attempt to Explain the Former Changes of the Earth's Surface, by Reference to Causes Now in Operation*, London: John Murray, 1830, vol. 1, p. 1.

49 Meira Gold, 'Ancient Egypt and the geological antiquity of man, 1847–1863', *History of Science* (2019) 57, pp. 194–230.

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parts of the world; rather, this development was a direct result of colonization and its associated processes of racialization.[50]

As Pratik Chakrabarti details for colonial India, aboriginal and indigenous populations in the present were seen as relics of the prehistoric past. The geological history of the Earth was approached and analysed in terms of human racial evolution, as in the naming of the prehistoric supercontinent of Gondwanaland after the 'primitive' Gond tribe, designated by British ethnologists as a branch of the aboriginal 'Dravidian' peoples who inhabited the Indian subcontinent before its hypothesized invasion by Aryans.[51] Finally, the very nature of geological fieldwork enabled not only European colonial scientists, but also anti-imperialists outside Europe, to make claims about present-day racial and civilizational superiority. Sigrid Schmalzer and Grace Yen Shen show that geological expeditions in twentieth-century China had racial implications both in terms of the potential discovery of human fossils or other evidence of prehistoric human activity, and in terms of the physical capabilities of Chinese geologists themselves to document and analyse the national landscape.[52]

Racialization and its afterlives in data sciences and technology

How did race as an epistemic object of study, as well as a scientific category of analysis, enable the production and practice of emerging scientific disciplines? In this section, inspired by the recent work of Iris Clever, we examine the methodological and technological underpinnings of the new fields called data science and 'artificial intelligence' or machine learning.[53] These fields rely on a foundation of statistics, as well as technologies to generate and process data, such as the spirometer, the camera and the electronic computer. Both statistics and these associated technologies have enjoyed a public perception of providing 'objective' and trustworthy information about the natural world, overcoming the inevitable human bias of individual researchers.[54] But in fact race played a significant role in the disciplinary emergence of statistics and the evolving notion of quantitative objectivity as a key scientific value. For example, Suman Seth highlights the medical statistics recorded for European military forces deployed in overseas colonies as the site of a numerical reification of racial difference.[55] Alain Desrosières, Theodore Porter and Ian Hacking have explored the linked rise of statistical thinking and race science within nineteenth-century Europe.[56] The entangled emergence of race science and statistics was not incidental. The availability of ever-increasing volumes of racial

50 James A. Secord, 'Global geology and the tectonics of empire', in Helen Anne Curry, Nicholas Jardine, James Andrew Secord and Emma C. Spary (eds.), *Worlds of Natural History*, Cambridge: Cambridge University Press, 2018, pp. 401–17.

51 Pratik Chakrabarti, *Inscriptions of Nature: Geology and the Naturalization of Antiquity*, Baltimore: Johns Hopkins University Press, 2020. See also Sumathi Ramaswamy's analysis of the hypothetical lost continent of Lemuria, which was similarly proposed as a geological explanation for the origins of Tamils or other 'pre-Dravidian' races in India. Sumathi Ramaswamy, *The Lost Land of Lemuria: Fabulous Geographies, Catastrophic Histories*, Berkeley: University of California Press, 2004.

52 Sigrid Schmalzer, *The People's Peking Man: Popular Science and Human Identity in Twentieth-Century China*, Chicago: The University of Chicago Press, 2008; Grace Yen Shen, *Unearthing the Nation: Modern Geology and Nationalism in Republican China*, Chicago: The University of Chicago Press, 2014.

53 Iris Clever, 'The lives and afterlives of skulls: the development of biometric methods of measuring race (1880–1950)', PhD dissertation, University of California, Los Angeles, 2020.

54 Theodore M. Porter, *Trust in Numbers: The Pursuit of Objectivity in Science and Public Life*, new edn, Princeton, NJ: Princeton University Press, 2020.

55 Projit Bihari Mukharji *et al.*, 'A roundtable discussion on collecting demographics data', *Isis* (2020) 111, pp. 310–53, 331–3.

56 Alain Desrosières, *The Politics of Large Numbers: A History of Statistical Reasoning* (tr. Camille Naish), Cambridge, MA: Harvard University Press, 1998; Theodore M. Porter, *The Rise of Statistical Thinking, 1820–1900*, new edn, Princeton, NJ: Princeton University Press, 2020.

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anthropometric data and the demand of race scientists for more nuanced and precise techniques to sort racial categories facilitated the development of new data management practices and statistical formulae to determine similarity and difference between groups in quantitative terms.[57]

These statistical developments were often intertwined not only with the interests of colonial officials, but also with those of anti-colonial nationalist scientists.[58] In 1922, Nelson Annandale, the Scottish director of the Zoological Survey of India (ZSI), collected anthropometric data (such as nasal index, head length and stature) from two hundred Anglo-Indians. In 1922, he asked Indian statistician Prasanta Chandra Mahalanobis to statistically analyse the data since they represented 'a true biologically mixed population'.[59] Mahalanobis used Karl Pearson's method of calculating the racial proximity of two groups in analysing the Anglo-Indian data set. In doing so, however, Mahalanobis encountered the limitations of Pearson's coefficient of racial likeness (CRL). While the CRL could determine whether or not two groups were racially connected, it failed to determine the magnitude of racial proximity. The CRL was therefore inadequate for Mahalanobis and Indian anthropologists in this period, who were focused on finding out the extent to which each caste, tribe and religious group in the subcontinent had racially mixed with others.[60] Following his work with Annandale, Mahalanobis tasked himself with developing a statistical formula that could measure racial intermixture. He devised the coefficient of generalized distance, later popularized as the 'Mahalanobis distance' by English statistician Ronald A. Fisher.[61]

The Mahalanobis distance is a calculation of the distance between a data point within one population group and the mean value of another population group's data set. As one of India's major original contributions to international statistics, the Mahalanobis distance formula has since been applied to many other statistical contexts, such as population growth, agricultural output and financial calculations.[62] Recently it has been incorporated into machine learning and facial-recognition technologies, discussed below.[63] Yet institutional and biographical histories of Indian statistics tend to overlook or deliberately ignore the relationship between statistical innovation and race science. The statistical tools that Mahalanobis developed were shaped by the specific problem he aimed to solve, namely the extent to which Anglo-Indians had racially mixed with other Indian communities. Racial questions and data sets often served as conditions for the fact that many of these methods are now applied for other purposes does not make their origins in race science irrelevant. Rather, it reveals the extent to which our contemporary forms of allegedly objective quantitative data analysis were made possible through investigations of racial difference.

57 Iris Clever, 'Biometry against fascism: Geoffrey Morant, race, and anti-racism in twentieth-century physical anthropology', *Isis* (2023) 114, pp. 25–49.

58 Ghoshal, op. cit. (20).

59 Prasanta Chandra Mahalanobis, 'Anthropological observations on the Anglo-Indians of Culcutta part I: analysis of male stature', *Records of the Zoological Survey of India* (1922) 23, pp. 1–96, 6.

60 Projit Bihari Mukharji, 'Profiling the profiloscope: facialization of race technologies and the rise of biometric nationalism in inter-war British India', *History and Technology* (2015) 31, pp. 376–96.

61 Prasanta Chandra Mahalanobis, 'The application of statistical methods in physical anthropometry', *Sankhya: The Indian Journal of Statistics* (1940) 4, pp. 594–8.

62 Mark Kritzman and Yuanzhen Li, 'Skulls, financial turbulence, and risk management', *Financial Analysts Journal* (2010) 66, pp. 30–41.

63 Simon Michael Taylor, Kalervo N. Gulson and Duncan McDuie-Ra, 'Artificial intelligence from colonial India: race, statistics, and facial recognition in the global South', *Science, Technology, & Human Values* (2023) 48, pp. 663–89; Sananda Sahoo, 'Biometric data's colonial imaginaries continue in Aadhaar's minimal data', *BJHS Themes* (2023) 8, pp. 205–20.

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Projects of statistical race making involved not only abstract formulae, but also concrete technologies of measurement. For instance, Lundy Braun shows that the spirometer, a mechanical device used to measure lung capacity, served as both a conduit and a consequence of nineteenth-century racial ideas. Lung capacity was considered an important measure of health and strength, and the spirometer enabled the large-scale accumulation of data for the calculation of statistical averages for different social groups, which in turn were used to determine group members' life insurance assessments and the suitability for particular occupations. Following its application to comparing the lung capacity of white and black farmers, spirometry data came to be seen as objective evidence for the hereditary nature of racial differences, and therefore a legitimate basis for racialized divisions of labour. By reinforcing expectations of different physiological norms of lung capacity for different races, the spirometer led to the introduction of statistical mechanisms of 'race correction' in the collection of medical data. Modified spirometry devices are still in use today, as is their associated statistical legacy of race correction, which advocates now try to corroborate with genetic markers.[64]

As a final case, we examine photographic technologies, which historians of science and medicine have analysed as key to the concept of mechanical objectivity in scientific imagery. Mechanical cameras rely upon physical and chemical principles to capture light and create an endlessly reproducible image. For nineteenth-century scientists, these features seemed to make the camera able to faithfully document true appearances and therefore exceptionally robust to human errors of perception. Scientific researchers, from physicists to microbiologists, quickly incorporated cameras into their laboratory equipment.[65] Yet the allegedly objective camera likewise soon became 'a major medium in the scientific study of race' through the creation of anthropometric photography, which aimed to provide unbiased and even standardized evidence of physical racial differences.[66] Meanwhile, art historians have analysed how the physical and chemical processes of photography engaged British and American cultural anxieties about racial difference, particularly skin colour. In the nineteenth century, the chemical properties of silver nitrate, which darkens upon light exposure, led British writers to coin a literary trope that cameras temporarily transformed their users from racially white to 'Negroes' through the form of the photographic negative (and sometimes through staining the skin of amateur enthusiasts who were careless with the substance).[67]

Following the mid-twentieth-century rise of colour film photography, camera film manufacturers like Kodak were confronted with the fact that their product was not capable of realistically depicting white and dark-skinned people in the same frame. The film's chemical emulsion was designed to capture the high reflectivity of white complexions, and rendered nearly invisible any others in the frame with darker skin tones. Kodak attempted to solve this problem by issuing 'multiracial' colour-calibration reference cards (called 'Shirley cards').[68] In another instance, during the 1970s, the Polaroid Corporation was accused of serving the interests of South Africa's apartheid regime

64 Lundy Braun, *Breathing Race into the Machine: The Surprising Career of the Spirometer from Plantation to Genetics*, Minneapolis: University of Minnesota Press, 2014.

65 Lorraine Daston and Peter Galison, *Objectivity*, New York: Zone Books, 2010.

66 Amos Morris-Reich, *Race and Photography: Racial Photography as Scientific Evidence, 1876–1980*, Chicago: The University of Chicago Press, 2016, p. 1; Gabriela Zamorano, 'Traitorous physiognomy: photography and the racialization of Bolivian Indians by the Créqui–Montfort expedition (1903)', *Journal of Latin American and Caribbean Anthropology* (2011) 16, pp. 425–55.

67 Tanya Sheehan, 'Comical conflations: racial identity and the science of photography', *Photography and Culture* (2011) 4, pp. 133–55.

68 Lorna Roth, 'Looking at Shirley, the ultimate norm: colour balance, image technologies, and cognitive equity', *Canadian Journal of Communication* (2009) 34, pp. 111–36.

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through sale of its I.D.-2 camera system, which produced instant photographs for identification cards, and included an enhanced flash allegedly designed to better capture dark skin tones. This technology was used to enforce the notorious passbook system to control and surveil the movements of black South Africans. In response, a number of Polaroid employees formed the Polaroid Workers Revolutionary Movement, which campaigned for boycotting the company.[69]

Such instances unfortunately cannot be relegated to a racist past in contrast to a progressive present. The technological transition from film to digital cameras, relying on electronic sensors and computer visualization beginning in the 1990s, did not eliminate racial bias in the camera itself nor in its social uses. Digital photography paved the way for artificial-intelligence (machine-learning) programs for facial recognition; the higher failure rates of facial recognition technologies for dark-skinned people, including Africans, are now well documented in the literature of science and technology studies.[70] In 2009, a Taiwanese American blogger noted how every time she attempted to take a photograph of herself or her family with her newly purchased Nikon S630 digital camera, the camera's user interface would ask if someone in the frame had blinked.[71] This feature was programmed into the camera's facial-recognition system to ensure that subjects had their eyes fully open before taking a photograph. Such features, as James Bridle notes, clearly 'failed to account for the different physiognomy of non-Caucasians'.[72] Thus racial biases are embedded into technology through dominant notions of what constitutes the normal, which inevitably reflect 'the systemic inequalities still present within today's technological workforce, where those developing and testing the systems are still predominantly white'.[73] In other words, depending on where the technology is coded and who does the coding, what is normal becomes racially inflected.

Contemporary governments' increasing reliance on facial recognition as a biometric technology to control and surveil people and borders does not reduce the long-standing impact of racial (and other) biases in policing. For example, in India's north-east, the 1958 Armed Forces Special Powers Act (AFSPA) enables the state to detain and arrest people who 'look like' a militant. Discussing racial profiling in this context, scholars note that machine learning in facial recognition 'has the potential to extend and embolden these systems of occupation. Routine arrest and detention add more facial profiles to the database, making matching easier and justifiable in ongoing surveillance', and creating a self-reinforcing loop of suspicion and matching individuals.[74] These ongoing situations demonstrate that modern technology does not eliminate racial biases, despite the promise of biometric technologies to capture personalized individual identities rather than group categories. Even if the output of machine learning is progressively more independent of human intervention, it remains inherently dependent on historical data imbued with racialized biases about how 'normal' humans look, speak and act. Technologies are produced within contexts of power imbalance and social hierarchies, and consequently tend to reinforce these biases rather than neutralize them.

69 Eric J. Morgan, 'The world is watching: Polaroid and South Africa', *Enterprise & Society* (2006) 7, pp. 520–49; Joseph N. Mait, 'Polaroid's experiment in South Africa', *Optics and Photonics News* (2021) 32, pp. 43–9.

70 Simone Browne, 'Digital epidermalization: race, identity and biometrics', *Critical Sociology* (2010) 36, pp. 131–50; Ruha Benjamin, *Race after Technology: Abolitionist Tools for the New Jim Code*, Medford, MA: Polity, 2019.

71 Jozjozjoz, 'No, racist camera, I did not blink; I'm just Asian', *8asians.com*, 13 May 2009, at www.8asians.com/2009/05/13/racist-camera-no-i-did-not-blink-im-just-asian (accessed 24 March 2024).

72 James Bridle, *New Dark Age: Technology, Knowledge and the End of the Future*, London: Verso, 2018, pp. 142–3.

73 Bridle, op. cit. (72), p. 143.

74 Taylor, Gulson and McDuie-Ra, op. cit. (63), p. 680.

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Conclusion

The 1993 reflections on 'big-picture' historiographies of science offered a range of perspectives on the desirability of big pictures, as well as the strategies to be used in creating them. Regardless, the contributors all agreed that a genuine big picture would 'not presume … distinctions between science, technology and medicine', would make room for many possible 'ways of knowing', and would be, fundamentally, a social history.[75] Specifically, any successful big picture would require a narrative addressing the relation of science to social and political power.[76] Yet race was conspicuously marginal to their visions of the power structures and social priorities shaping the overlapping historical developments of science, technology and medicine. In the last thirty years, historical scholarship on race concepts and racialization processes, as well as on their entanglements with science, technology and medicine, has dramatically expanded. Cumulatively, the 'minute particulars' of these many social histories of race demand a reckoning.[77] Attention to race in historical scholarship not only is indicative of how 'circumstances have changed' for historians' understanding of science and society in our present moment.[78] It also demonstrates a new possibility for a 'big' narrative, covering large temporal and geographic scales and many fields of science, and providing an indisputable link between scientific activities and socio-economic power structures. From the eighteenth century to the twentieth, race science was a significant field of mainstream research engaging all of the human sciences. In addition to its methodological expansiveness, race science was geographically global: it came to function simultaneously as a strategy of European colonial governance and as a tool for anticolonial nationalist aspirations in Asia and Africa. However, the place of race within the history of science cannot be relegated to 'race science' as a subset of disciplines specifically concerned with racial classification, such as anthropology, biology or medicine. Beginning in the early modern period, racialized economies of unfree labour sustained the economic and intellectual infrastructures of gentlemanly science. European economic dominance through various forms of colonization and enslavement transformed non-Europeans into 'native informants', 'knowledge brokers' or, at worst, experimental bodies. The body of knowledge formerly called Western or modern science substantially incorporates the manual and intellectual labour of peoples excluded from social and political power, due to perceived and measured physical and cultural differences deemed racial. We conclude that any big picture of the history of science cannot be drawn without a reflection on how theories and methodologies of constructing racial difference have continued to inform and shape all scientific fields and related technologies.

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75 John V. Pickstone, 'Ways of knowing: towards a historical sociology of science, technology and medicine', *BJHS* (1993) 26, pp. 433–58, 433, 441. See also Andrew Cunningham and Perry Williams, 'De-centring the "big picture": *The Origins of Modern Science* and the modern origins of science', *BJHS* (1993) 26, pp. 407–32.

76 J.R.R. Christie, 'Aurora, Nemesis and Clio', *BJHS* (1993) 26, pp. 391–405, 403–5.

77 Pickstone, op. cit. (75), p. 458.

78 Cunningham and Williams, op. cit. (75), p. 409.

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