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SCIENCE AND IMPERIALISM SINCE 1870

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Science and imperialism emerged as dynamic and significant fields of inquiry within the history of science, the history of imperialism, and postcolonial studies in the 1970s.[1] There is now a clear understanding that the work of scientists in and for European colonies was not a marginal aspect of modern Western science but was integral to its development overall, and especially so in the biological and environmental sciences. At the same time, the impact of science in colonial territories has become a key theme in histories of imperialism, the histories of different colonies, histories of the Third World countries, and postcolonial studies, which is a diverse field of cultural analysis that explores new perspectives on the previously dominant historical narratives.[2] Science and imperialism is now a vibrant field of enquiry, perhaps nothing less than the global history of science. A single chapter on this topic for the long twentieth century has, therefore, to be selective, and should be read in conjunction with the other contributions to this volume that consider particular regions and countries. Our approach is to discuss specific sites and sciences, principally, but not exclusively, in India and Africa and to focus on the biological and environmental sciences.

Interest in science and imperialism came from the new attention historians gave from the 1960s to the social history of science, which drew inspiration from a growing anti-positivist philosophy of science, and engaged more with the production, circulation, and validation of knowledge, with practices, and with social impacts. Seeing science as socially constructed knowledge opened possibilities for understanding its

[1] Roy MacLeod, "Reading the Discourse of Colonial Science," in *Les Sciences hors d'Occident au XXeme siècle*, vol. 2: *Les Sciences coloniales: figures et institutions*, ed. Patrick Petitjean (Paris: ORSTOM, 1996), pp. 87–98; Richard Drayton, "Science and European Empires," *Journal of Imperial and Commonwealth History*, 23 (1995), 503–10.

[2] Sandra G. Harding, *Is Science Multicultural? Postcolonialisms, Feminisms, and Epistemologies* (Bloomington, Ind.: Indiana University Press, 1998); Gyan Prakash, *Another Reason: Science and the Imagination of Modern India* (Princeton, NJ: Princeton University Press, 1999).

development in cultural contexts beyond Western Europe and North America. At the same time, the Eurocentric prejudices of scientific visions were being critiqued, for example in global mapping, which had previously placed Europe at the center of the distribution of land masses, and in the need for sciences and technologies appropriate for non-Western cultures.[3] Another important factor in the change was the scholarship of historians in former colonies and the distinctive perspectives they created.

The key historiographical shift was the move away from seeing the diffusion of modern science as a source of enlightenment and progress, with the inevitable displacement of traditional, non-scientific beliefs. In its place, historians showed that science was also a force of domination and was one of the key features of Western civilization that legitimated the subjugation of peoples and contributed to their exploitation.[4] Such perspectives suggested fresh ways of looking at the question of the constitution of scientific knowledge and the formulation of new frameworks within which scientific knowledge can be located. Thus historians and, later, postcolonial theorists looked towards colonial empires for alternative analyses of science and modernity. They moved away from the assumption of a single narrative of the diffusion from "centers" to "peripheries," to accounts of complex interactions and networks, in diverse locations, between different types of scientists and forms of scientific activity.[5] While it remains useful to consider science as a "tool of empire" in terms of political control and economic

[3] Derek Gregory and David Livingstone have argued that the visual representation of the world in the forms of maps can be a powerful and insidious way of conveying cultural prejudices. Derek Gregory, *Geographical Imagination* (Oxford: Oxford University Press, 1994); David N. Livingstone, "The Spaces of Knowledge: Contributions Towards a Historical Geography of Science," *Environment and Planning D: Society and Space*, 13 (1995), 5–34. Nicolas A. Rupke in an interesting article has shown how the continental drift theory incorporated the prejudices of "continentalism," that is, the belief in the geographical superiority of one continent over another. Nicolas A. Rupke, "Eurocentric Ideology of Continental Drift," *History of Science*, 34 (1996), 251–72.

[4] Michael Adas, *Machines as the Measure of Men: Science, Technology and Ideologies of Western Dominance* (Ithaca, NY: Cornell University Press, 1989).

[5] George Basalla, "The Spread of Western Science," *Science*, 156 (1967), 611–22; George Basalla, "The Spread of Western Science Revisited," in *Mundializacion de cienca y cultura nacional*, ed. Antonio Lafuente et al. (Madrid: Ediciones Doce Calles, 1993), pp. 599–603; Dhruv Raina, "From West to Non-West? Basalla's Three Stage Model Revisited," *Science as Culture*, 8 (1999), 497–516; Warwick Anderson, "Remembering the Spread of Western Science," *Historical Records of Australian Science*, 29 (2018), 73–81. Based on studies of specific European colonies, Lewis Pyenson argued that neither knowledge nor practice was influenced by the colonial context. See Lewis Pyenson, *Cultural Imperialism and the Exact Sciences: German Expansion Overseas, 1900–1930* (New York: Peter Lang, 1985); Lewis Pyenson, *Empire of Reason: Exact Sciences in Indonesia, 1840–1940* (Leiden: E. J. Brill, 1989); Lewis Pyenson, *Civilising Mission: Exact Science in French Overseas Expansion, 1830–1940* (Baltimore, Md.: Johns Hopkins University Press, 1993); Lewis Pyenson, "Why Science May Serve Political Ends: Cultural Imperialism and the Mission to Civilise," *Berichte zur Wissenschafigeschichte*, 13 (1990), 69–78. However, his claims have attracted criticism, with other historians arguing that his case studies are highly selective and his focus narrow, and that more widely and generally sciences in the colonies were constituted in the context of cultural and material domination and directly served imperial power. See Paolo Palladino and Michael Worboys, "Science and Imperialism," *Isis*, 84 (1993), 91–102; Lewis Pyenson, "Cultural Imperialism and Exact Sciences Revisited," *Isis*, 84 (1993), 103–8.

exploitation, there is greater recognition of its, often contested, cultural and ideological uses by colonists, especially as part of the "civilizing missions," and of resistance by colonial peoples.[6]

These new frameworks of interactions and circulation include the notion of "moving metropoles," "multi-sited histories," and "polycentric communications networks," which all stress the interconnectedness and changing relations of power and influence of scientific activity across the world.[7] These have highlighted the need to move away from the "binary" and "deterministic" understanding of the history of imperial science and to understand the relations of science and empire in "contingent, nondeterministic and unstable ways."[8] Such approaches draw upon new approaches in imperial history, which have seen the global history of European empires as "connected history."[9] Drawing from diverse historical settings, historians have challenged the idea that modern science is "Western." They now stress the complex negotiations and exchanges between Europeans and others, and argue that the history of modern science is one of hybrid origin and articulation and that modern science is neither Western nor colonial, but "global." To an extent, the "global" has thus replaced or redefined the "imperial" as a key historical category.[10]

While this recent work has been significant, particularly in using the imperial context to explore the history of diversity and plurality of scientific experiences, it does not have a unique methodology for critically understanding networks and connected histories themselves. While it opens up new possibilities of extending the spatial and intellectual field of science, it also introduces the problem of "placelessness" to such histories. As "networks" have become the key theme in writing imperial history of science, they themselves have not received the same critical analysis and as a result can appear as all encompassing, abstract, and unproblematic. Imperial networks, through which goods, profits, and laborers traveled, were key to imperial exploitation, profit, and privilege. Therefore, when history of

[6] Patrick Petitjean, "Science and the 'Civilizing Mission': France and the Colonial Enterprise," in *Science Across the European Empires 1800–1950*, ed. Benedikt Stutchey (Oxford: Oxford University Press, 2005), pp. 107–28.

[7] Roy M. MacLeod, "On Visiting the 'Moving Metropolis': Reflections on the Architecture of Imperial Science," *Historical Records of Australian Science*, 5 (1982), 1–16; Warwick Anderson, "Postcolonial Histories of Medicine," in *Locating Medical History: The Stories and Their Meanings*, ed. Frank Huisman and John Harley Warner (Baltimore, Md.: Johns Hopkins University Press, 2004), pp. 285–307, on 287; David Wade-Chambers and Richard Gillespie, "Locality in the History of Colonial Science," *Osiris*, 15 (2000), 221–40.

[8] Brett M. Bennett and Joseph M. Hodge, *Science and Empire: Knowledge Across the British Empire, 1800–1970* (Basingstoke: Palgrave Macmillan, 2011), pp. 13–16.

[9] Christopher Bayly, *The Birth of the Modern World, 1780–1914: Global Connections and Comparisons* (Oxford: Blackwell, 2004); John Darwin, *After Tamerlane: The Rise and Fall of Global Empires, 1400–2000* (London: Penguin, 2008).

[10] "Focus" section of journal titled "Global Histories of Science," organized by Sujit Sivasundaram, *Isis*, 101 (2010), 95–158; Lissa Roberts, "Situating Science in Global History: Local Exchanges and Networks of Circulation," *Itinerario*, 33 (2009), 9–30.

science uses "networks" as an approach, it needs to also incorporate such themes in its critical analysis. While it is certainly true that modern science absorbed ideas, objects, and plants from various parts of the world, at the same time its global capital of knowledge and materials brought it into world trade and power struggles. This enabled scientists to create "universal" scales of classification and theorization; however, there is still work to do in analyzing how modern science, in its global invention and reflection, privileged European institutions and empires over other forms of knowledge and polities. Seeing imperial histories as "connected histories" also makes it difficult to appreciate the narratives around different empires and types of colonies, different sites and types of scientific practice, different sciences and their relations with indigenous knowledge and practices, and changing forms of hegemony and resistance.[11]

Yet there is a need for "big pictures." Mark Harrison has raised the significant question, "how we might do justice to the peculiarities of place without losing sight of the 'big picture'," and wondered whether historians "ought to dispense with such frameworks altogether, [because] they represent a Eurocentric and inherently imperialist perspective." However, he concludes otherwise and argues that "big pictures" histories of science and imperialism are essential to understand relations between centers and peripheries, to include not just "communication networks," but all forms of power.[12]

IMPERIALISM

Imperialism is typically characterized as one country imposing its control over another territory, including the subjugation of the indigenous peoples, the attempt to establish cultural hegemony, and the development of unequal economic relations. The term gained currency in political discourse in the nineteenth century, but its use after Lenin has been principally pejorative, and focused on the creation of formal and informal "empires" by Western European powers and the United States in the decades after 1870. The paradigmatic imperial power was Great Britain, which, in the grand era of empires at the turn of the twentieth century, had the largest formal empire by land area, and on which famously the "sun never set," plus significant spheres of influence in many other countries. In historical studies, the diversity of empires and imperial power relations has meant that the deployment of the term has been problematic and contested; however, its continued currency demonstrates its value descriptively and analytically.

[11] Nathan Reingold and M. Rothenberg, eds., *Scientific Colonialism: A Cross-Cultural Comparison* (Washington DC: Smithsonian Institution Press, 1987).

[12] Mark Harrison, "Review of Benedikt Stuchtey, ed., *Science across the European Empires, 1800–1950*," *English Historical Review*, 122 (2007), 494.

The term "colonialism" in imperial history is strangely of later vintage, only being adopted by scholars from the 1950s and, interestingly, coincident with the end of formal imperialism as colonial territories gained political independence. "Colony" and "colonial" have a very long history, with most uses showing continuity with its origins as an estate, settlement, or community in a new part of the Roman Empire. Before the eighteenth century, the term was best known as applying to the North American colonies of European settlement and the slave plantations of the West Indies. In the struggles for independence in the Americas, "colonial" assumed negative associations of societies that were dependent, derivative, and dominated, a position to be reversed by achieving independence. This critical connotation remained and gained currency with the emergence of independence movements in colonial territories in the twentieth century, which rejected the legitimacy of annexing of territories and the creation of relations of dependency based on the exploitation of resources and labor that had been established by force, economic policies, and cultural hegemony.[13]

Imperialism took its classic modern form in the second half of the nineteenth century when Britain, France, and other Western European nations as well as the United States expanded their empires territorially, annexing unclaimed areas of Africa, Asia, South America, and Oceania in the context of the further internationalization of industrial capitalism. By this time, there were broadly three types of colonies. First, there were those, like Canada and Australia, where Europeans had settled in lands, typically with temperate or continental climates that had seemed un- or underpopulated, where the indigenous population, typically hugely reduced in number since European settlement, had been pushed to marginal lands, where they had a precarious existence. Second, there were colonies, like India and Algeria, where a small number of Europeans ruled, by force and negotiation, large populations with developed cultures and economies. Third, there were colonies, like the newly annexed ones in Africa, which were mostly tropical, with indigenous populations seen to be "primitive" or "backward," and which were said to constitute "undeveloped estates." European rule was justified variously by the economic imperative of the development of resources and markets, the "civilizing mission" to bring Christianity and modernity, and a mandate for social development and welfare. At the same time, the major industrial nations developed "informal empires," particularly in Latin America in politically independent countries that had previously formed parts of the Spanish and Portuguese empires. Private business interests established modes of controlling a crucial sector of the

[13] A common distinction is to use imperialism for the whole system of powerful states ruling other lands and peoples, and reserve colonialism to refer to the local features of the imperial enterprise. In other words, imperialism and colonialism were different sides of the same coin, or, as Thornton has argued, that colonialism is "imperialism seen from below." Archibald P. Thornton, *Doctrines of Imperialism* (New York: John Wiley, 1965), p. 6.

economy, which brought power and influence without direct political control.[14]

SCIENCE AND "CONSTRUCTIVE" IMPERIALISM, 1870–1914

Emblematic of the new imperialism of the late nineteenth century was the "Scramble for Africa" amongst European countries. At the Berlin Conference in 1885, "spheres of influence" were agreed, which precipitated the annexation of territories as colonies and the formation of local administrations, with military support if needed, to establish power over indigenous peoples and their lands. The boundaries of the new colonies were often in areas unexplored by Europeans, a situation most obvious in the straight lines used for boundaries of many North African colonies, and were driven by political rivalry rather than obvious economic opportunities. Eric Hobsbawm observed that "at the end of the nineteenth century the economic case for annexing large tracts of jungle, bush and desert was not overwhelming," but there were expectations that mining and agriculture would be developed to supply European industry and consumers, and in the longer term markets for European manufactures.[15] In this context, European imperial governments saw science as a means to discover and then develop the natural resources of their new colonies. The amateur explorer, driven by curiosity and adventure, was to be replaced by the professional scientist and engineer with the expertise to survey, assess, and advise on the exploitation of natural resources. The clearest statement of this view was in the policy of "constructive imperialism" announced by the British Colonial Secretary Joseph Chamberlain in 1895, which looked to science to lead the exploitation of the "undeveloped estates" of the Empire. He was thinking mainly about Africa, but the policy seemed relevant to the whole Empire, including long-established colonies.

There were questions about how this new deployment of science would be organized. What was the appropriate balance between central, imperial scientific agencies in Europe, close to centers of science research and education, and scientists attached to colonial administrations at the periphery, working in the local physical and cultural environment? Would the training in the natural sciences given at European universities be adaptable, transferable, and applicable to colonial, mostly tropical, environments? These questions were novel for the new African colonies, but had already been answered for British India, as seen in the development of its Geological

[14] J. Gallagher and R. Robinson, "The Imperialism of Free Trade," *Economic History Review*, 6 (1953), 1–15.

[15] E. Hobsbawm, *Industry and Empire: An Economic History of Britain from 1870 to the Present Day* (London: Weidenfeld and Nicholson, 1968), p. 128.

Survey and in the work of the Imperial Forestry Department.[16] Geology, because of its links with mineral resources such as coal, was identified as a key feature of post-1860s imperial science. Geologists had become increasingly conscious of their possible role in exploiting the mineral potential of India and began to undertake studies along similar lines to those pursued in Europe.[17] Britain's leading geologist, Roderick Murchison, advocated the exploration of the mineral resources in colonies and in the "informal empire."[18] Robert A. Stafford has argued that British geologists played a "sub-imperialist" role in their efforts to extend mineralogical research to the colonies.[19] This role was evident in their "desire for new data, new careers, new satisfactory conquests, a new voice in administrative affairs – meshing with the needs of the imperial government" in the formation of organizations like the Geological Survey of India.[20]

One of the key themes of imperial environmental history has been the destruction of the existing ecologies of the tropical colonies through the impact of colonial agriculture, plantation, and animal husbandry, which historian John M. MacKenzie has described as a narrative of "Ecological Apocalypse."[21] Historians such as Helge Kjekshus have shown how colonialism in East Africa from the 1890s led to a series of environmental and medical disasters.[22] Clearing of forests led to droughts, and old pastoral systems and lifestyles were destroyed. Others have argued that major ecological changes resulted from the combined influences of capitalist agriculture, industrialization, and colonial administration. In Madagascar, French colonialism from 1896 and the introduction of coffee cultivation led to a massive decrease in tropical forest cover. The growth of coffee plantations also led to an increase in settlements of laborers, who cleared forests to make space for shifting cultivation and were forced to live in insanitary conditions.[23] For India, in the book *The Fissured Land*, Ram Guha and Madhav Gadgil show how colonial rule and the quest for teak required for railways and ships destroyed the precolonial balance between humans and the environment. This process continued in the twentieth century with other major

[16] Pratik Chakrabarti, *Western Science in Modern India: Metropolitan Methods, Colonial Practices* (New Delhi: Permanent Black, 2004), pp. 96–7.
[17] Robert A. Stafford, "Geological Surveys, Mineral Discoveries, and British Expansion, 1835–71," *Journal of Imperial and Commonwealth History*, 12 (1984), 5–32; Robert A. Stafford, *Scientist of Empire, Sir Roderick Murchison, Scientific Explorations and Victorian Imperialism* (Cambridge: Cambridge University Press, 1989).
[18] Stafford, "Geological Surveys," pp. 16–19.
[19] Stafford, *Scientist of Empire*, p. 223.
[20] Ibid.
[21] John M. MacKenzie, "Empire and the Ecological Apocalypse: The Historiography of the Imperial Environment," in *Ecology and Empire: Environmental History of Settler Societies*, ed. Tom Griffiths and Libby Robin (Melbourne: University of Melbourne Press, 1997), pp. 215–28.
[22] Helge Kjekshus, *Ecology, Control and Economic Development in East African History* (London: Heinemann Educational, 1977).
[23] Lucy Jarosz, "Defining and Explaining Tropical Deforestation: Shifting Cultivation and Population Growth in Colonial Madagascar (1896–1940)," *Economic Geography*, 69 (1993), 366–79.

development projects.[24] However, there is an alternative narrative in which historians have argued that colonial settlers also brought with them notions of environmental awareness and a desire to preserve ecosystems and landscape.[25] The colonial environmental policies, they argue, bore imprints of this ecological consciousness.

The role of indigenous populations in deforestation is a complex issue. In 1996, James Fairhead and Melissa Leach challenged the claim that large parts of tropical Africa had suffered from deforestation, due to increasing human settlement in these regions.[26] They suggested that forest cover, particularly in the Kissidougou area of Guinea in West Africa, had not disappeared significantly, but that people learned to live in "mosaic" patterns of forests and agricultural land. This challenged the earlier understanding of Kissidougou's landscape as degraded from the pristine forests of the past, and also highlighted the fallacy of Western forestry policies, which sought to restrict agricultural and husbandry practices within designated and protected forest regions. According to Fairhead and Leach, this stemmed from a fundamental misconception about the coexistence of "natural and social phenomenon" in these regions.[27]

Historians of south Asia have suggested that the same misconception guided the policies of modern forestry in colonial India, which sought to exclude forest dwellers, in the pursuit of pristine, protected, tropical forests. Traditionally, in India, large sections of the rural population depended on forests for their everyday sustenance. The various traditional customs and practices allowed this use of forest resources. In other words, tropical forests were not "pristine"; they were used and managed by the local inhabitants. However, imperial forestry policy was focused on halting what officials saw as deforestation and, led by German experts, introduced the notion of "scientific forestry" into India.[28] Peoples who had lived in certain forest regions were expelled and large tracts were turned into "reserves," to be used only for timber production for the colonial economy.[29] This alienation of people from their forests continued in the postcolonial period and led to significant resistances, such as the "Chipko movement" in northern India.[30]

[24] Madhav Gadgil and Ramachandra Guha, *This Fissured Land: An Ecological History of India* (Berkeley, Calif.: University of California Press, 1992).

[25] Tim Bonyhady, *The Colonial Earth* (Melbourne: The Miegunyah Press, 2000); Richard H. Grove, *Green Imperialism: Colonial Expansion, Tropical Island Edens and the Origins of Environmentalism, 1600–1860* (Cambridge: Cambridge University Press, 1995).

[26] James Fairhead and Melissa Leach, *Misreading the African Landscape: Society and Ecology in a Forest-Savanna Mosaic* (Cambridge: Cambridge University Press, 1996).

[27] Ibid., p. 8.

[28] Ramchandra Guha, "The Prehistory of Community Forestry in India," *Environmental History*, 6 (2001), 213–38, on 214.

[29] Ramachandra Guha and Madhav Gadgil, "State Forestry and Social Conflict in British India," *Past & Present*, 123 (1989), 141–77.

[30] Ramachandra Guha, *The Unquiet Woods: Ecological Change and Peasant Resistance in the Himalaya* (Oxford: Oxford University Press, 1991).

The creation of science-based agricultural agencies for and in the Empire came later, and in the case of India not until 1905. This was because of the prior success of the networks of botanical gardens in exchanging plants and encouraging the cultivation of crops in new settings. At the center of the two largest empires were the Jardin d'Acclimatation in Paris and Royal Botanic Gardens at Kew in London. In the first half of the nineteenth century, French biologists, influenced by the ideas of Lamarck on the inheritance of acquired characteristics, were heavily invested in acclimatization, the process of adapting plants and animals to thrive and become economically valuable in new habitats. It was not just a French enterprise. At the end of the nineteenth century there were over fifty acclimatization societies across the world, and it was a central feature of the work of most botanical gardens. Acclimatization was also practiced with animals, which extended to trying to produce a mule–zebra hybrid that would be disease resistant and able to serve as a draught animal in South Africa.[31] Michael A. Osborne has argued that acclimation was the "paradigmatic colonial science," taking his lead from Auguste Hardy, head of the Jardin d'Essai, who wrote in 1860 that "the whole of colonization is a vast deed of acclimatization."[32] Osborne writes that acclimatization was promoted "as the incarnation of a cooperative and humanistic civilizing mission" and "as a utilitarian activity that promised economic betterment . . . for Europeans."[33] Colonial peoples were assumed to benefit, but only secondarily. However, in the case of French North Africa, Osborne argues that benefits were in fact one-sided as "the extension of export agriculture . . . resulted in diminished diets and famine for the Algerian peoples."[34] Most acclimatization projects failed in their own terms as scientists struggled with ecological complexities, with their lack of knowledge of novel organisms and environments – a situation not helped by their dismissal of the practices and ideas of local peoples – and with the economic, political, and cultural conditions in which they worked.

For the British Empire, Kew Gardens was at the center of a network of botanists and plant collectors, described as "a great exchange house" of plants of potential agricultural and horticultural value.[35] Its greatest economic success was the development of rubber cultivation in the Malay Peninsula.[36] In the early 1870s, the India Office had recommended the collection of rubber plants from Brazil and their distribution to British Asian colonies. Kew dispatched an expedition, which rushed seeds back to

[31] James Cossar Ewart, *The Penycuik Experiments* (London: Adam and Charles Black, 1899).
[32] Michael A. Osborne, "Acclimatizing the World: A History of the Paradigmatic Colonial Science," *Osiris*, 15 (2000), 135–51.
[33] Ibid., 150.
[34] Ibid.
[35] Richard H. Drayton, *Nature's Government: Science, Imperial Britain and the "Improvement" of the World* (New Haven, Conn.: Yale University Press, 2000).
[36] John H. Drabble, *Rubber in Malaya, 1876–1922: The Genesis of an Industry* (Oxford: Oxford University Press, 1973), pp. 7–12.

London, where they were nurtured before being sent on to Sri Lanka, from where they were distributed, principally to Java and Singapore.[37] Seeds were grown and plants propagated in botanical gardens, but experiments on how to extract latex efficiently were unsuccessful until the late 1880s. Then, the new Director of the Singapore Botanical Garden, Henry N. Ridley, found a way to remove latex without damaging the tree.[38] Ridley was later known as "Rubber Ridley" or "Mad Ridley" for his enthusiastic promotion of rubber plantations, an industry that grew rapidly from the 1900s. The botanical garden in the colony continued to be a source of expertise, advising on everything from soil through to processing, including the dangers of monoculture, though this role was taken over by a newly formed Department of Agriculture when Ridley retired in 1912.

The story of rubber in Malaya was important to colonial policy throughout the era of imperialism. It demonstrated how a colony could develop economically by supplying a natural product to industrialized countries. It was based on the principle, which dated back to Sir Walter Raleigh returning from the Americas with the potato, that certain plants would grow better in a new environment where the climate might be more favorable, where there were fewer pests, and where breeders, farmers, and scientists could use their superior knowledge. Moreover, rubber in Malaya was an exemplar of a new type of science-led development, where expert knowledge and experimentation, undertaken locally, had initiated and sustained the expansion of the industry. Ridley's science was eclectic. He had studied natural sciences at Cambridge and then won a scholarship in geology, before learning economic botany in post at Kew. His work on rubber in Singapore involved analytical investigations, laboratory experiments, and field trials, and once plantations were established, natural product chemistry, plant pathology, and forestry. The scale and relative isolation of such science at the periphery demanded cross- and interdisciplinary work, and gave scientists the space and freedom to innovate. Other crops in other colonies were expected to follow, but there were few similar successes in any of the European empires before the First World War.

In London, the British government created a "Kew for Chemistry" in 1887, the Imperial Institute at the center of the South Kensington cultural complex in London.[39] The Institute aimed to serve as a commercial clearinghouse and applied research laboratory, housing displays of minerals and natural products from around the Empire, which British entrepreneurs

[37] P. R. Wycherley, "The Singapore Botanical Garden and Rubber in Malaya," *Gardens Bulletin, Singapore*, 17 (1958), 175–86.

[38] E. J. Salisbury, "Ridley, Henry Nicholas (1855–1956)," in *Oxford Dictionary of National Biography* (Oxford: Oxford University Press, 2004), available at www.oxforddnb.com/view/article/35753 (accessed 8 February 2017).

[39] Michael Worboys, "The Imperial Institute: The State and the Development of the Natural Resources of the Colonial Empire, 1887–1923," in *Imperialism and the Natural World*, ed. John MacKenzie (Manchester: Manchester University Press, 1990), pp. 164–86.

could assess for potential trade or exploitation. It was the paradigmatic central institution, which all colonial governments were invited to support and use. Many colonies, notably India, Australia, and Canada, refused to subscribe, claiming that they had their own local facilities and saw no benefit in paying for a remote and unaccountable central institution. This rejection nicely illustrates Roy MacLeod's notion of a "moving metropolis," where centers of scientific activity move or are newly created as political, economic, and scientific relations change.[40] With minerals and natural resources, by the final decades of the nineteenth century, India, Australia, and Canada had colleges and universities with the facilities and expertise in applied chemistry that were also more in tune with local conditions, businesses, and peoples.

Medicine had a similar polycentric character. Research and teaching was only centralized in tropical medicine, a specialism established around 1900 in all of the European empires. Its aim in the first instance was to protect colonial officials, settlers, entrepreneurs, and missionaries and then to investigate the novel endemic and epidemic disease problems in the old and new tropical colonies. In the older colonies, medical schools and colleges had been established in the second half of the nineteenth century, teaching students from the local population an essentially Western medicine curriculum. Medical developments in (and for) the colonies of the French Empire illustrate the complexities and variability of center–periphery relations. Michael A. Osborne has recently shown the importance of Bordeaux and Marseille, as well as Paris, from the late nineteenth century as tropical medicine changed from a primarily naval to a military and colonial administrative enterprise.[41] Medical schools were established in French North African colonies in the last quarter of the nineteenth century. The small college in Algiers was founded in 1879 as part of reforms across the country and followed from the administrative position of French overseas territories as *départements* of the nation. However, colleges were not created in French Indochina until the early twentieth century as distance, climate, and culture were more challenging. The major innovation at this time was the development of overseas Pasteur Institutes, the first of which opened in South East Asia in Saigon in 1891 and Nha Trang in 1895, and in North Africa in Tunis in 1893 and Algiers a year later.[42] The Pasteur Institute in Paris had been founded in 1887, funded by a public subscription to create an institution that would continue Louis Pasteur's work in microbiology and the development of vaccines. As Pratik Chakrabarti has shown, this represented the

[40] MacLeod, "On Visiting," pp. 1–2.

[41] Michael A. Osborne, *The Emergence of Tropical Medicine in France* (Chicago, Ill.: University of Chicago Press, 2014), pp. 155–216. On the practice of medicine in villages in Algeria, see Hannah-Louise Clark, "Expressing Entitlement in Colonial Algeria: Villagers, Medical Doctors, and the State in the Early 20th Century," *International Journal of Middle East Studies*, 48 (2016), 445–72.

[42] Annick Guénel, "The Creation of the First Overseas Pasteur Institute, or the Beginning of Albert Calmette's Pastorian Career," *Medical History*, 43 (1999), 1–25; John Strachan, "The Pasteurization of Algeria?," *French History*, 20 (2006), 260–75.

convergence of "the imperial idiom of tropical medicine and panacean rhetoric of Pasteurian bacteriology."[43]

The origins of the overseas Pasteur Institutes were various: the entrepreneurialism of scientists trained in the Pasteurian tradition; the demands of local colonial governments and businesses; and competition with the scientific endeavors of other imperial powers.[44] In the 1900s, the institutes received recognition as the centers of discovery and innovation, with Charles Nicolle's work on typhus fever in Tunis, and with improvements and adaptations to vaccines.[45] Pasteur Institutes were not confined to the French Empire. The first in India in 1900 was at Kasauli, followed by ten others by 1910.[46] The institutes constituted an informal network, with shared "Pastorian methods" and personnel, with the general goal of improving public health by developing vaccines and providing bacteriological services. They were administratively, financially, and scientifically independent. Each was dependent upon local support and worked on local disease problems. They became centers of bacteriological research of variable range: some specific to a city, but others becoming national and regional hubs of reference and research.

THE NEW COLONIALISM, 1918–1945

There are four dominant themes in the history of science and imperialism in the interwar period. First, there was the continuing proliferation of scientific centers in colonies and the weakening of central and metropolitan institutions. In India, science and its institutions were more overtly politicized with the development of nationalism and calls for independence.[47] Second, in the context of the global economic crisis and the growth of protectionism, a new policy was planned, though not always implemented, of an intensification of scientific efforts to exploit colonies as producers of raw materials and foodstuffs, both for export and to ameliorate local economic problems. In line with wider changes in policy and rhetoric, there was no longer talk of "imperial science," but of science in and for the development of colonies; in the French empire it was termed

[43] Pratik Chakrabarti, *Bacteriology in British India: Laboratory Medicine in the Tropics* (Rochester, NY: University of Rochester Press, 2013), p. 34.

[44] Anne Marie Moulin, "Patriarchal Science: The Network of the Overseas Pasteur Institutes," in *Sciences and Empires: Historical Studies about Scientific Development and European Expansion*, ed. Patrick Petitjean et al. (Dordrecht: Kluwer, 1992), pp. 307–22.

[45] K. Pelis, *Charles Nicolle, Pasteur's Imperial Missionary: Typhus and Tunisia* (Rochester, NY: University of Rochester Press, 2006); Pratik Chakrabarti, "'Living Versus Dead': The Pasteurian Paradigm and Imperial Vaccine Research," *Bulletin of the History of Medicine*, 84 (2010), 387–423.

[46] Pelis, *Charles Nicolle*, 66–71; I. Löwy, "Yellow Fever in Rio de Janeiro and the Pasteur Institute Mission (1901–1905): The Transfer of Science to the Periphery," *Medical History*, 34 (1990), 144–63.

[47] Chakrabarti, *Western Science*, pp. 180–218.

"la colonisation rationnelle."[48] Third, colonial development became linked to the "welfare" of indigenous populations with the aim of improving their nutrition, sanitary conditions, and healthcare, which was in large part a response to political unrest and to ameliorate poor social and economic conditions. Colonial development was still seen primarily as a biological matter, though there was greater investment in the social sciences, particularly anthropology, to better understand and manage colonial subjects. Fourth, innovative interdisciplinary knowledges and practices were created in some colonies, which were facilitated by the cross-disciplinary and cross-cultural engagements of scientists at the periphery. Helen Tilley has claimed that in the 1930s European scientists in Africa challenged the authority of established disciplines and, through interdisciplinary working and selective adaptations of "native" knowledge, produced what she has termed "vernacular science."[49]

In India, historians have stressed the processes of "alienation," "displacement," and "cultural transformation" through which Indian scientists sought to redefine modern science.[50] They have shown how Orientalist or European ideas were challenged, and a "cultural redefinition" of science took place, with the hope of an alternative tradition of science being established. Gyan Prakash has shown that around 1900, within the emerging popular culture of India, science was challenged, redefined, and absorbed as an indigenous tradition.[51] However, this perceived redefinition was based upon both a glorification of indigenous traditions and resistances, and a naïve understanding of cultural redefinition. Knowledge systems, which emerge from a particular geographical and social setting, typically undergo transformations when situated in another context. A closer examination of these various histories of transformation, translation, and redefinition, across colonies and empires, shows that rather than providing clear alternatives to Western ideas of science, they tended to reiterate European notions of nature, rationality, and truth through indigenous imageries and language. In most cases, what they presented as indigenous or vernacular tradition was itself an invented and modern one. Therefore, the alternative trajectories of modernity and development through science that these scientists prescribed remained in important ways derivatives of Western science.[52]

[48] Christophe Bonneuil, *Des Savants pour l'Empire: la structuration des recherches scientifiques coloniales au temps de la "mise en valeur des colonies françaises," 1917–1945* (Paris: ORSTOM, 1991), p. 95.

[49] Helen Tilley, "Global Histories, Vernacular Science, and African Genealogies; Or, Is the History of Science Ready for the World?," *Isis*, 101 (2010), 110–19.

[50] Dhruv Raina and S. Irfan Habib, "Bhadralok Perception of Science, Technology and Cultural Nationalism," *Indian Economic and Social History Review*, 32 (1995), 95–117; S. Irfan Habib and Dhruv Raina, "Copernicus, Columbus, and Colonialism and the Role of Science in Nineteenth Century India," *Social Scientist*, 17 (1989), 51–66. Also see Dhruv Raina, "Evolving Perspectives on Science and History: A Chronicle of Modern India's Scientific Enchantment and Disenchantment (1850–1980)," *Social Epistemology*, 2 (1997), 3–4.

[51] Prakash, *Another Reason*, pp. 49–85 and 201–26.

[52] Chakrabarti, *Western Science*, pp. 258–97.

In the interwar period there was a new intensity in efforts to develop agriculture in colonial territories.[53] Science-led policies were still to the fore, with agricultural officers taking over from botanical garden staff and offering more advice on husbandry through the establishment of experimental stations and extension services. In many colonies there was little prospect of Europeans investing in plantations, and hence, attention shifted to encouraging the local farmers to grow export crops. This development was said to have the dual benefit of supplying industrial economies, as well as drawing famers and associated workers into the market economy. The policy assumed, wrongly as it turned out in most areas, that the greater productivity and rewards of export crops would allow the local population to grow or buy sufficient food crops. In his work on agricultural science in French colonies, Christophe Bonneuil concluded that scientists fostered the "technocratization of the colonial administration" and construction of colonial development as a "technical problem." Bonneuil quotes the British biologist E. B. Worthington, who wrote in 1931 that Africa was a "fruitful field in history for experiment concerning the place of expert scientific knowledge," which saw the formulation of a common technocratic, developmentalist policy across empires, sites, crops, and agricultural systems.[54] Unlike in the British Empire, in France there was a drive in the 1920s to develop metropolitan institutes and a "collective effort to avoid the mistakes of improvisation and the necessity of sharing tasks." However, this came up against the need to understand specific local economic, political, and environmental conditions, and in the 1930s there was a shift away from centralization towards developing local "colonial sciences" at the periphery in new centers that aimed to serve other colonies.[55] Bonneuil characterized the new enterprise as "development by experiment," as colonial agricultural officers were dealing with crops, environments, and cultures about which they had much to learn.[56] Officers established experimental stations to disseminate advice and seeds for new crops, but they still faced difficulties in adaptation and adoption. This led scientists to narrow their focus to the "technical," as in Senegal, where failure to change local practices in the cultivation of peanuts led scientists to restrict their work to improving seed types.[57]

[53] Michael Havinden and David Meredith, *Colonialism and Development: Britain and its Tropical Colonies, 1850–1960* (London: Routledge, 1993), pp. 115–86; Geoffrey B. Masefield, *A History of the Colonial Agricultural Service* (Oxford: Clarendon Press, 1972).

[54] Christophe Bonneuil, "Development as Experiment: Science and State Building in Late Colonial and Postcolonial Africa, 1930–1970," *Osiris*, 15 (2000), 258–81, on 258.

[55] Pierre Singaravélou, *Professer l'empire. Les Sciences coloniales en France sous la IIIe Republique* (Paris: Publications de la Sorbonne, 2011).

[56] Bonneuil, "Development as Experiment."

[57] Christophe Bonneuil, "Penetrating the Natives: Peanut Breeding, Peasants and the Colonial State in Senegal (1900–1950)," *Science, Technology and Society*, 4 (1999), 273–302; Christophe Bonneuil, "Crafting and Disciplining the Tropics," in *Science in the Twentieth Century*, ed. John Krige and Dominique Pestre (Amsterdam: Harwood Academic Publishers, 1997), pp. 77–96.

Other historians have taken up the notion of Africa as a development "laboratory." In his studies of British colonial science policy in the interwar period, Joseph Hodge has shown the many shifts in policy and practice.[58] Through the 1920s, the policy of "constructive imperialism" emphasized attracting investment and encouraging European entrepreneurs, supported by efforts to improve transport and communication. These policies were complemented by a continuation of "science for development" policies, where development was principally conceived as a biological enterprise. To provide the experts needed, an Imperial College of Tropical Agriculture (ICTA) was established in Trinidad in the West Indies in 1922. Its role was to train British biology graduates to serve in agricultural departments in the growing number of colonial technical departments. Tropical agriculture was constructed primarily as an export-crop-focused, "universal" science that provided students with the knowledge and skills to work in any colony across the empire. Once in post, officers with this largely technical knowledge were confronted with the economic, cultural, political, and environmental complexities of their district, many of which covered large areas and had great diversity. Technical officers also had to work with political and other technical staff and, given the British policy of "indirect rule," with local political leaders and institutions. They had to adapt their supposed universal tropical agricultural science to local circumstances, which led to a proliferation of experimental and demonstration facilities, along with measures to deal with novel plant diseases and insect pests, such as locusts. They also had to determine what kind of agricultural system "worked," taking cognizance of different systems of land tenure, social relations, cultural practices, and local markets.

In the 1930s Hodge points to "the emergence of relatively autonomous colonial scientific communities centered around regional institutions and networks," which saw the ICTA in a new regional role, and the establishment of rubber and tea research institutes in south Asian colonies.[59] The economic depression reduced colonial revenues, and while the rhetoric emphasized meeting the economic crisis with stronger inter-imperial relations, the reality was that scientists in the colonies were increasingly isolated from the metropole and developed regional networks and loyalties. The characteristic colonial scientific activity remained research, development, and extension work in the biological sciences. Policy initiatives promoted more systematic exploitation of existing systems, the expansion of plantations, and the production of cash crops by local farmers. An example of the complexities they faced can be seen in the responses to diseases of cocoa trees

[58] Joseph M. Hodge, *Triumph of the Expert: Agrarian Doctrines of Development and the Legacies of British Colonialism* (Athens, OH: Ohio University Press, 2007).

[59] Joseph M. Hodge, "Science, Development and Empire: The Colonial Advisory Council on Agriculture and Animal Health, 1929–43," *Journal of Imperial and Commonwealth History*, 30 (2002), 1–26, on 6.

in the Gold Coast. There was a policy divide between scientists who emphasized an ecological approach, emphasizing conservation, and other scientists who favored a reductionist, disease-centered, "cutting out" policy.[60] The ecological approach was favored by colonial forestry officers who argued that loss of forests led to climate change and desiccation of the soil, and made cocoa trees more susceptible to disease, all of which reduced yields. African cocoa producers largely shared their views. However, researchers at the new coffee research station at Tafo in the Gold Coast, supported by agricultural officers, suggested that the main issue was the spread of the virus of swollen shoot disease and the solution was removing and replacing infected trees. Needless to say, the policy of "cutting out" was resisted by farmers, leading to riots and disturbances from 1948, when the nationalist movement took up the issue; they anticipated that alternative solutions would be developed after independence.[61]

Scientific practice in and for British African colonies in the interwar period was systematically reviewed in Lord Hailey's *African Survey*, published in 1938.[62] Significantly, it was accompanied by an equally lengthy review of scientific research in Africa, written by E. B. Worthington.[63] These two studies are the focus of Helen Tilley's *Africa as a Living Laboratory*, which argues that colonial agricultural, medical, and other officers, along with natural and social scientists working in Africa, both supported and critiqued colonial development policies.[64] In agriculture, they continued to promote the growing of cash crops for export, while at the same time warning that it led to soil erosion, overgrazing, and the proliferation of pests and diseases, and pointing to the economic and ecological risks in the reliance on single crops.[65] Tilley shows that scientists and technical officers increasingly turned their attention to supporting the growth of food crops and accepted that they had much to learn from the local cultivation practices. This shift led to the creation of Tilley's notion of "vernacular sciences," hybrids of Western and African knowledge and practice, framed ecologically against biological reductionism, that were interdisciplinary across the natural and social sciences, and combined

[60] Joseph M. Hodge, "Colonial Foresters Versus Agriculturalists: The Debate over Climate Change and Cocoa Production in the Gold Coast," *Agricultural History*, 83 (2009), 201–20.

[61] Francis K. Danquah, "Rural Discontent and Decolonization in Ghana, 1945–1951," *Agricultural History*, 68 (1994), 1–19. This episode is the context of Timothy M. Aluko's novel *One Man, One Matchet* (1964) set in Ghana in the late 1940s. A central character is Henry Gregory, who is an agricultural officer charged with supervising the cutting out of diseased cocoa trees.

[62] Lord Hailey, *An African Survey: A Study of Problems Arising in Africa South of the Sahara* (London: Oxford University Press, 1938).

[63] E. B. Worthington, *Science in Africa: A Review of Scientific Research Relating to Tropical and Southern Africa* (Oxford: Oxford University Press, 1938).

[64] Helen Tilley, *Africa as a Living Laboratory: Empire, Development, and the Problem of Scientific Knowledge, 1870–1950* (Chicago, Ill.: University of Chicago Press, 2011).

[65] Ibid., pp. 115–69. William Beinart, "Soil Erosion, Conservationism and Ideas about Development: A Southern African Exploration, 1900–1960," *Journal of Southern African Studies*, 11 (1984), 52–83, on 52–8.

expert and lay knowledge.[66] These hybrids were seen across the agricultural and medical sciences, and one example that links these was the "discovery" of colonial malnutrition. Metropolitan experts and government officials constructed this as a technical problem of unbalanced diets, whereas locally it was also seen as arising from the neglect of food crops in colonial development policy and lack of interest in local dietaries.[67]

Tilley also explores race in the biological sciences and anthropology.[68] Her central argument is that scientists were ambivalent about race: in part because it was a taken-for-granted category, but more importantly because their new work and experience undermined race as a category of human difference. In the debates over education in Kenya in the early 1930s, while not accepting equality between the African and European mind, scientists argued that indigenes should be given, and would benefit from, schooling. In anthropology during the interwar period, the dominant approach moved from physical to social anthropology, and from diffusionism (the spread and progress of cultures) to functionalism (how cultures were structured and operated). Tilley shows how the findings and advice of social anthropologists on how indigenous societies "worked" were increasingly used by colonial administrators and other officials to inform their actions. Moreover, by showing the context-appropriate "rationality" of African belief systems and social relations, social scientists questioned the moral and cultural authority of colonial rule. Lyn Schumaker's study of the work of the Manchester School of anthropology in Northern Rhodesia (Zambia) makes similar points about the context-specific and increasingly critical character of anthropologists' writing.[69] Although she does not use the term, her work can also be seen as illustrating "vernacular science," as she demonstrates how knowledge was made, not just by researchers but co-produced with local networks of assistants and by the African subjects who the anthropologists spoke with, lived with, and befriended.

The remaking of colonial development policy in the 1930s was increasingly also shaped by political unrest in many colonies. The wider context was the growth of nationalism and calls for independence in India. Hodge observes that amongst the experts in the colonial technical services there was a "candid reckoning . . . over the mistakes of past colonial interventions and the consequences of unfettered exploitation."[70] These problems became more pressing with the exigencies of the Second World War and led to the

[66] Tilley, *Africa as a Living Laboratory*, pp. 26–30, 122, 134–59.
[67] Michael Worboys, "The 'Discovery' of Colonial Malnutrition," in *Imperial Medicine and Indigenous Societies*, ed. David Arnold (Manchester: Manchester University Press, 1988), pp. 208–25.
[68] Tilley, *Africa as a Living Laboratory*, pp. 217–60, 260–312.
[69] Lyn Schumaker, *Africanizing Anthropology: Fieldwork, Networks, and the Making of Cultural Knowledge in Central Africa* (Durham, NC: Duke University Press, 2001).
[70] Joseph M. Hodge, "Colonial Experts, Developmental and Environmental Doctrines and the Legacies of Late British Colonialism," in *Cultivating the Colony: Colonial States and Their*

Colonial Development and Welfare Acts, 1940. The key change was the explicit addition of "welfare" to the more economically focused 1929 Act. Nonetheless, as Hodge has shown, science remained a lynchpin in development policy, as the new Acts saw "a new commitment . . . to integrated planning and coordination, led by a bureaucracy that was increasingly scientific."[71]

DEVELOPMENT AND WELFARE, 1945–2000

The scale and ambition of the support of the economic and social development of the colonies of colonial powers increased massively after 1945.[72] Science became an even more pivotal ideological and practical element in development policies, with economic and social change being catalyzed by what became known as "technical assistance." The impact of science on military and civil technologies during the Second World War fostered greater optimism about its peacetime potential, which was captured in the title of Vannevar Bush's 1945 report for the United States government: *Science, The Endless Frontier*.[73] Indeed, in 1949, President Harry S. Truman announced his government's Point Four Program, which he described as "a bold new program for making the benefits of our scientific advances and industrial progress available for the improvement and growth of underdeveloped areas."[74] In many ways, this was "constructive imperialism" for a new age, now cast as "know how" and "technological innovation." Many of Truman's "underdeveloped areas" were colonial territories of European powers, and there was explicit critique of "The old imperialism – exploitation for foreign profit."[75] While the motives of the Point Four Program were in part humanitarian, they were also part of American Cold War policies to counter the influence of the Soviet Union in Africa, Asia, and Latin America, and challenge the world role of Britain and France. Nonetheless, the steep change in colonial development efforts of the European powers was in line with post-war reconstruction efforts across the world, while also helping the economic recovery of industrialized countries and meeting the challenge of nationalism and calls for independence.

Environmental Legacies, ed. Christina Ax et al. (Athens, OH: Ohio University Press, 2011), pp. 300–26, on 302.

[71] Ibid., p. 303.

[72] Havinden and Meredith, *Colonialism and Development*, pp. 206–56; Amy L. S. Staples, *The Birth of Development: How the World Bank, Food and Agriculture Organization, and World Health Organization Changed the World, 1945–1963* (Kent, OH: The Kent State University Press, 2006).

[73] Vannevar Bush, *Science, The Endless Frontier* (Washington DC: US Government Printing Office, 1945).

[74] Stephen Macekura, "The Point Four Program and U.S. International Development Policy," *Political Science Quarterly*, 128 (2013), 127–60

[75] Ibid., quotation on p. 127.

In the post-war years, science in and for Europe's ever shrinking number of colonies was in competition with the new international organizations for health, agriculture, and culture created by the United Nations (UN). The League of Nations had been active in health in the 1920s and 1930s, but the UN's World Health Organization (WHO), which began work in 1948, had more ambitious aims and support. The UN's Food and Agriculture Organization (UNFAO) had started three years earlier, with the aim of combating hunger by increasing production and productivity. Tellingly, its first head was the Scottish nutritionist John Boyd Orr, who had been a key figure in the identification of colonial malnutrition, while the United Nations Educational, Scientific and Cultural Organization (UNESCO), which aimed to promote international collaboration to foster understanding and promote security, was headed by the British biologist Julian Huxley. Huxley had also been active in British colonial science, especially through his book *Africa View* (1931), which promoted conservation and wildlife reserves, tacitly reinforcing the notion that colonial development and welfare were primarily "biological."[76]

The best-known and now notorious post-war project of technical assistance to promote colonial development was the scheme to grow groundnuts in Tanganyika (now Tanzania).[77] The idea came from a senior figure in Unilever, a company that had longstanding investment in palm oil in West Africa and Latin America. The scheme promised to link the interests of the company, in cheap margarine and other goods for the British consumer, with the development of the "empty lands" of the colony. A plan was drawn up on the advice of John Wakefield, a colonial agricultural officer with years of experience in the colony, and also included ambitious schemes of public health to prevent tropical diseases and promote welfare. It was given the go ahead by the British government in 1947. Four years later it was abandoned having failed to reach its production targets.[78] The scheme has recently been termed a "technocratic dream," based on inadequate knowledge of ecological conditions, over-optimism about the transferability of agricultural technologies, and failure to link the "technical" to economic and social issues.[79] Similar, though in time much better informed and planned approaches were followed by the British Colonial Office across the sciences, in what Sabine Clarke points to as "a strong technocratic turn in official thinking," as "Britain gave the activity of research related to the British

[76] Julian Huxley, *Africa View* (London: Chatto & Windus, 1931).

[77] J. S. Hogendorn and K. M. Scott, "The East African Groundnut Scheme: Lessons of a Large-Scale Agricultural Failure," *African Economic History*, 10 (1981), 81–115.

[78] M. Rizzo, "What Was Left of the Groundnut Scheme? Development Disaster and Labour Market in Southern Tanganyika 1946–1952," *Journal of Agrarian Change*, 6 (2006), 205–38.

[79] Stefan Esselborn, "Environment, Memory, and the Groundnut Scheme: Britain's Largest Colonial Agricultural Development Project and Its Global Legacy," *Global Environment*, 6 (2013), 58–93; M. Van Beusekom and Dorothy L. Hodgson, "Lessons Learned? Development Experiences in the Late Colonial Period," *Journal of African History*, 41 (2000), 29–33.

colonies its highest ever priority."[80] The foundations of these efforts remained in biological sciences, specifically in agriculture, forestry, soil conservation, public health, and pest control, but expanded to include production and processing technologies, water supplies, and other infrastructure projects.[81]

Typical of the approaches of the new era, though not initiated by any colonial government, was the "Green Revolution," a term first used in 1968, but which has come to cover programs of agricultural development in previous colonial territories, which were renamed variously as "underdeveloped," "developing," and "Third World" countries.[82] The Green Revolution was based on an old model of the introduction of novel crops, in the form of seed varieties, to new sites, but now backed up by the introduction of chemical fertilizers and pesticides, plus improved irrigation and mechanization, to transform peasant farming in Africa, Asia, and Latin America. By avoiding food shortages and their socio-political consequences, the Green Revolution was projected to counter possible "Red Revolutions" that would follow growing Soviet influence in developing countries.[83] The main agencies involved were philanthropic foundations, initially including the Rockefeller Foundation, which began cooperation with the Mexican government in 1943 to develop new corn varieties.[84] The Foundation's efforts resulted in the establishment of the International Maize and Wheat Improvement Center (CIMMYT) in 1963. The Ford Foundation and Kellogg Foundation also supported agricultural research and extension, joining forces with the UNFAO, the World Bank, and large agrochemical companies.[85] Joseph Hodge has shown continuities between the "thinking and practice of late colonial agricultural development" and those of the philanthropic, UN, US, and other agencies of the Green Revolution. In fact, he shows how "British Colonial Expertise" was remobilized with former scientists and technical officers occupying key roles in development projects, where they seemingly embraced top-down, technocratic modernism that had been eschewed by the interwar precursors.[86]

[80] Sabine Clarke, "A Technocratic Imperial State? The Colonial Office and Scientific Research, 1940–1960," *Twentieth Century British History*, 18 (2007), 453–80.

[81] On one science-led policy of colonial industrial development, see Sabine Clarke, *Science at the End of Empire: Experts and the Development of the British Caribbean, 1940–62* (Manchester: Manchester University Press, 2018).

[82] Gordon Conway, *The Doubly Green Revolution: Food for All in the Twentieth Century* (New York: Comstock, 1997); George Blyn, "The Green Revolution Revisited," *Economic Development and Cultural Change*, 31 (1983), 705–25.

[83] John H. Perkins, *Geopolitics and the Green Revolution: Wheat, Genes, and the Cold War* (Oxford: Oxford University Press, 1997).

[84] David Nally and Stephen Taylor, "The Politics of Self-Help: The Rockefeller Foundation, Philanthropy and the 'Long' Green Revolution," *Political Geography*, 49 (2015), 51–63.

[85] Deborah Fitzgerald, "Exporting American Agriculture: The Rockefeller Foundation in Mexico, 1943–1953," *Social Studies of Science*, 44 (1986), 457–83; Jonathan Harwood, "Peasant Friendly Plant Breeding and the Early Years of the Green Revolution in Mexico," *Agricultural History*, 83 (2009), 384–410; Robert Anderson, "The Origins of the International Rice Research Institute," *Minerva*, 29 (1991), 61–89.

[86] Hodge, *Triumph of the Expert*. See also Timothy Mitchell, *Rule of Experts: Egypt, Techno-Politics, Modernity* (Berkeley, Calif.: University of California Press, 2002).

Historians have pointed to the continuities in the Green Revolution, not just with colonial science for development policies, but also with the intensification of agricultural production in all countries since the nineteenth century.[87] In India the new policies were introduced in the context of political independence, economic planning, avoidance of food shortages and famines, and modernization of rural areas. Such efforts built on a colonial heritage.[88] The Indian Council for Agricultural Research (ICAR) was established in 1929 and then radically reorganized in 1965 for achieving India's self-sufficiency through the Green Revolution.[89] The ICAR developed new strains of high yield value (HYV) seeds, mainly wheat and rice, but also millet and corn. The most noteworthy was the K68 variety for wheat, which – along with the increased use of fertilizers, irrigation, and mechanization – improved yields and overall food supplies. From 1961 to 2000, agricultural productivity kept pace with the near doubling of the Indian population. Over the period, the production of cereals rose from seventy million tons to one hundred and eighty million tons, potatoes from three million tons to twenty million and sugar from six to eighteen million tons.[90] The Green Revolution had seemingly achieved its primary goal of large-scale increase of agricultural productivity to feed India's population.

However, the Green Revolution has been criticized for creating regional and social disparities and ecological problems. Investments tended only to be made in already favored areas with regular supplies of water, where large inputs of fertilizers could be sourced, and where there was adequate farm credit. It also increased income disparities: higher income growth and reduced incidence of poverty were found in the states where yields increased the most, and lower income growth and little change in the incidence of poverty in other states.[91] Vandana Shiva has discussed the interrelationships between agriculture, ecology, and politics, particularly in Punjab.[92] She argues that the "quick fix" promise of large gains in output by the Green Revolution was at the expense of an alternative agricultural strategy that was much more in tune with the environmental knowledge of the peasants and the principles of an egalitarian village-based society. There was also a loss of genetic diversity and reduction in soil fertility, which contributed to economic problems and social and political conflicts. While Shiva's polemical

[87] Alan L. Olmstead and Paul W. Rhode, *Creating Abundance: Biological Innovation and American Agricultural Development* (Cambridge: Cambridge University Press, 2008).
[88] Sunil S. Amrith, "Food and Welfare in India, c. 1900–1950," *Comparative Studies in Society and History*, 50 (2008), 1010–35.
[89] David Arnold, "Agriculture and 'Improvement' in Early Colonial India: A Pre-History of Development," *Journal of Agrarian Change*, 5 (2005), 505–25.
[90] Pushpa M. Bhargava and Chandana Chakrabarti, *The Saga of Indian Science since Independence: In a Nutshell* (Hyderabad: Universities Press, 2003), p. 105.
[91] Ibid., p. 108.
[92] Vandana Shiva, *The Violence of the Green Revolution: Third World Agriculture, Ecology and Politics* (London: Zed, 1991).

style often idealizes peasant life, it nevertheless raises an important question about postcolonial science in India in the last century: how do we integrate science with a society that is still predominantly agrarian? Along with that it raises the question of agency and participation of farmers in development projects.

A different view of the Green Revolution has been advanced by Corinna Unger, who stresses that it was shaped by a diversity of opinions, objectives, and ideas about development and welfare, which were promoted by different actors, such as government policy makers, agriculturalists, private companies, the Rockefeller Foundation, and different biotechnological research institutes, as well as peasants and agricultural laborers. Thus, any assessment of its impact needs to take into account this complex relationship of interests and ambitions. While acknowledging the mixed assessments of the benefits of the Green Revolution, Unger notes that few have questioned the need for changes in agricultural practices in postcolonial nations. The challenge remains as to how to increase agricultural productivity and achieve a more equitable distribution of food and other resources in a sustainable way.[93]

Taking a broad and historical view of the role of biotechnologies in postcolonial development, Sheila Jasanoff suggested that its ideas, practices, and products have helped to create and perpetuate a new form of imperialism, with top-down collaborations between multinational corporations and national governments.[94]

CONCLUSION

In recent decades, historians of science and historians of imperialism have recognized that since 1870 science has played a central role in imperial expansion, colonial rule, and postcolonial development. Institutions were established and scientists put to work to address European interests in acclimatization, to facilitate plantation and other export crop agricultural systems, to exploit mineral resources, to improve health and welfare of colonizers and then the colonized, and overall to support colonial political power. Science's role was also cultural, representing European superiority and legitimating imperial domination across Africa, Asia, and beyond. All areas of science were impacted by this involvement, but especially the biological, environmental, medical, human, and social sciences. The movement of people, ideas, and practices between metropoles and peripheries was two-way. However, the flows were not of equal quality and quantity, and

[93] Corinna R. Unger, "India's Green Revolution: Towards a New Historical Perspective," *South Asia Chronicle*, 4 (2014), 254–70, available at http://edoc.hu-berlin.de/suedasien/band-4/254/PDF/254.pdf, accessed September 26, 2019.

[94] Sheila Jasanoff, "Biotechnology and Empire: The Global Power of Seeds and Science," *Osiris*, 21 (2006), 273–92, on 291–2.

scientists working in colonies spoke of local constraints as often as opportunities. However, their relative autonomy, particularly during the interwar period, allowed them to develop innovative ideas and practices that stemmed in part from greater respect for local conditions and the knowledge of local peoples.

In the years after 1945, with the founding of new international agencies and the development of the Cold War, there was a step change upwards in the scale of science in and for the colonies of Western powers and newly independent states. Perhaps paradoxically, science sometimes became the cornerstone for postcolonial national development plans. Science in newly independent states was to be used to harness the mineral wealth and expand the agricultural productivity to address problems of poverty and malnutrition. One of the problems of science in the modern era, whether in the imperial or the national context, has been its bureaucratization and whether access to its benefits has remained limited. Although indigenous scientific traditions sought to democratize science, in the postcolonial era science was adopted by nation-states for grand technocratic schemes of national development, often referred to as "big science." These major projects had mixed results. They made important, but uneven contributions to economic and social welfare, while at the same time creating new inequalities and environmental problems. However, science itself has tended to remain confined to elite institutions. Grassroots movements around science, whereby science becomes more accessible to a larger section of the population and would be used by citizens in their everyday lives, would not only benefit society, but also remodel science in more dynamic and inventive ways.