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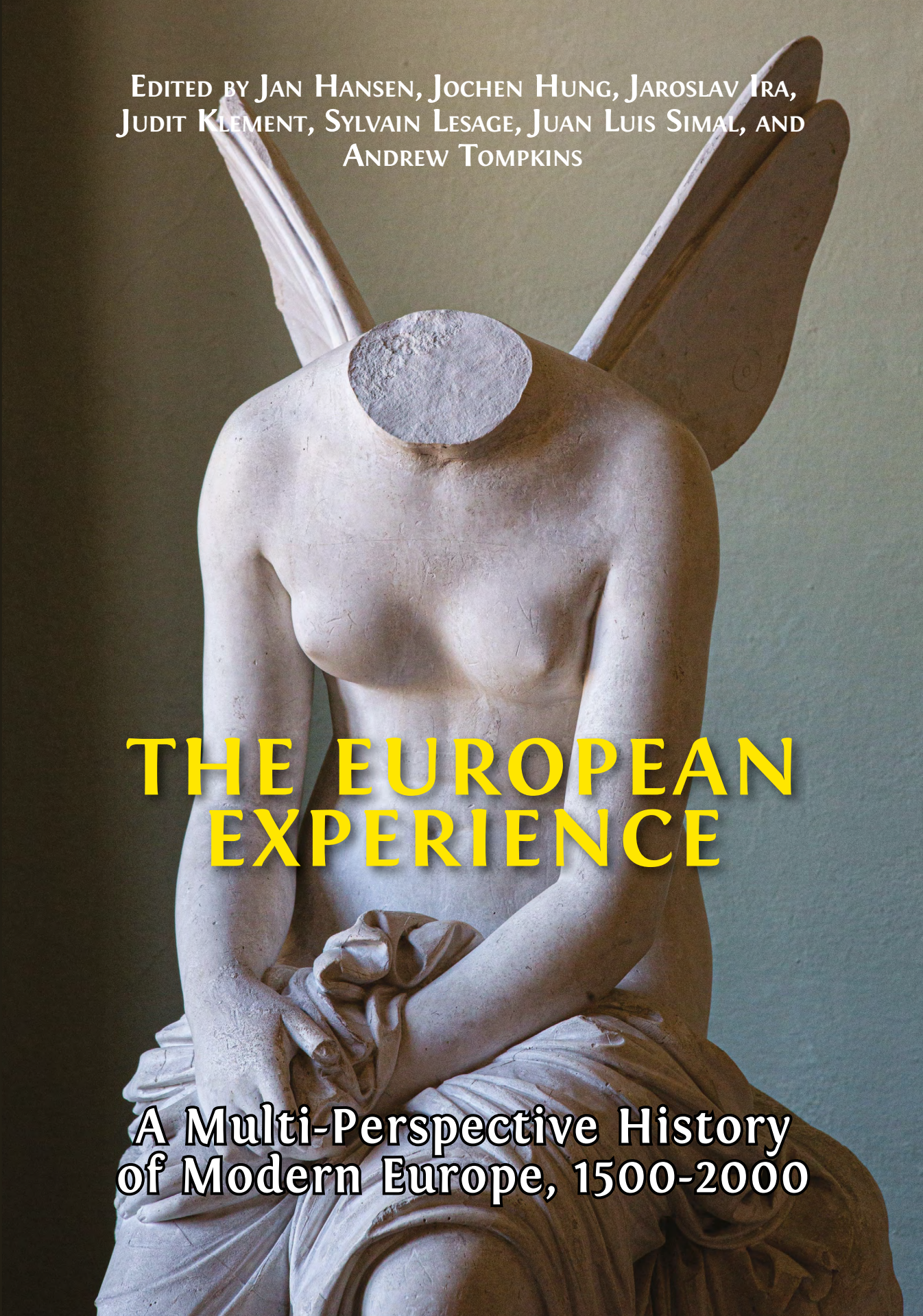

The European Experience

A Multi-Perspective History of Modern Europe, 1500-2000

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4.1.2 Science and Technological Change in Modern History (ca. 1800–1900)

Mathias Grote, Jiří Janáč, and Darina Martykánová

Introduction

The period between the French Revolution (1789–1799) and the outbreak of the First World War (1914–1918) was marked by the unforeseen dynamism of research and technology, by the formation of the independent academic disciplines that we know today (including biology, chemistry, history, philology and the first social sciences), and also by a growing gap between the sciences (*sciences*, *Naturwissenschaften*) and the humanities (*lettres*, *Geisteswissenschaften*). It was also a period in which technology radically transformed the production of goods and came to shape the everyday lives of a growing number of people in Europe and across the world, increasing human interconnectedness. While the relationship between science and technology has always been far from straightforward, the long nineteenth century was characterised by growing efforts to organise and institutionalise the links between the two, particularly under the logic of utility and profit, but also with the aim to expand human knowledge, in fields such as astronomy. Moreover, this period witnessed the professionalisation of scientific pursuits: due to the broadening field of state intervention and the growing investment of governing elites in science and technology, more and more people—mostly, but not exclusively, men—could earn their livelihoods 'doing science'. While science and technology were presented and understood as universal, they were shaped by existing relations of power and their imbalances, which were particularly pronounced in the era of the 'Great Divergence', the socioeconomic shift during the nineteenth century in which the Western sphere emerged as the wealthiest civilisation, eclipsing the rest of the world. European powers used technology and science

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to extend their domination around the globe and to exploit their domains with greater efficiency, while those residing in the colonies and in the independent countries beyond Europe (including Japan, the Ottoman Empire, Latin American republics, and the Kingdom of Hawai'i) creatively appropriated both science and technology in an effort to resist European and American imperialism and to strengthen their own position in the world—in military, political, economic, and also cultural terms.

Science and Medicine

The turn of the nineteenth century saw, in addition to political upheaval and a new ordering of the empires and nations of Europe, other events understood as revolutionary. Chemistry, for example, underwent dramatic changes: the introduction of modern elements (the story of oxygen and Antoine de Lavoisier is well-known), animal electricity (Luigi Galvani and Alessandro Volta), chemical formula, the periodic system (Dmitri I. Mendeleev) and the chemistry of life—the conceptual innovations of this fledgling discipline were spread across Europe. Like pearls on a chronological chain, these discoveries help to illustrate, in retrospect, a notion of scientific progress that became the pride of the emerging professions of academic researchers and teachers. However, recent historiography of science has taken a skeptical stance on such a notion of progress and its focus on individuals. Nevertheless, chemistry illustrates the technological and economic potential of science for the nineteenth-century state. Entire industries were built around the knowledge of carbon compounds that were isolated from industrial mining products, such as coal tar, and these industries would later change the material world through innovations in hygiene, pharmaceuticals, nutrition, or textiles.

The extent to which the sciences were a source of material wealth as well as a secularising force can be demonstrated by the most important development in nineteenth-century biology: the theory of biological species formation through variation and selection—evolution—as formulated by the Victorian scientist, Charles Darwin. Darwin's theory was tied to geological insights into the long history of the Earth (fossils) and to practices of breeding. The rules of heredity, first analysed by the famous pea cross-breeding experiments of Moravian monk Gregor Mendel, were only 're-discovered' in 1900. Evolution promoted a secular account of the descent of humankind, becoming thereby both a cornerstone of a modern scientific worldview as well as an object of contestation by religion. The theory of natural selection—of species changing and adapting to their environments over time—has of course changed its purview dramatically in the past 150 years. The theory also reveals science's connections to the exploration of the world by European powers: Darwin's

voyage on the ship, *HMS Beagle*, bore testimony to this, as did Alexander von Humboldt's earlier trip to Spanish Latin America, as do the vast collections in the natural history museums of European capitals to this day. The provenance of these collections and discoveries in regimes of colonial domination stands in stark contrast to their insight into the diversity of life and its ecological dimensions, thus revealing a downside of scientific 'progress'. Similar could be said of the damage done to humankind and the environment by the developing industries of this period.

Diseases such as cholera or tuberculosis became a challenge to medical science in the nineteenth century, spreading due to the pauperisation and urbanisation of industrialising states, as well as increasing international commerce. The European empires each pursued research on what came to be known as infections of the human body by 'invading' microorganisms: Louis Pasteur, Robert Koch, and Joseph Lister were celebrated as heroes of the triumphalist narratives of scientific modernity. This has sometimes obscured competing explanations, which gave the social factors of suffering and epidemics more weight than biology. State-sanctioned hygiene policies (disinfection, vaccination) and state-funded institutions—ultimately undergirded by the persistent dream of 'silver bullets' that would free humankind of these scourges—remain an enduring heritage of the late-nineteenth century and the golden age of both hygiene and bacteriology. Equally persistent, though, is the critique of such ideals of health and purity, not least regarding the colonial context or eugenics.

The global expansion of the British and French empires in particular, but also all kinds of lesser actors, along with transatlantic exchange, migration, and commerce, brought with it the need for faster communication, which was established in this period by intercontinental telegraph cables. In turn, these electrical networks had repercussions on the perception of space and time, paving the way towards conceptual innovations that culminated in the theory of relativity in the 1910s. Time zones, or the standardisation of units in the metric system, would cast an ever-growing web of measurement across the planet and the universe, supported by ideas of universal languages and repositories which could catalogue the masses of new knowledge. But the prestige of science's pursuit of an ideal of mechanical objectivity, bolstered by technologies such as photography, did not remain uncontested. Critique and scepticism of the positivist ideal abounded in literature, religious activities, and the humanities, pitching it against the individual, tradition, or irrationalism. Even a founding figure of the social sciences such as Max Weber would soberly concede in 1917 that the sciences could only yield descriptive causal analyses, but could never tell a human being what they ought to do in a normative sense. Thus, at the turn of the twentieth century, the modern

individual living in a world of science and technology—with all its insight into, and power over, nature and society—was also perceived as contingent, isolated, and vulnerable.

Fig. 1: Robert Charles Dudley, "H.M.S. Agamemnon Laying the Atlantic Telegraph Cable in 1858: a Whale Crosses the Line" (1866), CC0 Public Domain, Metropolitan Museum of Art, https://www.metmuseum.org/art/collection/search/383810. This painting shows the method by which American and British ships uncoiled the first transatlantic telegraph cable in the middle of the nineteenth century.

Technology and Politics

Technology came to be seen as historical in itself during the period considered here. As a field of human activity and politics, a specific technological domain hardly existed prior to the arrival of industrialisation. Only since the mid-eighteenth century had the concept of technology entered public and academic discourses, being as it were a significant component of the transition from the pre-modern social order to a new industrial one. Simultaneously, new practices of technology politics emerged, pitting technological development (innovations) as a driving force of progress and modernity and a vital precondition for prosperity. States started to intervene heavily in the development and adoption of new technologies in their territories, establishing engineering schools, universities and research institutions (see for instance the French École Polytechnique, 1794, the Prague Polytechnical Institute, 1806, or the Delft University of Technology, 1842).

This emphasis on technology marked a shift from protecting stability towards nurturing perpetual technological change. Sometimes associated with the expansion of liberal capitalism and industrial production (Schumpeter), this shift coproduced a rapid development of new technologies throughout the nineteenth century. While the initial phase of the Industrial Revolution was built upon incremental innovations in textile and steel production and the associated transition to the mechanisation of production, the so-called Second Industrial Revolution brought significant leaps in many fields of technological knowledge and production, this time properly engineered and science-based. To list just a few examples: the rapid development of electrical engineering, including the telegraph, lighting, electric generators, and radio; chemical industry such as fertilisers—see the work of the German scientist and engineer Justus von Liebig (1803–1873); and machinery such as the steam turbine for generating electricity, developed by the British engineer Charles Parsons (1854–1931), or the famous internal combustion engine designed by Rudolf Diesel on the basis of the principles of thermodynamics. These advances significantly increased energy efficiency in the production of industrial and agricultural goods and transformed livelihoods across European societies.

During the nineteenth century, Europeans started to identify with technology, which they began seeing as a defining characteristic of their civilisation and essential proof of its superiority. In the words of Michael Adas, technology became a "Measure of Men"—not only in encounters with non-European cultures, but also within Europe. Following the Great Exhibition of Products of French Industry held in Paris in 1798, annual national industrial fairs and exhibitions became a common sight in European capitals in the first half of the nineteenth century, providing an opportunity for regions to demonstrate and compete over their technological prowess. The Great Exhibition of the Works of Industry of All Nations, organised in London in 1851, for which the Crystal Palace was famously constructed, shifted the competition to an international level.

International competition sometimes transformed into a broader rivalry, or fit into a pre-existing one. Such was the case of the Franco-Prussian 'Great Train Race' between 1815 and 1914. National politics of technology required centralisation and control over the adoption and development of new technologies. State authorities made considerable efforts to standardise, supervise and organise implementation of these new innovations. Often, especially in case of communication and transport infrastructures, the military played an important part in technological expansion. Some even speak in this sense of the formation of the 'infrastructural state', characterised by an ideology of centralisation, expanding state-controlled networks, and the administration of 'development' by growing expert bureaucracies. Both France and Prussia

(and later Germany) faced difficulties in pursuing national railway policies, associated with the demands of private companies and the diverging policies of the many German states. In the end, especially after 1870, military interests drove both countries to outdo each other in terms of the absolute length and relative density of their railway networks.

Despite such efforts towards nation-building, however, technology contributed significantly to the gradual formation of Europe as a cultural and economic unit. The international standardisation of national communication and transport networks enabled a growing intensity of contact between European regions and peoples. The Bern Convention of 1886 offers a good example of such cooperation. Until then, Europe had been divided by the Alps into three largely incompatible railway networks (roughly French, Italian, and German). Construction of a trans-alpine connection interlinking the three networks required harmonisation between the differing standards, and in that regard the Bern Convention was a success. Prior to the First World War, a unique European railway regulatory regime was developed, combining various national, commercial, and non-governmental bodies and institutions. This system would manage an efficient operation of rolling stock on the network extending from the Atlantic to Russia. Standards developed in Europe often became universal standards and found application around the globe, driving the wheels of—and being driven by—the Europe-led expansion of global capitalism.

Technology, Science, and Global Capitalism

Europeans in the long nineteenth century, particularly those living in urban areas, experienced an unprecedented technological transformation of their work and everyday lives. Changes ranged from the sewing machine to the rise of the factory workplace, from the systematic construction, expansion, and maintenance of sewers to the gasification and electrification of the main streets and the development of urban public transport. In rural areas, changes consisted mainly of the growing possibilities of commercialising agricultural goods, stemming from new and improved infrastructures (roads, railways, steamships) that expanded the range of foodstuffs that could be sold for profit in faraway places. Railways and steamships became the fetishes of the century, symbols of the progress of civilisation. They fostered commerce and facilitated the spread of revolutionary ideas, diseases such as cholera, as well as massive European migration to America. At the same time, they were tools of imperialism that helped governments to get a tighter grip on their territories, in Europe and beyond. The (in)famous term ‘gunboat diplomacy’, linked to European and US imperialism, points to the less benign aspects of

nineteenth-century technologies. As the long century progressed, torpedoes, rapid-firing weapons, personal defence weapons and poison gases greatly improved the capacity of humans to kill each other in huge numbers; aviation, still in its beginnings, would soon take part in this mortal enterprise. Weapons and the war material successfully conquered the world, not only in the hands of European and American colonisers, but also in those of others—rulers and rebels all over the world who bought, adapted, produced, or used these armaments.

Not all novelties were as striking as the steam engine, but many brought with them revolutionary changes, too, from the spinning mule of the first Industrial Revolution to the industrial applications of modern chemistry in the second. Sewing machines made it possible for many women to earn a decent living from home, while bicycles facilitated the everyday mobility of hundreds of thousands of Europeans. Daguerreotype and photography made it possible even for poorer people to have their loved ones 'immortalised'. A German migrant to Buenos Aires could send a postcard with a panoramic view of the city to the family she left behind. Mass production of goods, whether or not they were accompanied by technological improvements, made many luxury commodities (iron tools, boots, china, furniture) more affordable for urban and rural dwellers in Europe and beyond. Technological changes and the re-organisation of production in factories, combined with the widespread discourse of freedom, equality and usefulness, together had collateral impact on the rise of labour movements and working-class identities.

Technological change has often been represented as the work of geniuses. It has also often been understood as derived from scientific knowledge. Regarding the first of the two ideas, the nineteenth century is largely 'at fault'. Men like James Watt, George Stephenson, Nikola Tesla, Thomas A. Edison, Guglielmo Marconi or the Lumière brothers embodied the notion of a bright inventor with great efficiency. However, many of their innovations were in fact the collective works of many people, and were improved and adapted as they circulated around the world. Regarding the second idea, the links between technology and science were much more fluid and less unidirectional than is often imagined. Many nineteenth-century inventions were not based on a scientific understanding of the principles of their operation, nor were they derived from research. Many of the people who invented or improved machines, tools, or procedures had little scientific knowledge. It is true, though, that these links became more solid and organised towards the end of the century, and that efforts were made to institutionalise the cooperation between scientific research and industry. The blurred frontiers between the old and the new, between science and technology, between knowledge and skills were evident in, for example, the coexistence of the patent system with

the free circulation of knowledge cherished by scholarly culture. While men of science received a great part of their status and prestige from publicising their discoveries and theories, anyone who engaged in the commercialisation of technologies strove to keep some of the information secret. Or, within the liberal logic of free trade and industry, they appealed to the state to establish and protect their 'right' to be financially rewarded for their innovations from those who wished to produce them for profit. The tension between these two opposing cultures, of intellectual commons versus property, characterised the century.

Europe was a hub both of high-profile scientific institutions and of industrial production, in which technology played a key role. The continent was also the site of several colonial metropolises from which projects of colonial conquest and rule were designed and launched, turning new technologies such as steamships, railways, and innovative firing arms into instruments of European domination in Asia and Africa. In some cases, most famous being that of Egypt and the Suez Canal, investment in construction projects, railways and new military technologies led to the substantial indebtment of local rulers, and the failure to pay such debts was used to legitimise direct or indirect takeover of these countries by European powers. Nonetheless, it would not be accurate to understand Europe purely as a centre from which science and technology radiated to the rest of the world. For instance, the prestigious engineering and medical schools of Paris, Liège, Lausanne, Zurich, and Vienna only remained global centres of knowledge transmission so long as elites from the Balkans, Latin America, or Asia acknowledged them as such, and continued to send their youth to study there. Among those elites we see a major change in the reputation of engineering schools towards the end of the century, with the popularity of Belgian, Swiss, and German institutions on the rise to the detriment of the French schools. Moreover, many of the greatest works of nineteenth-century engineering were built outside of Europe, such as the Suez and Panama Canals. European and North American experts and investors played an essential role in their construction, but so did local and migrant workers, along with local rulers and bureaucrats. This constant intermingling of efforts was essential to making technology and technology-related professions truly global, irreducible to any specific race, nationality, ethno-religious identity, social class, or gender.

Conclusion

The nineteenth century was often perceived by its contemporaries as the century of progress. If asked why it deserved such a label, they would most probably list some of the technological wonders that characterised the

period, such as railways, steamships, telegraph and iron constructions, gas lighting and electricity, or refer to scientific discoveries and procedures, such as modern medicine's capacity to explain—and to a lesser extent cure—a growing number of diseases. They might speak of a 'revolution' in chemistry and its huge impact on agriculture (fertilisers) and industry (dyes), or the world-shattering theory of evolution that made the millenarian notion of divine creation hard to sustain on anything other than a symbolic level. Science and technology were deemed useful by governments in Europe and beyond, and they proved ready to invest in them, driven by military but also administrative and economic concerns. The speed of these changes and their place in the more general *Weltanschauung* of the 'progress of civilisation' led to a proliferation of narratives and projects of a better future, in which science and technology played an important role. Scientific utopias did not convince everyone and, in parallel, anxieties emerged over the corrupting effects of new technologies and the consequences of replacing a religious worldview with a scientific one. The hopes deposited in the sciences and technologies as tools of social change were accompanied by dystopian visions of madness, dehumanisation, and annihilation. For the most part, though, explanations and practices based on scientific knowledge acquired weight in justifying new legislation and in legitimising political action by both governments and by subversive movements. They became more and more present in public debate and even in the private lives of women and men in Europe and beyond. Science and technology often served to showcase European superiority and legitimise imperialist intervention and domination. But because they were understood as universal, they were often welcomed and creatively appropriated by people in different parts of the world, who saw science and technology as part of a process of regeneration that would save them from perishing under the boot of foreigners. By the end of the nineteenth century, sciences and technologies had become weapons in both the material and symbolic realms.

Discussion questions

1. Which of all the inventions mentioned in the text was the most consequential in your opinion? Why?
2. Modern technology was a force for good in nineteenth-century Europe. Discuss.
3. In which ways is our world still shaped by the inventions of the nineteenth century?

Suggested reading

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

Cahan, John, *From Natural Philosophy to the Sciences* (Chicago: Chicago University Press, 2003).

Daston, Lorraine and Peter Galison, *Objectivity* (Cambridge, MA: Zone Books, 2007).

Hård, Mikael, and Andrew Jamison, *Hubris and Hybrids: A Cultural History of Technology and Science* (New York: Routledge, 2005).

Headrick, Daniel R., *The Tentacles of Progress: Technology Transfer in the Age of Imperialism, 1850–1940* (Oxford: Oxford University Press, 1988).

Guldi, Jo, *Roads to Power: Britain Invents the Infrastructure State* (Cambridge, MA: Harvard University Press, 2012).

Jardine, Nicholas, Emma C. Spary, James Andrew Secord and Helen Anne Curry, eds, *Worlds of Natural History* (Cambridge: Cambridge University Press, 2018).

Kaiser, Wolfram and Johan Schot, *Writing the Rules for Europe: Experts, Cartels, International Organizations* (Basingstoke: Palgrave Macmillan, 2014.)

Mitchell, Allan, *The Great Train Race: Railways and the Franco-German Rivalry, 1815–1914* (New York: Berghahn, 2000).

Osterhammel, Jürgen, *The Transformation of the World: A Global History of the Nineteenth Century* (Princeton: Princeton University Press, 2014).