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## Preface to the Revised Edition

This book outlines the development of technology and its dissemination around the world over a thousand years of history, from AD 1000 to the present day. The discussion is shaped by three key ideas: technological dialogue, environmental constraints, and industrial revolution.

The term *technological dialogue* is used here to characterize the responses of people and communities to unfamiliar technology. When a new technology is introduced to a region, the original invention is often modified, or undergoes further innovation. Of many examples mentioned, some of the clearest relate to the invention of firearms, including handguns and cannon, as discussed in chapters 3 and 8. While several of the initial inventions were made centuries ago in China, they were followed by innovations in Europe and later in Turkey and India.

A more recent example, not discussed elsewhere in the book, is the way Inuit communities in the Arctic responded when motorized sledges—snowmobiles—were first introduced. Although the Inuit had no tradition of mechanical technology, they quickly became highly skilled in maintaining the machines, even modifying maintenance protocols and improving the procedure to be followed when engines had to be taken apart and reassembled. Observers found this rapid acquisition and active participation in a new skill difficult to understand until research on ethnomathematics demonstrated the very discriminating sense of spatial relationships that is part of Inuit culture, evident also in their carving and sculpture.<sup>1</sup> This case is especially significant as an example of how the culture of a people can have a bearing on the way new technology is received.

A very different example dates from 1929, when a British firm that had introduced new power looms into Japanese textile factories ended up adopting

modifications of the looms made in those same factories by Japanese technicians (see chapter 9 on the Toyoda loom). There was a real, two-way dialogue in this instance between the British manufacturers and the Japanese adopters.

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A second concept that recurs in this book is that of limits or constraints (and opportunities for improvement in technology) arising from the natural environment, and the responses of inventors, technicians and entrepreneurs in dealing with them.

One constraint occurring periodically throughout history is the shortage of some critical material, such as timber for shipbuilding. When China experienced a timber shortage at the turn of the fourteenth and fifteenth centuries, one response was to use a greater variety of different timbers in ships; another was to complement local supplies by importing more from Southeast Asia (chapter 3). In Britain, oak was the preferred shipbuilding material. When native oak became scarce in the eighteenth century, one response was again to use different kinds of timber and to import more, including softwood from Baltic countries. Another response was to outsource the building of some ships to regions with more plentiful timber, such as the east coast of North America, and also India, where teak was the timber used (chapter 7). Soon after, in the early nineteenth century, shortages of timber became irrelevant as it became possible to begin building ships of iron.

With regard to constraints related to energy resources, most examples of technology discussed in chapters 1–6 depended on basic natural sources of energy: wood or charcoal for fuel, human or animal muscle for power, wind to propel ships or drive mills, and flowing water to turn wheels. The relatively modest amount of energy available from these sources in any one place became a constraint on development, overcome during the eighteenth century by the invention of the steam engine, with the steam generated by coal-fired boilers. Steam engines were first used to replace horses or waterwheels when these were found to be providing insufficient power. At about the same time, ways were found to use coal in the form of coke for smelting iron (chapter 7).

But of course there are constraints which may affect the use of coal, including limits to its availability and the effects of coal smoke in the atmosphere. To begin with, these constraints were felt only locally, but during

the nineteenth century coal smoke became a major hazard to health and a cause of fog and other weather events in heavily industrialized urban areas (chapter 12).

However, construction materials such as timber, and fuels such as firewood, charcoal, and coal are not the only natural resources to consider. There are also biological resources of the kind that are used to produce food, fibers, and medicines. Just as the invention of the steam engine led to a breakthrough in industrial development, so the discovery or dissemination of biological resources could lead to the relief of constraints holding back human development in other ways. A discovery of new biological resources of exactly this kind was stumbled on by Europeans when the Americas became an integral part of world history, after the voyages of Columbus. Highly productive crops such as potatoes and maize were quickly adopted, not only in Europe but also in the Philippines, China, and other parts of the world, relieving constraints on food supplies and allowing populations to grow. This highly significant but underappreciated phase in world history is discussed in chapter 4, and there is more discussion of biological resources in chapter 11.

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Apart from some limited and early use of coal for iron smelting in China (chapter 1), the exploitation of new sources of energy based on coal in the eighteenth century, first in Britain and Europe but soon after all over the world, was a notable characteristic of what became known as the Industrial Revolution. A sequence of other, later industrial revolutions has been identified, but this is a subject for which much of the interpretation depends on definitions. If industrial revolutions are mainly thought of as spurts of economic growth arising from the introduction of new technologies, then there were indeed further industrial revolutions, associated, for example, with the development of railroads in the nineteenth century (chapter 9), the later development of the chemical industry, or the introduction of electric light (chapter 10). More such revolutions followed in the twentieth and twenty-first centuries, triggered by innovations in fields including petrochemicals, aerospace, electronics, and new sources of energy (chapter 12). Alternatively, if industrial revolutions are defined according to the social changes and changes in the organization of production that accompanied them, such as the factory system in the eighteenth century, then the

development of automation and robotics and the new information technologies of recent times indisputably constitute new industrial revolutions.

But talk of revolutions can distract us from significant continuities. There have certainly been what some commentators have called *waves of innovation* in the nineteenth and twentieth centuries and up to the present (chapter 12), but it is debatable how many can be reasonably counted as transformative in certain crucial respects that we can no longer discount. What is particularly striking is that none of these so-called industrial revolutions has yet (by 2020) fundamentally changed the energy base of industrial civilization, which still depends on coal and other fossil fuels to an extraordinary degree, even though other energy sources—nuclear and renewable—have been developed.

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When the first edition of the book was written during the 1980s, debates then current about technology transfer and international development made it seem necessary to make a case for a better understanding of technological dialogue, and that became the central theme. When revising the book thirty years later, the invitation to add an extra chapter and bring the narrative forward into the twenty-first century inevitably raised questions about the waves of innovation and the possible new industrial revolutions that have occurred—depending on one's interpretation of events—and questions regarding limits and constraints have also become more important. Although much of the book is little changed in the new edition, thinking about issues raised by the new chapter has prompted some revisions in the earlier chapters, giving them a slightly different gloss.

In tackling these large subjects, what I have attempted here is only a broad outline, believing that many readers will find this helpful as a broad view is sometimes useful to gain perspective. More information on the subjects covered can be found from sources referred to in the endnotes, which have been expanded for this revised edition.

I am indebted not only to the books referred to in the notes but also to the opportunity to examine objects in museums and occasionally in factories or workshops. Among such institutions are the Victoria and Albert Museum, the National Maritime Museum (Greenwich), and the National Army Museum, all in London; the Smithsonian in Washington, DC; the

Ironbridge Gorge Museum in Shropshire (UK); the Beijing Ancient Observatory and the Sichuan Brocade Factory, Chengdu (China).

I am grateful to staff in several of these organizations, and I have many more personal debts to friends and colleagues. Most of these were sufficiently listed in the first edition, but the most personal debt of all is to my late father for a sense of world civilization, which he often expressed by repeating, in Chinese and English, the words appearing opposite the title page. These are from the Chinese classic *The Book of Rites*, or *Liji* (literally *The Record of Rites*), a collection of texts describing the social forms and ceremonial rites of the Zhou dynasty.

My warmest thanks in connection with this revised edition go to my publisher, Katie Helke, and my coauthor, Francesca Bray, both of whom have given me much encouragement.





## Coauthor's Note

I was delighted to be invited by Arnold Pacey to help him prepare the revised edition of *Technology in World Civilization*. I first read the book in 1992, two years after it came out, and I was an instant fan. As a contributor to Joseph Needham's *Science and Civilisation in China*, a project dedicated to challenging the standard view of the period that science was a uniquely Western product, I greatly appreciated Pacey's iconoclastic, cosmopolitan approach.

Unlike other general histories of technology at the time, which traced the apparently inevitable rise to supremacy of Western civilization, Pacey unfolded his thousand-year history as a continuous, global process of dialogue or exchange. Rather than treating Africa, Asia, and the Americas as peripheries, with Europe as the center of historical change and significant innovation, the book's case studies of technological dialogue—for example, between China and West Asia in the eleventh century, Africa and the Islamic world a little later, and India and Britain post-1700—vividly illustrated the complex braiding of peoples and institutions, skills and knowledge, materials, styles, and markets that interwove technological systems from different parts of the world, often resulting in the relocation of centers of technology, the reshaping of linkages, and the resurfacing of systems in unexpected guises and places. The original *Technology in World Civilization* was a pace setter, heralding several radical changes to come.

Throughout, the book makes a powerful case for what global historians were soon to term the *provincialization* of Europe, or the *decentering* of Western civilization. It challenges standard story lines about the roots and resources of the Industrial Revolution, acknowledging specific factors that helped Europe forge ahead in technical innovation and organizational

change at that moment in history, but also foregrounding the indispensable contributions in skill and knowledge from around the world that shaped the newly emerging machine age. The chapter on railway empires, likewise, instead of focusing primarily on the British Empire or the opening of the American West, highlights the cases of Russia and Japan, showing how these aspiring world powers used railroads to extend their zones of influence. The final chapters unfold the modern histories of electronics and energy, aeronautics and agroforestry, as stories of transnational dialogue— dialogues to which not only physicists and engineers but also forest farmers and smartphone users contribute.

Today the history of technology is a very different field from what it was in 1990, when *Technology in World Civilization* was first published. Global, environmental, and postcolonial history have all contributed to the change. Studies abound of particular technological encounters between societies, of specific cases of technological entanglement or creolization—all approaches closely related to Pacey's explorations of technological dialogues.<sup>1</sup> Whereas progress was formerly gauged by rates of technical innovation and increased efficiency in generating output and profits, today the environmental impact of technologies past, present, and future is, as in Pacey's approach, a primary concern. In other words, the main themes of *Technology in World Civilization* are as relevant as ever, and in its broad geographical and historical scope, the book remains a unique and valuable introduction to the shaping of the modern world.<sup>2</sup>

For all these reasons I enthusiastically accepted the invitation to help prepare a revised edition of *Technology in World Civilization*, in a collaboration that I have found thoroughly rewarding. My principal contribution has been to update and expand the references to integrate the recent literature into the argument—but in one or two places I couldn't resist adding a new case or an additional thread that I felt added an interesting angle to the argument.