Part II

Constructing Landscape

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The Nature of Industrialization

Sara B. Pritchard and Thomas Zeller

Most people born after 1960 and raised in Western Europe or North America have experienced more deindustrialization than industrialization. The closing of large-scale integrated factories since World War II has contributed to the economic decline of many historically important and once proud regions, including Germany's Ruhr Valley and the Rust Belt of the American Midwest. Decontaminating former industrial sites and deciding how to use old steel mills and other facilities, now tellingly called brownfields, are some of the most pressing issues these communities face today. For example, entire landscapes in eastern Germany, once vast, open-pit coal mines, have been turned into expansive recreational lakes. Coal, mining cages, and machine operators have been replaced by water, jet skis, and sunbathers. In the United States, former steel mills near Pittsburgh, Pennsylvania, have been succeeded by endless shopping malls, while the lush greens of a posh golf course now cover remediated copper-mine tailings in Anaconda, Montana. One might deduce from these changes that technology, which once reigned supreme in the coal and steel centers of the first and second "industrial revolutions," is retreating to make room for nature. Those with ironic sensibilities might even argue that if industrial technology once conquered nature, the empire of nature is striking back. Indeed, many scholars have asserted that industrialization not only reinforced but widened the gulf between two supposedly mutually exclusive spheres: the cultural and the natural, the social and the material, human and nonhuman nature.

Nothing could be further from the truth. We argue here that industrialization was as natural as other large-scale transformations in human history and that contemporary deindustrialization in Western Europe and North America is not a return to nature but rather one more chapter in the long history of human interactions with the natural environment and anthropogenic change to the landscape, which calls into question a simplistic divide between nature and culture, humanity and the natural world. Put another way, this essay *naturalizes* industrialization. To be clear: naturalizing industrialization does not mean that the processes associated with industrial production and consumption were either inevitable or progressive. Scholars have identified historical reasons for the emergence of industrialization in mid-eighteenth-century Britain and shown how certain groups benefited from these changes, while many others (some human, some nonhuman) suffered from them. Naturalizing industrialization instead highlights the ways in which industrial processes were embedded within, and thus ultimately dependent upon, natural resources, environmental processes, and ecosystems. Yet seeing nature and technology in dichotomous terms masks these interconnections. Naturalizing industrialization also stresses the ways in which industrialization involved not only significant social, economic, and technological change but also fundamental shifts in how people in industrializing societies perceived and interacted with nonhuman nature. These arguments therefore challenge the common assumption that industrialization is entirely separate from and perhaps even antithetical to nature, as well as normative ideas associated with models of ecological stability and stasis.

But what is industrialization? At its most basic level, industrialization involved the rise to prominence and eventual dominance of the industrial sector within a national economy, or to put it conversely, the decline of farming, silviculture, and craft production based in the small workshop or family economy. Beginning in Britain in the mid-eighteenth century, a new industrial mode of production began to flourish, accompanied by and facilitating rapid demographic growth and urbanization. Industrialization rested on the twin pillars of reorganizing business practices, most prominently the emergence of the factory system, and introducing new technologies that enabled the large-scale production of cheap commercial goods. Together they contributed to the development of an industrial work process characterized by a strong division of labor, specialization, mechanization, strict discipline, perceived deskilling, and widening social hierarchies. These changes increased the volume and diversity of available goods while decreasing prices. Working- and middle-class consumers became able to buy what had been luxury items, but heightened socioeconomic inequalities, both within Western powers and between European metropoles and their colonies, characterized this emergent industrial economy.[1]

Recent scholarship has dramatically revised our understanding of these complex processes that together made up industrialization. Earlier generations of historians used the term *Industrial Revolution,* following parlance from the 1830s on. As this term suggests, these historians, as well as many nineteenth-century contemporaries, saw industrialization as a radical break with the past. Many, if not most, economic historians today have reservations about the presumed unity and unilinearity underlying this term, instead framing industrialization (or even industrializations) as an uneven, locally differentiated set of processes. Scholars have also begun to challenge a singular model of industrial change defined by the British experience. In addition, earlier theories about revolutionary technologies, most famously the steam engine and the spinning jenny, which supposedly transformed England and then spread to the rest of the world, have given way to a variedly textured canvas of preindustrial and industrializing regions in various parts of the globe undergoing uneven industrial development. As this last point suggests, most historians of technology have shifted from seeing technology as the driving engine of socioeconomic change to emphasizing the ways in which technologies are thoroughly embedded within the social fabric and therefore shaped by a given society. For this reason, recent scholars have stressed that changes associated with industrialization were the results of human choice, social relations, and ultimately power, not inevitable historical outcomes.[2]

Many older interpretations tend to frame industrialization as increasing human domination over nature. For some scholars, this is, in fact, one of its defining features. For instance, when assessing the importance of industrialization in world history, Carlo Cipolla proclaimed, "For centuries . . . the world of Mankind remained a world of plants and animals. The Industrial Revolution opened up a completely different world of new and untapped sources of energy such as coal, oil, electricity, and the atom." Cipolla even went so far as to state that the Industrial Revolution had transformed "Man" from farmer-shepherd into a "manipulator of machines worked by inanimate energy."[3] Cipolla asserted, then, that industrialization was without precedent in human history, and he constructed a smooth narrative around the complete transition from a wholly natural to an entirely technological world. Similarly, the historian David Landes, in his influential *Unbound Prometheus,* postulated three principles that defined industrialization, all of which rested on increasing human control of and distancing from nature: the substitution of machines for human skill and labor; the substitution of inanimate for animate sources of power; and the use of new and far more abundant raw materials.[4]

For both Cipolla and Landes, industrialization involved a fundamental rupture in the way humans interacted with their environment. Instead of being constrained by natural cycles and the immediacy of the farmer's attachment to the land, humans were now free to expand both their livelihoods and their economies. According to this view, industrialization enabled those in the industrializing West to surpass limits historically posed by the natural world. Implicit is the idea that humans in industrial societies had managed to get outside nature through technological innovation and what was understood to be progress. Humanity was finally unbound, if only it followed the path of the Industrial Revolution.

Writing more than a generation after these authors, it is hard to share their triumphant optimism. Moreover, several of their assumptions seem questionable. For starters, the clear separation, if not rupture, between a preindustrial mode of environmental constraint and an industrial conquest of nature appears far too neat and categorical. Preindustrial, industrial, and postindustrial modes of production fundamentally *share* an engagement with the natural world, but they differ in the type as well as the extent and degree of mediation. None should be described as a complete distancing from nature or a total mastery of either humanity or the environment.[5]

However, the seeming distance that industrial technologies create between humans and nonhuman nature is one reason why industrialization has so often appeared unnatural— to both contemporaries and modern scholars. Many technological artifacts and systems help make human connections to the environment invisible (or at least less readily visible), but industrial technologies are especially effective in decontextualizing them.[6] For example, seemingly mundane technologies in twenty-first-century America, such as electricity, plumbing, and highways, obscure human links to the soil, air, and water. It is doubtful that many people in the industrialized West recognize their ties to the hydrologic cycle each time they turn on the tap or consider the pollution associated with various kinds of electricity production when they watch television. Often, it takes technological failures like blackouts and floods to remind industrialized Westerners of the continued presence of nature in their homes, cities, and landscapes. Due to their cultural conditioning, they are more apt to see nature as explicitly present in agricultural, nomadic, or preindustrial societies, a tendency that perpetuates the dangerous representation of these cultures as more "primitive," in part because they are somehow "closer to nature."[7] One of the most influential legacies of industrialization, then, is the way in which industrial technologies have helped to obscure humans' connections to, and thus dependency upon, the environment.

In this essay we seek to highlight these continued connections by exposing the ecological roots and contexts of industrialization. Instead of making the impulsive assertion that industrialization is fundamentally unnatural, thereby implying that it somehow occurred outside an environmental context, this approach emphasizes the ways in which humans in industrial and industrializing societies engaged with and transformed that very context through the diverse sociotechnical processes that together composed industrialization. It draws particular attention to the ways in which human interactions with environmental conditions, in addition to diverse social groups, shifted through industrial development. In other words, industrialization necessitated a reworking of interactions between human and nonhuman nature, just as industrial processes involved important social changes within hierarchies of class, gender, and race. Most scholars of industrialization have tended to focus on the social, economic, and technological changes that it entailed: technical inventions, increased productivity, widened social disparities, and so on. Yet industrialization simultaneously involved not only ecological change (traditionally described as the environmental "impacts" or "consequences" of industrial development, including the environmental impacts of new industrial technologies) but also important shifts in relations between humans and nature. This avenue of inquiry does not dismiss the momentous socioeconomic changes that took place in industrializing societies, which social historians have ably documented. Rather, it calls attention to the essential but often overlooked ecological dimensions of industrialization by foregrounding the ways in which these processes involved both environmental change and shifts in relations between humans and nature.

An examination of the environmental history of industrialization thus stresses the centrality of nonhuman nature to it. Thus, we underscore here the profound connections of industrial development and industrial societies to the environment. Again, these arguments neither legitimate nor excuse dramatic environmental change. Nor do they exonerate the heightened socio-environmental inequities that have historically occurred within industrial and industrializing societies. Instead, they aim to present a fresh perspective on, and ultimately "thicker" (to use the anthropologist Clifford Geertz's term) historical account of, industrialization by exposing continued human ties to the environment. While those from the "Western tradition" tend to rhetorically separate nature and technology, the complex histories and landscapes of industrialization belie this tidy distinction. Furthermore, these issues have pressing relevance today as industrialization transforms large parts of the global South and humans across the world contend with the challenging legacies of industrialization, including global climate change, the atomic age, the quality and distribution of fresh water, and more.

In this essay we therefore examine the interconnection of nature and technology in the industrial age by focusing on several important themes and using case studies to develop those themes. We begin with the two quintessential industrial commodities, coal and cotton, but challenge traditional narratives about these resources and offer a new, envirotechnical interpretation. Then we examine the theme of fueling industrialization by exploring how minerals, water, bison, and sugar literally powered various components of this new industrial envirotechnical system. Next, we consider how industrialization involved important shifts in the relationship of nature and technology with respect to geographical and temporal scale. Finally, we conclude with some broader thoughts on the nature of industrialization.

Coal and Cotton: Toward an Envirotechnical History of Industrialization

Traditional histories of the Industrial Revolution generally center on two artifacts: the spinning jenny and the steam engine. While the former helped mechanize textile production, the latter enabled the extraction of coal from deep mines and then literally became a driving force in the industrialization of transportation and manufacturing technologies. Many thinkers have identified the growing importance of these two artifacts with a fundamentally different regime of resource management, in other words, a distancing of humans from the natural world. For instance, in the 1920s the German economist Werner Sombart asserted in his ambitious, synthetic study of the origins of modern capitalism that the later economic preponderance of heavy industry as a result of industrialization marked an important shift from an organic economy (such as textile manufacturing, no matter how mechanized) to the inorganic (such as mining and metallurgy). In making this division, Sombart asserted that a former unity had been ripped asunder. In this new industrial age, humans and nature were distinct parts of a relationship that once had been one and the same. Such exercises in classification and periodization almost inevitably result in binaries. About a decade after Sombart's widely received publication, the American cultural critic Lewis Mumford declared his awe at the breadth of Sombart's study but admitted that the German's characterization of the shift from the organic to the inorganic was "too neat and confident."[8] It certainly was.

Examining one of industrialization's most well known elements, coal, offers a more complex picture than the one Sombart proposed. In the first place, coal is the carboniferous remains of ancient plants. Like other fossil fuels, it constitutes stored solar energy, having caught and accumulated the sun's rays of days millions of years ago. After all, *fossil fuel* is not just a phrase; it describes the ecological roots of modern energy. On this level alone, nineteenth-century cotton and ancient vegetation, which eventually fueled industrialized textile production, are separated by the time frame of their origin, not their core ecological properties. Of course, the ancient Precambrian plants that ultimately yielded coal were submerged, put under enormous pressure, and reshaped for vast spans of geological time before they landed in Victorian steam engines. Yet plant products they were still, just like the fluffy growth of the cotton bush, which had to be spun and woven before it could become fabric. A close examination of the physical properties of coal and cotton thus blurs Sombart's sharp distinction between the organic and the inorganic in favor of a more ambiguous continuum.

Another way to rethink the apparent distinction between the organic and the inorganic is to examine the historical treatment of these materials for human purposes. Most coal has to be extracted from its subterranean environment. Leaving aside the development of open-pit mining, the coal mine is an impressive human creation, one that has often been likened to an underground city. The absence of forests, streams, and readily apparent biological life forms led Mumford to proclaim that the coal mine "is the first completely inorganic environment to be created and lived in by man."[9] But like Sombart, Mumford went too far in his assertions. Historical research on the density and complexity of early Chinese cities and ancient Rome has demonstrated, for instance, that these urban environments were also complex human creations. More importantly, the supposedly inorganic mine is only inorganic if one assumes that humans and their creations are outside nature. Alternatively, one can see mines, either the ones so colorfully described by Georg Agricola in the early sixteenth century or more recent industrial ones, as simultaneously natural and cultural artifacts. Another comparison with cotton is helpful here: "Natural" cotton fibers are as useless to humans as coal deep beneath the surface of the earth. Both need to be accessed, harvested, processed, and reprocessed in order to become more usable and consequently valuable; in other words, they must be transformed from nature into natural resources.[10] Deciding at which point in that lengthy process they lose their natural properties and become artificial is a human valorization, not one that is inherent in the materiality of either coal or cotton.[11]

Furthermore, there are many other ways in which nature is present in the engineered, seemingly artificial environment of the mine. Hydrology presents numerous challenges to mining engineers, who try to control the flow of water through subterranean environments. Thousands of board acre-feet of wood must be lowered down into the mine in order to timber and reinforce the labyrinth of shafts and corridors. Pack animals, including horses and mules, help move tons of coal ore, wood, mining equipment, and human laborers. The temperature and air quality of the mine must be regulated in order to allow the presence of humans and other animals, especially in mines a mile or more underground.[12] The legal and environmental historian Arthur McEvoy has also asserted that the body of the human worker should be considered part of the nature of industrial factories and workplaces.[13] Water, trees, air, animals, and human bodies themselves are thus all organic components of a mine's complex technological system, what scholars working at the intersection of technology studies and environmental history increasingly see, in fact, as *envirotechnical systems*.[14]

Of course, mines, mining technologies, and mine environments have changed over time and across cultures. Human relations to natural resources and ecosystems have also shifted, as have cultural views of these interactions. The complexity of these historical relations and the fluidity of this discourse reveal how historically and culturally specific the boundary is between natural and unnatural, organic and inorganic, further demonstrating the danger of sweeping transhistorical, transcultural generalizations. For example, if Sombart or Mumford had written after the dawn of the atomic age, coal might have appeared organic in comparison with its new nuclear rival. Indeed, in subsequent publications Mumford envisioned a "neotechnic" era based on supposedly clean electricity generated in hydroelectric plants, while recent Westerners who are affluent enough to buy "eco" cotton have begun to criticize industrially produced textiles. Yet hydroelectricity may appear far less clean to migratory fish, while poor people around the globe have rightly questioned the social costs of environmental protection. Similarly, recent calls for a switch from a petroleum- to a biofuels-based, "post-carbon" economy often ignore the fact that corn, sugar cane, and other crops can and do feed people, not just machines. Moreover, producing adequate supplies of biofuels such as ethanol may actually require the expansion of the post-1945 agro-industrial complex with its attendant high environmental costs, not to mention raising the prices of certain crops perhaps beyond the reach of poorer communities.[15] The management and use of natural resources, whether cotton, coal, or rivers, are therefore not equally beneficial or damaging either to all humans or to other species. However, sharp demarcations

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Coal mine, Pittston, Pennsylvania, January 1911, photograph from the U.S. National Child Labor Committee (NCLC) records. This photograph and the NCLC's original text reveal the profoundly envirotechnical character of the mine. The NCLC lamented the thirteen-year-old boy's health issues, commented on the presence of gas nearby, and noted that mine walls were whitewashed to improve lighting. These references allude to the challenges that the environment of the mine posed to engineers and workers. Notice, too, the mules and the extensive use of timber (the door, framing, and railroad ties) and pipes (it is unclear whether they are for water or air circulation), not to mention the miners themselves. (Library of Congress Prints and Photographs Division)

between the organic and the inorganic, the natural and the unnatural, may not only misrepresent but also prove unhelpful for understanding the environmental histories of the things we eat, wear, or burn. Moreover, modern conceptions do not necessarily reflect how historical actors thought about these complex issues.

Silver, Water, Bison, and Sugar: Fueling Industrialization

"New World" nature in the form of silver and gold became essential capital for early modern Europe and eventually fueled industrialization there. The famous mining town of Potosí, Bolivia, is a prime example of this process. Located at an altitude of 14,000 feet in the Andes Mountains, Potosí was, and remains, an important mining center. The mine itself, Cerro Rico (Rich Hill), perches above the town. The Spanish were not the first to mine the "Rich Hill." Incans mined silver there just as they mined gold elsewhere in their vast empire, but indigenous mining was primarily for religious, not commercial, purposes. While the global gold rush of the mid- and late nineteenth century is more famous, the lesser-known silver rush of the sixteenth and seventeenth centuries made Potosí the largest city in the Hispanic Americas. In fact, its population in 1573 rivaled that of London.

For more than two centuries after Spanish *conquistadores* defeated the Incan empire, a steady stream of silver ore flowed down the slopes of Cerro Rico through the furnaces, smelters, and mints of Potosí and eventually made its way across the Atlantic Ocean to Spain. Between 1560 and 1685 the Spanish Americas sent 25,000 to 35,000 tons of silver annually to Spain. Over the next 125 years this sum doubled. Moreover, official records undoubtedly underestimated the total volume of minerals that ultimately reached Europe.

The immense mineral wealth of the Americas greatly expanded the coffers of western Europe, with far-reaching political and economic consequences. Beginning in the late fifteenth century, European exploration and conquest had incorporated the Americas into the existing world system. Starting in the sixteenth century, Latin American specie accelerated the accumulation of capital in western Europe. American silver shipped to Europe during the sixteenth and seventeenth centuries far exceeded existing European reserves and increased Europeans' capital reserves at unprecedented rates. As Europeans gained economic power from extracting wealth from their colonies, protectorates, and empires, they began to gain more political and economic power; in other words, capital accumulation begat capital accumulation. European states could afford bigger militaries, improved transportation and commercial networks, greater investment in technology, and larger industries thanks to this surge in wealth. These things, in turn, enabled Europeans to extract even more wealth from their growing empires.

Historians have argued that Latin America's mineral resources provided crucial financial means for European powers to wage large-scale war both within and beyond Europe. As minerals became capital, they fueled competition among European powers, especially as the vast resources of the New World became apparent and Europe's monarchies vied for control of that wealth. Scholars have also shown how the mineral resources of the Americas were channeled into Europe's modest but expanding commercial networks. These patterns eventually had a major impact on the global economy as well as on Europe's place in that economy. In short, scholars have concluded that

New World minerals help explain nascent global capitalism and why western Europe became the center of this new economic system. New World silver therefore played a key role in Europe's remarkable economic development and expansion during the sixteenth and seventeenth centuries, which helped set the stage for industrialization in the mid-eighteenth century.

This incredible wealth was generated at great costs, however. Mining entailed important environmental consequences, especially as high-grade silver ore ran out and mercury-based refining of lower-grade ore expanded. There were also enormous tolls on human communities. Hundreds of thousands of indigenous laborers worked in the mines of the Hispanic Americas. Thousands died each year. Those who did not die suffered from horrific working conditions, rampant disease, and poverty. One of the richest places on earth created tremendous wealth for a handful of European and indigenous elites, while it scarred the landscape and, perhaps most ironically, generated great poverty for many others.[16]

Harnessed and regulated hydrologic systems also fueled industrialization, doing so as literal sources of power. The management of several rivers illustrates this pattern as industrialization itself changed from the eighteenth century to the twentieth. Although it was not the focal point of her study, the historian of technology Judith McGaw described how nineteenth-century paper manufacturers in western Massachusetts selected mill sites based partly on their environmental suitability for industrial production. They attempted to locate early paper mills near large stands of trees, but they also identified ample, clean sources of water. Also focusing on nineteenth-century New England, the environmental historian Ted Steinberg showed how early American industrialists tapped that region's rivers in order to power grist, lumber, and other early industrial mills, of which the textile mills in Lowell are perhaps the most famous. Mill owners built small dams and attempted to manage rivers' flow to assure steady streams of water. Diverting some of the rivers' flow and modifying riparian environments had consequences, however, for neighboring farmers, fishermen, and other groups who had historically used these rivers in other ways. Droughts only intensified competition among the rivers' human users. Early American industrialization therefore relied upon rivers, but their growing economic importance also led to the industrialization of these environments. Like Steinberg, other historians have highlighted how the industrialization of rivers exacerbated conflicts over a river's actual or potential uses, since it could be managed for multiple, often competing goals.[17]

Industrial production thus depended upon a simplified, regulated, and disciplined nature. At least this often was the goal.[18] Containing floods by shortening rivers and assigning them a fixed bed had been one objective of nineteenth-century river "corrections." The environmental historian Mark Cioc's well-researched study of the Rhine and its transformation since the early nineteenth century shows that the reengineering of the river was planned and executed in the manner of a military campaign, leading to a less malarious, faster-flowing, and ultimately more commercially viable Rhine. It became a crucial transportation corridor for industries across continental Europe. Repeated catastrophic floods pushed state engineers to undertake similar projects on lesser-known rivers such as France's Rhône.[19]

The development of hydroelectricity revived the importance of rivers during the Second Industrial Revolution, of the late nineteenth and early twentieth centuries. The Columbia River provides one compelling example. Large-scale, multipurpose dams aimed to generate vast supplies of electricity while distributing water through newly expanded irrigation networks in eastern Washington and Idaho. However, World War II altered the political and economic imperatives of Franklin Delano Roosevelt's New Deal as the Columbia's electricity soon fueled essential wartime production. Energy-heavy industries

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The Canal du Rhône au Rhin at Mulhausen, Alsace-Lorraine, between 1890 and 1900. The Canal Rhin-Rhône was completed between 1784 and 1833 and updated in the late nineteenth century as part of state efforts to modernize rural France. The canal exemplifies extensive river reengineering efforts in Europe and elsewhere. At times these projects have involved remaking rivers within their "original" channels; other times, river reengineering projects have entailed more substantial shifts. Yet as this photograph conveys, even grossly simplified, channelized, and industrialized "rivers" like the Canal Rhin-Rhône remain part of larger hydrologic systems even as they transform those very systems. (Library of Congress Prints and Photographs Division) central to the new aviation industry, including aluminum processing, relied on the river's hydroelectricity. The establishment and expansion of the Hanford plutonium-processing site during the war brought the Columbia into the atomic age when its water began to cool nuclear reactors and dilute radioactive materials.[20]

Globally speaking, the scale of riverine control and development dramatically expanded over the course of the twentieth century. Hundreds of individual rivers became incorporated into large-scale technological systems, including hydroelectric dams, nuclear reactors, irrigation networks, and urban water systems. The geographical reach of this high modernist hydrologic engineering also expanded as these systems covered virtually the entire globe by the end of the twentieth century. As recent projects in India and China suggest, industrializing rivers has often proved a critical step in the industrialization of the so-called developing world.[21] According to an academic estimate from the year 2000, there were more than forty-five thousand large dams in the world that year. One of the lasting legacies of the twentieth century might well be its propensity to dam rivers.[22] Yet it is important to realize that these dams were built into rivers. Even high modernist structures did not entirely eliminate or destroy them. After all, hydroelectric turbines would not work without the river that they simultaneously transformed. Examples like these offer compelling illustrations of the concept of envirotechnical systems.[23]

Industrialization also had significant repercussions on populations of animals, parts of whose bodies became literal components of these systems. For instance, industrializing America helped bring about the near extinction of the bison by the 1870s. Great Plains Indians had hunted bison in great numbers ever since they adopted the Spanish-introduced horse, and many Indian groups adopted horse-centered nomadism in the sixteenth and seventeenth centuries, trading with their sedentary Indian neighbors. They also began to trade with Euro-Americans who began to move into the trans-Mississippi West. By the 1840s, Indian hunters traded annually one hundred thousand bison robes, in addition to hunting bison necessary to meet their subsistence requirements. As Euro-American expansion across the western United States increased during the years just before and then following the U.S. Civil War, both Indian and white hunters killed more and more bison. The construction of the transcontinental railroads only facilitated and thus accelerated the hunt. By the 1870s the combined impact of Indian and Euro-American hunts had basically destroyed free-ranging bison herds across the Great Plains.

Most of these hunters, both Indians and whites, were not engaged in a subsistence economy. Rather, they hunted and traded for what had become not only valuable but also essential industrial goods. Nineteenth-century industrialization dramatically increased the value of bison hides, as they could be stripped, cut, and treated in order to provide thousands of miles of leather belts that connected the steam engines and other machinery of the industrial age. Before the invention of rubberized belting, cattle and bison hides literally connected and turned the wheels of industrial production. Moreover, the size, strength, and quality of bison hides gave them significant advantages over cattle hides. For these reasons, the vast bison herds of the Great Plains became targets of intense hunting and trade in the mid-nineteenth century. As contemporary photographs and paintings show, the Great Plains became littered with the skeletons of millions of bison. Yet hunters, and ultimately the industrial factories of the eastern United States, desired very little of the bison's body. In general, only their hides went east. Bison, via their hides, had become an essential component of the emergent factory system—literal links in this increasingly complex system—and thus of the industrial economy of nineteenth-century America.[24]

The large-scale production of sugar cane also helped fuel industrialization by feeding the bodies of human laborers within the industrial system. Sugar was an exotic novelty in medieval Europe, but the crop had a long history in South Asia. Scholars believe that the plant is indigenous to New Guinea. They estimate that it was domesticated about ten thousand years ago and then spread throughout much of southern Asia. The emergence and expansion of the Islamic empire at the end of the first millennium and the beginning of the second eventually brought sugar to Europe, where consumption was limited to the nobility and the wealthiest of the merchant class. The Crusades exposed Europeans to Muslim methods of cultivating and processing sugar cane in western Asia. When Muslims expelled Europeans from the contested Holy Land, they returned home and brought this knowledge with them.

Europeans began to cultivate sugar on the islands of the Mediterranean. Historians believe that Cyprus served as the initial laboratory for European sugar production during the thirteenth and fourteenth centuries. This early version of what became known as the plantation complex was based on large tracts of land devoted to the cultivation of a single crop. Early plantation owners, usually rich Italian merchants, invested in irrigation systems to expand sugar production. Their plantations also included on-site processing facilities, which used the latest milling technologies to turn raw cane into milled sugar. Although sugar cultivation and processing depended on irrigation networks and these protoindustrial technologies, the plantation complex also relied on human labor, and like Muslim sugar producers, Europeans used slave labor. This model of sugar production eventually spread throughout the sugar-growing regions of the Mediterranean. Then Europeans exported it to the islands off the coast of West Africa during the second half of the fifteenth century.

These islands became the proving ground for Europe's mass production and consumption of sugar in several ways. The Portuguese found that sugar grew well on the islands, and the plantation complex proved an especially effective model of agricultural production. They were also able to profitably transport sugar over long distances. In addition, they identified an enormous, growing, and largely unmet European demand for sugar. Finally, when the Portuguese began to use African slaves to work the plantations, they forged a powerful link between sugar production, the African slave trade, and Europe's economy. In short, the transformation of sugar from a luxury item to a mass industrial commodity began here. In the process, the islands of West Africa became a leading edge of Europe's nascent commercial and industrial revolutions.

Europeans' introduction of sugar to the Americas accelerated these processes. Europeans immediately seized on the crop's potential in the Caribbean. Columbus discussed sugar in his 1493 report on the "Indies." By 1513 a sugar mill had been built on Hispaniola, now part of Haiti. Despite this promising start, sugar production remained extremely limited due to labor shortages. European diseases had nearly wiped out indigenous populations, while there were too few Europeans to conduct large-scale agriculture. The high costs of irrigation and milling technology also constrained sugar production for the first half-century of Europeans' presence in the New World.

By the mid-sixteenth century, however, these limits had begun to fade. The Portuguese began to investigate sugar's potential in Brazil and found that its climate and environment were ideal. Furthermore, Brazil's relative proximity to both Europe and West Africa had significant advantages. Slave ships could reach Brazil more quickly than they could reach other parts of South America; likewise, milled sugar from Brazil could arrive in European markets more quickly. As a result, Brazil became sugar's laboratory in the Americas. Once established and profitable there, production expanded in the Caribbean. By 1750 the Portuguese were growing sugar in Brazil, the English in Jamaica and Barbados, the Dutch in Surinam and the Netherlands Antilles, and the Spanish and French in Santo Domingo. By 1800 nearly 250,000 tons of sugar reached consumers through the world market. Thus, by the beginning of the nineteenth century sugar had begun its permanent transition from an exotic, luxury item to a global, industrial commodity.[25]

This eighteenth-century "Sugar Revolution" aided the more famous Industrial Revolution of the same era. Scholars have asserted that sugar should be seen as one of the first industrial goods for at least two reasons. In his now classic study *Sweetness and Power* the anthropologist Sidney Mintz argued that one of the world's first modern industries actually originated in the sugar plantations of the New World. Mintz characterized sugar production in the Americas as an "agro-industry," a blending of industrial methods and organization of labor in an agricultural environment. New World sugar production displayed some of the key elements of what historians usually define as industrialization, including a clear organization of labor, the interchangeability of workers, greater managerial control over the labor process, a disciplined and time-conscious work process and workplace, and separation of the production and consumption of industrial goods.

Descriptions of sugar processing reveal other important commonalities between the factories of industrializing Europe and the sugar plantations of the Americas. The early twentieth-century scholar W. L. Mathieson concluded that "the production of sugar was the most onerous of West Indian [e.g., Caribbean] industries," going on to describe eighteenth-century sugar production as follows:

> So rapid was the motion of the mill, and so rapid also the combustion of the dried canes or "trash" used as fuel in the boiling house that the work of the millers and firemen, though light enough in itself, was exhausting. A French writer described as "prodigious" the galloping of the mules attached to the sweeps of the mill; but "still more surprising" in his opinion was the ceaseless celerity with which the firemen kept up a full blaze of the cane-trash. Those who fed the mill were liable, especially when tired or half-asleep, to have their fingers caught between the rollers. A hatchet was kept in readiness to sever the arm, which in such cases was always drawn in; and this no doubt explains the number of maimed watchmen.[26]

Control of the work environment included, then, not only processing natural resources such as sugar cane but also regulating workers and their bodies. The dangers of this hectic, difficult work were, however, all but invisible to the consumers of sugar thousands of miles away. Yet they were an industrial reality, foremost for those who toiled in the booming sugar industry.

Scholars have also argued that this Sugar Revolution helped feed (literally) Europe's Industrial Revolution. The mass production of sugar created a cheap, calorie-dense food base for the growing class of industrial wage laborers who lived in large cities and no longer had access to self-sufficient food production. As the poignant novels of Charles Dickens and Émile Zola suggest, sweetened tea and jam-covered bread became essential foods of the working class. The industrial production and processing of a biological species (sugar cane) therefore helped fuel industrialization in western Europe by feeding the hungry bodies of industrial workers who labored in factories. In short, industrialized white sugar fed, so to speak, the early capitalist, industrial system.

Rather than reinforcing tidy distinctions between the natural and the unnatural, the natural and the technological, the cases of mining, river reengineering, bison, and sugar production show how industrialization in fact deepened the links between humans and nonhuman nature. While these ties were, and still remain, often invisible, industrialization made them both broader and deeper—broader because more environments and natural resources were integrated into industrial networks, deeper because the range of linkages between humans and the natural world multiplied and expanded. For example, burning coal in steam engines and steel mills turned vast amounts of prehistoric stored solar energy into heat, thus bringing the nature of the distant past to the domestic and industrial hearths of industrialized countries. The techniques used to mine that coal may have changed over time, but they did not, indeed could not, sever the connections between humans and the environment. Indeed, the quantity and pace of coal use only amplified, rather than eliminated, these connections.

The bodies of bison and humans also helped power industrialization. The hides of America's bison linked and turned the wheels of industrialization before the development of rubber. Because industrializing America valued and needed bison leather, and therefore consumed great quantities of it, the once vast herds of the Great Plains were reduced to a few hundred in the space of several decades. Meanwhile, the example of sugar illustrates how the bodies of industrial workers received industrially grown and processed sweeteners that brought tropical sun and heat into the cooler climates of Europe and North America. Only the combination of large-scale technologies, forced labor, and natural opportunities made possible the growth of the sugar industry, whose success, in turn, augmented the scope of industrialization. While the social costs of sweet jams were largely imperceptible to the hungry workers of Europe, laborers across the Americas viscerally experienced them with their own bodies.

Finally, the dramatic remaking of rivers during the nineteenth and twentieth centuries, initially cloaked in the language of warfare and executed by military engineers, did not lead to a defeat of these environments. Large-scale engineering projects did transform these rivers into important transportation and commercial corridors, which became indispensable for shipping raw materials as well as industrial goods. Later these rivers produced power through hydroelectric dams and nuclear power plants. Thus, the rivers themselves became industrialized waterscapes. Attempts at governing natural waterways spurred ever more elaborate efforts to control them, while also generating valuable knowledge about rivers' complex, dynamic ecologies. However, the unintended consequences of river management are not only pressing issues of public policy (as the case of the Mississippi after Hurricanes Katrina and Rita in 2005 has made cruelly clear); they also show that dealing with rivers involves a more nuanced understanding of the interactions between humans and riparian environments.[27] Profoundly transformed rivers are engineered ecosystems, but floods, siltation, and dike breakage demonstrate the continued presence of environmental processes in these hybrid landscapes.[28] Industrialization fundamentally depended, then, upon intensifying both the temporal pace and the spatial scale of natural resource and ecological transformation rather than either eroding or erasing them.

Scale: Geography and Space

Nineteenth-century observers acknowledged that industrialization, in particular the rise of new modes of transportation, created new spatial relationships. Both social and natural spaces seemed to shrink rapidly over the course of the nineteenth century. For instance, exiled to Paris, the German poet Heinrich Heine mused in the 1840s that the railway had killed space; only time remained. Heine envisaged the "mountains and forests of all countries" approaching Paris, famously claiming that he could already smell the bouquet of German linden trees from the French capital: "the North Sea breaks in front of my home door."[29]

Seen from Paris, London, or Berlin, the industrial world appeared to be shrinking. Intra-European and intra-American travel shortened dramatically as railroads covered in days or even hours what had taken weeks by horse carriage or on foot. With urbanization, commutes into the city center by train or tram became a daily occurrence, at least for the middle class. Railroad companies also began offering one-day excursion tickets for metropolitan residents who were eager to escape dense, polluted urban environments and sought regeneration in nature, thereby turning formerly sleepy country villages into bustling weekend tourist destinations. Long-distance travel, whether one-way tickets in the case of millionfold emigration to the Americas for the lower classes and opportunity-seekers or leisurely round-trip fares for the wealthy, exploded. More people were on the move, both geographically and socially. Or at least they could aspire to it.

Yet industrialization also made the world appear much bigger. Urbanization yielded sprawl, forcing city residents to navigate the increasingly complex, ever-expanding geographies of growing cities. Working-class laborers frequently found themselves unable to afford housing in convenient city centers. Class, race, and immigrant status thus became mapped onto urban space in metropoles such as Paris or London, a pattern that has undoubtedly continued to this day. For the middle and upper classes, railroads and steamships widened the possibilities of travel. Commerce and tourism both followed and fostered what the historian Daniel Headrick has called "the tentacles of progress."[30] Meanwhile, as hinterlands, sometimes located literally halfway around the globe, became increasingly crucial to European and American metropoles, the barons of industrial capitalism were forced to concern themselves with events there. A crop blight, a hurricane, civil unrest, war, or an outright political revolt might threaten their entire enterprise.

From an economic point of view, it was this vast expansion of commercial space, not its disappearance, that was a hallmark of the new capitalist, industrial economy.[31] The example of tropical sugar consumed in Europe and North America already pointed to the emergence of an Atlantic, and increasingly global, network of shipping, commerce, and industrial capitalism under the auspices of colonialism and imperialism. Political and economic elites in these colonial powers declared that the valuable raw materials of Africa, Asia, and the Americas made the imperial project commercially viable and thus set in motion an expanding network of uneven trade relations. For instance, German stores specializing in sugar, coffee, tobacco, and spices were tellingly called *Kolonialwarenhandlungen,* purveyors of colonial goods. Elites in the colonies and the metropole relied upon a steady, scheduled, and ever-cheaper movement of natural resources across the world's oceans. These resources provided the raw materials from which cheap industrial goods were made at factories in the home countries or in other manufacturing centers. The imperial powers then encouraged their colonial populations to buy those goods. It was painfully ironic, then, when India, which had been a world leader in textile production before British industrialization, became a net importer of cloth in the nineteenth century.

Over the course of this crucial century, trade routes, backed by ever-expanding political and military might, came to connect more parts of the globe. Although goods moved both ways along these commercial and transportation corridors, this exchange was profoundly unequal in several respects. On the one hand, contrary to European views at the time, industrial metropoles depended upon the resources and peoples of hinterlands around the globe. Thus, so-called colonial peripheries were, in fact, integral, not peripheral, to the economic life of the industrial metropole, thereby challenging the hierarchical assumptions behind the terms *colony* and *periphery*. On the other hand, as many colonial societies shifted from more diverse economies that met subsistence needs toward integration into a market economy, they became more and more vulnerable to global economic instability. For instance, as the historian Donald Wright has shown in his valuable study of the Gambia, by the late nineteenth century Gambian families were growing peanuts for export and purchased all other essential goods, including food and clothing. A single drought, bad harvest, or collapse in peanut prices on the world market could wipe out the economic base of a family or an entire community. One bad year could even result in a downward spiral of permanent economic dependence. Yet indigenous elites often urged local participation in this system, dealing with some of the threats that colonization posed to their own power by forging alliances with Europeans who needed supporters on the ground.

These commercial and transportation networks were indeed conveyors of rising inequality not only around the globe but also within industrial centers. For example, the development of trade routes privileged some ports and shippers but marginalized others. The same was true for electronic communications. Although contemporaries were amazed that a telegraph message from London to New Delhi only took several hours, they were not surprised to find that a letter from a remote Welsh village would spend far more time in transit before it reached the British capital. Economic, political, and industrial purposes shaped the remaking and reordering of space, a process that generally bolstered the powerful interest groups behind these endeavors.[32]

This new spatiality of the industrial age functioned on many levels. Railways remade the landscapes that they traversed. Within Europe, the railway also contributed to a new culture of travel, which involved new understandings of the surrounding environment. A generation ago, the cultural historian Wolfgang Schivelbusch described riding the rails as tantamount to a new way to see the landscape. Rather than focusing on the small and the particular in the foreground, train passengers now spent their time exploring the broad contours of the landscape as it quickly passed by their compartment windows. The railroad helped construct the environment as scenic background, The image placed here in the print version has been intentionally omitted

Torrington, England, 1890s. This is an envirotechnical system in action. It shows two railway lines crossing. More importantly, the roads, rails, train station, tunnel, bridges, river, dwellings, fields, and forests were made by humans and other natural actors. Of course, the degree of human intervention varies, but the most unnatural element in this landscape is our understanding of the border between what is natural and what is technological. (Library of Congress Prints and Photographs Division)

shifting travelers' attention from close detail to the aggregate view. Many were bored by these new prospects, preferring instead to read newspapers, magazines, and novels tailored specifically to the traveling crowd of the growing middle class. These industrial travelers had begun to see and experience the space and environment through which they passed in a different way.[33]

Industrial technologies such as the nineteenth-century railroad and the early twentieth-century automobile also allowed people with sufficient means to escape urban environments. As the historian Peter Schmitt showed, a number of social organizations aimed to take late nineteenth- and early twentieth-century Americans "back to nature." From birding groups to the Boy Scouts, numerous clubs, organizations, and children's groups aimed to educate, recreate, and thus restore American bodies, foremost the white male body, which had become threatened by industrial cities and workplaces.[34] This goal also partly underlay the New Deal's Civilian Conservation Corps during the 1930s.[35] Access to national parks in the United States, which had first been designed around railroads, increasingly relied on automobiles, which delighted car manufacturers and promoters of domestic tourism but prompted advocates of "wilderness" to think of roadless spaces as more authentic environments. In Europe, car clubs supported the creation of national parks, including those in Italy. During the mid-twentieth century, planners on both sides of the Atlantic sought technological means to reconcile nature and technology in the form of sweeping parkways and tourist roads.[36]

The quintessential industrial transportation technologies of the nineteenth and twentieth centuries—the railroad and the car—therefore helped cultivate middle-class urbanites' appreciation of and concern for landscapes. While these technologies of industrial capitalism extracted and exploited more and more of the global environment, they also spurred conservation movements.[37] A geographical perspective helps reconcile the seemingly contradictory views of industrial technologies, both as "destroyers" and "protectors" of nature. Over the nineteenth and twentieth centuries distinct spaces of extraction and protection emerged. For instance, national parks around the globe offered antidotes to industrial and urban life. Yet as the diverse cases of Yosemite, Central Park, and African national parks suggest, often their creators removed indigenous groups and the poor in order to "save" these remarkable "natural" areas.[38]

While the environmental legacies of the car and the railroad are perhaps surprising, it was clear even to contemporary observers how much transportation networks like the highway system and railroads modified their environments. As Schivelbusch pointed out, the design of Victorian railway lines led to a geometrical reordering of landscapes. In Europe, where labor was abundant but land was scarce, train tracks were built as straight and level as possible, which meant that countless cuttings, embankments, and bridges added new layers of human activity on lands historically used primarily for farming. In the land-rich but labor-poor United States, engineers were more likely to allow railroad tracks to meander, designing technological systems that made some adjustments to the existing landscape. These quintessential icons of the industrial age undoubtedly played an important role in modifying environments in these different national contexts. Although scholars tend to focus on the environmental impacts of their construction, the day-to-day operation and maintenance of these technological systems required additional resources.[39]

In ecological terms, railroads, and later cars and airplanes, widened the geographical scale and increased the temporal pace of biodiversity change in the areas through which they passed. Since railroad cars and engines, not to mention their human and animal passengers, brought with them spores and seeds from faraway places, neophytes began to flourish. One recent phytosociological paper asserts that some of the European habitats that are richest in species today are, in fact, railway stations. As transportation hubs, they concentrated biological diversity, and ecologists are still busy cataloging the different species that migrated along railroad corridors.[40] This pattern highlights the dual role of transportation technologies. They dramatically transformed some landscapes as hungry consumers of natural resources. At the same time, by serving as vectors of ecological change, they added new species to the existing mix of flora and fauna in urbanized and industrialized areas. While scientists have raised concerns about certain non-native species, the industrialization of mobility was neither a period of constant environmental declension, as many critics have argued, nor an era of increasing human triumph over nature, which older progressive narratives proclaimed.

Lastly, one consequence of the ostensible industrial shrinking of space has been increased attention to not only the remote and the exotic but also the local. Some analysts of contemporary globalization use the term *glocalization* to draw attention to the concurrent strengthening, and thus interdependence, of global and small-scale processes.[41] The historical record reveals some striking parallels in the nineteenth century. That era witnessed faster and more regular travel between European centers and global metropoles—from New York to New Delhi. Yet folklore societies also flourished in many of Europe's emergent nation-states. Members of these organizations highlighted and celebrated distinct variations in local and regional landscapes, dress, dialect, and food.[42] In a fractured body politic such as nineteenth-century Germany, political discourse was constantly marked by a tension over adhering to both the region and the new nation. Desires to protect local and regional landscapes, not national ones, motivated Germany's first conservationists. The "invention of tradition" was therefore contingent upon the advent of spatial modernity and should be seen as both a reaction to and part of it.[43] In other words, space did not cease to matter. Rather, it took on different and seemingly contradictory forms during industrialization. It compressed as it expanded, while fast travel was extolled as much as it was feared.

Scale: Time

Industrialization also transformed the temporal relationship between human societies and the environment with respect to both the deep geological past and the distant future. For instance, industrialization significantly altered the temporal scale of natural-resource extraction by intensely tapping deep geological time rather than depending on, and thus being constrained by, annual solar flows and humans' limited ability to store energy. Coal and petroleum are the two primary examples here. Furthermore, while coal epitomizes the First Industrial Revolution, of the long nineteenth century, oil nicely symbolizes the Second.

In 1750 the world's estimated 750 million people depended on what one scholar has called the "biological old regime." Basic necessities—food, clothing, shelter, and fuel—generally came from local environments. They were produced from what could be captured from annual energy flows from the sun to the earth. Relatively little energy could be stored for a long period. For example, clothing banked the energy of textile production from one year to the next, while seeds and preserved food helped communities survive long winters unless bad harvests, disease, famine, pests, or other factors intervened.[44]

It was not just these basic necessities that were part of the biological old regime. Human societies had historically relied upon the combined labor of people (both free and enslaved), animals, wind, and water. In addition, early industries such as the textile and leather industries and construction depended directly upon agricultural and forestry products. Even early iron- and steel-making, which might be seen as first steps toward an industrial mode of production, occurred within the biological old regime, for they generally relied on charcoal, a concentrated form of energy produced by burning wood.

The energy regime of western Europe and eastern North America changed dramatically, however, between 1750 and 1850. During this formative century, more and more Europeans began to use coal to produce heat for both domestic and industrial consumption. Coal use was certainly not new. Much of seventeenth-century London had depended on coal, which explains why John Evelyn published *Fumifugium, or the Inconvenience of the Aer and Smoak of London Dissipated,* a comprehensive analysis of the smoke problem in England's capital, in 1661. Yet between the mid-eighteenth and the mid-nineteenth century early industrialists, engineers, and entrepreneurs began to capture the heat generated by coal to fuel repetitive motion through coal-fueled, steam-powered machines. This growing reliance on coal did not free industrializing societies from natural sources of energy, but it did free them from the limits of annual solar-energy flows. Instead, humans could tap this enormous energy source, which had been built up over millions and millions of years, in a mere fraction of the time it had taken to produce all that energy. The industrial use of coal was therefore extremely significant because it allowed industrializing societies to be freed from the ecological constraints of the biological old regime. Consequently, they were able to increase their economic production and growth dramatically by tapping these vast stores of energy at unprecedented rates.[45]

The histories of coal and oil are similar in some important respects. Given the industrialized world's dependency on petroleum at the beginning of the twenty-first century, it is easy to forget that the oil age is only a little more than a century old.[46] It was not until the mid- to late nineteenth century that efforts to extract and exploit petroleum on a commercial scale began. Hard-rock oil drilling started in Pennsylvania in 1859, but the first real gushers were found near the Caspian Sea during the 1870s. In early 1901 American oilmen found their first major strike in Texas.

Two motives spurred the interest in obtaining large quantities of this new energy source and overcoming challenges associated with the extraction, refining, storage, and transportation of oil. First, supplies of existing lubricants derived from whales and vegetables proved inadequate for the expanding demands of industrial machinery. Before the modern oil age, these animal and plant oils literally lubricated the wheels of industrialization, just as bison hides connected them. Second, whale oil, which lit most of the homes and workplaces of the industrial world at the end of the nineteenth century, was becoming increasingly expensive and scarce. Crude oil could be refined, however, into kerosene for lighting and thereby offer an effective and apparently more abundant alternative to whale oil.

Although oil's primary original use was for lighting, the pattern of petroleum consumption changed in the early twentieth century with the development of oil-burning furnaces for home and industry. Indeed, by 1909 fuel oil already composed about half of this growing industry. The development and improvement of the internal combustion engine and the expansion of the automobile industry in the first two decades of the twentieth century dramatically increased the demand for oil as fuel. By 1930 gasoline had become the primary refined oil product made by the oil industry in the United States. The expansion of the aviation industry and the widespread adoption of the car, especially after World War II, further increased the demands for cheap gasoline and oil. Seemingly plentiful supplies of crude oil and numerous technological innovations over the twentieth century led to the development of a whole range of derivative materials, including fertilizers, plastics, synthetic fibers, pharmaceuticals, and (petro)chemicals. These products have had widespread consequences for food systems, industrial production, transportation, and consumption around the globe.

Oil was thus to the Second Industrial Revolution what coal had been to the First. In 1890 global oil consumption totaled 10 million tons. By 1920 it had increased to 95 million, and by 1940 it had reached 294 million tons. After that it doubled every decade, so that by the 1970s global petroleum use came to 2.5 billion tons. While these figures demonstrate the boom in oil consumption, they tend to mask the ways in which increasing oil consumption simultaneously entailed a shift away from other sources of energy and thus a growing reliance on fewer and fewer kinds of energy. In 1900 oil provided about 4 percent of the world's energy, but by the 1970s it provided half. Moreover, these figures do not take into account the growth over the past few decades. Nor do they illuminate the vast disparities in oil production and consumption rates worldwide. However, as with coal, the development and expansion of oil extraction, refining, and consumption enabled societies that controlled this petroleum network to rapidly increase their economic production, quickly outpacing the historical limits of the biological old regime. Intensive coal and petroleum extraction, processing, and use thus transformed industrializing humans' relationship to deep geological time backward by tapping energy stored for millions of years and expending that power in a mere fraction of that time.[47]

What coal and oil did for deep geological time, the atomic age has done for future generations. The emergence of the atomic age created new temporal scales of environmental pollution and risk. Radioactive materials gradually lose their radioactivity. A radioactive element's half-life is the time it takes for half of its radioactivity to dissipate. Yet half-lives can vary dramatically, from hours to thousands of years. As a result, historical and contemporary decisions related to nuclear materials—from weapons and energy production to dealing with radioactive waste—can have consequences for dozens of generations into the future. Controversy over the storage of radioactive waste produced at sites around the United States suggests how difficult it is to regulate dynamic environments to accommodate the extremely long life of some radioactive materials. Radioactive contamination and pollution may pose problems on the scale of thousands of years, not days, months, years, or even decades. While new civilizations have often been built, quite literally, on the ash heaps of older ones, it is difficult to conceive of intentional developments on former nuclear sites. Thinking about what language or visual images humans might understand thousands of years in the future is a serious component of dealing with the legacy of the atomic age. The temporal dimensions of atomic waste are extremely important in such cases.[48]

Conclusion

On this grand tour of silver and sugar, bison and cotton, coal and oil, time and space, humans interacted with the natural world through industrialization in countless ways. Instead of framing industrialization solely as a potent force of denaturalization, we argue that it actually illuminates humans' relationships with nonhuman nature. Admittedly, the logic of industrialization has tended to transform a vast, complex, and even chaotic environment into natural resources that could be reconnoitered, rearranged, simplified, extracted, marketed, and ultimately sold. Yet industrializing humans have not developed entirely unique interactions with the environment as they have industrialized their economies, societies, and ultimately the planet itself since the mid-eighteenth century. Resource extraction and the improved predictability of food and other essentials have been important features of human societies since the Neolithic Revolution. In this respect, it would be ahistorical to speak of a complete rupture in the relationship between humans and the environment with the advent of industrialization. It is far more fruitful to examine the shifts, albeit at times quite significant, in those very relations.

What is at stake is not whether humans have subdued nature, or nature still rules, either imperceptibly or overtly, but rather the scale and politics of both movements and efforts. The results of these interdependent movements have often been surprising. Preindustrial agriculture may have been home to less species diversity than twentieth-century railway stations. The term *urban wilderness* might be more apt in ecological terms than it appears on the surface, as the growing population of mountain lions in abandoned Southern California subdivisions indicates. More humans have access to fruits and vegetables that not long ago were deemed exotic, unaffordable, or both.

But this is only part of the story. While the middle and upper classes of the industrialized world have generally been able to reap many of the benefits of industrialization in social, economic, and ecological terms, the lower classes in these societies and poorer countries have not. Pollution had different meanings for underprivileged workers and elites in late nineteenth-century London, and the same is true in China's Shandong Province today. A banana in an American supermarket may be the product of tropical nature, but it is also an artifact of unequally rewarded human labor. The simplification and commodification of naturally derived products, from sisal to pharmaceuticals, has undoubtedly produced winners and losers, both economically and ecologically.

While industrialization has proved a profoundly unequal and uneven process, it has nonetheless simultaneously strengthened, even deepened, interactions between humans and nonhuman nature, even though industrial artifacts and systems belie their very nature. One or two generations ago scholars celebrated industrialization as the final step in the dominion of "man" over nature. More recently, many environmentalists have deplored industrial societies as deeply alienating to both humans and the environment, as evidence of perennial ecological decline. Yet neither position is sufficiently complex to explain the natural history of industrialization. Instead, it is important to realize that humans are still part of the natural world in the industrial age, while the environment has not been fully controlled or understood, in preindustrial as well as industrial societies.

Industrialization exemplifies the deepening interdependence between the two to the extent that it becomes analytically questionable to separate humans and nature as neatly as is often done. In this essay we have sought to develop a more nuanced understanding of the industrialized entanglement of humanity and the environment, while paying attention to historic winners and losers. Moreover, just as the opposition of nature and technology masks as much as it reveals, the dichotomy between nature and humanity proves equally problematic and ultimately unhelpful. Such binaries and other categories are appealing in their simplistic sorting of the world, but industrialization epitomizes the complications that call for a new understanding and language of interconnected spaces—of the *envirotechnical landscapes* in which we work, live, and play, of the *envirotechnical systems* that we partly create and upon which we are dependent, of the ways in which cultural, technological, and ecological systems are, in fact, mutually embedded and reliant. In the end, this might prove a lasting product of humanity's industrializing urge over the past three centuries.

Notes

1. Brooke Hindle and Steven Lubar, *Engines of Change: The American Industrial Revolution, 1790–1860* (Washington, DC: Smithsonian Institution Press, 1991), 9; Arnold Pacey, *Technology in World Civilization* (Cambridge: MIT Press, 1991), ch. 7.
2. Toni Pierenkemper, *Umstrittene Revolutionen: Die Industrialisierung im 19. Jahrhundert* [Contested revolutions: Industrialization in the 19th century] (Frankfurt am Main: Fischer, 1996), 11–26; Peter N. Stearns, *Interpreting the Industrial Revolution* (Washington, DC: American Historical Association, 1991); idem, *The Industrial Revolution in World History,* 3d ed. (Cambridge, MA: Perseus, 2007).
3. C. M. Cipolla, introduction to *The Industrial Revolution, 1700–1914,* ed. Cipolla (New York: Harvester, 1976), 7.
4. David S. Landes, *The Unbound Prometheus: Technological Change and Industrial Development in Western Europe from 1750 to the Present,* 2d ed. (Cambridge: Cambridge University Press, 2003), 41.
5. In a recent overview, Joel Mokyr characterized the Industrial Revolution as a "change in the *degree* of change," but he still maintained the fundamental rupture of the event and included in his preconditions for it "a growing understanding of nature (physics, chemistry, biology)." Joel Mokyr, "Industrial Revolution," in *Oxford Encyclopedia of Economic History,*

ed. Joel Mokyr, 5 vols. (Oxford and New York: Oxford University Press, 2003), 3:49–56. The latter point is controversial, as many historians of technology would point to predominantly nonscientific understandings of nature in the eighteenth and nineteenth centuries.

6. As Richard White writes in an extensive discussion of labor and nature, "*All* work, and not just the work of loggers, farmers, fishers, and ranchers, intersects with nature. Technology, an artifact of our work, serves to mask these connections. There are clearly better and worse technologies, but there are no technologies that remove us from nature." " 'Are You an Environmentalist or Do You Work for a Living?': Work and Nature," in *Uncommon Ground: Toward Reinventing Nature,* ed. William Cronon (New York: Norton, 1995), 182, emphasis in the original.
7. This assertion is not meant to imply that agricultural, nomadic, and preindustrial societies are indeed closer to nature. To the contrary, seeing these societies as somehow closer to nature, and therefore industrial and industrializing societies as farther from nature, replicates problematic divisions between nature and technology, not to mention quasi-, if not blatant, racist views of "primitive" cultures. In addition, deconstructing both *technological* and *failure* is central to technology studies.
8. Lewis Mumford, *Technics and Civilization* (1934; reprint, San Diego: Harcourt Brace Jovanovich, 1963), 470.
9. Ibid., 69.
10. By making this point we do not deny the "value" of a natural resource in its raw, unprocessed state, but Marx was right that human labor increases nature's value. We thank Martin Reuss for pointing out this argument.
11. Bruno Latour emphasizes that such categorization is a historical process and product. As a result, categories cannot be assumed a priori. The lesson seems especially applicable here.
12. Timothy J. LeCain, *Mass Destruction: The Men and Giant Mines That Wired America and Scarred the Planet* (New Brunswick, NJ: Rutgers University Press, 2009). Kent Curtis discusses the transformation of copper-mine tailings into a golf course in "Greening Anaconda: EPA, ARCO, and the Politics of Space in Postindustrial Montana," in *Beyond the Ruins: The Meanings of Deindustrialization,* ed. Jefferson Cowie and Joseph Heathcott (Ithaca, NY: Cornell University Press, 2003), 91–111. For a fictional account of nineteenth-century French mines, see Emile Zola's novel *Germinal.* For a brief discussion of key socioenvironmental themes in Zola's novel, see Sara B. Pritchard, "Mining Land and Labor," *Environmental History* 10 (2005): 731–33.
13. Arthur F. McEvoy, "Working Environments: An Ecological Approach to Industrial Health and Safety," *Technology and Culture* 36 (April 1995): S145–S173.
14. Within the Envirotech community, the term *envirotechnical system* has become common parlance. It draws on but also modifies Thomas P. Hughes's concept of "technological system." See Hughes's classic *Networks of Power* (Baltimore: Johns Hopkins University Press, 1983). In his more recent *Human-Built World* (Chicago: University of Chicago Press, 2004), Hughes uses *ecotechnological system,* but he does not develop this term as an analytic concept. For an overview of envirotech literature until the late 1990s, see Jeffrey Stine and Joel Tarr, "At the Intersection of Histories: Technology and the Environment," *Technology and Culture* 39 (1998): 601–40. For an extensive discussion and elaboration of the concept of "envirotechnical system," see Sara B. Pritchard, *Confluence: The Nature of Technology and the Remaking of the Rhône* (Cambridge, MA: Harvard University Press, forthcoming). For a study integrating environment and technology through the landscape approach, see Thomas Zeller, *Driving Germany: The Landscape of the German Autobahn,* trans. Thomas Dunlap (New York: Berghahn Books, 2007).

15. Deborah Kay Fitzgerald, *Every Farm a Factory: The Industrial Ideal in American Agriculture* (New Haven, CT: Yale University Press, 2003). For a popular account of the emergence of the agro-industrial complex in the United States, see Michael Pollan, *The Omnivore's Dilemma* (New York: Penguin, 2007). On how envirotechnical analysis might aid contemporary energy debates, see Sara B. Pritchard, "Toward an Envirotechnical Approach to Energy History and Policy" (paper presented at the annual meeting of the Society for the History of Technology, Lisbon, Portugal, October 2008).
16. Janet L. Abu-Lughod, *Before European Hegemony: The World System, AD 1250–1350* (New York: Oxford University Press, 1991); P. J. Bakewell, *A History of Latin America: c. 1450 to the Present,* 2d ed. (Malden, MA: Blackwell, 2004); Eduardo Galeano, *Open Veins of Latin America: Five Centuries of the Pillage of a Continent,* 25th anniversary ed. (New York: Monthly Review, 1997); Duncan Green, *Faces of Latin America,* 3d ed. (New York: Monthly Review, 2006); Robert Tignor et al., eds., *Worlds Together, Worlds Apart: A History of the Modern World* (New York: Norton, 2002).
17. Judith A. McGaw, *Most Wonderful Machine: Mechanization and Social Change in Berkshire Paper Making, 1801–1885* (Princeton, NJ: Princeton University Press, 1987), ch. 1; Theodore Steinberg, *Nature Incorporated: Industrialization and the Waters of New England* (Cambridge: Cambridge University Press, 1991); Robert B. Gordon and Patrick M. Malone, *The Texture of Industry: An Archaeological View of the Industrialization of North America* (New York: Oxford University Press, 1994). Of course, one can also consider the industrialization of Europe's rivers. See, for instance, Eva Jakobsson, "Industrialized Rivers: The Development of Swedish Hydropower," in *Nordic Energy Systems: Historical Perspectives and Current Issues,* ed. Arne Kaijser and Marika Hedin (Canton, MA: Science History, 1995), 55–74. On conflicts among users, a few historical studies include Pritchard, *Confluence;* Joseph E. Taylor III, *Making Salmon: An Environmental History of the Northwest Fisheries Crisis* (Seattle: University of Washington Press, 1999); and Richard White, *The Organic Machine* (New York: Hill & Wang, 1995).
18. James C. Scott, *Seeing Like a State: How Certain Schemes to Improve the Human Condition Have Failed* (New Haven, CT: Yale University Press, 1998).
19. Mark Cioc, *The Rhine: An Eco-Biography* (Seattle: University of Washington Press, 2002); Pritchard, *Confluence.*
20. White, *Organic Machine.*
21. For two critiques from the global South, see Arundhati Roy, *The Cost of Living* (New York: Modern Library, 1999); and Amita Baviskar, *Waterscapes: The Cultural Politics of a Natural Resource* (New Delhi: Permanent Black, 2007).
22. Christof Mauch and Thomas Zeller, eds., *Rivers in History: Perspectives on Waterways in Europe and North America* (Pittsburgh: University of Pittsburgh Press, 2008); Terje Tvedt and Eva Jakobsson, eds., *A History of Water* (London: I. B. Tauris, 2006); Paul Josephson, *Industrialized Nature: Brute Force Technology and the Transformation of the Natural World* (Washington, DC: Island Press, 2002).
23. Pritchard, *Confluence.*
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43. The literature on this topic is considerable. For German-speaking contexts, see, for example, Thomas Lekan and Thomas Zeller, eds., *Germany's Nature: Cultural Landscapes and Environmental History* (New Brunswick, NJ: Rutgers University Press, 2005).
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