technology and the environment in history

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Chapter One

Food and Food Systems

Eating is a natural activity. Like breathing air and drinking water, eating food is vital to sustaining life. These ostensibly natural acts, however, have envirotechnical dimensions both past and present. The act of breathing is made possible in unforgiving environments (high altitudes, bodies of water, space) by the storage and delivery of pressurized oxygen. Drinking water is rendered safe and abundant by several technical systems, including sewage treatment, chemical disinfection, and desalination. The food we eat is subject to a complex and varied set of relationships between technologies and the environment.[1]

We may see that food is subject to these relationships when we go to a store and purchase groceries that traveled hundreds or even thousands of miles from their point of origin. We also know that highly processed foods such as candy may have colors, textures, and tastes that do not appear in nature. These are just two present-day examples of the complex interactions between nature and technology in food in the industrialized world, and they reflect a long history of such interactions that scholars have investigated in recent years.

The history of food is in many respects the history of human experience. Many of the major changes in human history—the development of nomadic tribes, the rise of agricultural societies, the emergence of civilizations, the increasingly broad scope of trade and exchange, and the Industrial Revolution—are results of human endeavor to increase food security.

Much of this history may be understood as the history of food *systems*, the process of humans negotiating the opportunities that nature and technology afford for sustained human benefit. Food systems comprise the processes and infrastructure involved in bringing food to a society. These steps may include the growing, harvesting, processing, preserving, packaging, transporting, consumption, and disposal of food. An envirotechnical approach to the history of food systems allows us to understand the myriad ways in which we humans have fed ourselves and to assess how we have cultivated and manipulated organisms, the materials harvested from organisms, and the land and water used to develop crops and livestock. The systemic organization of these manipulations has provided abundant, attractive, and delectable foods for the world's peoples since the advent of river valley civilizations.

Technology and the Rise of Agriculture

Eating has involved mediations between technology and nature since the earliest societies, and changes in these mediations have had significant effects on human and environmental history. Until approximately 10,000 BCE, the vast majority of human societies were organized as hunters and gatherers. These societies were nomadic and small (perhaps two dozen humans), and all members were involved in producing food for their group. Because these societies traveled to where food sources existed, hunter-gatherers built few permanent structures.[2]

Hunter-gatherer societies still exist, but were succeeded by agricultural societies as the dominant form of human organization during the Neolithic Revolution. The transition to the domestication of plants and animals began in river valleys in Mesopotamia (now the Middle East, also known as the Fertile Crescent) and elsewhere. Mesopotamian farmers domesticated barley and wheat, then lentils, peas, chickpeas, and flax.[3]

Agriculture still required most members of a society to produce food; however, the conditions and scale of food production changed. Agricultural societies, unlike those of hunter-gatherers, required tending a fixed plot of land over a succession of seasons. This food system depended on fertile soil, adequate water, and human and animal labor to function; it was vulnerable to drought, pestilence, and war. Yet it produced far more-stable systems of supplying food to the population, and the population of agricultural societies grew much larger. Fixed communities in river valleys gave rise to civilizations in the Middle East, India, and China—and with them, new technologies, new agricultural practices, and new wars, as fixed societies defended their crops and livestock from invaders. The transition from hunting and gathering to agriculture was gradual, with agriculture emerging as the dominant form of global food production by 2500 BCE.

Using an environmental determinist approach, Jared Diamond argues that East Asia and Europe developed agriculture ahead of sub-Saharan Africa and Central Asia because of their location in temperate climates (with suitable plants and animals) and in relatively remote terrain, safe from invasion.[4]

Agriculture in the Americas involved the domestication of crops distinctly different from those in Africa, Asia, or Europe, and the food systems of the Americas did not interact with the rest of the world until 1492. Domesticated crops in the Americas included maize, potatoes, and squashes. The cultivation of agriculture by indigenous peoples involved several manipulations of the land, including the selective application of fire in forests to till soil, and uses of polyculture (agriculture in which more than one species is grown) that English colonists supplanted in replicating their homeland's "world of fields and fences" in order to intensively produce particular crops.[5]

The rise of agriculture reshaped societies and provided a context for new technological innovations as humans cultivated and manipulated species of plants and animals. Although many of these are beyond the scope of this chapter, major technological advances in food production included the creation of water wheels to irrigate fields in Mesopotamia and, over time, the advent of iron sickles and ploughs to till soil. These tools were often used in conjunction with animals to power the planting and harvesting of agricultural crops. Indeed, the use of animal labor is an ongoing theme in envirotechnical history. For example, humans altered horses' physiology to maximize their use in transportation and industry, transforming the animals into "living machines."[6]

The Columbian Exchange

Technological innovation in food systems accelerated with advanced transportation technologies. The successful (if initially inadvertent) linking of Eurasia and the Americas by wooden sailboats linked the agricultural crops of the Americas with the existing food systems in other parts of the world. The establishment of transatlantic trade had vast consequences for food systems, bringing New World crops not only to Europe but to Africa and Asia as well.

The influx of maize, squash, and other New World foods reshaped agricultural production in Africa. Between the sixteenth century and the end of the twentieth century, maize accounted for more than half the calories ingested by people in several African nations, as the crop supplanted the continent's indigenous grains of sorghum, millet, and rice. Such transformations altered the makeup of human bodies; they also contributed to the reduction of biodiversity in ecosystems across Earth.[7]

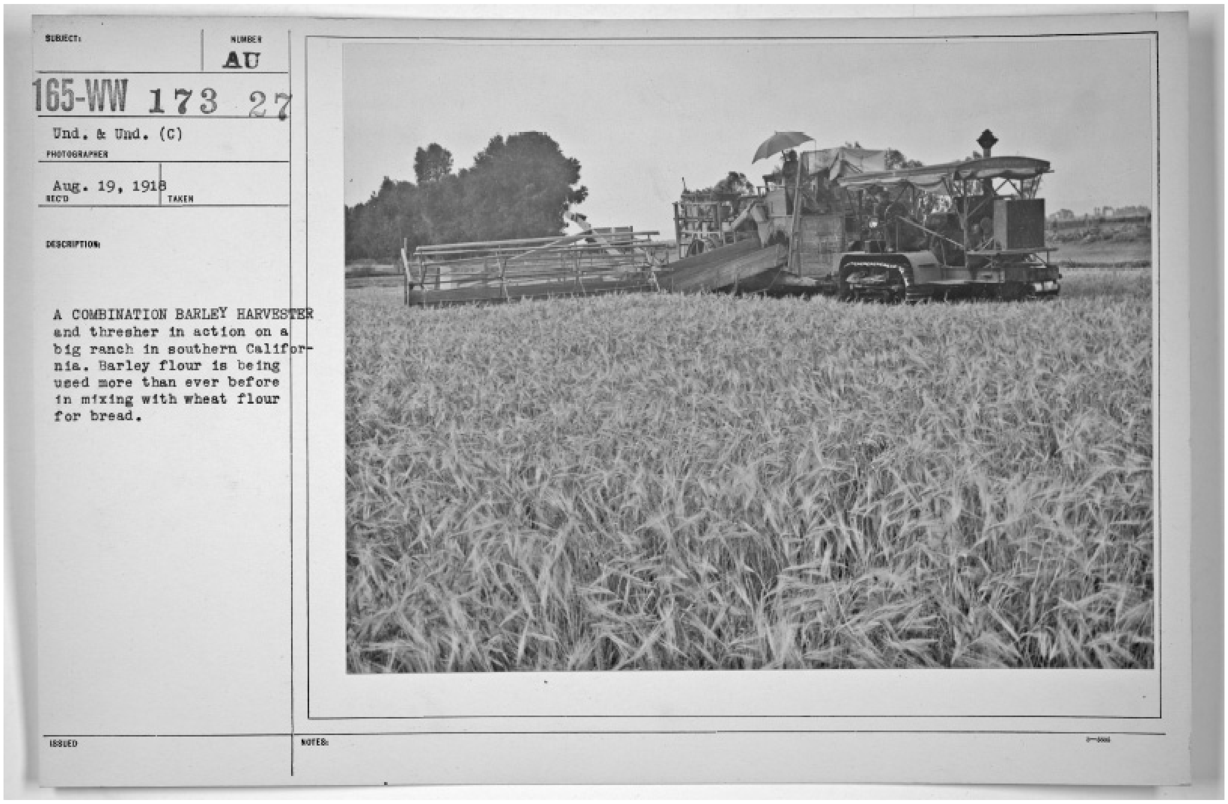
As crops from the Americas transformed food systems in Europe, European agricultural practices transformed land use in the Americas. English farming practices reshaped the land in colonial Massachusetts. A significant technological innovation was the use of fences to restrict one farmer's land from another's, thereby establishing private property that could be used for growing commodity crops. These human structures made of wood interrupted landscapes and posed barriers to migrating animals, producing hierarchies on the land that placed human needs above those of other species. (The monocultural production this organization would generate unintentionally prioritized the needs and wants of animals that could breach fences and thrive on the vast acreages of food. Humans subsequently attempted further technological innovations to retain dominance over the land; some of these attempts are explored later in this chapter.)[8]

European emphasis on commodity crops shaped the growth of plantations so as to maximize the value of New World crops, shaping food systems in ways that were crucial to the development of industrial systems. Sugar production in the Caribbean, Central America, and South America may be seen as an "agro-industry," blending industrial methods and organization of labor in an agricultural environment. This food system not only manipulated the land to produce increased yields of a commodity crop, but also transformed human labor forcibly into "cogs in the machine" that produced a commodity for consumption an ocean away from where it was grown.[9]

The food thus produced transformed bodies across Europe by providing affordable, calorie-dense nutrients for the growing class of industrial, urbanized wage laborers in cities from London (UK) to Moscow (Russia). Wooden ships facilitated the global trade in sugar, spices, and salt, additives that could alter the caloric density, durability, and taste of foods.[10]

Industrialized Food Systems

The global sugar trade prefigured major changes in food systems rendered by the Industrial Revolution. Since the early nineteenth century, the use of fossil fuels and mechanized harvesting, processing, and distribution technologies have transformed the foods we eat.



This combined barley harvester and thresher from 1917–1918, shown "in action on a big ranch in southern California," exemplifies an industrial food system in the United States. *US National Archives and Records Administration (31482104)*

Although envirotechnical relationships have formed food systems throughout human history, the complexity and scale of the negotiations between technology and nature expanded with the advent of industrialized food systems in the nineteenth and twentieth centuries. Certainly much of the attention that scholars of technology and nature have given to food systems focuses on this period, and for good reason. Mechanical, chemical, and genetic advances have transformed modern food systems into technological artifacts distinct from their preindustrial precedents. Those same advances have produced environmental consequences that are distinct in both degree and kind.

William Cronon's environmental histories show the transitions of food systems in the Americas. His *Changes in the Land* depicts the transition from polyculture food production to more intensive monoculture in New England during the colonial era. The rise of industry revolutionized food production. For the first time, the majority of a society's people need not focus on producing food for that society. The successful harnessing of fossil fuels and machinery to cultivate the land, harvest crops, slaughter animals, and preserve and transport food reshaped food systems and societies.

Cronon's *Nature's Metropolis* depicts the advent of an industrialized, national food system that transported animals and grains from across the midwestern United States to Chicago via rail. There, the animals were slaughtered at a rate approaching 70,000 per day and turned into meat. Meat and grains then left Chicago via rail to produce a standardized set of foods available across the United States.[11]

This broad story has many particulars that involve the dynamic intersection of nature and technology. A national food system involving meat required the innovation of refrigeration for homes and rail cars. In the northern Great Lakes region, an industry emerged focused on harvesting ice. Grain requirements spurred innovation in storage and transportation, including standardized rail cars and grain elevators. The traffic of commodity foods by rail required adherence to precise clock time to predict shipping schedules; in this way, fields and factories alike came to depend on industrial concepts of time.[12]

Chicago was home to the advent, in the 1860s, of an industrialized national food system that transported animals and grains from across the midwestern United States to the city via rail. The Union Stock Yards on Chicago's South Side was the final destination of animals transported to Chicago. There, the animals were slaughtered and turned into meat in mechanized slaughterhouses. The same railroads then distributed meat and grains to cities across the country. *Library of Congress, Prints and Photographs Division (LCCN 2005694947)*

Industrialized agriculture required new and expanded technologies of food preservation. Salting and drying meats had been practiced for centuries before Nicholas Appert developed canning in France at the outset of the nineteenth century, when supplies of sugar and salt, ingredients traditionally used to preserve foods, were cut off by the Napoleonic Wars. Canning allowed food processors to store their goods for months or even years, and offered packaging for easily transporting and stocking them.[13]

American tomato production became increasingly mechanized after 1870. Prior to that time, canning was done by hand, with recent immigrants and African Americans performing the bulk of this labor and working for low wages. Over the following half century, tomato producers introduced a series of innovations to distance the process from human hands. These included machines that made and capped the tin cans and steam retorts that functioned like pressure cookers to reduce cooking time and more reliably kill bacteria. By 1920, the largest companies had automated most of the tomato-canning process and boasted that " 'no human hands' had touched their products."[14]

As production methods evolved between 1850 and 1950, so too did transportation systems and outlets for consumption. Reliable rail transit (including refrigerated cars to store meats) nationalized food systems—a trend strengthened with the construction of highways and proliferation of trucks, as well as iron ships and shipping containers that allowed for reliable transoceanic imports.[15]

Human labor was and is an important part of industrialized food systems across the world, with wage or forced labor playing roles in the cultivation, harvesting, and processing of foods ranging from oranges to bananas to meat. Workers involved in food systems fall into contested categories of "skilled" and "unskilled." These include seasonal field workers paid low wages, exposed to chemical and environmental hazards, and at risk of replacement. Workers also include the chemists and engineers who serve to coordinate systems of fertilization, pest control, irrigation, and crop yield.[16]

The skills and other requirements of agricultural work have evolved over time, as has work throughout industrialized society. Prior to the mass production of meat in slaughterhouses, skilled butchers who apprenticed for years served local markets. The increase in the world of edible goods allowed consumers to bypass the skilled butcher and local farmers in favor of possibly cheaper outlets for more-distant foods. After World War II, an increasing number of American consumers could find their groceries at supermarkets, a trend that swept through much of the industrialized world by the end of the century. Centralization of food production—and the ability to ship foods great distances—reorganized labor, so that most human labor involved in food systems rendered services such as stocking packages and exchanging money for mass-produced foods often harvested hundreds or thousands of miles away.[17]

Many of the foods found in markets required packaging more varied than the cans and bottles of the prewar era. By the 1960s, "TV dinners," apportioned in metal trays and foil and encased in cardboard outer packaging, became staples of US consumption. In the half century since their introduction, plastic trays, caps, and wraps have become recognizable parts of the packaging of many foods, including those marketed as convenience foods or suitable for packing in children's lunches. The proliferation of packaging has increased the amount of solid wastes produced and landfilled, adding economic and environmental burdens to municipalities. Industrial systems produced goods marketed as individual conveniences to consumers, even as they shifted responsibility for disposing of packaging from producers to consumers and municipalities.[18]

Food production was accelerated by the industrial reorganization of water supplies to ensure steady sources of irrigation. Dams made of steel and concrete provided this water; they also appealed to governments because they provided hydroelectric power and thousands of construction jobs. By the mid-twentieth century, governments in the United States, the Soviet Union, India, Egypt, and elsewhere were in the business of building dams. These dramatic interruptions of waterways produced immense bounty in agricultural products, drinking water, and hydropower. Over time, they also revealed the limits of extracting value from river systems as ecological damage and declining farm productivity raised questions about the long-term sustainability of societies heavily dependent on dams.[19]

States in nations around the world also regulated land use and applications of fertilizer and pesticides and subsidized cultivation of particular crops. Whether nations had economies defined as command-control or free market, state regulatory instruments helped industrialize rural land, waterways, and food production.[20]

Dedication of resources to maximize agricultural yields became known as the Green Revolution. During the second half of the twentieth century, states in giant nations such as India, the People's Republic of China, and the Soviet Union, as well as in smaller nations such as Sri Lanka, pursued policies to increase yields of grains and livestock. State-sponsored efforts to industrialize food systems involved coordination with universities and corporations to innovate new techniques, chemicals, machinery, and even genetic engineering.[21]

Irrigated forest plantations, like this one in Punjab, India, in the mid-twentieth century, showed how the industrial reorganization of water for irrigation could also alter forests and agricultural landscapes. They also challenge common definitions of technology. As the linear, planned layout of this forest suggests, experts treated trees as technologies to maximize growth, yields, and therefore profit. Yet, fundamentally, these forests still relied on water. Irrigated forest plantations thus illustrate the idea of envirotechnical systems. *G. D. Kitchingman, "The Punjab Irrigated Plantations,"* Empire Forestry Service *23, no. 2 (December 1944) via Wikimedia Commons*

The African experience with maize in the second half of the twentieth century represents part of the Green Revolution that transformed industrialized agriculture worldwide. Maize came from the Americas and became dominant in African fields in the twentieth century. Though not native to the continent, the grain grew fast and required less labor than other grains. Given political instability and fears of drought in nations like Ethiopia, corn became popular with farmers seeking reliable crops. Breakthroughs in cultivating urbanized plants, with the aid of synthetic fertilizers and pesticides, to produce greater yields of grains (which in turn fed humans and livestock) transformed food systems in Africa, the Americas, Asia, Europe, and Australia, and those of several island societies.[22]

Engineer J. A. L. Horn took this photograph of Japanese rice terraces in 1935. Rice production, including "wet field" cultivation, has a long history in Japan. Rice terraces suggest a highly managed approach to raising crops that materializes in the landscape itself. Nonetheless, rice raised in this manner still depended on water. *National Museum of Denmark via Wikimedia Commons*

A crucial dimension to this transformation was the human alteration of the nitrogen cycle (the process by which nitrogen is converted into multiple chemicals as it circulates through the atmospheric, terrestrial, and aquatic ecosystems), initially in the nineteenth century, and then with growing intensity in the twentieth century. Instead of relying on the natural ecosystem services that plants and animals perform in returning nitrogen to the soil, chemists harnessed nitrogen on a far wider scale to maximize the land's productivity. Similar manipulations of phosphorous led humans to move from harvesting the mineral from bird excrement to mining and distributing it in concentration. This engineering achievement increased crop yields, along with the productivity and affordability of foods, allowing the worldwide human population to grow from just over two billion in 1930 to over seven billion in 2015. It also upset the balance of aquatic ecosystems, producing algal blooms that choked oxygen from reaching indigenous organisms, creating dead zones in oceans and seas, and exacerbating environmental consequences for industrialized food production.[23]

Industrializing Agricultural Disasters

While human manipulations of nature have shaped the food systems we have depended on, they have also produced long- and short-term consequences for air, land, water, other species, and human health. By 1000 BCE, deforestation carried out in the Chinese uplands to clear land for agriculture had resulted in centuries of silting and flooding. In the twentieth century, industrialized agriculture accelerated the speed and magnitude of environmental consequences. Donald Worster argues that an industrial capitalist treatment of the land for harvesting monocultural crops produced the soil erosion in the United States' Great Plains that became known as the Dust Bowl (when soil erosion affected more than 100 million acres in Texas, Oklahoma, New Mexico, Colorado, and Kansas, displacing tens of thousands of farmers during the 1930s). The devastation of the region's farms during the Dust Bowl was—far from being a "natural disaster"—a human-engineered disaster. Dams allowed the expansion of agricultural production on previously arid lands; yet such transformations meant that the flora and fauna of affected lands "went through an upheaval comparable only to the cataclysmic postglacial extinctions."[24]

Industrialization transformed lands used for intensive growing of plants and animals in rural areas. Demand for grain and meat in urban centers meant that rural landscapes were planted in ever-increasing amounts of corn, wheat, rice, and soybeans, and used for ever-larger livestock operations preparing cattle, hogs, chickens, sheep, and other animals for slaughter in centralized urban meatpacking facilities.

Industrial meat production centralized slaughtering and processing; in the United States, these activities were concentrated in Chicago, where the meatpackers dumped their wastes into the South Fork of the South Branch of the Chicago River. A small tributary with a weak current, the waterway was immediately overwhelmed with meatpacking plant wastes in the 1850s; by the 1880s, it earned the nickname "Bubbly Creek" because of the methane bubbling from decayed organic matter. Bubbly Creek emitted odors that nearby residents complained about. The volume of solid waste entering the stream by 1911 produced a skin atop the water's surface that chickens and even humans could stand on.

The consequences of industrial meat production were conspicuous, especially after their vivid description in *The Jungle*, in which author Upton Sinclair described Bubbly Creek as a "great open sewer."[25] Environmental damage from other food production methods could be even greater, if less obvious. Soil erosion had consequences for the humans and animals who lived on affected lands. The hydroelectric dams that governments in the United States, the Soviet Union, China, and India constructed between 1920 and 1970 reshaped watersheds, lands, and the fortunes of plants and animals within ecosystems. Despite the addition of "salmon ladders," structures designed to allow migrating fish to pass over or around dams in the US Pacific Northwest, salmon populations in the Columbia River plummeted. In response, commercial fisheries developed salmon farms, which produced commodity fish while creating new challenges relating to disease and genetic diversity. The engineering of waterways represented a disaster for wild salmon that commercial food producers mitigated with domesticated fish.[26]

An enduring theme involves the technologies humans develop to control nature, and the intended and unintended consequences that result from the applications of these technologies. Chemical manipulation of ecosystems had ramifications. Beyond the aforementioned interruption of the nitrogen cycle, monoculture production necessitated eradicating unwanted plant species (classified as weeds) from fields, a process often involving the use of chemical herbicides. Aside from effects on animals that ingested the herbicides and on the groundwater beneath the fields, herbicide use produced homogenous yields of a single crop. Though a boon for industrialized agriculture and its quest for maximizing value extracted from the land, successful monoculture bore the unintended consequence of producing abundant food for unwanted organisms classified as pestilence. Species that could eat acre after acre of crops could multiply exponentially and devastate harvests. A popular solution to this problem was to apply more chemical poisons, classified as insecticides, to fields. Insecticides also had potential consequences for human and livestock health, necessitating washing of harvested foods. As with herbicides, insecticides exposed agricultural labor to poisons and seeped into groundwater, poisoning drinking water for humans and animals.[27]

Industrial research and development during the twentieth century produced new herbicides and insecticides focused on particular threats. The insecticide dichlorodiphenyltrichloroethane (DDT), developed for military uses during World War II, saw widespread application in the postwar era to "protect" human and livestock health. This expanded use exacerbated observed hazards of the chemical as a toxin to fish, birds, and humans as it accumulated in the tissues of plants and animals and caused illness and death. Rachel Carson, alarmed by the consequences, published *Silent Spring* in 1962. The book's title referred to the absence of birdsong due to the devastating impact of chemical poisons on bird populations. *Silent Spring* altered public discourse on the merits and perils of chemical innovation. Results have included a federal ban on DDT use in the United States and sustained public and regulatory concerns about the effects of agriculture-related chemicals on human and environmental health.[28]

Food systems raise broad issues of continuity and change within the history of technology. Changing technologies in industrial society have led to shifts in the ways by which people acquire and prepare food. Stoves and ovens powered by electricity and natural gas became standard appliances in American homes in the second half of the twentieth century, increasing food preparers' control of temperature. The microwave oven became a mass consumer amenity after 1970; its history shows the complex interactions between technology and sensory history. Microwaves increase convenience; they also produce tastes and textures different from those electric or gas stoves produce.

Increased convenience in domestic food preparation appliances shaped the production and packaging of foods. The proliferation of ice boxes in the early twentieth century expanded the reach of American dairies as delivery of milk in reusable glass bottles became commonplace. Prepackaged foods could save consumers time at the market, reshape where and what kinds of foods were available, and expand the reach of food producers, from local to regional and global scopes.[29]

Industrialization's reshaping of a host of institutions, from schools to hospitals to road systems, has produced concomitant changes in food systems. Transportation systems—including railroads with refrigerated cars, interstate highways, ships, and airplanes—have allowed food producers to "annihilate geography." By the turn of the twentieth century, Chicago could proclaim itself "Hog Butcher to the World" because pork products shipped from there across the United States.[30]

In the twenty-first century, transportation networks allow diners in New York City sushi restaurants to eat fish caught in Japan, butchers in London to sell lamb from New Zealand, and grocery customers in Minneapolis (USA) to eat blueberries grown in Chile. The rise of modern domestic kitchens after World War II led to packaged prepared foods. The microwave oven allowed mass production of new foods, such as bags of microwave popcorn.[31]

Industrialization also shaped foods people could eat in retail outlets and other institutions. Interstate highway construction led to the rise of fast food in the United States, with White Castle's proliferation in the 1920s anticipating a plethora of restaurants offering affordable, elaborately packaged and highly processed meals suitable for eating in a car. McDonald's, Pizza Hut, Taco Bell, and dozens of other chains use this model in thousands of restaurants around the world. The growth of schools, hospitals, and corporations created markets for cafeterias that purchased and produced foods in bulk, at times valuing preservation over taste. Packaged, processed foods became commonplace in these institutions, joining fast foods as time- and money-saving innovations in the food humans ate.[32]

The large technological system of industrialized food production required further reorganization of land, capital, labor, and technology as inputs. Monoculture produces higher yields; it also leaves crops vulnerable to predators adapted to eating particular crops. Pestilence produces blight and economic loss. Industrial food systems' adaptations in response to pestilence include the use of chemical pesticides and herbicides. One of the reasons for *Silent Spring*'s impact on the public in 1962 is that readers linked the chemical innovations to harm to humans, and this narrative has informed discussion of chemicals in food production for more than half a century.

As Upton Sinclair wryly noted about the reception of his 1904 exposé, *The Jungle*, public concern about food systems focused on the quality of the food produced rather than the working conditions of the people employed to produce it. This pattern of regulation, focused largely on the food rather than the workers, continued throughout the twentieth century. Industrialized foods have led to conflicts between regulators and consumers over food safety and quality, with laypeople struggling to combat technical experts' definitions and measurements of safety. Examples include battles over the quality of Mexico City (Mexico) sausage at the turn of the twentieth century, and between consumer advocates and the FDA over peanut butter in the 1960s and 1970s.[33]

Industrialized food systems transcend political boundaries; Dole Fruit and C&H's interest in the Pacific helped shape the United States' interest in Hawaii as a territory in the 1890s and the islands' subsequent admittance as a state, in 1959. One of the results of the 1994 North American Free Trade Agreement was an expansion over the next decade of tomato crops grown in Mexico for consumption in the United States.

Transnational activities complicate the regulation of pesticide and herbicide applications, posing health risks to agricultural workers as several carcinogenic and endocrine disruptions (discussed in chapter 5) are associated with agricultural chemicals. Susanna Rankin Bohme points to lower male fertility among Hawaiian and Central American workers exposed to the pesticide dibromochloropropane (DBCP). These hazards were results of humans seeking ever-greater bounty from the land, and they raised worries by the 1970s about the costs to environmental and human health that such efforts exacted. Those worries would intensify by the end of the twentieth century.[34]

Genetic Engineering and Food Systems

Recent concern about food systems centers on the genetic engineering of organisms. Although the history of genetically engineering commodity foods begins in the 1980s, such work has important continuities with earlier efforts to breed plant and animal species. In one of the landmark books in the history of technology and the environment, *Industrializing Organisms: Introducing Evolutionary History* (2004), the contributing authors discuss several of these efforts in the nineteenth and twentieth centuries. More than a decade after its publication, the authors' analyses of nineteenth-century manipulation of sugar, wheat, and cows, as well as of twentieth-century chicken and hog production, remain relevant to our understanding of industrialized food systems in general, and the historic precedents for genetically engineered organisms that shape the twenty-first-century food supply.[35]

The precedent established, genetic engineering (GE), is also dramatically different from past manipulations. Writing in *The Illusory Boundary*, Edmund Russell argues that "genetic engineering offers a faster, more precise way of doing what breeders have long done. But the novelty of genetic engineering lies in its ability to move genes across wildly divergent taxonomic groups, such as between plants and animals. Scientists implant firefly genes in tobacco plants and frogs to make them glow, and rice plants in Missouri (USA) manufacture human proteins courtesy of imported human genes."[36] Russell concludes, "Opponents of genetic engineering usually portray it as something radically new, which it is. Never before have we been able to move genes between plants and animals. Proponents of genetic engineering, on the other hand, portray it as but the latest phase in the production of biotechnologies, which it also is. For all of us who think history has something useful to say about the present and future, it is essential that we recognize both the disjunction and the continuity between past and present."[37]

In the twenty-first century, the most widespread use of genetic engineering involves corn and soy crops, which serve as food supplies for livestock. About 100 million acres of farmland in the United States were planted with GE crops in the year 2000. According to one estimate in 2001, more than two-thirds of the food in America's supermarkets involved genetically engineered organisms in some proportion. As Ann Vileisis notes, "Corn, in particular, was engineered to include the bacterium *Bacillus thuringiensis*, which produced its own insecticide, Bt. Subsequent studies revealed that Bt expressed in the pollen of GE corn was toxic to beneficial insects, which raised the broader ethical and policy question of why ecological studies had not been conducted *before* the GE crop was released for use on millions of acres of farmland."[38]

Economics and taste have influenced the concentration on these crops, which have become vital to both processed foods and industrialized meat production. Corn's application in high-fructose corn syrup, which became an economically viable replacement for cane sugar by 1980, has made corn a staple of processed foods from the obvious (soda, candy) to the subtle (bread, pasta sauces). Surveys of convenience stores in the United States reveal a majority of the edible products for sale include corn in some way. Genetically engineering the crop for maximum yield makes economic sense, even as it further intensifies a monoculture that requires interference in the nitrogen cycle and demands killing or repelling unwanted organisms in the fields.

Meat-based diets rely increasingly on genetically engineered crops. In the United States, increased corn production between 1970 and the end of the century meant that cattle's diets shifted from grasses to corn, producing animals that reach market weight faster and have fattier tissue in the harvested meat. With less protein and more fat, the American hamburger in 2015 tastes and feels substantially different from its 1970 predecessor. Hogs, too, consume more corn and soy because of the economics of those grains, with similar outcomes in the meat thus produced.

The continuing debates surrounding GE organisms reveal the complex interactions of technology and nature, and the potential consequences to the food system, to human bodies, and to ecosystems. The foods that people living in twenty-first-century industrial society eat are the dynamic products of nature and technology, evolution and history. Such a statement may seem obvious, with the proliferation of highly processed foods such as breakfast cereal, bread, candy, ketchup, and soda, but it is also true of corn, tomatoes, carrots, rice, beef, pork, and chicken. Russell reminds us that cheese production is a biotechnological process, as is the brewing or distillation of alcoholic beverages such as beer, wine, and spirits.[39]

Modern food systems reflect such enmeshed relationships between technology and the environment that reactions against them reveal industrialization's depth and complexity. The use of fertilizers, pesticides, hybrid strains designed for maximizing caloric content, chemical preservation, and other processing has raised concerns over the quality of the food supply and its effects on ecosystems and human health. Groundwater pollution and cancer clusters in agricultural regions joined alarm over increases in obesity, diabetes, and cardiovascular disease in much of the industrialized world by the end of the twentieth century. Since the late 1960s, organic and locavore food systems have grown in reaction to industrialized agribusiness. These developments, however, have resulted not in preindustrial modes of food production, but rather alternative industrial systems that differ from the mainstream systems more in degree than in kind. By 2010, the chain supermarkets Whole Foods and Walmart had developed systems of distributing both organically produced and locally grown foods to the same store shelves that stocked globalized processed foods.[40]

This chapter offers a few of the ways in which historians have explored how the food humans eat represent past and present mediations between technology and the environment. If the packaged candies and sodas on supermarket shelves represent the most obviously artificial engineering of raw materials into edibles, they sit on a continuum with the meats, fruits, vegetables, grains, and beverages that have structured industrial society's diets. Historically, these foods and the systems that deliver them have allowed humans to multiply and thrive. But they have also resulted in serious consequences for ecosystems, biodiversity, and human health.

Attempts to create more-sustainable food systems in the future must take this history into account. "If many billions of people are to live on Earth peacefully and equitably in thriving economies," Hugh Gorman argues, "industrialized societies have no choice but to construct a guide that places ethical and practical boundaries on human interactions with the planet." Gorman is one of the school of historians of technology and the environment whose work shows how central the food systems developed to serve humanity have become in producing this vexing problem.[41]

The Natural History of the Chicken (2000)
Sustainable: A Documentary (2016)

Chapter 2. Industrialization

Recommended Readings

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Schrepfer, Susan R., and Philip Scranton, eds. *Industrializing Organisms: Introducing Evolutionary History*. New York: Routledge, 2004.
Steinberg, Theodore L. "An Ecological Perspective on the Origins of Industrialization." *Environmental Review* 10, no. 4 (1986): 261–76.
Tarr, Joel A. *The Search for the Ultimate Sink: Urban Pollution in Historical Perspective*. Akron, OH: University of Akron Press, 1996.

Websites

Industrial Revolution. https://sourcebooks.fordham.edu/mod/modsbook14.asp.
The 1911 Triangle Factory Fire. https://trianglefire.ilr.cornell.edu/.
Teaching with Primary Sources: "The Industrial Revolution in the United States." Library of Congress. http://www.loc.gov/teachers/classroommaterials/primarysourcesets/industrial-revolution/pdf/teacher_guide.pdf.

Films

The Day the World Took Off (2004)
Germinal (1993)
Hard Times (1994)
The Luddites (1988)

Chapter 3. Discards

Recommended Readings

MacBride, Samantha. *Recycling Reconsidered: The Present Failure and Future Promise of Environmental Action in the United States*.

Cambridge, MA: MIT Press, 2011.
Melosi, Martin V. *The Sanitary City: Environmental Services in Urban America from Colonial Times to the Present*. Abridged Edition. Pittsburgh: University of Pittsburgh, 2008.
Royte, Elizabeth. *Garbage Land: On the Secret Trail of Trash*. New York: Little, Brown, 2005.
Strasser, Susan. *Waste and Want: A Social History of Trash*. New York: Metropolitan Books, 1999.
Tarr, Joel A. *The Search for the Ultimate Sink: Urban Pollution in Historical Perspective*. Akron, OH: University of Akron Press, 1996.
Zimring, Carl A., and William L. Rathje, eds. *Encyclopedia of Consumption and Waste: The Social Science of Garbage*. Thousand Oaks, CA: Sage, 2012.

Websites

Basel Action Network. http://ban.org.
Center for Health, Environment, and Justice. http://chej.org.
Discard Studies. http://discardstudies.com/.
Zero Waste International Alliance. http://zwia.org.

Films

Scrappers (2010)
The Story of Stuff (2007)
Trashed (2012)
Waste Land (2010)

Chapter 4. Disasters

Recommended Readings

Fortun, Kim, and Scott Frickel, “Making a Case for Disaster Science and Technology Studies.” An STS Forum on the East Japan Disaster, accessed May 15, 2018. https://fukushimaforum.wordpress.com/online-forum-2/online-forum/making-a-case-for-disaster-science-and-technology-studies/.
Knowles, Scott Gabriel. “Learning from Disaster? The History of Technology and the Future of Disaster Research.” *Technology and*

Anthropocene Is Functionally and Stratigraphically Distinct from the Holocene." For just a few of the influential humanistic critiques of the Anthropocene and alternative framings, see Haraway, "Anthropocene, Capitalocene, Plantationocene, Chthulucene"; Haraway, *Staying with the Trouble*; Moore, *Anthropocene or Capitalocene?*; Moore, "The Capitalocene, Part I"; Moore, "The Capitalocene, Part II"; Hecht, "Inter-scalar Vehicles for an African Anthropocene"; Hecht, "The African Anthropocene"; and Yusoff, *A Billion Black Anthropocenes or None*.

Chapter 1. Food and Food Systems

1. On extreme environments on Earth and elsewhere, see Olson, "Political Ecology in the Extreme"; and Pyne, *Between Two Fires*, and Pyne's many related books on the role of fire in American environmental history.

2. McNeill and McNeill, *The Human Web*.

3. McNeill and McNeill, *The Human Web*; Zohary and Hopf, *Domestication of Plants in the Old World*.

4. Diamond, *Guns, Germs, and Steel*.

5. Cronon, *Changes in the Land*; Krech, *The Ecological Indian*.

6. Schrepfer and Scranton, *Industrializing Organisms*; Reynolds, *Stronger than a Hundred Men*; McShane and Tarr, *The Horse in the City*; Greene, *Horses at Work*.

7. Crosby, *The Columbian Exchange*; McCann, *Maize and Grace*; Ott, *Pumpkin*.

8. Cronon, *Changes in the Land*.

9. Mintz, *Sweetness and Power*.

10. Kurlansky, *Salt*; Gilbert and Reynolds, *Trading Tastes*; Abbot, *Sugar*; Finger, "Trading Spaces."

11. Cronon, *Nature's Metropolis*; Pacyga, *Slaughterhouse*.

12. Cronon, *Nature's Metropolis*.

13. Vileisis, "Are Tomatoes Natural?"

14. Bitting, *The Canning of Foods*; Freidberg, *Fresh*; Vileisis, "Are Tomatoes Natural?"

15. Cronon, *Nature's Metropolis*; Hamilton, *Trucking Country*.

16. Sawyer, *To Make a Spotless Orange*; Fitzgerald, *Every Farm a Factory*; Sackman, *Orange Empire*; Hutchings, "Consuming Nature."

17. Deutsch, *Building a Housewife's Paradise*.

18. Melosi, *Garbage in the Cities*; Elmore, *Citizen Coke*; Zimring, *Aluminum Upcycled*.

19. Pisani, *From the Family Farm to Agribusiness*; Worster, *Rivers of Empire*; Pfaffenberger, "The Harsh Facts of Hydraulics"; Shallat, *Structures in the Stream*; Fiege, *Irrigated Eden*; Josephson, *Industrialized Nature*.

20. Stoll, *The Fruits of Natural Advantage*; Wright, *A Fishery for Modern Times*; MacLachlan, *Kill and Chill*; Li, *Fighting Famine in North China*; Muscolino, *Fishing Wars and Environmental Change in Late Imperial and Modern China*.

21. Russell, "Introduction: The Garden in the Machine"; Harlan, *Crops and Man*; Kloppenburg, *First the Seed*; Fitzgerald, *The Business of Breeding*; Perkins, *Geopolitics and the Green Revolution*.

22. McCann, *Maize and Grace*; Gammage, *The Biggest Estate on Earth*; Moon, *The Plough That Broke the Steppes*.

23. Gorman, *The Story of N*; Gunderson and Hollings, *Panarchy*; Werner and Newton, *Nitrogen Fixation in Agriculture, Forestry, Ecology, and the Environment*; Melillo, "The First Green Revolution"; Cushman, *Guano and the Opening of the Pacific World*.

24. Worster, *The Dust Bowl*; Worster, *Rivers of Empire*, 10 (quotation).

25. Sinclair, *The Jungle*; Young, *Pure Food*; Cronon, *Nature's Metropolis*; Washington, *Packing Them In*; Zimring and Bryson, "Infamous Past, Invisible Present."

26. Taylor, *Making Salmon*.

27. Russell, *War and Nature*; Anderson, "War on Weeds." Zachary J. S. Falck's discussion of urban and suburban efforts to classify and control weeds is also instructive of human attitudes toward undesired organisms. See Falck, *Weeds*.

28. Carson, *Silent Spring*; Russell, "The Strange Career of DDT."

29. Friedel, "American Bottles"; Smith-Howard, *Pure and Modern Milk*.

30. Cronon, *Nature's Metropolis*, 207.

31. Cohen, *A Consumers' Republic*; Cooper, "Microlessons."

32. Hogan, *Selling 'Em by the Sack*; Hamilton, *Trucking Country*; Josephson, "The Ocean's Hot Dog."

33. Sinclair, *The Jungle*; Pilcher, *The Sausage Rebellion*; Boyce, " 'When Does It Stop Being Peanut Butter?' "

34. Bohme, *Toxic Injustice*.

35. Schrepfer and Scranton, *Industrializing Organisms*.

36. Russell, "Can Organisms Be Technology?" 257.

37. Russell, "Can Organisms Be Technology?" 257–58.

38. Martineau, *First Fruit*, 229, 233; Vileisis, "Are Tomatoes Natural?" 237–38.

39. Russell, "Are Organisms Technology?" 254; Paxson, *The Life of Cheese*.

40. Pollan, *The Omnivore's Dilemma*; Smil and Kobayashi, *Japan's Dietary Transition and Its Impacts*; Winson, *The Industrial Diet*.

41. Gorman, *The Story of N*, 162.

Chapter 2. Industrialization

1. Pritchard and Zeller, "The Nature of Industrialization"; Pritchard, "Toward an Environmental History of Technology."

2. For a broad overview, see Pacey, *Technology in World Civilization*. On Britain, see Allen, *The British Industrial Revolution in Global Perspective*. On France, see Horn, *The Path Not Taken*. On the United States, see Licht, *Industrializing America*; Hindle and Lubar, *Engines of Change*. More recent work has emphasized the global dimensions of industrialization. See, for instance, Stearns, *The Industrial Revolution in World History*. Although more focused on the history of capitalism, Sven Beckert's *Empire of Cotton* can also be read through the lens of global industrialization. Similarly, Sidney Mintz's classic *Sweetness and Power* argues that plantation agriculture in the Caribbean offered a critical model for industrialization in Britain.

3. Karl Marx, *Capital*; Engels, *The Condition of the Working Class in England*. For overviews of US industrialization, see Licht, *Industrializing America*; and Hindle and Lubar, *Engines of Change*.

4. Berg, *The Age of Manufacturers*; Honeyman, *Women, Gender, and Industrialization in England*.

5. Toynbee, *Lectures on the Industrial Revolution in England*; Wilson, "Arnold Toynbee and the Industrial Revolution." For one example that complicates a radical rupture, see Shulman, *Coal and Empire*, which