Introduction

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In mid-May of 2017, the twenty-seven environment ministers of the EU met for the fifth time in less than two years in order to craft a compromise on the legal definition of endocrine disruptors. This definition is a mandatory step in the implementation of the EU-wide agreement on the regulation of chemicals (Regulation, Evaluation, and Authorization of Chemicals—better known as REACH) because the definition will determine which substances might be banned or restricted under the REACH provisions. Once again, the meeting failed. At the core of the disagreements this time was an amendment introduced by the European Commission and supported by Germany that stated that pesticides specifically designed to disrupt insect hormonal regulation should be taken out of the endocrine disruptors package, thus creating a major loophole in the law. Perhaps not surprisingly, the meeting had been preceded by a rise in lobbying and publicizing activities. Organizations funded by the chemical industry (the European Crop Protection Association, the European Chemical Industry Council, and PlasticsEurope) advocated for the amendment, whereas it was opposed by medical and scientific societies (the Endocrine Society, the European Society of Endocrinology, the European Society of Pediatric Endocrinology). Moreover, the European press had published a whole range of internal documents from PlasticsEurope acknowledging that the situation looked bleak since "current scientific evidence show that plastics display endocrine disruptors properties" and arguing for the "financing of more research."[1] Endocrine disruptors are a concern pertaining to both ecology and food quality: pesticides are not only disseminated in the environment but are also persistent contaminants in the products of industrial agriculture. An announcement in mid-June by the European Chemical Agency underlined this risk, identifying bisphenol A (also known as BPA) as an endocrine disruptor associated with increased human risks of cancer, diabetes, obesity, and neurobehavioral disorders.[2] BPA leaches from many of the plastic containers used in the food processing industry. Even as industry disputes the degree of health hazards they pose, endocrine disruptors have become a pervasive contaminant in the food supply.

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The now thirty-year-old controversy about endocrine disruptors may be viewed as a paradigmatic case of the emerging downside of the industrial production of food, long hailed as a triumph of technology.[3] Technical solutions invented to increase agricultural productivity and "solve" the food security problem have become the source of new and hard-to-quantify risks, not to mention the questionable nutritional value of many processed foods. It may also be viewed as a paradigmatic case of the contemporary production of ignorance, in which vested interests obstruct or call into question scientific knowledge.[4] The European press regularly reports conflicts of interests within the national and EU regulatory agencies, as well as massive and powerful lobbying activities in Brussels. The camps seem clear: the chemical industry defends its markets against scientists, physicians, and public health authorities—the latter relying on published experimental evidence, the former pointing to knowledge gaps and uncertainty. This dispute over endocrine disruptors seems poised to be the twenty-first-century analogue of the twentieth-century "tobacco and cancer" affair, this time touching a consumable that is not voluntary—namely, food.[5]

Standing behind this one politically charged example are a host of research and regulatory complexities, which are multiplied when one adds the many other hazardous food contaminants, from *Salmonella* to mercury. While the chemical industries have many ways of constructing markets—including strategies of substitution, delocalization, and green-washing—the production of evidence regarding the thousands of chemicals employed in making food is not only meager but also multiple and often contradictory, in part due to the many levels of control as edibles circulate through the global commodities market. Why, after a century of technological progress and regulatory oversight, does the safety of industrialized food appear so elusive? To answer that question requires an in-depth look at how researchers, companies, and agencies have determined risk and safety, produced knowledge as well as commodities, and dealt with uncertainty and conflict. *Risk on the Table* tries to understand the history behind the ongoing heartburn of food worries.[6]

The purity and safety of the food supply is an old issue for ordinary people, experts, and state authorities. However, the growing use of chemicals in food production and the industrialization of agriculture catalyzed a new set of controversies in the twentieth century about the risks of food. Several developments were implicated in these debates, including the reporting of health issues in the media; the proliferation of synthetic chemicals as additives, preservatives, pesticides, drugs, and packaging; the biological selection of newly pathogenic bacteria by use of antibiotics and containment facilities in agriculture; and improved techniques for detecting minute levels of contaminants along with new understandings of health hazards for low-dose exposures. The industrialization of the food supply has been a theme in studies of business and agriculture for forty years, as illustrated by Harvey Levenstein's influential *Revolution at the Table: The Transformation of the American Diet* (1988). However, whereas this earlier scholarship tended to take for granted the role of scientific and technical expertise in the expansion and management of the food industry, including issues of its safety, our authors examine the changing nature of expert knowledge, as well as the potential conflicts among the perspectives offered by microbiologists, nutritionists, toxicologists, epidemiologists, and economists. In many cases, technological innovations designed to address the productivity and safety of the food supply—such as the tremendous postwar growth in pesticide usage—ended up generating novel hazards. This introduction briefly recounts the history of the industrialization of food and how emerging dangers from this production system prompted new scientific research and regulation. We then turn to the chapters of this book and how they contribute to understanding how science and technology have become implicated in both creating and controlling food risk.

The Industrialization of Food

The mass production in factory settings of ready-to-eat food began in the nineteenth century with the commercial canning industry.[7] As Alfred Chandler notes, American food manufacturers were among the first to take advantage of new continuous process technologies. Grain mills led the way, as exemplified by the Pillsbury brothers' automatic all-roller, gradual reduction mill. A key feature of continuous process factories was their high unit output. In the case of new industrial foodstuffs such as oatmeal, production volume required the development of new markets. Henry P. Crowell started selling Quaker Oats as a breakfast cereal, creating a now ubiquitous food product line. National companies such as Crowell's used mass advertising campaigns to promote brand name recognition and increase sales.[8] Heinz, Armour, and National Biscuit Company (NABISCO) soon joined in the mass production and distribution of food products. Quality assurance and food safety were a key part of what firms were marketing in tins and boxes. Industrial self-regulation was thus closely tied to fostering a base of customers, and their trust, nationwide.

Farms themselves did not become mechanized, large-scale elements of the US food system until the twentieth century—and later in much of Europe.[9] Vast fields of monoculture crops were appetizing to insects, plant pathogens, and vermin, spurring a growing reliance on so-called economic poisons (such as arsenic-containing chemicals) to protect the plants.[10] Industrialized farms became as dependent on agrochemicals, especially fertilizers and pesticides, as they were on the tractors, crop planes, and mechanized equipment. In 1955, the term "agribusiness" was coined by Harvard Business School's John H. Davis to describe this new system, with its heavy reliance on the chemical industry. His term was increasingly linked to the loss of small family farms to large corporate owners, as opposed to the government regulation, scientific research, labor patterns, and marketing networks that Davis saw as integral to this system—elements we seek to re-examine here.[11] Technologies for food processing were also critical to industrialization. Bacteriologists provided a scientific rationale for older food preservation practices such as conserving and canning, and contributed new methods (such as sterile processing and pasteurization) to control contamination and enable long-term preservation for the growing geographical reach of food distribution.[12]

By the 1930s, what has been called the "chemogastric revolution" introduced a wide range of new chemicals into food production, aimed at preventing spoilage, extending shelf life, making edible goods more appealing, and increasing agricultural productivity.[13] (Refrigeration and the emergence of the "cold chain" similarly transformed the storage of perishables.[14]) Food additives were not new, nor were they necessarily unnatural. Ascorbic acid, an antioxidant widely used as a preservative, remains better known by its common name, vitamin C.[15] But during the first half of the twentieth century, the chemical industry produced a host of new food chemicals, especially antioxidants and agents for stabilizing and emulsifying; five hundred were on the market by 1947, and that number nearly doubled in the following decade.[16] Many chemical additives enhanced the appearance of foods (or stopped their color from fading), making them more appetizing or even more natural-looking.[17] In fact, manufacturers of processed foods promoted the image of their products as fresh and familiar, even as they relied on an increasing array of chemicals for preservation, taste, and appearance.

By virtue of these chemicals, as well as industrial packaging and distribution systems, convenience foods multiplied on grocery store and (increasingly) supermarket shelves, including frozen foods, cake mixes, instant coffee, and also orange juice, which used 25 percent of Florida's orange crop in 1950, and 70 percent in 1960.[18] The growth of the Florida citrus juice industry provided a cautionary tale: in the 1940s, thiourea was being used as a preservative for juice oranges, but pharmacologists at the FDA subsequently documented its unexpected toxicity.[19] Beyond issues of safety, the FDA struggled to regulate standards and labeling for "fresh" orange juice, which was often reconstituted and chemically enhanced.[20]

There was also a dramatic increase after World War II in the volume of food chemicals used in agricultural production and crop storage, such as herbicides, rodenticides, insecticides, and other pesticides, especially the highly effective organochloride and organophosphate pesticides. In 1953, there were about fifty different synthetic pesticides available, but by 1964 this number had risen to five hundred.[21] In addition, the volume of pesticide production increased massively, from 100,000 tons worldwide in 1945 to near 1.5 million tons by 1970.[22] The best known organophosphate compound is DDT, but a wide range of other organic insecticides were being used in agriculture, such as dieldrin, aldrin, malathion, and parathion.[23] These compounds are generally toxic, persistent (i.e., do not break down rapidly), and also concentrate as they move up the food chain, due to their solubility in fat.[24] In addition, growth-promoting substances, such as antibiotics and diethylstilbestrol, were routinely added to livestock feed.[25] Residues of many of these chemicals began to be detected in produce, meat, and processed food that reached the market. So long as these residues were well below levels toxic to humans, the benefits of agrochemicals were seen as justifying their use. However, over the mid-twentieth century, conceptions of toxicity and tools for detecting toxins were changing.

In 1940, the food coloring agent "butter yellow" was shown by two independent scientists to be carcinogenic—after it had been used in Germany since the 1870s to tint butter and margarine.[26] This prompted political and legislative action for more stringent control of food additives in Germany.[27] Other reports about the possible carcinogenicity of food additives and chemical residues surfaced through the 1950s in Europe and in the US, alarming consumers and putting both regulatory agencies and industry on the defensive.[28] Most pesticides were known to be poisonous (they are, after all, designed to kill other living organisms), but representatives of both industry and government insisted that the so-called "tolerance" levels specified by national regulatory bodies protected consumers against hazardous pesticide exposures.[29] The so-called "cranberry scare" in the US, when the entire crop of cranberries was recalled by the government just before Thanksgiving of 1959 due to concerns about aminotriazole residues, left the public jittery about farmers' indiscriminate use of pesticides (in this case, an unauthorized use).[30]

After the publication of Rachel Carson's *Silent Spring* in 1962, consumers and environmental groups were increasingly skeptical of industry claims about the safety of chemical residues in food, as well as in the environment.[31] Since the nineteenth century, the food industry had sought to foster public trust in their products as a way to expand markets; by the 1970s, reports of the risks of synthetic chemicals in both processed and fresh foods corroded public confidence. Books such as *Eating May Be Hazardous to Your Health* and *The Chemical Feast* castigated the US government for failing to protect its citizens.[32]

Ultimately, new risks associated with these postwar food chemicals did not simply replace earlier dangers associated with pathogenic germs and toxins, but rather supplemented them.[33] While bacteriological and pasteurization techniques did enable relatively safe mass production and transportation of perishable foods (as did refrigeration), the industrialization of agriculture, including containment methods for livestock production and widespread

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antibiotic usage, contributed to emerging problems such as antibiotic resistance.[34] In addition to selecting for antibiotic resistance in known pathogenic bacteria, these conditions have produced new human pathogens from previously innocuous bacteria, such as the strain of *Escherichia coli* that carries the Shigella toxin (*E coli.* O157:H7). Bacterial contamination and pathogenicity continued to be problems alongside dangers from a host of new chemical residues.

In addition, reliance on agrochemicals introduced new kinds of environmental damage, in ways that manifested more slowly. The massive decrease in insect populations, including bees crucial to agricultural pollination, is linked to longstanding use of neonicotinoid insecticides.[35] Excess nitrate from fertilizer runoff in waterways has stimulated the overgrowth of algae, leading to vast "dead zones" where oxygen is insufficient for fish.[36] The agricultural herbicide atrazine is a major suspect for widespread reproductive anomalies and population declines observed in wild frogs.[37] The ecological consequences of cheap food illustrate a disconnect between, on the one hand, environmental protection and food safety and, on the other, the different kinds of regulatory science that inform them, to which we now turn.

Shifting Dangers and Regulatory Science

Early regulation of foods often focused on adulteration and quality, although there were also efforts to oversee safety in food related to public health efforts to identify disease agents and toxic substances.[38] In the late nineteenth century, the new tools of bacteriology had brought into view germs in air, water, and food responsible for many human diseases.[39] The contamination of milk with tuberculosis bacilli became a major public health concern in the early twentieth century; Upton Sinclair's 1906 novel *The Jungle* also drew attention to the unhygienic conditions in meat-packing plants.[40] In addition, microbes, now identifiable through bacteriological culturing techniques, were often found to be the cause of food spoilage. For their part, analytical chemists identified adulterants, often suspected as unsafe, as well as poisons (such as arsenic) in food. National food regulation authorities, such as the US Food and Drug Administration (FDA), relied on a staff of bacteriologists and chemists to oversee food safety and quality.[41] Below we focus on the actions of the FDA, which has been especially well studied, though the United States was certainly not the only—or even the first—nation with emerging regulatory oversight of food chemicals.[42]

Over the first half of the twentieth century, government officials and consumers became increasingly concerned about chemicals added to food in manufacturing, starting with bleaching agents in flour and caffeine in Coca-Cola.[43] Until the 1938 Food, Drug and Cosmetic Act, not even drugs needed to be tested for safety in the US.[44] The 1938 act spurred the development of testing regimes in pharmacology and toxicology, the latter of which was also stimulated by the rise of "industrial hygiene," largely concerned with occupational safety in chemical factories (and usually overseen by firms themselves).[45] Animal research was the main mechanism for assessing hazards from exposure to chemicals. Toxicologists developed standardized protocols for rodent tests (such as dose-response curves and determination of the LD-50, the dose toxic for half of an exposed animal population) used in evaluating the safety of chemicals, including food additives, colorants, preservatives, and agricultural chemicals.[46] Even before there were premarket testing requirements in the United States for such substances, the FDA's own pharmacologists began determining the toxicity of food impurities and adulterants, as well as testing drugs.[47]

In general, toxicologists assumed a level below which exposure hazards would be negligible; this threshold model put into practice the longstanding adage "the dose makes the poison."[48] However, this assumption was being called into question by scientists in two different fields. After World War II, national atomic energy agencies sponsored a great deal of genetics research on the effects of ionizing radiation. Geneticists found that radiation induced mutations even at low doses, casting doubt on the long-held assumption that exposures below a threshold were not harmful.[49] A new model of linear nonthreshold damage came to be standard for analyzing and regulating radiation exposure. This model raised questions as well about existing guidelines for low-level exposure to food chemicals, particularly carcinogens.[50] Second, pharmacologist Hermann Druckrey in Germany argued (1) that cancer was always provoked by environmental factors, (2) that there was no safe dose of a carcinogen, and (3) that carcinogens exercised cumulative and irreversible effects. The Druckrey-Küpfmüller equation, a statement of linear proportionality of carcinogenic dose to cancer incidence, became especially important in debates over food additives.[51] So while toxicology tests such as the LD-50 became widely used in screening chemicals, such laboratory experiments could not resolve whether there existed an exposure level for carcinogens low enough to be considered safe, especially for chronic, rather than one-time, exposure.[52]

Not all approaches to identifying exposure risks were laboratory based. After World War II, epidemiology became critical in tracking food-borne illnesses in populations—and, in some cases, discovering them in the first place. If invisible microbial dangers of food often made themselves known to the unwary consumer quickly, many of the newer hazards of food additives and contaminants were long-acting or latent, contributing to cancers or diseases that might appear years after exposure. Population-based studies could be used to identify long-term effects of exposure, although effects had to be very consistent to be detectable by epidemiologists. The multiplicity of scientific approaches to evaluating food safety generated the potential for conflicting findings and contested expertise. Was "pure" food defined by the lack of pathogenic microbes or absence of dangerous chemical contaminants? Were laboratory-based animal studies sufficient to identify toxicity and carcinogenicity of chemicals, especially at low doses? When epidemiological studies did not support results from toxicology tests about cancer risk, which form of scientific knowledge should be trusted?

In the US, congressional hearings in the late 1950s and 1960 about the safety of food additives led to new classifications of colorants by the FDA, as well as the so-called Delaney Amendment in 1958, which banned the use of carcinogenic food additives, exempting pesticides and common food compounds that were "generally recognized as safe."[53] This law reflected public perceptions of natural as healthy and artificial as dangerous, as well as a particular anxiety about residual chemical carcinogens in food, no matter how small the quantities. In this sense the zero-tolerance guideline for additives aimed not only to prevent carcinogenic exposures, but also to reinforce public trust in the safety of processed foods.

In contrast to the Delaney Amendment, US pesticide oversight was not governed by a zero-tolerance principle but by the need to balance costs and benefits of these economic poisons.[54] Similar arguments were made in response to public worries about residues of hormones and antibiotics given to livestock. In the view of industrial chemists, as well as that of most farmers and regulators, the advantages of chemical technologies in food production outweighed any disadvantages to consumers and wildlife.[55] By the 1970s and 1980s, such trade-offs were generally formulated in terms of risk, as seen in the proliferation of risk assessment in environmental regulation.[56]

Even as agrochemicals became indispensable to the functioning of the late twentieth-century food system, questions remained about the adequacy of regulations in place to safeguard human health and the environment. Beyond the technical complexities in calculating safety standards for food residues was the difficulty of justifying food chemicals to a public that would prefer "pure" food. The safety issues went beyond agricultural processes, as other pollutants reached the food supply through the environment. The potential for commercial chemical production to contaminate the food supply was made vivid in Japan in 1959, when an ongoing epidemic of neurological disease, with a mortality rate of 35 percent, was finally traced to mercury contamination in seafood from industrial wastewater released into Minimata Bay.[57] Thus, by the 1970s, dangerous residues on food could include microbial contamination, pesticides and other agrochemicals, substances used in food processing and packaging, and pollutants from industry and waste disposal. While the FDA remained the central oversight body for food safety in the US, these problems also implicated the USDA, EPA, and Public Health Service.

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In most European nations, analogous regulations emerged within ministerial departments. While not attempting a comprehensive global history, the chapters in this volume address some of the developments in the United Kingdom, France, and Germany. Studies of regulation have often approached the transatlantic divide as a question of delay: continental Europe was accordingly slow at adopting the FDA model of independent regulatory agencies with the consequence that mounting demands for European harmonization of the markets for drugs and food played a critical role in its generalization in the last decades of the twentieth century.[58] This volume amends this scenario in two ways. First, it shows that, from antibiotics to pesticides, issues were often similar, with numerous views on the nature of risks and the acceptable responses crossing the Atlantic.[59] Second, it suggests that the relative weakness of the agency model up to the 1970s was balanced by the strength of another "way of regulating"—that is, the regulation by professional bodies gathering veterinarians, pharmacists, or physicians whose role originated in an ancient delegation of power from the state to the professions with the granting of sales' monopolies and mandatory prescription as its core ingredients.[60]

International agencies, such as the UN's Food and Agriculture Organization or the World Health Organization, were also introduced during the period covered. The volume thus pays attention to international efforts at oversight of the food supply in what was then called the Third World. A rapidly expanding international food trade implied that similar risks could become matters of concerns in Europe and Africa or Asia, especially when exports from the latter to the former were at stake. However, the ways in which problems were framed and the responses designed and implemented rarely converged.[61] Inhabitants of the developed and developing world experienced somewhat different food risks—such as acute food scarcity in many parts of the global South as opposed to the overabundance of calorie-rich and nutrient-poor processed foods in many areas of the world—even if as the twentieth century came to a close most humans came to encounter food markets shaped by industrial capital and processing technologies. As our contributors show, this new reality did not lead to universal experiences; depending on which side of the great North/South divide one happened to live, available foods and safety regulations differed greatly.[62]

The Book

Our first section, "Objectifying Dangers," focuses on how certain scientific developments alongside the industrialization of food produced new kinds of expertise and perceptions of risk. These chapters focus on the changing tools and models that researchers used to assess the health hazards of exposure to

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low-level contaminants in food. They show how new knowledge challenges settled methods and assumptions for certifying safety in foods. Our authors focus on the detection of pathogenic bacteria, radioactivity, and carcinogens in food, hazards that caused widespread public concern as well as professional scrutiny—and areas bedeviled by critical scientific uncertainties.

As Anne Hardy shows in "Salad Days: The Science and Medicine of Bad Greens, 1870–2000," the popularity of watercress as a "wholesome breakfast salad" in Victorian England caused alarm among astute physicians. The streams necessary for growing watercress were often contaminated by sewage, so the greens could carry pathogens from human waste right back to the table. By the early 1900s, bacteriological methods confirmed the role of contaminated watercress in outbreaks of typhoid. Hardy notes that what we now call food poisoning became identifiable as such because enteric diseases such as cholera and typhoid declined in the early twentieth century (in the industrialized West). Moreover, the growing consumption of fresh raw vegetables over the twentieth-century, large-scale agricultural methods (including chlorine dipping of bagged greens), and increasing distance between production and market have provided new opportunities for the growth of pathogenic bacteria, including not only the well-known *Salmonella* Typhimurium and norovirus but also novel threats, such as the Shiga-toxin-producing strain of the usually harmless enteric bacterium *Escherichia coli* (*E. coli* O157:H7). Contemporary monitoring systems combine public health reporting with molecular genetic methods of typing to try to keep pace with, and contain, these new risks. Consequently, the tracking of pathogenic microbes in food now follows the genetic fingerprints of isolates, not only their species and strain.

Soraya de Chadarevian reminds us that it was the atomic age that first illustrated the potential for global contamination problems through the dispersion of fallout from atomic weapons testing. Radioactivity in the environment could make its way into the human food chain when contamination from weapons testing was taken up by fish in the ocean or by grazing cattle. Strontium-90 was one of the by-products of atomic fission that raised particular health concerns as it is chemically similar to calcium and is thus a "bone-seeker" in mammals. Moreover, it poses a long-term threat once in the body, given its half-life of over twenty-five years. In 1962, the British atomic energy plant Harwell conducted a thirty-day human experiment in which volunteer scientists were fed milk and beef contaminated with strontium isotopes. If this experiment, widely reported in the British media, was aimed at quelling apprehension about a radioactive diet, it did not succeed. Officials began monitoring milk for radioactive contamination and even working on possible methods to decontaminate affected milk. In the end, concerns about radioactive contamination making its way from the environment into food were soon extended to industrial pollutants, especially synthetic chemicals.

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Looking at the postwar German debates on food additives and their putative carcinogenic potency, Heiko Stoff highlights one turning point in the assessment of cancer risk—namely, the increasing tensions between academic experts, who insisted that there was no threshold below which absolutely safe conditions existed for carcinogens, and regulatory agencies, who argued that such thresholds were necessary in order to accommodate existing food production, avoid banning too many substances, and mitigate burdensome regulation on industry. The compromises thus crafted were the "acceptable daily intake" numbers written into the 1958 German food law. In contrast to the Delaney Amendment, the German regulatory regime admitted that zero exposure to potentially hazardous food chemicals was not feasible. Yet ideals of purity remained salient to German debates on food, which in the postwar period perpetuated discourses around "poison" that had been applied to the social body during the period of National Socialism.

Complicating the growth of knowledge about food contaminants and their hazards was a growing awareness that even the natural constituents of food may not be harmless.[63] As Angela Creager's chapter details, tools developed to detect hazardous environmental chemicals were turned on dietary plants, fruits, and meats, both raw and cooked—with striking results. After developing a quick laboratory test for mutagenic chemicals (as a screen for potential carcinogens), biochemist Bruce Ames found that many foods and beverages tested positive. Epidemiologists such as Richard Doll were also analyzing the contribution of diet to human cancer, often by looking at disparities in the incidence of particular cancers (e.g., breast, stomach) across continent or country. In an influential 1981 review article, Doll and Richard Peto estimated that 35 percent of human cancer was attributable to diet. Efforts to identify which constituents of food were carcinogenic, either inherently or due to cooking processes, led to countless publications and stories in the media. Results were often contested, but behind the debate was a growing consensus that diet, including the chemical composition of foodstuffs and cooking methods, was an important aspect of environmental exposure. This chapter connects the risk from food chemicals to the confusing, ever-changing medical literature (and media coverage) on diet and disease.

Also following the line of hazards in natural foods, Lucas Mueller addresses research into one of the most potent carcinogens known, the mold-produced aflatoxin. In the early 1960s, British researchers discovered that the deaths of more than a hundred thousand turkeys were due to aflatoxin-contaminated animal feed.[64] Soon thereafter, aflatoxin ingestion was found to be associated with liver cancer in human populations, especially in Africa. Although aflatoxin is a "natural" carcinogen, its presence in human food (as well as livestock feed) is a by-product of large-scale agricultural production and crop storage. As Mueller demonstrates, the food safety controls in the first world, where

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aflatoxin-contaminated crops were routinely destroyed, proved too politically costly to implement in the developing world. Public health concerns about mold contamination were countered by issues of nutritional needs (especially for protein) in postcolonial nations of the global South. These considerations impacted the calculations of acceptable contamination levels, which now appear to have carried their own health costs for children. Aflatoxin thus poses a conundrum for food regulators, pitting the struggle against food scarcity directly against health safeguards.[65]

Aurélien Féron's chapter analyzes the problems that have arisen from the family of toxic chemicals called polychlorinated biphenyls, or PCBs. These synthetic substances were produced in massive quantities since the 1930s and used in a variety of industrial and consumer products, from insulating fluids for capacitors and electrical transformers to carbonless copy paper. It has now become a nearly ubiquitous global environmental contaminant, found in wildlife from remote corners of the earth as well as in human populations. Its toxicity, long observed in the realm of occupational health, was publicly demonstrated in 1968, when PCB-contaminated rice oil in Japan poisoned approximately 1,600 people, killing five. As this example illustrates, dietary exposure is the way in which PCBs most threaten people, in part because the compound is soluble in fat, bioaccumulates (concentrates in living organisms), and magnifies up the food chain. Although national and transnational polices have been implemented since the 1970s toward the phasing-out of the manufacture, use, and disposal of PCBs, contamination continues to be a serious problem. In France, fishing remains prohibited in many bays and rivers because the concentrations of PCBs in the fish exceed the thresholds set for human consumption. Féron shows that the existing frameworks designed to bring pollution levels under control have not been efficient enough to fulfill food safety requirements that motivated these regulations. PCBs, as he demonstrates, are a recalcitrant problem for both social and material reasons.

The second set of chapters, "Ordering Risks," examines how industry, government officials, and consumers have understood the costs and benefits of agricultural and food-processing chemicals. National government agencies, as well as intergovernmental organizations (such as the UN's Food and Agriculture Organization), wrestled with regulatory regimes that would reduce chemical dangers without damaging food production—or the powerful agricultural and chemical industries behind them—but the result was the complex and multilayered set of laws, agencies, and safety systems that often protect business interests more than consumer health or the environment.

We begin this section with the use of growth-promoting substances in industrial meat production. Arsenicals, hormones, and antibiotics were widely used in livestock feed before their potential hazards to consumers were recognized. However, the thin line between growth-promoting and therapeutic uses of these substances in massive livestock containment lots complicated efforts at effective regulation. In "Trace Amounts at Industrial Scale: Arsenicals and Medicated Feed in the Production of the 'Western Diet,'" Hannah Landecker examines the rise of medicated animal feed and its close connection to the chemical industry. While the (over)use of diethylstilbestrol and antibiotics in livestock farming are commonly acknowledged, the first growth-promoting chemicals to be used in commercial animal feed were arsenic-based compounds. Organoarsenicals were first explored for industrial farming as a way to control diseases common in large chicken lots, but their surprising growth-promoting properties soon took center stage. By the mid-1940s they became a standard and widely advertised ingredient in chicken feed. Landecker shows how the attempt to chemically define and control growth, both in animals and humans, reflected a new understanding of animal economy, one that was literally fed by industrial production of chemicals. Inconsistent evidence that arsenicals were carcinogenic led to the relative neglect of this concern until the late-twentieth century, when the metabolism of arsenic in mammals was more thoroughly investigated. In turn, new conceptions of food and metabolism have shown the industrial framework that still undergirds livestock agriculture to be dangerously misguided, and, in the meantime, environmental arsenic pollution has also emerged as a major concern—one that has literally changed the living world and health risks for both humans and nonhumans.

Claas Kirchhelle's chapter examines why antibiotics proved so difficult to manage in the United States, focusing on how public health, agriculture, and drug regulation are separated into different government agencies. Introduced on an industrial scale to US agriculture in 1949, antibiotics were soon routinely given to animals to boost weight gain and combat disease, sprayed on plants, and used to preserve fish and poultry. Concerned scientists and consumers soon accused livestock farmers of leaving hazardous residues in food and of selecting for antimicrobial resistance (AMR). Regulators struggled to reassure critics. Traditionally, US drug regulation had been geared to regulate substances at the point of licensing. After licensing, it was nearly impossible to control drug use by lay users like farmers. The chapter reveals how officials in the FDA and the Centers for Disease Control (CDC) attempted to reconcile new risk scenarios such as horizontal AMR proliferation with classic regulatory protocols centering on the establishment of thresholds for hazardous substances and the containment of bacterial organisms. Kirchhelle argues that the US regulatory system's focus on proof of harm and preoccupation with toxic and carcinogenic substances repeatedly impaired its ability to recognize emerging nontraditional threats like AMR and to control food-related consumption of antibiotics, which remains unabated.

The remaining three chapters in this section further explore the conflicting demands made on the regulatory systems for food safety. Jean-Paul Gaudillière's contribution provides a fresh look at the "diethylstilbestrol and meat affair," which in the early 1970s focused on the carcinogenic effects of this analog of estrogen, especially its uses as a growth enhancer in agriculture. Concerns about residues of this synthetic hormone in meat led to important technical debates over the possibility of carcinogenicity at low doses, the presence of residues in consumed products, and the benefits of increased productivity. Using the records of the trial, in which the FDA—which had banned agricultural uses of DES in beef in 1973—had to defend its rule in the face of a challenge from industry, the chapter focuses on the influence corporations exerted on the production of knowledge and the process of expertise—that is, the conjunction of commissioned research, assessment of the published literature, and political action before and during the controversy. Discussing the merits and limitations of three main categories (conflict of interest, ignorance, and capture) that historians and social scientists have used for understanding influence, the chapter concludes with a plea for including *hegemony* in the palette.

In their chapter, Maricel Maffini and Sarah Vogel look back at the FDA's Delaney clause, which (as mentioned above) banned the addition to food of any substance that had proven carcinogenic in animals and/or humans. This decision stands out as exceptionally precautionary in a country whose regulatory frameworks more often accommodate industry, especially in the realm of agriculture. Why was this rule enacted and how did it last so long before being revamped in the 1990s? The authors explain that the exemption of "generally recognized as safe" (so-called GRAS) substances, which included many chemicals already used by the food industry, limited the actual effects of the law, and the slow pace of animal testing for carcinogenicity meant there were few additions to the list of banned chemicals. Thus even as Congress was credited with redressing known inadequacies of the 1938 food law, the GRAS clause created a self-certification mechanism that effectively enabled the food industry to by-pass agency oversight in most cases. In addition, the law provided no directives or incentives for academic or government scientists to engage in laboratory testing that would enable scrutiny of carcinogenicity data provided by industry. Such structural asymmetry is more often the rule than the exception and, in this case, explains why the number of chemicals tested and evaluated actually declined after the 1950s.

Xaq Frohlich examines another aspect of the FDA's regulation, namely the way in which the agency has created and maintained a distinction between food and drugs. As the regulation of drugs shifted from safety and standard dosages to utility, as seen in the 1962 reform and the introduction of clinical trials, the regulation of food not only remained solely a matter of safety but also became increasingly rooted in a paradigm of consumers' individual informed choices. Yet this distinction often breaks down in practice, both for consumers

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and producers, as illustrated by the growing "functional foods" market or the nutritional supplements industry. While scholars often point to examples of inadequate standards for food safety based on out-of-date science, Frohlich shows that regulation can be a source of innovation. The comparison between foods and drugs illuminates another point that is reflected by many other chapters. From the 1930s through the 1960s, manufacturers and FDA regulators generally tried to emphasize the inherent differences between food and drugs, drawing on the commonplace notion that food is familiar and self-evident in contrast to pharmacologically engineered drugs, whose manufacture is more complex. In fact, however, chemical technology is central to both the food and drug industries, which also share many toxicological practices and assumptions. Yet their regulatory regimes remain distinct. For one thing, whereas drugs must be shown to be efficacious as well as safe in order to enter the market, the nutritional value of food is not relevant to whether it can be sold, but only to how it can be labeled.

Legal differences between drug regulation and oversight of food production clearly guide industrial testing regimes. The burden of proof for the safety and efficacy of drugs is on industry, even as there are firm guidelines for what constitutes acceptable data. The pharmaceutical industry often complains that this burden, along with the expense of new research, is what keeps prices of prescription drugs so high. By contrast, firms in the agro-industry do not have to integrate (or even know about) health-related "use value" in their evaluation of products and their market potential. Safety matters, but the state's priority in assuring inexpensive foodstuffs means that certain levels of pesticides (still termed "economic poisons" in law) and other food chemicals are tolerated. When it comes to regulatory mechanisms, this translates into the infeasibility of instituting marketing authorization procedures for products from the food industry that would require data comparable to that produced by clinical trials—that is, involving medical scientists who are looking for health-related outcomes. It also perpetuates the fiction that food is "natural" and "traditional" while drugs are innovative. Additives have been the exception that proves the rule in terms of safety testing.

Taken together, the chapters in this section document two aspects of food regulation that might seem contradictory. On the one hand, we see the relative openness of debates, the permanent contestation of the regulatory proposals by industry, and the contingency of the legislation and rules adopted at some point. On the other hand are the pervading, almost permanent, structural asymmetries that were built in the regulatory machine accounting for the very limited impact new scientific knowledge has had on the practices of food production and food processing.

Considering this section of the book alongside the essays in part I leads to two further observations. First, many of the chemicals of concern were

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introduced to address other food risks, such as microbial contamination and crop failures. In this sense, chemical food risks arose in part due to the systematic efforts to make agriculture as economically productive as possible, and in part as a by-product of technological solutions to ensure sanitary food. Scientific and economic solutions to some kinds of risk—safety and scarcity—have, in turn, generated new risks of their own. Second, consequent to the massive reliance on agrochemicals in the mid-twentieth century, there have been significant changes in the technical knowledge and methods used to assess exposure risk, such as in the field of toxicology. This means that earlier standards for safety were based on what is now regarded as obsolete science—and in many cases, these older guidelines persist in the regulatory framework. Such technical obsolescence is a recurrent feature of high-tech societies, which must rely on the state of knowledge at a given moment for oversight of food safety. Yet this observation should not lead us to conclude that problems with existing regulatory regimes derive solely from scientific and technical inadequacies. To put it another way, the perceived "lag" between law and science draws attention away from the actual aims of existing regulation, including mollifying public distrust, providing industry with reliable standards and review processes, and not interfering with economic growth or innovation. Indeed, the food sector is a major market for the chemical industry, and safety standards generally reinforce mass production and heavy reliance on agrochemicals.

Conclusions

As a whole, *Risk on the Table* speaks to three important issues in the social science and environmental studies literature. First, as the title suggests, the book is in dialogue with a literature on risk that goes back to the 1986 publication of Ulrich Beck's *Risk Society*.[66] Pointing to risks in the nuclear industry as emblematic, Beck depicts technology's dangers as outpacing the ability of experts to control them. The history of food risk is in some ways a confirmation of Beck's pessimism. The turn to agro- and food chemicals in the twentieth century was aimed at increasing agricultural productivity and protecting food from spoilage and pathogens (as well as pests more generally). As we have highlighted, residues of these chemicals in food turned out to have their own hazards, and large-scale containment facilities for livestock have contributed to a resurgence of pathogens in food as well as antibiotic resistance in the clinic. That said, the cultural interpretation of risk by Mary Douglas is also especially salient for food.[67] Douglas argued that risk is a matter of cultural perception, not simply technological hazards. Notions of purity in food are deeply cultural, from bacteria-free milk to wholesome pesticide-free produce. Part of what has made consumers so suspicious of food chemicals is the perception that they are contaminating, impure. In the case of pre–World War II Germany, these cultural perceptions around food purity overlapped with ideals of a "pure" body politic, reinforcing anti-Semitism and the horrific policies of National Socialism. More recent politics of food purity have led to green consumerism without addressing the continuing massive reliance on agrochemicals in most food production. In sum, cultural frames about risk and purity complicate any simple critique of technology as endangering the food supply.[68]

Second, we ask what we can learn by comparing food and drugs when it comes to mass production and regulation. The social worlds of food and drugs share many features. Both were once in the realm of small-scale craft production before being massively industrialized, which has given marketing a central role in the making of value; both involve not only engineers and production plants but also older professionals with their own training and organization; and both are research-intensive domains giving the chemical sciences a fundamental place in the innovation machinery. Yet historiographies of food and drugs in the twentieth century have—in spite of a common interest by business historians—developed in rather different directions. The recent historiography of drugs has been dominated by three issues: the "molecularization" of therapeutic agents after World War II and its relationship with the rise of biomedicine; regulation and its relationship to clinical practice with the emergence of statistically based clinical trials as a gate-keeping mechanism; and the changing relationship between firms and physicians and the former's role in framing prescriptions and uses. By contrast, until recently the historiography of food placed less emphasis on the industries, focusing on farmers, local systems of production and their ecology, the diversity of their knowledge basis, and the inequalities associated with international trade and mass processing.[69] As a consequence, its scholarship often overlaps with environmental history—for instance, in studies of traditional food products, from rice to cheese.[70] By looking at food risks, the science used to define them, and associated regulations, this volume opens a path for a more systematic engagement between histories of food and drugs. As argued above, the comparison helps us understand the constraints that shape their regulatory patterns. Rather than offering a straightforward comparison, our collection interrogates the existence of the divide between food and drugs, shedding light on ways in which the boundary has been both crossed and (re)constructed during the past century.

Third, the meaning of "environment" is very much at stake in debates over food risk. For the last quarter century, environmental historians have been challenging scholars to rethink what they mean by "nature." Among others, William Cronon showed "wilderness" to be a romantic, sometimes nationalistic construct, and there is now a substantial literature on urban environments.[71] Our collection reinforces an observation made in recent scholarship that the distinction between "natural" and "artificial" is unstable and often symbolic.[72]

Even the whole foods that arrive on our tables are the products of complex technological systems. We worry about the hazards of added and contaminating chemicals in the food supply, even as researchers document the "natural" hazards of foods and traditional preparation techniques.[73] Moreover, standards of food safety tend to be based on laboratory studies dealing with single substances, pure chemicals, and controlled doses. By contrast, food consists of complex mixtures, whose nutritional content seems nearly irreducible to known constituents. Perhaps most significantly, eating is a major way in which we are exposed to our environment—by making it part of us. This collection helps us rethink longstanding ontologies of natural/artificial, pure/mixture, and outside/inside in an attempt to see food—its healthiness and hazards—in new ways.

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Notes

1. Foucart and Horel, "Le Bisphénol A"; Foucart and Horel, "Perturbateurs endocriniens."
2. European Chemicals Agency, "MSC Unanimously Agrees"; Vogel, *Is It Safe?* On the longer history of endocrine disruptors, see also Langston, *Toxic Bodies*.
3. After the events mentioned above and a negative vote on the proposed definition by the European Parliament, the European Commission revised its position, and the amendment Germany had proposed was deleted, thus clearing the way for a qualified vote on endocrine disruptors identification criteria, which took place in December 2017. Most scientists nonetheless consider the definition passed to be very restrictive and drastically limiting the number of chemicals falling under the REACH-based regulation of endocrine disruptors.

4. Proctor and Schiebinger, *Agnotology*; Oreskes and Conway, *Merchants of Doubt*; Nestle, *Unsavory Truth*.
5. For the tobacco story: Michaels, *Doubt Is Their Product*; Proctor, *Golden Holocaust*, who questions the voluntary nature of tobacco use for regular smokers.
6. As compared with earlier work (e.g., Levenstein's more comprehensive *Fear of Food*), we focus on worrisome contaminants associated with industrialization and agrochemicals in the twentieth century, as risk became a key regulatory category.
7. Petrick, "Industrialization of Food"; Zeide, *Canned*.
8. Chandler, *Visible Hand*, especially 287–314.
9. Stoll, *Fruits of Natural Advantage*; Fitzgerald, *Every Farm*; Harwood, *Europe's Green Revolution*.
10. Whorton, *Before Silent Spring*. In 1910, an Insecticide Act in the US was passed that set labeling standards for insecticides. But the board that enforced this act was situated within the USDA, whose mission was to promote American agriculture, including use of so-called economic poisons. Davis, *Banned*, 5–6.
11. Hamilton, "Analyzing Commodity Chains," 23.
12. Petrick, "Ambivalent Diet"; Petrick, "Like Ribbons."
13. White, "Chemogastric Revolution." She borrows the term from historian James Harvey Young, "Oral History of the U.S. Food and Drug Administration: Pharmacology, 1980," transcript, History of Medicine Manuscripts Division, National Library of Medicine, Bethesda, MD, on 123.
14. Freidberg, *Fresh*; Rees, *Refrigeration Nation*.
15. White, "Chemistry and Controversy," 225.
16. Ibid., 227; Levenstein, *Paradox of Plenty*, 109.
17. Hisano, *Visualizing Taste*.
18. White, "Chemistry and Controversy," 223.
19. Ibid., 230.
20. Hamilton, *Squeezed*.
21. Jas, "Public Health and Pesticide Regulation," 377.
22. Tilman et al., "Agricultural Sustainability."
23. Dunlap, *DDT*; Nash, *Inescapable Ecologies*, 127–69.
24. McGinn, "POPs Culture."
25. Marcus, *Cancer from Beef*; Landecker, "Metabolic History."
26. Schwerin, "Vom Gift im Essen"; Stoff, "Zur Kritik der Chemisierung"; Stoff, *Gift in der Nahrung*. For nineteenth-century uses of dyes from the chemical industry in food production, see Cobbold, "Introduction of Chemical Dyes"; for the growing use of food colors in the twentieth-century US, and their regulation, see Hisano, *Visualizing Taste*.
27. Stoff, *Gift in der Nahrung*.
28. Gaudillière, "Food, Drug and Consumer Regulation."
29. Wargo, *Our Children's Toxic Legacy*.
30. White, "Chemistry and Controversy," 362–409; Bosso, *Pesticides and Politics*.
31. Dunlap, *DDT*; Bosso, *Pesticides and Politics*; Marcus, *Cancer from Beef*.
32. Verrett and Carpet, *Eating May Be Hazardous*; Turner, *Chemical Feast*.; see also Wellford, *Sowing the Wind*.
33. Hardy, *Salmonella Infections*.
34. Podolsky, *Antibiotic Era*; Kirchhelle, "Pharming Animals"; Kirchhelle, *Pyrrhic Progress*.
35. Suryanarayanan and Kleinman, *Vanishing Bees*.

36. Biello, "Fertilizer Runoff."
37. Helgen, *Peril in the Ponds*.
38. Wilson, *Swindled*; French and Phillips, *Cheated Not Poisoned*.
39. Sturdy and Cooter, "Science, Scientific Management."
40. Smith-Howard, *Pure and Modern Milk*; Young, *Pure Food*; Cohen, *Pure Adulteration*; Sinclair, *The Jungle*. As is often noted, Sinclair's book was meant to draw attention to the appalling conditions for stockyard and meat packaging workers (in the name of promoting socialism), but it was the unsanitary food that horrified the public.
41. Young, *Pure Food*; White, "Chemistry and Controversy"; Cohen, *Pure Adulteration*.
42. E.g., French and Phillips, *Cheated Not Poisoned*; Jas, "Public Health and Pesticide Regulation"; Ramsingh, "History of International Food Safety Standards."
43. White, "Chemistry and Controversy."
44. Parascandola, "Historical Perspectives," 88.
45. Davis, *Banned*; Christopher C. Sellers, *Hazards of the Job*.
46. Lehman et al., "Procedures."
47. White, "Chemistry and Controversy," 194; Davis, *Banned*, 27–28. In 1947, federal pesticides regulation was strengthened to require premarket registration and authorization of fungicides, insecticides, and rodenticides. However, the US Department of Agriculture, which administered the law, was primarily committed to protecting farmers rather than consumers or wildlife. Bosso, *Pesticides and Politics*, 45–60.
48. Grandjean, "Paracelsus Revisited."
49. Creager, "Radiation, Cancer, and Mutation"; Schwerin, "Low Dose Intoxication"; Schwerin, "Vom Gift im Essen."
50. Boudia, "From Threshold to Risk."
51. Druckrey developed his theory in 1948 with Karl Küpfmüller while they were in an internment camp. See Stoff, this volume; Stoff, *Gift in der Nahrung*; Wunderlich, "Zur Entstehungsgeschichte"; Wunderlich, "'Mit Papier, Bleistift und Rechenschieber.'" For evidence of how Druckrey's views influenced discussions of carcinogens in food additives, see International Union Against Cancer, "Report of Symposium."
52. Pharmacologists at the FDA from the late 1930s through the 1950s led the development of toxicity testing, especially for chronic effects. White, "Chemistry and Controversy," 211–14; Davis, *Banned*.
53. National Research Council, *Regulating Pesticides in Food*; Maffini and Vogel, this volume.
54. Bosco, *Pesticides and Politics*.
55. See, for example, this book by a Dow chemist, whose rhetorical question he answers affirmatively: Barron, *Are Pesticides Really Necessary?*
56. Boudia, "From Threshold to Risk"; Demortain, *Science of Bureaucracy*.
57. Walker, *Toxic Archipelago*, 137–75.
58. Smith and Phillips, *Food, Science, Policy and Regulation*; Vogel, *The Politics of Precaution*; Daemmrich, *Pharmacopolitics*; Demortain, *Science of Bureaucracy*.
59. See also Kirchhelle, *Pyrrhic Progress*; Kirchhelle, "Toxic Confusion"; Stoff and von Schwerin, "Eine Geschichte gefährlicher Dinge"; Stoff, *Gift in der Nahrung*; Jas, "Adapting to Reality."
60. See also Gaudillière and Hess, *Ways of Regulating Drugs*; Anderson, "Drug Regulation and the Welfare State"; Corley and Godley, "The Veterinary Medicines Industry"; Jas,

"Public Health and Pesticides Regulation"; Bonnaud and Fortané, "L'état sanitaire de la profession vétérinaire."

61. Staples, *The Birth of Development*; Winickoff and Bushey, "Science and Power in Global Food Regulation"; Cornilleau and Joly, "La revolution verte."
62. See especially the chapter by Mueller, "Risk on the Negotiating Table."
63. The potential hazards of food's natural constituents also became visible in connection with food allergies, which generated intense medical and social controversy. Smith, *Another Person's Poison*.
64. The outbreak was referred to as "Turkey X," though it quickly became clear that it affected other animals and was responsible for trout hepatoma. Goldblatt, *Aflatoxin*; Linsell and Peers, "Field Studies."
65. Aflatoxin posed a conundrum for mold classification as well, since the toxin-producing strain is so similar to that used by Japanese to ferment foods. Lee, "Wild Toxicity."
66. Beck, *Risikogesellschaft*, translated as *Risk Society*. For a useful guide, see Boudia and Jas, "Introduction."
67. Douglas and Wildavsky, *Risk and Culture*; Douglas, *Risk and Blame*.
68. Along related lines: Shotwell, *Against Purity*; Tsing, *Mushroom at the End of the World*.
69. Excellent examples of the recent focus on food industry are Cohen, *Pure Adulteration*; Hamilton, *Squeezed*; Hisano, *Visualizing Taste*; Zeide, *Canned*.
70. Ceccarelli, Grandi, and Magagnoli, *Typicality in History*; Paxson, *Life of Cheese*.
71. For example, Cronon, *Uncommon Ground*; Ammon, *Bulldozer*.
72. Berenstein, "Making a Global Sensation"; Levinovitz, *Natural*.
73. Nash, *Inescapable Ecologies*.

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