ONE

California Strawberry Assemblages

Effective soil fumigation has been the forerunner of dramatic changes in the California strawberry industry. Instead of growing the crop 4–6 years, it is now grown as an annual or biennial crop, and planting is timed for each variety to achieve high first-year yields. First-year berries are superior to those of later years in fruit size and quality, and are the most economical to harvest. Also, through the research of Driscoll Strawberry Associates, Inc., a California corporation, it has become possible to grow a considerable acreage of the large-fruiting everbearing class of strawberries (the French remontant class). These exceptionally fruitful strawberries could not be grown on non-fumigated land because of extreme susceptibility to root diseases. Commercial breeding for *Verticillium* wilt resistance in strawberries has now been discontinued in California, and the breeding, thus, has been greatly *simplified*. Most importantly, soil fumigation has made lands available for strawberries which were previously avoided. These were the rich, fertile, alluvial lands with long crop histories.

Agricultural Scientists Stephen Wilhelm, Richard C. Storkan, and John M. Wilhelm, "Preplant Soil Fumigation with Methyl Bromide-Chloropicrin Mixtures for Control of Soil-Borne Diseases of Strawberries: A Summary of Fifteen Years of Development," 1974[1]

The *simplifications* of industrial farming multiply beyond the original target species. The multispecies modifications create ever more monsters—exploding numbers of parasites, drug-resistant bacteria, and more virulent diseases—by disrupting and torqueing the species that sustain life. The ecological simplifications of the modern world—products of the abhorrence of monsters—have turned monstrosity back against us, conjuring new threats to livability.

Anthropologists Heather Swanson, Anna Tsing, Nils Bubandt, and Elaine Gan, "Introduction: Bodies Tumbled into Bodies," 2017[2]

IN 2015, I WAS INVITED TO SACRAMENTO, California's state capital, to discuss my research with the director of the Department of Pesticide Regulation (DPR), Brian Leahy. Leahy is a former organic farmer who once presided over California Certified Organic Farmers, one of the premier organic farming organizations in the United States. Leahy was appointed director in 2012 by Democratic governor Jerry Brown following that tumultuous period when the previous DPR director, appointed by Republican governor Arnold Schwarzenegger, had all but ignored California environmental laws and her own agency staff in registering the highly toxic soil fumigant methyl iodide for use. It was expected that Leahy would take a more balanced approach to pesticide regulation, using science to weigh growers' needs against increasing concerns about the human and environmental health effects of agrochemicals. Having held many leadership roles in agriculture, Leahy had a reputation for working collaboratively with environmental organizations, agricultural groups, trade associations, and local government officials.[3]

I had just completed the interview phase of a project designed to understand how strawberry growers were faring with tighter regulations on soil fumigants. These regulatory changes included not only the international phaseout of methyl bromide and the abrupt withdrawal of methyl iodide from commercial use, but also tighter use restrictions on the remaining allowable chemicals. For fifty years growers had been using fumigants to control soilborne pests, most notably the fungal pathogen *Verticillium dahliae*, which can make plants wilt and die. At every regulatory juncture, the industry claimed that without these chemicals, it itself would wilt and die, and consumers would no longer see the luscious berries stacked on supermarket displays year-round. Director Leahy summoned me specifically to ask where strawberry growers now stood with soil fumigants. Just two years before, under his leadership, DPR had published an action plan for the development of practical and cost-effective ways to grow strawberries without soil fumigants. Along with laying out several lines of research for industry investment, the report suggested that fumigants were not long for this (California) world.[4] So Leahy was genuinely curious to know whether strawberry growers were undigging their heels, as it were.

I told him that fumigation restrictions were just one of the concerns irking growers. They were also complaining, mightily, of labor shortages, drought, high land values, low crop prices, and . . . bad press. "Yeah," he said, "the strawberry production system is insanely complicated." He was not the first or last to make such a comment. How can a crop, for many imagined as an inconsequential spring delight, garner so much adversity?

In many regions of the world, strawberries are a minor crop, available for a few short weeks in the late spring. But in California, specialty crops, grown for a national market, are big business. As early as the 1870s California farmers were abandoning wheat and barley production to produce oranges, stone fruit, and grapes—crops that were highly desirable if not always essential, according to the nutrition canons of the day. Dried, canned, or refrigerated, these crops were shipped in railway cars so consumers in colder climes could have a taste of summer year-round. Intensive vegetable production began some three decades later, when iceberg lettuce gained ascendance.[5] Strawberries were late in taking their place among California's pantheon of specialty crops. But by 2017, they were the sixth most important crop in terms of sales. In that same year, California was growing 88 percent of the nation's strawberries, while Driscoll's, a California company albeit with operations elsewhere, was selling 29 percent of the world's.[6] Only in recent years have other berries become economically important as well, as many of the major strawberry shippers have diversified into blueberries, blackberries, and raspberries. But strawberries remain the undisputed leader in the field, even as they are reportedly the most challenging to grow.[7]

California strawberries became big business because of the extraordinary gains in productivity that fumigation and other technologies propelled. With such productivity the strawberry industry needed equally robust markets and, thus, it needed consumers who would see strawberries as a near necessity. Luckily, changing ideas in nutrition came to its aid. Nutritionists rarely see eye to eye on anything these days, but one thing they do agree on is that fresh fruits and vegetables should be the cornerstone of diets. Among recommended fruits, berries rate as particularly virtuous. Not only are they not too sweet—a problem for the glucose-concerned crowd—they are supposedly chock-full of essential vitamins, minerals, fiber, and antioxidants.[8] Parents love them because their kids will eat them—one of the few fruits and vegetables that don't require too much cajoling. As it happens, much public knowledge of the health benefits of strawberries came as a result of the vigorous public-relations efforts of the California strawberry industry, whose gluts in production compelled attention to marketing.[9] These efforts apparently paid off. Per capita consumption of fresh strawberries in the United States almost doubled between 1994 and 2014, and berries as a group became the number one produce category for US grocery retailers.[10]

Despite these successes, the California strawberry industry is undoubtedly beleaguered. And it *has* had a lot of bad press. Take the report "California's Strawberry Industry Is Hooked on Dangerous Pesticides," published by the

FIGURE 1. Cheap, abundant strawberries at Haymarket Boston in February. Photo by author.

Center for Investigative Reporting in its *Reveal News* in 2014. In that report, reporters blasted the industry for its use of highly toxic soil fumigants and called out regulators for failing to adequately control them.[11] Or consider that strawberries continue to rank first in the Environmental Working Group's "Dirty Dozen," the list of fresh fruits and vegetables tested to have the highest amounts of pesticide residues.[12] This ranking does not even include soil fumigants, which are applied to the soil before plants go in the ground and therefore do not directly contact the fruit. With the highest pounds per acre of active ingredients applied, strawberry production entails the most intensive agrochemical regime of all California crops.[13]

Pesticides are not the only arena in which the strawberry industry has been the object of journalists' derision. In 1995, Eric Schlosser, future author of the muckraking *Fast Food Nation* (2001), published an exposé in the *Atlantic Monthly* about the California industry. The piece condemned a sharecropping system in which farmworkers are enticed into becoming farmers, incurring mounds of debt along the way.[14] Nor have labor pay and conditions escaped the eyes of the press. Beginning in 2015, Driscoll's became subject to a highly publicized boycott when strawberry workers on both sides of the US-Mexico border called for union negotiations to address the poor pay of strawberry workers at certain berry farms. Although Driscoll's wasn't the chief offender—and Driscoll's itself doesn't even have farming operations—the idea of the boycott was to pressure Driscoll's, as the largest berry shipper in the world, to exert leverage on its contract growers to recognize a union.[15]

Denunciations of labor conditions and pesticide use have been standard fare for specialty crop industries—those that produce high-value fruits and vegetables. This is because the delicateness and perishability of many specialty crops require abundant, cheap labor at harvest time and chemical treatments to make the produce both affordable and attractive.[16] But, unusually, the strawberry industry has received a spate of unflattering press about its plant breeding arrangements, too. This occurred when two University of California plant breeders announced their intentions to leave the university and join a private plant breeding company where they could make a lot more money. A series of lawsuits ensued, precipitating much bad faith among institutions that were once allied and accusations that at least some in the industry are driven by naked greed.[17]

No wonder the strawberry industry has become so defensive—and elusive. Websites of industry organizations and shippers increasingly emphasize the industry's contributions to sustainability, grower and farmworker livelihoods, and economic stability in strawberry farming communities, while the ever-enlarging group of interested researchers and journalists find that actually talking to people in the industry is pretty challenging. It was no small matter for me as a researcher to get in the door to speak with growers and other industry representatives. Some of those who generously agreed to be interviewed did so based on the implied understanding that I would tell their side of the story. In certain respects that is what I am going to do in this book, although perhaps not always to their liking.

Wilted is not a muckraking account, and I'm not interested in shaming the strawberry industry just because. My goal, instead, is to show how the very features that once made strawberry production so lucrative in the Golden State now pose grave threats to that very industry. It is not only that chemical fumigation is under the gun because of its toxicity to humans. It is that the entire production system has been built on the presumption of fumigation, rendering it resistant to change—at the same time that several other once-advantageous conditions have evaporated, leaving a suite of problems that are all the more intractable because of their interconnections.[18] Moreover, years of managing pests with chemical solutions amid dynamic environments has unleashed organisms that defy control. These heterogeneous and interactive threats make it nearly impossible to continue to produce what was once a luxury crop, available for a short time and at high prices, for the mass market. In that way, the solution of fumigation, once lauded for its efficacy and the "dramatic changes" it brought to the rest of the production system (as noted in the opening epigraph) has become the problem. Fumigation, I suggest, is the source of iatrogenic harm, referring to the problem of a cure causing illness.

The uncertain fate of the California strawberry industry certainly makes for a cautionary tale about industrial agriculture, referring to scaled-up, *simplified* monoculture accompanied by forms of exploited and often spatially transported labor.[19] It also exemplifies more generally the frailties of the so-called plantationocene, a term coined with the "ocene" suffix to denote plantation agriculture's imbrications with human-induced planetary crisis.[20] Scaled-up agriculture—with its dependence on environment-changing fossil fuels and pesticides, that is—has both contributed to the crisis of the so-called Anthropocene, but is also highly vulnerable to the pests, pathogens, and other environmental problems (for instance saltwater intrusions) that have come with climate change.[21] But unlike some who have deployed the arguably apocalyptic language of the plantationocene in oddly optimistic terms, I'm less certain that ruination is an assured outcome, or sanguine that it presents a way forward. The social, economic, and environmental conditions in which strawberry plantations are embedded, not least of which are the high-octane real estate markets of California, are unlikely to create the space for more heterogeneous and de-scaled kinds of food production anytime soon.[22]

Unfortunately, my conclusions are unlikely to satisfy either activists or the industry. Activists imagine an agro-ecological ideal that can be achieved with the right kind of experimentation. They imagine that the problem lies with the intransigence of farmers. I will show that it's the intransigence of the entire edifice that has been created through 150 years of strawberry growing in California. For their part, the industry sees a public out of touch with the realities of growing food that is affordable, appetizing, and widely available. The industry wants to stop being shamed and gain public acceptance of its practices. Those in the industry imagine that the problem lies with public misperceptions of the possible. Both parties, in other words, see the problem as one of opposing worldviews that need to be altered.[23] While it cannot be denied that activists and growers see the challenges differently, neither party wants to admit how political-economic limits have interfaced with ecological dynamics to make sustainable and just strawberry production highly elusive except in rare and not readily replicable cases.

EXPLAINING INTRANSIGENCE

Wilted traces how California strawberry production, so ripe with possibility in the early years, became so challenging. Much hinges on the emergence of soil-based plant pathogens and the solution of chemical fumigation as a way to address them. Once widely adopted, fumigation reverberated throughout the rest of the production system—in plant breeding, land access, labor practices, marketing, and more—locking in a particular way of doing things, at the same time that the social and ecological conditions of strawberry production were themselves changing to make fumigation less effective. Elaborating this explanation requires attention to three different kinds of actors and, in two cases, their guiding rationales. The first is *growers*, whose embeddedness in political-economic dynamics typical of agro-industry has made fumigation seem to them a necessity; the second is *agricultural scientists*, whose role has been to support growers through practices of repair; and the third has been the *multifarious nonhuman entities, materials, and forces* that have collaborated with the industry at some moments and thwarted it at others. Together, these actors have formed what I will refer to as a *more-than-human assemblage* that has increasingly come up against the *limits of repair*. In discussing the scholarship that has brought attention to the roles of these three groups of actors as well as to the fragility of agricultural assemblages, I provide a methodological framework for understanding the fate of the strawberry industry in California.

Growers and Political-Economic Dynamics

Although romantics like to see farmers as pursuing the virtuous vocations of tending land and feeding people, modern growers are businesspeople, imbricated in the dynamics of capitalism. They grow food to make a profit, and therefore they worry about accessing capital and having crop yields and sales adequate to pay their debts, wages, and land rents. This mindset has been especially true in California. Early orange growers in California, for example, saw themselves as businesspeople, not "dirt farmers," and approached the work of fruit production with the same zeal as their corporate brethren, embracing industrialization at every turn.[24] Today, as geographer Richard Walker has detailed, California agriculture has been saturated with capital through and through—capital, he writes, is the "invisible thread" "that weaves together all of the elements of the agribusiness system."[25] It is hardly a stretch, therefore, to draw on capitalist exigencies to explain the strawberry industry's heavy reliance on chemical fumigants. Indeed, social scientists of agriculture have typically employed the tools of agrarian political economy precisely to explain how farmers meet numerous challenges in crop (and animal) production.

At the core of explanations in agrarian political economy are questions of how agricultural industries have formed, and how they have come to both serve farmers and constrain them. As it happens, many of these explanations also revolve around the role of nonhumans in farm production. Indeed, agrarian political economy's central departure from classical political economy is its attention to the difference nature makes in agricultural production, distinct from in manufacturing, and how those differences create particular challenges for growers.[26] For one, unpredictable weather, perishability, seasonality, and various pests are major sources of risk. Yields may falter from disease, for example, or crops may rot before they are sold, diminishing farmers' chances to earn revenue.[27] Second, land in agrarian production is not just a site of production, as it is in manufacturing. Land itself is a condition of production, making soil fertility and quality something of value, and diseased or degraded soil something of concern. Since the quality of land affects yield, it also affects land costs.[28] Third, agricultural labor processes are different than in manufacturing. Workers do not actually apply their labor directly to produce crops, which grow through biological processes. Therefore, the role of agricultural laborers is to tend to these biological processes to enable yields, and then of course to harvest the crops once they are ready.[29] Given the seasonality of cropping, this labor is rarely needed year-round, which in theory has created challenges in recruitment.

Much of technological development in agriculture has been spurred by these challenges, with the aim of mitigating crop risk, making land more fertile, and easing and smoothing the work of farmers and farm laborers. Agrochemicals, fertilizers, breeding-enhanced cultivars (plant varieties), and farm machinery are all in these ways supposed to assist farmers—to make their incomes less volatile. But the production of these technologies has largely been hived off by businesses that manufacture the inputs and sell them back to farmers, in a process that agrarian political economist David Goodman and colleagues coined "appropriationism."[30] Examples of how appropriationism tends to reduce the centrality and risk of on-farm processes, yet forces farmers to pay for inputs, include the replacement of animal power with farm machinery, saved seeds with hybrid or transgenic seeds, cover crops and manure with synthetic fertilizers, and in situ biodiversity as pest control with manufactured chemicals.

Meanwhile, growers have generally not been well positioned to market their crops. Not only is marketing a distinct task from farming, but moving fruit to distant markets is more economical with dedicated cooling, packing, and shipping facilities to address issues of fragility and perishability. Although many of the original shippers of California fruit were organized as growers' cooperatives, including those for strawberries, nearly all fruit shippers have since become for-profit businesses. Some distribute only crops that others grow, while others—grower-shippers—market their own and others' crops. Since there have been many more growers than shippers, and growers must sell the crops in which they have invested or lose money, growers generally have had little bargaining power relative to shippers. Shippers have thus tended to set the terms of contracts with growers, including the prices they will pay for produce and the quality they expect. Even marketing cooperatives have tended to set high standards and often low prices.[31] Furthering their position of strength relative to growers, some shippers have developed capacity at both ends of the supply chain: selling inputs to farmers and then buying the fruit back for marketing. This remains the business model of Driscoll's, which fairly long ago ceased farming except for research purposes.

Suppliers and buyers are not the only ones that eat into growers' profits. To access the capital to pay for their up-front investments, growers must borrow from banks or others, and they must pay interest on those loans. To obtain the vital condition of production called land, they must pay either rents to landowners or mortgage payments to banks, unless they are so lucky as to have inherited land. And of course to access the labor of others to tend and harvest the fruit, they must pay wages—and sometimes a lot of wages, given the labor intensity of a fruit like strawberries. In short, growers must pay suppliers, creditors, landowners, and workers, while they are subject to what are often the low prices received from buyers, along with quality standards that force growers to discard crops that buyers deem unsellable.[32] Under these circumstances, it is no wonder that growers feel they have little choice but to use chemicals in the (anodyne) name of "crop protection." Without chemicals, their quality and yields may decline to the extent that their sales are inadequate to pay their expenses. Mortgage bankers and insurers may even stipulate that growers use pesticides.[33]

In effect, as agrarian political economists have argued, farmers are squeezed between suppliers and buyers.[34] Growers in fully capitalized farming systems, as California strawberry growers are, must purchase their farm equipment, fertilizers, seeds or (in the case of strawberries) starts, irrigation infrastructure, and agrochemicals from suppliers and then, once crops are ready, be subject to buyers' exacting quality standards and prices. Under these conditions, growers are attracted to yield-enhancing technologies in hopes that additional sales will help their income. Plant breeding, in that way, has come into play as a technology of not only risk reduction but also yield improvement, making plants grow bigger and faster.[35] The folly here is that as innovative farmers adopt yield-enhancing technologies, others join in, and production increases even more. Scholars have referred to this process as the technology treadmill, and strawberry growers are implicated in it as much as anyone. In the end, overproduction is a fool's game, since excess supply in the market generates competition and the poor prices that ensue—unless markets themselves are expanded.[36] Such competitive dynamics are beneficial to consumers, however, when they result in lower supermarket prices.

What I have described thus far is how most strawberry growers see their predicament: if they do not fumigate, they risk significant crop loss, and they may not survive economically. As individuals they of course vary in the degree of risk they are willing to face, prices they are able to obtain, and concern with the health risks of fumigants. But without a scalable alternative, or an economic cushion from elsewhere (for instance an inheritance), this is the bind they face. If they don't adopt the latest yield-enhancing technologies, they lose out, too, as others will, and prices will fall regardless. But they do not make these decisions on their own. They have turned to universities and other supporting institutions for both the development of these technologies and advice about when, where, and how to use them.

Agricultural Scientists and Institutions of Repair

In *Brazil and the Struggle for Rubber: A Study in Environmental History* (1987), environmental historian Warren Dean writes of an agricultural industry that never came to be due to the fungus *Microcylcus ulei*, endemic to the Amazon region. Although tapping wild rubber trees was of critical importance to Brazil's entry into the world economy, with rubber once comprising 40 percent of its exports, efforts at rubber cultivation were unsuccessful. The action of the fungus, discovered in plantations in Trinidad, defoliated the trees and decreased yield tremendously when it did not cause death. Wild trees were apparently spaced sufficiently apart to prevent a buildup of the pathogenic inoculum (the disease-inducing plant material), but not so plantation trees. Yet, as Dean argues, it was not the fungus per se that thwarted the development of the industry. Rather, human ignorance of a means to stop or ameliorate fungus attacks rendered rubber cultivation uneconomical.[37] This ignorance rested on insufficient institutional investment in investigating the problem and, hence, developing solutions. And so rubber cultivation was taken up elsewhere, where the fungus was not endemic, inexorably altering Brazil's economic development. The ill fate of the Amazonian rubber industry can be contrasted with that of the banana industry, which was also plagued with disease in its earlier years. Here the culprit was a strain of *Fusarium*, specifically *Fusarium oxysporum f. sp. Cubense*, responsible for what came to be known as Panama disease. Rather than thwarting the industry's development, as environmental historian John Soluri tells it, the appearance of fungal disease gave rise to new scientific endeavors, ultimately creating an institutional apparatus that would become part of the banana industry.[38]

Managing the biological characteristics of production to ensure the integrity of the end product is essential in any agricultural production scheme.[39] Since management requires knowledge, and since organisms, as well as inorganic elements, cannot speak for themselves, science has served as both a mediator of understanding as well as a means of improvement. Yet science is both a collective endeavor and a costly one, requiring not only instrumentation, laboratory space, and biomaterial but also collections of past knowledge to draw upon.[40] As a result, individual growers, in need of scientific expertise, have rarely been able to manufacture it alone. Instead, the development of agriculture and agro-forestry industries has required pooling resources and enlisting science and the state to do what private capital would or could not do by itself.[41]

And the state has for the most part complied. In the United States this support has largely come from the land grant universities, agricultural experiment stations, and research and extension services, all founded on the proposition that the government should support the practical professions.[42] Cooperative extension services, especially, enshrined in the Smith-Lever Act of 1914, were created to teach farmers the latest in agricultural techniques designed and tested by the agricultural experiment stations. With farmers as the primary clientele of research and extension, the agenda for agricultural science was set with farmers' interests in mind, and scientific findings have been translated in ways that are applicable to farmers.[43] Therefore, many extension scientists engage in the business of what the historian of science Christopher Henke calls "repair." Repair connotes the work of maintaining a system in the face of constant change—and sometimes crisis.[44]

In general, land grant university scientists have been highly responsive to the needs of farmers, and this is certainly true in California. In California fruit production, specialized shippers produced specialized growers whose economic advantages lay in specialized equipment and know-how. But the resulting monocultures attracted insects with no natural enemies. When pests threatened these emergent agricultural industries, the land grant universities stepped in to support the industries, first experimenting with biological controls and later aiding in the development of new pesticides.[45] These institutions, until recently supported almost entirely by the taxpaying public, have therefore provided a significant subsidy to agriculture.

The strawberry industry was one such beneficiary of the University of California's largesse. When industry leaders called upon UC for help in the 1920s, UC responded first with attention to identifying the diseases that were plaguing the industry, then with significant investments in plant breeding, and eventually with the development of fumigation. The success of fumigation freed the university to develop other techniques that would further improve productivity and shipping, including the use of plastic tarping, drip irrigation, cold storage, and much else. Indeed, it was the university's initial success in repairing these problems that brought the industry great success. As a mode of pest control, however, repair in the form of fumigation may have undermined future conditions of production, in no small part because of the role of the pests and other nonhuman actors, including, soil, plants, changing climates, and, for that matter, human bodies as biological entities.

More-Than-Human Assemblages

In his 2002 essay "Can the Mosquito Speak?" political theorist Timothy Mitchell wrote about how a set of seemingly unrelated elements coalesced to produce major outbreaks of malaria in 1940s Egypt, where the disease had not existed before.[46] These elements included the hydro-engineering of the Nile River, which created new habitat for the *Anopheles gambiae* mosquito. It included wartime-induced fertilizer shortages, as ammonium nitrate was diverted to war uses, resulting in famine and malnutrition that made humans more vulnerable to infection. It included sugarcane juice. Workers in the nascent sugar industry would chew on cane, not knowing that sugar worsened the effects of malaria. And, of course, the feeding patterns of the parasitic mosquito that requires human hosts to complete its life cycle figured importantly in these outbreaks.[47] Mitchell's purpose for this essay was twofold. One was to show the limits of sociological explanations when incommensurable, heterogeneous elements and conditions, many nonhuman and operating at different time frames and spatial scales, together helped bring the malaria epidemic into being. The other was to show the limits of human intention, action, and technics to fix these problems of hybrid nature, when interventions themselves depend on working with nonhuman actors.

In explaining the emergence of malaria, Mitchell essentially described what others have come to call a socio-natural assemblage, a constellation of heterogeneous elements and forces that in coming together are consequential.[48] Assemblage thinking enriches the explanation about how the strawberry industry came to rely on fumigants, as well as how this same reliance ultimately undermined the conditions of strawberry production, leading to iatrogenic harm. For one, assemblage thinking goes beyond agrarian political economy and its treatment of nature as a source of somewhat passive constraints or opportunities. In assemblage thinking, nonhumans play an active role of bringing phenomena into being. The implied agency of nonhumans is intended to connote not intentionality, but rather an object's capacity to produce an effect on another object.[49] A second is that it attends to the role of *multiple and disparate* objects, bodies, and forces that together produce phenomena, effectively acknowledging "distributed agency."[50] A third is that it recognizes the influence constituent elements have on one another; indeed, it is their "intra-action" that makes for the dynamism of assemblages.[51] In an assemblage, that is, constituent parts articulate so that perturbations in one area can affect others and even reverberate throughout the whole. In that way an assemblage "is not a mere collection of entities and things, but a complex and dynamic process whereupon the collective's properties exceed their constitutive elements."[52]

Some readers will recognize that assemblage thinking has affinities with actor network theory (ANT), and for that reason some have argued that assemblage thinking and agrarian political economy are incompatible. The fracture between these two approaches is significant. Political economy draws on a critical realist ontology that takes abstract and generalizable dynamics, tendencies, and concepts, such as capital accumulation or racism, as having as real and significant force in the world, whereas actor network theory imagines reality as based solely in the tangible material of the world, with the social constituted by the practices and conventions that translate this tangible material.[53] I follow those who use assemblage more ecumenically, who consider both the material elements and the abstract dynamics that come together in world making.[54] For the strawberry story, this explanatory heterodoxy is important. Not only have the intra-actions of plants, soils, fungi, chemicals, climate, and human bodies shaped the conditions of possibility for strawberry production, but so have tendencies, dynamics, and institutions like profit appropriation, land speculation, regulatory mechanisms, and university science.[55] Critically, sometimes these abstract forces work in tension with the tangible, material world. As we will see, land as property, a social relation, operates differently in the strawberry assemblage than land as soil, a material condition of production, just as labor as a factor of production has different valences than living, breathing, laboring bodies.

Assemblage thinking has been usefully employed by other scholars besides Mitchell who have sought to trace the emergences of diseases and blight.[56] Through this framework, states of disease or blight are *not* caused by a pathogenic entity that invades an otherwise-healthy body or plant. Neither the so-called pathogen nor the host have a particular essence. Instead, states of disease are imminent, and emerge as an effect of intra-action among the multiple agents that come to constitute the disease assemblage.[57] Writing on livestock diseases, geographers Steve Hinchcliffe and company take it a step further to suggest that it is the intensities of assemblage intra-action that create virulence—what they call a topological understanding of disease.[58] An example they provide is the proliferation of *Campylobacter* bacteria, a major source of foodborne illness. A variety of conditions make broiler chickens in mass-market production susceptible to the bacterium. Genetic uniformity, confined housing operations, and the purposeful repression of competing microflora such as *Salmonella* all seem to produce "the necessary physio-chemical conditions for the bacterium to spread both within the body and throughout the concentrated population." Yet things reach a tipping point when birds are sleep deprived and have their feed and water removed for twenty-four hours before slaughter. It is then that they are sufficiently weakened to become ill, making the disease not caught as much as incubated.[59] In discussing how the pathogens came to occupy the strawberry and preoccupy the strawberry industry, I draw on this topological understanding of disease.

Assemblage thinking has also been used to trace how efforts to intervene in disease situations are consequential—and not according to human intentions. Here Timothy Mitchell's comments are again useful, as he notes that human attempts to solve problems depend on collaborating with nonhuman actors whose actions often remain beyond human control. Notably, these nonhuman actors are not only other species, but may include nonliving actors such as chemicals.[60] So, for example, the use of DDT in malaria eradication campaigns had far-reaching consequences. These campaigns were highly effective in some areas because of DDT's ability to persist in the environment. But not only did the mosquito develop resistance to its use, DDT's accumulation in fat tissues spread its by-products throughout the food web. Its apparent ability to disrupt hormonal function, which was its strength, was passed on to other organisms. The pesticide, as Mitchell says, "had purposes of its own, well beyond the intension of research scientists and the eradication teams." So did malaria the disease, as it became resistant to the quinine drugs used to treat it.[61]

Anthropologist Alex Nading's work on dengue fever in Nicaragua uses something like assemblage thinking to make a similar case, but in addition includes how interventions can affect the bodies of workers in the business of intervention. Dengue fever is not only an outcome of complex entanglements that implicate such disparate elements as viruses, international trade, mosquito habits, water infrastructure, indoor/outdoor housing structures, and public health priorities.[62] Since *Aedes aegypti*, the mosquito responsible for dengue, lays its eggs in the tiniest of water fixtures, including flowerpots, tubs, puddles, old tires, and empty cartons, health care workers have been charged with visiting homes and attempting to eliminate mosquito breeding sites by slipping granules of a highly toxic chemical into these small bodies of water. As these health workers are exposed to these toxins through the skin, their own bodies are entangled in the dengue assemblage.[63]

These transitive harms, if you will, between chemical, target organism, and nontarget organism also occur in the strawberry assemblage, where efforts to control pathogens materialize into new pathogens and harm to the humans intimately involved in the assemblage. A "sad irony of pesticide use," geographer Ryan Galt wrote, "is the unintentional displacement of disease from one organism (the crop plant) to another (humans)."[64] But this book is about more than chemical toxic exposure to human bodies as a so-called unintended consequence of fumigation—as bad as it is in that respect. The changes wrought by the solution of fumigation, extolled in the opening epigraph, have extended into many other realms of strawberry production, creating something akin to what some theorists now call chemo-sociality, the relationships and emergent social (and ecological) forms that arise from widespread and unavoidable chemical exposures and dependencies.[65] Unfortunately, these new problems are not easily addressed through existing institutions and their ways of knowing.

Iatrogenic Harm and the Limits of Repair

A sine qua non of assemblage thinking is that assemblages are provisional: "relations form, take hold, and endure, but they also may change or be disrupted."[66] Often what holds them together, to achieve a kind of stability, is a great deal of human effort, taking the form of repair. For example, the Norwegian domesticated salmon assemblage requires constant checking, tinkering, checking, and repairing to hold it together. Despite this care, not only have parasitic sea lice proliferated, but previously unknown viral and bacterial diseases have appeared in the highly managed Norwegian fjords.[67] Norwegian salmon farming, while of quite recent provenance, is probably more elaborated than California strawberry production, which has been developing for over one hundred and fifty years. In any case, both employ an array of practices that constitute "cutting-edge" production schemes that build upon one another, thereby creating path dependencies for future operations. And yet, these over-evolved infrastructures, with their veneer of stability, can be a perhaps surprising source of fragility. With industry practices and infrastructures so rigidly developed, that is, the nonhuman aspects of the assemblage that escape human control become highly disruptive. Like plants that are pampered by not being exposed to pathogens, these highly pampered infrastructures are not resilient to perturbations, to immanent pathologies.

Assemblages are also vulnerable to changes among their constitutive elements. It is well established that pests can evolve to resist their chemical treatments and become more virulent, inducing farmers to increase the amount and frequency of treatment or seek even more powerful chemicals. This is the phenomenon referred to as a pesticide treadmill, but which some call a pest treadmill, denoting that the pests become the stronger.[68] Yet other nonhuman elements can play a role as well. For instance, in Costa Rican vegetable production, crop production in the cloud belt is much more susceptible to blight because of the relatively high temperatures and humidity levels. In particular, *Phytophthora infestans*, responsible for the highly potent fungal disease called late blight, depends on leaf wetness for ten to twelve hours to reproduce. Therefore, the resource-poor farmers who are relegated to land in the cloud belt are most prone to overuse pesticides, which in turn further deteriorates the soil, effectively undermining the future conditions of production as well as their own livelihoods.[69]

Crucially, many actors affect the conditions of possibility for strawberry production, and not all are subject to scientists' technical interventions—indeed, many exceed the capabilities of technologies to control them. In addition, many forces that bear on the conditions of production are simply outside the scope of institutions of repair.[70] As we will see, climate change is contributing to the appearance of novel pathogens and financial markets are raising land values, all affecting the future of strawberry production. Such dynamics are concatenating with one another as well, in ways that further constrain the ability to farm without fumigants. Truly, a range of socionatural threats bear on the strawberry assemblage, and any could break it apart. I will examine some in great detail as the book progresses.

Here, though, I want to introduce an additional, often overlooked, source of assemblage fragility, and that is a lack of scientific attention to the ecological changes the assemblage has produced, making the institutions of repair not well equipped to "repair the repair."[71] One impediment centers on the limited range of solutions that crop science can offer, given its scientific remit and its predilections for technologies that increase productivity or limit crop loss. University science has been much better at addressing underproduction than overproduction, the latter more a marketing and policy problem.[72] But again, overproduction has been a perennial source of problems for farmers, who lose out when gluts cause prices to fall. If success is measured by the ability to keep farmers in business, the record is not very strong for that reason alone. More generally, many problems have not been amenable to technological solutions (for instance, labor shortages until the introduction of robotics), and even those that appear to be (for example drought) may animate solutions not designed with cognizance to how they reverberate through the rest of the assemblage. Scientific specialization, while not the sole source of unexamined consequences, does not help.

A second impediment is that extension science has been caught up in a wave of privatization that threatens to make important innovations less accessible. Plant breeding, a major arena of repair, was never solely in the hands of the university. The development of hybridization allowed the "biological patenting" of plants, since hybrid cultivars do not "breed true" and must be clonally reproduced. This would send growers to the nursery or seed company every year, where their purchases would compensate the producers of these hybrid cultivars. The Plant Patent Act of 1930 gave additional protections for the inventions of private breeders. So despite the role of the land grant universities in improving hybridization technologies, much plant breeding was taken up by private interests.[73] In the case of strawberries, private breeders were involved in cultivar development from the get-go. Even after the University of California stepped in to became a major force in creating the so-called university varieties, their efforts were quickly matched by the Driscoll family and their breeding efforts. But the role of the universities in plant breeding became even more complex when universities began to see funding shortfalls due to public disinvestment and became more interested in industry collaborations that could support university activity. The Bayh-Dole Act of 1980 specifically extended patenting and licensing privileges to university inventors to encourage technology transfer to industry, while allowing the university and the inventor to retain revenue. So although the agricultural colleges, unlike the non–land grant sectors of the university, had long been transferring technology to the private sector, this new context creating salable technologies was encouraged by the university.[74] Since the Bayh-Dole law allowed university scientists to earn personal revenue from their inventions, it unleased an additional dynamic: university researchers, now making money on their inventions, saw opportunities to make even more money outside of the university. One of the crises threatening the industry is the deepening of these proprietary behaviors, as knowledge itself is increasingly squirreled away while growers have to pay for it in the form of license fees and high price inputs.

A third impediment centers on "undone science." The term "agnotology"—the study of ignorance—was coined by scholars investigating the deliberate suppression of scientific findings that would challenge state or corporate interests, such as science that disparages cigarettes or, for that matter, agrochemicals.[75] But other scholars have suggested additional reasons, besides deliberate suppression, why science can remain undone. Sometimes the research questions are not of interest to those commissioning it, or sometimes scientific norms constrain the development of certain forms of knowledge.[76] Sometimes science remains undone owing to the character of the institutions assigned the production and dissemination of the science. The fragmentation of disciplines can itself be a source of ignorance.[77] Soil science, for example, is a subfield of agronomic science, while soil science itself has many subfields. With the vast array of cropping systems in California, extension scientists specialize not only in agronomic subfields, but also in particular crops.[78] Therefore, agricultural scientists and extension scientists tend to be narrowly trained and focused, which undermines their ability to address the connections among various parts of agricultural assemblages.

Yet perhaps the most significant aspect of undone science is that past technologies of repair have created ignorance about the problems they induce. Given their mission to serve farmers, university agricultural scientists tend to ask only those questions that can lead to already imaginable and easy solutions.[79] Easy solutions, in turn, obliterate the need for further study, creating what some call "unknown unknowns."[80] Historian of science Frank Uekötter's work on the fate of biological approaches to soil fertility in postwar Germany is illustrative. As he writes, biological methods such as biodynamics remained in vogue in the 1930s, and much research was conducted on soil microbiology. Yet the answers this science produced were uncertain, and scientists investigating these approaches "faced stiff competition from the fertilizer industry and its army of advisors." So farmers abandoned complexity and embraced the easy fix of agrochemistry.[81] The fate of UC's Division of Biological Control followed a similar path. Even though the use of predator bugs to control pests proved reasonably successful at controlling cotton cushiony scale on oranges, ultimately growers found chemicals simply easier. Nevertheless, the easy solutions may have caused problems down the road that more refined approaches might have prevented.[82]

To be sure, the embrace of easy solutions often confounds understanding of how problems arise along with how the cures actually work.[83] Mitchell writes that engineers in Egypt could see that DDT was effective at eradicating the *Anopheles gambiae*, but they didn't know how.[84] Uekötter argues that the availability of fixes such as synthetic mineral fertilizers, chemicals, and machinery made investigations of much more complex ecological relations seem unnecessary. What answers might have arisen could never compete in their expediency.[85] Ignorance became strength, as Uekötter puts it, among farmers who wanted definitive answers and advisors who wanted to please their clientele.[86] Now, however, such ignorance can be added to the list of threats. With their tendencies to simplify ecologies through eradication, chemical solutions are particularly prone to introduce iatrogenic harm by altering the ecosystems they are supposed to mend.[87]

TELLING AN ASSEMBLAGE

Wilted tells how an industry grew out of many of the advantages that nature offered, including the heterozygosity (genetic variability) of the ancient strawberry, mild climate and sandy soils, the fumigant action of chemicals, and the energy of working bodies. These were intimately connected with many of the political-economic advantages the industry also had at its disposal: loose pesticide regulation, publicly supported agricultural science, undeveloped land markets, and politically constructed labor surpluses. But efforts to control emerging pathogens led to the singular solution of fumigation, which in turn ramified throughout the assemblage, changing breeding priorities, land use patterns, the cost of doing business, marketing needs—and the strawberry ecosystem itself, in ways yet to be countenanced. Additional threats emerged when those earlier political-economic advantages inverted into stricter regulations on fumigant use, tighter land markets, labor shortages, and an increasingly proprietary scientific apparatus. As the assemblage became more pathological, both ecologically and economically, the future of the California strawberry industry became more tenuous. Indeed, the strawberry assemblage became much like the strawberry itself: perishable, fragile, easily rotted, needlessly big because it is "bred" for the wrong things, and not particularly resilient.

I am not the first scholar to note that the intransigence of the socio-natural entanglements of California strawberry production has become a source of frailty. As sociologist Brian Gareau wrote in 2008:

> Some agro-industrial complexes, such as those tied to California's strawberry production, are built around particular historico-geographically constituted production conditions that are difficult to change. California strawberry production relies on certain technological innovations (e.g., strawberry varieties dependent on certain chemicals to combat plant pathogens), the creation of certain ecological conditions (e.g., climatic, soil and hillside conditions that make water-soluble chemicals difficult to apply), and a consistent labor supply (i.e., seasonal Mexican and Mexican-American laborers). Without these specific production conditions, the system would likely fail due to foreign competition.[88]

I expand on Gareau's comments by giving a detailed empirical account of those constraints, revealing the degree of entanglement and entrenchment of the strawberry production system, and suggesting that these conditions have continued to evolve in relation to one another and to human intervention. This has turned many of these erstwhile advantages into threats, regardless of foreign competition. In addition, I emphasize the role of science in attempting to improve the conditions of production but, owing to the nature of productivity-oriented applied science, failing to recognize, much less address, the socioecological changes that scientific interventions have bequeathed.

In telling the story I will use the term "industry" when referring to a set of human institutions and actors connected to the business of growing strawberries for a profit. Today that includes a collection of growers (about three hundred in California, reduced from prior years) who farm anywhere from a half an acre to more than a thousand; dozens of businesses that provide goods and services to the growers, such as nurseries, chemical applicators, pest-control advisors, and farm-labor contractors; and a relatively small number of buyers (grower-shippers, stand-alone shippers, and processors). I will separately refer to the institutions of repair that facilitated the industry's development, and include not only universities and the scientists they employ, but also grower cooperatives and growers' advocacy organizations. I will use the term "assemblage" when referring to the constellation of material things and social forces entangled in strawberry production: the organisms, bodies, plants, chemicals, soils, climatic conditions, border policy, land rents, and more. Even though industry actors and scientists are also part of the assemblage, treating them as distinct will reveal an industry operating according to capitalist, productivist logics yet enmeshed with organisms, infrastructures, and political conditions outside of its control, and closely tied to institutions of repair that have tried to bring those things under control.

I have chosen to organize the text around a few key elements of the assemblage—which, strikingly, I first identified through growers' laments. I begin with the soil pathogen *Verticillium dahliae*, the first of several soil-based diseases to have appeared in California strawberry fields. Soil pathogens are not the only pests that threaten the strawberry industry. Strawberries are affected by a range of other diseases and pests, including anthracnose brown rot, powdery mildew, bacterial angular leafspot, and mites.[89] Yet it was soil pathogens that first induced the nascent strawberry industry to call on the University of California to help, and it was soil pathogens that were addressed by fumigation. Telling the story of the pathogen thus provides the