Chapter Title: CONCLUSION. Corporate Bodies and Chemical Bonds: A Call for Industrial Embodiment

Book Title: Fractivism
Book Subtitle: Corporate Bodies and Chemical Bonds
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Published by: Duke University Press. (2018)
Stable URL: https://www.jstor.org/stable/j.ctv11sn393.16

CONCLUSION

Corporate Bodies and Chemical Bonds

A Call for Industrial Embodiment

> Those things which we see with our eyes and understand by means of our senses are more clearly to be demonstrated than if learned by means of reason.
> —GEORGIUS AGRICOLA (1546)

The science of metallurgy and mining did not emerge from theoretical structural chemistry, but rather from the physical experience of mining and forging metals. Through studying mines, miners, and metalsmiths across early Renaissance Europe, Georgius Agricola was the first to systematize the embodied knowledge developed by miners and metallurgists across centuries. Similarly, the practice of fracking emerged from drillers' physical experiences of attempting to increase well productivity in the real world, not in laboratories (Montgomery and Smith 2010).

In these cases, embodied experiences gained credence and became the grounds upon which to build new practices. Conversely, the embodied experiences of landowners and workers whose lives and landscapes are transformed by the shale gas industry are readily dismissed, silenced, and forgotten. Their stories of loss—of health, property, livelihood, social stability, even control over their own bodies—are deemed anecdotal, not scientific. Their exposures and illnesses are impossible to prove through traditional scientific methods.

Mike Edelstein (2003) described the physical and mental trauma experienced by communities and individuals impacted by toxic contamination as "inherently uncertain."

However, to residents experiencing the hazards of this expanding industry, harm is not "inherently uncertain." They *know* it through their *senses* and from their *experiences*, and they *learn* it through sharing their *histories*. As readily as fracking developed through tireless field testing to optimize the process for the broadest profit margin (Begos 2012; Shellenberger et al. 2012), Rick Roles, as one who suffers the costs and reaps little reward from fracking, was well placed to recognize its risks. This book began with Rick's fantasy of giving a taste of his embodied experience to an industry PR person by "breaking his jaw and letting him drink it." The "it" in this case was condensate, an industry waste product that the spokesperson purports was nothing but "guar gum and water." Rick implicitly asserted that the body is the proving ground where PR is tested against material risk and consequence.

This conclusion calls for an interdisciplinary effort toward industrial embodiment to record, aggregate, and remediate the material risks posed by this industrial activity so that the lives of those it harms can be improved. To build a networked understanding of our shared *corporate bodies*—the industrial systems that enable, sustain, and also endanger contemporary societies—environmental health research must begin with the embodied experiences of individuals. Building on Haraway's "Cyborg Manifesto" (1991), which urges feminists to embrace that our bodies are now both organic and technical systems, this conclusion asks us to build methods of accounting for the organic, bodily worlds built through industrial systems.

Bodies are not solely biologically determined. They are socially shaped. Definitions of what counts as a body depend on historical and cultural factors. Indeed research on embodiment finds that postmodern bodies are "spacing out" to become something people actively and self-consciously construct.[1] Based on this literature and inspired by the call for a "new materialism"[2] in academic work focused on connecting social critique to material change, this conclusion pushes further to ask, does expanding our notions of bodies to include industrial systems better account for industry's environmental and social impacts? Forming open-source informatics networks and supporting grassroots place-based research can help us collectively recognize ourselves as part of corporate bodies whose future is collectively determined by the shared physical and social relationships formed through networks of production and consumption.

The chemistry of endocrine disruptors connects us materially to the twentieth century's petrochemical fossil fuel–driven industries, forming "chemical bonds" that reveal our entangled biological connections to our environments. We cannot extract ourselves from these relationships by walling off our bodies into some separate space. Instead we are constituted by our interconnections (Haraway 1997: 37). To responsibly build our industries we need methods to trace, connect, socially reflect on, and shape these bonds that draw us each into new relationships of risks and possibility. How are we to account for chemicals that change the male-female sex ratio in a community or impact the rate of preterm birth (D. Scott 2010)? Presently science and technology assist in obfuscating these infrastructural connections, disabling effective collective understanding and oversight of these vital industries (Murphy 2006; Hess 2007a, 2015; Frickel et al. 2010; Frickel and Edwards 2014).

Merging critically applied and politically engaged environmental health and social science research can help draw this industry back into a space of civic contemplation (Faber 2008, 2011). "Civic" describes the collective body of common interest. A civic science rather than "simply serv[ing] the state" enables communities to "question the state of things" and investigate issues of collective urgency to shape them to preserve the commons (Fortun and Fortun 2005: 50). In pursuit of civic science, I argue for an informatics of industrial embodiment that enables us to have more participatory and recursive relationships with infrastructures that shape our everyday lives and embodied experiences (Kelty 2008). Our lack of awareness of our energy and chemical infrastructure is a product of strategies enacted by energy extractors and producers that *disembody* key infrastructures, making them into a heterogeneous entity that cannot be collected into a socially, historically, and geographically coherent whole that could be accountable for its actions (Mitchell 2011).

This book traced these processes of disembodiment. The conclusion summarizes and systematizes them so that future social and environmental health scientists can apply this model to other extractive industries and infrastructures. Methods of embodied industrial research are developed that counter corporate techniques that disconnect the oil and gas industry from places, people, and its own history. How can we better recognize, support, and teach these methods to form a corporeal civic science that enables us to democratically account for the bodily consequences of industry?

Rick's fantasy of forcing a PR person to physically share the risks he experiences relates three important properties of bodies.[3] First, they are materially connected to the world around them. Second, they shape and are shaped by the environments through which they travel, socially and physically. Bodies have histories that can be traced. They occupy space in measurable ways using a variety of metrics. However, bodily boundaries are porous, contested, extensive, and socially constructed. For example, a mother's body extends to her child during its development. An amputee's prosthesis becomes part of her body, both neurologically and socially. Third, bodies are therefore loci for exerting and impressing social and physical power (Foucault 1979).

Modern democratic states inscribed in law and socially normalized the idea of the bounded, rights-bearing individual body (Foucault 1979; J. Scott 1998). But scientific and technological development, history, and our own experiences show that bodies' boundaries are more flexible and porous than this (Landecker 2010; D. Scott 2010). As constellations of cells, organs, microbes, hormones, water, nitrogen, and oxygen that circulate blood, respire air, taste, and smell, bodies are sustained by and help sustain their "environments." The distinction between where a body ends and where an environment begins is a matter of scale and contested boundaries (Coole and Frost 2010). Research on microbiomes shows our bodies are constituted and co-inhabited by millions of other unseen organisms. These organisms travel within, on, between, and around us, extending beyond the corporeal to inhabit our environments (Betts 2011; Lax et al. 2014). Families carry similar microbial populations, comprising and sustaining a shared ecosystem (Dominguez-Bello et al. 2010). Freezing eggs for in vitro fertilization and cultivating stem cell lines from tissue samples change the boundaries of where our bodies begin and end (Landecker 2010). What (historically privileged) vision tells us is an exterior world, other senses and processes—touch, taste, smell, respiration, digestion, fever and pain, and technological intervention—remind us is a continuum with our bodies (Merleau-Ponty 2008). Bodies are complex selection systems adapted to make use of available materials useful for sustaining or reproducing our systems. They are vulnerable to materials to which we are unaccustomed and ideally expel those experienced and known as harmful.

Bodies are "legacy systems" organized in part by processes that historically enabled self-perpetuation and/or reproduction. Theoretically and on a molecular level, every living organism can trace back its ancestry. Bodies lit-

erally have history, though we require technoscience or other cultural mechanisms to divine it. For example, immune systems respond to germs, leaving antibodies behind that are both a hallmark of prior exposure and a system for recognizing and organizing future responses to a pathogen. Babies inherit from their mothers the bacterial cultures that inhabit digestive systems and help process food (Dominguez-Bello et al. 2010). Viruses leave their genetic imprints on human DNA, sending their encrypted genetic materials across bodily and species boundaries.

Bodies are also "feedback systems"; they process, transform, and expel materials that shape and are shaped by the worlds through which they move. As birds deposit plant seeds with their excrement, our bodies consciously and unconsciously select and support the life cycles and evolution of other lifeforms (Pollan 2001). Bodies' feedback mechanisms are vital aspects of both constituting and preserving the "self." For instance, hormonal mechanisms remind us we are sated with food. By technically manipulating food biochemistry with sucrose substitutes, like high-fructose corn syrup, that do not trigger satiation and artificially flavoring food in the 20th century, we began playing a whole range of sensorial tricks on our bodies that dislocate feedback loops evolved to help human bodies eat nutritious foods in limited quantities (Stanhope et al. 2009; Yang 2010; Page et al. 2013). These ongoing "self-experiments" baffle our feedback systems. They shift our biological legacies in open-ended, unpredictable ways and have so far produced not only low-cost foods but also rising obesity and type 2 diabetes, along with swathes of mono-cropped, pesticide-intensive, government-subsidized fields of patented corn and concentrated economic power in the hands of industrial agriculture and processed food companies (Johnson and Gower 2008; Lynch and Bjerga 2013; Ng et al. 2014).[4]

Thus bodies are complex environmental records that document how the world moves through them, and they leave traces, whether it be chemicals lodged in fats or virus DNA. Our bodies hold clues that can help us understand changes in our environmental human health (Betts 2011). There are no better sensors or indicators for our lived world than our bodies. It is time for environmental and social science to take this seriously and to apply what we can learn from it to counter manufactured hazards.

In addition to environmental science focused on the physical characteristics of body environments like the microbiome and exposome (the totality of human environmental exposures after conception) (Wild 2005; Rappaport and Smith 2010), social science needs to *listen carefully* to people's self-reported experiences and connect them to larger social, political, and economic changes.

Focusing on the body does not imply ignoring or eliding a person's reported experiences. People's unique biological and social histories "attune" them to different experiences. Chemically sensitive individuals are more apt to register and recognize their bodies' responses to chemical exposure (Shapiro 2015). Moreover, people can become attuned to recognizing bodily experiences, as an asthmatic may recognize triggers in an environment (Csordas 1994; Choy 2012a). Such sentinels' reports are frequently dismissed as the ramblings of hysterics, the irrational convictions of "nervous nellies," or baseless preoccupations of people who are peculiarly sensitive or otherwise pathological (Edelstein 2003; Allen 2004; Murphy 2006). We need to develop collective literacy around experiential phenomena so we have the facility to recognize, articulate, archive, and act on these embodied experiences (Shapiro 2015). It is particularly important to generate scientific and regulatory responses when embodied changes are collectively experienced and reported (P. Brown et al. 2004; P. Brown 2007). Such information should produce new collective questions for shared research.

Rick dreams of fighting this disregard in an embodied fashion, through physical violence to assert the reality of his experience. His anger was directed at the PR person, the corporately designated and paid social and political broker between the industry, the state, and the community. The spokesperson's assertion that frack effluents were "just guar gum and water" exemplifies the official industry dismissal of Rick's embodied experience. Rick knew that the PR person was wrong because (1) he lived surrounded by oil and gas extraction; (2) he was sick; (3) he was talking with his sick friends and neighbors; (4) his livestock was sick; and (5) he had occupational exposures while "roughnecking" (working) on rigs. Rick is an experiential witness to the adverse physio-social impacts of unconventional gas extraction. Despite over 15 years of communities expressing environmental health impacts associated with fracking, there is still *no formal mechanism for aggregating and collectively studying their experiences*. To expand on the body metaphor, there is no effective feedback mechanism to limit the activities of this corporate body. Rick could not occupy the privileged and privately funded position of spokesperson. His body and experience were excluded and dismissed.

Some may feel disquieted by Rick's fantasy of assaulting the PR representative with contaminated water. However, the interpersonal violence he imagined was physically direct and preventable. The violence done to Rick's body, on the other hand, resulted from different, persistent, long-term processes (Nixon 2011). No one forced him to drink condensate. Had that happened, he could have sued the culprit, established a point of exposure, and

been treated and received restitution. Because we have organized tort law around the idea of rights-bearing individuals, we have relatively well-developed, though frequently ineffective, systems for accounting for person-to-person violence. We lack similar systems to manage collective, systemic violence perpetuated directly or indirectly in the pursuit of profit (D. Scott 2010; Nixon 2011).

The damage Rick and others endure came from undocumented changes in the air they respired through their skin and lungs and the undisclosed pollution of the water they drank. Who bears responsibility? The drilling company? The fracking company? The leaseholder? The negligent workers who spilled frack fluid on his property? The chemist who designed frack fluid for its effectiveness in releasing gas from shale beds and who neglected to consider its impacts on surface life? Congress for exempting fracking from the Safe Drinking Water Act?

The agents of Rick's damage are impossible to pin down (Beck 1992). And this brings us back to the third relevant property of modern bodies: in modernity we developed a host of tools for tracking and tracing, disciplining, and socializing bodies (Foucault 1979). Unfortunately, Rick's opponent has no body. Unlike Rick's named, addressed, historically continuous and geographically transcribed body, the "industry" (comprising corporate "persons") is amorphous, multiple, heterogeneous, and ahistorical. We lack feedback technologies to track the legacy systems that perpetuate this industry and make the physical hazards it creates tangible, open to regulation, and hazardous to its continuity in the same way that its hazards are tangible and hazardous to Rick's survival (Fortun 2012).

However, the oil and gas industry does have a physical infrastructure. It is a circulatory system through which the world passes and is reconstituted. Its operations occur in particular places and are performed by particular people. It creates links between them and involves processes like extraction, circulation, refining, and emission, and it functions, in some senses, like a physical body. Under U.S. law, corporations have legal standing as people with constitutional rights to freedom of speech among other things (Hartmann 2002; Nace 2003; Wiist 2011). However, beyond the provision of rudimentary taxation systems, the "industry" lacks any mechanisms of recognizing either itself as a body or its physical, daily impacts on the organisms who inhabit it and social and physical environments it interacts with. Without this embodied information, it is extremely hard to call the industry to account for its assaults on others' bodily livelihoods. How and why is this very material, very physical, eminently traceable industry that is infrastructural to

contemporary society so hard to connect to both physical place and history?[5] How has it been socially disembodied?

Informatic Techniques of Industrial Disembodiment

This book empirically evidences two overarching approaches to disembodiment used in shale gas production: informatic and material. Together, they make the oil and gas industry hard to aggregate and to trace historically and geographically. Informatic techniques of disembodiment manage how the industry can be known and how it knows the world. These practices determine its relationship to history and enable it to shape the future. This book describes three techniques of informatic disembodiment seen in the oil and gas industry's development of the shale gas boom: agnotology, synoptic data-gathering systems, and PR practices.

AGNOTOLOGY

Agnotology is defined as the process of structured forgetting. It shapes what can be known about something by effecting what is or is not archived (Fig 2005; Proctor and Schiebinger 2008). Fracking's exemption from the Safe Drinking Water Act (EPA 2005) is the primary example of this practice, discussed in chapter 1. The Halliburton loophole made it impossible for the Environmental Protection Agency (EPA) to track and monitor fracking. In seeking to preserve themselves by protecting intellectual property, oilfield services companies created a regime of imperceptibility in which the tools and infrastructures of environmental protection, in this case the EPA, actually function to make hazards less perceptible (Murphy 2006; Frickel and Edwards 2014).

Nondisclosure agreements such as Laura Amos's are another tool of industrial agnotology. Laura is unable to definitively prove a link between her cancer and 2-Butoxyethanol (2-BE) exposure. She is forced to sign away her constitutional right to free speech in order to afford to leave her contaminated space. This systematically excludes her and others' stories from the archive. It wipes from history not the physical threat of harm (the contamination is still there) but the ability to socially mark her and her families' bodies and property, as well as the ability to connect her story with others in the future. It erases history and shapes the industry's future knowability and thereby accountability.

As also discussed in Laura's case, a third agnotological technique that helps to erase the industry's history is the use of subcontractual arrangements and corporate acquisitions (Appel 2011). Subcontracts mean that the histories of multiple operators at one well site are separated, making it very challenging to tell a combined coherent narrative about the place where they converge. Corporate acquisitions also create holes in history where the new well owner can deny knowledge of and/or refuse responsibility for what happened at the site before the change in well ownership (Fortun 2001). These agnotological informatic practices make it impossible to trace what happened at one well, or to one family, and to connect that information with others' experiences.

SYNOPTIC AND EXTRACTIVE INFORMATIC SYSTEMS

Synoptic approaches to information gathering that extract, centralize, and internalize knowledge and decision making, as discussed in chapters 5 and 8, are another important informatic technique of disembodiment. Seismic and satellite imaging exemplify this process in three ways. They (1) export data from regions of extraction to centers of calculation (Latour 1990); (2) reconfigure workers' bodies as mechanical and replaceable; and (3) are developed by engineers who have little contact with regions of extraction or meaningful understanding of the political and social consequences of the tools they develop.

Modern states and corporations come together in their shared interest in synoptic forms of data collection and representation (Chandler 1977; J. Scott 1998). To represent a space synoptically is to organize data so that one can view, from a single point (e.g., a map or a schematic diagram of a building) a landscape or system as a whole. This is the point of view of the architect or the manager who operates with a simplified and abstracted representation of the world that highlights only the features germane to their interests. A seismic map is controlled for surface noise and focused on the subsurface. It does not represent the surface because to do so would muddle the picture. Modern states develop such synoptic tools to manage their populations and territories as described in chapter 8 (Campbell-Kelly and Aspray 1996; J. Scott 1998; Bowker 2005; Manovich 2002; Foucault 2007). For both states and corporations, the mapping practices entailed within satellite imagery and seismic data collection enable calculation and decision making at a distance. The satellite is synoptic when working seamlessly because it offers a bird's-eye perspective over vast territories without having to transgress physical boundaries. Satellites collect abundant information while those who are imaged are

kept unaware. They are excellent tools for spying on neighboring states or people without visibly violating territorial boundaries. The development of satellite monitoring during the Cold War is not incidental. Satellites enable those who receive and therefore control the processed information to plan the future of faraway places without involving their residents (Farman 2010).

Seismic data similarly exported by oilfield services companies become treasure maps through which oil majors make plans for how they will configure social, political, and physical landscapes in order to access their subterranean resources. They help oil and gas prospectors decide where they will seek leases, from whom, what configuration of wells will maximize extraction, what legal and political barriers exist, how they can organize supplies to this region to support development, and which service companies will act as subcontractors.

These synoptic systems effectively disembody the industry from locations of extraction because inhabitants there have little awareness and even less control over the development of these plans that will literally shape their futures. Chapter 7 exemplifies this process with Ohio's eradication of home rule, or local control of zoning for mineral resource development. Political wrangling happened years in advance of well development without the awareness of suburban inhabitants whose lives and livelihoods would be impacted by the activities of extractive industries. Synoptic data-gathering tools are crucial to the industry's ability to shape experiences of time in regions of extraction, particularly the experience of acceleration as plans made at a distance rapidly unfold.

Chapter 5 describes how the technical design of synoptic information systems modularizes workers. These capital-intensive cyborg systems are designed to fit the bodies of workers, and workers are entrained to use these systems via simulations. A worker's individuality is irrelevant. The mind and history of John or Jane Citizen is not vital to operations. Instead, a choreographed role is developed into which any similarly trained worker can be slotted. Workers are organized to perform their tasks without having to understand the other parts of the whole system in order to keep it operating. This is agnotological too, because the workers become replaceable, like machine parts. Each worker-component can be calculated, trained, managed, and replaced. The historical particularities of individual worker bodies are removed.

Those designing these technologies and analyzing their resulting data experience similar detachment, as investigated in chapters 5 and 10. Engineers

are rarely trained to understand the social-economic implications of their work, and they do not see how technical systems enable different structures of power (Noble 1977).

PUBLIC RELATIONS PRACTICES

PR practices are not agnotological (enabling forgetting and shaping what's forgotten). Rather, PR shapes what is known, who knows what, and how they know about it (A. Brandt 2007; Oreskes and Conway 2010). This book describes a number of interoperating PR tactics: (1) the third man technique, which uses a trusted expert to expound a company message because that person's seeming independence and social capital promote consumer trust (A. Brandt 2007); (2) industry-related think tanks and research institutes that strategically produce research to create doubt about research on the industry's health and social hazards (Oreskes and Conway 2010); and (3) industry lobbying strategies and groups such as the American Petroleum Institute and American Chemistry Council that employ economic capital to promote favorable policies (Rampton and Stauber 2000).

Unlike the neoliberal academy, large-scale corporations take social science very seriously. While espousing ideals of individual choice and free markets filled with rational consumers, corporations fund advertising, research, and high-profile public figures in order to influence public perception of their products and to create and maintain markets (A. Brandt 2007). These practices are structured to tie the industries' interests to those of consumers and to create self-identification (A. Brandt 2007; Dumit 2012). For example, *Drill Here, Drill Now* ties shale gas development to national security. The "Mature Region with Youthful Potential" campaign tied shale gas development to economic progress and job growth in the Marcellus Shale region (IOGCC 2005). Corporations also create histories that tie them to states' economic and social histories (Fortun 2001; Rajak 2014).

Such campaigns are supported by industry spokespeople who are different in form and content than the replicable bodies of the mechanical workers inside their technical systems. Spokespeople are valued for who they are, for their individual social capital, life histories, and their ability to stand as experts. Experts, such as Secretary of Energy Ernest Moniz, frequently have revolving-door histories with academia and industry, allowing them to act simultaneously as disinterested experts and industry consultants, board members, and shareholders (Bender 2013; Connor and Galbraith 2013). Moniz

helps build the industry's market by accelerating approvals for liquid natural gas terminals that expand U.S. export markets and by advocating for switching to gas-fired power plants (Silverstein 2013). Such figures help create industrial niches that perpetuate the industry.

Experts connected to industry, particularly those who serve on panels to evaluate the health and safety of industry-related practices, are of immense value. As occurred with the 2004 EPA review, scientific and technical experts lend credibility to research and enable agnotological outcomes favorable to the industry's continued development.

PR disembodies industry, making its interest and influence very hard to trace. It manufactures doubt and builds myths and promises without having to produce deliverables. Its campaigns focus citizen-consumers emotively on their self-interest. They promote domestic oil and gas development on the grounds that it will help protect the homeland from terrorist violence, an agnotological move that ignores the historical collusion between western governments, the oil industry, and autocratic regime formation in regions of energy extraction (Bowker 1987; Peluso and Watts 2001; Hodges 2004; Ferguson 2005, 2006; Santiago 2006; Mitchell 2011). The U.S. role in creating Saudi Arabia's repressive monarchical autocracy in order to secure access to oil is well documented. It was described as America's "oil colony" in 1947 by the U.S. Secretary of State and was the homeland to Osama Bin Laden (Vitalis 2007: 31; Mitchell 2011; Nixon 2011). For all the rhetoric of oil producing national security, reliance on this system has driven humanity into a self-perpetuating state of permanent war in the name of security (Bennis et al. 2007; Mitchell 2011; Houen 2014). While natural gas promises to end our dependence on foreign (Middle Eastern, Venezuelan, Nigerian, etc.) energy supplies, we ignore that the same companies, the same tools, the same practices shape the extraction of this resource in the United States. In other words, these same companies (particularly oilfield services companies) are working on and profiting from domestic and international frontiers. Indeed the violence and instability of foreign energy resources are used to justify the sacrifice of gas-patch communities in the United States. The structural and transnational forms of violence inherent in this lucrative industry are made harder to see because the public expects laws and monitoring systems to protect them, along with elected and appointed regulators ready to defend the public.[6] How can we ensure that these legacy industrial systems do not perpetuate the economic, social, and political asymmetries that have historically appeared wherever this industry operates (Ferguson 2005, 2006; Santiago 2006; Mitchell 2011)?

Material Practices of Disembodiment

Informatic tools of disembodiment are supported by material practices that physically separate areas of extraction from centers of calculation and consumption as well as sites of extraction from surrounding social and physical landscapes. These material practices manage the oil and gas industry's relationship to place (Bowker 1987, 1994; Ferguson 2005, 2006; Appel 2011).

ENCLAVING

As described in chapters 4, 6, and 7, the practice of enclaving in oil and gas extraction was developed to extract oil efficiently for export while only minimally interacting with troublesome surface inhabitants (people). Enclaves build their own roads, run their own electricity, and operate behind "no trespassing" signs on a 24-hour basis. They disembody by reshaping landscapes through physical, legal, and social barriers. Enclaves try to operate in separate space-times. Life on the inside is organized around rapidly developing wells and drilling. The twin pressures of efficiently using high-cost machinery and the technical processes of well drilling, which must continually recycle drilling muds to keep the well walls stable, accelerate these procedures. Once established, a well operates 24/7 (Bowker 1994; Santiago 2006; Appel 2011). When not in the rush of technical development or production, or when gas prices are too low to make development cost-effective, the well pad is dormant, land-locked in idleness. Alternating acceleration and idleness creates temporal as well as physical disjunctures with other land-use patterns (Tsing 2004).

MOBILE, MODULARIZED LABOR

While the well pad itself is designed to remain for the term of the lease, the rest of drilling's physical infrastructure is mobile and modular (Appel 2011). Man camps house workers who sleep in bunks; they have no physical space for themselves and move in a cycle between spaces. The camps themselves are designed as mobile homes that can move from place to place so workers can be in the same space anywhere in the world. Using mobile migratory labor obscures the role of place and shared embodied experience in shaping workers' histories and bodies. Laborers generally work two weeks on, two weeks off, commuting to distant parts of the country, making it hard for

them to connect with the extraction region's inhabitants or with each other. This makes it very difficult for workers to form a shared understanding of their conditions. Local workers are brought in to do low-level work, including driving trucks and stocking and delivering materials. These positions do not enable them to envisage the whole system. Furthermore, migratory workers tend to be missed by epidemiological studies because of their temporary residency. Social science research has repeatedly illustrated the role of workers' wives, partners, and families in documenting environmental health problems (Brown and Mikkelson 1997; Allen 2003). Housewives, partners, and mothers in communities are well positioned to recognize emerging health problems by sharing stories. They realize when problems like birth defects or rashes are common. By building an industry around migratory workers, the formation of place-based community connections is thwarted. This makes popular epidemiology, one of the primary ways in which toxic contamination is effectively recognized, much more challenging (Brown and Mikkelson 1997). Place-based environmental health problems may well occur, but they are more difficult to recognize because place-based shared experiences and community are severed.

LEASING

This modular mobility characterizes the whole organization of fracking down to the very land-use contract structure of leasing. The term "leasing minerals" connotes a fundamentally inaccurate picture. In most circumstances when an object is leased, it is used and given back. Minerals are not leased. They are extracted and removed. The land is not returned in the same or even close to the same condition as it was before the lease. Furthermore, the long-term ramifications of that extraction that continue to exist in land and water are not borne by the leasing company, because it does not own the physical space. The practice of "remediating" surface acreage is the final piece of this historical erasure, creating a surface mask suggesting that land can be returned close to its former condition. As landowner stories repeatedly show (chapter 6), even surface remediation is rarely done correctly. Many states have literally forgotten where wells are because of poor requirements for well documentation and monitoring (Pennsylvania Department of Environmental Protection 2000). The EPA's research showed that these abandoned orphan wells create routes in which fracking chemicals and buried hazards can resurface (Horwitt 2011).

INSTRUMENTALIZING MATTER

The instrumental design, development, and use of chemical tools also obscure industry's connection to place. Biocides, acidizers, and 2-BE are all used in fracking to form and stabilize connections between the surface and subsurface. Biocides clear surface water of bacteria that might block the well, acidizers clean inside pipes, and 2-BE breaks up thick fracking fluid so gas can come to the surface. However, each of these chemicals also has material consequences for surface life. They can be poisons. Focusing on them as instruments in a particular task ignores their consequences for life. These risks are manifold and go far beyond the initial point of use. First, they include the risks of manufacturing such chemicals. In 2011 two companies manufacturing fracking chemicals exploded in Texas and Louisiana, respectively (Stengle 2011; Burdeau and McConnaughey 2011). Second, housing large volumes of such chemicals in urban areas have resulted in explosions, acid clouds, and evacuations (Frolik 2006; Hrin 2012). Third, bulk-transporting concentrated chemicals occurs along poorly maintained roads and railways,[7] and, fourth, there are continuing impacts, such as bio-accumulation, magnification, and recombination, once chemicals are used and in circulation (EPA Region 5 2014). Storage of wastes in open-air pits releases breakdown products into the air. Inadequate or faulty infrastructures cause fracking and other waste fluids to be released into waterways and soils (Horwitt 2011; Beans 2013; Jacobson 2015).

MATERIAL MIMICRY

Mimicry is the final material method of disembodiment examined in this book. Many chemicals came into common circulation as mimics (Wylie 2011b). Synthetic dyes replaced plant-based dyes and smuggled in totally different production methods (J. Beer 1959; Travis 1993). Plastics also mimicked available products. Consumers misrecognize such mimics as "just like" glass or plant-based dyes, but entirely new production processes are instituted (Fenichell 1996). Any product claiming to mimic an existing tool must be approached with great caution and its production processes carefully compared and evaluated (Taussig 1993). Many people leasing early in the Marcellus play believed that the wells they discussed with landmen would be just like existing shallow oil and gas wells (Grow, Schneyer, and Driver 2012). This misrecognition led them to sign leases quickly without considering the

industrial infrastructure associated with the production of shale gas versus conventional gas.

Taken together, these material and informatic techniques of disembodiment disrupt our collective ability to correctly perceive this industry's history and its relationship to physical places and people—our shared corporate bodies. They actively prevent the industry's embodiment, where embodiment is establishing traceable connections to physical places and people to create historical and geographic coherence so that the industry's future development can be shaped through disciplinary measures.

Informatics of Industrial Embodiment

These disembodiment strategies are legacy systems developed by the oil and gas industry to perpetuate its immense profitability by externalizing costs, limiting profit distribution, and rendering itself infrastructural (Mitchell 2011). The shale gas boom in the United States provides new opportunities to embody this industry, to make it democratically accountable, by creating feedback systems. I argue that this can be achieved through developing informatics of embodiment that trace and tie the industry back to place, consciously connecting the humans who inhabit this system and methodically gathering narrative data for decentralized analysis from multiple points of view. These techniques would enhance our understanding of this system and track its impacts on the physical and social well-being of people and places.

While this may sound like far-fetched idealism, it is important to recall that historically humans have not had such dislocated, disembodied relationships to their technical systems; embodied relationships to key infrastructures were vital to creating representative democracy as illustrated in chapter 9's brief history of coal and oil development. Gas and oil's structural invisibility actively impedes the grassroots formation of political power derived from influence over vital infrastructures. Communities along pipelines are unaware of the hazards beneath their feet. City pipeline infrastructures are so old that they leak massive quantities of methane (Phillips et al. 2013). Workers who become ill are not able to recognize that their illnesses might be work-related. Even if they do have Rick's insights, workers often lack the political and social infrastructure to investigate and settle their claims. This problem scales up to whole communities where cities are outbid for rights to their watersheds, leaving them powerless to protect their natural resources and intervene in shale gas extraction (Buchanan 2006; Lofholm 2006; Miller 2006; Spaulding

2006a). An embodied awareness of this infrastructure is urgently needed. Creating media to connect these communities and their experiences could bring energy production back into civic contemplation by enabling community involvement in gas development. The section that follows describes how tracing these relationships using informatics of industrial embodiment effectively develops feedback systems for corporate bodies.

TECHNIQUES OF INDUSTRIAL EMBODIMENT

Becoming a Beagle—Tracking and Collecting Surprises. Metaphors shape how we organize knowledge and perceive the world (Lakoff and Johnson 2003). As discussed in chapter 2, many scientific discoveries are framed around vision; geniuses have great insights or they reveal hidden truths. The scientific fixation on vision is bound up with ideas of objectivity that separate the observer from the observed (Haraway 1991; Daston and Galison 2007). This dichotomy is logically problematic. It perpetuates the illusion of being able to establish boundaries between two positions that are impossible to systematically maintain. Nor does this separation accurately account for the material processes through which new forms of knowledge or new material arrangements are made (Deleuze and Guattari 1987).

The social theorists Gilles Deleuze and Félix Guattari describe an alternative approach to both science and engineering that begins with physical experience (1987). Physical knowing does not generate a separation between the observer and observed. Rather, the two inhabit the same space, and one must identify the connections or "relationships of becoming" between things that at a glance appear separate. Deleuze and Guattari illustrate this co-location by contrasting two different ways of defining territory. The first way of knowing is built around synoptic tools like maps. A land is discovered, explored, and mapped. The map travels to the metropole where a state marks its newfound property by a boundary line drawn on the map. This line is then inscribed socially in the physical landscape. They describe this as "royal science," the process of separating form from content. Conversely, a second way of marking a territory is typified by dropping seeds into a river, waiting a while, then following the river to see wherever the seeds have planted and calling that one's territory. This second way engages with the environment by following how changes (seeds) travel through a system. It acknowledges that one can come to understand how a terrain operates only through its interconnections. While the first method represents a space and attempts to impose boundaries on it, the second interacts with an environment by inducing

change in the system and following it to understand how the system is composed. The second method is required to understand how a new element, seeds, or chemicals, in the case of oil and gas extraction, interact with and transform the systems through which they travel.

As argued in chapter 2, Theo Colborn implemented the latter method. I playfully called this beagling. She stopped trying to organize matter by the philosophy that toxic chemicals=cancer and instead started following and gathering up problems that appeared to be scattered, like accidents. Taken together these accidents told a story about a shared exposure to a flow of chemicals through a food chain and a shared vulnerability through similar biological systems and ecological positions. Colborn's beagling, or following the scent, took place from within the landscape rather than from above it. Her interdisciplinary aggregation of cases made the transition to a mode of research that followed relationships of becoming. Following and gathering these previously unimagined relationships formed by endocrine disrupting chemicals across the terrain of the Great Lakes mapped a complex interconnected system that had been systematically occluded by academic disciplines that separated information.

This is the first method of embodied research described in this book. It is a way of knowing that is less about standing back to see a terrain and fit it into a known pattern than following surprises and putting them together in a new configuration. Following Deleuze and Guattari, I imagine this as physically similar to the experience of building the first arch from pieces of stone. The physical skill needed to construct unlike pieces of rock together to stabilize a new flow of force across them into an arch requires integrated senses. As Agricola describes them, connections are felt and then seen. The finished arch can then be analyzed, studied, and diagrammed, and stones can be perfectly cut, so that arches can be readily and easily made. However, making this new form possible required a different process of knowing and making that follows connections to bring new possible arrangements of matter into being. Exploratory and embodied science made endocrine disruption visible. This is the kind of science best suited to perceiving the system-transforming dynamics of shale gas production.

BUILDING ON RELATIONSHIPS OF BECOMING

While mimicry is a method of disembodiment for those duped by what is mimicked, it can also be a powerful method of embodiment by revealing previously obscured relationships. The anthropologist Michael Taussig de-

scribes mimicry as the "nature culture uses to make second nature" (1993: xiii). This encapsulates the idea that mimicry, which at first glance seems to be a method for copying (reproducing the same), is actually a powerful force for social and material change. The phenomenon of endocrine disruption rests on mimicry, on the signal produced by a synthetic chemical being similar enough to the natural one to be misrecognized as an endogenous chemical signal, potentially changing the biological fate of the developing fetus. I refer to these errant chemical signals as chemical bonds. Like the seeds traveling through terrain in the earlier example, these chemicals create new relationships and connections across places. They bond people and organisms that are exposed into new relationships across and in a shared system based on shared vulnerability. This has been described as "chemical or toxic trespass" based on the logic that these chemicals transgress boundaries (Doyle 2004), but they actually follow and describe connections across perceived boundaries. For instance, estrogen and estrogen receptors evolutionarily make up the most ancient hormonal system (Thornton 2001). Hence, although mammals, fish, and birds may have diverged evolutionarily, they share biochemically similar estrogen-response pathways and hence a shared susceptibility to estrogen mimics.

This discovery of biochemical relationships can be both positive and negative. In our present system, where these bonds are created and systematically rendered imperceptible by techniques of disembodiment, they are indeed a form of bondage that torque a person's life off biological and social course (Bowker and Star 2000). However, these shared risks and susceptibilities can also describe new potential forms of social organization (Beck 1992). Such relationships of becoming might be leveraged to undermine this industry's insistence on modularization, individuation, and structured forgetting.

COLLECTIVE COMMUNICATION OF SITUATED KNOWLEDGE

To create a shared recognition of the phenomenon of endocrine disruption, Colborn brought together researchers connected to each individual piece of the puzzle to share data at the Wingspread conference. Organizing these researchers and separating them from their normal disciplinary habits to listen to each other's work created a social space in which they could, for the first time, recognize interrelationships between their data. With their findings put together, they could articulate a new, coherent story that no one individual had ever articulated. The formation of the Wingspread Group and their collective statement literally embodied endocrine disruption. It created a

heterogeneous group of professionals who now saw themselves as interrelated and researching part of the same problem. Their collective knowledge came not from being distanced observers but from their specific connection to a particular field of knowledge, and a newfound recognition of its connection to another specific or situated knowledge (Haraway 1988; Harding 2004). Networking these situated knowledges created its own disruptions: a pack of researchers calling for change in how disciplines are organized, how data are structured, and how toxicology is studied and applied.

HEIRSHIP—A FOCUS ON THE FUTURE THROUGH A CONNECTION TO THE PAST

Unlike disembodied and purportedly value-neutral objective science, embodied research is oriented to explore how research questions and methods are culturally based and politically shaped. Starting from the premise that we coconstruct our environments and communities through our scientific, social, and technical interventions, HEIRship regards humanity as the inheritors of our technical choices and evaluates our activities based on how they influence the next generation. HEIRship prioritizes the rights of the next generation, from an ecological perspective, one that sees humans not as masters of their environments or separate from them, but rather as recursively, organically bound to them through a family tree. It values rapid responses to emerging hazards, particularly those that may affect fetal development. HEIRship differs from laboratory-centric "basic" research because it investigates the consequences of human engineering on humans—in the field biologically, socially, and ecologically.

While informatics is normally counterposed to embodiment, with data being extracted from physical objects to be manipulated in computation (Haraway 1991), The Endocrine Disruption Exchange (TEDX) use of HEIRship (as described in chapter 3) attempts to capture how databases can enable embodiment by creating historical consistency and comparison across fields. HEIRship is fundamentally an archival practice that operates by following (beagling) and collecting surprises, then arranging them by their connections (the database structure does not predate the data) in order to recognize relationships of becoming. Lorraine Daston has described how databases are sites for research because they enable new lateral patterns to emerge across archived materials (2012). HEIRship aims not to necessarily answer existing research questions but to generate new questions.

As a proactive form of research, HEIRship connects multiple kinds of actors to shared questions simultaneously so that they can begin investigating them in their different arenas (Fortun 2004). Rick Roles could take the TEDX database to his neighbors, Josh Fox could use it to begin his film narration, Susan Nagel could begin studying endocrine disruptors in water sources, and the EPA could begin examining fracking under Superfund designation.

HEIRship describes both the scientific and socially produced data gaps caused by regulatory exemptions, such as the problems with material safety data sheets and the use of trade-secret laws that made studying shale gas's chemical hazards impossible. Fusing these two forms of data analysis, TEDX enabled both scientific and political partners of the organization to begin working on the different attributes of this problem. The database of potential health effects of chemicals used in gas extraction became therefore a platform for "sound advocacy" (see chapter 3), a map through which to begin contesting, questioning, and researching the safety of unconventional extraction from many perspectives simultaneously.

Royal science and technology development are tuned to state and corporate interests in tracking and instrumentally mapping citizen-consumers and resources. As discussed in chapter 8 the development of computer databases and maps is bound up with the state in developing tools to count, tax, and map citizens (Campbell-Kelly and Aspray 1996; Manovich 2002; Bowker 2005). With the emergence of the Internet, decentralized or participatory maps and databases became possible and can be used to contest formal maps (Farman 2010). Presently, however, the informatics of the state are being channeled into protecting the state, for example, by aiming to sort terrorists from nonterrorists. The National Security Agency's PRISM program, as an example, illustrates the huge scale of state-based informatics (Gellman and Poitras 2013; Greenwald and MacAskill 2013). Similarly, the use of the web's metadata properties, including the traceability of online presence, enables corporate counting, classification, and individuation of consumers (Levy 2010; Vaidhyanathan 2011; Madrigal 2012).

By focusing purely on economic measures of corporate activity and conceptualizing them as chiefly economic rather than social, scientific, and environmental actors, we relinquish the ability to evaluate their activities from the perspective of civil society, or to understand the vast industrial systems that employ people and shape environments worldwide. From a social science perspective, HEIRship would create informatics systems that embody corporate actors rather than citizens, recording coherent histories for corporations,

connecting them to places and people, and improving our ability to hold them socially and politically accountable. ExtrAct's shift to informatics was inspired by Colborn's use of databases, described in chapters 3 and 4. ExtrAct began from embodiment by focusing on collecting and networking communities' experiences and knowledge.

WITNESSING AND DEVELOPING EXPERIMENTAL ENVIRONMENTAL SCIENCE

Importantly, both Colborn's database and ExtrAct (see chapter 6) began their research with the lived experiences of people who are encountering industry in their everyday lives. In environmental science as it is currently configured, such "findings" are frequently dismissed as anecdotal. This word is an absurdity when examined in the context of both experimental research and legal paradigms. Representative democracies built legal systems around the idea that humans can credibly witness and report on events. Testimony is not disregarded because it is anecdotal. Indeed, experimental science is also built around the concept of witnessing, as research in science and technology studies shows. The experimental program is built around the idea that humans can gather to watch an experiment, observe the phenomenon, report upon it, and come to an agreement about what they have seen (Shapin and Schaffer 1985). Why do we accept such witnessing in the lab and disregard it in the field? In part because we fail to recognize that the field is a space of experiment.

One central problem in building an environmental science focused on connecting industrial hazards to environmental and human health issues is that we currently develop knowledge about industrial harms in laboratories where chemical behaviors are modeled. Laboratory results in model organisms or testing regimes are used to establish regulatory limits, without a thorough feedback system documenting the actual behavior of those chemicals in the environment to determine whether or not the initial model is accurate or protective of human health (Murphy 2006; Frickel and Edwards 2014). An environmental health science built around gathering and connecting embodied experiences would be a first step toward systematically monitoring the large-scale, industry-based environmental experiments to which we are currently subject. Epidemiology attempts this kind of process through cohort studies, but because it is not organized by exposure route, that is, connecting industry workers and communities living near fracking, or networking communities as active developers of research programs, it misses large bodies of

potential information. Instead, epidemiologists are left to work with abstract public health statistics and insufficient data about exposure. And communities are left to experience their problems in isolation.

Embodied experiences should be gathered and networked to understand whether they have a systematic basis. Specifically, informatics networks should be generated to interconnect workers, thereby counteracting frayed community knowledge produced by migratory labor. Similarly with work in experimental sciences, any surprises should become the departure point of further research (Rheinberger 1997).

PARTICIPATORY AND RECURSIVE DATABASES AND MAPS

Gas and oil activities need to be reconnected to both physical places and histories via the development of maps and databases that enable communities to begin taking an active role in describing and shaping the infrastructures that produce their social and physical realities. Properly designed platforms like WellWatch could connect individuals with similar problems to help them form communities. These could then connect those individuals to experts who would offer advice and make visible systemwide problems. These databases should be public, open-source, and collectively maintained through academic-community collaborations. Taken together such systems could articulate corporate bodies by connecting diverse people whose lives and livelihoods are shaped by these structures in order for them to (1) understand their structural interdependence and (2) enable them to project possible alternative arrangements (DiSalvo 2009). If industry contamination damages property, then that damage should be socially marked and people should be properly recompensed, enabled to move and connected with a community of similarly displaced persons who can together watch-dog the industry and advise others who may be forced into similar circumstances in the future. Our system presently displaces these costs onto impacted landowners, encouraging them to mimic industry practices, that is, to hide damage done to their property so they might be able to resell it and escape (Wylie and Albright 2014). This divisive thinking perpetuates, obfuscates, and devalues injury rather than analyzing it, accounting for it, and remembering it.

It is this tangible record, a valuation of embodied witnessed impacts, that WellWatch tried to gather. It is the networked and diverse impacts of all the different fracking chemicals that TEDX's database attempted to capture and make legible. We have informatics tools available to predict and recognize

these chemical bonds and to gather and collectively visualize the grassroots hands-on experiences of workers and residents. Organized through online databases, we can build participatory and recursive relationships to infrastructures like the energy and chemical industries (Kelty 2008). As occurred with the earlier history of coal, we can develop a shared infrastructural awareness and work toward reshaping that infrastructure to reduce environmental health hazards and increase social and political accountability.

GRASSROOTS SCIENCE

To more fully engage citizen-consumers' agency in creating industrial systems, people should be empowered to make knowledge about this system through grassroots research (Wylie et al. 2014). Citizens can do much more than simply report on their experiences. They can gather data systematically, through structured observation or by using scientific tools as basic as phone cameras (Corburn 2005; Ramirez 2014; Wylie et al. 2014). We need to empower ourselves to be the researchers and engineers of our own conditions by designing tools for grassroots research (Brown and Mikkelson 1997; Allen 2003; Ottinger 2010). We already see these trends in health and environmental controversies, where communities organize their own research, fundraising, and even laboratories (Allen 2003; Corburn 2005; P. Brown et al. 2006; Ottinger and Cohen 2011). Organizations like Public Lab and TEDX, along with communities, are becoming proactive in filling in the gaps in our understanding of industrial systems through local air- and water-quality monitoring efforts (Colborn et al. 2014; Macey et al. 2014). Making the most of this ability requires creating systems for data validation that make use of digital metadata to time-stamp and GPS findings, store raw data, create chains of custody, and prove tool calibration, similar to methods used in meteorological or ornithological citizen science (Fritz et al. 2009; Edwards 2010; Marris 2010; Timmer 2010; Khatib et al. 2011). Humans can expand their social-technical sensorium to track and collectively study industrial systems just as we have "natural" ones. Rather than exporting data, the products of this research would be owned by communities and licensed for use in public interest research (Wylie et al. 2014). Aggregated results from such systems should be available to companies, but these systems should not be owned or operated by vested industry interests for whom obscuring, minimizing, or erasing damages is beneficial.

Conclusion

To enable inhabitants and laborers in regions of oil and gas production and consumers of oil, gas, and related synthetic chemicals to scientifically study and democratically account for the embodied impacts of these industrial systems, I argue that we need to develop an informatics of industrial embodiment: (1) to develop and sustain open-source, decentralized informatics systems that network communities in extraction zones; (2) to begin research with individuals who have everyday experiences of living and working amid extraction industries and empower them to study and share their experiences; and (3) to actively connect these communities with academics, regulatory agencies, journalists, and lawyers in order to form responsive research and monitoring networks. Such networks should be protected as sites of research rather than legally constrained as websites, and they should be funded publicly as part of the public interest in protecting environments and health and civil liberties.

Clearly, there are barriers to these sweeping changes within contemporary governance structures, including secrecy, efforts to prevent coordination between agencies, and the influence of large-scale industries within government agencies, universities, and among regulators. However, it is important to note that citizens do not have to ask permission to express subjective experiences or to do research on their private property or on public property. Nor are there barriers preventing open-source research tool and software development in the public interest. Similarly, academics are free to work with communities and many agencies have mandates for public engagement. Public libraries, nonprofit organizations, and science museums could make excellent partners for further developing grassroots environmental health research.

Movements are aggregations of small-scale acts that evoke change from the ground up. The goal of the projects and methods described here is to create spaces that facilitate such embodied recognition and collaboration to transform shared physical and social energy infrastructures. If civil society is to monitor and thoroughly account for an industry as vast, distributed, and politically, technologically, and economically influential as the oil and gas industry, then the academy, bureaucracies, and advocacy organizations must transform themselves to rise to this challenge. Participatory and recursive databasing and mapping offer novel opportunities for such transformations. They enable deeper civic engagement in embodied knowledge development and industrial monitoring. The question remains: Can we make the academic, social, and political investments to realize these possibilities?

Agricola, the 16th-century "father of metallurgy" stressed the importance of demonstration and experience in coming to know a substance. He argued that though "many persons hold the opinion that the metal industries are fortuitous and that the occupation is one of sordid toil, and altogether a kind of business requiring not so much skill as labour," the metal industries are actually grounded in both physical skill and natural philosophy stemming from a physical awareness and understanding of surface and subterranean landscapes (1556: 1). He listed seven arts and sciences of which the miner must be knowledgeable: natural philosophy, medicine, astronomy, surveying, mathematics, architecture, and law. Remarkably, medicine is listed as the second most important skill that the miner should possess so that he might be able "to look after his diggers and other workmen that they do not meet with those diseases to which they are more liable than workmen in other occupations, or if they do meet with them, that he himself may be able to heal them or may see that the doctors do so" (1556: 3–4). This prescient insight and prescription is sadly unfilled today (Esswein et al. 2013, 2014).