Why do Biologists and Chemists do safety differently? The Reproduction of Cultural Variation through Pragmatic Regulation

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Abstract

Explanations for the variation in compliance with legal regulations range from accounts of inconsistent and lax enforcement to misaligned incentives, with much recent scholarship and policy advocates recommending innovative nudges to push behavior to reduce anticipated risks. This paper describes the distinctive ways in which biologists and chemists respond to the legal regulation of their laboratories, to increased surveillance and inspection, prescribed training programs, and retraining. Although academic scientists enjoy unusual degrees of autonomy in setting their professional agendas, this work describes how scientists forgo more common resistance to organizational nudges by deferring to institutional pressures to transform laboratory routines. Why do they comply when resistance is more common? We suggest that organizational deference to the varied cultures of biology and chemistry encourage compliance: each science can do safety in ways consistent with the history and sociology of its science. Deference to local epistemic cultures works to improve regulatory compliance.

Importantly, those charged with implementing the legal mandate to create consistent conformity with environmental, health and safety laws adopted a pragmatic approach. Instead of succumbing to legal pressures to enforce standardized, one-size fits all procedures, they varied details of implementation to the local cultures of different disciplines and departments, thus seducing scientists to accept a surveillance system they may have more likely resisted. This was not, however, planned as such. It developed step by step as professionals with expertise in various technical fields (e.g. radiation, toxins, chemical waste, biological hazards) confronted competing mandates and interests: to create consistent conformity in compliance with environmental and safety regulations and to support the cutting edge scientific research that was the source of institutional reputation and resources.

With observations, interviews and archival data from an ethnographic study of the creation and implementation of an environmental health and safety system for managing hazards in academic laboratories, this paper presents the results of a natural experiment. Two departments (biology and chemistry) with similar risks and amounts of hazardous waste ultimately comply with legal regulations while varying in their interpretations of the responsibility of the scientist: as part of science for the chemists, as part of the context but not the content of science for the biologists. This unexpected variation is explained in terms of the pragmatic adaptations of the safety administrators to the distinctive (historical, sociological and epistemic) cultures of the two sciences.

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11. Why Do Biologists and Chemists Do Safety Differently?

THE REPRODUCTION OF CULTURAL VARIATION THROUGH PRAGMATIC REGULATION

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Explanations for the variation in compliance with legal regulations range from accounts of inconsistent and lax enforcement to misaligned incentives (Hawkins and Thomas 1984b; Wilson 1980; Deutch and Lester 2004), with much recent scholarship and policy advocates recommending innovative nudges to push behavior to reduce anticipated risks (Thaler and Sunstein 2008). Rather than traditional policy levers such as restrictions, penalties, and education, nudge promoters recommend designing choice contexts to push decisions in desired directions. Nudge enters the panoply of regulatory approaches by addressing individual cognition as the means of aligning decisions with legal mandates and goals. Yet, the empirical studies that test nudges for shaping regulatory compliance and pro-social behavior challenges meaningful synthesis or clear predictions (Huising and Silbey 2018). Moreover, "what is typically missing is any evidence about the underlying mechanisms through which these policies affect behavior" (Grüne-Yanoff 2016, 464) or how individual action aggregates to produce compliance at the organizational level.

If the organization is the salient actor, observers also identify a range of responses to regulatory requirements and pressures (Gunningham, Kagan, and Thornton 2004). Managerial attention to and interpretation of the legal environment, competitive forces, strategic issues, and operational factors are said to generate variation in organizations' responses to regulation. This body of work identifies organization-level variables that predict formal responses to regulations but overlooks the internal organizational processes and mechanisms through which the everyday

priorities and work routines, decision-making networks, and ways of interacting and talking coordinate with regulatory requirements.

For decades, studies of regulatory implementation and compliance have proposed one or another dimension of social action—institutional, legal, economic, or cognitive—with which to explain variation in responses to regulatory requirements. Whatever is proposed ultimately fails to fully account for or affect the variations at the organizational or individual level; empirical observations consistently document a gap between the explanatory model and practices on the ground.

Because the ostensible goal of regulation is to shape what constitutes routine action, attention to the internal and habitual processes offers an alternative path to understanding how compliance (or noncompliance) is actually produced. Eschewing at the outset a formal, abstracted model or explanation allows us to see what may be more often overlooked as the detritus of organizational performance: the local variations that are overlooked or discarded as we search for a central tendency in the data.

This chapter describes the distinctive ways in which biologists and chemists respond to the legal regulation of their laboratories, to increased surveillance and inspection, prescribed training programs, and retraining. Although academic scientists enjoy unusual degrees of autonomy in setting their professional agendas, we describe how scientists forgo more common resistance to organizational nudges and instead defer to a range of institutional pressures and incentives to transform laboratory routines. Why do they comply when resistance is more common? We suggest that deference to the varied cultures of biology and chemistry encouraged compliance: each science can do safety in ways that are consistent with the history and sociology of its science. Deference to local epistemic cultures worked to improve regulatory compliance.

Importantly, those charged with implementing the legal mandate to create consistent conformity with environmental, health, and safety laws adopted a pragmatic approach. Instead of succumbing to legal pressures to enforce standardized, one-size-fits-all procedures, they varied details of implementation to the local cultures of different disciplines and departments, thus seducing scientists to accept a surveillance system they more likely may have resisted. This was not, however, planned as such. It developed step by step as professionals with expertise in various technical fields (e.g., radiation, toxins, chemical waste, biological hazards, air quality) confronted competing mandates and interests: to create consistent conformity in compliance with environmental and safety regulations and to support the cutting-edge scientific research that was the source of institutional reputation and resources.

In this institutional encounter between law and science, law seems to triumph but, importantly, does so because it adjusts to the local circumstances to become part of scientific practice. Both biologists and chemists defer to the law's authority to set limits to laboratory practices. Crucially, however, what might look like institutional conformity (Drori et al. 2003) on closer observation turns out to be an instance of scientific variation[1]: biologists and chemists vary in *the ways in which*

they defer. The deference to law, the acceptance and participation in the environmental health and safety (EHS) management system, is based not on a simple victory of law against science but on multiple interpretations (Rosental 2003) of the responsibility of scientists and the procedures of compliance. I provide evidence of three forms of disciplinary variation that together explain biologists' and chemists' interpretations and positioning before the law.

First, the authority and expertise of biology and chemistry have been built with different meanings and relevance of contamination and hazard. As such, the introduction of the law into the processes of doing science takes on very different interpretations—*as part of science for the chemists; as part of the context but not the content for the biologists*. For centuries, chemists have been constructing labs with protections against contamination, fumes, and fire. Since the mid-nineteenth century, close relations among academic and industrial labs reinforced the legitimacy of safety protocols, including periodic lobbying and support for uniform government regulations. In contrast, molecular biology is a young science with a recently developed industry that emerged during an era of hostility to government regulation.

Second, the social and spatial organizations of the labs vary. Academic biology labs normally have a permanent staff of managers, technicians, and longer-term postdoctoral fellows as well as graduate students. Chemistry labs rarely employ any permanent staff and rely entirely on an ever-changing population of postdocs and students. At Eastern University, every biology lab was constructed from a common template with substantial space shared among colleagues; each chemistry lab was individually designed to the specifications of the principal scientist with very limited common spaces.

Third, biologists and chemists produce their results differently. Biologists seek statistically significant variation in a population, whereas organic and inorganic chemists are trying to create a particular chemical reaction, to increase the yield in a system in which they can already detect a useful difference. Notably, not every chemist was on board, "doing safety" perfectly well by himself, and not every biologist was less than welcoming. Nonetheless, there were marked differences in the responses of the departments in the name of their faculty: the chemists considered the environmental and safety regulations as part of the practice of chemistry, and the biologists defined the new system as yet another, inescapable institutional constraint on science, something they could delegate to others.

Regulatory compliance was embedded within familiar activities through adaptation of the system's requirements to the local contexts. While the particularities varied from one department to another, a general script prescribing obligations and expectations was differentially implemented. The abstract demand for consistent conformity was achieved through pragmatic adjustment of historic custom to new purposes.

This chapter proceeds by first establishing the legal context for the regulation of scientific laboratories. In the mid-1990s, the U.S. Environmental Protection Agency (EPA) decided to turn its attention to heretofore ignored sources of

pollution: municipalities, the military, and educational institutions. I begin with an EPA inspection of a university that became the impetus for mandated changes for containing environmental, health, and safety hazards in research laboratories. The following section, "Trouble in the House of Science," points to the habitus of academic scientists that was disturbed by the EPA inspection and the subsequent consent decree promising organizational changes. I continue with an account of the ethnographic methods used to track the creation, introduction, and responses to this legal intervention, describing what turned out to be a natural experiment comparing different organizational responses to the mandated change. The biologists' and chemists' responses are presented topically and chronologically. The departmental variations are explained in terms of the different sciences' histories and relations with industry, organization of laboratory spaces and research groups, and, finally, experimental processes. In sum, I show how legal challenges to organizational autonomy are mediated through professional expertise and local habitus. In a process of pragmatic regulatory implementation, cultural variation among the sciences is reproduced, a new form of variation—legal subjectivity—is observed among scientists, and deference to legal regulations is achieved specifically by accommodating these different interpretations of the legal responsibilities of the scientific researcher.

A MANAGEMENT SYSTEM FOR LABORATORY HAZARDS

The Provocation

In late June 2001, the federal court[2] recorded a consent decree between the EPA and Eastern University in which the EPA alleged that the university violated certain provisions of the Resource Conservation and Recovery Act (RCRA), the Clean Air Act (CAA), and the Clean Water Act (CWA).[3] Without admitting any violation of law or any liability, the university agreed in the decree to settle the matter without a trial on any matters of fact or law. From the district court's perspective, this was a minor case that took little time or attention. From the perspective of the EPA and the university, however, this was a major occasion, the culmination of three years of lengthy, detailed negotiations that both parties hoped would ultimately produce the means for sustainable, environmentally sound research practices for the nation. All parties viewed this agreement as an opportunity to create a model of safe and "green"[4] laboratories.

Three years prior to the filing of the consent decree, the EPA gave notice to Eastern, along with dozens of other universities, that it would be conducting campus inspections. Immediately, negotiations began to determine which of the more than four hundred laboratories would be inspected and when. Given the wide range of activities and types of possible contaminants, it was important to see different kinds of laboratories and functional areas; yet, it would be impossible to visit

every location where there might be emissions, spills, or hazardous waste. Eastern had established a very good record for compliance with Occupational Safety and Health Administration (OSHA) regulations. It had also invested heavily in a diverse array of expert managers with over a dozen different offices and committees distributing responsibility for keeping toxic and radioactive materials secure and the animals, students, staff, and faculty safe. Although there were accidents every once in a while—a fire in a laboratory, an eye damaged by a laser because the warning light was not observed by an intruder—Eastern's record displayed a relatively low rate of accidents. Most important, there had been no toxic emissions, spills, radioactive leaks, and improper disposal of hazardous materials.

Nonetheless, when the EPA completed its five-day inspection, it recorded more than three thousand violations of RCRA, CAA, CWA and their implementing regulations. Despite the large number of discrete violations, both the EPA and the university regarded all but one as minor infractions. Eastern's major failure, according to the EPA, was its lack of uniform practices across the laboratories. One laboratory was a model of good practice, whereas another produced no accidents, spills, or emissions but was littered with uncapped chemical bottles, unlabeled waste, and students working without protective clothing or safety glasses. The university could not identify which policies enabled such extraordinary variation and yet prevented serious accidents. There was no clear, hierarchical organizational infrastructure for compliance with environmental laws, no systems approach to environmental management, no clear delineation of roles and responsibilities, and, most important, no obvious modes of accountability for either compliance or violations. The line of command from the laboratory through the safety office to the leadership of the university was opaque to the inspectors, and thus it was impossible to say who was responsible for what. The academic freedom celebrated and protected by the faculty and Eastern administration looked like mismanagement and anarchy to the EPA.

The consistent, uniform conformity required by the EPA is abhorred by the university (Paradeise and Thoenig 2013; Thoenig and Paradeise 2014). Yet, herein lies the gravamen of the EPA's complaint and the heart of the organizational problem. In response to having the university's culture of autonomy and invention exposed as chaotic and irresponsible, the consent decree required what had never before existed: consistent uniform practices across all departments and labs, clear lines of command, and transparent legibility for all environmental and safety procedures.

The consent decree stipulated a five-year deadline for compliance. Normally, EPA consent decrees demand compliance within a year. The five-year window signaled a new kind of regulation "that seeks directly to promote the management of private firms in ways that meet public goals" (Coglianese and Lazar 2003). Although most regulation attempts to manage some activities of private firms, this strategy supplants more conventional policies that mandate either the use of specific technologies or specific levels of performance. This management-based strategy locates the design, standard-setting, and implementation of regulation squarely within the

regulated organization itself, creating a form of private management in the public interest, a form of corporatism, or what scholars of governmentality call "regulation at a distance" (Foucault and Lemke 1999). A private organization not only reforms its own practices but assumes responsibility to invent and publicly disseminate new models of environmental, health, and safety management.

From the point of view of both the Eastern administration and the EPA, the consent decree turned liabilities into investments, creating the possibility of a win-win situation. From the government's perspective, private educational institutions are notoriously difficult to regulate. Not only do they enjoy privileged autonomy, moral responsibility, and epistemological authority, but the vast range of activities, dispersed and opaque practices typical of institutions of higher education create seemingly intransigent obstacles to regulation, especially environmental and workplace safety standards that were designed primarily for mass-production industries with more tightly disciplined and coordinated workforces. By extending the time frame for compliance, and contracting with Eastern to invent a new management system for research universities across the nation, the consent decree offered the EPA an opportunity to solve some of its most intractable problems.

From the Eastern administration's point of view, the agreement was an opportunity to repair what it saw as its now tarnished reputation for excellence and innovation. The alleged violations threatened the university's reputation while also creating the prospect of heavy fines and costs. Litigation to challenge the allegations would expose Eastern to unfavorable publicity and expense, with no assurance of an ultimately favorable outcome. Although it took three years to negotiate, the EPA considered Eastern a compliant and cooperative organization, "*gracefully acknowledging its failures*" and "*immediately asking what it could do to make repairs.*"[5] In addition, from the perspective of the university's attorney, this was the first hurdle in what would become a make-or-break case for career advancement. And from the perspective of the university's environmental and safety staff, it was also an opportunity to rebuild their credibility and professional status.

A Management System

The consent order between Eastern University and the EPA promised the adoption of a comprehensive EHS management system, which was designed and put in place between 2001 and 2007. The management practices in the consent order call for control systems specifically designed to ensure accountability through constant surveillance, data collection, and informational feedback loops. Designed to make organizational functions and ground-level performance immediately transparent to university administration as well as internal and external auditors, such systems are promoted as the preferred means for containing risks (e.g., financial, environmental, safety) as well as assuring regulatory compliance (itself a form of risk management). Often referred to and marketed as *enterprise resource planning systems* (ERP; ERM, or enterprise resource management; or CBS, computer business systems),

these omnipresent software packages use relatively simple linked digital applications to electronically represent the organization and its workflow.

From the perspective of the scientists at Eastern University, the management system is a tool for surveillance, routinely observing and recording performance and outcomes. From the administration's point of view—especially the EHS staff dedicated to supporting laboratory science (for example, by managing licenses to work with radioactive isotopes, proscribed toxins, and chemical and biological materials to prevent their introduction into water systems or uncontrolled waste)—the system is a tool for collecting, analyzing, and responding to information about laboratory hazards. All groups seemed to understand that if the management system functioned as expected, it would become an apparatus for controlling scientific work: information collected through inspections of laboratories would become information for new policies, training, and, ultimately, changed practices. All hazardous activities within the labs would be made visible, if not entirely legible, to observers outside the labs.

In general, management systems work by mechanizing these functions—storing and analyzing data—through the digital technologies. At one end of a continuum of constraint, the system can be used to channel and control work as completely as possible. Here, the management system functions like the Taylorist assembly line, where the production process is divided into sequential units, each of which is designed to require the minimal human action (or decisions) necessary to add a particular supplement to a progressive assembly of the work process or final product. The system recommended for the Eastern laboratories, as well as labs at other universities, operates at the other end of a spectrum of standardization and control. The Eastern EHS system would be designed to coordinate and make visible the labor of actors whose work processes are more varied, often complex, with many interconnected procedures, each requiring expert decision-making, and whose work product cannot be standardized or completely digitized. Although any individual may do the same task many times, variation in the workflow is much greater than in the assembly-line model. These university and research management systems are designed for workers who are themselves decision makers who must interpret rules and protocols within the immediate, diverse, and variable conditions of production. Often this work is invisible to others not immediately involved, and even sometimes to those involved as well.

In practical and immediate effect, the creation of the system involved the reallocation of responsibility within the labs, within the administrative staff, and between the two that constitute the loosely coupled organization of the university (Perrow 2011; Weick 1976). This chapter describes and analyzes the responses of biologists and chemists to these legally mandated changes.

TROUBLE IN THE HOUSE OF SCIENCE

Under any circumstances, planned organizational change is famously difficult (Barnett and Carroll 1995; Armenakis and Bedeian 1999). Decoupling of organizational

practices from institutional norms is common, and change projects rarely enact prescribed designs completely (Turco 2012; Huising 2015). Imposed from outside or above, legally mandated change simply exacerbates the normal difficulties. Professional agendas frequently shape organizational compliance because regulations are not self-enforcing, not until they become, with time and repetition, commonplace, habituated features of organizational everyday life. Although implementation can be built into product designs or instantiated in urban planning through traffic signals and lane markers, within complex organizations, experts and professionals often become the active enforcement agents. Professions can enhance their status by taking on new regulatory responsibilities or retain greater control by self-regulating in line with legal mandates. However, professional agendas and organizational interests may also undermine regulatory mandates (Gallagher, Jung, and Dobbin 2015). Policy goals may be contested even after legislative enactment (Stone 2002); compliance may be primarily symbolic (Edelman 1992); and well-intentioned implementation may produce intractable struggles among managers and experts or among different, if not competing, professional communities (Waring and Currie 2009; Kellogg 2009, 2011; Brivot 2011; Barrett et al. 2012; Huising 2014; Galperin 2015).

Although all social fields rely on interchange with other social fields, scientists may be distinguished by an unusual degree of autonomy in setting professional agendas and in the degree to which they successfully guard their authority and conditions of work (Bourdieu 1975, 1991). Scientists aggressively police the boundaries of what constitutes science and nonscience, denying legitimate or merely comparable authority and status to pseudoscientists, "protecting the autonomy of scientific research from political interference" (Gieryn 1983, 781). Of course, this autonomy is not absolute, and as "pressure to patent and commercialize scientific research increases, the scientific field becomes less autonomous and more subject to external forces impinging from without" (Foster, Rzhetsky, and Evans 2015, 902; see also Berman 2008, 2012; Camic 2011, 2013; Powell and Owen-Smith 1998). Despite the law's direct authorization for so much of the recently generated wealth for scientists and innovation for the nation (through patenting and licensing of scientific discoveries), transactions between law and science are often characterized by incomprehensibility and opposition, producing what one scholar calls the "use and misuse of science in law" (Faigman 1999).

Thus, it is not unusual to observe scientists actively resisting legal efforts to constrain the ways in which science is done, including requirements adopted in the name of health and safety. For example, nanotechnologists and materials scientists have been shown to display "extremely hostile reactions" to studies of the risks of their research for human health, claiming instead that "such research was itself a major risk to the health (i.e. funding and public acceptance)" of science itself (Kelty 2009, 80). And although most scientists may—usually after multiply repeated requests—complete mandatory safety training, respond to legal requirements to label hazardous waste, or remove equipment blocking corridors and exits, they often interpret these mandates as impediments to their work (Gray and Silbey 2014)

and frequently do not sustain compliance with required changes beyond particular inspection or audit (Bruns 2009).

Safety regulations aim to prevent adverse effects of lethal substances on the scientists themselves as well as the public, but the scientists are primarily concerned about the adverse effects on their experiments (Evans and Silbey 2021). Scientists may rely on administrative nonscientist staff for financial and material support, response to accidents, and actually improved laboratory management at the same time that they resent requirements to wear lab coats and safety glasses (Huising and Silbey 2011), material handling and storage, security measures, the disposal of contaminated and hazardous materials, institutional review boards (Stark 2011), and required documentation (Stephens, Atkinson, and Glasner 2011). Scientists interpret such prescriptive rules as more than intrusions. To the extent that legal regulations engender activities "separate from those actions that suffice to meet the scientists' professional concerns" (Bruns 2009, 1399), legal mandates are experienced and described as hindrances to the smooth operation of the laboratory, obstacles to the autonomy of science, and impediments to scientific progress (Evans 2012, 2014). Outsiders' demands for new or different ways of working "are trivialized by insiders because outsiders make those claims without understanding what will be displaced" (Heimer 2008, 30). To scientists, legal regulators, like most nonscientists, lack understanding of the real processes of science and organization of laboratories (Gray and Silbey 2014).

To the degree that the consent decree between the EPA and Eastern University sought to achieve uniform, consistent and legible practices across the university's laboratories, it threatened the scientists' expertise instantiated in their research processes but also in their relatively autonomous control of their laboratories and supervision of their graduate students' education and training. There is reason to believe that the proposed EHS system signaled a direct challenge to the authority and expertise of the university scientists, which would have discernible consequences for the shape, capacities, and penetration of the system into laboratory routines.

RESEARCH METHODS

A Case Study

The negotiated settlement between the EPA and Eastern University to design and implement an environmental health and safety system for academic laboratories represented trouble for science, locally for the scientists at Eastern but also for American academic scientists in general, because Eastern agreed to make its system available for the nation's research universities. In their now canonical 1941 account of how to study the "law-stuff of a culture," the anthropologist E. Adamson Hoebel and fabled jurisprudential scholar Karl Llewellyn[6] urged scholars with interests in

understanding how law really worked—especially in settings where formal professions and institutions were not immediately observable—to look at "instances of hitch, dispute, grievance, trouble," inquiring what the trouble was and what was done about it. "It is rare in a . . . group or society," they wrote, "that the 'norms' which are felt or known as proper ones to control behavior are not made in the image of at least some of the actually prevalent behavior; and it is rare, on the other hand, that [the norms] do not to some extent become active in their turn and aid in patterning behavior further." Norms build up over time with amazing emotional and material power, often attaching moral meanings to what may be simply accident, habit, or convenience. Thus, instances of hitch, trouble, or dispute lay bare the community's norms as both moments of deviation and repair. What may be latent is made manifest and what appeared consensual becomes the subject of open, explicit contest. By following the events set in motion by this consent order between Eastern and the EPA, by observing the ways in which it is trouble for the university, I began a journey into the taken-for-granted, habitual, reputably consensual norms of contemporary laboratories to discover whether—and if so, in what ways—the law is part of the constitution of modern science.

This chapter is based on six years of ethnographic fieldwork at Eastern University to document and analyze the creation of the new EHS system for research laboratories. As such, it is a single case with both common and atypical features. Eastern University, included among the sixty Association of American Universities in the United States and Canada, shares with others the common organizational structure of a professional bureaucracy (Mintzberg 1979; Freidson 2001). Disciplinary departments are managed by chairpersons who report to deans managing collections of departments within schools. Deans report to the provost, who is responsible to the president, with whom s/he continually confers. The highest-level academic meetings for budget, appointment, and policy decisions include participation by the president, provost, school deans, and chair of the faculty, plus high-level administrators such as the vice president for finance, vice president for research, general counsel, heads of facilities and libraries, as well as the administrators for undergraduate and graduate student affairs. The president reports monthly to an executive committee of the board of trustees and thrice annually to the full board.

On paper it looks like a standard bureaucracy, although, as mentioned earlier, authority on the administrative side flows from the top down, whereas on the academic side, faculty ostensibly located at the ground of the hierarchy populate the highest academic offices (president, provost, deans, chair of the faculty) enjoying enormous autonomy as the ostensible source of the university's educational and research value.

The university is a loosely coupled but complex organization in which multiple goals can be pursued through nonlinear yet simultaneous, often unpredictable interactions (Perrow 2011). Unexpected or negative events can occur because of unplanned, unforeseen interactions and will occur regardless of the intentions

or planning processes (Merton 1936). Sources of error or malfunction—whether financial, educational, or environmental—are not easily identifiable in complex systems. This is the case for laboratory hazards, especially during the confusion that accompanies an accident.

The university is a loosely coupled system also characterized by decentralized operations, multiple interests, amorphous and ambiguous performance standards, and, as already mentioned, flexible social control mechanisms. Processes do not flow in rigid Sequences. Locally practical solutions are often instituted, providing alternative paths to any particular goal with substitute processes and equipment. Variation is readily accommodated. This was, of course, exactly the situation that the EPA found to be chaotic in its inspection of Eastern. Just as importantly, loosely coupled complex organizations are not designed for efficiency or for unidirectional action. Thus, the creation of an EHS management system represented a major challenge to the university's organization, processes, and culture.

Although Eastern's organizational profile is not unusual, I make no claim that this is a typical large organization or an average university. Eastern is an elite institution and as such commands greater-than-average private endowment, national attention, public and private research support. The terms of the EPA consent decree were explicitly negotiated because of Eastern's resources—human, economic, and cultural—to serve as a national prototype for more effective management of laboratory hazards across the nation's hundreds of universities. If Eastern could manage to secure faculty compliance and a more reliable safety culture, its model could, it was hoped, replace previous compliance efforts that had turned out to be unsuccessful in mobilizing faculty support for safer laboratory practices. As an atypical institution, this is an outlier case pursued as an opportunity to identify new empirical facts and conditions of variation, build rather than test theory, uncover mechanisms, and trace processes (Small 2009a). The persuasiveness of the evidence will depend less on the representativeness of the events (although I do think they are not uncommon) than on the "logically sensible" linkages (Small 2009a) identified between scientific expertise and legal subjectivity, between actors' and groups' professional authority alongside efforts at organizational change.

Data Collection

The fieldwork activities included interviews, observation, and document collection. These were supplemented by systematic data collection with standardized instruments for observation and surveys. Because my focus is the intersection of three social phenomena—government agencies and regulations, university organization, and scientific laboratories—my sites included the university administration, changes in those offices in response to the regulatory mandate, scientific laboratories and changes in response to regulation, as well as interviews with government officials and observations of their interactions with university personnel. Given the

breadth of the sites and length of time, I worked with a team of research assistants, some very accomplished, others in training.

We began observations with the announcement of the consent decree to faculty just preceding the court hearing and followed through the next six years when the EPA came to inspect and assess compliance. The formal meetings we observed included those of a committee for facilities, a committee for research laboratories, and a committee of administrators and faculty overseeing the work of these two working committees. One or two of us attended each meeting, sitting silently at the side of the room, taking notes on the proceedings. I interviewed members of the committees individually; we received copies of all documents and were included in all mailing lists. We also conducted individual interviews with senior administrators, key faculty, and members of the committees overseeing health, safety, and environmental policies. This includes safety and chemical hygiene officers within labs and on the EHS staff. We observed most meetings where the university attorneys and EHS representatives met with EPA attorneys. We followed the intermediate audits of the system conducted by consulting firms contracted for this purpose and the final audit and inspection conducted by the EPA before the consent decree was lifted.

Laboratory observations are key to this project. These observations took place in laboratories across a spectrum in which past practice and need for improvement varied, as did the authority structure and degree of environmental and health risk in the lab. We conducted participant observation in more than twenty laboratories in five sciences, plus medical and engineering departments, for at least three months each. We expected the observations to provide us with evidence of the variations in managerial style of the principal investigators (PIs): how involved each was in the logistical and material organization of the lab.

I approached faculty members for permission to "hang around" their laboratories, and for my research assistants to do so as well. Although it is important to follow the discussions out of which the EHS system design emerged, it is even more critical to trace the ways in which the law, the EPA, and the regulatory regime were being interpreted and responded to by actors at the ground level of the organization. The entire EHS organization is created and mobilized to serve ongoing research in the laboratories. The culture of autonomy and freedom that characterizes the university has its *raison d'être* at this ground and center of the university's organization. If there is to be compliance, or violation of federal law, it will be in the laboratories. If trust and autonomy are threatened or enhanced by this systemic surveillance, it will be visible at this ground level. If there will be routine changes in scientific practices spurred by this legal intervention, they will be apparent in the labs.

All field notes were typed up using Microsoft Word and kept in files arranged by organizational locus and topic. We recorded descriptions of what was going on in front of us as well as our queries about what was happening that we did not understand. These notes were typed at the end of every day or, at most, at the end of two days. All notes and queries were shared among the team members and discussed in

weekly group meetings (Evans, Huising, and Silbey 2016). All recorded interviews were transcribed by a person hired for this purpose. The transcriptions and notes were entered into and coded using Atlas.ti.

Data Analysis

A natural experiment. This work, at its base, analyzes how the authority of one form of knowledge interacts with the authority of other forms of knowledge and expertise (Espeland 2003;1998; Heimer and Staffen 1998; Guetzkow, Lamont, and Mallard 2004; Lamont 2009). Here, a legally mandated organizational change, a management system with scripted protocols and laboratory routines, as well as standard operating procedures, was imposed uniformly across hundreds of laboratories. The introduction of the management system constituted, in effect, a natural experiment in which to observe organizational responses to legally mandated changes, a treatment applied across the varied subjects. How would scientists respond to this legally mandated intrusion into their professional domain? We had every reason to believe that they would resist if they did not find ways to make the requirements minimally intrusive. The job of the administration was to make the burden as light as possible. As the university attorney told me, "It is my job to make this work. We are not going to stop their research, so it has to work in one way or another." Eventually, managers hoped, it would become just another lab routine, part of the expert knowledge and habits of experimental science.

Of course, we did not believe that responses would be uniform. At the outset, we hypothesized that the responses to the new regulations might vary with aspects of laboratory organization and levels of risk. For example, some labs are tightly managed with weekly group meetings that include reports of all "problems," "accidents," and other housekeeping matters as well as detailed discussion of the research. As one PI told me, "I don't want them to tell me every time there is a jar without a cap, or a torn label, but they sure enough better tell me at the end of the week how many there have been this week. Otherwise how I am going to correct the problem?" "How do you correct the problem?" I asked. "It depends. This is an educational institution after all. You always get a chance to improve. But if there is a character who is creating repeated problems, and dangerous conditions for everyone, I don't want him in my lab." Other PIs don't want to be bothered daily, weekly, or monthly. They want this delegated to a dedicated person.

Laboratories also vary in the degree to which they pose health, safety, or environmental risk. Some laboratories are using toxic chemicals and biological and radioactive materials. Others are using lasers on biological and/or toxic substances. Yet others use no biological or radioactive materials but very heavy equipment with high voltage. Finally, some laboratories have no specifically designated biological substances, radioactive materials, or large equipment but may have relatively harmless solvents and cleaners that nonetheless require special handling. Solvents and cleaners constitute environmental hazards, exactly because of the lack of local sensitivity to their risks. Using the legislated standards of risk for controlled substances,

the laboratories we observed range from those in which there are only solvents and cleansers (low risk)—for example, used in stage productions or for care of musical instruments—to those using radioactive materials on biological phenomenon (high perceived risk). In between, we have laboratories that use lasers and other potentially risky equipment on various materials. Finally, the laboratories vary by the degree to which they have been considered good or bad actors in the past, model citizens, or needing improvement.

Thus, we expected some variation by standard organizational features: past practices, organizational hierarchy or collegiality, and material conditions of greater or less risk. We did not expect variation by discipline. Nor would we have expected variation between biology and chemistry, disciplines that shared more features than those distinguishing them. All labs in both departments have an abundance of chemical solvents and radioactive materials. Many chemistry labs have biomatter. Together they produce 70 percent of all hazardous waste on campus and occupy adjoining buildings. In terms of hazards and risk, they looked more like each other and different from many other departments, for example physics. We expected resistance to legal intrusion; we did not expect deference, and we did not expect disciplinary variation.

How could we explain these unanticipated findings? We analyzed the field notes and interviews in search of an explanation for the different reactions of the biologists and chemists to the EHS system. For this chapter, we collected all text that referenced or was coded for biology and chemistry, authority, expertise, history, industry, laboratory fixtures and spaces, dispute or conflict, as well as specific codes for components of the management system.

In the next section, I lay out the responses of biologists and chemists to the proposed regulatory regime. The implementation of EPA guidelines is observable not just through differences in outcome measures—whether one set of actors complies more or less than another—but also in the ways in which the legal norms of environmental regulation are part of the culture of the organizational units (table 11.1).

TABLE 11.1
Differential Responses to Legal Regulation of Laboratories

	Biology	Chemistry
Introduction of EHS system	No time for this; need to do research.	Do it already and do it better; part of being a chemist and good scientist.
Staff positions for EHS	EHS coordinator cannot be a member of the department; needs authority of university administration to reign in difficult or resistant faculty.	EHS coordinator must be a member of the department; no one other than chemistry member could navigate the varied lab materials and hazards. Prized autonomy and did not want central administration looking closely inside the department.

(*continued*)

TABLE 11.1 (*continued*)
Differential Responses to Legal Regulation of Laboratories

	Biology	Chemistry
Compromise: EHS staff and department partners	Partnership welcomed with expectation that the central EHS partner would be the leader. First appointment immediately embedded and comfortable handling crises as well as routines within department.	Partnership accepted with expectation that the department partner would be the leader. Several personnel changes before settling on coordinator accepted by department.
Inspections and auditing	Inspection by central EHS staff contact and department coordinator.	Inspection by a department committee of the EHS coordinator, rotating faculty member, and rotating graduate students.
Inspection tools	Prefer standard form used in all lab inspections across all university labs.	Use inspection form designed by chemistry, not limited to university-wide form or digital record.
Standard operating procedures	Requested list of most important safety procedures to post above sink in every lab.	Objected to posting of a standard list, as there are no standard hazards or processes across all labs.
Other variations	Requested training by central EHS staff for students. EHS to keep records of training and inspections; since they insist on these procedures, they should have the responsibility.	Provide own training and will continue to do so. Keep their own records; these are learning and research processes, not policing.

DIFFERENTIAL RESPONSES TO LEGAL REGULATION

How have faculty responded to this generalized apparatus for identifying, preventing, and responding uniformly to environmental, health, and safety risks? Very early in the process of planning the new system, it became unambiguously clear that the responses were patterned along disciplinary and departmental lines rather than any of our hypothesized organizational features, degrees of risk, or possibly idiosyncratic inspection histories. In full department meetings, when the system was being introduced to faculty across the university, as well as in the smaller committee meetings,

in which the system was being designed, biologists and chemists interpreted and responded to the new system differently. Laboratory observations and interviews confirmed these variations.

Introduction of New EHS System

At the outset, the biologists were skeptical, if not outright hostile, to this project. They were reluctant to be burdened, the biologists said, by additional demands on their time and resources that were not part of their research. They were like many others for whom the law usually looks like a hindrance, an impediment to productivity. Those who view the regulations this way offer accounts of how constrained they are by all the rules and how afraid they are by what might happen with a "new improved" system, which is surely going to mean yet more rules.

One biologist explained to me that outside monitoring of laboratory materials and processes is a waste; no one cares more than the PI[7] to secure his laboratory and the students and postdocs within it, and for sure to protect the research animals. "Look," he said, "it's a big pain because we want the mice healthy. People are going to want them healthy because they can't do their experiments [otherwise]." The scientists care more because they have a direct interest in securing the health and safety of their experimental animals, he claimed. There are years of investment in these animals; the loss of any one could mean years of work down the drain. The spot inspections and detective work that the government agencies require were described as a big waste of time and energy.

The most consistently voiced complaint had less to do with the animals than with that most precious commodity: human labor time. A typical response was repeated at almost every stage of the design and implementation of the management system: "My students don't have the time for this; they have to do their research." When the organizational scheme, training, inventory, and auditing processes were presented at a meeting of the biologists, the first faculty member to speak asked, "Why don't we just tell them that we don't want to do this?" This called forth a great deal of laughter. The notion that the university could "just say no" had not occurred to the rest of the group as a possible or reasonable tactic. When the laughter died down, the speaker went on to explain that the hazards in her lab were considerably less than what gets poured down the drain in every kitchen and laundry every day. "Why doesn't the EPA go bother the real problems?" Thus, the earliest and loudest message was that the safety regime—the law—was external to the research. It created unnecessary and costly obstacles to doing great science. "We are doing important work, and we are not the nation's problem."

In contrast to this reaction, a chemist remarked one day in conversation with one of the biology faculty, "The environmental practices we're trying to get everyone to adopt are not additions to what we do. We have to see these things as part of what we do. We can't be scientists one way and environmental citizens in another." This carefully parsed statement does not fully capture the energy and emotion that

was expressed both orally and bodily, as the chemist almost leapt across the table to restrain the biologist who kept insisting that he and his students had no time for all "this bureaucratic stuff."

The chemists did not necessarily have greater respect for the safety inspectors. Indeed, it turns out they had much less. But their immediate response was that they already do it better. "We didn't think all that much of the guys who did come by, or the guys who make the rules," a chemist told me, "because they weren't as smart in chemistry as we are, and they came and were saying 'you're not using this or that properly.' But they didn't know what the structure and properties of the chemicals were. They would lose credibility in front of the students. It was a really bad situation." As a consequence, the chemists did not object to a renewed commitment by the university to address laboratory hazards, but they insisted that they would do it themselves.

I don't want to misrepresent this. Not every chemist was on board, already "doing safety" perfectly well by themselves, and not every biologist was less than welcoming. Nonetheless, there were differences in the responses of the departments in the name of their faculty and the faculty in university committees in the name of their departments. Importantly, although chemists were not at all deferential to what they called "the environmental police," they considered the environmental and safety regulations as part of the practice of chemistry; the biologists defined the new system as yet another institutional constraint on science.

Staff Positions for EHS

These initial differential and resistant responses to the prospect of a university-wide environmental, health, and safety management system were resolved when the Eastern administration agreed to hire personnel in new positions to handle the new rules and procedures. The resistance that had characterized the initial discussions dissipated entirely when the administration said that it would allocate five positions to the science and engineering departments proportionately according to need. Need was defined by the degree and amount of regulation to which the labs in each department were subject. Degree of regulation (from most to least regulated) was scaled quantitatively and qualitatively; that is, by the amount of hazardous waste and number of different hazards. The EHS staff generally recognizes five classes of hazard: chemicals; biological materials; radiation, including lasers; air quality; and safety, including heavy equipment, magnets, hoists, and major electrical power. Biology and chemistry were the most heavily regulated departments. From the very beginning, before this conception of regulatory oversight was actually operationalized in the design of the new system, the disproportionate attention was developed intuitively. When a metric was needed with which to justify the allocation of new resources, the impressionistic assessment of need was confirmed with what was described as hard data. As such, the allocation of resources received no critique or pushback. Together, chemists and biologists represented approximately

70 percent of all the hazardous waste on campus. Together, they were assigned four of five of the new coordinators for the EHS system. Other departments would reallocate existing staff.

Once the commitment was made to hire additional staff to manage the new EHS regime in the labs, another difference emerged between the two sciences. The biologists did not want the EHS coordinator, whom they called an "agent," to be a member of the department. They voiced concern that a member of the department would be unable to assert sufficient authority to ensure success of the EHS system. How could a member of the department staff tell a senior faculty member that his or her lab was dirty or dangerous? What if the faculty member resisted complying with rules or recommendations for good practice? Faculty status and pressure would compromise the new EHS role. Apparently, the previous record of the department, known to the EHS staff and revealed in the EPA inspection, was notably checkered. Some labs were models of safety; others were among those that had some of the most flagrant and numerous violations recorded by the EPA. In their comments, members of the department suggested a history of individualistic favoritism rather than consistent management by department heads. Thus, the biologists thought it entirely appropriate that the university should provide the manpower to handle these new demands. The system would work best, they argued, if the new EHS staff were indeed agents of the central administration who could act with authority, rather than department personnel who might become embedded in local politics within the department. Consistent with their view that these EHS regulations were demands from outside of science, the staff entrusted with their enforcement belonged with the source of those regulations, outside of science.

In contrast, the chemists would not have an EHS coordinator involved in training or auditing chemistry labs and personnel. One account focused on practicality. Only members of the department—students, faculty, staff—could function effectively. Only members of the department could understand sufficiently the range of hazards, varieties of practice, and legitimacy of particular routines. Only department members could understand the actual chemistry of matter and the culture of the chemists, including the various subcultures among organic, inorganic, bio, and physical chemists. And only members of the department "command the respect and authority to influence what goes on in a department." Here the chemists seemed to agree with the biologists that the ability to influence what happens in the department would affect the ability to secure a safe environment: the biologists sought to create a countervailing authority to the faculty within the department, and the chemists sought to secure and guard that which already existed within. To an important extent, this difference may have derived from the fact that the chemists did not want, and seemed not to need, change, while the biologists recognized that their distribution of influence and authority had not heretofore secured uniformly good practices and that they needed organizational change.

The second ground for resisting an EHS agent within the chemistry department was simply scientific autonomy. As one member of the department said, " I look at

this from my point of view in chemistry. Do I want someone from central administration overseeing my department?" They did not want safety to become a matter of policing.

Since 1990, when OSHA enacted what is known as the Lab Standard, the chemists had demonstrated their expertise in self-regulation by putting in place training and inspection processes, a system that had won national recognition and become a model for others. They saw no need to change what they had already institutionalized. They could easily expand their existing system to include environmental hazards but would not trust someone from outside to take over the job. Experience had demonstrated the effectiveness of their practices, at the same time as other departments were revealed in the EPA inspection to have deficient practices.

The 1990 Lab Standard had been created because the OSHA rules in place at the time had been designed and implemented primarily for industrial sites and seemed not to work well for research laboratories. Industrial sites do the same things over and over again.[8] Because of this standardized repetition, the forms and processes of industrial safety can, like the work, also be routinized. By contrast, most scientific laboratories perform a wide array of activities, some of them infrequently. They also typically perform these actions on a smaller scale, using smaller quantities of potentially hazardous materials. Because of the variation in processes and materials, it is difficult to anticipate the kinds of dangers that might be involved. "There are lots of things," Professor Laslett, the Chemistry Department safety and chemical hygiene officer, said, "for which hazards are not known. They're new substances we've created as part of our research. And so research lab people said [to the federal government about the OSHA regulations] that the laws that are being applied to us really are not relevant." In other words, the dangers that attach to research laboratories are to a significant degree unspecifiable in advance. As a consequence, according to Laslett, the chemists have taken on the role of regulating themselves. Laslett described the department's process.

> We tried to change the culture of safety. . . . I would say the prior situation was an adversarial relationship between the safety police and researchers and faculty. Occasionally some sort of proclamation would come through—like you can't wear shorts if you work in the lab—that people would treat derisively and ignore totally. . . . It was a really bad situation.
>
> We had, in a sense, to reinvent our whole safety regime. So it was an opportunity to do this differently. It's as if you're saying we're throwing out our entire legal code and rewriting it.
>
> The OSHA lab standard is an interesting performance-based law, which means that it doesn't lay out in detail [that] under the following conditions you must wear safety glasses, under the following different conditions you don't. Instead, what it comes down to is [that] it says you must appoint a person called the chemical hygiene officer and you must write something called the chemical hygiene plan. And it doesn't specify what you put in there. What it does say is that this has to be effective in protecting all researchers from hazards. We're not telling you what a safe laboratory is. You are going to make up rules that make a safe

laboratory. That's what the law, the federal law says. . . . They did not lay out in excruciating detail one-size-fits all safety rules. It says "we will allow you to . . . design your own safety plan." We may inspect and determine if it is effectively protecting people . . . but we are not going to micromanage things.

When the law went into effect, the first thing [we] had to do was to decide how are we going to comply with it. Are we going to have a single safety chemical hygiene officer who would be safety czar over the entire [university], or are we going to make every PI, every professor, a chemical hygiene officer . . .

So, the most important decision we made was that safety should begin at the grass roots. . . . If we didn't enlist the people affected by these rules in the creation of new rules [it wouldn't work]. . . . The idea was that we would create a structure. The creation of the new safety rules would be done cooperatively by faculty, students, and administrators within each department. And the enforcement of compliance—monitoring the compliance and enforcing would similarly involve not only faculty administrators and authority figures but those researchers, the people who are affected by the rules. [This was] to overcome the adversarial relationship that otherwise inevitably develops if you have people outside of the community creating rules and monitoring compliance and enforcing them.

After a lot of debate we came up with a plan, which would be more or less equivalent [across the university]. Every department would have its own chemical hygiene officer and plan. We felt that it was unrealistic for each individual laboratory professor to have one.

But, he continued, it was also not good policy to have one policy for the entire university. In the past, that hadn't produced an effective safety system because of the hostility between the researchers affected and the professional safety people.

The researchers felt that they had no stake in the creation of the laws. And the laws, any rules, tend to interfere in some way with research if only in terms of making it less convenient to do certain things. And the fact is that some of the benefits are not immediately apparent, like am I going to get cancer thirty years from now. It is not necessarily easy for people to see the long-term benefits of these short-term inconveniences. The inconveniences are being applied from on high, naturally people are less cooperative.

My agenda was that if we involved everybody at the beginning making rules, they were more likely to appreciate why these are important and necessary; they are more likely to cooperate.

Of course, their cooperation must be verified, Lasslett explained.

It is very important not just to have an initial training lecture and to give people copies of these documents, it's also important that we check that they're working in compliance with it. So what we have, in our department, is a system of inspections. Every research lab—that means every group—is inspected, unannounced, unannounced inspection twice a year . . . by a team consisting of one faculty member and one graduate student from the chemical hygiene and safety committee.

The chemistry department's success at self-regulation, under the requirements of the OSHA lab standard, encouraged resistance to newly centralized regulation under the EPA consent order. Although all departments had created chemical hygiene plans and appointed chemical hygiene officers in response to the 1990 OSHA lab standard, uniformity had ended there. The chemical hygiene officers met once a year for one to two hours to go over any new regulations. Most plans inscribed in thick binders sat on shelves gathering dust, rarely changed from year to year. It was unclear whether departments other than chemistry were doing as well; some others, including biology, had training protocols in place, although it seemed that few had instituted the systematic and rigorous inspection system that was the central feature of the chemists' program.

If the OSHA lab standard had initiated a process of self-regulation, adopted very unevenly across the university, the consent order, unlike the OSHA rules, demanded consistent conformity across the university, just that conformity that the EPA inspection exposed as absent under the OSHA lab standard. Thus, whereas the biologists wanted someone who operated with the authority of the university administration behind them, not an employee subordinate to the department faculty, the chemists would have no one working in the department who was not a member, one of themselves, familiar with the local, existing, rigorous safety culture of chemistry.

Compromise: Partners in Regulation

These different approaches stymied the committees that were designing an organizational structure for the new EHS system. The consent decree required direct, transparent lines of authority. Individual faculty PIs and the department chairs had to be included within the lines of reporting as well as responsibility. The biologists wanted these lines to include an EHS person who would be dedicated to the department but reporting to the university administration, and the chemists wanted someone within the department who would report to the department chair.

In the end, a compromise was developed whereby each department would have an internal EHS person and a partner in the EHS central office. In this way, teams composed of both internal and central administrative personnel would serve every department. For the biologists, it was imagined during discussions, the central EHS partner might be the dominant actor. Reporting to the EHS office hierarchy up to a vice president, such a staff member could draw on central administrative authority to persuade or discipline uncooperative faculty, if it were necessary. For the chemists, it was imagined, the department EHS coordinator would be the dominant team member, and the central EHS office partner would be an additional resource only if needed, which was not expected.

The biologists hired a department EHS coordinator (to partner with the central staff EHS contact person), who very quickly and quietly immersed herself in the local organization, becoming immediately both acquainted with and comfortable in the department. Indeed, her incorporation was so facile and uneventful that

by her second month on the job, she was handling crises and reorganizing hazardous practices with minimal resistance. The chemistry department EHS coordinator (also to partner with a central EHS contact person) was hired at the same time but left within three weeks, unhappy at her lack of authority and autonomy. It took several personnel changes until a satisfactory person was in place in chemistry.

Inspection and Auditing

Inspection and auditing are central features of the new EHS system, features that are stipulated in the consent order in greater detail than any of the other elements, such as requirements for universal training and inventory control. The consent order required five levels of monitoring: weekly self-examination of each investigator's laboratory and group; regular department-level inspections at intervals to be determined but not less than once a year; inspections by the central EHS office, at intervals to be determined but not less than once a year; auditing by the university auditors every few years; and outside auditing every three to five years.

In the standard accounts of audit culture (Power 1997; Strathern 2000), inspection and auditing are distinct activities. Inspections are thought to be universal oversight and surveillance of all relevant aspects of work and the spaces of work. Inspection involves the collection of empirical evidence of compliance with protocols and possibly standardized metrics operationalizing the prescriptive rules. For example, each lab is expected to have weekly checks of the short-term (less than thirty-day) hazardous waste collection areas to ensure that all containers are properly capped and labeled, ready for pickup and transfer to the long-term (up to ninety-day) central university storage areas. Those conducting the weekly inspection will verify that the procedures are being followed by observing consistency between the rules and practices while noting and correcting any inconsistencies. Similarly, the weekly, monthly, or semiannual departmental and EHS inspections will also survey every laboratory space and all materials to ensure full compliance with all relevant rules; for example, availability and good working condition of all personal protective equipment such as lab coats and safety glasses, as well as exhaust hoods, emergency eye washes, and safety showers.

Audits, however, do not actually involve observing the subject phenomena; audits do not collect empirical evidence, as inspections do, that the laboratory looks and functions as the regulations prescribe. Audits are procedures that are adopted to see that the inspection system itself, rather than the lab, is working properly. Audits sample the data collected by the inspections and the responses generated by the organization but do not normally match the samples to the field evidence. They operate at a remove from the hazards themselves to monitor the system for producing safety (inspections, training, etc.) rather than the system's product (safe labs).

As discussions for implementing the inspection system progressed, it became clear that the commitment to five levels of inspection and audit could create a significant burden on laboratory time, especially if each inspection was independent of every other as originally anticipated. Since the department and central EHS staff were to

be partnered, some on the planning committees suggested that the central inspection might be conducted alongside, simultaneously with the department inspection. This compromise was communicated to and approved by the EPA attorneys.

With regard to the forms to be used at each inspection level (auditing was left to future discussions), the EHS office had hoped to computerize the entire process so that lab inspections might be quickly entered into a data bank for central collation and analysis while identifying not only systematic overall compliance but perhaps also problem patterns across the university, as well as individual so-called bad apples. In the second year of the design and implementation process, financial resources were significantly constricted, and plans for computerized inspection via handheld devices with checklists that would automatically send the data to a central storehouse, as well as automation of the future inventory system, were put on hold. Planning would focus on a temporary data collection system for inspections, leaving computerization and automation for future discussions and richer budgets. This paper-based system remained in place for at least fifteen years.

Two heated discussions within the faculty planning group revealed yet another source of variation among the scientists. The biologists were now basically satisfied with the design of the roles and staffing and had become supporters of the university-wide management system. Their approach in year two had become more than conciliatory. They sought out the EHS planning group and staff to help them do a better job. Could the EHS staff provide them with some standard rules or operating procedures for the most common waste materials that could be printed and posted above the hazardous waste collection areas? Could the EHS staff help them standardize the processes in order to create greater efficiency? Specifically, with regard to the inspections, they were perfectly happy to have the central EHS accompany the departmental EHS coordinator on inspections. They had hoped that the central staff would do these inspections all along, and the partnering solution, they thought, had formalized this. If the EHS central staff wanted to use a standard set of questions for all university lab inspections, it was fine with them. If the EHS staff wanted to use multiple forms, some tailored for the department and some for general use, that was also fine.

The chemists did not agree. Not only would they not use a standard university-wide form for their inspections, they did not want the department committees who conducted the semiannual inspections to be burdened with the need to coordinate with any central staff EHS personnel. The rationales for this resistance varied from one meeting to another. At one of the first general meetings on the subject, the chemistry representative voiced his lack of confidence in the EHS staff. He said that the department did not trust the central staff, whom they believed were deficient in the basic science and thus ignorant of the degrees of hazard in the great variety of materials in chemistry labs. Here, the public discussion reiterated what I had been told in one-on-one interviews when I began the project: nonchemists just did not have sufficient chemical knowledge to recognize unusual hazards or, conversely, what was not actually a hazard. The intrusion of nonexperts in the labs had

been the source of resistance to regulation over a decade earlier and had been overcome, the chemists argued, by instituting their own system of self-regulation. This would be going backwards.

At a smaller subsequent meeting, the dismissive tone of a highly expert academic speaking to the rabble was moderated considerably. Now, the objection was practical and voiced as a concern that the university's entire system would falter by trying to spread limited resources too thinly. It was just not possible, the chemists claimed, for the central EHS staff to inspect every university lab twice a year. This was minimally a two-hour activity for more than forty department labs, no less the more than four hundred laboratories university-wide, each inspection requiring the presence of at least three persons (a member of the department faculty or staff, a graduate student, and now a member of the central staff). Just coordinating the persons to schedule these inspections—which were to be unannounced, surprise visits—would be an impossible job. The effectiveness of the surprise—for ensuring daily compliance—would be impeded if they tried to systematize the visits, and without systematizing, it would be impossible to schedule without hiring many more people, which was just not possible. The EHS staff would never have enough people, the chemistry representative claimed, to go on all the inspections. The central EHS participation in inspections would just have to be less frequent so as not to complicate the department's well-oiled surveillance machine. At the end of this meeting, it appeared to this observer that the collaboration with the central staff had come to an end, at least in the chemistry department.

In a series of committee and then one-on-one meetings between representatives of the department and the Eastern attorneys participating in the design of the EHS system, the chemists continually objected to being included in any general set of university-wide processes, although they wanted such a system for everyone else. One of the attorneys managing the project explained to me as I followed along after one of these meetings that he was not all that worried. Indeed, the chemists were not really a *safety* problem, because they had produced an effective system of self-regulation. They were an *organizational* and *regulatory* problem, however, if they would not participate in the general university-wide system because the EPA required consistency across the university. The attorney recognized the posturing and was not surprised, he said, that the roles had become reversed between the difficult (first biology and now chemistry) and cooperative (first chemistry and now biology) departments. Over time, he expected the roles might shift again. He explained the situation: "In essence, they were saying, 'don't mess with what we have here. We do it well, and will continue to. Stay out.' I can understand that. We will work it out."

For perhaps six months, the chemists continued to refuse to use a standard form for their departmental inspections, although the form adopted by the planning committees was developed by tweaking the chemists' existing protocols. Over time, they moderated the disrespectful language about the competence of the EHS staff and compromised their reservations about the logistical problems of having EHS personnel observe or accompany them on inspections. There would be twice-a-year,

unannounced, surprise inspections. One semiannual inspection would be done by the departmental committee alone, and one inspection would include the EHS staff partner along with the department committee members.

Other Variations

The biology department said it would like the central staff to provide training for students and postdocs and a simple poster to be tacked above every lab sink with the ten most important rules. Furthermore, the department had no problem with EHS staff keeping training and inspection records centrally so long as they were kept and the department would not "have to reproduce something in the future for which they were unprepared because the EHS took responsibility and did not fulfill it." In contrast, the chemists did not want the central staff involved in training. Also, it was not possible to have a single poster with rules for every lab; not only did the particular chemicals create different risks, but if you posted only ten rules, the nonposted safety practices would be ignored. Chemistry had a system in place, and it worked fine. Moreover, they did not want any central recordkeeping. This was a learning and research activity, not a police surveillance activity.

Before moving to possible explanations, I reiterate that this variation was not what we expected at the outset of the research. We originally thought that variation in responses might derive from the degree of risk from the number and degree of hazards in the different laboratories, or the organization of the labs as more or less hierarchical or as one big family, and, finally, whether the lab's previous experience indicated that it was problematic (that is, dirty, or a site of violations in the inspection) or a reliably compliant lab. We never imagined that the differences would fall out along department and disciplinary lines. Today, departments and disciplines may be considered somewhat arbitrary because, for example, biological research and nano-scale (molecular/chemical) investigations are everywhere in the university. Radiation and chemical waste are also ubiquitous. Moreover, some members of the chemistry department are biochemists doing basic chemical reactions on biological molecules, and all biologists use chemical reagents. But it turns out that these two departments are excellent sites from which to learn about responses to regulation and surveillance because they do constitute 70 percent of all the chemical waste on campus. Even if there were some biologists who resembled chemists and some chemists who sounded more like biologists, there were very few such outliers, and those responses were silenced by the conversations in department meetings and policies established at the departmental level.

Although we may see an increasing movement to interdisciplinarity across universities, departments are the organizational location and normative community in which academic scientists live and work: gathering material resources, being allocated space, teaching courses, and admitting, selecting, training, and mentoring graduate students who perform the laboratory research. Departments constitute the organizational node through which faculty are linked hierarchically to the

TABLE 11.2
Accounting for Differences

	Biology	Chemistry
History of the field and relationship to industrial practice	Contemporary molecular biology begins in 1970s with invention of recombinant DNA, causing public panic and research moratorium.	Over two hundred years old.
	Biologists collaborate at Asilomar in 1975 to develop criteria for safe handling of bio-matter, protection against spread. Typology of levels of hazard adopted by Centers for Disease Control and NIH. Protections built into lab architecture and standardized equipment and clothing protections.	Long-standing recognition that chemists working with very with hazardous materials.
	Biology industry grows exponentially during 1980s, period of antigovernment regulation. Development of bio-safety industry with dedicated professionals.	Since 1700s, laboratories built with chimneys to exhaust fumes, separating materials to prevent fires. Hoods invented in 1800s.
		First requested U.S. government regulation for safe handling of chemicals in 1880s.
		Two-hundred-year-old industry adopting relatively uniform safety procedures and equipment for exhausts, separation of materials, protective clothing.
Social organization of the lab	Permanent staff of lab managers and technicians supervising work within each lab, with often large number of postdoctoral fellows and much smaller number of graduate and undergraduate students. Multiple layers of hierarchy before reaching principal investigator.	No lab managers or technicians. Many graduate students and fewer postdoctoral fellows and undergraduates. Relatively flat hierarchy within the lab: the PI and her students.
	All labs built from a standard model.	Each lab individually designed.
	Approximately one-third of biology building space shared, e.g., autoclaves, refrigerators, culture rooms.	No shared spaces of facilities, other than those shared across all university departments, e.g., magnet lab, atomic force microscopy.

(*continued*)

TABLE 11.2 (*continued*)
Accounting for Differences

	Biology	Chemistry
Experimental practices	Often work with standard kits for repetitive steps of an experiment of many steps.	Organic and inorganic chemists create a particular reaction or molecule; variation and contamination must be excluded.
	Chemical reactions are technical resources.	Chemical reactions are the epistemic object to be explored, controlled.
	Seeking small but significant statistical or probabilistic variation in a large population of samples.	Seeking to increase the yield in a system where they have already detected a useful product in some amount, to become standard process for kits that biologists and others use.
	Integrated dynamic, complex systems where much still unknown.	Foundational knowledge relatively secure and well accepted.

larger university and where the local matters of curriculum, teaching, research, and employment are coordinated and contested with other departments. How can we account for these differences in the responses of the chemists and biologists? Table 11.2 outlines the differences in the disciplines' histories and relations with industry, social and physical organization of the labs, and epistemological foundations of their experimental processes that together account for the different responses of the chemists and biologists to the new legal regulations governing their labs.

INHERITED EXPERTISE, DIFFERENTIALLY ORGANIZED, AND EXPERIMENTALLY ENACTED

Important scholarship in the sociology of science lends support to the notion that part of the cultural authority of science derives from its ability to guard its boundaries (Gieryn 1983) to make persuasive claims for science as against pseudoscience, ideology, faith, and administrative demands as much as it does from its claim to objective methods and powerful technologies of observation. Neither the chemists nor the biologists willingly ceded authority to define the boundaries of their fields. Although both biological and chemical research is spread across many university

departments—for example chemical engineering, geology, civil engineering, and neuroscience—neither the chemists nor the biologists deferred to others outside their departments the authority to define "good biology" or "good chemistry." Nonetheless, despite this common practice of boundary control, one science erected repeated hurdles to the intrusion of institutional safety systems and personnel while the other staked its claim to scientific autonomy by defining the safety regime as not science, inviting the safety personnel to inhabit, not merely visit, the biology labs.

How can we account for these differences in the responses of the chemists and biologists to the prospect of new and intrusive legal regulation? I suggest that this variation in response to the emergent EHS system is consonant with the different ways in which science is done in biology and chemistry. What do I mean? If we look at the different aspects of doing science and being a scientist, we can find variations in the way the work is organized, the relationship between academic and industrial or corporate science, as well as the embodied and cognitive tasks of being a biologist or chemist—what science studies describe in ethnographies of laboratory practices and the epistemologies of the different sciences (Knorr Cetina 1995; Doing 2008; Shapin 2004). Pragmatist philosophy (Haack 2006) and practice sociology (Bourdieu 1977, 1990) urge us to take note of how strongly individuals are committed to and invested in their hard-won knowledge and how much of what seem like minor interactions or small adjustments seem to threaten long-established habits, knowledge, and consequent authority. In effect, this literature argues that knowledge, including scientific knowledge, is localized, embedded, and invested in practices (MacIntyre 2007). Planned systems of change and innovation must take account of these local practices in order to create boundary-spanning objects or practices. If the law seeks to regulate these dense practices, it, too, needs to be a system of not only abstract logical principles but also practical tools, "thought on its way to action" in Holmes's words (Novick 1995, 3:502). In other words, for law to succeed, it may also need to be practical as well as principled (Ewick and Silbey 1998).

History of the Fields and Relationship to Industrial Practice

Modern chemistry is simply older than biology—older in the sense that its foundational knowledge was in place more than a century before modern molecular and genetic biology started. Indeed, alongside evolutionary theory, much of contemporary biology derives from advances in chemistry. Almost every chemist with whom I inquired about the newly planned EHS system mentioned the age of the field and the fact that chemists have understood for several centuries that they are working with hazardous materials. "Doing chemistry—especially doing chemical experiments—was a smelly, dangerous business, best kept below stairs, well away from polite society," which may help to explain why "eighteenth century chemists—whether they were doing experiments or producing commercial products—worked in laboratories, while most natural philosophers (physicists) did not" (Jackson 2016, 299).

Even the earliest proto-chemical laboratories, spaces for alchemists, assayers, and pharmacists, displayed a recognition of contamination and hazard by placing the multiple furnaces of different configurations at a distance from the work with vessels of flammable materials. The archetypal safety device, the fume hood, evolved from the chimneys that drew furnace smoke upward while coincidentally drawing off the noxious odors with the smoke. As far back as the seventeenth century (Morris 2015, 98), there are examples of early exhaust devices. Placing the hood above the work table, as we know it today, rather than the furnace began in the mid-eighteenth century with labs in Germany, London, and Pennsylvania. The standard histories describe the development of modern chemistry throughout the nineteenth century as a progression of increasing control over laboratory hazards with elaborate ventilation systems for frequent air changes, specialized cabinets for hydrogen sulphide, bomb ovens (also called *ballistic cabinets*) for explosive mixtures, rooms for gas analysis, clean rooms for balances, and workspaces at windows and in adjoining outdoor areas for dissipating fumes.

Technologically elaborated features of these nineteenth-century labs are the ubiquitous features of contemporary labs. Some fixtures address storage issues; others provide for new apparatus, especially glass lines for controlling syntheses and characterization of substances within relatively closed systems; "but many others [are] concerned with maintaining a safe working environment, particularly for inexperienced chemists in training" (Jackson 2016, 299). "The novel risks inherent in teaching and doing organic synthesis were significant in driving and shaping the construction of late-nineteenth century institutional chemical laboratories, and . . . these laboratories were essential to the disciplinary development of chemistry" (Jackson 2011, 55). "The management of risks [was] so severe [that] they could no longer be left in the hands of the individual" and thus became an institutional, professional obligation built into chemistry pedagogy (Jackson 2011, 61). Purpose-built laboratories became essential. "Chemists understood the significance of the purpose-built laboratories in advertising the status of their discipline, but their laboratories were also manifestations in bricks and mortar of the integrated system of training and research by which chemical knowledge was produced" (Jackson 2011, 61).

As important as the chemists' familiarity with laboratory hazards has been, the existence of an established chemical industry, also more than two hundred years old, is part of the disciplinary legacy. Industrial labs were the site, for example, where specialized laboratory clothing first became commonplace[9] (Morris 2015, 257). The movement back and forth between industry and academia created an intimacy with legal regulation and safety regimes in chemistry that has emerged only in the last few decades in biology. Thus, part of the local culture among chemists—which has distinguished them from biologists until recently—is their shared understanding of the dangers attached to the materials with which they work and the techniques, instruments, and habits that mitigate these hazards, which have become an engineered part of the chemical industry. As one chemist told me, "we

don't want to be embarrassed when we send out students to DuPont. They have one of the best safety regimes anywhere. We don't want them telling us that we don't train our students well."

For biologists, industrial development is new; and the history of contemporary biology may have worked against a concern with safety. Several centuries after chemistry labs included safety precautions, and while the profession regularly requested regulations for containment through prescribed modes for shipping and handling chemicals, a National Research Council report on the design, construction, and equipment of laboratories for teaching and industry was published with no specific mention of biology or the particular needs of biology labs (Coleman and Wank 1951). Although containment cabinets were fashioned in the mid-1940s for use in the biological warfare laboratories at Fort Dietrich, Maryland, and, by the mid-1950s, the biological warfare experts began distributing their expertise more widely, it was not until the mid-1960s that nonclassified researchers were included in these biosafety discussions.

When recombinant DNA techniques—the foundation of contemporary microbiology—were first announced, a public panic developed, associating basic research with the fears of biological warfare and unconstrained contamination. Immediately, a moratorium on academic biological research was instituted in Cambridge, Massachusetts, where recombinant DNA was developed, while negotiations ensued between local officials and academic researchers. Commissions were set up, public hearings were held; scientists were required by government and the public to account for themselves and to assuage fears that they, the researchers, were not creating genetic agents in their laboratories that would leak into the local air and water systems, infiltrating the urban infrastructure and contaminating the human genetic pool. About one hundred forty biologists across the nation responded to the Cambridge moratorium, organizing themselves at a meeting held at Asilomar in Monterey, California, during which they formulated processes for working safely with genetic material. The researchers had been taken unawares; they were unprepared for the public furor, surprised by what they regarded as unfounded hysteria. Nonetheless, they took the lead in controlling the consequences, ultimately succeeding in muting the discourse surrounding the implications of genetic engineering and limiting attention to the technical problems of containing unfamiliar hazards. Silencing the discussion of purposive genetic engineering allowed the biologists to control the discourse when it entered Congress and to counter emerging regulatory legislation. They also succeeded in defanging new guidelines by the National Institutes of Health (NIH) to create what the biologists saw as real obstacles to the pursuit of particular lines of research and development (Wright 1994, 256).

Discussions at the 1975 Asilomar conference produced the current standard definitions of risk and protocols for managing four levels of biohazard risk based on the particular agents or organism on which the research is being conducted. The Centers for Disease Control and NIH adopted the Asilomar protocols as the model for mandated federal regulations for containing unknown as well as known

hazards in biology laboratories. Each level builds on the previous one, adding constraints and barriers. Beginning with agents that pose a minimal potential threat to laboratory workers and the environment and do not consistently cause disease in healthy adults, the regulations call for dedicated training in standard microbiological techniques, personal protective equipment (lab coats, glasses, shoes rather than open sandals), prescribed handling of sharps (needles), decontamination of work surfaces and hands, and a prohibition on eating or drinking within labs. At each of the levels of greater hazard, the regulations prescribed enhancements in physical containment, waste handling, and body protection. The laboratories are built with prescribed airflow direction, limited or no air recirculation, and surfaces that resist contamination and ease of decontamination. At the highest level of hazard (BSL 4), the laboratories are physically isolated in buildings located at a distance from populations and other labs, workers wear full body-suits, and air is not only exhausted but filtered.[10]

For our effort to understand the different responses of biologists and chemists to the university safety system and thus the varied contexts within which successful regulation would need to adapt, two features seem important. First, there may be remnants of resistance to government regulation and overreaching, as we heard in the biologists' early responses, "Why don't we just tell them that we don't want to do this?" Second, biosafety has become a major industry with a worldwide professional field of specialists (Huising 2019). Scholars of regulation and public policy have begun to refer to the network of private actors who offer assistance to secure not only biosafety but regulatory compliance generally as "regulatory intermediaries" (Abbott, Levi-Faur, and Snidal 2017). The public fears concerning research processes, the demonizing of the researchers, and the drift from biosafety to biosecurity may have encouraged what now seems like the biologists' more comfortable remove from the management of local hazards.

Social Organization of the Laboratory

Scientists live and work within university-wide hierarchies of power and authority. Both chemists and biologists occupy privileged positions with respect to university staff, for example, radiation experts overseeing licensing and handling of all radioactive isotopes as well as lasers, and industrial hygienists working to design hoods, airflow, surfaces, and bodily protections. Scientists also enjoy almost total power within in the organization of their individual research groups: postdocs, technicians, graduate students, and undergraduates, all of whom are aware of their place in the hierarchy and the absolute and ultimate authority of the principal investigator.[11]Yet, again, there are significant differences between the biologists and the chemists in the ways in which their laboratories are organized. I suspect, moreover, that this difference may be even more salient than their histories and relations to industry, which may be slowly converging. There are many more technicians, permanent assistants, and lab managers in biology laboratories than in chemistry,

where there are almost no permanent technical staff or managers—only the regular flow, cycling in and out, of students and postdoctoral fellows. Moreover, biology labs often have many more postdocs than graduate students. The relationship between the chemistry professor and her students is much more direct and unmediated by the layers of lab workers.

There are also systematic differences in the architecture of the biology and chemistry laboratories. Two items illustrate this spatial variation. Both the biology and chemistry departments at Eastern experienced large-scale renovations in recent years with construction of entirely new buildings. In the biology buildings, approximately half of the new construction comprises standard-issue labs: that is, there is a single model that was repeated in over half the allocated space. In the chemistry building, every lab was individually designed. The necessities are all there—hoods, benches, student desks, refrigerators, freezers, stock closets—but in each chemist's allocated space, the spatial organization of equipment and work surfaces is individually designed. When an entirely new biology building was constructed ten years earlier, not one laboratory was individually designed. I asked the dean, "how come the chemists got to design each of their labs individually and the biologists used a standard arrangement?" He replied that the then chair of biology did not want cost overruns and would not allow any variations. But that explanation really avoids the issue. The dean does not claim that cost overruns are permitted in chemistry but not in biology. When I asked the vice presidents for finance and research, I was told that it is "just the way the chemists are." But that is the question; I am trying to figure out "the way chemists are" that is different from the way biologists are.

Further inquiry at the biology department provided more information. Touring all the spaces and analyzing the architect's plans, I noticed that the main biology building (where all the labs had a single design) allocated approximately one-quarter to one-third of all floor space to shared facilities: autoclaves, refrigerators and freezers, steam baths, centrifuges, and so on. Further inquiry revealed that there were three kinds of shared spaces among the biologists. Very large facilities, such as the mouse-breeding facility that served many faculty, were staffed by a permanent team of specially trained technicians and "governed" (a term used by faculty who described this to me) by a director and faculty committee. There were also partnered facilities when two—or, less often, three—faculty members applied for funding for a particular piece of equipment. Finally, there were spaces and machines that were provided by the department for everyone's use but that required no special governance, for example, autoclaves (for destroying all biological matter before disposal: a consequence of those RDNA regulations). In contrast, the chemistry department had few shared spaces or facilities (a few large computers and access to general university facilities, such as the spectroscopy or magnet labs, which were also used by biologists and physicists as well as engineers.) They were not solely chemistry department space or facilities, although the director might be a chemist or a physicist.

Experimental Practices

Although both chemists and biologists are "generator(s) of surprises" (Hoagland 1990, xvii), there are notable differences between the biologists and chemists in their experimental practices, specifically different bench routines and explanatory logics. Indeed, the repetitive routine in biological experiments may be one of the major differences. Microbiologists produce their results through statistical analysis of variation in their samples. One biochemist explained to me that "biologists are still looking for basic determinants; they work with more integrated, dynamic systems where mechanisms may not be as easily isolated. Because there is still much unknown in the fundamentals, it is what I call an open system where biologists seek small differences in their data that can be built upon as a heretofore unannounced if minor mechanism. Because so much is still unknown, the probability of purification—the chemist's task—is not analytically possible." The explanations are within quite large error bars, as compared with the synthetic chemists. "In molecular biology and cloning studies, the desired species may be a very minor component (e.g., chemical), yet the methodologies may not be sensitive enough to detect the minor components that are being sought. Biologists thus often select for some activity (e.g., infectivity by a nucleic acid or replicative expansion), shown by the minor component, allowing enrichment based, for example, one function rather than abundance." Organic and inorganic chemists are not attempting to create or document systematic variation in a population. They are trying to understand and create a particular, unique chemical reaction, or to increase the yield in a system where they can already detect a product in some amount. They vary conditions and experimental parameters, optimizing what they can produce. They are able to do this because their foundational knowledge has become validated and entered the core of scientific truths. In comparison with the microbiologists, chemistry is a relatively closed system with the foundational knowledge—the elements and most but, of course, not all molecular structures—well known.

Here are some indicators of the different experimental practices. Ironically, despite the openness of biology relative to chemistry, biologists purchase many standard packages or kits for the various steps in their experimental protocols that are in effect closed. Scholars of science studies call ready-made processes "black boxes" (Clarke and Fujimura 2014; Fujimura 1992), a stabilized tool that "is no longer questioned, examined or viewed as problematic, but is taken for granted. A black boxed tool has become part of the tacit skills or material equipment of the laboratory, a circumstance or element of the situation, often rather invisible."[12] The chemists, however, use relatively fewer, if any, ready-made packages and expend a great deal of effort "unboxing" chemical reactions that take place within what may have become standard tools. In addition, it appears that the biologists use a wider array of materials and techniques than do the chemists, more numerous as well as more fixed recipes. As one chemist explained, "We try to invent a new process, a new reaction, that then can be used by the others—chemists and biologists—to produce something

they need. But what we do is figure out a generic or universal reaction." Obviously, this is just one kind of chemistry.

Here is a further indicator about equipment. The glass lines in chemistry laboratories with which the syntheses are produced were early recognized by chemists as an independent source of hazard, with exploding glass a not-infrequent occurrence. The absolute amount of glass as against plastic may be another source of variation. Nonetheless, the number of steps, number of machines, and use of standard recipes and packages seem to vary between the fields.

These differences in experimental systems have been described in terms of variations in the particular *epistemic and technical objects*, as well as local cultures (Knorr Cetina 2009). The epistemic objects "are material entities or processes—physical structures, chemical reactions, biological functions—that constitute the object of inquiry . . . present[ing] themselves in a characteristic irreducible vagueness . . . embody[ing] what one does not yet know" (Rheinberger 1997, 27). The object is not yet defined, so much so that its description is merely a list of components into which the addition of any new component changes the object (Latour 1987). The technical things/objects compose the experimental process through which the definition of the epistemic object emerges. Whereas the epistemic object is in progress and unstable, with experiments composed of technical things used to define the epistemic object, technical objects have become stabilized. Importantly, "it is through these technical conditions that the institutional context passes down to the bench work in terms of local measuring facilities, supplies of materials, laboratory animals, research traditions, and accumulated skills. . . . In contrast to epistemic objects, these experimental conditions tend to be characteristically *determined within the given standards of purity and precision*" of the particular science (Rheinberger 1997, 29; emphasis added). Although with time, epistemic objects can become stabilized to become themselves technical things, part of the technical repertoire, "both types of elements are engaged in a non-trivial interplay" (29).

This analysis of the differences between chemists' and biologists' responses to safety regulations shows how that transformation can work in the opposite direction: the biologists' technical objects can serve as the chemists' epistemic object. If chemists work to make the reaction that biologists use to decode DNA, one scientist's epistemic thing can be another's technical object with associated standards of purity and precision.

DISCUSSION

Although professional agendas frequently shape regulatory compliance, scientists may be extraordinary in the degree to which they successfully guard their professional authority to control their laboratories and conditions of work, as well as status and expertise. Using data from a study of the creation of a system to manage environmental, health, and safety hazards in laboratories, this chapter shows that

rather than resist legal intrusions, biologists and chemists ultimately deferred to legal demands to transform laboratory routines. This willingness to bow before the law was not a product of generalized respect or deference; rather, the biologists and chemists mobilized their disciplinary authority, relying on their historical relations with government regulation, conventional lab organizations and practices, and ways of doing science to insist that if they comply with the new regulatory regime, they do so in ways that did not disturb their disciplinary habitus. By accommodating what appeared to be idiosyncrasies of these departments, the in-house regulators (EHS staff of Eastern University) were able to install the new management system, pass an EPA audit, and thereby comply with the federal court order. The system worked because it was locally responsive, instantiating a basic pragmatic insight. Semiannual inspections conducted within the EHS system processes show that both departments have indistinguishable numbers of findings—that is, noncompliance. Can we claim that variation in legal subjectivity—the ways in which the biologists and chemists interpret law and regulation—is a generalizable observation beyond Eastern University? Perhaps there is something extraordinary about this particular university.

Because "every experimental scientist knows just how little a single experiment can prove or convince" (Fleck 1979, 96), we attempted to assess the generalizability of our findings about the deference of these scientists to the legally mandated regulation of their labs. We distributed a survey to EHS managers at several hundred American universities (receiving 177 responses) to determine ways in which our observations at Eastern were or were not comparable with other universities. The survey was designed to assess whether the extent and structure of a university's EHS system—its design and formal properties—led to differential rates of penetration into the labs. We hypothesized that the scientific status of the university (measured by department rankings, research funding, and AAU membership) and legal environment (EPA inspection status, presence of in-house counsel and risk management officer, and membership in an EPA partnership, section alliance or university consortium) would influence the shape and extent of the EHS management at the university.

The data showed that the presence of an EHS system did not affect the attention to at least ten or more EHS-related issues on campus: 58 percent of universities without EHS and 66 percent with management systems addressed ten or more issues. We did not find strong support for the argument that penetration is a function of the broader university environment. Only professional networks have a marginally significant effect on penetration, such that universities that are members of an environmental, health, and safety consortium tend to have a penetration score that is approximately 8.6 percent higher than universities not involved in these networks. Also, penetration into the labs does not vary with the degree of legal regulation to which the university was subject (having had an EPA inspection or legal counsel on campus) or its professional status relative to other universities. However, we did find that discipline influenced penetration of environmental, health,

and safety procedures into the laboratories. Specifically, we explored whether penetration was more pronounced when biology or chemistry departments were heavily involved in EHS. We found that penetration, measured by responses to questions about routine laboratory safety practices, is significantly stronger when chemistry is heavily involved in EHS policies, irrespective of the biology department's involvement. Penetration is greater when chemistry is a key player, and this effect holds both when biology is also heavily involved and when biology is not heavily involved. I reiterate that this variation is not what we expected at the outset of the fieldwork, and thus we developed the survey to see whether the observations at Eastern were reproduced at other universities. They were.

The introduction of an environmental, health, and safety management system into scientific laboratories brings the audit culture (Power 1997; Strathern 2000)—in this case, legally mandated—directly into the habitat of the scientist. This approach to regulation is a response to experience and learning, itself a form of pragmatic, experimental public policy (Dewey [1927] 1954). It is the consequence of a shift in the EPA's and other agencies' agendas to focus on classes of organizations whose activities have proved much harder to regulate: the military, municipal and state offices, and the subject of this paper, educational and research institutions. But, more fundamentally than the site of regulation, this form of performance-based regulation signals a direct response to criticisms about the limitations of regulation as command and control (Deutch and Lester 2004) and increasing demands for regulations adapted to local organizational cultures (National Research Council 2014; Huising and Silbey 2018). Although most legal regulation attempts to manage some activities of organizations, this strategy supplants more conventional policies that mandate either the use of specific technologies or specific levels of performance by locating the design, standard-setting, and implementation of regulation within the regulated organization itself, in the hopes of co-opting the local governance processes that operate within these institutions to meet public, rather than private, goals (Coglianese 1997, 2001; Huising and Silbey 2011).

From a larger perspective, however, this risk management strategy is not just about accommodating and thus mobilizing existing organizational capacities; it is also symptomatic of a long historical shift in social relations, which Giddens (1990, 17) refers to as "reflexive modernization": the systematic, "reflexive ordering and reordering of social relations in the light of continual inputs of knowledge." A series of transformations in the loci and objects of trust, differentiating modern from traditional societies, mark this historical shift. Trust is "a form of faith in which confidence vested in probable outcomes expresses a commitment to something rather than just a cognitive understanding"(1990, 27). In contemporary societies, trust no longer attaches as critically and pervasively to kin, communities, or religious cosmologies as it does to personally chosen networks alongside the very opposite: abstract systems, especially expert systems. Those expert systems are technical accomplishments that organize large areas of the material and social environments in which we live and work today. Knorr Cetina (2009) describes the

knowledge-based organizations that suffuse our daily life as epistemic cultures, practiced and practicing knowledge; scientific research laboratories are the ideal type of a knowledge-based organization, an expert system that has evolved over the last four centuries. By assigning responsibility to the university for designing, implementing, and, most important, auditing its own protocols for environmental safety, the consent order required that the scientists' expert knowledge be extracted, collected from its local authorities in the labs and safety personnel, generalized, and embedded in protocols distributed and audited through the management system (Huising 2014).

Further, we can see this regulatory apparatus as just another in the long stream of administrative ordering of society, what Scott (1998) describes as projects of high modernist faith (i.e., trust) in the ability to rationally plan and, most importantly, make legible and transparent what is usually unspoken and tacit. For sure, the EHS management system did just that; it revealed the deeply sedimented routines and taken-for-granted practices that differentiated biology from chemistry, so much so that consistent conformity with safety demands required locally crafted protocols. While Scott (1998, 5) describes modernist nation-building projects as features of authoritarian states' capacities to "run roughshod" over a prostrate civil society, the scientist subjects of the EHS systems successfully marshalled forms of legitimation denied to ordinary citizens even in flourishing democracies. If legibility creates the capacity for social engineering, it remains an open question how much scientists will be able to retain their privileges in the face of concerted efforts at social control.

The biologists and chemists at Eastern University went along with this appropriation of their authority and expertise only to the extent that the processes were consistent with their varied local habitus. I suspect that the willingness to bow down to the legal demand to produce safe laboratories and reorganize local cultures to do so is only in part a deference to law. More likely, I think, there is an aspect here of that recursive reflexivity Giddens describes, because this particular legal authority is constructed in part by science in its identification and specification of what constitutes a safety hazard. The identification of hazards is an ongoing process, constantly in the making. Thus, as science contributes to the institutionalization of safety as a part of our regimes of knowledge and risk, it subordinates itself, like the canonical liberal legal subject, to the principles and knowledge it helps to establish.

Nonetheless, by subjecting science to the same processes and techniques of accountability as just about everyone else—including industry, finance, and the police—this risk management of laboratories challenges the independence and autonomy that have characterized, if not fueled, the productivity of science. By demanding attention to the safety of laboratory habits, the regulatory regime appropriates attention, always a scarce resource. Regulatory activity is ultimately "focused on devising methods for ensuring that organizations and their staff pay attention to the "right" things. . . . Allocation of attention is not just about using a scarce resource efficiently, but is also about the right to decide for oneself what is important" (Heimer 2008, 30). Here is where the challenge to scientific authority may be most significant.

"In responding to the demand for [accountability], scientists are reshaping the relationships between existing disciplines . . . [and] the very matter they are creating" (McCarthy and Kelty, 2008, 3; 2010), engineering safety concerns into the very molecules they are synthesizing, making them "safe by design" (Kelty 2009).

If legally mandated organizational change is notoriously difficult, there is also evidence that organizational practices do change, often in response to institutional pressures and regulatory enforcement (Coslovsky 2011; Pires 2011; Huising and Silbey 2011), to which this chapter contributes another example. Perhaps repeated proclamations of regulatory failure and organizational sluggishness are simply a consequence of concentrated focus on the tails rather than the hump of the distribution of implementation and compliance practices (Silbey 2013; Land 2014; Basbug and Silbey 2021). Most legal regulation succeeds. That is, most people follow the rules most of the time (Ewick and Silbey 1998). This applies to the widest range of activities concerning, for example, economic markets and production, financial transactions, the education of children, the provision of medical care, and the organization of city streets and traffic lanes. Active law enforcement is normally directed to the few transactions, often less than 5 to 10 percent, that fall outside prescribed pathways. Success goes unnoticed because it "has become thoroughly institutionalized" (Heimer 2013; Heimer and Kuo 2021; Short 2013), part and parcel of the habituated and taken-for-granted conditions of everyday life, for example, through safety standards for building materials, logistical organization of public spaces, or the security of drinking water. Thus, while we might have appropriately expected faculty to be among the ten percent who frequently resist new regulatory mandates, especially those that interfere with investigator autonomy and laboratory habits, it is also possible that the mandated environmental management system might eventually become as routine—even if resented—as equal employment personnel policies, conflict-of-interest protocols, and institutional review boards (Stark 2011).

It is certainly too early to say whether these observations and hypotheses will prove prescient, or how the several variables (history, organization, practice) will plait to describe other laboratory cultures. If asked to predict, I would imagine that both the biologists and the chemists will sustain well-functioning EHS processes within their departments. I would expect that the next EPA inspection would not show much variation in compliance or violations between the two departments. What remains unclear, however, is how they connect to the university in general and what this experience bodes for other forms of legal regulation and control. After all, it was the particular cultures of biology and chemistry that mediated—by moderating—the demands for change. To the biologists, the EHS system appears to be just another piece of equipment, like another technician or a facility made available by the department—a set of externally imposed or available constraints, like the rules they so much opposed at the outset. Conversely, for the chemists, their work, labs, and students are personalized, and the safety regime is as well. For the chemists, the safety regime will be an internalized part of their laboratory practice and identity—while for the biologists, it will be another material resource.

> The chymists are a strange class of mortals, impelled by an almost insane impulse to seek their pleasures amid smoke and vapor, soot and flame, poisons and poverty. Yet among all these evils I seem to live so sweetly that may I die if I were to change places with the Persian King.
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> —Johann Joachim Becher, *Physica Subterranea*, 1667

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NOTES

1. The sociology of science has documented the ways in which science varies: by the degrees of social embeddedness and material exchange (Kaiser, Ito, and Hall 2004; Shibayama, Walsh, and Baba 2012); networks of collaboration (Powell et al. 2005; Collins, Evans, and Gorman 2007); organization of space (Lynch 1991; Gieryn 1999b, 2002; Silbey and Ewick 2003) and of bodies (Myers 2008, 2012; Peterson 2015); degree to which scientists invest in tradition or innovation (Foster, Rzhetsky and Evans 2015); production of intellectual property (Owen-Smith and Powell 2001); relationships among theory, experiments, and available technology (Galison 1997); experimental systems (Rheinberger 1997); meanings of data (Latour and Woolgar 1986; Lynch 1985; Collins and Pinch 1998); and the differential constructions of truth, or what Knorr Cetina (2009) calls the "epistemic cultures"—the ways in which different fields of science constitute knowledge.
2. I do not specify the exact date or federal circuit because we do not name the institution or the persons, using pseudonyms only.
3. Resource Conservation and Recovery Act 1976 (RCRA), 40 C.F.R. part 260–280; Clean Air Act 1990 (CAA) Title 42, chap. 85; Clean Water Act (CWA) P.O. 92–500, 86 Stat. 816 (1972), 33 U.S.C. 1251 et seq.
4. I use the term *green* as a colloquial label to designate a wide spectrum of conditions and practices designed to secure clean air and water and conservation of natural resources. It is not meant to suggest or ally with any political party or lobby.
5. Interview with EPA attorneys on file with author.
6. For Hoebel and Llewellyn (1941), one route to the law stuff of a culture was ideological and traced the extant rules of social control for proper channeling and controlling behavior. In this first path, the scholar would attempt to map the official, formal norms of a society, those rules of right behavior for which individuals do not retain authority to define. The second mode of legal inquiry should explore, they urged, the patterns