Introduction: Environmental Justice and the Transformation of Science and Engineering

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For nearly thirty years, the environmental justice (EJ) movement has been engaged in what Cole and Foster (2001) describe as "transformative politics." In the course of agitating to correct inequities in the distribution of environmental hazards, the movement has transformed the victims of environmental injustices, turning formerly quiescent minority and low-income neighborhoods into organized, politically engaged communities, and residents once intimidated by powerful corporations and state institutions into outspoken, politically savvy advocates for their communities. Environmental justice activism has also played a role in changing environmental policy, as U.S. agencies have been forced to consider the health and environmental consequences of their decisions for communities of color and low-income communities (see Cole and Foster 2001, 26; Toffolon-Weiss and Roberts 2005; Gordon and Harley 2005; NRC, 2009; NAS, 2009). In addition, the environmental justice movement has transformed the shape of environmental activism, calling environmentalists' attention to the places where we "live, work, and play," as leading EJ advocate Robert Bullard put it, and pioneering a networked, grassroots structure that arguably enables the movement to remain community-driven (Schweizer 1999; Schlosberg 1999; Agyeman 2005).

Expanding the notion of environmental justice as transformative politics, this book contends that the environmental justice movement has also been transforming science and engineering. The book's chapters present case studies of technical experts' encounters with environmental justice activists and issues, inquiring into the transformative potential of these interactions. The contributors ask: To what extent has working with EJ activists enabled scientists and engineers to forge new scientific practices and identities? What has constrained their ability to do so? They also ask parallel questions of technical professionals' activities in

mainstream scientific institutions, including places such as regulatory agencies and universities, where commitments to environmental justice have been (partially) institutionalized in a variety of ways: How, and in what ways, have the practices of science and the identities of scientists within scientific institutions changed as a result of pressure from the EJ movement? What are the structures that have stood in the way of more fundamental change?

In addressing these questions, we draw on an understanding of science and engineering as multivalent with respect to environmental justice. Studies of environmental justice activism have highlighted the central roles that technical practices and technical experts often play, not only in creating environmental injustices, but in confronting and correcting them as well. The literature, that is, documents the heterogeneity of environmental justice activists' engagements with experts and their knowledge. It demonstrates that the activities of technical professionals may contribute to the structural inequities that put communities of color and low-income communities in harm's way while at the same time offering resources in those communities' pursuit of justice. Nor are these possibilities mutually exclusive: even scientists seeking to aid community groups may inadvertently reproduce the structures of injustice that they seek to counter (Cable, Mix, and Hastings 2005; Hoffman, chapter 2, this volume).

Besides being multivalent and heterogeneous in the context of environmental justice, science and engineering are dynamic by nature and therefore transformable. This book contends that the dynamism of technical practices has gone largely unacknowledged by earlier EJ research. Researchers have highlighted the culturally contingent nature of science and the values, biases, and systemic blind spots inherent in it through, for example, studies that contrast community understandings and representations of local environmental conditions with "scientific" understandings and representations (Wynne 1996b; Bryant 1995; Head 1995; Tesh 2000). However, scientific knowledge is largely regarded as relatively stable in this work, its shortcomings predictable and enduring, rather than as an ongoing cultural creation, made and remade through the daily practices of scientists and engineers. Researchers have tended to represent alternative forms of science, if found at all, as challenges to—rather than extensions or refashionings of—the official knowledge produced in mainstream scientific institutions (e.g., Brown 1992; Corburn 2005). Those institutions along with the scientists and engineers who populate them are even less likely to be characterized as dynamic and

changeable; for the most part, EJ studies present technical practitioners as static, external agents who "parachute in" to predetermined scenarios (see Irwin, Dale, and Smith 1996).

Perhaps because they are viewed as static, scientific knowledge, institutions, and experts have largely been excluded from accounts of environmental justice's transformative nature. Works that document ordinary citizens' journeys from quiet homemakers to outspoken activists (e.g., Cole and Foster 2001; Pardo 1998) lack counterparts describing allied scientists' journeys from bench researchers to experts willing to advocate on communities' behalf (though Allen 1998 is a partial exception). Similarly, research that asks how the environmental concerns of poor and minority communities have changed the shape of the "mainstream" environmental movement (Schlosberg 1999; Brulle and Essoka 2005) has not been extended to consider how government acknowledgment of environmental justice concerns has changed the shape of environmental regulatory institutions and the science practiced therein.

In this book, we extend researchers' and practitioners' understanding of environmental justice as a transformative movement by showing how environmental justice activism has created opportunities for changing technical practices—and, in a few cases, has even made possible significant transformations. Drawing on insights from science and technology studies (STS), we offer a theory of how science and engineering can change—namely through technical professionals' responses to routine "ruptures" in their practice. The size of the ruptures, we suggest, determines the extent of science's dynamism—that is, the degree to which institutional contexts allow scientists room to maneuver limits their ability to bring about fundamental change.

Our theory of rupture and room to maneuver provides a framework for understanding the transformations—achieved and hoped-for, thorough and incomplete—explored in the case studies that comprise the book. Each chapter documents a rupture, an opportunity for change, created through the interactions of scientists and engineers with environmental justice activists and issues. Each also points to the ways that the larger structures that constitute the contexts for scientists and engineers' work either help them to take advantage of those ruptures or, more often, constrain their room to maneuver and stand in the way of fundamental transformation. By rendering technical practices as potentially malleable, this book suggests how they might be remade in the service of environmental justice. Beyond our theory of rupture and constraint, the individual chapters suggest strategies that might be employed in order to

bring about change, and they detail obstacles in order that activists and practitioners may look for a way around them.

In the introductory remarks that follow, we first discuss the variety of ways in which science and technology have been engaged by the environmental justice movement. We then elaborate on how work documenting the dynamic, contingent character of science and technology allows us to identify and analyze ways that engagement in the environmental justice movement has opened up spaces for transformation of the scientific enterprise. In the subsequent section, we discuss the two classes of transformation that divide the book into two parts—those initiated by scientists and engineers and those provoked by pressure from EJ advocates—before we make the ideas of rupture and constraint, opportunity and obstacle, concrete through a discussion of how the twinned concepts appear as driving themes in the chapters, even if not invoked explicitly by contributors. In the end, we argue for the value of understanding technical practices as multivalent and dynamic, showing that environmental injustice is an important source of ruptures in technical practice and thus a powerful force for the transformation of science.

Environmental Justice's Multivalent Engagement with Expertise

Research and advocacy around environmental justice issues have made clear that environmental racism and injustice are structural problems (Bullard 2000; Cole and Foster 2001). Focused on instances where community groups have successfully mobilized against these structures, researchers and advocates have also stressed that environmental injustices can be overcome (Pellow and Brulle 2005; Lerner 2005). In activists' battles to dismantle the structures of environmental injustice, we suggest, technical expertise appears on both sides. Scientific practices, technological infrastructures, and the authority of technical experts all help produce and reinforce the structures that create environmental injustices. At the same time, science and expertise have also been powerful weapons in struggles to overcome environmental injustices.

Industrialization and its associated sociotechnical infrastructures have both produced the environmental hazards faced by communities and shaped practices for generating and acting on scientific knowledge. In the post–World War II era of Big Science, cycles of industrial production, consumption, and disposal grew on an unprecedented scale. The increase in production-consumption cycles throughout the twentieth century has been the source for the environmental hazards that communities,

including those instrumental in the rise of the EJ movement, have organized to confront. The polychlorinated biphenyl (PCB)–contaminated soil that African-American residents of Warren County, North Carolina, fought to keep out of their community in 1982, for example, originated as a by-product of industrial processes to make components for electrical systems (such as insulators and heating fluids) and plasticizers for a generation of new polymeric materials (Bullard 2000). The leaking drums of chemical wastes that a white community in Love Canal, New York, fought to have cleaned up in the late 1970s had their genesis thirty years prior with the closing of a chemical production facility (Blum 2008). The construction and expansion of petrochemical facilities in the latter half of the century had ramifications for communities, as in the case of Norco, Louisiana, where a company's decision to build a new facility in the 1960s sandwiched a historic African-American community between a chemical plant and an oil refinery (Lerner 2005).

Such cases comprise a central plank in an environmental justice movement, where minority and low-income communities have fought new sources of pollution that added to their disproportionate burdens, insisted on cleaner and safer processes at existing production and processing facilities, demanded that environmental laws be fully enforced in their communities, and defended their right to participate in decisions that would affect the health of their families and neighborhoods. When viewed together, the cases show how historical patterns of residential segregation have combined with local zoning ordinances to make hazardous facilities more likely to be sited near communities of color or how residency patterns encourage particular land-use policies by local governments. They illustrate practices used to silence low-income, minority, and immigrant communities and privilege corporations and wealthier citizens in policymaking processes (Cole and Foster 2001; Shrader-Frechette 2002). They speak, that is, to the structural issues at play in environmentally unjust scenarios.

The growth of twentieth-century industry was intertwined with another structural contributor to environmental injustice: the rise of an expert class whose claims to authority were, and are, based in specialized, technical training. While "the scientist" and "the engineer" both developed professional identities before the twentieth century, they acquired new status in a modern industrial system that relies on science and technology to generate wealth. The authority of technical experts has, paradoxically, been bolstered by the environmental hazards associated with the industrial system: unprecedented environmental problems

have created a situation—characterized by Ulrich Beck (1992) as a "risk society"—in which only science and technology can provide solutions to the problems created by science and technology. In the risk society, as Pellow and Brulle (2005) point out, technical experts are deeply implicated in creating and maintaining environmental injustices. Experts' calculations, political and economic as well as technical, inform the siting and enforcement decisions that concentrate environmental risks in low-income communities and communities of color. Called to help solve environmental problems, scientists and engineers are likely to favor research aligned with the goals of the laboratory or the agency or the corporation, not the community beyond the fenceline (Hess 2007, 2009). The increasing influence of neoliberal agendas, where market-based solutions define the form of response to environmental problems, further embeds science and engineering within structures of capitalist production (Liévanos, London, and Sze, chapter 8, this volume). They also value certain kinds of evidence and discount others; the "local knowledge" or "citizen science" that community groups could bring to environmental problems, for example, is frequently disregarded or deemed irrelevant in the context of mainstream scientific practice (Ottinger 2010).

In concrete terms, experts' centrality to the modern industrial system has been directly consequential for environmental justice struggles. Communities seeking to demonstrate that their health is (or would be) harmed by nearby hazards often find little help in accepted modes of scientific practice. Inquiry into the potential health effects of chemical exposures, where it occurs at all, is constructed in a way that makes it extremely difficult to show that chemicals cause illness in humans under the conditions experienced by communities engaged in environmental justice struggles. Epidemiological studies, for instance, routinely miss or even deliberately obscure the effects of environmental hazards on community health (Lewis, Keating, and Russell 1992; Head 1995; Tesh 2000). Technical experts' participation in public hearings and other decision-making processes can limit citizens' ability to have their voices heard (Gauna 1998). Nor are the cases only the result of status quo passivity, since research by government agencies in a number of influential cases was designed specifically to obscure any connections between illness and pollution (Allen 2003; Lewis, Keating, and Russell 1992).

The dominant place of experts and expert knowledge also constrains communities' ability to see local environmental hazards addressed. Policymakers will rarely take action to mitigate the effects of pollution on a

community until they have proven that pollution *causes* residents' health issues—an almost insurmountable hurdle given scientists' standards for proof (Bryant 1995). Simultaneously, with technical information about facilities and their environmental risks given privileged status in siting decisions and other public policy processes, residents frequently find their ability to participate fairly in those processes circumscribed. Community members' lack of familiarity with highly technical terminology can limit their ability to challenge the bases on which policy decisions are made, since their contributions to public hearings and other deliberations are likely to be devalued for not being "scientific." Compounding the barriers faced by communities is a regulatory regime that draws from the technical expert class to set and define standards based on scientific norms produced in labs and outside affected communities.

Intertwined with modern industry, science, technology, and expertise are thus integral to the social and political structures that produce environmental injustices. Accordingly, EJ advocates have in many cases taken expert knowledge as a target. In particular, they have challenged claims that communities are not harmed by industrial pollution. Arguing that environmental health science routinely fails to incorporate relevant "local knowledge," EJ advocates emphasize that those situated understandings of local environmental conditions and behavioral patterns are likely to influence community exposures to toxins (DiChiro 1998; Sze and London 2008). They have also shown that scientists' ignorance of or faulty assumptions about local conditions can result in significant distortions in scientific studies and risk assessments (Harris and Harper 1997; Corburn 2005; see also Powell and Powell, chapter 6, as well as Johnson and Ranco, chapter 7, this volume).

Yet, as we noted above, EJ activists have also used science as a resource in mobilizing against the structures of injustice. Communities have enlisted the support of experts sympathetic to residents' claims about the health effects of environmental hazards; some have even worked with experts to produce alternative studies that capture residents' local understandings of environmental and health problems (Brown and Mikkelson 1990; Brown 1992; Singleton and Legator 1997). Expert activists have, in conjunction with community members, developed other new methods for representing patterns of illness in polluted communities, including the mapping techniques that Barbara Allen (2000, 2003) describes. In other cases, community groups have used environmental monitoring technologies to produce scientific data about their exposures to chemicals as a way to hold industrial facilities and

environmental regulatory agencies accountable for chemical pollution (O'Rourke and Macey 2003; Overdevest and Mayer 2008; Ottinger 2010). These efforts draw on the authority of science and scientists to further communities' environmental justice goals. Yet they do not merely reproduce established scientific practices. Rather, in mobilizing science for their own ends, grassroots groups have been creating alternative methods for knowing about and representing the health effects of pollution. The epidemiological, monitoring, and mapping methods that EJ advocates have pioneered provide technical information that represents local knowledge and fills gaps in existing science.

We can see environmental justice activists' effort to turn science to their own ends, creating new knowledge and practices in the process, in one of two ways. Their efforts can be regarded as a unique endeavor distinct from and opposed to conventional forms of science and expertise. But they can also be seen as an extension of established scientific practices that aims to alter the shape and direction of those practices. In the first view, the alternative forms of science created in the service of environmental justice are combative; in the second, they are transformative. We see communities' engagements with science, technology, and technical experts as having the potential to transform scientific practices and methods, a view that raises new questions for the study of relations between science and environmental justice. What are the processes through which transformation takes place? Are there particular points of leverage that can be used to facilitate change, or stumbling blocks that stand in the way of efforts to alter technical practices? And how can EJ advocates orient their efforts to promote the transformation of science so that it becomes less often an obstacle to environmental justice and more often a resource?

Constructing and Reconstructing Science

Asking how science can be—and has been—transformed by environmental justice advocacy depends, first, on understanding science as active and evolving. Too often in the cases noted above, scientific knowledge has been regarded as relatively stable, its shortcomings predictable and enduring. Technical practitioners, likewise, tend to be represented as static, external agents parachuting in to communities to apply pre-established skill sets. In contrast, we see science and engineering as flexible, contingent, and continuously under revision. In these dynamic enterprises, transformations grow out of routine ruptures in everyday

technical practices, where scientists and engineers have room to make new choices about how to do their work.

Viewing science as dynamic and subject to constant revision, rather than fixed and stable, follows from the insight that science is a culturally situated set of practices.[1] Developed in the decades since Thomas Kuhn's ([1962] 1996) postpositivist history and philosophy of science, this understanding of science contrasts with older, though more publicly familiar, positivist conceptions of science. That earlier work conceived of an asocial, rational science devoted to uncovering timeless and place-less facts about the natural world (see Turner 2008). Since Kuhn, numerous studies of the actual practices of scientific knowledge production have come to find that science is a more complicated, more culturally embedded, and more dynamic social system than positivist portrayals can account for. Notably, this research has argued that scientific "facts" do not enter the social world fully formed; rather, they are produced in the course of working out other kinds of political and social arguments (see Sismondo 2004, 2008; Yearley 2005). Nor can the development of technology be understood as the straightforward application of scientific principles to preestablished problems; technology too is shaped by a variety of social and political negotiations that simultaneously define an object's form, its meaning, and the societal problems to which it is a solution (Winner 1986; Bijker, Hughes, and Pinch 1987; MacKenzie and Wajcman 1999; Oudshoorn and Pinch 2003).

Science and technology are actively constructed through the efforts of a variety of actors embedded in specific relations of power and systems of cultural meaning. Without suggesting that the situatedness and historical contingency of science and technology are a priori good or bad, the finding has directed scholarly attention to the actual processes through which facts and artifacts are made (see, for example, Daston and Galison 2007 on objectivity; Latour and Woolgar [1979] 1986, Knorr Cetina 1981, and Lynch 1985 on microlevel laboratory studies; and Frickel and Moore 2006, Hess 2007, and Hess 2009 on meso- and macrolevel institutions and networks). Scholars' interest in understanding science as a culturally situated production also extends to exploring the very processes through which scientific practitioners are constructed as "experts." Research on boundary drawing and the creation of scientific personae, specifically, document how scientists claim authority over particular domains of knowledge (Gieryn 1999; Daston and Sibum 2003; Carson 2003; Browne 2003; Thorpe and Shapin 2000).

Understanding science, technology, and expertise as actively produced rather than pregiven indicates the dynamism of scientific and engineering enterprises. Science is not only made, it is constantly in the process of being remade in response to shifts in cultural terrain. The active character of technical practice suggests the possibility for scientists to deliberately refashion their practices, institutions, and identities to bring about changes in the nature of scientific research or the bases for expert authority. Scholars have traced such developments in the last few decades with examples ranging from the fields of genetic toxicology (Frickel 2005) and conservation biology (Galusky 2000) to individual "politicoscientists" in the post–World War II era (Egan 2007; Moore 2008). Even more broadly, Shapin (2008) has shown how the very idea and moral constitution of science and "the scientist" have evolved into a vocation in the past century. Nor is making and remaking science the province of practitioners alone. Epstein (1996) and Hess (2007), for instance, have chronicled the effects that social movement groups have had on the shape of scientific research and technological development; Nowotny, Scott, and Gibbons (2001) argue in their explication of "Mode 2" science that research agendas are now set beyond the confines of disciplinary homes, even if not by the social movement actors Epstein and Hess refer to.

Although science and technology are always in the process of reconstruction, we argue that significant transformation has the greatest opportunity to occur at moments where there are disruptions in everyday technical practices. As a social practice, science is constructed through the everyday choices and activities of practitioners as they go about their work (Bourdieu 1977; De Certeau 1984). Those activities are always aided, constrained, and given meaning by the broader world in which practitioners are situated—in fact, the reconstructions are mostly shaped in subtle ways within power structures of dominant institutions—yet these situations always come with indeterminacy, and thus maneuverability, in their choices. The bounded but indeterminate nature of practice creates rifts, ruptures, or "spaces between" that, like an earthquake breaking apart the land or a knife slicing a loaf of rising bread, produce more area than existed before (Serres 1983; Deleuze and Guattari 1987; Traweek 2000). These are sites of transformation and, ultimately, the source of the flexibility and dynamism that STS scholars have shown to be characteristic of science.

Environmental justice activity is a powerful source of ruptures and "spaces between" in technical practice. Where scientists and engineers

respond to the demands of stakeholders, affected users, and collaborators from the environmental justice movement, the broader world that aids and constrains their work expands, spaces open up, and the choices available to them multiply. By heightening the indeterminacy of technical practices, experts' involvement with EJ expands the opportunities for transformation. The transformative opportunities introduced by environmental justice are not unbounded, however. Technical practices remain constrained by the institutions and power relations within which scientists and engineers operate, circumscribing the possibilities for transformation.

These opposing dynamics—of opportunity and obstacle—are made concrete by the case studies collected here. In chronicling various kinds of interactions between technical practitioners and environmental justice advocates, they show how EJ engagement, voluntary or involuntary, generates ruptures and broadens experts' room to maneuver. Simultaneously, they highlight systemic and structural obstacles experts face in pursuing transformative opportunities. Individually and together, they suggest ways that environmental justice advocates' engagements with science can be made more effective in changing technical practice.

Rupturing Practice from within and without: Opportunities and Obstacles

The studies assembled in this book examine ruptures in technical practice created by environmental justice activity. Focusing on a moment or site where technical practitioners meet activists, issues, and informational needs associated with the EJ movement, the chapters explore how these interactions create opportunities for transformation, analyze the degree to which change is realized, and theorize the factors that foster or limit change.

The diversity of the collected case studies points to two sources of rupture. The chapters in part I of the book discuss opportunities for transformation that occur as a result of experts' deliberate efforts to support the broader movement for environmental justice through their technical practices. In contrast, chapters in part II highlight how science and engineering practice within mainstream institutions has been disrupted by outside pressures on the institutions to incorporate environmental justice sensibilities into their work. In the first half, the examples illustrate cases of invited change; in the second half, they show cases where changes were not invited.

The authors show that the transformative potential of both kinds of rupture stands in tension with constraints created by the institutional contexts and cultural milieus in which technical practitioners operate. While the obstacles to change within established institutions such as regulatory agencies and undergraduate training programs are all too predictable, chapters in part II nonetheless describe indications of important shifts in technical practices and identities that have occurred as a result of EJ activism. Conversely, the case studies in part I find that even where scientists and engineers actively seek change, their ability to transform their practices may be constrained by the nature of their scientific networks, by accepted standards of practice, and by their own understanding of their role as experts.

The transformative interventions of scientists and engineers showcased in part I include pioneering research in environmental health science, the focus of Scott Frickel's chapter (chapter 1) exploring how scientists come to be expert activists in the EJ movement; a nonprofit organization's scientists' efforts, analyzed by Karen Hoffman in chapter 2, to share their expertise and the political influence that goes with it with community members without formal technical training; the development of websites to make information about the releases of toxic chemicals into communities widely available, critically examined by Jason Delborne and Wyatt Galusky in chapter 3; a collaborative project among researchers (including the lead author of chapter 4, Rachel Morello-Frosch), environmental justice groups, and community partners to provide community members with meaningful information about the levels of toxic chemicals in their bodies; and a project by Sri Lankan engineers to promote renewable energy development in the country's rural communities, analyzed by Dean Nieusma in chapter 5.

The heterogeneity of those cases emphasizes the range of settings in which scientists, engineers, and other experts find and create opportunities for change. Cases of toxicologists, epidemiologists, and other scientists cooperating with community groups to develop new methods for investigating environmental health problems—the kinds of cases invoked by Frickel and Morello-Frosch et al.—have become relatively familiar (e.g., Allen 2000; Brown 1992, 1997; Corburn 2005). But these chapters additionally show energy engineers (Nieusma) and web developers (Delborne and Galusky) attempting to deploy their particular skills in ways that support the goals of environmental justice. Moreover, they show experts working to reshape multiple aspects of technical practice—not

only processes of knowledge production but also methods of disseminating technical information (Morello-Frosch et al.; Delborne and Galusky) and relationships between experts, community members, and policymakers (Hoffman; Nieusma).

Simultaneously, part I's chapters detail systemic challenges faced by scientists and engineers wishing to change various aspects of their practice. Some of the work highlights experts' ongoing connections to pre-existing professional networks and identities as particularly significant in limiting the success of transformative efforts. New approaches to reporting research results back to community groups, for example, must contend with entrenched understandings of ethical practice, as Morello-Frosch and colleagues show. Likewise, scientists and engineers' sincere efforts to empower community members by transferring technical information and authority are, in the cases developed by Delborne and Galusky as well as Hoffman, constrained by their own preconceptions of the respective roles and abilities of technical experts and "laypeople" in achieving environmental justice ends. The chapters by Frickel and Nieusma underscore the importance of professional networks by exploring the particular conditions under which scientists and engineers can use their networks to help them be effective environmental justice advocates. Identifying and characterizing such challenges provide a necessary precondition for working toward future transformations. If the goal is to discuss ruptures and flexible joints in technical practice, then it is also necessary to mark out locations of particular intractability so that, in the future, practitioners can feel their way around the situation like a demolition crew looking for weak points in a building, seeking new chances to exploit break points yet unfound.

The second half of the book focuses on the transformative potential of *un*invited ruptures produced by environmental justice activity, showing in a range of cases how scientists and engineers are adapting to EJ advocates' push for new kinds of technical practice. Three of the chapters focus on the regulatory arena. In chapter 6, Maria Powell and Jim Powell document their EJ organization's efforts to change regulators' approach to evaluating and providing information about the health risks of subsistence fishing by minority communities in the polluted lakes of Madison, Wisconsin; in chapter 7, Jaclyn R. Johnson and Darren J. Ranco discuss the ways that the EPA has engaged Native American communities and scientists in a joint effort to create culturally appropriate methods of risk assessment; and in chapter 8, Raoul S. Liévanos, Jonathan K. London, and Julie Sze analyze how the California Department of Pesticide

Regulation accommodated the concerns of environmental justice activists, including calls for attention to the cumulative impact of assorted environmental hazards and an ethic of precaution, into its study of the effects of pesticides on the Latino community of Lindsay, California. The section's fourth chapter (chapter 9) considers ruptures in the training and socializing of technical professionals. There, Gwen Ottinger discusses undergraduate engineering students' responses to term projects that assigned them a role as expert activists for communities engaged in environmental justice struggles.

Like those in the first half of the book, the chapters in part II also point out obstacles to change in mainstream technical practices. They detail how regulatory structures obscure differences of race and culture (Powell and Powell; Johnson and Ranco) and resist fundamental changes to established paradigms of risk assessment (Johnson and Ranco; Liévanos, London, and Sze). They highlight how differences in power between regulatory agencies and community groups are an important obstacle to fundamental change (Johnson and Ranco), as is the robust "expert" identity that scientists and engineers are encouraged to develop as part of their specialized training (Ottinger).

Despite the barriers to change, the chapters in part II also document not only opportunities for, but actual moments of, transformation in technical practice. Describing instances where the practices of regulatory scientists have incorporated the principles of environmental justice (Johnson and Ranco; Liévanos, London, and Sze), these chapters offer evidence that institutional commitments to EJ won through social movement activism have affected the way that scientific research is both conducted and used in policy processes. The chapters also draw attention to technical practitioners' growing awareness of environmental justice issues, highlighting personal transformations as an important part of the process of transforming the practices and institutions of science (Ottinger; Powell and Powell). Even where the transformations in part II are uneven and authors critique the ways EJ advocates fall short of the fundamental changes they imagine, the chapters offer hope and optimism about the dynamism of all technical practices—not just those explicitly allied with EJ—and the transformative potential of ruptures created by environmental justice activism. In her afterword, Kim Fortun echoes this optimism, adopting the metaphor of "faultlines" to amplify the book's theme of ruptures and breaks. It is where faultlines appear, Fortun observes, that advocates have the chance to produce new thinking, new policies, and new practices.

Science and the Transformative Politics of Environmental Justice

Through their activism and scholarship, environmental justice advocates have shown how science-as-usual tends to stand in the way of EJ goals. Their work makes clear that achieving environmental justice requires transforming scientific and technological practices. This book aims to contribute to the proactive reconstruction of science—a project shared by STS scholars concerned with making science more democratic[2]—by understanding the processes through which transformation has and could occur, along with the obstacles that stand in the way of change. In the process of providing grounded analyses of technical practitioners' engagements with environmental justice, the authors suggest hypotheses for EJ scholars to test in future research and lessons for practitioners in similar situations wishing to maximize the transformative effects of their activities.

In addition to the insights of the individual chapters, the book as a whole offers three key insights of value to environmental justice advocates. The first and most straightforward is that technical practitioners' engagement with environmental justice issues—and EJ activists' engagement with science, technology, and experts—do produce ruptures in technical practice. These, in turn, make space available for culturally authorized experts in nonprofits, universities, and regulatory agencies alike to build new practices and to alter the scientific enterprise more generally. In the case of the biomonitoring studies described by Morello-Frosch et al., collaborating with environmental justice groups forced scientists to question the ethical frameworks in place for reporting data back to the individuals from whom it was collected. Collaboration between scientists and activists thus produced a new ethical framework for reporting results. In the collaboration analyzed by Hoffman, scientists from a nonprofit organization allied with community groups reconsidered how they should play their role as "experts" in public hearings in order to give community members a potentially greater voice in the proceedings. For engineering students in Ottinger's chapter, involvement with EJ activists suggested the need to develop new approaches to analyzing data—approaches that would help represent the experiences of community members in quantitative terms—as well as the need to include activists in problem solving in order to incorporate those experiences. Among other innovations documented in the following chapters, these new approaches to scientific ethics, to data analysis, and to participation in knowledge and policymaking processes were made possible—and

indeed necessary—through interactions with activists that introduce new demands and new resources to technical practice.

The finding that technical practitioners' engagements with environmental justice can be transformative has clear practical implications. Chief among these is that interested actors can and should create more areas of contact between scientists, engineers, and the environmental justice movement—and, in so doing, actively nurture networks of expert activists—so as to expand the spaces available for rethinking technical practices. Such contact needs to be encouraged, fostered, and instigated wherever possible, be that in classrooms, public meetings, instances of regulatory reform, or community organizing forums. Certainly collaborations of this nature can be difficult, but even where the transformative opportunities of such interactions are not fully met, they are worth pursuing for the room to maneuver that they create. It is incumbent on practitioners of today to foster such spaces where future advocates can operate.

The collection's second conclusion is that transformations of power relations are integral to scientific transformations. The authors' analyses of obstacles to change make clear the importance of power relations, particularly the constraints that limit technical practitioners' room to reconfigure their activities. In Johnson and Ranco's account in chapter 7, for example, the new and culturally relevant concept of "health" offered by EPA's Tribal Science Council ultimately had little impact on regulators' practices of environmental risk assessment because the agency was unwilling to share its decision-making power. Similarly, in the case described by Hoffman in chapter 2, the status afforded to authoritative experts in public hearings made it difficult for scientists who were also EJ advocates to facilitate the participation of nonexpert groups. In these and other cases, efforts to create new ways to generate, analyze, or make available scientific data fell short, in the authors' estimation, because they attempted to alter scientific practice without affecting underlying power relations. In contrast, the most meaningful and effective of the transformative projects chronicled in this book altered the ways that scientists and engineers related to activists and community members, the ways that relatively powerless nonexperts were included in political decision making, and/or the ways that scientific data was connected to political action (e.g., Ottinger; Morello-Frosch et al.; Nieusma).

The concrete implications of this finding are not as simple to articulate or implement, yet they are essential to EJ advocates' efforts. The environmental justice movement already engages power relations. To

take but one example, recognizing the relative powerlessness of poor communities of color against industrial facilities owned by large companies, EJ activists have organized multiple communities affected by one multinational corporation's pollution into an opposition movement that targets the corporation's global brand (see Doyle 2002). But activists' critical engagements with power do not always extend to their scientific activities: community-generated data are frequently inserted into expert-controlled regulatory processes, where it is readily dismissed. To make community-based science more effective, and hasten the transformation of scientific practices more generally, EJ activists need to begin to target the larger structures of power—including standardized practices and other institutionalized ideas of "good" and "bad" science (see Ottinger 2010)—that insulate science from participation by "laypeople." Our point is not that attention to power dynamics is new in EJ history, but that we need to enfold the processes of scientific and technological practices into the same conversations of structural change and empowerment.

Finally, the cases collected here show that established institutional structures, most often obstacles to change, can also provide resources for transformation. Frickel's chapter (chapter 1), for example, shows how scientific networks can play an important role in inspiring and fostering engagement between scientists and activists and in supporting technical professionals in the development of hybrid scientist-activist identities. Similarly, the energy engineers that Nieusma's chapter (chapter 5) focuses on were able to bring community voices to high-level policy discussions because of their unique, midlevel institutional location. The third recommendation of this book, then, is for experts themselves to look for ways to strategically employ their structural positions to broaden engagements between technical practice and environmental justice issues, and to help reconfigure power relations to give community groups more of a voice.

We conclude this book with the observation that science and technical practice are constantly in a process of transformation, that transformations in the direction of a more environmentally just science and technology are possible and are fostered by the engagement of technical practitioners with the EJ movement, and that transformative projects are made difficult by heterogeneous structural constraints. So it is that environmentally just transformations of technical practice are inevitably difficult, uneven, and partial—just as transformations of environmentally unjust incidents have been throughout decades of activism. If, as we suggest, change occurs as a result of disruptions in practice that provide

scientists and engineers with new room to maneuver, the project of transformation becomes one of identifying, broadening, and benefiting from those ruptures. In such a project, not only EJ activists but also social scientific researchers and especially technical practitioners themselves are agents of change.

Notes

1. For clarity, we will refer to the now expansive field of STS through that acronym, not to suggest a unified theoretical or methodological approach in such literature but to point to a common umbrella term under which disparate and usually interdisciplinary scholars find common terms of reference and citation.

2. A number of researchers have posited a role for scholarship in transforming the scientific enterprise to make it more democratic, offering proposals for increasing citizen participation in policy decisions about science and technology (e.g., Fiorino 1990; Fischer 1999, 2000; Guston 1999), designing technology with the principles of democracy in mind (Sclove 1995, 2000; Nieusma 2004a), and using theory developed in the social studies of science to determine the relevance of different kinds of expertise to policy dilemmas (Collins and Evans 2002). Our approach differs from these in its emphasis on the race, class, and power disparities thematized by the environmental justice movement, which tend not to be represented in either the movements of scientists themselves or in STS proposals for democratizing science (though Nieusma 2004a is an exception). The environmentally just science and technology that we envision would incorporate the principles of sustainable and democratic science and technology while keeping equity issues central.