Creating Green Chemistry: Discursive Strategies of a Scientific Movement

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Abstract

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In this dissertation, I examine the evolution of the green chemistry movement from its inception in the early 1990s to the present day. I focus my study on the discursive strategies employed by leaders of the movement to establish green chemistry and to develop and institute changes in the practice of the chemical sciences. The study looks specifically at three different strategies. The first is the construction of a historical narrative. This history comes from the intersection of the chemical sciences with environmentalism in the United States retold to place chemistry in a central position for understanding global environmental health issues and green chemistry as the natural response to these problems. The second involves the attempts made to develop a concrete definition for green chemistry as well as a set of guiding principles for the practice of this alternative form of chemistry. The establishment of the definition and the principles, I argue, constitutes an important move in constituting the field as a very specific interdisciplinary group with a forged identity and the beginnings of a system for determining what properly 'counts' as green chemistry. The third comes from the intersection of this history within the defining principles of the movement intersect to create a specific set of green chemistry practices, and how these practices manifest themselves in conference and pedagogical settings. Finally, I offer an overview of where the movement currently stands, offering a critical perspective on the future potential of the field. I argue that recent episodes indicate that the movement has not succeeded in accomplishing what it set out to do, and will continue to encounter problems unless a refashioning of the movement takes place. To offer perspective on green chemistry as a movement, I examine it through the lens of other (e.g., Frickel and Gross 2005) attempts to explore scientific movements as a special class of social movements.

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Chapter 1: Introduction and Overview

> "There are those who argue that sustainability is far more than a scientific and technological challenge, that it involves complex social interactions and value systems. They may be correct. However, while they endeavor to change the hearts, minds, and behavior of six billion people to make society more sustainable, it is the responsibility of the small percentage of the population that is knowledgeable in science and engineering to make current (and likely future) behavior as sustainable as possible. This can be done through the design of intrinsically benign products and processes. It is not a feasible option simply to tell the developing world that increasing their quality of life is an unrealistic expectation. To make that increased quality of life have a minimal negative impact on the Earth is our greatest challenge and an attainable one."
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> - Paul Anastas and Rebecca Lankey[1]

> "IPAT [impact = population x affluence x technology] is just what one would expect from physical scientists […]. It counts what's countable. It makes rational sense. But it ignores the manipulation, the oppression, the profits. It ignores a factor that [natural] scientists have a hard time quantifying and therefore don't like to talk about: economic and political power. IPAT may be physically indisputable. But it is politically naïve."
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> - Donella Meadows[2]

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[1] Anastas and Lankey (2002, p. 11).

[2] Meadows (1995), quoted Maniates (2002, p. 61).

I begin with these two epigraphs because they both deal with the issue of ecological collapse, the global environment, and sustainability. They differ, however, in their vision of how these issues ought to be understood, and therefore who should take the lead in protecting global society(ies) from impending doom. In the first quote, Paul Anastas and Rebecca Lankey outline two approaches to the issue of sustainability from the perspective of green chemistry. On the one hand, we have the "complex social interactions and value systems" with which to contend. On the other, we have the "scientific and technological challenge." From the perspective of the authors, we have two spheres, if not entirely distinct at the very least definitely separable. While some may work to "change the hearts, minds, and behaviors of six billion people," those working within the techno-scientific infrastructure of this country and the world have "a duty" to tackle the much greater (and more realistic it would seem) challenge of making our current lifestyles sustainable. The issue is presented as if it were cast in black and white, making the either/or decision making process that much easier. Deal with the politics or with the technology? Change the behaviors or make the behaviors less damaging? Continue to develop the world to look like the most 'developed' portions of the global North, or tell the rest of the world that they cannot have an increased quality of life? The resulting dichotomies governing the problem of sustainability serve as a call to arms to those engaged in scientific and technological pursuits and as the foundation for the green chemistry movement.

The second epigraph, while not originating in a discussion of green chemistry, offers a critique of the position presented in the first. In the context of a discussion about how best to move beyond 'IPAT', Michael Maniates explains how the formula derives from the attempt to demonstrate the relationship between environmental damage resulting from growth of populations and increasing affluence, which results in increasing consumption and strain on the technologies employed by the populations in question. By placing *population*, *affluence*, and *technology* on a par mathematically, the problem is transformed into a multi-variable equation that allows attention to any one of those variables to relieve the stress and pressure on the others. Thus, as the quotation from Anastas and Lankey illustrates, it becomes obvious how focusing on the *technology* issue alone allows for the spread of *affluence* to a *larger population* while creating a net decrease (where the technology allows it) in the overall impact on the environment.

In his critique of this formula, Maniates suggests (following with Meadows) that it does not present an accurate or fair representation of the issues because it equates everything with everything else, ignoring blatant and obvious power differentials. Meadows elaborates on the problem: "IPAT is a bloodless, misleading, cop-out explanation for the world's ills […]. […] It leads one to hold poor women responsible for population growth without asking who is putting pressures on those women to have so many babies. It lays a guilt trip on Western consumers, while ignoring the forces that whip up their desire for ever more consumption" (Meadows 1995, quoted in Maniates 2002, pp. 60-61). Through these sorts of mathematical reconfigurations of reality, everyone becomes equally culpable, and the issues of underlying societal structures simply vanish somewhere within the equals sign of the equation. Despite this vanishing act, this grand homogenization of ecological and sustainability issues, most societal and scientific movements follow this model. The green chemistry movement proves no different.

In this dissertation, I explore the discursive strategies employed by proponents of green chemistry as they seek to build a scientific movement. These strategies support the aim of transforming the practices of chemistry in ways which create processes and products that cause less environmental damage. These moves also place chemists at the forefront of global efforts to achieve sustainability. I elucidate how a scientific movement that frames global issues solely in terms of their techno-scientific character attempts to mobilize other scientists and engineers into this movement. And I show what sorts of practices emerge out of a movement that fails to consider the social and political contours of the sustainability issue.

The general idea of green chemistry discussed within these contexts can be summarized broadly as: an attempt to reconstruct the chemical sciences and their practices (industrial and academic) so that they internalize the need to ameliorate growing environmental and human health problems, taken to be the root of public concerns and scrutiny, and to design both chemical processes and products so that they serve this purpose.[3] My analysis of the movement is divided into three parts, each of which outlines the varying strategies used by proponents of green chemistry in order to construct, frame, and further the agenda of green chemistry. First, I examine the assemblage and iteration of a history of the field. Second, I trace out the process of articulating a definition for green chemistry as well as the establishment of the

[3] The issue of how green chemistry *ought* to be defined as a strategy for the construction of a green chemistry movement is discussed in Chapter 3.

twelve principles of green chemistry, which present the practical side of the definition and allow green chemistry to differentiate itself from other sustainability practices as well as reach out to new potential practitioners. Finally, I offer an analysis of the establishment of a unique set of practices that emerge out of this strategic construction of the movement.

Green chemistry presents problems not commonly found in the emergence or creation of a new science. The field does not have fixed boundaries, and thus finds itself repositioned and readjusted in each new circumstance. Its uncertain location within and adjacent to the chemical sciences has left it vulnerable to the risk of cooptation by other agents. And unlike many other scientific movements, green chemistry has not sought to replace or displace chemistry, but instead has attempted to transform the chemical sciences from within the field. Finally, green chemistry at times has appeared to be chemistry only in name, incorporating research objects and techniques from a variety of related, but decidedly *non*-chemical sciences. The case of green chemistry has resisted easy accommodation within traditional discussions of emerging sciences and boundary work. The nuanced features of this movement offer the opportunity for elaboration and analysis of the distinction between disciplinary and interdisciplinary sciences, and examination of the ways in which movements involving the construction of interdisciplinary sciences differ from those that reform established disciplines.

Green Chemistry as Scientific Movement

The framework of the scientific movement that I adopt follows closely on a number of recent works that introduce the conceptual and methodological apparatus of social movement theory into science studies.[4] These texts unite various threads coming from social movement theory in order to rethink scientific movements as social movements, resulting in the concomitant extension of the range and scope of social movement theory. In characterizing green chemistry as a scientific movement, I point out unique features of the case, which will create an opportunity to examine how discussions of social and scientific movements might be incorporated into the issues dealt with in science studies.

Organizational and Intellectual Leadership

Within the green chemistry movement, the organizational and scientific leadership roles are divided rather than unified. This stands in contrast to other scientific and intellectual movements, where the leaders of the movement are not coincidentally also the intellectual and/or scientific leaders of the movement. Frickel and Gross (2005, p. 212) note that "a SIM [scientific/intellectual movement] is ultimately dependent on the contributions of its intellectual leaders, who articulate its program and do the intellectual or scientific work that comes to be seen as the hallmark of the movement." Within green chemistry, these duties are divided between a number of different individuals and locations. The situation is exaggerated because of two

[4] See, for example, Frickel (2004), Frickel and Gross (2005), Gross (2002), Hess (2005), and Woodhouse and Breyman (2005).

compounding factors: the presence of the Green Chemistry Institute and the interdisciplinary structure of the movement.

The Green Chemistry Institute (GCI) serves as the organizational headquarters of the green chemistry movement. Established in 1997, the GCI exists as a non-profit organization "dedicated to promoting and advancing green chemistry."[5] The institute, as an independent and autonomous organization, found a home in the EPA and Los Alamos National Laboratory under various directors before being offered a more permanent home within the American Chemical Society in 2004 under the aegis of its first full-time director, Paul Anastas.[6] The migration of the GCI into the infrastructure of the American Chemical Society (ACS) presents a number of questions in itself. On the one hand, placement of the GCI within the ACS provides access to a number of resources not previously available. The ACS leverages not only enormous capital and membership numbers through its international presence, but it also offers direct links into both government and industry. Although the green chemistry movement locates its roots within government—specifically, the EPA—the lobbying power of the American Chemical Society provides access to new individuals and new networks of power for pushing green chemistry initiatives.[7] However, locating the GCI within the

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[5] See the GCI web page: http://www.chemistry.org/portal/a/c/s/1/acsdisplay.html?DOC=greenchemistryinstitute\aboutgci.html.

[6] Cf. Woodhouse and Breyman (2005, p. 207).

[7] One might nonetheless ask how successful this strategy has been for the green chemistry movement. In both 2004 and 2005, green chemistry research bills were stranded in various stages of congressional hearings.

walls (literal and otherwise) of the ACS has additional consequences. For instance, the rigid structure of the ACS and its component divisions requires green chemistry to try to fit within a structure that by its very nature green chemistry challenges. That is, green chemistry, as an interdiscipline, offers a direct challenge to what does and what should *count* as requisite chemical knowledge and practice. Locating the interdiscipline within the confines of the structure that it seeks to transform effectively silences some of the more radical voices and requires proponents of reform to work within current organizational and power structures.

The current director of the GCI, and the undisputed leader of the green chemistry movement, is Paul Anastas. Anastas, however, is not a practicing chemist in the obvious sense. He moved directly from his Ph.D. in chemistry at Brandeis University to a position at the EPA, to a position at the White House Office of Science and Technology Policy, to his current position as director of the GCI.[8] Anastas (often in collaboration with others) has done far more than anyone else to develop the political and organizational structures for the movement. And with John Warner, in their *Green Chemistry: Theory and Practice* (1998, hereafter *GCTP*), he largely framed the movement, its issues, and its goals. Despite the fact that Anastas worked to construct the "principles" of green chemistry and despite the numerous publications with which he is associated, his work presents only one aspect of the movement's agenda. The remainder of the scientific work that provides the

[8] He also held a position at Nottingham University in the UK as a "special professor" and is currently (2005-6) a visiting fellow at the Kennedy School of Government at Harvard University.

underpinnings and proof of the movement's efficacy comes from other members. And so at the very foundation there is a fracture between organizational leadership for the *green chemistry movement* and the broader *green chemistry community* that is shaped and molded by the institutional leadership.

The interdisciplinary nature of green chemistry, however, also presents organizational complications in mobilizing chemists. Rather than presenting a unified front that offers alternative ways of doing chemistry, the coming chapters will show that the green chemistry movement has become a place for the trading of ideas and development of previously marginalized sciences.[9] Rather than constructing more boundaries, green chemistry has weakened and made permeable boundaries surrounding the chemical sciences, which has allowed other groups opportunities for entry and infection.[10] For example, toxicity and catalysis, topics traditionally kept isolated in pockets of the chemical community, have found prominent positions within the green chemistry movement. The intellectual work that demonstrates these ideas and crossovers comes from a number of disparate research locations that loosely affiliated themselves with green chemistry. Thus the concrete examples that provide the scientific merit for the foundational principles emerge from different locations, leaving the green chemistry movement somehow hierarchical but simultaneously diffuse.

[9] See especially the discussions in chapter 3, and the summary in chapter 5.

[10] On the role of permeable boundaries in interdisciplines, see Frickel (2004) and Hess (2005).

Intellectual Roots

The green chemistry movement is neither a movement of *elites* of the field, nor a *mass movement* of chemists more generally. Its roots cannot be located in frustration or resistance on the part of a select group of scientists, as is often the case in the construction of a scientific or social movement.[11] Rather, the green chemistry movement locates its origins in a legislative act—the Pollution Prevention Act of 1990—and a government agency—the U.S. Environmental Protection Agency. But the identification of the movement as an outgrowth of the EPA and as a result of the Pollution Prevention Act places the origin and operations of green chemistry distinctly *outside* mainstream chemistry. The field is not split into factions that must struggle with one another for control, but rather those internal to mainstream chemical sciences and those now working within green chemistry and struggling for its acceptance.

This also presents an *audience* and *framing* issue for the movement. Because the green chemistry movement did not begin from internal resistances and frustrations, proponents must find a way to make the ideas and goals resonate with individuals who may see no need for a transformation of the chemical sciences.[12] This in fact seems to be what happened when the movement has struggled to gain ground, especially in more academic arenas. In part, this may be due to the inability to

[11] See Frickel and Gross (2005); cf. Woodhouse and Breyman (2005).

[12] See Frickel (2004), Frickel and Gross (2005), and Gross (2002). For more on the issue of 'framing' in social movement theory more generally: see McAdam, McCarthy, and Zald (1996); McAdam (1996a and b); Snow et al (1986); and Zald (1996).

convert elite individuals from prominent and notable institutions—a fact obvious from the perusal of conference programs and publications.

But if green chemistry is not a movement of elites, or grounded in the frustrations of elites, it is not a movement of the masses either.[13] The transience of interested parties becomes evident in attendance at events such as the prestigious and normally forward-looking Gordon Research Conferences.[14] The problem of gaining and maintaining interest in the movement emerges, too, from the more general lack of enthusiasm present within such institutions as the American Chemical Society. While the ACS leadership is quick to praise the work, it has failed to show any real commitment (most notably in terms of dollars) to the movement more generally.[15] And while there may be more green chemistry meetings than there have been in the past, this seems more of an artifact of the movement's enrollment of other groups than the actual growth of the field. Green chemistry's lack of roots within the chemical sciences exacerbates the problems of organizational leadership within the group and perpetuates the dearth of available available resources to green chemists for both research and advancement.[16]

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[13] See Woodhouse and Breyman (2005, pp. 209ff).

[14] For more on this topic see the discussion in chapter 4.

[15] See Woodhouse (unpublished).

[16] As Frickel and Gross note, a successful SIM must find a way to provide its members access to key resources (2005, pp. 213ff.).

Resource Issues

This lack of resources has forced the proponents of green chemistry to seek funding and access to other resources within traditional chemical structures. This situation creates two characteristics that put the green chemistry movement in an awkward position compared to other scientific movements. First, green chemistry must work *within* the resource structure of current chemical sciences because alternative support systems do not exist. This requirement to use the master's tools to rebuild the house places constraints on the construction of a truly *green* chemistry. But this predicament has also forced many within the green chemistry movement to pursue an alternative not available to most other scientific movements, namely, support from industry.

Industry has become an important locus for green chemistry research. One might argue that industry has played a similar role in the chemical sciences for at least the last century or more. However, in the context of the green chemistry movement, this relationship creates its own set of peculiarities, many of which manifest themselves in the ways in which the field has evolved since its inception in the early 1990s. In the past five years or so, green chemistry has become increasingly tied to 'corporate sustainability' measures and initiatives. The central message has shifted from one of pollution prevention to economic benefits and competitiveness through pollution prevention and green chemistry.[17] Dependence on industry

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[17] This shift in argument is not unique to green chemistry. It has become a common feature of many environmental movements as they seek to gain ground anywhere they can in struggles with corporate polluters, especially as the U.S. federal government has scaled back its own

resources has reshaped the message of the movement. That is, the institutional links play an active role in shaping the practices of green chemistry. This issue compounds those already established problems with the determination of audience and message, and the insider/outsider status of the movement. While the chemical industry plays an intimate role in the practices of the chemical sciences at nearly all levels in one form or another, a movement housed predominantly within the chemical industry that seeks to transform the chemical sciences will be viewed by those not in industry as a movement that simply does not involve them, speak to them, or require their assistance or allegiance for success.

Integration and Transformation

Green chemistry is not a rival to chemistry, i.e., it does not aim to replace or displace chemistry; rather, green chemists seek internal transformation and integration into the chemical sciences. Thus, the case differs markedly from those discusses by Frickel and Gross (2005) where disillusionment has created a new faction, the new faction presents a rival system, and the ultimate goal of the rival-science can be defined as supplanting or replacing the old science. Aiming for integration and transformation of a current science (or set of sciences) creates challenges not encountered in those other cases, and these challenges are compounded by the interdisciplinary nature of green chemistry. Perhaps the most pressing and difficult question for green chemists to answer might be stated this way: how can they make green chemistry be different

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monitoring and regulatory procedures. See the discussions in Hajer (1997) and the various chapters in Fischer and Hajer (1999).

enough to warrant attention and inclusion without being so different that they get cast out as rival scientists? And because green chemistry, as currently configured, requires them to work within the resource structures currently available to chemists, the possibility of marginalization or banishment would effectively mark the death of the movement—unless other resources could be found.

Green chemists employ a number of strategies to make sure that their identity as chemists remains fixed and stable. They argue it is essential for chemists to address the growing environmental crises in their routine technical work by espousing a new history of the enterprise as one always, already, and everywhere engaged with these problems, thus striving to make the point that green chemistry, too, comes as a natural outgrowth of the chemical sciences. They introduce practices and objects from neighboring sciences, defining chemistry in the broadest and most universal sense possible, as concerned with molecules, and not as a fixed or determined discipline or department. On this conception, chemistry has always been a flexible, growing, and evolving field that always sought new tools for its work, even when they have come from areas that might appear outside of the field. Thus, green chemistry must seem to be always and in every way, chemistry.

But green chemistry can't be exactly chemistry; otherwise there would be no way and no need—and no way—to differentiate it from chemistry. Green chemists offer chemists a new way of thinking about their work, and (hopefully) a new way of seeing and handling traditional chemical objects. It is, according to Paul Anastas and John Warner, a "philosophy" for doing chemistry (1998). Green chemists do not argue for a new chemistry, just a new way of *doing* chemistry. But as anyone working in the field of science studies knows, ways of doing cannot be cleanly separated from ways of knowing, ways of thinking, or ways of constructing and analyzing experiments. Nor can they be separated from decisions about objects and outcomes for research, or about who will conduct research—and for whom it will be conducted. For this reason, changing ways of doing chemistry quickly becomes a quite complicated endeavor. Audience and message matter in the construction of a scientific movement. Of special interest here, a proponent of change must argue effectively that change is required. This is exactly what green chemists must do if they want to succeed in transforming the chemical sciences from within rather than setting up as a rival system.

The Mark of Success

In keeping with the goal of integration and transformation, green chemists claim that success for the movement will be marked by its own dissolution and dispersal into the chemical sciences. While Frickel and Gross (2005, p. 208) note that all scientific and intellectual movements meet their "death" either through effective disappearance or transformation into a more stabilized entity, the (supposed) desire for green chemistry to willingly go away doesn't quite seem to fit within this either/or model. If, indeed, the goal is to be assumed into chemistry, the death of a successful green chemistry might look much more like a staged vanishing act, not a simple disappearance. On the other hand, however, it would seem that green chemistry must avoid at all costs the types of stabilization that Frickel and Gross discuss. That is, green chemists must negotiate a tricky terrain: to succeed in going away willingly means not being forced to go away (due to lack of interest), but not being forced to stay either (by becoming a stabilized tool for other purposes).

Perhaps it is on this point that the case of green chemistry has much to offer to the idea of scientific movements. Frickel and Gross (2005) note at the conclusion of their general study that much more work needs to be done to account for the different ways in which scientific and intellectual movements do and do not succeed. Hess (2005), too, notes that a deeper philosophical understanding of these situations is required for telling the stories and learning from movements within and with the sciences in our societies. As I outlined in the previous section, transformation and integration present some ways of thinking about success and failure in movements. Perhaps one possible scenario for interdisciplines like green chemistry might involve the role that they play in the creation of spaces for contact, collaboration, and contamination. As Frickel (2004) notes, interdisciplines are characterized not by the construction of new rigid boundaries, but instead survive because they succeed in making boundaries permeable. This suggests that green chemistry is best conceived as an interstitial field that finds itself (by design) wedged within and between other fields—chemistry, toxicology, catalysis, molecular biology—and that it provides a place where boundaries between these fields can become more accessible, open to cross-contamination.[18] Like Galison's "trading zones" (1997), interdisciplines provide a safe space for the actors from various groups to meet and exchange their scientific

[18] On the role of interdisciplinary theories rupturing the boundaries of established disciplines, see also Darden and Maull (1977) and Darden (1991). For more general discussions of the natures and practices of interdisciplines, see, e.g.: Messer-Davidow, Shumway, and Sylvan (1993); Klein (1996, 2005).

goods, whether they be ideas, instruments, or objects and procedures of other sorts. And, perhaps more importantly, they provide a space for the goods to be tried, experimented with, and evaluated before being taken back into laboratories, offices, or professional societies. In this case, green chemistry simply disappears when chemistry has changed significantly enough that there is nothing left to trade. That is the success story that seems to the goals that many of the proponents of green chemistry articulate. Failure, in this case, would mean a space that no one ever cares to visit.

In the following chapters, I will expand upon these five features of the green chemistry movement—organizational leadership, intellectual roots, resources, integration/transformation, and markers for success—as a backdrop to an exploration of the strategies employed by its participants as they seek to create a space for green chemistry and to use that space to successfully link a number of scientific fields with the goal of transforming the practice of chemistry. I will argue that green chemistry attempts to create a space for itself by merging the histories of chemical enterprises in the second half of the twentieth century with that of the environmental movement during the same period. This new history treats green chemistry as emerging as a natural outgrowth of the entanglement of chemistry with the awareness of environmental damage and suggests that a *properly* practiced and defined green chemistry (as described in chapters 3 and 4) can work to make the chemical enterprise into a leader in efforts to continue current lifestyles and 'development' projects by basing them on 'sustainable' practices.

Theoretical Frames

In the next three chapters, I borrow and employ a number of different theoretical frameworks besides those of social/scientific movement theory for the elucidation of the complexities behind the case of the green chemistry movement. To minimize clutter in the empirical chapters, in this section I discuss many of the important ideas and tools and introduce the ways in which I put them to use. As we move through the chapters, it will become clear how variations of these themes apply to various elements of the story.

Boundaries

Boundaries, as cultural constructions, work to create demarcation. In differentiating between spaces, they also act to create spaces. Boundaries mark not only territories, but also those who occupy the territories under construction. Thus, boundaries play a significant role in identity construction. Tom Gieryn puts it this way: “Boundaries differentiate this thing from that; borders create spaces with occupants homogenous and generalized in some respect (though they may vary in other ways)” (1999, p. 7). Boundaries perform an identity construction function for newly emerging groups, but these lines do not remain in place. Like the lines of a map, boundaries can change. Boundaries, and maps, are often more of an experiment than a statement of fact.

I suggest there are three general classes of boundary work required in the construction of identity: boundary construction, maintenance, and destruction. Boundary work takes place within fields that already occupy a space. The creation of a new space, then, involves the re-drawing of old boundaries. This re-drawing is both a constructive and destructive act. The new boundaries have effects not only on the new space being created, but also on the previous field that occupied that space. Even in a case where a territory might be shared, or co-occupied (as in a Venn diagram), the creation of the new field necessarily changes the constitution of both groups.[19]

The processes of construction, destruction, and maintenance of boundaries also offer a point of intervention. Maintenance of established boundaries mark established divides between one space and another. Boundaries are themselves political: they separate one territory from another, keeping separate systems of power, resources, and populaces. They demarcate knowledge by setting the limits on what is known and what can be known, and keep separate other forms of knowledge.

Tracing out the boundaries of green chemistry while they are under construction provides one way of learning about the identity of green chemists, itself also under construction. The placement of boundaries proves important because it helps to define what is and is not a component part of the identity of green chemists

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[19] This is similar to Peter Galison's discussion of the construction of trading zones (1997). The creation of a space between two groups, and thus a passage-point not previously available, necessarily re-creates the identities of the each of the groups. For me, this is the most important lesson of the trading zones. For all that happens in the trading zone, people still go back to their home institutions at the end of the day. However, their identities have been changed as a result of their experiences in the trading zone. The home institutions, too, are then exposed to these changes as a result of their experiences with that individual. The differences, then, are infectious. They may not all take, but the very presence of these differences requires some action to be taken. Thus, a ripple of effects comes from each trip to/through the trading zone. The creation of multi-/inter-/cross-disciplinary activities within previously established boundaries, I contend, acts in much the same way.

and chemistry—who has power and how it's distributed, what counts as knowledge specific to green chemistry, and the values constitutive of the new science. As a place for identity construction, boundaries also present an opportunity for identity reconstruction.

Discipline

To construct and maintain boundaries, a group must make sure it engages in the active disciplining of its members. Disciplining creates order and homogenizes what otherwise exists only as a heterogeneous mixture of actors. Or, as Messer-Davidow, Shumway, and Sylvan write: "[…] we could say that disciplinarity is the means by which ensembles of diverse parts are brought into particular types of knowledge relations with each other" (p. 3). The need to discipline is neither arbitrary, nor ambiguous. Rather, the disciplining action aims towards specific goals. It incorporates specific strategies.

The strategies employed to discipline green chemists into existence and to create and maintain a practice distinctly known and identifiable as green chemistry involved two main thrusts: the creation of a specific definition for green chemistry and the establishment of the Twelve Principles of Green Chemistry. The establishment of a definition creates a sense of unity, and the principles work to create a sense of correct practice and order. The principles describe the work of green chemistry in that they provide a sketch of the approach taken to problems and their solutions; and they are normative in that they support a specific vision of what problems ought to be addressed and by what means. Thus, the principles inform outsiders of what makes green chemistry something different while also working to maintain uniformity within the field. The resulting community incorporates these characteristics in its functioning. In most cases, these types of disciplining strategies would lead towards the establishment of a discipline. That is, a community gravitating towards similar goals, using similar methods, and organized in such a way as to provide coherence. Tim Lenoir puts it this way: "*Disciplines are dynamic structures for assembling, channeling, and replicating the social and technical practices essential to the functioning of the political economy and the systems of power relations that actualize it*" (Lenoir 1993, p. 72, emphasis in original).[20] But the use of the language of boundaries and disciplines does not fully and adequately capture the situation facing the creation of green chemistry. Despite its disciplining techniques, it does not seek to become a discipline. Nor is it an experimental system, as described by Rheinberger in the case of molecular biology. Rather, green chemistry stands separate, but within chemistry as an attempt to transform this already established field.

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[20] As an example of this type of work, Lenoir looks to Robert Kohler's work on the transition from medical chemistry to biochemistry. See Kohler (1982). A more recent example that highlights the research program side more carefully is Hans-Jörg Rheinberger's (1997) work that carefully lays out the emerging field of molecular biology as scientists work to synthesize proteins. Rather than taking part in the building of a new discipline, however, Rheinberger stresses the role of the "experimental system" as a place where this research takes place.

Coalitions and Disunity

To describe how disparate elements can come together to present a unified front, Maarten Hajer employs the concept of *discourse coalition*. Hajer draws on the work of Foucault to explain how groups of people can come together under a common discursive system despite their differences. In his discussions of environmental politics, Hajer points to the construction of "story-lines" as one way of creating these discourse coalitions. Hajer, in his discussion of environmentalism, puts it this way:

> "These so-called discourse coalitions somehow develop and sustain a particular discourse, a particular way of talking and thinking about environmental politics. These coalitions are unconventional in the sense that the actors have not necessarily met, let alone that they follow a carefully laid out and agreed upon strategy. What unties these coalitions and what gives them their political power is the fact that its actors group around specific story-lines that they employ whilst engaging in environmental politics. It can be shown that although these actors might share a specific set of story-lines, they might nevertheless interpret the meaning of these story-lines rather differently and might have their own particular interests" (Hajer 1997, p.13).

Diverse actors come together to advance a shared project, even if they may have different understandings of what that goal is, or what exactly their work entails. Saul Halfon picks up this last point and expands on it in his discussions of the politics of international policies set out to govern population growth. He holds that to understand how groups with seemingly drastically different agendas can come together in agreement we need to rethink our understanding of what is meant by consensus. Rather than seeing consensus as a presentation of 'unity' by these actors, we ought to see consensus as "structured disunity." Halfon develops this term in the context of his discussions of the Cairo Conference on Population and Development. Here, individuals representing 179 countries seemingly came to consensus on a number of issues related to population growth and controls, particularly in the 'developing' world, yet walked away with very different understandings of what exactly had been agreed upon in the statement. To explain this consensus and diversity, Halfon rethinks consensus as a metaphor for "a particularly robust network, one which allows various actors to act 'as if' they were all doing and thinking the same thing (that is, 'as if' there were unity). He goes on: "I reflexively use the notion of consensus […] as a stand-in, or metaphor, for a particularly robust and deeply networked realm of policy coordination—a realm that appears to embody and can be convincingly articulated as cognitive agreement" (Halfon 2006).[21] Halfon's move to reconceive consensus as a metaphor for a socio-technical network sheds light on the situation confronted here with respect to the construction of the green chemistry community. The alliances created here are not only or merely political in the sense that they involve only or merely social dimensions. The construction of the green chemistry community involves broader socio-technical negotiations. What is under

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[21] In her work on the development of national standards for science education in America, Jane Lehr picks up a similar point with respect to the construction of a consensus on the need for these standards. See her (2006).

negotiation in this boundary-work is not just *who* is in and who is out of the field, but also *what*—in terms of instrumentation, laboratory methodologies, experimental objects, qualifications for publication, what one knows about molecules and their interactions, and judgments on the adequacy of that knowledge.

Halfon places emphasis on the epistemological consequences of this perspective. Indeed, this is an important break from some of the material cited earlier on the construction of boundaries. One feature of boundary-work discussions that seems to be present in almost all of the discussions is this idea that knowledge is something already present, that simply gets divided, cut-off, compartmentalized by the construction of boundaries. Halfon also sees a problem with this perspective and works instead to show that the production of knowledge—what kind, for whom, by whom—is one of the issues that needs to be reconsidered when looking at the politics of socio-technical networks. I think one of the more important points that we can take from the boundary-work discussions is that knowledge itself is an emergent property of these bounded spaces, and thus how the space is bounded—who/what is in or out—becomes a critical question.

What I take from Hajer and Halfon is a way of thinking about how such a diverse set of actors can come together and see themselves working towards a common goal even if they happen to perform very different practices and find themselves in very different locations. Green chemistry, as a quasi-unified community, results from a coalition of representatives from across academic fields and subfields. Perhaps more importantly, the chemists come from a variety of institutional locations. They work in traditional academic laboratories within chemistry departments, and they work in within the chemical industry. But government representatives are also involved. Green chemists reach ‘consensus’ on such issues as the name of the field and the principles that define it. Yet, they leave with very different understandings of that consensus. However, the structured disunity that emerges out of these meetings is enough to create a new space that has the potential for constructing new knowledge, and indeed a new chemical science. Understanding green chemistry community as a ‘discourse community’ and their ties in terms of ‘structured disunity’ presents opportunities for a project of critical engagement with the field.

Creating Practices

Following Joseph Rouse (1996), I argue that the practice of green chemistry shapes and is shaped both by the actions of green chemists and the place in which those actions take place (p. 133). Rouse’s conceptualization of practice expands the traditional notion of practice in an effort to move past dualisms of actors ‘practicing’ and the world in which those practices take place. In a series of ten theses, Rouse describes what he means by the term *practice* (pp. 134-135ff.). Several of these are important for my considerations here. Take, for instance, the following statements:

> “[P]ractices are identifiable as patterns of ongoing engagement with the world”

> “[T]hese patterns are sustained only through the establishment and enforcement of ‘norms’”

> "[P]ractices are therefore sustained only against resistance and difference and always engage relations of power"

> "[A]gency and the agents (not necessarily limited to individual human beings) who participate in practices are both partially constituted by how that participation actually develops"

> "[P]ractices are not just patterns of action, but the meaningful configurations of the world within which actions can take place intelligibly, and thus practices incorporate the objects that they are enacted with and on and the settings in which they are enacted"

These theses, placed into the context of green chemistry, help to reinforce the ways in which the community building activities explored above lend themselves to the creation of this space where practices emerge, but also help to establish the roles that these practices then play in ordering and organizing the field into something coherent and stable. We can look to the roles of the twelve principles in defining not just action, but correct action, and how this helps in the creation of specific, repetitive, engagement with the world. And we can see the ways in which the principles function as norms for these actions. The practices of the green chemists must be reinforced by contrasting them with the actions of non-green chemists. This, the boundaries defined by the community are reinforced by continued use of those elements that make green chemistry different. The resistance can also come from within the community, as practitioners seek to more solidly define the boundaries of the community and its practices by developing new techniques or bringing in new objects that have yet to be tested for their 'greenness' and therefore their compatibility with the rest of the community.[22] But issues of resistance also involve power relations. Who decides whether or not something is green? Resistance helps to outline where these structures of power are, and how power is distributed within them. Practices, then, help to show what the field of green chemistry looks like; while at the same time shaping the field through its reinforcement of specifically defined actions and organizational schemes.

Practices also define and demonstrate the identity of those within this space. Engagement with the twelve principles or invocations of the history of the field are among the practices that do this, while at the same time delimiting what agency is

[22] The story of ionic liquids is a great example of this. Ionic liquids are a class of solvents that involve the use of ions held in solution (think of salt water). The beauty (and greenness) of these solvents is that 1) they can be tailored to the system so that one can optimize the solvent rather than using a large quantity of a solvent that simply works, and 2) in general nearly all of the solvent can be recovered following the reaction. However, the chemicals commonly used for these solvents are frequently among the nastiest ones around. Many have questioned whether ionic liquids should be included amongst other 'green' technologies. In a move that seemed to declare their inclusion, Robin Rogers of the University of Alabama, and one of the most ardent supporters of ionic liquids, received the 2005 Presidential Green Chemistry Challenge Award for his work. However, in a recent issue of *Nature*, the issues associated with these chemicals rose again in a news piece titled, "Warning Shot for Green Chemists: Some Solvents with an Environmentally Friendly Reputation May Kill Fish" (2005). Not only are many of the solvents toxic, they are potentially toxic at *far* smaller quantities than traditional solvents. Thus the resistance faced by ionic liquids and attempts to include them in the field continues to shape the space and practice of green chemistry.

available to these agents. Practices such as those made possible within the principles define and confine the green chemist. This is due in part to the fact that, as Rouse points out, practices are "meaningful configurations of the world" that then "incorporate the objects that they are enacted with and on and the settings in which they are enacted." Green chemists, as objects themselves of that field, are thereby constituted with and through their practices.

Throughout the remainder of the chapter, I will highlight more specifically how these practices are constituted and what they look like. Specifically, I'll be concerned with how the current practices of green chemistry define the terms of its project solely in terms of the remedy of techno-scientific failures that require similar fixes. I'll then show how these practices are taught to newcomers of the field, which reinforces this current structure of problem-solution definition.

Green Chemistry and Ecological Modernization

The green chemistry movement fits into a broader context of 'ecological modernization' described by Maarten Hajer and David Harvey, to name but two,[23] in that it attempts to frame the 'environmental problem' in terms of the failure of certain aspects of the techno-scientific infrastructure of the chemical enterprise (and the society that supports it), but continues to believe that the solutions to these problems exist within the same structures without requiring a change in these most basic institutions. Green chemists, then, attempt to collapse distinctions between

[23] For more on ecological modernization, its history, application, and critiques, see: Massa, (2000); Mol (1995); Mol and Sonnenfeld (2000); Orsato and Clegg (2005); and Young (2000).

environmental protection and economic growth by proposing the 'win-win' scenario that characterizes ecological modernization.

The acceptance within environmental circles of ecological modernization creates a new dilemma for activists of environmental conservation and environmental justice. Harvey explains it this way. The thesis has two, sometimes contradictory, effects. First, it creates a common discursive structure for various groups to encounter and challenge power structures that otherwise remain invisible, and therefore uncontestable. Second, however, the thesis places a certain emphasis on rationality in critique that undermines moral critiques of those power structures. This emphasis on the rational over the moral makes the thesis—and those engaged with it—susceptible to cooptation by the same politico-economic structures they confront.[24]

Green chemistry fits within Harvey's discussion of ecological modernization because of the proposed/supposed benefits of adopting green chemistry as a philosophy and methodology for chemical practices. Harvey writes that, perhaps the most powerful element of the thesis of ecological modernization lies in its rejection of the 'zero-sum' trade-offs between economic profitability and environmental protection/conservation. "The general persuasiveness," Harvey writes, lies in the

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[24] "The thesis of ecological modernization has now become deeply entrenched within many segments of the environmental movement. The effects, as we shall see, have been somewhat contradictory. On the one hand, ecological modernization provides a common discursive basis for a contested rapprochement between them and dominant forms of political-economic power. But on the other, it presumes a certain kind of rationality that lessens the force of more purely moral arguments […] and exposes much of the environmental movement to the dangers of political co-optation" (Harvey 1998, p.166).

refusal "to see the supposed trade-off between environmental concerns and economic growth in zero-sums. What are known as 'win-win' examples of ecological control are increasingly emphasized. Given the power of money, it is vital to show that ecological modernization can be profitable" (Harvey 1998, p. 166). Harvey's description of the power of economic arguments and a desire to move away from 'zero-sum' equations provides a fitting outline for most of the green chemistry argument, which focuses on the economic incentives—indeed imperatives—offered through this approach.[25]

Hajer framed the move towards the thesis of ecological modernization historically by reference to the emerging recognition in the late 1970s of serious problems within basic industrial working environments and the belief that these problems could not be contained within the confines of the workplace. This new awareness and its reaction differed from the previous, more radical, environmental movements of the early 1970s by suggesting that these problems could be solved through and by the current social institutions. A key tenet of this new movement was the belief that "environmental management is seen as a positive-sum game: pollution prevention pays."[26]

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[25] At the 2005 Innovation Day held at the Chemical Heritage Foundation, Anastas noted with excitement that CEOs at such places as Dow and Dupont now recognized green chemistry as a fundamental business imperative for the chemical industry.

[26] "The historical argument, in brief, is that a new way of conceiving environmental problems has emerged since the late 1970s. This policy discourse of ecological modernization recognizes the ecological crisis as evidence of a fundamental omission in the workings of the institutions of modern society. Yet, unlike the radical environmental movements of the 1970s, it suggests that environmental problems can be solved in accordance with the workings

And it is not only industries that have been drawn to the concept of ecological modernization. Environmental groups, too, increasingly employ it in a number of ways. Ecological modernization provides a framework for presenting arguments to the public. It creates a way of making something positive out of the situation by offering a compromise between what the groups are actually striving for and what they feel they can realistically accomplish.[27] These convictions are shared by proponents of green chemistry who believe that environmental concerns can be reconciled with business profitability, and that the two can be mutually beneficial. This is the "revolutionary" force behind pollution prevention and the green chemistry movement (Anastas 1994, p. 3).

Structure of the Dissertation

In the coming chapters, I examine how select discursive strategies employed by proponents of green chemistry develop within the movement and guide the future directions that it takes. Because my concern in this dissertation is to understand how the organizing mechanisms of green chemistry help to construct the *proper* way to do green chemistry, I emphasize the work being done by the organizational leadership of the green chemistry movement, rather than the broader range of interdisciplinary work that might be labeled green chemistry research. I focus on the formalized practices that emerge out of these strategies rather than the activities and localized

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of the main institutional arrangements of society. Environmental management is seen as a positive-sum game: pollution prevention pays" (Hajer 1997, p.3).

[27] Harvey (1998 p. 168).

resistances that might characterize a much larger swath of chemical activities. The point is to understand how green chemistry functions *as a movement*, and how it gains (or fails to gain) institutional legitimacy and leverage in supporting alternative practices.

I trace out the strategies employed by proponents of green chemistry as they create a stabilized set of practices that come to define the field of green chemistry. As Joseph Rouse notes, practices, taken broadly to include much more than the typical understanding of the routinized actions of scientists, comprise a set of "patterns of ongoing engagement" that are "simultaneously material and discursive" (1996, pp. 134, 135). Practicing is more than *doing* in this sense. "Practices incorporate the *setting* of action as well as the action itself" (p. 135). Practice is *process*. Action and setting are not separable; the action recreates the setting, which continues to make the action possible. Building from this understanding of practice, I will demonstrate how the practices of green chemistry become established within green chemistry and how they are linked to issues of identity construction for the community. In particular, I focus on how the construction of an identity for the green chemistry movement creates a specific understanding of the problems that the field hopes to address, as well as the range of solutions that would count as acceptable. Thus, the movement's identity is caught up with its understanding of its mission and the role it plays in addressing these issues—establishing and maintaining a distinct set of green chemistry practices.

My analysis of these practices centers on two essential actions: 1) historical (re)construction, and 2) disciplining green chemistry participants through the stabilization of the field and the establishment of 'right practice' guidelines. Each of these is crucial in the construction of the green chemistry community.

Chapter 2 shows how proponents of green chemistry construct their own history. This history integrates the evolution of the chemical sciences in the twentieth century with that of the evolving environmental movement. One way in which the key figures use this history is as a tool for forging the identity of the green chemistry community. Understanding how this history is constituted thus offers insights into how proponents of green chemistry frame their work inside of and contiguous with a larger context of competing and companion practices. As Frickel and Gross note (2005, pp. 223ff), historical narrative construction serves as an important tool in the framing of a movement for both coherence of goals and setting of audience. Thus the setting in place of a history is the first, and perhaps most important, move a movement makes in establishing itself.

The history that emerges from this process is unique to green chemistry, and it presents a series of challenges for the movement. By uniting green chemistry with the history of the environmental movement, green chemists have perhaps inadvertently affiliated themselves with a set of groups that have little to no credibility within the academic or industrial sectors of chemistry. Green chemists inherit this legacy when they adopt this history. Similarly, by presenting the history of environmental disasters and chemical catastrophes as a mixture of unintended consequences and technical failures, green chemists have created a history of the chemical sciences that has been scrubbed clean of any wrongdoing or accountability. Issues of corporate negligence, environmental justice, or widespread ecological destruction have simply disappeared.

It is no wonder, then, that some environmentalists and others have a hard time accepting green chemistry as anything more than an elaborate corporate green washing scheme. While the role of the movement history is to offer support and structure, it would seem that the history constructed by green chemists might be proving detrimental to their cause.

Chapter 3 will utilize the previous discussions of movement construction, which I base upon the ideas of *boundary construction*, *disciplining*, *discourse coalitions*, and *structured disunity* and in order to highlight the formation of a distinct identity for *green chemistry*. Proponents of green chemistry employ two strategies towards this end. The first involves the establishment of a set definition for green chemistry. Deciding what green chemistry *is* also helps to determine *what it is not*. This distinction helps to establish what happens in the space green chemistry is carving out for itself. It also helps set a course of action for deciding to what other fields it ought to attach itself. That is, as an interdiscipline, existing interstitially between a number of other fields, properly defining green chemistry indicates where the movement sits in relation to other sciences, where attachments ought to be made, and what boundaries it will encounter in so doing.

To reinforce this definition, and to develop a stronger sense of identity within the movement, proponents adopted a set of twelve principles to guide the practices of green chemistry. These challenges to the placement of other boundaries amounted to attempts to ‘infect’ the practices of other fields with those of the green chemists. These occurred through cross-publications and the co-optation of conferences and meetings. Despite these efforts, however, green chemists have not been as unified as it might appear. They continued to exist as a heterogeneous group, the members of which, even though they nominally accepted common definitions, principles for practice, conferences, etc., still assigned different meanings to the key terms and continued to have differing opinions about what should properly count as green chemistry. Thus, I conclude that the field of green chemistry finds itself in a state of “structured disunity” (Halfon, forthcoming). That is, the field of green chemistry remains very much in flux.

Chapter 4 will engage the issue of *practice*, for which I draw on the work of Joseph Rouse to help situate our understanding of practice as something more complex than simply *doing*, but instead views the term in a broader sense of process, which takes into account the systematic relationships within which practices are created and propagated. I will frame green chemistry in terms of the broader context of *ecological modernization*, as discussed previously, in order to show how the movement measures up to other attempts to address issues of sustainability. In particular, I look at how the history adopted by the field and the types of people involved in the community create a specific framework for viewing both the problems to be addressed and their acceptable solutions. Drawing on the history of the field, proponents and practitioners pose problems in terms of breakdowns in techno-scientific systems. By viewing the past in this way, green chemists create a situation where techno-scientific solutions (and *only* technological solutions) can work. Thus, green chemists attempt to position themselves (and chemists more generally) as the natural leaders in combating the ecological crises we face and in the creation of a sustainable society.

One example of this occurs in the pedagogical outreach of the green chemistry movement, exemplified by the ways in which these ideas were passed on to the next generation of green chemists at the 2004 Green Chemistry Summer School. In this context, students were introduced to the green chemistry movement and its formalized practices. That is, they were instructed on the proper ways to frame environmental problems by emphasizing techno-scientific perspectives to the exclusion of compounding factors. I argue that the framing of issues in these terms fails to address environmental problems as systemic, thus failing to create any real opportunities for change and that by training new students in this approach we run the risk of perpetuating problems rather than creating solutions.

In the final chapter, I consider whether or not we ought to consider green chemistry to be a scientific movement. I offer a summary of the development and emergence of green chemistry described in detail in chapters 2-4, and then evaluate the current situation based upon some recent examples of green chemistry's attempt to expand and strengthen its influence. Based on this work, I compare green chemistry with the characteristics of other scientific and intellectual movements as outlined by Frickel and Gross (2005). In the end, I believe we are left with little choice but to consider green chemistry a scientific movement even if it doesn't quite mesh with other examples. Interestingly, however, as I argue, the green chemistry case offers the opportunity for further exploration and examination of scientific movements because of the fractured state within which it exists. While green chemistry has some of the organizational body of a movement, this is in many ways disconnected from the community of scholars that *practice* green chemistry. While green chemistry, the movement, may have a number of issues to overcome with respect to the framing of its cause, a growing community has grown in support of the overall mission of doing green chemistry.

Throughout this project, I argue that the case of green chemistry offers insights into our understanding of scientific movements through the ways in which it establishes a set of discursive strategies and the ways in which the field has sought to define itself and its goals. In what follows, I highlight the extent to which the case of green chemistry might begin a more engaged dialogue about how scientific movements work, and perhaps what role we in science studies might play in their future constructions.

Chapter 2: Uses of History

The history of a movement—social, scientific or socio-scientific—forms not only an important part of the participants' identity, but also becomes embodied in the physical and conceptual apparatuses of the group, i.e., the *practices* of the field.[1] The construction of this history is a strategic move. In the case of green chemistry, these strategies manifest themselves in, for example, the establishment of the twelve principles of green chemistry. History shapes identity, which shapes practice. The narratives shared and crafted in the texts and talks of green chemistry's proponents retell many familiar events, but interprets them from the perspective of the techno-scientific. This is especially noticeable when discussing the failure of a system that has led to deaths or pollution. By defining the past failures in terms of technological breakdowns, proponents of green chemistry create and legitimate technological solutions. History, then, prescribes certain actions to be taken in the present. The historical reconstructions of the green chemistry movement contain three interrelated perspectives: 1) the establishment of an 'origin story' for the group; 2) the relation between the construction of the history and the construction/constitution of the movement; and 3) how the history acts to reinforce a particular identity.

Having a history serves an important function, especially for new and emerging movements. Frickel and Gross (2005) argue that the success of these new movements is often contingent upon their ability to frame the ideas of the movement in a way that is meaningful for those that work within the field in question. This framing

[1] See Frickel and Gross (2005). For more on how historical narratives become a part of technologies in particular, see Galusky (2004, chapter 5).

requires "rhetorical constructions of the movement's collective identity, its historical origins, and its relationship to various competitor movements" (p. 222). That is, "participants in a SIM [scientific/intellectual movement] must construct historical narratives of it" (p. 223). These narratives provide a system of cohesion and legitimation.[2] They are also largely responsible for ensuring the movement's ability to grow and to garner new resources. The historical narrative must make the group appear to be in a place of prominence, intellectually as well as historically. Frickel and Gross:

> […] recruitment into the movement and the sustaining of its intellectual energy is partially dependent on the capacity of movement participants to depict themselves as caught up in some grand sweep of intellectual history. The more successful movements are those that effectively frame their SIM as the natural outgrowth of and the heir to some set of values, beliefs, assumptions, and identities widely held among the intellectuals who compose its potential recruitment base, or among those who control access to key resources […]" (p. 223).

The goal of this construction project in this case attempts to place green chemistry at the end of an evolving linear history of environmental awareness and concern plays an

[2] As I hinted at in the previous chapter, green chemistry continues to have problems with legitimation. The historical constructions of the field play a large part in this legitimacy problem. This is discussed more in the final chapter as it relates to the framing and audience of green chemistry. Cf. the stories recounted in Graham, Lepenies, and Weingart (1983).

important role for the constitution of the movement. An examination of the story that has emerged over the last decade proves useful for understanding what identity proponents of green chemistry have attempted to construct for the field and its members. The framing aspect of this history has been crucially important for understanding how the evolution of the green chemistry movement unfolds in the following chapters. I believe it to be important to understand the ways in which proponents of green chemistry frame their own narrative, and so I will devote much of this chapter to a presentation of the nuances within this history as it has been told by its creators. Much of my work focuses on the first textbook written for the field, *GCTP*. It is a comprehensive, but immensely accessible, review of the green chemistry movement. As such, it is easy to see how the history told in its pages matches the role of textbook histories as discussed by Kuhn, for instance, in *The Structure of Scientific Revolutions*. Kuhn reminds us that almost all textbooks contain history—but just a little. History helps to frame and reinforce the field's treatment of its "paradigmatic problems," and the solutions to those problems. As a result, textbooks "refer only to that part of the work […] that can easily be viewed as contributions to the statement and solution of the texts' paradigm problems" ([1962] 1996, p. 138). The concretized form of the green chemistry history provides additional credence to understanding how it functions within the movement. Despite context, audience, and speaker, the basic tenets of the story always remain the same. This pattern structures nearly all discussions of the past/present/future of the green chemistry movement, and in so doing it forms a framework within which the movement both operates and attempts to connect to potential audiences.

The History of Green Chemistry

The history of the emergence of the green chemistry movement, as told by its proponents, results from the sometimes uneasy mixing of two other histories: the rise of environmentalism (especially in the US) and the growth and expansion of the chemical sciences (more specifically the chemical industries) during the twentieth century. The crucial junction comes in the 1960s with the publication of Rachel Carson's *Silent Spring* in 1962 and the fire on the Cuyahoga River in 1969. It is at these points, according to the proponents of green chemistry, that the histories of the environmental movement and the chemical industries become inextricably intertwined, sharing prominent points on each of their timelines. From this merged history, several new issues arise: public perception of the chemical sciences, the role of chemical accidents, declining enrollment in chemistry programs, and the increasing cost of doing business in the chemical industries resulting from growing regulation. All of this leads to the eventual formation of the Green Chemistry Program at the EPA. Proponents of green chemistry naturalize the movement by portraying it as an inevitable outgrowth of these two merged histories.[3]

Rather than offering extensive comments and corrections to the green chemistry narratives, I provide a number of places where the reader might wish to go to find out more about the specific cases and issues incorporated into the green

[3] Paul Anastas (2004) made this point explicitly during an interview when he claimed that green chemistry would necessarily have had to happen if it had not been created when it was. For more on this, see chapter 4.

chemistry history. The importance lies in how green chemists have constructed this history, and the role that it plays in formulating their identity.

What legacy has chemistry of the twentieth century left? Competing perceptions exist, particularly in regard to both the accidents and achievements of the enterprise as a whole. Anastas and Warner open their *GCTP* (1998) by addressing this problem specifically:

> The status of chemistry in society is a profound dichotomy of perceptions, and neither of these perceptions are in consistent agreement with the facts. While those engaged in the science and industry of chemistry hail the accomplishments that have come from the central science, there are a large number of people who view chemicals and chemistry as something to be afraid of, curtailed, and avoided wherever possible (Anastas and Warner 1998, p. 1).

Thus the chemical sciences find themselves in a situation where they must reconcile what some see as the successes of their works with an increasingly hostile public that is at the least skeptical and at the worst openly resentful and increasingly antagonistic as a result of problems stemming from the chemical industries. James Clark, the first editor of the journal *Green Chemistry*, confirmed this problem in his inaugural editorial:[4]

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[4] The journal is published by the Royal Society of Chemistry (UK) and began publication in 1999.

> The twentieth century has been highly successful for chemistry and society has come to depend on the products of the chemical industry to maintain our current standard of living and improve our quality of life. On the eve of the 21st century, however, the public are more aware of the hazardous substances that many chemical processes use and generate than the benefits of the products. Chemistry and the chemical industry have tarnished images (Clark 1999, p. G2).

For Clark, it's not as much about common misconceptions as it is a new awareness on the part of the public—a move away from an awareness of the benefits and towards the hazards. And Kenneth Hancock and Margaret Cavanaugh raised this issue in the first collected volume of green chemistry papers back in 1994.[5]

> Chemistry is in the news, and the news isn't always good. Though today's high standard of living rests firmly on the creative contributions of chemists—from food preservatives to pharmaceuticals, from crop-enhancing agrochemicals to synthetic fibers and plastics—chemists have also created, as byproducts of their prodigious productivity, a host of environmental problems. Some of the most publicized in recent years have been the depletion of stratospheric ozone by

[5] The exact naming of green chemistry and its associated concepts—of which this is one—is a bit muddled. See the discussion in the following chapter for some discussion of this issue. Cf. Woodhouse and Breyman (2005).

CFCs, global warming by greenhouse gases, chemical spills in the Rhine River, and nitrous oxide as a byproduct of nylon production.

With continuing innovation, several hundred new chemicals are introduced each year, while thousands of new stacks and pipes release chemical effluents into the air, soil, and water. These new products, like their predecessors, are the building blocks of a technology-based economy. […] Clearly, the economic vitality of the chemical industry must be maintained, and at the same time the behavior of chemicals in the environment must be determined in order to avoid risks they might pose to humans and other organisms.

In addition to the many sound health and economic reasons to worry about the environment, there is another urgent moral imperative: we have a responsibility to preserve the environment and a fair share of its natural, non-renewable resources for our children and for the generations that follow (Hancock and Cavanaugh 1994, pp. 23-4).

Here, Hancock and Cavanaugh expand the conversation. They acknowledge the bad press that surrounds the chemical enterprise, and they note that people are increasingly aware of the problems associated with the production of commercial chemicals. However, they also draw attention to something more. They note that the industries have been growing at a tremendous rate, and that current systems for monitoring new chemicals simply cannot keep pace with new production. And, while the innovations of the chemical industries are still celebrated as the foundation of our nation's economy and the bedrock for our high quality of life, the authors here appeal to the moral necessity for addressing the very real threats to the environment and future economies. This statement pulls together nicely many of the elements explored by proponents of green chemistry in the crafting of their history, including the growth of regulation and its ultimate (perceived) failure, the increasingly distrustful public, the demand for a new approach to dealing with the chemical enterprise. The authors also carefully tie the existence and continued survival of the chemical industries to the overall strength of the national (and international) economy.

Interestingly, Hancock and Cavanaugh also make a plea here on moral grounds. Despite the incorporation of this sentiment in one of the earliest texts, this argument has all but disappeared from conversations in and about green chemistry. It should become more evident why this is the case as we examine green chemistry from the perspective of ecological modernization—which favors the 'win-win' economic argument to the moral argument—in this and subsequent chapters.[6]

Despite the initial discussion of the problems facing the chemical enterprise in the wake of these high profile incidents, proponents of green chemistry nonetheless paint a positive portrait of the past successes and the present potential in their collective

[6] An anecdote illustrates this point: during the Second Annual Innovation Day this past September at the Chemical Heritage Foundation I asked an attendee to the section on "Environmental Chemistry" about the impressions he gleaned from Paul Anastas' presentation on green chemistry. The attendee simply responded: "We're not going to do green chemistry because we're good guys." A few moments later, this same attendee sought me out to clarify the statement: competition is tough right now, and without a clear economic benefit the switch to green chemistry techniques simply makes no sense.

narratives. Anastas and Warner (1998) quickly move away from the troubled image and towards one more optimistic and celebratory:

> Chemistry has resulted in the medical revolution of the past century in which drugs such as antibiotics have been used to cure diseases that have ravaged mankind for millennia. […] In virtually every arena and every aspect of material life—transportation, communication, clothing, shelter, etc.—chemistry has resulted in an improvement, not merely in the trappings of life, but also in the quality of the lives of the billions of individuals who now inhabit the planet.
> These almost unbelievable achievements have come at a price. That price is the toll that the manufacture, use, and disposal of synthetic chemicals have taken on human health and the environment (Anastas and Warner 1998, pp. 1-2).

From this perspective, chemistry in the twentieth century has furnished humans with a plethora of advances in everything from the way we treat our sick to the way we eat and where we live. This strategy appears in a number of green chemistry works. Before calling for a change to current practice, those offering an alternative view must pay their respects to what has come before them.[7]

The resulting tales told here that combine both benefits and emerging crises has led to a loss in the public's confidence in the chemical enterprise. Green chemistry, as a result, stresses its role in addressing not only the *problems* causing

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[7] For an example of this in the field of hydrology, see Silliman, et al. (unpublished).

these crises, but also the broader resulting *perception* of chemistry. The strength of this argument has made it an important and consistent feature of green chemistry presentations.

Where the evolution of the chemical industries meets the environmental movement, new problems emerge and, according to proponents of green chemistry, the role of the government in response to these issues grew in parallel to the public's increasingly loud outcries. Anastas and Warner sum it up this way:

> In the subsequent decades of the 1960s, 1970s, and 1980s, a pattern emerged: an environmental problem would manifest itself, where chemical substances were having adverse effects well beyond their intended use, a vocal outcry would follow, and laws and regulations would be generated to govern and address the problem of chemicals in the environment (Anastas and Warner 1998, p. 4).

Thus we have a very simple flowchart:

environmental problem → outcry → regulation[8]

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[8] Note, though, the careful wording used here: "environmental problems" manifested themselves (no causal connection) where chemicals had "effects well beyond their intended use" (an accident, certainly not someone's fault) that resulted in public outcry and new laws. The re-constituted history told within the context of green chemistry has been scrubbed clean of any intentional wrong-doing, intent to cover-up problems, or the fights that were often required for the government to act.

These problems grabbed attention in a number of different ways: sometimes books or articles attracted attention to a problem, as in the cases of DDT or the Cuyahoga River fire of 1969. Sometimes an 'accident' occurred somewhere in the US or abroad, such as those incidents in Bhopal, India or Seveso, Italy. Take for instance the role of the publication of *Silent Spring* and the resultant attention on DDT:

> In 1962, Rachel Carson wrote the book *Silent Spring*, which detailed the effects of certain pesticides on the eggs of various birds. It illustrated how the use of DDT and other pesticides could spread throughout the food chain, causing irreparable and unanticipated harm. It was the unanticipated nature of the harm that caused a public outcry and resulted in regulatory controls on pesticides which are manufactured and used in the United States (Anastas and Warner 1998, pp. 2-3).

The authors note, just as many others have, the important touchstone that *Silent Spring* provides for understanding emerging tensions between the chemical enterprise and the public.[9] During the same time, there were new scares associated with the drug thalidomide.[10]

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[9] For more on issues around the publication of *Silent Spring*, see Dunlap (1981); Galusky (2004); Graham (1970); and Hynes (1989).

[10] For more on the case of the use of thalidomide, see Daemmrich (2002).

> In 1961, there was a scare in Europe about a substance called thalidomide, which was used by pregnant women to lessen the effects of nausea and vomiting during pregnancy ('morning sickness'). As a result of using this drug, the children of the women taking the drug suffered acute birth defects, in many cases in the form of missing or grossly deformed limbs. About 10 000 such children were born world-wide, with 5000 in Germany alone. (Doubts concerning the drug's safety had prevented its sale in the United States.) The tragedy led to stringent governmental regulations for testing new drugs for teratogenic (malformation-inducing) hazards. These 'thalidomide-babies', as they are sometimes referred to, caused a great deal of fear in the general public about the effects of synthetic chemicals and the unintended effects that they could have on humans (Anastas and Warner 1998, p. 3).

Like the case of DDT above, the tremendous attention garnered by the effects of the use of Thalidomide increased fear in the public. This in turn resulted in increasing government oversight of new drugs and chemicals that might also pose a threat. But these examples are unique compared to many of the examples that follow. Unlike the former, they occurred with chemicals that were either used by the government (or governments) or at the very least sanctioned by the government for use. These examples deal with 'accidents' in the production, storage, use, and/or disposal of chemicals rather than the effects of specific chemicals. Times Beach, Missouri:

> In 1982 the soil along the roads in Times Beach was found to be contaminated with the toxic chemical dioxin. (The town was one of at least 26 and perhaps as

> many as 100 sites in Missouri that may have been contaminated when dioxin-tainted waste oil was sprayed on the roads a decade ago. The level of dioxin in the soil at these sites varied from around 300 to 740 parts per billion. The federal Center for Disease Control (CDC) rates soil with dioxin readings of over one part per billion as unsafe for long-term contact.) The problems of Times Beach residents were compounded by a flood in late 1982, which forced about 700 families to leave their homes. Government officials urged residents not to attempt to clean up the contaminated mud and debris that had been deposited in their homes by the flood. The federal government provided temporary shelter and, in an unprecedented decision, arranged to buy the entire town, using $33 million from the special fund for toxic waste clean-up (Anastas and Warner 1998, p. 4).

In the instance of Times Beach, we see the first large-scale intervention on the part of the federal government to move in and address an environmental catastrophe resulting from a chemical toxin.[11] This pattern only increases through the 1960s and into the 1970s as a number of other high-profile cases made it to the front page of the nations newspapers. Perhaps the most familiar case is that of Love Canal:

> Long-term contamination was involved in the disastrous events at the Love Canal in Niagara Falls, NY. A chemical and plastics company had used an old

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[11] For more on the case of the problems at Times Beach, see Sun (1983). For the timeline and summary information offered by the EPA, see: http://www.epa.gov/history/topics/times/index.htm.

> canal bed in this area as a chemical dump from the 1930s to the early 1950s. The land was given to the city of Niagara Falls in 1953, and a new school and a housing tract were built on it. In 1971, the chemical substances that had been dumped there years before began leaking through the clay trap that sealed the dump, and the area was contaminated by at least 82 chemicals, including a number of suspected carcinogens: benzene, some chlorinated hydrocarbons, and dioxin. Health effects that were linked to the chemical exposure at Love Canal included high birth defect and miscarriage rates, as well as liver cancer and a high incidence of seizure-inducing nervous disease among the neighborhood children. The region was declared an official disaster area. The state paid about $10 million to buy some of the homes and another $10 million to try and stop the leakage. About 1000 families had to be relocated. Portions of the site were cleaned up sufficiently by 1990 for houses located there to be put up for sale (Anastas and Warner 1998, p. 5).

The events at Love Canal present another stepping stone in the evolution of the environmental movement, and also the history of green chemistry. It occurred as the result of "long-term contamination" rather than the result of an isolated accident.[12] Here we begin to see the emergence of a system that links together chemical waste,

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[12] One reason the Love Canal case has become so prominent is that it not only involved children (a school was situated on top of a toxic waste dump that was leaking), but it also involved local organization, and attention to the problems of race, and poverty. For overviews of the case its effects on US legislation, and its role in the growth of the environmental justice movement, see Galusky (2004, chapter 4); Gibbs (1982); Levine (1982); and Szasz (1994).

prolonged health effects, widespread contamination, and massive government attention all attached to tremendous public outrage. This outrage involves another changing variable: time. Time becomes an element for debate here as those involved grapple with prolonged exposure over unspecified times, delays in action, and postponed closure. This element is also present in the other cases highlighted by Anastas and Warner. Take for instance the well-known incidents at Seveso (Italy),[13] Bhopal (India),[14] and the fire on the Cuyahoga River (US):[15]

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[13] Seveso was the first large-scale industrial accident to involve the chemical dioxin. For more on the Seveso case, see Dickson (1983), Perrow (1999, chs. 4 and 8), Stone (1993), Strigini and Torriani (1977), Walsh (1977), and Whiteside (1979).

[14] As the worst chemical accident in history, many, with many different opinions, have told the story of what happened at Bhopal. Bhopal has gained at least some new attention recently following the marking of the twentieth anniversary of the incident last December. For a sampling of academic works on Bhopal, see Bogard (1989); Galusky (2004, chapter 4); Kurzman (1987); Shrivastava (1987); and Wilkins (1987). For a discussion of the problems in putting together the story of Bhopal, see the fantastic work by Kim Fortun (2001). For an appraisal of the event on its twentieth anniversary, see the report compiled by Amnesty International (2004). And for a focus on the issues of risk, see the volume edited by Jasanoff (1994). The effects of Bhopal on the chemical industries were, of course, profound to say the least. While the story is a fascinating one, I'll defer to the authors mentioned here to tell it. I will note, however, just two things. First, the incident succeeded in unifying the chemical industries in a way that was not typical beforehand (see Fortun on this point). The industries as a whole realized that they had a lot to lose or gain collectively on how they dealt with this issue. One of the results was the creation of the Responsible Care® initiative, seen by many proponents of green chemistry as an important precursor to their movement. Second, there has been much speculation on what exactly the death toll from the gas leak was (or is, if you continue to count people dying from chronic health problems, as some groups do). While it is impossible to get an absolutely accurate number, there are some minimums that are agreed upon by almost everyone. At this point, that minimum is in the neighborhood of 3500 (even

Environmental disasters have often resulted in new, and specific, laws being enacted. In the early 1970s, the Cuyahoga River in Ohio was so acutely polluted that it caught on fire. The sight of a major river in flames because of chemical pollution prompted calls for legislation to ensure clean water controls through regulation. Nightly news reports showing the brown haze of the Los Angeles or Pittsburgh skylines of the 1960s and 1970s resulted in a variety of Clean Air legislation, including the Clean Air Act. In the 1980s, as the nature of the impact of chlorofluorocarbons (CFCs) on the stratospheric ozone layer became clearer through the use of satellite photographs and the work of Nobel laureate chemists Rowland and Molina, the Montreal Protocol which first called for CFCs to be phased out was adopted. Accidental chemical disasters such as the tragedy at Bhopal, India, where hundreds of people were killed as a result of an accident at a Union Carbide plant that generated the extremely toxic methyl isocyanate, generated the Emergency Planning and Community Right-to-Know Act of 1986 (Anastas and Warner 1998, pp. 5-6).

Dow uses this as a baseline on their website discussing the leak found at www.bhopal.com). Thus, the numbers given here by Anastas and Warner (and repeated on p. 54 of the same volume) are off by several factors. That is, *at least* 3500 died (not several hundred) with some estimates reaching into the hundreds of thousands.

[15] The story of the Cuyahoga River fire is also an interesting one, perhaps because the fire that sparked this controversy was only one of many fires on the river over the course of several decades. The difference this time was how the fire caught the eye of a national journalist and added fuel to debates in Washington about the health and safety of the nation's water and air. For more on these fires, see: Adler (2002) and the articles in the *Cleveland Plain Dealer* (1969) and *Time* (1969).

Large scale industrial accidents like those at Seveso and Bhopal and seemingly unnatural disasters like that on the Cuyahoga River helped to gain the attention of a concerned public, as well as channel new strength into environmental advocacy groups already working by this time to draw attention to issues of environmental degradation. These events helped to put a face and a name to something previously abstract, and the possibility for similar accidents here in the U.S. drew enough backlash and concern to make the federal government act. Thus, according to the authors here, we now have the establishment of our reaction flowchart outlined above:

> In both of the above cases [thalidomide and DDT], the public was well aware that the substances in question were designed by scientists, people that the public felt had a great deal more knowledge than they about the chemicals that were being made. Despite the confidence that they had placed in scientists, to provide innovations for society, the public began to realize that unintended and catastrophic consequences could result from the use of chemical substances. It was unclear to the public whether anyone could control the effects of these substances, and the result was that the government was brought in to control these substances through the regulatory process (Anastas and Warner 1998, p. 4).

And, again, here:

> Both the Times Beach and Love Canal events caused sufficient public dismay to prompt the United States Congress to pass new laws to deal with the particular problems that were of the highest visibility. Congress passed the law that became known as Superfund, which would require the clean-up of designated toxic waste sites throughout the country (Anastas and Warner 1998, p. 5).

These examples are presented as comprising a larger set of “unforeseen chemical consequences” by the authors. They present the ugly side of an industrial society based on science—there are some things that we just can’t know ahead of time, and unfortunately, sometimes despite the very best efforts and intentions, things go wrong. Perhaps even more unfortunate, is that these accidents and unforeseen consequences have led to a slew of new regulations by the federal government—regulations that do not necessarily address the issues in a meaningful way. But, while the regulation may not actually prevent more accidents, they do often have the negative impact of impeding further research and making the business more costly. This story is borne out in a number of ways:

> All of these examples are of unforeseen chemical consequences resulting in tragedy, and the tragedy resulting in public outrage, and the public outrage resulting in legislation to control the manufacture, use, or disposal of chemical substances. But the question should be asked, what has been the nature of these new laws to control chemical substances and are they the only way or the most effective way of protecting human health and the environment from unanticipated outcomes (Anastas and Warner 1998, p. 6)?

Similar sentiments are also found here:

> The growth in environmental regulations has produced dramatic and beneficial results to the environment over the course of the past generation. However, the costs both to industry and society have made this approach, as a unilateral strategy, unsustainable (Anastas and Lankey 2000, p. 289).

The more complete story that sets up the emergence of green chemistry begins to take shape here in these comments. Not only do we have the earlier flowchart documenting what happens when a problem involving chemicals or the broader chemical enterprise arises, but also how these incidents effect the chemical industry and society through the increased cost of doing business (passed on to consumers), the hampering of research and development, and with no net increase in our overall safety from these same types of disasters.

There were other problems, too. Bad press has meant that many students have not chosen to associate themselves with chemistry (viewed as the problem) but rather have moved into other fields that gave them the opportunity to be a part of the solution.[16] Again, James Clark:

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[16] Incorporating the ideas of green chemistry into the chemistry curriculum has been the focus of several papers, workshops, and presentations. See, for instance: Breen et al. (1998); Brush (2002, 2004); Cai et al. (2003); Cann (1999, 2001, 2004); Causey et al. (2002); T. Collins (1995); W. Collins (2004); Fukano (2004); Gordon (2002); Hjeresen et al. (2000); Kirchoff

The choice of university subject is certainly influenced by career opportunities and financial reward (although we must remember that we want chemistry graduates in more walks of life than the chemicals and related industries and academia!), but it is also heavily influenced by interest and perceived reputation and status. Over many years chemistry has attracted many able young minds because it was seen as a challenging and interesting subject of real value to society. Unfortunately chemistry seems mostly to grab the headlines these days as a result of a disaster rather than an invention or benefit to society. If we are to continue to attract bright young people into chemistry and to encourage a wider participation in chemical subjects, then we must address the fundamental issue of subject image.

[…] Young people are instinctively interested in environmental issues. If the apparent environmental aspects of chemistry are negative, *i.e.* chemistry is considered to be damaging to the environment, then many young people will be antagonistic towards the subject. On the other hand, we can attract students if we emphasise the vital role chemistry has to play in understanding our environment, and how the principles of green chemistry are being used to better manage the environment and to provide the lifestyle we want at minimum cost to the environment. […]

(2001, 2002); Kitazume (2002); Lancaster (2000) Poliakoff et al. (2002); Santos et al. (2004); Williamson (1996); Zeng and Song (1995).

> […] Even before students are taught chemistry as a distinct subject, they can learn about green chemistry aspects of environmental issues. It is important that our children are brought up believing that chemistry is for the environment not against it (Clark 1999b, p. G117)!

Towards the end of the twentieth century, the chemical communities are facing a number of difficulties. First, the increasing evidence that the chemical industries were directly linked to the environmental damage being uncovered by a host of governments and non-governmental groups created serious issues in the public relations of the entire enterprise. Public perceptions of the industries, and their associated scientific fields were becoming tarnished. And anxious governments placed regulation after regulation on these industries in an attempt to alleviate fears and keep a growing industrial sector in check. However, this created an unfortunate cost to both the industries and society. Hancock and Cavanaugh:

> The magnitude of environmental problems—around the world—is daunting. Increasingly, the public is aware of these problems, worried about the future, and ready to demand action, not only from politicians but also from the science and technology community. Some problems are within our present scientific and engineering capabilities if we have the public will to act. Others are not. The need for science and engineering research related to the environment is not only great, but urgent. Moreover, the U.S. industrial base, built in many cases around older technology than the industries of our newer manufacturing

> competitors, needs new knowledge and technology to remain economically competitive. […]
>
> For the United States, the crux of the problem is that economic growth and environmental quality are now both at risk. Clearly there are costs to environmental preservation. However, sound economics recognizes that calculating profit and loss must account for resource depletion and waste production and management. The regulatory environment alone is increasingly forcing chemistry-based industries to adapt new technology or close down environmentally unacceptable operations. Thus, economic competitiveness and environmental quality are intertwined—they can be mutually addressed in a "win/win" approach or be mutually ignored—inviting double losses (Hancock and Cavanaugh 1994, p. 24).

According to the authors, the stage had now been set for the emergence of green chemistry in the early 1990s in the United States. The evolution of green chemistry places it at the end of a 30-40 year process by which the federal government had attempted to regulate the chemical industries in an attempt to deal with a growing number of problems associated with the production and use of certain chemicals. The evolution, most broadly outlined, moves from attempts to mitigate the problems associated with the industry eventually to policies that attempt to prevent pollution before it begins—enter green chemistry. The early years of this history go something like this:

The United States's approach toward dealing with environmental problems has evolved since the early stages of the environmental movement in the 1960s and early 1970s. Most approaches have centered around the 'command and control' approach to pollution. In its earliest form this involved the government allowing potential releasers of toxic substances to release materials only in certain limited amounts and/or requiring them to obtain permits to dispose of toxic chemicals, often to air or water. At the time, this tactic was described by the rather black-humor rhyme, '<u>dilution</u> is the <u>solution</u> to <u>pollution</u>.' As the environmental movement progressed, it became more common for the government to require treatment of various wastes prior to their release to the environment. Usually this involved sufficient treatment techniques such that the concentration of the toxic substance was reduced to an acceptable level. It is only within the last several years that the U.S. approach to dealing with pollution prevention has been not to create the polluting substances in the first place. This is the basis of pollution prevention. […]

The costs of the command and control approach to environmental problems are staggering. Estimates of how much business is spending on control and treatment technologies are as high as $115 billion dollars annually. Still with all of this money invested in pollution control, over three billion pounds of waste were released to the environment in 1992 […] according to the U.S. EPA's Toxic Release Inventory, which has tracked the release of only approximately 300 chemicals. Since over 70,000 chemicals are currently in commerce in the United States, it is easily seen that despite efforts of regulatory agencies to

> control the release of chemicals to the environment, they are only capable of focusing on those few of highest priority. Most of these documented chemical releases have been to the air […].
>
> It is certainly desirable for industry to reduce its operating costs associated with the compliance with local, state, and federal regulations, waste treatment and waste disposal. By focusing on reducing the amount of waste that is generated, a company will be able to achieve economic benefits associated with avoiding these operating costs. This type of economic incentive is encouraging companies to look inward to find ways to regulate themselves and reduce their environmental releases. The private sector is finding pollution prevention makes good business sense as evidenced by the examples of the Dow Chemical Corporation's WRAP Program (Waste Reduction Always Pays) and 3M's 3P Program (Pollution Prevention Pays). It is revolutionary in the fullest sense of the word when environmental stewardship is transformed from being perceived by industry as an economic burden to being perceived as necessary for increased profitability and competitiveness. This is the fundamental difference between pollution prevention and the previous command and control approaches to dealing with environmental problems and this is why there is the promise of profound effectiveness with this approach (Anastas 1994, p. 3).

And, as the story goes, it was only a matter of time before people began to associate environmental problems with the chemical sciences and industries.

> It is only fairly recently that the issue of the 'environmental impact' of chemical substances has come into the public dialogue and been fully recognized as a problem. In the years following World War II, there were little or no environmental regulations to speak of that effected [sic] the manner in which chemical substances could be manufactured, used, or disposed of. It wasn't until the late 1950s and early 1960s that concern developed over how chemical substances may cause harm to human health and environment (Anastas and Warner 1998, p. 2).

Thus, the emergence of concern over the environment sits alongside the development of the modern environmental movement in the 1950s and 60s.[17] These decades were a boom for the chemical industry in the wake of the Second World War. But, according to the authors here, the combination of a growing industry, increased attention to a series of bad incidents involving production or use of chemicals, and the growing environmental movement—spurred on by rabble-rousers like Rachel Carson—created a

[17] It should be noted, however, that public outcries against the pollution coming from the chemical industries was not new in the 1950s and 60s. Indeed, concerns over noxious gases, etc. emitted from these plants grew in tandem with the industry itself. For some recent work that examines issues of pollution from chemical plants in the nineteenth century, see for example the articles in Homburg et al (1998). There was, perhaps, something unique about the concerns being raised in the era discussed above. In previous times, concerns were more focused on the *immediately* tangible—smoke, soot, noxious smells, waste in the rivers—while the concerns in the second half of the twentieth century became more focused on specific chemicals and their *potential* health effects—e.g., DDT, thalidomide. However, this transition in the object of concern is not universal (concerns still exist with the broad categories of production and proximity to production, smell, waste in rivers, etc.) and doesn't provide enough of a transition point to say that there was no concern before the 1950s and 60s.

situation where chemicals were now seen as “problems” rather than “solutions” to a host of human conditions. According to proponents of green chemistry, however, the response by the government to these issues has been both inadequate and misdirected. The rather lengthy quotes here help to provide a summary of the guiding principles that become folded into the history of green chemistry, and become a part of the movement itself. They highlight key issues and broader patterns within the socio-technical networks of the chemical enterprise. The role of the chemical sciences and associated industries cannot be separated from the increase in quality of life, and must be viewed as a driving force in the economy of the United States. Thus, to go against the chemical industries means to stand in the way of progress and to threaten the foundation of the entire economic system of the nation. The government’s reaction to the aforementioned incidents falls under heavy critique. According to the authors, the government—by continuously increasing it’s oversight and regulation—has added to the economic burden of conducting business in the chemical trades (costs that have been passed on to the public directly through the increased cost of products and indirectly through the diversion of research and development costs towards regulatory compliance). Government has also taken an unhelpful approach to the problem by focusing on pollution after it has occurred (command and control) rather than preventing it’s production in the first place (pollution prevention). The shift towards this latter stance is, in the eyes of the proponents of green chemistry discussed here, a remedy to both of these ills. Green chemistry, as a central tool for pollution prevention, offers the opportunity to decrease costs, increase profits, and prevent pollution before it occurs.

In an attempt to refocus the nation's strategies for dealing with pollution, Congress passed the Pollution Prevention Act of 1990. The legislation reorders national priorities in dealing with pollution by placing a new emphasis on prevention rather than remediation. The Act led to the creation of the Green Chemistry Program within the EPA, which became one of many such programs to emerge on the international scene. The eventual creation of the Presidential Green Chemistry Challenge in 1995 added further status to the program and again sets the tone for several other versions in other countries. Anastas and Kirchoff tell the story here:

> In the United States, the Pollution Prevention Act of 1990 established source reduction as the highest priority in solving environmental problems. Passage of this act signaled a move away from the "command and control" response to environmental issues and toward pollution prevention as a more effective strategy that focused on preventing waste from being formed in the first place. Shortly after the passage of the Pollution Prevention Act, it was recognized that a variety of disciplines needed to be involved in source reduction. This recognition extended to chemists, the designers of molecular structures and transformations. In 1991, the Office of Pollution Prevention and Toxics in the U.S. Environmental Protection Agency launched the first research initiative of the Green Chemistry Program, the Alternative Synthetic Pathways research solicitation. Foundational work in chemistry and engineering at the National Science Foundation's program on Environmentally Benign Syntheses and Processes was launched in 1992, and formed a partnership with EPA through a Memorandum of Understanding that same year. In 1993, the EPA program

officially adopted the name "U.S. Green Chemistry Program". Since its inception, the U.S. Green Chemistry Program has served as a focal point for major activities within the United States, such as the Presidential Green Chemistry Challenge Awards and the annual Green Chemistry and Engineering Conference.

In the first half of the 1990s, both Italy and the United Kingdom launched major initiatives in green chemistry. Several researchers in the U.K. established research and education programs in green chemistry. In Italy, a multiuniversity consortium (INCA) featured research on green chemistry as one of its central themes. During the last half of the decade, Japan organized the Green and Sustainable Chemistry Network (GSCN), with an emphasis on promoting research and development on green and sustainable chemistry. The first books, papers, and symposia on the subject of green chemistry were introduced in the 1990s. The inaugural edition of the journal *Green Chemistry*, sponsored by the Royal Society of Chemistry, appeared in 1999. Research groups in many countries quickly coalesced, and adoption by industry was evident but difficult to quantify.

In 1995, the U.S. Presidential Green Chemistry Challenge Award was announced as a way of recognizing accomplishments by industry, academia, and government in green chemistry. The five awards first given in 1996, along with the numerous nominations for the award, provided a first, if understated, measure of adoption of green chemistry. Japan, Italy, the U.K., Australia, and other nations have adopted green chemistry awards for the purpose of

> highlighting the environmental and economic accomplishments of green chemistry (Anastas and Kirchoff 2002, pp. 686-7)[18]

Green chemistry—through its practical methodology, awards program, and pedagogical outreach—is situated in a space specifically designed to address the issues raised earlier. But, of course it is. This is the important role of creating a history for itself. It wouldn't make sense to tell this story and *not* have green chemistry as the logical outcome. As Frickel and Gross note "[t]he more successful movements are those that effectively frame their SIM as the natural outgrowth of and the heir to some set of values, beliefs, assumptions, and identities widely held among the intellectuals who compose its potential recruitment base, or among those who control access to key resources […]" (2005, p. 223). The history provided here articulates a certain history, but it also creates a nuanced understanding of the present situation, and offers a specific way into the future. That way into the future is through the practice of green chemistry.

Creating a Frame for Green Chemistry

The stories told above follow a well-trodden path. That is, much of this history comes from the standard history of the rise of the environmental movement in the United States beginning in the 1960s, maybe a little sooner.[19] First there was Rachel Carson, who alerted the public to the fact that some very specific chemicals might pose

[18] Cf. Anastas 1994.

[19] Most works that cover the evolution of the American environmental movement tell very similar stories. Cf. Sale (1993).

certain health risks, and that we ought to keep a closer eye on the chemical industry. And then came a number of highly visible events that concretized the threat introduced by Carson: thalidomide, Times Beach, Love Canal, Seveso, Bhopal, etc. As a response, public sentiment rose, and the federal government was forced into action. This action took the form of the creation of new administrative bodies (e.g., the EPA), and growth in the number of regulations.

According to the story told here, the increased reliance on regulations proved to be costly, both to the industry and to society. And, unfortunately, a cleaner and less harmful environment did not result, only a more difficult environment in which to conduct research in the chemical sciences. In an acknowledgment of the situation's increasing need for attention, and in an effort to address the clear failures of the previous strategies for combating pollution and the rising costs of research, the federal government instituted a policy of preventing pollution rather than cleaning it up. A small group within the EPA took this opportunity to create a new approach to cleaning up dirty industrial practices, which had the benefit of also offering the opportunity to clean up the image of those same industries—all while saving money and without the presence of further regulations. This approach, dubbed 'green chemistry' by those working within the EPA, was positioned to transform the chemical enterprise through the recruitment of scientists from across a broad range of specialties who might offer new perspectives on how chemistry might be conducted.

Chapter 3: Building a Movement

This chapter explores the construction of the green chemistry community—how it defines itself, where it locates itself, and how it keeps itself in order. The creation of the movement sometimes happens by carving directly into other already established fields, sometimes through innovations unique to green chemistry, sometimes through strategic alliances. Like most loosely contained fields, however, the boundaries of green chemistry are flexible, fluid, and almost always permeable. The movement faces a number of challenges. On the one hand, to gain legitimacy, access to resources, and a voice in the future direction of the chemical sciences, green chemists must work to *establish* the field of green chemistry. However, this must be balanced, on the other hand, with the stated goal of green chemistry, i.e., to transform the chemical enterprise and effectively result in the *purposeful disappearance* of green chemistry. Proponents must work to bring green chemistry into being in the hopes that it might give rise to a new chemistry, but that in the end this new chemistry will be enfolded by the already existing structures of the chemical sciences such that it becomes inseparable from what we know as chemistry.[1]

Here, I examine three strategies employed in the construction of the green chemistry community. The first involves settling on a name and definition for the movement that will become *green chemistry*. I explore the role that the "Twelve

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[1] For example Paul Anastas and Mary Kirchoff say it this way: "When the 12 Principles of Green Chemistry are simply incorporated as an integral part of everyday chemistry, there will no longer be a need for the focusing, highlighting, and label of green chemistry" (2002, p. 691).

Principles of Green Chemistry" play in the construction, maintenance, and policing of green chemistry boundaries. And in the third instance, I discuss how green chemists, operating from a more solidly established field, take the practice of green chemistry into other fields. Green chemistry, as an interdiscipline, must exist and operate interstitially between already existing scientific fields. The definition of green chemistry and the choice of this term, the principles of green chemistry, and the attempts to incorporate the work of other scientific spaces are the efforts to make this space stable and habitable.

Despite these community-building activities, however, I argue that green chemistry exists in a fractured state. On the one hand, there are individuals and institutions involved in the creation of a scientific movement. It is here that decisions are made about what sorts of strategies to employ, how to frame the green chemistry movement, and decisions about who the target audience is take place. Alongside this group, but not always overlapping with it, sits the community of green chemists, which is composed of the individuals who *use* green chemistry. They are its practitioners. They are the ones that publish in *Green Chemistry*, who sometimes attend meetings, and who for the most part work to integrate green chemistry into the everyday life of the chemical enterprise without regard or concern for the strategies involved in the construction and maintenance of the movement.

Discipline and Publish, Part I: The Creation of *Green Chemistry*

In 1994, the first volume of papers was published in the American Chemical Society's Symposium Series under the title *Benign by Design: Alternative Synthetic Pathways* *for Pollution Prevention*. The volume contained papers delivered at the annual meeting of the American Chemical Society in 1993, which included the recipients of the initial seed grants offered by the EPA. The next volume of papers was published two years later in 1996. Several other volumes followed in close succession. However, these volumes had a notable difference. Each brandished the name, "Green Chemistry" somewhere in their titles. What had happened during this short period of time? I wanted to know why, in such a short period of time, the name had changed from "Alternative Synthetic Design for Pollution Prevention" to "Benign by Design" to "Green Chemistry." I asked Paul Anastas during an interview. He had this to offer: "It actually wasn't a name change. The name of the solicitation was Alternative Synthetic Design for Pollution Prevention - Alternative Synthetic Pathways for Pollution Prevention. That's because we were focusing on the synthesis part of Green Chemistry. The Benign by Design was just a heck of a good book title. […] Green chemistry and the name and the definition and things like that [were] in existence in '91" (Anastas 2004). Unfortunately, Anastas is one of very few people from those early days at the EPA still living.[2] And so, we are left with the personal account of Anastas—present in the interview and his many publications, which always possess a

[2] The two other key figures from that time, according to Anastas, were Joe Breen and Roger Garret. Breen and Garret have since passed away. This leaves Anastas, and Carol Farris, a member of the EPA office where the green chemistry program was born. Farris, whom I interviewed in December of 2005, was able to provide me with a wealth of materials from those early days. However, it seems as though much of the conceptual work occurred between Anastas, Breen, and Garret.

short history of the field—and a few miscellaneous documents collected during that time period and still on file at the EPA in the office of the Green Chemistry Program.

Yet, this story seems to gloss over many of the artifacts left behind during this same period.[3] Take for instance the discrepancy found in the records of the first Gordon Research Conferences held on these topics. According to the records of the GRC archived at the Chemical Heritage Foundation, the first two Gordon Research Conferences, held in 1996 and 1997, were entitled "Environmentally Benign Organic Synthesis." These two conferences are now filed under "Green Chemistry" on the GRC online database.[4] In fact, the term green chemistry is nowhere listed on the program for the 1996 conference, and only appears in the 1997 program in reference to a presentation by Anastas on "Principles of Green Chemistry: Theory and Practice," and as a subject heading, "Green Chemistry and Biocatalytic Synthesis."

There exists, as well, some evidence that terms like green chemistry and clean chemistry found use in other places as early as 1990. Take for instance the exchange published in *Chemistry in Britain* in 1991 between an 8 year old concerned about saving animals from pollution and a chemist named M. Donnelly, which ran under the title "Green Chemistry." Or the article "Green Chemistry – Dream or Reality (Minimum Impact Chemistry) published in the Czech journal *Chemicke Listy* in 1991 (Drasar 1991). In fact, the term did not appear in a U.S. context (publicly, at least), until 1993, in an article by Ivan Amato in *Science* titled "The Slow Birth of Green

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[3]. Cf. Woodhouse and Breyman (2005).

[4] Available at: http://www.grc.org/ and then searching the "All Conferences Database" for Green Chemistry."

Chemistry." The report deals explicitly with future directions of research in chemistry, and talks at length about the NSF program initiated by Kenneth Hancock that provided the seed money for the research that eventually went to press in the volume *Benign by Design*. And Amato discusses the links between the NSF and the EPA in establishing this program. However, Amato does not actually refer to any of this as 'green chemistry' except in the title of the article. Rather, early phrases such as environmentally benign chemical synthesis run alongside discussions of environmental chemistry and the chemical industry's Responsible Care® program. Finding out just when 'green chemistry' emerged as such, then, proves elusive.

The following figures demonstrate how this confusion of terminology existed at the time, and shows how in many ways it extends into the present. Using the "Web of Science" Science Citation Index, I preformed a number of "topics searches. Here, the growth of the term green chemistry runs alongside the terms and phrases: *benign by design* (bbd), *environmentally benign chemical synthesis* (ebcs), *industrial ecology* (ie), *life-cycle analysis* (lca), *cradle to cradle* (c2c), *pollution prevention* (pp), and *clean chemistry* (cc).[5]

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[5] Note that I did perform a search for the phrase *alternative synthetic pathways for pollution prevention* (asppp), but it failed to return any results. Also, no data is given for the term *sustainability* since the number of hits far out paces any of the others and so does not return meaningful data for this chart. Finally, the chart begins in 1990 because the phrase "green chemistry" appears for the first time this year. It also represents the year of the 'birth' of green chemistry—according to the history told in chapter 2—when the "Pollution Prevention Act of 1990" becomes law. However, data for previous years does exist for the phrases life-cycle analysis and pollution prevention.

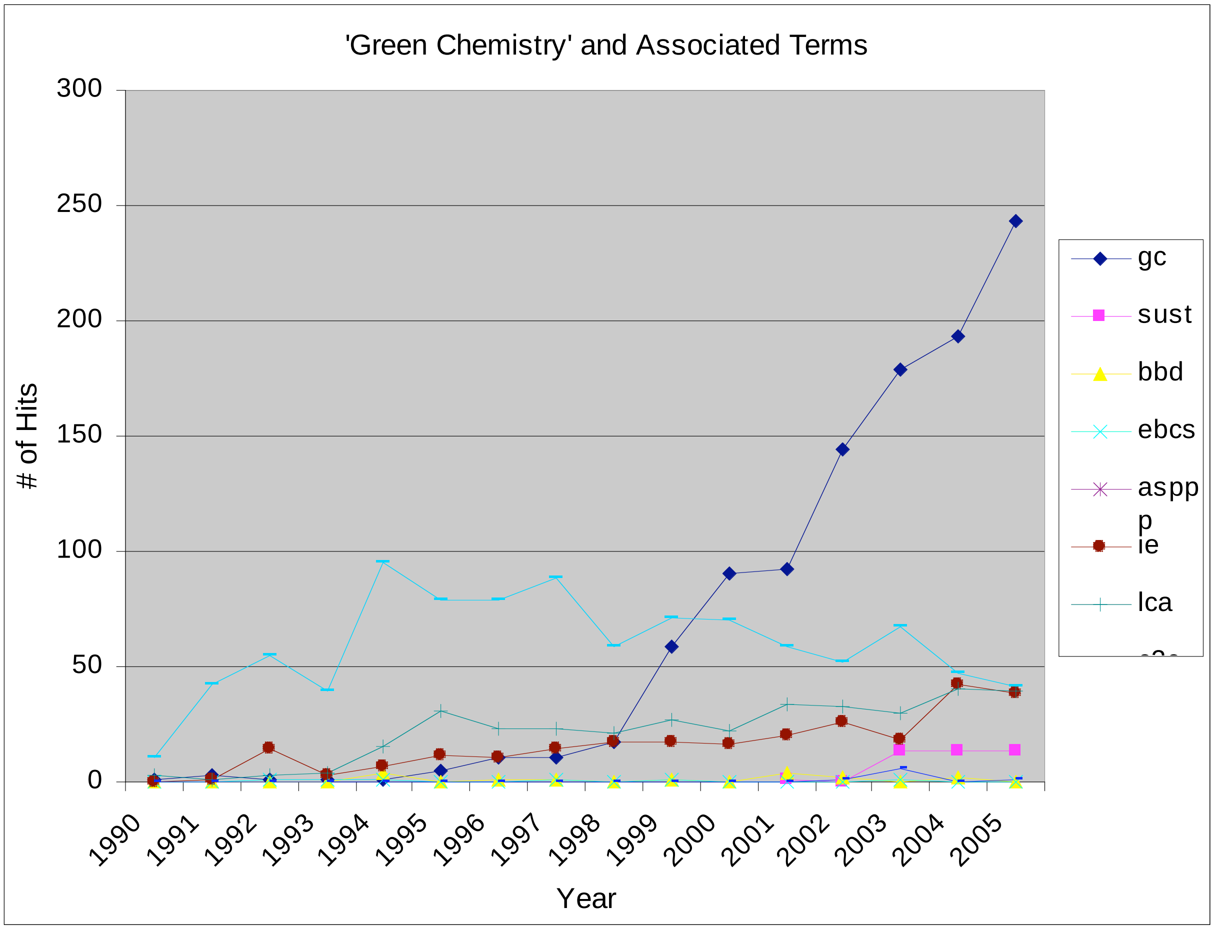

Figure 1: Growth of the term 'Green Chemistry' compared with other associated terms.

As Figure 1 shows, prior to 1999, a number of terms came into limited use to describe various aspects of what might be broadly termed pollution prevention. However, in the years following the publication of *GCTP*, even though many of the other terms don't wholly disappear, the term 'green chemistry' clearly becomes a dominant term. Rather, green chemistry incorporates those terms and stands alongside of them. In the next figure, I have taken the data from the same searches above, but I have matched the instances when green chemistry is used in conjunction with one of the other terms.

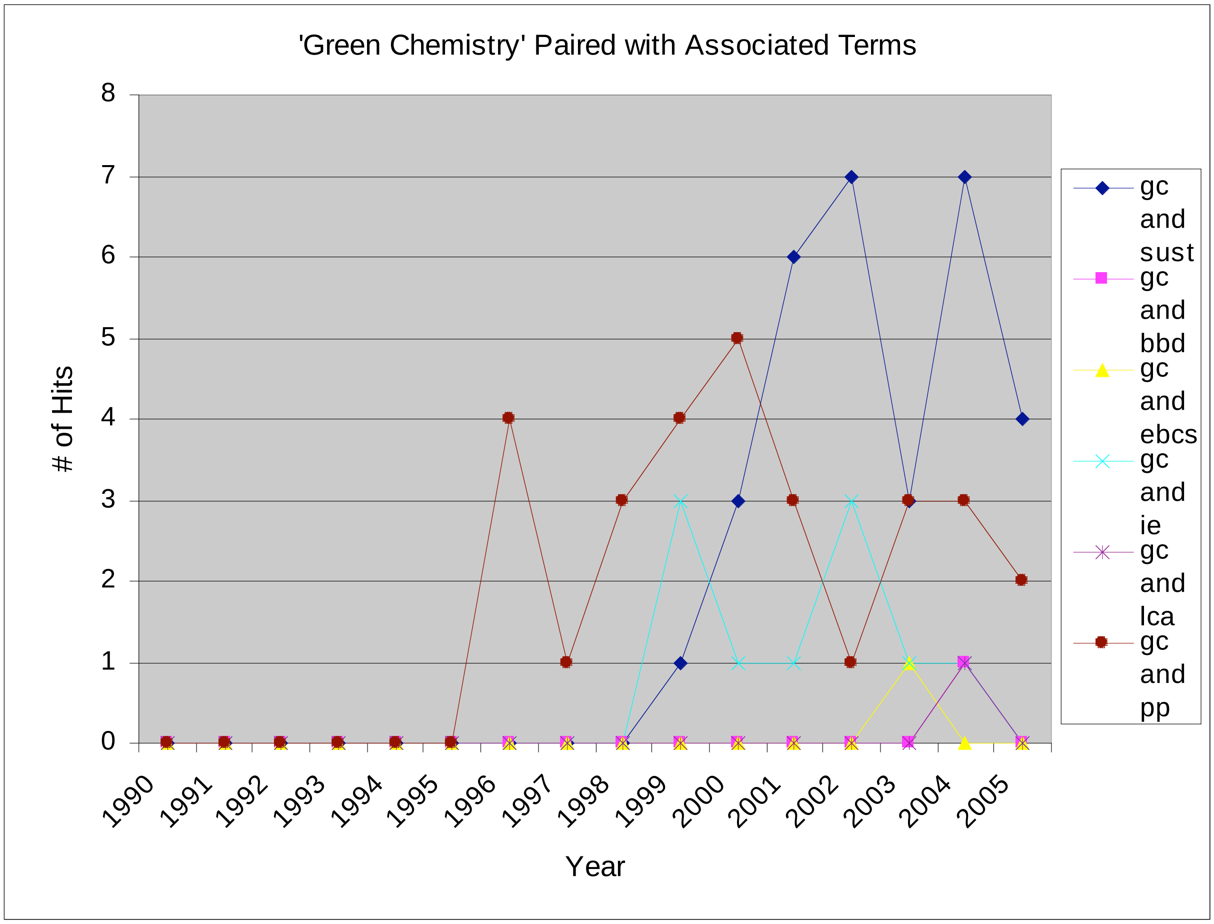

Figure 2: Pairings of the term green chemistry with other associated terms.

Here again, the years after 1998—with the publishing of *GCTP* and the establishment of the Royal Society of Chemistry journal, *Green Chemistry*, in 1999—display a marked difference from the previous years. Not only does green chemistry become a more common term, but it also associates itself with a number of other terms besides 'pollution prevention'.

While an exploration into the statistics of the rise and fall of green chemistry provides some important information, the important point here remains the way in which the story gets told, and not necessarily how accurate that story might be. As far as this history goes, 'green chemistry' has been the name since the beginning.

That is, the function of having the name seamless through the history plays an important role in providing continuity for the community. What matters is that "Green Chemistry" *did* exist then, at least according to the current history of the field. And what matters is how "Green Chemistry" comes to replace and incorporate whatever "Benign by Design" or "Alternative Synthetic Pathways for Pollution Prevention" were at some point in the past.

The move to incorporate these alternative frames into one history for the field becomes clear, among other places, in the introduction to *GCTP*: "Green chemistry, environmentally benign chemical synthesis, alternative synthetic pathways for pollution prevention, benign by design: these phrases all essentially describe the same concept" (Anastas and Warner 1998, p. 11). Thus, the early labels were rendered silent by being replaced by 'green chemistry'. The correlations and co-optations extend even further a year later in an article written for *Critical Reviews in Analytical Chemistry*, where Anastas incorporates two more elements under the umbrella of green chemistry: "Over the last few years, the chemistry community has been mobilized to develop new chemistries that are less hazardous to human health and the environment. This new approach has received extensive attention and goes by many names, including Green Chemistry, Clean Chemistry, Environmentally Benign Chemistry, Atom Economy and Benign by Design Chemistry" (Anastas 1999, p. 167). These are important strategical moves because they allow the history of the field to be written with one voice. The continuity of the history then extends into the continuity of the field—first, by creating a stabilized name for the field: green chemistry. Thus, past movements are brought into the green chemistry movement, and the history is adjusted at all times to reflect this. What should be noted here is that by 1998 and the publication of *GCTP*, enough momentum and solidity existed to begin a more drastic reappraisal of the past for the purposes of building a green chemistry community. First, I want to show how a solid definition of green chemistry emerged in the second half of the mid 1990s, which allowed for a more stable foundation for the movement.

Perhaps the first systematic attempt to define and capture the goals of green chemistry came in 1998 with the publishing of *GCTP* by Anastas and John Warner. *GCTP* offers the first sustained discussion of the green chemistry movement—what it is and is not and what it hopes to become. The book follows the same familiar pattern that I've discussed above repeatedly. Pulling together works from the previous years, the book established a standard historical narrative, a firm definition of green chemistry, and a set of goals for the movement—in addition to a set of principles to guide the movement, which will be discussed in greater detail in the next section. Here, then, are some of the ways in which the authors first attempt to describe the scope of green chemistry and its mission (pp. 8-10):

> "Green chemistry [...] is a particular type of pollution prevention. While there are other methods of achieving pollution prevention that are useful and necessary options, green chemistry is an approach that provides a fundamental methodology for changing the intrinsic nature of a chemical product or process so that it is inherently of less risk to human health and the environment."

"Green chemistry involves the design and redesign of chemical syntheses and chemical products to prevent pollution and thereby solve environmental problems."

"Green chemistry is the use of chemical principles and methodologies for source reduction, the most desirable form of pollution prevention."

"Green chemistry incorporates pollution prevention practices in the manufacturing of chemicals and promotes pollution prevention and industrial ecology."

"Green chemistry is a new way of looking at chemicals and their manufacturing processes to minimize any negative environmental effects."

"The goal of green chemistry, or benign chemistry, is to design synthetic methodologies that reduce or eliminate the use or generation of toxic feedstocks, by-products, solvents, and all other associated products."

The authors expand this list in the following chapter in which they explicitly work to set out a definition for green chemistry. In the first page of this chapter, green chemistry is defined in these ways: (p. 11):

> "Green chemistry, environmentally benign chemical synthesis, alternative synthetic pathways for pollution prevention, benign by design: these phrases all essentially describe the same concept."

> "Green Chemistry is the utilization of a set of principles that reduces or eliminates the use or generation of hazardous substances in the design, manufacture and application of chemical products."

> [Green chemistry] holds as its goal nothing less than perfection, while recognizing that all of the advances and innovations towards this goal will contain some discrete risk."

The statements assembled here offer insights into the constitution of the field. Green chemistry is a particular type of pollution prevention, but is different from other forms of pollution prevention. In particular, the authors assert that green chemistry ought to be viewed as a methodology focused on altering intrinsic properties of chemical products and processes. Thus, first and foremost, green chemistry is about altering the chemistry of molecules. This work, according to the second statement above, involves the purposeful design of the chemistry of products and processes. Through emphasis on products and processes, green chemistry attempts to eliminate not only the generation of hazardous chemicals, but also their use in the generation of products.

Green chemistry, then, incorporates the essence of a number of other methodologies into its own definition. The result is a green chemistry, bounded and guided by methodological principles, that works to prevent pollution through chemical design. According to the definition offered in *GCTP*, "Green Chemistry is the utilization of a set of principles that reduces or eliminates the use or generation of hazardous substances in the design, manufacture and application of chemical products," which places a substantial role on the development and adherence to these principles. And, since from this point forward this becomes the de facto definition of the field, the principles, too, come to play an important function in constituting the field.

It did not take long for the definition put forth in *GCTP* to take hold and provide an anchor for the field. A year later, when the Royal Society of Chemistry began publication of the journal *Green Chemistry*, the inaugural editor James Clark drew heavily from the mission established in *GCTP*. The founding of the journal, and the choices made for its name, purpose, and scope prove crucially important. As Clark's first editorial highlights, the issue of defining the movement was still clearly a question open for debate. This issue manifested itself during the debate over what to name the journal. Clark notes that: "The title *Green Chemistry* was itself the subject of considerable discussion and debate. We considered many alternatives, but none carried the same combination of widespread use and appreciation, as well as simplicity and impact" (1999a, p. G1). He also notes the importance of having green chemistry terminology already in circulation. "We are particularly indebted to colleagues in the United States who have been largely responsible for getting the terminology into common practice as well as for giving it credibility and value through initiatives such as the Presidential Green Chemistry Challenge Scheme" (1999a, p.

G1). But, perhaps most importantly was Clark's move in dealing with the purpose and scope of the journal. Here, Clark again defers to already established work. In defining the field of green chemistry and the scope of the journal, Clark quotes directly from Anastas and Warner: "The definition of Green Chemistry given by the individual who has done the most to promote it, Paul Anastas, and his co-author John Warner serves nicely to define the main objectives of this journal: *Green Chemistry is the utilisation of a set of principles that reduces or eliminates the use or generation of hazardous substances in the design, manufacture and application of chemical products*" (1999a, p. G1, emphasis in original). One definition had now been given sole domain over the green chemistry movement.

Following publication of the definition in both *GCTP* and *Green Chemistry*, the phrase quickly became ubiquitous in a variety of other publications (see Figure 1). However, this does not mean that the definition was free from challenges, modifications, and reinterpretations. Just a year later, once again on the editorial pages of *Green Chemistry*, the guest editor Roger Sheldon offered a retrospective of the journal's first year in print. Two important elements crop up in this note. First, Sheldon offers a slightly modified definition of green chemistry, breaking ranks from the rote recitation that most others follow in their publications. Sheldon states: "Although it is not easy to succinctly describe what green chemistry encompasses, the following is a reasonable working definition: *Green chemistry efficiently utilises (preferably renewable) raw materials, eliminates waste and avoids the use of toxic and/or hazardous reagents and solvents in the manufacture and application of chemical products*" (Roger Sheldon 2000, p. G1). Much of the same is there, but it is an important move that he does not offer the same word for word definition that so many others do. This simple act has the potential to reopen discussion of what counts as green chemistry. Second, Sheldon hints at a year of debates about the applicability of the name green chemistry as an accurate summary of activities and ideas. There are other candidates available. For instance, why is green chemistry not simply "sustainability" or "sustainable development"? And why would some prefer these latter terms to green chemistry? Sheldon examines this issue: "Industry appears to prefer the terms *sustainability* or *sustainable development*, defined as development that meets the needs of the present, without compromising the ability of future generations to meet their needs. The word 'green' apparently has too many political associations in many countries. This is a pity because green chemistry is probably more meaningful to the general public. Moreover, perhaps the two terms are not mutually exclusive: sustainability is the goal and green chemistry is the means to achieve it" (2000, p. G1).

Green chemistry, then, still needs to define what it is, but increasingly it must define what it is in relation to a host of other terms, which often get paired with it: benign by design;[6] environmentally benign chemistry; pollution prevention;[7] industrial ecology;[8] clean chemistry;[9] sustainability and sustainable development;[10] life cycle

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[6] See, for example, Warner et al. (2004).

[7] See, for example, Anastas and Kirchoff (2003), Tickener et al. (2005), Warner (2004) and Williamson and Anastas (1999).

[8] See, for example, Anastas and Lankey (2000), Breen (1999), and Graedel (1999).

[9] See, for example, Prado (2003) and Wardencki et al. (2005).

[10] See, for example, Anastas (2003), Kirchoff (2005), Mestres (2005), and Thornton (2001).

analysis;[11] and simply the word 'green'. Many of these terms and their baggage were dealt with early on in the movement, as we've already seen, by simply incorporating them into green chemistry. Others were written out as explicitly not green chemistry. For example, Anastas and Tracy Williamson draw a line between pollution prevention techniques that are green chemistry and those that are not:

> "There have been innovative chemistries developed to treat chemical wastes and remediate hazardous waste sites. New monitoring and analytical tools have been developed for detecting contamination in air, water and soils. New handling procedures and contaminant technologies have been developed to minimize exposure. While these areas are laudable efforts in the reduction of risk, they are not pollution prevention or Green Chemistry, but rather are approaches to pollutant control. Many different ways to accomplish pollution prevention have been demonstrated and include engineering solutions, inventory control and "housekeeping" changes. Approaches such as these are necessary and have been successful in preventing pollution, but they also are not Green Chemistry. There is excellent chemistry that is not pollution prevention and there are pollution prevention technologies that are not chemistry. Green Chemistry is using chemistry for pollution prevention" (1996, pp. 2-3).

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[11] See for example Anastas and Lankey 2000 and Lankey and Anastas 2002 on the connections between industrial ecology, life cycle analysis, and green chemistry. As is discussed below, this latter article explicitly connects these three terms with the broader project of "sustainability."

In the 1990s, a number of competing movements were also vying for space. These movements, such as industrial ecology and sustainable development, had their own politics, and in many cases succeeded in garnering far more attention than did green chemistry, especially outside of the chemical community. Also, as Sheldon hinted in his editorial, many groups within industry appeared leery of a movement with the word ‘green’ in its name. After all, the Chemical Manufacturers of America (now the American Chemistry Council) had already developed the “Responsible Care” program as a way of addressing the environmental and human health consequences of the chemical industries. At the same time, the term “sustainable development” was gaining increased attention, especially in the wake of the Brundtland Report, *Our Common Future* (Brundtland 1987). It became increasingly important, then, to begin associating green chemistry with “sustainability” as much and as often as possible. Beginning around 1999, a number of green chemistry publications began to draw these connections.[12] In 2002, an Article by Rebecca Lankey and Anastas addressed this issue explicitly by connecting green chemistry to sustainability in a way that is in line with Sheldon’s earlier comments: sustainability is the goal, and green chemistry is the means for getting there. Anastas and Lankey put it this way:

> “In the past decade, there have been numerous publications describing the principles of sustainability and characteristics of sustainable systems. However, there is no one definitive method for implementing and applying these ideas to

[12] See, for example: Andrews (1999), Glaze (2000), Mulholland, et al. (2000); Rasten (2000), Warner (1999; 2000), and Williamson (1999). See Table 3.2.

current industrial and economic activities. A variety of qualitative or semi-quantitative tools and concepts have become popularized, such as cleaner production, eco-efficiency, full-cost accounting, green chemistry and engineering (GC&E), industrial ecology, life-cycle assessment (LCA), the Natural Step, pollution prevention, triple bottom line, and others" (2002, p. 4498, see figure 1).

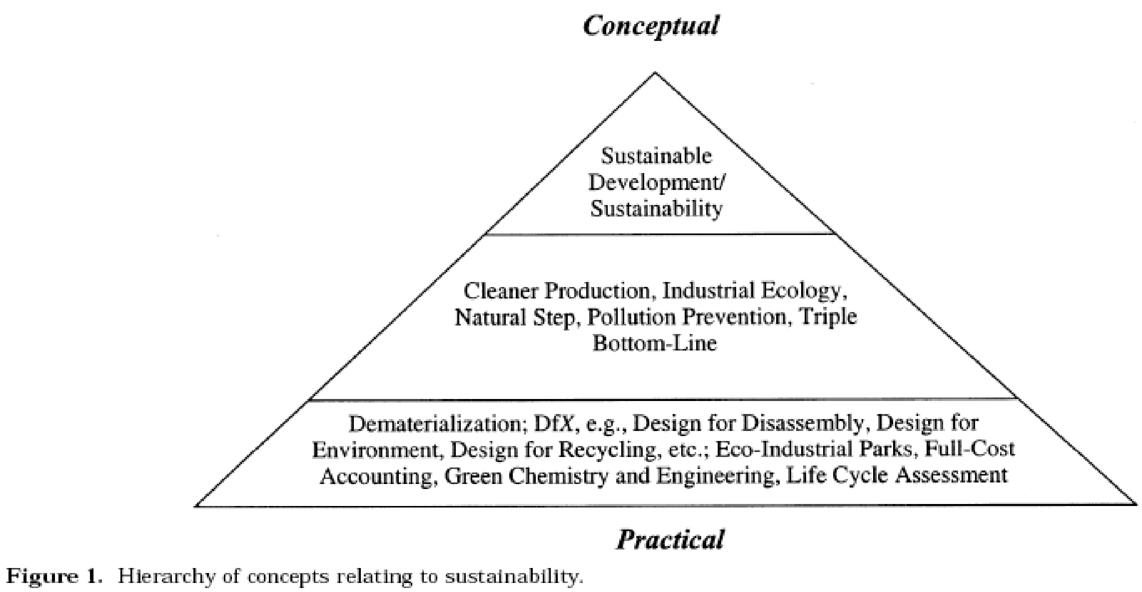

Figure 3: The conceptual pyramid drawing together the concepts of industrial ecology, life cycle analysis, green chemistry, and sustainability. Taken from Lankey and Anastas (2002, p. 4499).

However, this attempt to link different concepts was not a universal project. Some resisted the linking of green chemistry to sustainability. Take for instance the comments made in a *Green Chemistry* guest editorial in 1999. Here, Ian Brindle states his concerns over the potential loss of green chemistry within the broader, more general (and perhaps misleading) concept of sustainability:

> "A little over a year ago, the Organization for Economic Co-operation and Development (OECD) held a workshop in Venice on 'Sustainable Chemistry'. Problems arose from the difficulties that the delegates had trying to incorporate the perspective of the Brundtland Report on sustainability into the already established notion of green chemistry. The idea of sustainable chemistry creates a new set of problems. Green chemistry, in my view, remains a better descriptor than sustainable chemistry. Extraction of non-renewable resources is, by its nature, not sustainable and so the notion of doing sustainable things with an unsustainable end sounds perverse" (Brindle 1999, p. G156).

In a number of ways, Brindle's comments echo deeper concerns that many people have with terms such as sustainable development.[13] But in the context of community building and identity construction for green chemistry, the concern takes on added dimensions. Will green chemistry be lost within sustainability? There are other concerns, too, like those addressed in Sheldon's comments discussed earlier. Industry favors the term sustainable development. Chemists, like Brindle, are concerned with the adoption of such ideas. Who, then, ought to decide how green chemistry identifies itself? Who is in the green chemistry movement, and who is being written out of it?

Despite these attempts to give a concise definition for green chemistry, the authors acknowledge that scientific fields are defined first and foremost by their

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[13] See for instance Hudson (2005), Luke (2005), and Redclift (2005).

work. Anastas and Warner note that: "the true definition of a subdiscipline or an area of investigation comes from the research and the accomplishments that are conducted therein. It is this organically grown definition that not only answers the question 'What is green chemistry?', but also provides the scope and range for green chemistry so that we can view where green chemistry can and will go in the future" (p. 29). As a way, then, of encapsulating the work already done that proponents of green chemistry wish to have incorporated into the field and as a way of guiding future research that will count as green chemistry, Anastas and Warner put forward in *GCTP* twelve principles that when working in combination with their definition of green chemistry simultaneously shape and define the field.

Discipline and Publish, Part II: The Twelve Principles of Green Chemistry

As I pointed out in the previous section, debates over both the name and definition of what is widely recognized as the green chemistry movement have been important and extended. Proponents of green chemistry continued to envelop previous work and deal with the emergence of new organizations that might be similar in character, scope, or purpose, while at the same time trying to maintain a rigid boundary for the constitution of their own field. By 1998 and the publication of *GCTP*, a relatively stable definition has emerged, a definition that gets repeated almost verbatim and to the exclusion of contrary definitions. But, as the authors note, publishing a definition is one thing; making practices a part of that definition another. In the case of *GCTP*, then, the authors also outline a set of twelve principles that are to serve 1) as a summary of work that has already been done, and 2) as a guide to the direction in which green chemistry will go in the future. By outlining the practices that will come to characterize the green chemistry movement in this way, the authors have at once claimed a large space of work that may not have been recognized as green chemistry in the past but will be now and, at the same time, have created a boundary within which green chemistry can grow. This boundary functions by both protecting the field and also placing certain constraints on the work that can/ought to be done under the auspices of green chemistry. The authors describe the principles as providing a "framework for thinking" about green chemistry. But by providing a "framework for thinking," the principles have already entered into their disciplining role—including and excluding work with respect to the field of green chemistry.[14]

The twelve principles listed in figure 4 set out methodological guidelines for designing chemical products and processes for pollution prevention. They outline a number of general considerations, as well as specific areas where new work could

[14] See Schön and Rein (1995) for a discussion of the construction of frameworks through metaphors and the ways in which these frameworks create conflict due to their thought-limiting roles. As the authors argue, because linguistic frames guide so much of our thinking, re-constructing a linguistic framework opens new possibilities in approaches to problems and their solutions. The authors include here a number of examples from political stalemates that were broken through these types of interventions. The work presented here is also similar to that of George Lakoff and Mark Johnson and their discussions of the role of metaphors in linking cognitive and physical experiences of the world (1980; 1999). Lakoff, too, has taken these lessons into the political realm lately. He argues that the structuring of political debates by conservatives creates a linguistic frame within which liberals have become stuck. The only way out of this situation, Lakoff claims, is to re-structure the frame of the debate. See, for example, his (2002). The understanding, then, of how these frameworks operate present yet another critical point for intervention in the re-construction of the green chemistry community.

potentially have great benefits to the prevention of the use or generation of hazardous chemicals.

1. It is better to prevent waste than to treat or clean up waste after it is formed.
2. Synthetic methods should be designed to maximize the incorporation of all materials used in the process into the final product.
3. Wherever practicable, synthetic methodologies should be designed to use and generate substances that possess little or no toxicity to human health and the environment.
4. Chemical products should be designed to preserve efficacy of function while reducing toxicity.
5. The use of auxiliary substances (e.g. solvents, separation agents, etc.) should be made unnecessary wherever possible and, innocuous when used.
6. Energy requirements should be recognized for their environmental and economic impacts and should be minimized. Synthetic methods should be conducted at ambient temperature and pressure.
7. A raw material feedstock should be renewable rather than depleting wherever technically and economically practicable.
8. Unnecessary derivatization (blocking group, protection/deprotection, temporary modification of physical/chemical processes) should be avoided whenever possible.
9. Catalytic reagents (as selective as possible) are superior to stoichiometric reagents.
10. Chemical products should be designed so that at the end of their function they do not persist in the environment and break down into innocuous degradation products.
11. Analytical methodologies need to be further developed to allow for real-time, in process monitoring and control prior to the formation of hazardous substances.
12. Substances and the form of a substance used in a chemical process should be chosen so as to minimize the potential for chemical accidents, including releases, explosions, and fires.

Figure 4: The Twelve Principles of Green Chemistry. See Anastas and Warner (1998, p. 30).

The Twelve Principles of Green Chemistry act to construct a boundary. The principles offer markers for those working in the field and outside of it—and help to inform others on which side of the divide they fall. The principles denote standard practices, methods, and goals. But they also clearly separate green chemistry from other types of pollution prevention. The principles work by creating a space for the practice of green chemistry and also defining and setting those practices.

The principles provide an answer to the question, "what is green chemistry?" The authors use the principles to both draw attention to previous work that counts as green chemistry and simultaneously mark out territory for future work. The answer to the question, then, is one rooted in what has already been done, and what ought to be done in the future. The authors put it this way:

> "The listing of the 'Twelve Principles of Green Chemistry' should be viewed as a reflection of the science that has been done within this nascent field in the recent past, as well as a direction that has been set by some of the pioneering scientists who have laid the groundwork for the future" (1998, p. 29).

One can think of the writing of the twelve principles, then, in the same way one thinks of the creation of the Periodic Table. The table displays two important functions, which have led to its continued utility: it both 'accommodates' previous information while 'predicting' what future work will uncover.[15] But to only focus on

[15] The Periodic Table is of course a very popular topic for scholars of chemistry. The Periodic Table has withstood the tests of time to a far greater extent that previous tables; See Cohen (2004) for a comparative discussion of chemical tables.

these two aspects of the table is to miss a far greater role of the table. The table also functions as a didactic tool. It guides research towards its openings, towards the holes left in it when all current information was successfully assimilated/accommodated. Its ability to 'predict' is strengthened—and made possible—by its ability to steer research.[16] The table instructs through disciplining its users.

The twelve principles also have a didactic function that is nicely illustrated by the structure and organization of the 2004 Gordon Research Conference and the 2004 Green Chemistry Summer School. The conference, which extended from Sunday evening until Thursday evening, consisted of thirteen separate sessions. The first session, "Overview," served as an introduction to the conference. The other twelve sessions were dedicated thematically to one of the twelve principles of green chemistry: "Prevention," "Atom Economy," Less Hazardous Synthesis," "Safer Chemicals," "Solvents and Auxiliaries," "Energy," "Renewable Feedstocks," "Reduce Derivatives," "Catalysis," "Degradation," "Analysis," and finally "Accident Prevention."[17]

One month later, at the American Chemical Society sponsored Green Chemistry Summer School, the twelve principles were deployed again to structure and discipline

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[16] For discussion of the didactic nature of the period table (within the context of other chemical tables), see Cohen (2004). Beyond this specific role of the table, Ursula Klein speaks more generally of chemical tables as "paper tools" for use in research. For more on this concept and a discussion of how these paper tools fit within the chemical laboratory, see her (2003, 2001a; 2001b; 1999).

[17] The program for the conference can be found at: http://www.grc.org/programs/2004/green.htm.

topics and discussion, although less obviously than at the GRC. The conference started with a presentation by Paul Anastas on the "Principles of Green Chemistry."[18] Like the books and articles authored by Anastas, the presentation set the stage for the unveiling of the principles. First came the overview of chemistry in the twentieth century: longer life span, greater food production, material advances. Next came the overview of approaches to dealing with environmental issues: waste treatment, emissions standards, 'command and control', and finally the increasing cost of regulation. Here, we have the emergence of green chemistry, its definition—"green chemistry is the design of chemical products and processes that reduce or eliminate the use and/or generation of hazardous substances"—and its principles. However, before going into detail on the twelve principles, Anastas offered this caveat: the principles are not meant to be taken as "commandments," or "rules" or anything else of the sort; instead, the principles ought to be treated as "guidelines" or a "framework for thinking." Indeed, this is precisely what they are, a framework for thinking. They are a tool—similar to the periodic table—for the 'proper' practice of green chemistry. The principles not only offer "guidelines" but also construct boundaries around what properly counts as green chemistry. If a chemical product or

[18] For more discussion on this presentation, see the section of the Summer School in Chapter 4 below. The slides from the presentation can be found at: http://www.chemistry.org/portal/a/c/s/1/acsdisplay.html?DOC=greenchemistryinstitute\summer_school\2004gcsummer.html.

processes cannot be adequately described using the principles, it simply isn't green chemistry. It doesn't mean it's 'bad' chemistry—it just isn't green.[19]

I focus here on the principles because of the tremendous effect they have on the field of green chemistry. The principles are important in that they offer an organizing principle. They help to bind a community together that otherwise has little or nothing in common. To demonstrate the vast diversity available within this field, it is enough to take note of the number of individuals who come and go, where they come from, and what each brings to, and takes away from, these conferences, workshops, symposia, etc. The principles offer a focal point. They are something that everyone can come back to on a regular basis. They are easily remembered, posted, translated, recited, etc. And, perhaps most importantly, they are worded in such a way as to be as politically neutral as possible. The principles effectively place the emphasis on the technical aspects of the chemical enterprise. Applying these

[19] Interestingly, in the front pages of *Green Chemistry* (the journal), Neil Winterton wrote in December of 2001 a short piece entitled, "Twelve More Principles of Green Chemistry." Here, Winterton attempted to capitalize on the success of the previous principles and to expand on these 'guidelines' by adding another dozen principles outlining how chemists might measure the "greenness" of their practices. A citation search of Winterton's comments piece, however, quickly shows that it has failed to have any real effect, at least none as significant as the original publication of the principles. More recently, a group of researchers has attempted to rewrite the principles to make them easier to teach to non-native English speakers and audiences outside of the chemical sciences. In this model, the authors develop the mnemonic PRODUCTIVELY to explain the twelve principles. However, to do this, the principles have has to undergo a rearrangement in both wording and order (see Tang, et al 2005). One of the more successful re-uses of the twelve principles idea has been the creation of the Twelve Principles of Green Engineering by Anastas and Julie Zimmerman (see Anastas and Zimmerman 2003).

principles to past and present predicaments recasts these issues, too, in a technical light. Thus we have can take an incident such as the one at Bhopal and rethink the conversation. Rather than debating issues of responsibility (legal and/or moral), or safety measures in place within and around the plant, or the broader socio-economics of having a plant like that one located in that place (and the one in Institute, WV for that matter), the discussion turns to the application of the twelve principles. It becomes an instructional tool. Ask students, "How could we apply the twelve principle to a situation like this one?" While helpful for creating an "inherently safer" chemical plant, the broader social, political, economic, and ethical issues simply disappear within this context. In making some dimensions disappear, the principles have the added function of connecting disparate places, gliding smoothly across places of practice: they fit just as easily in academic laboratories as they do in industrial ones or governmental agencies.

In spite of the reassurances from Anastas, the principles *do* provide something more solid than something like "guidelines" for the practice of green chemistry. The specific dangers to a field like green chemistry manifest themselves in three ways. First, the boundary constructed by the principles acknowledges the work of some individuals/groups/disciplines while it excludes other potential contributors. The arbitrary or premature drawing of this boundary potentially stifles important and innovative contributions to the field. As Anastas points out in his presentation to the summer school, green chemists must think of 'chemistry' in the dictionary, not the academic, sense. Thus, the emphasis on the principles potentially threatens the interdisciplinarity of the green chemistry enterprise. The boundary constructed by use of the twelve principles may not be permeable enough to allow green chemistry to remain flexibly open to an expansion of its interdisciplinary efforts.

Second, the principles define the green chemical enterprise in terms of technical challenges to be overcome through technical innovation. Yet, as the presentations at the GRC and the Summer School themselves admit, the practice of green chemistry is inseparable from a much broader context of economics, politics/policy, and understandings of public sentiments towards the chemical sciences, etc. Again, the principles stifle interdisciplinary contributions by defining green chemistry in terms of technical problems with technical solutions. Take for instance the following example: Ned Woodhouse, a political scientist and science studies scholar from Rensselaer Polytechnic Institute, is periodically engaged with the green chemistry community. He has helped to organize an international conference, testified before the House Science Committee in support of a funding measure for green chemistry research, and has recently published two pieces that examine green chemistry as a social movement within the broader chemical sciences.[20] Woodhouse, especially in his testimony before the House Science committee, places green chemistry and the chemical sciences into a broader context that examines not only technical constraints to the implementation of green chemistry, but also the socio-political climate within which these technical operations take place. In his testimony, Woodhouse stresses the need for a sustained campaign on behalf of green chemistry—to the government, the public, and chemists. I argue that Woodhouse's efforts fit well within the definition offered by the green chemistry community that defines their

[20] See his (2003; 2004) and, with Breyman, (2005).

work: it is the *purposeful design* of chemical products and processes that reduce or eliminate the *use and/or generation* of *hazardous* substances. Yet, by focusing on the twelve principles alone as a way of describing/defining the practices of green chemistry, the efforts of someone like Woodhouse to address and overcome the social and political obstacles facing green chemistry get excluded because they emphasize something other than the technical. The exclusion of this type of work certainly comes at the detriment of the green chemistry movement.

Third, the principles act through their boundary making and boundary policing to concretize a field that seeks not to become permanent, but to transform what already exists. In personal communications with two core proponents of the field, I heard this same line: if we're still talking about green chemistry in 20 years then we've failed. Failed because green chemistry would still be on the outside, something else, a different way of doing things, but not *the* way of practicing chemistry. The principles alone are not responsible for this concretization, this making of green chemistry permanent, but they do play a significant role. While in a benign way, the principles offer some measure of the 'greenness' of a product or process, taken to their more generalized use, the principles define what does or does not count as green chemistry. It fails to speak to all other chemical practices, therefore leaving them perfectly intact. Becoming green is voluntary, but also exclusive, a strategy that can easily backfire.

Thus, the principles of Green Chemistry play an ambiguous role in the green chemistry community. Importantly, they help to draw together disparate people/groups/disciplines that have something at stake in the green chemistry movement. However, this solidity comes at a price. First, as a didactic tool, the principles constrain and discipline their users to think about green chemistry within a certain, preordained framework. This is especially troubling in the context of a Summer School. Rather than playing off of the innovation and creativity of the 'next generation' of green chemists, the participants are indoctrinated into the system that the principles lay out almost immediately after arriving. The principles are also exclusionary, eliminating the participation of many through the strict technical focus of the principles. And finally, adherence and exaltation of the principles leads to unnecessary—and potentially dangerous—solidification of green chemistry as something other than chemistry in its broader sense.

Divide and Conquer: Taking Green Chemistry to the Masses

In this section, I highlight some ways in which proponents of green chemistry have reached out to other research areas to garner support and incorporate already existing work into their own as a final move in disciplining green chemistry into existence, and to gain and secure a space for itself. To accomplish this, advocates of green chemistry emphasize its confirmed successes,[21] while at the same time they try

[21] At the Ninth Annual Green Chemistry and Engineering Conference held this past June in Washington DC, a number of sessions were explicitly devoted to the topic "success stories." Interestingly, in the session on the politics of green chemistry organized by Ned Woodhouse, a number of people in the audience commented that they were excited to finally be discussing potential problems of the field rather than sitting through another session that only celebrated successes. It would seem that some of the newer and younger people in attending the conference are afraid that so much emphasis on the 'successes' of the field may be

to convince others outside of the field that they're already doing green chemistry. Proponents of green chemistry make their work fit *everything*. No one is outside because no one actually *wants* to do harm—to human health, to the environment. And yet, proponents of the field keep arguing for green chemistry to be included because it remains a fringe movement. Green chemistry suffers from some lingering legitimacy issues that are related to its association with all things 'environmental', its 'green' name, and issues of who does and does not actually practice green chemistry. Overcoming these legitimacy issues proves difficult and so proponents of green chemistry employ a number of strategies, including attempts to enroll others from a broader swath of field into the practice of green chemistry.

Proponents of green chemistry employ three main strategies for expanding the field. In the first, proponents of green chemistry tell the story of green chemistry in such a way that the field already includes all of the sub-fields of the chemical enterprise. Green chemistry, then, comes to incorporate the tools of organic, analytical, and inorganic chemistry, plus those of biochemistry, catalysis, and the like into its own identity. The move made works in dual directions: green chemistry draws from each of these fields while simultaneously arguing for it applicability to them as well. This move is exemplified by the following passage from the introduction to *Green Chemistry: Frontiers in Benign Chemical Syntheses and Processes*, where the authors state:

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distracted attention away from some of the more important problems that need to be addressed if the field is going to grow.

> The evaluation and elucidation of the various environmental problems that have occurred in the last several decades relied primarily on the work of analytical, physical, computational, and theoretical chemists conducting studies on atmospheric, aquatic, and terrestrial systems. Green Chemistry not only requires the talents of these subdisciplines of chemistry but also requires the subdisciplines of synthesis, organic and inorganic, catalysis, biochemistry, and materials science. Therefore, green Chemistry [sic] is *applicable to all areas of chemistry*. Green Chemistry is also applicable to all sectors of the chemical industry ranging from pharmaceuticals and specialty chemicals to the high volume manufacture of bulk chemicals. […]
>
> Advances have been made by both academia and industry in Green Chemistry research in the areas of synthetic organic chemistry, biochemistry, polymer chemistry, and materials science. Catalysis, including design, synthesis, and utilization, computational chemistry, and process modeling, are other areas in which Green Chemistry research is being conducted (Anastas and Williamson 1998a, p. 11).

Here, then, we see proponents of green chemistry fighting not to become a specialty unto themselves. Rather, they argue that they draw from all fields of chemistry and can also be applied back to all areas of chemistry. Green chemistry is not a new sub-field, but rather a new way of doing chemistry in general.

Besides making the more general argument that green chemistry is found in and can be applied to all sub-fields of chemistry, proponents also make more targeted pleas for the inclusion of green chemistry within a field. One place this is evident is in specific articles written for publication within a particular sub-field's journal that argues for the necessary inclusion of green chemistry. Anastas, writing an article for *Critical Reviews in Analytical Chemistry* (1999), repeats the same story that he and Williamson tell above in their introduction to the *Green Chemistry* volume,[22] but this time he continues by focusing on the indispensability of analytical chemistry in the mission of green chemistry.

Beyond reaching out to other subfields of the chemistry community, proponents of green chemistry also attempt to affiliate the movement with other groups. In an article by a group of authors for the magazine *Science*, it is argued that green chemistry is an important ally of both the Responsible Care® program of the American Chemistry Council, and to the "sustainable development" movement.[23] And these are not the only links. There are also those linking industrial ecology (noted earlier). Most substantial as of late have been the attempted links between green chemistry and "sustainability" issues, evidenced perhaps most recently by the incorporation of green chemistry into the "Symposium on Sustainability" at the American Chemical Society meeting of August 2005.[24]

All of these attempts at reaching out, incorporating the work from other fields, arguing for the inclusion of green chemistry into those same fields, and the attempts to link green chemistry to movements like industrial ecology and "sustainability" all involve boundary negotiations. They are attempts to create, maintain, and defend the

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[22] The quote is a word for word repeat from this previous volume. See (1999, p. 170).

[23] See Poliakoff, et al (2002, p.807).

[24] See also Lankey and Anastas (2002, p. xi).

identity of green chemistry while also protecting/expanding the space in which it does its work. Evidence that green chemistry has been attempting to renegotiate the boundaries it has with its neighbors comes not only from the written word demonstrated here, but also from the tremendous expansion in the number and types of conferences with sessions that are identified as devoted to green chemistry. Indeed, what 'counts' as a green chemistry conference, presentation, or symposium has broadened substantially to include conferences within a number of different disciplines devoted to a variety of different topics. The Green Chemistry Institute keeps a listing of these conferences on its website.[25] The conferences listed in the first few years include only the Gordon Research Conferences and eventually the Annual Green Chemistry and Engineering Conference. However, by 2004, there are more than 25 such events. No, these are not all explicitly 'green chemistry' events. Rather, many of them are conferences, workshops, or other events that either 1) incorporate some elements of green chemistry—session, keynote, etc, or 2) are a group that green chemistry is/could be affiliated with, such as Responsible Care®. Thus, the reach of green chemistry into other fields has grown. But, what has this done to the identity of the green chemistry community? Is the community any more unified now than it was, say, 10 years ago? Ultimately, what has been the effect of this boundary work?

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[25] See http://www.chemistry.org/portal/a/c/s/1/acsdisplay.html?DOC=greenchemistryinstitute\conferences.html for a listing of these conferences by year. Or, for a full listing of these events, which demonstrates the tremendous growth of the field, see Appendix A at the back of this dissertation.

Maintaining Identity in Heterogeneous Ooze

The creation of a green chemistry community involves the creation, destruction, and maintenance of boundaries. These boundaries serve to create a space for something called green chemistry by separating it out from other competing socio-scientific fields. Above, I explored several strategies used to create and maintain this intellectual space. In Proponents of green chemistry had to come to some agreement on how exactly green chemistry ought to be defined, and whether or not the term itself acted as an accurate descriptor of the goals of the movement and the practices undertaken within the field. *GCTP* provided a manifesto for proponents of green chemistry, which was reinforced a year later when the Royal Society of Chemistry began publishing *Green Chemistry*. This partial closure of the definition of green chemistry provided the support needed to begin establishing firm boundaries within, around, and between other socio-scientific fields.

At the same time that discussion of a definition for green chemistry was reaching some form of consensus, a set of principles designed to guide the practice of green chemistry was also emerging. Arguably the most important—and most influential—aspect of *GCTP* was the creation of the twelve principles of green chemistry. The principles serve a dual function. Outside of the boundary that they help to construct and maintain, they say to others: "this is what green chemists do." That is, they help to define and clarify a boundary between what is green chemistry and what is not green chemistry. At the same time, the principles speak to those inside of the boundary, those that already identify themselves as green chemists, reminding them: “this is what green chemists do.” That is, the principles work to discipline those within the boundaries reminding them where their efforts are expected to go and how to identify others potentially aligned with the field. The combination, then, of definition and principles provides a certain space within which to do green chemistry by providing an intellectual—if not material or physical—home for those that call themselves green chemists.

Unified and protected within their own boundaries, proponents of green chemistry are able to begin working on others ‘outside’ of the field to reconstruct the boundaries that separate them from others working in potentially allied fields. Work within specific research fields is targeted for inclusion within the territory of green chemistry. Socio-scientific movements that could be seen as competitors by some get incorporated into the mission of green chemistry. The boundaries, then, that encompass and define green chemistry are flexible and subject to renegotiation at any time. But why don’t the boundaries always hold? Especially within a community like green chemistry, the heterogeneous elements that comprise the field create an enormous amount of strain on the defining boundaries. Nevertheless, the field does function, at most times, as a unified whole.

There is also the matter of self-selection here to contend with as the green chemistry community attempts to recruit, and ultimately retain, ‘green chemists’ for its movement. Despite the missionary activities of the proponents of green chemistry, I’m left wondering how successful these recruitments have been. One measure of the solidity of the field, and the success of its recruitments is offered in the data on the Gordon Research Conferences. There are two reasons why this serves as an important indicator of the community. First, the GRCs traditionally function by bringing together the leaders in a field for a one week conference in which participants are asked to give open and honest assessments of the field—where it is and where it ought to be going. To help ensure this atmosphere, participants are asked not to discuss the technical information presented during the course of the conference with non-participants after the conference. Thus, GRCs are important agenda setting functions, which require the leaders of the field to be present and to decide on priorities, courses of action, and promising directions of research. Additionally, in this specific case, the conferences serves as an important marker of the development of the field because the establishment of a green chemistry GRC can be traced back to the early and formative days of the field—1996 when things were really just getting started.

Given the importance of these meetings, then, one might expect to find a core group of individuals attending these meetings. And, given the tremendous recruitment efforts of the field over the last decade, one would expect that these numbers would have steadily grown since that first meeting. However, when I analyzed the GRC records for green chemistry, I noticed that there is little, if any, continuity in the attendance of these meetings. A few quick statistics help to demonstrate this: the total number people attending the GRCs has increased from 85 in 1996 to 121 in 2004; over the course of the 7 meetings 557 different people have attended the meetings; on average each person attends only 1.27 meetings; only 16 people have attended more than 3 meetings—i.e., the majority of meetings; only 5 have attended more than 4; only 2 have attended more than 5; no one has attended all of them.[26] This lack of consistency and continuity at the conference meant to guide the field indicates that the community continues to struggle with its identity. This affects the ways in which green chemists are able to construct and practice their work.

What exactly are green chemists doing, and being trained to do? And what role does this play in the construction and reinforcement of the identity of the green chemist as constructed through the means discussed in these last two chapters education, technocracy, and expertise, as well as the general disinterest displayed for issues outside of the techno-scientific sphere—i.e., the political, social, and ethical issues. This will be the topic of the coming chapter.

[26] Interestingly, even James Clark the first editor of *Green Chemistry*, hasn't attended a meeting since 1999.

Chapter 4: Green Chemistry in Practice

In this chapter, I explore how the work of identity construction presented in the previous chapters becomes manifest in the projects and activities of green chemists, i.e., in the *practice* of green chemistry. Drawing on the ideas of Joseph Rouse, I'll show how the practices constructed by the green chemistry community fit within the framework of ecological modernization. Practicing green chemistry, while rethinking some aspects of more traditional chemical practices, does not involve any sort of sustained critique of the broader systems out of which the current practices have emerged. The claim, then, that green chemistry is "revolutionary" in its approach appears to overstate the case.

Here, I follow the practices of green chemistry into two areas. In the first, I look at the ways in which green chemists define the problems to be engaged, as well as the solutions offered to these problems. I argue that green chemists frame these issues strictly within the realm of technical expertise, i.e., breakdowns of the techno-scientific systems requiring a techno-scientific fix. Examples have already been discussed, for example in chapter 2 in the discussion of the gas leak in Bhopal, but here I emphasize that the result of this problem-solution framing is a narrow tailoring of the issues being dealt with to the exclusion of other perspectives, which places (green) chemists in the position of being the only qualified people to address the problem(s).

In the second instance, I show how this rhetoric moves into the classroom for the education of the first generation of explicitly trained green chemists. Drawing on my experiences at the Green Chemistry Summer School in 2004, I show how the framing of green chemistry created through the history discussed in chapter 2, the twelve principles discussed in chapter 3, and the techno-scientific perspective taken to issues of 'pollution prevention' become manifest in the instruction of 'right practice' for the students. Because these creations of the green chemistry community fail to take into account the full complexity of the systems with which they are dealing, the use of these tools in a pedagogical context serves to reinforce the same problematic structures that gave rise to these issues in the first place.

Defining Problems and Solutions

In 1990, Congress passed the "Pollution Prevention Act of 1990" mandating new approaches for dealing with pollution, which led to the eventual establishment of the green chemistry program within the U.S. EPA. The Act issued new priorities in dealing with hazardous wastes and pollution placing prevention at the top, followed by more traditional forms of management including recycling, treatment, and disposal.[1] As a response to this reprioritization, the EPA began its Green Chemistry Program. Initially conceived, green chemistry was created as a tool for the purpose of fixing the greater pollution problem facing the United States, and the world more generally. But

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[1] "The Congress hereby declares it to be the national policy of the United States that pollution should be prevented or reduced at the source whenever feasible; pollution that cannot be prevented should be recycled in an environmentally safe manner, whenever feasible; pollution that cannot be prevented or recycled should be treated in an environmentally safe manner whenever feasible; and disposal or other release into the environment should be employed only as a last resort and should be conducted in an environmentally safe manner."

deciding what exactly needed to be fixed and how that would happen was still unknown.

By 1998, with the publication of *GCTP* and a volume of collected papers, *Frontiers in Green Chemistry*, both the problem and the pathway toward a solution had been articulated with increased specificity. The introduction to the latter begins with a simple "statement of facts":

1. Chemistry and chemical products are the basis of the economy of virtually every industrialized nation.
2. The manufacture, processing, use, and disposal of certain chemical substances has [sic] resulted in significant and measurable damage to human health and the environment.
3. Over the past generation, more than a trillion dollars has been spent on environmental protection.
4. Currently, chemists now have the knowledge to design chemicals and chemical manufacturing processes that pose little or no risk to human health and the environment.
5. Research in 'green chemistry' is making dramatic achievements in the design of chemicals, chemical syntheses, and chemical processes that are environmentally benign and economically feasible (Anastas and Williamson 1998a, p. 1)

This "statement of facts" represents what we have already seen in the previous chapters, i.e., how the history plays out to place green chemistry in a unique position to solve these problems: chemicals can cause serious damage to humans and non-humans; however, chemicals form the basis of our economy; and chemicals cost a fortune to regulate; therefore, 'green chemistry' is needed to allow the chemical sciences to continue to act as the basis of our economy while making their products and processes safer while and removing the need for costly regulation. This neat encapsulation of 'facts' then folds the history of the field and the constitution of the community into a concise statement of the problem. This clarification of the problem paralleled that year's clarification of the solution. Moving from possible areas of research discussed in earlier volumes, *GCTP* went further, instituting the "Twelve Principles of Green Chemistry." The principles, as discussed in the previous chapter, were created to both reflect and guide the practice of green chemistry. Thus, the solution comes in the form of a number of technical fixes geared towards chemists working in both academic and industrial settings. And the twelve principles, in addition to their disciplining role, are also an easy "how to" outline for solving the problems articulated in the 'statement of facts' presented in *Frontiers*. More specifically, perhaps, the principles offer a way to maneuver around the issue of the "triple bottom line" currently in vogue, adeptly maneuvering between the interrelated concepts of "economic growth," "environmental protection," and "social responsibility."[2]

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[2] The triple bottom line rethinks the *economic* bottom line by placing it alongside issues of *environment* and *society* and is commonly used when businesses, in this case chemical businesses, discuss their commitment to 'sustainability', normally defined in the terms of the "Brundtland Report," published as *Our Common Future* (Brundtland 1987).

But, why should anyone bother to change? Many of these ideas are common sense, right? Don't use more than you have to use. If you can use something that's safe in the place of something hazardous, do so. There needs to be a solid reason (besides common sense, it seems) to make these changes. As we've already heard, the twentieth century is fraught with problems associated with chemical practices. However, since the authors of *GCTP* resist a moral argument,[3] they provide themselves with another leg to stand on for making their case: economics—trying to create the "win-win" situation paradigmatic of ecological modernization.[4] Regulations, which have been increasing at an exponential rate (see figure 4.1), cost the chemical industry (and chemistry departments) beau-coup bucks. Thus, we're told, "one of the true victims of the costs of using and generating hazardous

[3] "This book is not a moral judgment on chemistry but it does elucidate the obligations that chemists, as scientists, have in making choices when designing chemical methodologies" (Anastas and Warner 1998, p. v). Note the contrast with the quotation from Hancock and Cavanaugh in chapter 3, which claims, in part: "In addition to the many sound health and economic reasons to worry about the environment, there is another urgent moral imperative: we have a responsibility to preserve the environment and a fair share of its natural, non-renewable resources for our children and for the generations that follow" (Hancock and Cavanaugh 1994, p. 24).

[4] And here is where the real punch of ecological modernization comes into play: green chemists encourage people and companies to adopt these common sense principles and to show the economic, environmental, and social benefits of doing so, but they never bother to ask how these problems arose in the first place, nor do they ask why no one has decided to adopt these measures sooner. That is, in terms used in the ecological modernization thesis, it's assumed that change can be made without ever questioning the socio-politico-economic structures that currently exist, and it's certainly never considered that it might be these very structures that have given rise to the problems in the first place. Thus, in many ways, green chemistry is just "command and control" regulation for a much deeper problem.

substances is the further growth and innovation of the science and industry of chemistry."[5]

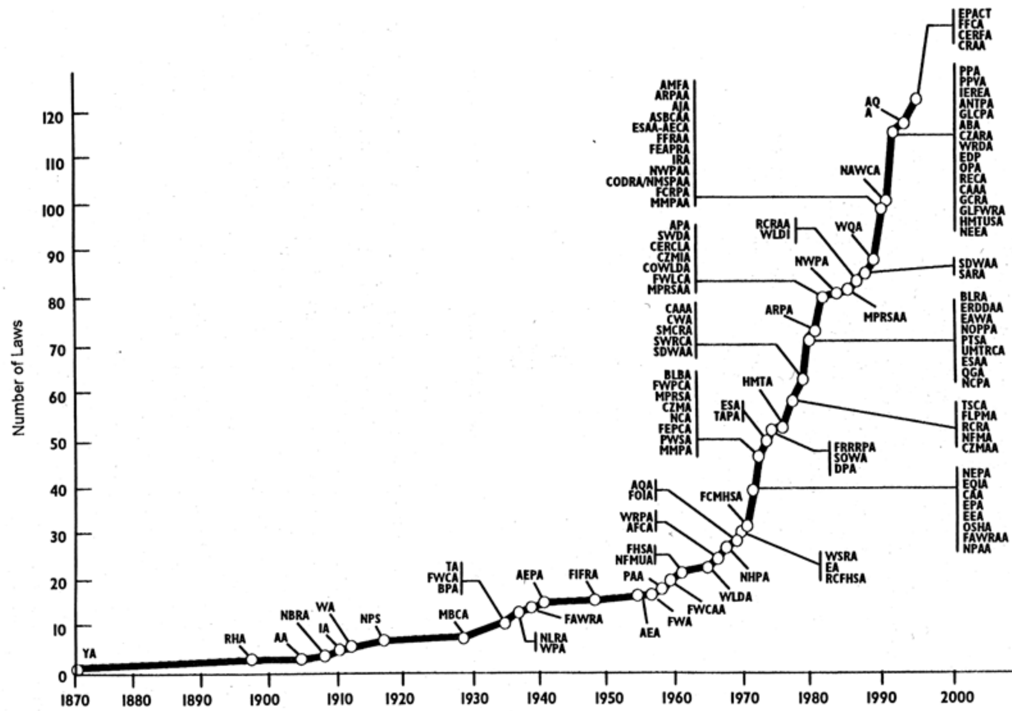

Fig. 1.1 Proliferation of environmental laws and regulations.

Figure 5: Graph depicting the growth of environmental regulations in the United States between the years 1870 and 2000.[6]

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[5] "It is staggering to imagine that in many of the large chemical companies in the United States, expenditures on research and development are equal to expenditures on environmental health and safety. In this statement lies the illustration that the [sic] one of the true victims of the costs of using and generating hazardous substances is the further growth and innovation of the science and industry of chemistry. Universities and small colleges are meeting the challenge of the cost of waste disposal from chemistry labs, both educational and research, by reducing either the number of laboratories or reducing the scale upon which laboratory experiments are run" (Anastas and Warner 1998, p. 31).

[6] At the Green Chemistry Summer School held in the summer of 2004, this graph was omnipresent. (See the link below to access the website with the presentations given at the summer school.) Berkeley "Buzz' Cue, a former VP at Pfizer and now working as an

Indeed, this was one of the primary motivations in moving away from the traditional 'command and control' approach to pollution and regulation, as the Pollution Prevention Act points out.[7] The rising costs of regulatory compliance, the argument goes, strips away money that could be used for further research and development costs. It's important to note that the rhetoric here is not geared towards threats to individual companies and their burdens, or the chemical industry as a whole. Instead, the language being used suggests a threat to the very practice of chemistry. Chemistry, if it does not change, will fall apart due to the economic stresses it currently faces. The authors are careful to link the economic imperatives to the environmental and social issues to which they are necessarily connected—through the triple bottom line—although the order of importance may be debatable. Finally, despite the role that the chemical sciences have played in the creation of sites that require extensive clean-up, despite the role they have played in environmental degradation; despite the wide public distrust, the chemical sciences are always defined as the solution to the problems.[8]

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independent consultant to the chemical industry, told the participants gathered there that this would be the scariest slide they would see. This sentiment was repeated recently by Paul Anastas at the Chemical Heritage Foundation's Second Annual Innovation Day.

[7] See note 6 above.

[8] "It is clear that the 'command and control' approach that has defined environmental protection for so many decades is not sustainable. *Economically*, costs associated with remediation activities must be reduced and reclaimed for use in research and development of the substances and methodologies that will be needed in support of future technologies and to enhance quality of life. *Environmentally*, it is essential that the chemical sciences and

As we saw in chapter 2, the history of recent chemistry put forward by proponents of green chemistry follows a standard approach. On that account, green chemistry steps in to offer a win-win situation—it offers all of the benefits by satisfying the 'triple bottom line' while reducing or eliminating these potential hazards.[9] This stance is indicative of the ecological modernization framework. Unfortunately, there is never any questioning of the basic institutions of the chemical enterprise that created much of this mess. Green chemistry works within the current framework, assuming that the win-win situation can be created without undergoing any major changes. Instead of raising these critical questions, a standard story-line is created, which frames a specific set of problems with very specific solutions—solutions that are easily controlled by chemists and without all the messiness of a "moral judgment."

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industries must also proceed in a manner that does not continue to cause harm to human health and damage to the environment. *Socially*, it is imperative that the populace become aware of the innocuous and even beneficial chemicals that have been manufactured and used, and that chemicals can be designed to be both safe and efficacious. Achieving these goals through the central science of chemistry is the primary objective of green chemistry" (Anastas and Williamson 1998a, pp. 5-6, my emphasis). Note that these three areas are the ones indicated above that define the 'triple bottom line' for sustainability.

[9] For example: "The remarkable technical innovations realized in this century by chemists and the central science of chemistry have resulted in enormous contributions to the world in the form of increased life span, food supply, and general quality of life. Many of these technical innovations, however, have been inextricably linked to hazards to human health and the environment posed by chemical products and their manufacture. With the advent of the new science of green chemistry that link is now being broken, as chemists discover new environmentally benign ways to continue to introduce scientific innovations into our daily lives" (Anastas and Williamson 1998b, p. vii).

The goals of green chemistry, as described by many of its proponents, involve the reduction of hazard (and therefore, according to them, risk) while maintaining the “quality of life achieved by society through chemistry.” This quality of life must now be maintained without compromised, while also achieving the additional goal of sustainability.[10]

In order to understand the role that the rhetoric of hazard plays in the green chemistry movement, one needs to see how hazard enters into a specific definition of risk. Risk, as defined in several places by proponents of green chemistry yields a simple mathematical equation:

$$\text{Risk} = \text{Hazard} \times \text{Exposure}$$

This equation plays an important role in understanding the shift sought in the practices of green chemistry. The traditional ‘command and control’ practices for regulating and controlling chemical risks place their focus on reducing one’s exposure to a hazardous material, therefore limiting risk. The argument put forward by proponents of green chemistry says that focusing on limiting exposure is 1) costly and 2) subject to failure. Regulating exposure is costly because it requires additional safety measures for manufacture, transportation, use, and storage of hazardous materials. It also involves expensive remediation projects when there is an ‘accident’

[10] “The goal of Green Chemistry is to reduce the hazards associated with products and processes that are essential not only to maintain the quality of life achieved by society through chemistry, but also to further advance the technological achievements of chemistry, and to do so in a sustainable manner” (Anastas 1999, p. 169).

involving a hazardous substance. Finally—and perhaps most importantly—regulations and limitations on exposure are not failsafe. That is, 'accidents' can—and do—occur, sometimes with catastrophic consequences. Thus, the cost—in terms of economics, social distrust, and loss of human life and ecological disruption—of addressing risk through exposure control is not an acceptable solution.[11]

In an effort to "alleviat[e] industry and society of those costs," proponents of green chemistry suggest making a shift away from exposure towards hazard as a means of controlling risk.[12] Hazard is as an important factor in the risk equation as exposure; reducing hazard provides an alternative mechanism for risk reduction. And, as the argument goes, reducing hazard avoids the pitfalls of reducing exposure: by ceasing the production of hazardous materials, costs drop, and hazard reduction is not susceptible to failure. The paradigmatic shift from exposure to control to limited use of hazardous materials thus presents an important, and profitable, opportunity for risk management.

However, the definition of the problem and solution within this equation also highlights the technocratic approach to handling risk that typifies green chemistry. In chapter 2, I showed that green chemistry frames the past and present problems in

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[11] "Green chemistry seeks to reduce or eliminate the risk associated with chemical activity by reducing or eliminating the hazard side of the risk equation [Risk = Hazard x Exposure], thereby obviating the need for exposure controls and, more importantly, preventing environmental incidents from ever occurring through accident" (Anastas 1999, p.169).

[12] "While most approaches to environmental protection historically have been economically costly, the Green Chemistry approach is a way of alleviating industry and society of those costs" (Anastas 1999, p. 168).

terms of a series of techno-scientific failures. The solution to these problems, then, is to make adjustments at that same techno-scientific level. This has the added effect of placing scientists and engineers at the fore in solving these problems. Thus, chemists—and chemists alone—have the capability to provide an effective alternative. This perspective is rooted in a confidence that chemists have a knowledge of chemicals and chemical practices that allow them to act as "architects of matter."[13] But, these sorts of comments are unsettling, not least because they imply a level of knowledge and expertise within the chemical sciences that might not actually exist. It assumes that in the past chemists have been mistaken or, at the very least, ignorant of the full nature of the products and processes with which they were working. However, now we know better, and so we should act without hesitation. That is, it leaves little if any room for future evaluation of decisions made now, thereby creating the potential for future predicaments not so different than the ones we now face. In the next section, I'll show how these problematic structures get deployed within the education of green chemists.

Educating the First Generation of Green Chemists

The green chemistry movement, like other movements that attempt to tinker with the internal functions of a scientific discipline, focuses on the (re)training of practicing chemists in the field and those who will stand in line as the next generation

[13] "Intrinsic to this definition is the recognition that chemists, as architects of matter, have in their power the ability to design products and processes that possess the properties they desire" (Anastas 1999, p. 169.). Cf. Anastas and Williamson (1998, p. 7).

of industrial and academic chemists. As we've seen already in the statement that opens this chapter, proponents of green chemistry argue that chemists, and chemists alone, stand poised ready to engineer society's way out of the current ecological crisis that confronts us. Training in green chemistry draws students' attention to the need to focus on the new challenges we as a society must face. Anastas and Lankey put it this way:

> "The ability to invent a sustainable future exists in the talents of our chemists and engineers. The two elements that are still needed are education and a sense of urgency. We need to expand our understanding of the molecular basis of hazard into the current chemistry curriculum. The seemingly miraculous ability of our chemists and chemical engineers to 'engineer away environmental problems' after they are formed must now be reoriented to include the design and implementation of processes that obviate the need for the utilization of hazards whenever feasible. This education, this action, must not be undertaken at pedestrian pace. It needs to be done now, with the sense of urgency that the sustainability of our planet warrants" (Anastas and Lankey 2002, p. 10).

The form of the education required to implement these changes must be analyzed. I maintain that the type of education fostered by green chemistry is likely to perpetuate many of the same problems that the movement is designed to address. To support this claim, let me start with a recent article that looks at the role environmental studies programs play in creating 'eco-managerialists' and how these new managers work within the current system rather than against it. This discussion sets up an examination of a few of the educational initiatives currently underway within the green chemistry movement that will highlight how the emphasis on our ecological crisis as a merely technological problem fits within a broader failure on the part of the new environmental movement to address the conditions of production and consumption that have created these crises in the first place.

Tim Luke discusses the role of university programs in environmental studies in partitioning nature into its constituent resources for proper/efficient utilization and protection. The modern research university, Luke argues, plays a vital role by "generating, accumulating, and then circulating" knowledge about nature that has been properly transformed into an intelligible manner so as to legitimate the use of nature's resources in any number of political projects.[14] That is, nature, through these discursive actions within the pedagogical setting of the university, actually aid in the commodification of nature through a redescription of the 'environment' as a series of 'resources' that require proper management. This act of making nature intelligible is not much different than what James Scott describes as the state's work

[14] "Before scientific disciplines or industrial technologies turn its matter and energy into products, nature already is being transformed by discursive work-ups into 'natural resources'. Once nature is rendered intelligible through these interpretative processes, it can be used to legitimize many political projects. One vital site for generating, accumulating, and then circulating such discursive knowledge about nature, as well as determining which particular human beings will be empowered to interpret nature to society, is the modern research university" (Luke 1999, p. 103).

to make simplify nature, to make it legible, and, finally, manipulable.[15] The most important difference seems to be that in Scott's case, which discusses late-eighteenth century practices of forest management, the state operated directly using scientific forestry as a tool for managing the land. In Luke's treatment of the more recent case of environmental studies programs, the university becomes the focal point for the creation of knowledge of nature, which adds three important features. First, the state disappears behind the veil of the university. The university acts, overtly or otherwise, as surrogate for state (and thus corporate) interest in knowledge of natural resources. Second, the surrogate university is able to capitalize on the objectivity of its scientific undertakings in a way that the state in Scott's example could not. The tools of eighteenth-century forest science were used in direct service of the state. While the state could base its claims on the objectivity of the instruments of scientific analysis, it could not hide the direct political-economic consequences of its studies. However, when the action shifts from the state to the university, the state and corporate interests that drive the analysis of natural resources are afforded a hiding place away from the direct lines linking the scientific research to its political-economic consequences.[16] Third, Luke's study highlights the important pedagogical role of the university in creating new technocrats who operate out in the field, armed with the knowledge of nature's resources rendered 'intelligible' and 'legible'.

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[15] See Scott (1998, pp. 11ff).

[16] Note the similarities to the shifts found in Foucualt's *Discipline and Punish* (1977); i.e., direct obvious power of the monarch to a system of distributed (and this hidden) power of the state through means of education, health, and societal rehabilitation.

Luke calls these new technocrats "eco-managerialists," and describes their approach to dealing with the current "environmental crisis." Universities produce these eco-managerialists, or "professional-technical workers" to analyze and solve the crisis using the very latest in scientific knowledge. They are given "specific knowledge—as it has been scientifically validated—and the operational power—as it is institutionally constructed" to operate upon nature using "sound scientific and technical grounds." However, this emphasis on presenting the problem and solution to the environmental crisis comes at the expense of any alternatives being offered that might allow for a reconceptualization of the problem or that might complicate the possible solutions. As Luke puts it, these programs leave "very little room for any other social objectives beyond the rationalizing performativity norms resting at the core of the economic regime."[17] This rationalizing spirit creates serious difficulties, though, for those that wish to see critiques of the modes of production and consumption remain a vital ingredient in environmental movements. But, with the production of eco-managerialists, attention increasingly focuses on performativity norms—especially economic performativity—as a means of framing the current problem rather than the goal of ecological preservation as a framework for action.

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[17] "These educational operations now routinely produce eco-managerialists, or professional-technical workers with the specific knowledge—as it has been scientifically validated—and the operational power—as it is institutionally constructed—to cope with 'the environmental crisis' on what are believed to be sound scientific and technical grounds. Increasingly, graduate teaching in such schools of the environment has very little room for any other social objectives beyond the rationalizing performativity norms resting at the core of the current economic regime" (Luke 1999, p. 103).

This, in turn, leads to a proliferation of "managerial solutions that blur the central role of capitalist economic growth in causing the environmental crisis" (Luke 1999, p. 104).

While Luke focuses specifically on graduate education in environmental studies, many of the same critiques leveled here apply equally well to the case of green chemistry, as is evident in the examination of the Green Chemistry Summer School sponsored by the Green Chemistry Institute and the American Chemical Society. Green chemistry involves many of the same technocratic themes that Luke points towards in environmental studies programs. These educational strategies are part of the larger technocratic approach to the greening of chemical practices.

Beginning in 2003, the American Chemical Society working in partnership with the Green Chemistry Institute, began offering an intensive, weeklong, summer school for advanced doctoral students and recent post doctorates in an attempt to create a sea change of sorts within the chemical community by training the new generation of academic and industrial chemists in the philosophy of green chemistry. The summer school is open to students in both within traditional chemistry programs as well as those in associated fields of study interested in learning the basics of green chemistry. In 2004, I attended the Green Chemistry Summer School, which was held at Carnegie Mellon University in Pittsburgh, PA.[18] Drawing from these experiences

[18] The workshop took place from July 31 – August 7 at the campus of Carnegie Mellon University. The Green Chemistry Gordon Research Conference occurred just three weeks earlier, from July 4 – July 9 at Roger Williams University in Rhode Island. The juxtaposition of these two events created a unique opportunity to view the green chemistry movement from different perspectives. At the Gordon Research Conference, attendees were expected to

helps to illuminate the ways in which green chemistry is taught and discussed while highlighting the technocratic nature inherent in these exercises.

The sessions were designed to introduce the participants to the many variants involved in green chemistry research according to the specialties of the instructors. Thus, for instance, we heard a lot about some topics—such as ionic liquids and pharmaceuticals—and very little about others—such as supercritical fluids and 'energy'. The technical aspects of the presentations are of interest, but I will focus instead on the way in which the summer school presentations fit within the broader scheme of green chemistry by training new 'chemists' to focus on technological and economic aspects of environmental problems exclusively.[19]

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present their ideas on where the future of the field lies. That is, the conference was designed to provide an intense week of debate in order to lay the groundwork for years to come. Just three weeks later, many of these same people presented their ideas about the foundations of the field. That is, the question "what is green chemistry?" quickly became the statement "green chemistry is."

[19] There are certainly a number of other issues that could be addressed with regard to these presentations. For instance, the study of ionic liquids is a very specific research field compared to something as ambiguous as 'energy' and yet it received nearly four times the amount of attention at this summer school. Ironically, the issue of whether or not ionic liquids could legitimately be considered an example of green chemistry was raised a number of times during the summer school. However, despite these other possible topics, I want to stay focused on how the summer school maintains a strict conformity to how problems should be perceived and dealt with from the perspective of green chemistry in order to highlight 1) the emphasis on expertise of chemists in dealing with these issues and 2) the strict technological nature of the problems. All of the Summer School presentations can be found at http://www.chemistry.org/portal/a/c/s/1/acsdisplay.html?DOC=greenchemistryinstitute\summer_school\2004gcsummer_presentations.html.

The first session of the summer school began with Paul Anastas' presentation, "Principles of Green Chemistry." He covered familiar territory with very little change in his recounting of the history and formation of the green chemistry movement. Perhaps this formulaic approach makes sense. Repeat the message until it takes hold. But, there are some elements built into this frame that require greater scrutiny. First, as I noted, regulation is demonized. It is demonized because it is seen as a failure. But we can only judge regulation as a failure if we define the role of regulation in very specific ways. For instance, if regulations are meant to end pollution, any observer would have to respond that regulation has had a mixed effect. Emissions of certain pollutants have certainly decreased following the passing of legislation. However, the corruptibility of regulation—the fact that regulations depend on enforcement, which is susceptible to political manipulation—certainly makes regulations only partially helpful. If, however, we consider the role regulations play in creating a system of corporate/individual accountability, then on might come to very different conclusions—still mixed, but different. Accountability is noticeably absent from these discussions within green chemistry. Regulation has failed because there are still messes to be cleaned up, therefore, we should abandon regulation. The argument doesn't make sense. Nor does the alternative, wait for corporations and individuals to make the changes themselves, offer a particularly useful model.

The alternative favored by Anastas—to make changes without regulation—is founded upon the idea that economics will prevail in all situations. Indeed, in Anastas' script, economics almost always precedes environmental/public health. For instance, in his presentation and discussion of the first Principle of Green Chemistry, "It is better to prevent waste than to treat or clean up waste after it is formed," Anastas gives two reasons to adhere to this principle: 1) not preventing waste leads to paying for materials three times, once as a raw material, once in the separation of product from wasted material, and once as disposed of waste; and 2) "environmental and health impacts." While this might not strike many as problematic as an isolated incident, the routine ordering of priorities in this way proves deeply troubling, especially at a workshop introducing the next generation of chemists to green chemistry. Unfortunately, the theme was repeated throughout the weeklong workshop.[20]

In her presentation on the relationship between green chemistry and energy issues, Joan Brennecke echoed the sentiments found in much of the green chemistry ethos. Her initial slides focused on energy as one of the top ten issues facing the global community over the next 50 years. Her slides presented a serious dilemma: as

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[20] For instance, take, the presentations by Mark Harmer of DuPont. He began them with questions to the audience intended to frame the discussion. One presentation began with the question, how do you convince the CEO of DuPont that green chemistry is a good idea? Participants offered a number of responses, but the exercise did not end until some gave the correct answer, "money." Couple this with Harmer's informal definition of sustainability—a gesture with his hand to an elevation about the height of his head along with comment, "keeping DuPont stock right about here"—and formal definition—economic attractiveness + ecological responsibility through technological innovation; and DuPont's commitment to "create shareholder and societal value while reducing our footrpint"—and things begin to look a little bleak. DuPont CEO Charles O. Holliday, Jr. also gives the same definition: "the creation of shareholder and societal value while decreasing our environmental footprint along the value chains in which we operate." See http://www2.dupont.com/Social_Commitment/en_US/SHE/.

the world's population increases over the next half-century, and as economic and industrial development spread to the far reaches of the globe, the demand for energy will nearly quintuple. In the face of this, however, Brennecke quickly ruled out the role of conservation and increased energy efficiency. The slide read:

> Conservation/Efficiency
>
> Great thing to do
>
> Not enough
>
> Can't keep up with population growth and increased worldwide demand

And just like that all discussion of conservation and efficiency in energy consumption disappeared. She quickly dismissed most other viable options as well: hydroelectric – not enough; wind – not enough; wave and tide – not enough; biomass – not enough; geothermal – geographically restricted and not enough. The only options left by the end of the presentation were nuclear and solar. But even these have complications. Nuclear offers a good supply, but has other associated problems (e.g., security). Solar requires a vast amount of area dedicated to the collection of energy, and also "Power Cables (superconductors, or quantum conductors) with which to rewire the electrical transmission grid, and enable continental, and even worldwide electrical energy transport…" (Brennecke 2004).

Perhaps much of this wouldn't seem so troubling if it were not all said and done in the context of a workshop designed to train the next generation of scientists and engineers who may be responsible in some way for dealing with these issues. The only options that are left are those that do no challenge the basic standards of our systems of production and consumption. While the means for producing energy are discussed, the modes of distribution and consumption are left perfectly intact. Decentralized energy production never enters the conversation. Instead, we learn that we will need an area roughly the size of Nebraska to generate enough solar energy for the U.S., and that we should begin thinking about how to transport that energy around the continent and possible the globe. The base (technological) determinism that saturates these discussions is unavoidable, and yet somehow invisible.

Proponents of green chemistry fancy the field an inter/cross/multi-disciplinary exercise that draws attention towards the chemical dimensions of issues involving pollution and sustainability. Jim Hutchison, who offered a presentation on "Green Chemistry challenges for the academic community," put it this way: "Green Chemistry is a multidisciplinary field, involving fundamental sciences, business, law, and engineering" (Hutchison 2004). One of the challenges, then, facing green chemists is finding a way to integrate the various threads of these fields into the course curriculum for chemistry students. But, challenging the orthodoxy of the chemistry community is difficult. In addition to the normal difficulties encountered when attempting to change something as programmatic as the entire curriculum for a disciplinary field, proponents of green chemistry contend against other obstacles. Green chemistry, Hutchison asserts, must "overcom[e] the misconception that green chemistry is less rigorous" than 'traditional' chemistry (Hutchison 2004). It would seem that the label 'green' can at times present certain images to those not familiar with the field and their mission. Indeed, Hutchison asserted a few times during the course of this presentation that green chemistry “isn’t tree hugging chemistry.” The previous presenter, John Warner, echoed this sentiment: “we’re doing hardcore research.” But, beyond the public relations campaign going on within the chemical sciences, another external campaign also rages, with green chemists attempting to play the role of ambassadors. Hutchison who has perhaps done more than anyone to incorporate green chemistry principles into an undergraduate curriculum, discussed how his classes and students offered help in that second campaign. “The approach” Hutchison said, “changes the way students think about chemical hazards and chemistry.” Testimonials from students supported this. One student wrote: “After taking this course I have a much better opinion of chemistry. … I feel like I am learning something that has an actual important application to the real world. Another wrote: ‘I have decided to get a minor in chemistry so I can make more conscious decisions regarding chemistry and avoid destructive practices for my health or the environment.” Hutchison concluded, green chemistry “empowers students to use chemistry to solve environmental problems [creating] ‘Ambassadors of Green Chemistry’. [It also c]hanges the way students and society view chemicals, chemistry and chemists – ‘Know the hazards, not all chemicals are hazardous’” (Hutchison 2004).

Many of these issues were highlighted theatrically by engaging the participants in a debate designed to challenge them to think about the complexity of the issues presented during the week of the summer school. The proposition for the debate was “Drugs that make people’s lives better take precedence over environmental protection.” I worked with the group that dissented from this position, arguing that the claim was false. The debate was of course interesting for the arguing points chosen by each side. Our group, for instance, was repeatedly counseled by our student guides[21] that we would have to engage the 'economics issue'. That is, we would have to address the fact that the drug will make money, and that somehow the 'worth' and 'cost' of the environment would have to be evaluated with respect to the profits the company stood to make. But, perhaps more alarming, the emphasis on profits over protection—which, I suppose, *is* a debate that occurs, whether or not it ought to take place in these terms—was the failure to question the premises underlying this statement. For instance, no one questioned whether "make[ing] peoples lives better" could be separated from "environmental protection." More importantly, the students were not encouraged to think of the issues in this way. That is, no one wondered whether environmental protection might actually be a part of making people's lives better. Secondly, no one questioned the distribution of harms and benefits. Would these drugs make *everyone's* lives better? Would we be protecting *everyone's* local environment? Or would the drug be for the improvement of *some* people's lives while taking a toll on *some* people's environments? This is the justice of environmental justice, right? Who benefits and who is harmed by the operation of the industries responsible from making these pharmaceuticals was not

[21] Each group was provided with a small number of students who were at the time affiliated with Terry Collins' lab at Carnegie Mellon. They had discussed these issues during a recent course and it was hope that their advice would help condense these complex issues into something manageable in less than a week.

raised as an issue.[22] In the end, economics dominated the discussion. And, not surprisingly, the affirmative group won the debate. The debate highlights how students (and non-students) were being asked to approach the topic of green chemistry. Environmental issues were portrayed as techno-scientific issues, and industry will save/make money, too, if they employed these strategies. But when it comes to dealing with more complex questions green chemistry had no answer because it has no way of dissecting, challenging, or rearranging these questions in such a way that they create a meaningful debate. This was unfortunate because the debate did offer an opportunity to enter the realm of reality. The question posed for the debate did indeed reflect the types of questions that are being asked within the chemical industries. Students, however, were no encouraged to take full advantage of this opportunity to flesh out the full implications of the current chemical industries and for thinking critically about what difference might be created.

What was not taught at the Summer School is just as important as what was. The presentations did more than reify the strict technological nature of the green chemistry problem-solution set. They also painted a very specific portrait of the

[22] Eventually, during a group session meant to decide more firmly on what issues the group would push in the debate, I did raise my concerns along these lines. To many, the point seemed much less important than trying to demonstrate that we can encourage companies to protect the environment and make profits through the application of green chemistry. However, there were a handful of students—mostly non-American—who agreed that this would be an important issue, and made sure that some attention was devoted to it during the debate. It was, in my opinion, the most well researched point made on both sides, and the most compelling point calling for a fundamental rethinking of how these types of questions ought to be approached in the first place.

problems, perceived and real, facing the students as they embark on their careers. For instance, little attention was paid to the role of the chemical sciences and industries in cases involving massive pollution and systematic attempts to deceive the various local, state, and federal agencies as well as the general public from knowledge of the hazards posed by chemical products and processes.[23] Instead, the focus remained on the role chemists must play in continuing to "engineer away" pollution problems after the fact and now before they occur. However, despite the unwillingness to engage with issues of culpability, there was one presentation that deviated drastically from this norm.

In a presentation by Devra Davis, participants watched a video and slide show depicting the terrible havoc wreaked by industrial air pollution in the nineteenth and twentieth centuries. Davis' material came from her recent book, *When Smoke Ran Like Water: Tales of Environmental Deception and the Battle Against Pollution* (2002), which catalogs a number of high profile cases of air pollution—including Donora, PA (1948), London, UK (1952), and Los Angeles, CA. However, unlike many other accounts of chemical accidents, incidents, and isolated events, Davis put much of her attention on prolonged exposure to air pollution and its health effects in an attempt to show the inadequacies of current systems to account for and regulate the low-dose exposures that all of us experience in our everyday lives. Her presentation, unlike those that came before it, did not demonize the regulatory system or

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[23] These sorts of (mis)deeds have been documented in a number of places, including: Colborn, Dumanoski, and Myers (1996); Davis (2002); Fagin and Lavelle (1999); Markowitz and Rosner (2002). Devra Davis' work is discussed here in greater detail.

regulatory laws. Instead, it presented a picture of black smoke spilling out of chemical and metal foundries, which turned day into night. This, Davis argued, continues today. While the smoke might be less visible, chemical companies continue to fight against regulation and elimination of chemicals that—despite their ambiguous classification by the government—have been causing serious health problems for decades. Davis, who served on the National Chemical Safety and Hazard Investigation Board under President Clinton spoke from her experiences on that board and her previous years as scholar at the National Academy of Sciences where she regularly consulted on issues of chemical toxicity and regulation.

Davis' talk, while a stark contrast to the tone of previous talks, might not have stood out so vividly had it not been singled out the following morning in István Horváth's presentation. His lecture was intended to cover "homogeneous catalysis." Instead, it began with a reaffirmation of the codified message of the Summer School. Horváth wrote his declaration on the white board at the front of the room:

> Chemistry is Great
>
> And we will make it better
>
> And we will market it better

And with that simple move, the theme of the summer school came back into focus. Proponents of green chemistry want to improve chemistry, but they also want to improve the perception of chemistry—for themselves as well as for everyone else. This ideology was of crucial importance in this setting. The people sitting at the tables watching these presentations are not yet proponents of green chemistry—not all of them anyhow. Most are interested, curious, looking for something more from the chemical sciences. They come from different fields, different backgrounds, different countries. The job of the presenters, then, was to rein these people in and keep them focused on the goals of green chemistry—the goals established by the institutionalized green chemistry. Thus, the best way to maintain focus, and to maintain a path towards achieving these goals, is to continually emphasize that these are merely technical problems. Technical problems require a technical fix.

Does Green Chemistry Go Far Enough?

Green chemistry offers a change in the objects that populate the space of the chemical sciences. For example, through the incorporation of its chosen history, the articulation of its definition, and the application and adherence to its twelve principles, green chemistry stands as an alternative vision of the chemical enterprise. But, are the practices that emerge out of and shape this field different enough to create any sort of meaningful change, or do they merely treat the problems symptomatically? Hajer and others might ask, does green chemistry offer the opportunity to challenge the underlying systems that have given rise to these problems in the first place or does it assume that they solutions will come from within these same systems?

In many ways, the debate here is a continuation of debates from the 1970s and onward between Paul Ehrlich and Barry Commoner. The two offered radically different approaches to dealing with the emerging environmental problems. Ehrlich argued for technological fixes to what were perceived to be technological problems.

Commoner, on the other hand, saw a flawed social structure that gave rise to the specific type of technological infrastructure in the first place. Andrew Feenberg sums up the debate this way:

> “At the core of the disagreement are very different views on the nature of technology. Fundamentalist environmentalism emphasizes control of growth because it can conceive of no change in the industrial order that would render it ecologically compatible. Technological determinism thus leads straight to a Malthusian position for which environmental and economic values must be traded off against each other. This is Ehrlich’s position. Commoner’s contrary view depends on a non-determinist philosophy of technology which admits the possibility of radical technical transformation. Only on this condition can growth and the environment be reconciled” (1999, p. 47).

Those involved in laying out the strategies of the green chemistry movement clearly come out on the line of the Malthusian argument of Ehrlich—with a new twist. Proponents argue that there is no longer the need to trade off economic and environmental concerns. Rather, technological fixes will make both economic growth and environmental protection feasible and profitable. Technological determinism is replaced in part by economic, political, and social determinism. People, politics, and capitalist markets become artifacts beyond reproach, around which flexible technologies can and must be engineered. But these are not separate spheres;

changes to the technological system alone cannot address the underlying complexities of the problems we face in this age of wide-scale environmental destruction.

Green chemistry attempts to shift the focus from remediation towards pollution prevention, but this is a complex move, not easily made without serious consideration of what conditions have created the horrendous destruction we've witnessed in the last century and more. Traditionally, Harvey writes, "[q]uestions of how and why 'wastes' in general and hazardous wastes in particular are produced in the first place are, of course, never even mentioned. […] But posing that question requires a discursive shift to the far more politically charged terrain of critique of the general characteristics of the mode of production and consumption in which we live" (David Harvey 1999, p. 155). Thus, Harvey argues, we cannot engage in a real analysis of these problems and their potential solutions on a technical level without also engaging with the underlying and broader social structures that gave rise to these issues in the first place. Green chemistry, constructed only around the technical aspects of these problems, fails to provide the sort of depth required to truly re-construct chemistry in a way that avoids making many of the same mistakes all over again.

Chapter 5: Green Chemistry's Promise and Problems

Why, after 15 years, do proponents of green chemistry keep presenting green chemistry as something new, "nascent," and on the horizon? Why, after 15 years, are they still struggling with issues of legitimacy—in the classroom and in the laboratory? In this chapter, I discuss the reasons for the failures, as I see them, of the green chemistry movement. No one should expect an easy transition into a 'green chemistry', but the core ideas remain important ones worth debating. The challenges faced by green chemists are not wholly unique, and perhaps the track record with other "explicitly normative sciences" is not entirely cheerful,[1] but the stakes are great enough that we ought not back out now. First, I'll recap what has happened in the last few chapters. This leads me to a more pointed critique of what I take to be the obvious failures of this movement and to examples of how these failures have manifested themselves recently.

Getting to the Present

In the previous chapters, I've described the emergence and characteristics of the green chemistry movement from three perspectives. In chapter two, I demonstrated how proponents of green chemistry have constructed a history for the field—their own origin story that serves as a way 1) to remind those in the field where they came from, 2) to seek guidance for where to go in the future, and 3) to assist in the

[1] See Galusky (2000) for a description of the "professional and political" challenges faced by the conservation biology movement.

indoctrination of others into these practices. Construction of this history is crucially important because it allows proponents of green chemistry to frame the problems on which the group works in such a way that the application of green chemistry is the only way to solve these problems. The history is interesting for a number of reasons. First, it is built, for the most part, on a history of the growth of the environmental movement in the United States until about 1990. This places proponents in an awkward situation because they must consistently distance themselves from the environmental movement for fear of losing credibility within the chemical sciences even while they build upon what it accomplished. At the same time, they also lack legitimacy within the more mainstream environmental community. Thus the history created by green chemists may actually add to their problems rather than placing them in a situation from which they can effectively act.

Despite the fact that this history parallels that of the environmental movement, it retells many of the main events on the timeline from a perspective based on chemistry, if such a thing exists. Take as an example the narrative of the Bhopal gas incident. Despite the amazing techno-socio-politico-scientific complexities of the events that have been explored and dissected over the last two decades, the standard green chemistry account of the incident frames it as simply a failure of techno-scientific mechanisms. The solution: use inherently safer chemicals and processes. It is true that inherently safer processes and chemicals would indeed prevent elements of "Bhopal" from recurring. However, to assume that the events at Bhopal merely represent the failure within this one specific sphere demonstrates a failure to truly appreciate all of the issues involved in this horrific disaster. More importantly, the telling of the story in this way codifies the problem as one that only involves techno-scientific factors and thus requires a techno-scientific remedy. This restriction of vision, in turn, becomes embedded in all aspects of green chemistry. We see its traces in many other fields of the broader community. The power of the history becomes manifest in the disciplining of green chemistry, in the limited range of solutions offered by green chemists, and in the physical and conceptual artifacts they construct. Thus, green chemists' history of the field puts into place the elements that help to construct the field as currently configured.

In chapter three, I turned my attention towards green chemists who have sought to differentiate and define themselves within a broader context of the chemical sciences and a host of other movements that are grappling with issues of 'sustainability' more broadly. I discussed the efforts that went into properly defining green chemistry, and how that definition has become a mantra within the field. I examined the role that the twelve principles of green chemistry played in disciplining the field by both adding focus and cohesion and a parallel function of keeping order within the ranks. Both the definition and the principles served (and continue to serve) an important role in making green chemistry something (else). The definition and the principles provided a space for green chemists to work within the chemical enterprise, but separate enough to allow for a unique identity—as is shown by the creation of a journal and a new Ph.D. program. From this space, green chemists and their proponents have been able to work their boundaries by attempting both to move into other areas and to co-opt separate but related fields.

Proponents of green chemistry claim that their ultimate goal is to remake chemistry so that it is always and everywhere green, by default. In private conversations, several people commented to me that "if we are still discussing green chemistry in 20 years then we will have failed." When all chemists think like green chemists there will be no need for a separate green chemistry. Chemistry itself will have already incorporated these principles into its practices. Yet, to transform chemistry and make it green, green chemistry itself has to become something without becoming something permanently separate, distinct, or other. Thus its success in creating a space for itself may result in its greatest challenge—disappearing again. But, while the field itself has secured a more fixed and permanent space, those that operate within and between its boundaries have remained anything but fixed. As the evidence from the conferences discussed in chapter three illustrates, very few individuals play an active and constant part in the construction of the field. What core there is remains small and seems to have trouble adding to its ranks.

Finally, in chapter four, I examined how elements of this history and community identity manifest themselves in the activities of green chemists. In particular, I paid special attention to the ways in which green chemists define the problems at hand, and their solutions. As currently configured, green chemists define the 'pollution problem' solely in technical terms. The events outlined in chapter two are all seen as failures of the techno-scientific system, so that such problems can be solved by straightforward techno-scientific changes. Additionally, the problems and solutions are defined in such a way as to position green chemists—unique in their inter/multi/cross-disciplinary approaches—as the only qualified people to handle this situation. Their technocratic expertise rules the day. I also demonstrate how this mode of action is transferred to the next (first?) generation of green chemists through pedagogical forums such as the Green Chemistry Summer School. The creation of the green chemist and the disciplining of the field become routinized in the activities of its members. Thus, the history developed in chapter 2 and the community building and maintenance of chapter 3 become a part of everyday life for green chemists and is shown by the approaches taken to education, outreach, and goal definition—i.e., the practice of green chemistry.

This chapter shows that green chemistry fits well within Hajer's discussion of "ecological modernization" and environmental discourses according to which attempts to solve current environmental crises can originate within the same systems that gave rise to them in the first place. While attempting to offer new approaches, especially to industry, the green chemistry movement fails to call into question key issues such as consumption, economic systems, or issues of development.

Dealing with the Present Situation

Despite claims to the contrary from within the movement, I'm left with the conclusion that green chemistry, as a scientific movement, simply is not working. This does not mean that no work is being done; on the contrary, a perusal of the pages of *Green Chemistry* and the citation trail of the papers published there shows tremendous effort in the name of green chemistry. What does not occur, however, is the broader adoption of the more general *philosophy* of green chemistry, as proponents refer to it. The ideas of green chemistry are touted by CEOs, VPs, and professors alike, but for different reasons. While many people are happy to voice their support for green chemistry, few are willing to make the sort of "revolutionary" changes required for the implementation of a truly *green* chemical enterprise.

Fortunately, many of the people involved in the broader green chemistry community are eager to move beyond the discussion of success stories and to find better ways to overcome the problems facing green chemistry. At the Ninth Annual Green Chemistry and Engineering Conference held in Washington DC in June of 2005, Ned Woodhouse organized a session on the social and political barriers to the implementation of green chemistry. Woodhouse's goal, he told the audience, was to initiate a serious and honest discussion about the types of problems the field is facing. He characterized the problems as being social as well as technical in nature. The response from the attendees was quite interesting. One person wondered why a session such as this wasn't held at the beginning of the conference to help frame the whole week.[2] Another participant remarked that she was tired of hearing about all of the successes of green chemistry. She wanted to talk about why green chemistry hasn't been taken more seriously by now, and what could be done about this situation. I believe these responses represent a serious issue within the green chemistry movement. While those responsible for the strategic organization of the field have celebrated the innovations made in industrial process design, other

[2] Woodhouse's session was during the last slot on the last day of the conference, and all sessions with the exception of the keynotes ran concurrently with at least a half-dozen other sessions.

interested parties have been left waiting for the real breakthroughs. The following examples highlight these troubles as I see them.

Green Chemistry and the Chlorine Sunset Policy

In the session of the Green Chemistry and Engineering Conference organized by Woodhouse, Jeff Howard presented a paper on the attempts to institute a chlorine sunset policy. He outlined the evolution of the attempts by some scientists and policy makers to impose a sunset on the use of chlorine in the chemical industry during the 1990s and strongly criticized the lack of support given by green chemists for the enactment of this sort of policy. During the Q&A following the presentation, Paul Anastas asked Howard whether he had considered the fact that those advancing green chemistry had purposefully decided not to engage in the debate because it didn't mesh with the strategy being employed by the leadership of green chemistry. The movement, according to Anastas, is less concerned with classes of chemicals—e.g., chlorinated chemicals—and instead has chosen to focus on chemical properties—e.g., acute toxicity. He repeatedly asked Howard whether or not he believed that the leadership of green chemistry had consciously chosen one approach over the other. Satisfied with the lack of an answer, Anastas left the room. Unfortunately, however, the question creates an artificial dichotomy and misses the point of Howard's critique. His point was not to question the strategies used to achieve the goals of green chemistry, but to call attention to the failure of the green chemistry leadership to make a political decision and to align itself against the chlorine industry. Joining the others on the side in favor of a chlorine sunset would not have required a change in strategies. In fact, it would have required almost no effort at all. The debate had already been formed. Green chemistry only had to choose a side.

I believe that this episode serves as a marker of significant problems within the green chemistry movement as it is currently configured. First of all, it demonstrates that the leadership of the green chemistry movement does not deal well with critique. The concerns raised by Howard were legitimate, and could have been addressed in a number of ways (and were by other members of the audience). However, Anastas' response amounted to the creation of a polemical dichotomy out of the issue that shut out alternative paths of action, leaving only a yes/no decision to accept or reject the strategies and decisions of those calling the shots. Furthermore, the exchange between Howard and Anastas highlights the fact that the green chemistry establishment lacks the political will to take a stand against any part of the chemical industry. Their courses of action tend to support the continued belief that they can act in a neutral fashion, praising good works done by anyone, and working to cleanup brown chemistry anywhere it is found while encouraging people to adopt green chemistry. The leadership still believes that industry can and will change, and so working from within this structure is the most effective way to bring about the greatest change. And, they still believe—or give the impression that they believe—that green chemistry is not a green wash for the industry. But, this perspective fails to take into account how the chemical industries use green chemistry. The fact is that companies *do* use these awards as a public relations tool to cover up the not so pretty sides of their activities. A simple search through headlines and stories from newspapers and news magazines yields examples of stories where the award is touted as how green the company is, despite the fact that the story had nothing to do with the exact product or process that led to the award.[3] To shy away from a debate such as the proposed chlorine sunset because it doesn't mesh with its strategies is to continue to portray green chemistry as somehow politically neutral, which makes the movement vulnerable to the most politically powerful.

Innovation Day

In September of 2005, the Chemical Heritage Foundation held its second annual Innovation Day, which focuses attention on breakthroughs being made in a variety of areas related to the chemical sciences. Paul Anastas spoke in the session devoted to "Environmental Chemistry." The talk, "Future Science: What will chemistry and engineering look like?" focused on the relationship between green chemistry and the creation of a sustainable chemical industry. His presentation followed the usual format that I've discussed throughout this dissertation. It comprised the standard introduction to green chemistry and contained little, if any, new information.

Despite the repetition, Anastas' presentation warrants discussion as it offers an opportunity for further reflection and criticism of the green chemistry project as a whole. I have already shown that green chemistry has become increasingly linked to the more general term of 'sustainability', especially as it is used in the chemical

[3] More recently, NPR has begun playing sponsorship clips from Merck that claim the company is promoting sustainability through its use of green chemistry. This blanket statement is a perfect example of how I believe the phrase green chemistry as been reestablished within a framework of corporate sustainability, which comes at the expense of the more specific claims that green chemistry leaders claim to be arguing for in their rhetoric.

sciences. But 'sustainability' is a term that has been tweaked and massaged to mean *corporate sustainability* first and foremost, so that, in these contexts, it is equated with the 'triple bottom line' and the "Brundtland Report."[4] The triple bottom line places *environmental protection* right alongside (but always after) *economic growth*, with *social responsibility* rounding out the pack. Thus green chemistry's attachment to sustainability offers it opportunities for incorporation into broader business spheres, but comes at the expense what was the primary focus of green chemistry—a transformation of the practices of the chemical sciences. More importantly, perhaps, the shifting of green chemistry into the realm of 'sustainability' as it is used in corporate circles places more of the direct emphasis onto the economic benefits to be had by adopting these practices. In the eyes of many, the term 'green chemistry', it seems, still evokes the wrong images for most people.[5] The chemical industry has gone for sustainability, and so has green chemistry.

Second, the green chemistry leaders' desire for acceptance by the chemical industries was clear from the beginning. It has become increasingly obvious where the

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[4] Representatives from chemical companies made this abundantly clear in their presentations, such as the talk that took place immediately following Anastas' at Innovation Day or the talks that comprised the "Symposium on Sustainability" at the American Chemical Society meeting in August of 2005. The program for this symposium is available at: http://oasys.acs.org/acs/230nm/techprogram/#programlocator.

[5] At a recent meeting on green chemistry at the Chemical Heritage Foundation, fears of the *green* image emerged twice during keynote addresses. The first speaker lamented the images of "tree huggers" and "hippies" green chemistry conjured up when he discussed these ideas in his chemistry department. The second worried that discussions of green chemistry at his pharmaceutical company evoked images of "people sitting in a circle singing Koom Ba Yah."

leadership has decided to put their efforts. Two markers of the move in this direction are the continued use of the "scary graph" depicting the growth of regulations or the preface to the definition of green chemistry—it's not some noble sentiment to save the birds and the bunnies—and the acknowledgement that the room was filled with representatives from companies that have won the Presidential Green Chemistry Challenge Awards.

Finally, after the presentation by Anastas, *there was not a single question*. I spoke with a few individuals who attended the session afterwards to find out their impressions. One attendee, a young woman from a major company, commented on the low attendance. She then remarked that the views presented during the session seemed to represent the perspective of upper management. And finally, she wanted to know why there was no mention of the need to engage and educate the public about green chemistry. These are all critical issues, especially these latter two. In the view from "upper management" one loses perspective on the efforts and potential found in the ranks. I believe this reinforces the data from the Gordon Conferences I discussed earlier. Most chemists who are interested enough in green chemistry to attend a conference or a session are walking away and not coming back. Perhaps this is because these chemists don't see where they fit in the movement's current configuration. Contrast this, then, with the comment made by another attendee, a middle-aged man in a management position, representing a major company: "We're not going to do green chemistry because we're good guys." This person found me a few moments later to clarify the statement: competition right now is tough, and no one can afford to make a move without knowing for sure that it will provide immediate economic benefits. In line with this comment, it is clear that the economic argument is the one that the proponents of green chemistry are emphasizing to gain legitimacy and acceptance from the chemical industries. But it is important to evaluate the effects of employing this line of argument, and the costs to the future development of the field. Is the leadership of the green chemistry movement ostracizing those who wish to take up the cause of green chemistry for reasons that are extra-economic—perhaps even *moral*?

RAND Report

In 2003, RAND published a report (Lempert et al 2003) commissioned by the Office of Science and Technology Policy that examined the topic of new and emerging environmental technologies and what effects they might have immediately and in the future on the prevention and elimination of waste in the chemical industries in the US.[6] The report, titled *Next Generation Environmental Technologies: Benefits and Barriers*, provided a less than optimistic outlook for the adoption of these technologies in the coming years, including those considered examples of green chemistry. The report focuses almost exclusively on green chemistry, its benefits and barriers, but uses the term next generation environmental technologies as a broader,

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[6] It ought to be noted that in 2003, Paul Anastas was no longer at the EPA but was then working at the White House Office of Science and Technology Policy, the same office that commissioned this report. It is unclear what role he had in the commissioning of the report, although one of the authors, in private communication, did indicate Anastas' displeasure with the report's conclusions. It would seem that Anastas was hoping for a more glowing endorsement of the 'successes' of green chemistry.

more inclusive term treating green chemistry as a specific subset of these technologies. The report examines 25 case studies to evaluate what motivated these initiatives, which innovations have proven track records, which have been adopted, and the prospects of adopting these technologies on larger scales.[7] The authors express a great deal of enthusiasm for these technologies and their potential. Indeed, in their summary, they draw the following conclusions: "NGETs [next generation environmental technologies] can provide significant benefits to society in all the areas considered in our study the environment, national security, occupational safety and health, and the economy." Additionally, "NGETs can in some cases eliminate the use and generation of hazardous substances at little or no additional cost" (p. xi). Despite this optimism, the authors are left to conclude: "Our case studies indicate that although green chemistry can be a powerful source of environmentally and economically beneficial technologies, its development is still in its infancy. Substantial work is needed both to create new NGETs and to encourage demand for their use" (p. xii).

There are many reasons for these problems. The report notes at least nine significant barriers, including a lack of uniformity of regulations globally, the economics of the implementation of green chemistry, lack of research funding, lack

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[7] The cases cover a range of topics considered to examples of green chemistry, from new synthetic process, to new products. See, for example, the cases of "Supercritical or Liquid CO_2 as Solvent" (pp. A11-A22); "Ibuprofen Synthesis" (pp. A23-A27); "Bio-Based Processes" (pp. A32-A51); "Production of Hydrogen Peroxide (H_2O_2) Directly from Hydrogen" (pp. A57-A62); "TAML™ Oxidant Activators for Hydrogen Peroxide" (p. A82); and "Biodegradable Polymers" (pp. A102-A105).

of guidance on "best practices" in green chemistry, lack of green chemistry in schools, and a culture that looks at products rather than processes (pp. 31-2). Perhaps more importantly, and in line with arguments made in the previous chapter, little is known about many of the green chemistry practices currently being advanced, which means that some, perhaps many, green chemistry practices might actually produce new hazards when implemented.[8] Despite the tremendous possibilities that the authors see for the further development and implementation of NGETs, they conclude that these technologies are not likely to be adopted now or in the near future.

But why can't green chemistry gain significant ground? In the introduction, I wrote that green chemistry ought to be thought of as a scientific movement, but whether or not it should count as a success or a failure seems unclear. In their article laying out a general theory of scientific and intellectual movements, Frickel and Gross lay out 4 propositions outlining the "dynamics of SIM emergence" (2005, pp. 209ff): 1) SIMs are more likely to emerge when high-status intellectuals harbor complaints; 2) SIMs are more likely to succeed when they provide access to key resources; 3) SIMs are more likely to succeed when they have access to "micromobilization" contexts, or opportunities in which to attract new members; and 4) the success of a SIM depends upon its ability to frame its issues in a way that resonates with the broader community it hopes to reach. In the following section, I apply these standards to green chemistry, offer some sense of how it measures up against other movements, and provide some criteria for estimating its relative progress. I also use my study of

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[8] See p. 26; p. 33, note 40. Cf. Note 2 in Chapter and the discussion there about possible toxicity issues related to ionic liquids.

green chemistry to suggest how the idea of SIMs might be expanded to improve its applicability to such movements as this.

Green Chemistry as a Scientific Movement?

In their article exploring the possibility of viewing green chemistry as a movement, Ned Woodhouse and Steve Breyman open with a tantalizingly optimistic thought experiment about the potential for scientists to participate in, or even lead, the fight for a sustainable and just future:

> Might environmentally responsible technological innovation ever be *led* by technoscientists working within mainstream corporate, governmental, and university institutions? Could it be that the sociotechnical value shifts and reforms called for by many progressive scholars and activists—peace, sustainability, genuine democracy, and social justice—will remain oppositional and marginal unless such innovations take root and blossom in established institutions? If so, if building an environmentally commendable civilization requires a larger and more influential coalition than well-meaning outsiders to the technosphere usually can muster, there may be no substitute for enrolling insiders as enthusiastic actors and even leaders in the endeavor rather than as resentful and legally mandated participants (2005, p 199).

The authors point the way towards some strategies that ought to be explored in the construction of a new environmental movement. The development of environmentally responsible technologies could, and perhaps should, be led by technoscientists working in collaboration with well-positioned corporate, governmental, and university institutions. To this list, I would add local citizen groups and institutions. But the statement quoted here also reinforces a number of artifacts of our current institutional structures that require serious reconsideration if technoscientists can be enrolled into this 'coalition of the willing' rather than a coalition of the "resentful and the legally mandated." As I've shown in the previous pages, however, it is not at all clear whether or not we would want green chemists, *alone*, to lead a new environmental charge. Part of this difficulty stems from the problem of how to classify green chemistry.

Should we think of the green chemistry movement in terms of a scientific movement? As a movement, green chemistry shares few of the defining characteristics of a SIM. Yet, if it cannot be called a scientific movement, how else should we refer to it? I argue that we have little choice but to call it a scientific movement—even if that requires a bending of the rules a laid out by Frickel and Gross. Additionally, I think that perhaps the problem lies not so much in calling this a *movement*, but in calling it *scientific*. More to the point, proponents of green chemistry have framed the issues in such a way as to make this a scientific movement, but instead the core issues belong more appropriately within a broader social movement that requires some techno-scientific assistance from those who might call themselves green chemists. Thus, the problems of the movement, whatever kind if might be, can be summed into those concerning audience and framework. I'll conclude with some thoughts on how these aspects might be reconsidered.

Frickel and Gross' first proposition concerning the emergence of a SIM looks at the role of high-powered elites in the creation of rival fields that lead to collective action and organizing. They note: "A SIM is more likely to emerge when high-status intellectual actors harbor complaints against what they understand to be the central intellectual tendencies of the day" (2005, p. 209). After all, as Kuhn has noted ([1962] 1996), and others have demonstrated,[9] changes from within scientific communities often come from those with the least to lose—namely those in power, and their students. Thus, as Frickel and Gross put it: "generally speaking, older intellectuals who occupy prestigious positions (often in prestigious departments) as well as their younger protégés who will be in the best position to lead a SIM" (p. 211). They include a number of cases in which these requirements have been met with success, and others where they have not been, leading to a failure to overcome "the weight of disciplinary authority" (p. 213). With respect to the green chemistry movement, this requirement clearly stands neglected. The green chemistry program initially emerged out of the U.S. EPA—not out of any academic unit, let alone a prestigious one. And the leaders of the movement hail from a variety of institutions, but none from a particular place of prominence. With the exception of a *very* few, those involved in the field are almost all young. And while many of the proponents themselves have good academic pedigrees, there has been little success in implementing anything

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[9] See, for example, Hufbauer (1982).

along the lines of serious discussions of green chemistry within top research institutions.

I think that the issue of having high-status people associated with the field ranks low in overall concerns for green chemistry—or at least ought to rank low. I agree with Frickel and Gross that having these sorts of individuals around to support a movement proves useful, but I don't believe it is necessary. In particular, the case for green chemistry involves numerous general issues found within the chemical sciences as a whole—issues that are unique to these sciences. For instance, chemistry is linked to a vast industrial complex, as well as their unique practices involved in the production of new objects in the world. This might be why the first proposition does not fit as neatly as it perhaps could. What the green chemistry movement lacks in institutional backing from academics, it has certainly tried to make up for with backing from the chemical industry, and to a smaller extent the federal government.[10] And certainly a case could be made for chemical companies, and not academic laboratories, driving innovation in the chemical sciences over the last century. However, in this case a new set of problems emerges. While the chemical industry (in partnership with the academy and the government) could make a push for a scientific movement, the values embodied in this type of movement would differ considerably from one centered within a different social institution. Thus, high-status

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[10] Relatively small government involvement, however, seems to be unique to the situation here in the U.S. rather than in many of the other countries now practicing green chemistry. Little work on these comparisons currently exists, but Alistair Iles is currently conducting case studies comparing the U.S., the U.K., and the EU, as well as an examination of the state of California.

individuals might be replaced by high-status companies, but to what end? And in this case, a green chemistry guided by academics leads to a very different place than a green chemistry guided by CEOs, CFOs, CTOs, and others within the engineering-managerial class.

Frickel and Gross' second proposition returns us to this issue of the structure within which a SIM operates. Like other social support systems, the structure a SIM constructs and operates within must provide necessary resources for the movement (and its proponents and adherents) to continue with their work. In other words, "a SIM's success is dependent on its capacity to help scientists and intellectuals collectively 'get by' given the everyday life circumstances they face" (p. 213). These circumstances come down to access financial resources and places for publication through three important avenues: opportunity for employment; intellectual prestige; and organizational resources (pp. 214ff). Despite the fact that green chemistry has been in existence—in one form or another—for roughly 15 years, some of these aspects of institutional support remain difficult to gauge. It has yet to be determined, in a significant way, whether or not those trained in green chemistry will have access to the same sorts of professional and career development as their peers in traditional chemical sciences. With John Warner's lab at the University of Massachusetts, Lowell and Terry Collins' lab at Carnegie Mellon University, we may now be on our way to finding answers to these questions. The other aspects of institutional support might be slightly easier to judge, but they also present some of the problems mentioned earlier with respect to the unique structure of the chemical sciences.

Publication venues for green chemistry research seem to be readily available. The work seems generally well accepted within traditional journals of the field—with the understanding that the work in green chemistry speaks to that particular specialty.[11] Proponents have also succeeded in establishing their own journal, *Green Chemistry*, which recently shifted from published 6 issues per year to publishing monthly. Funding, however, remains a different issue. The green chemistry program was initially funded by a small number of seed grants offered through a joint program of the NSF and EPA, which resulted in the conference and papers found in *Benign by Design*. However, in the decade since, few if any funds have been forthcoming from the federal government explicitly designated for research into green chemistry. This has left those that would be green chemists struggling to fit their work within the institutional structures that already support them. Situating green chemistry research within current funding structures in academic, government, and industrial labs leaves these activities vulnerable and potentially prone to manipulation by structural forces. That is, green chemistry in these contexts ceases to become green chemistry and instead becomes green chemistry in the service of something else. The concerns I raise above with respect to the vulnerability of green chemistry activities to the powers that be only become more manifest when research funding becomes permanently tied to these external structures. It is for this reason that Woodhouse (2004) argued in his testimony before the House Science Committee that green chemistry requires its own funding sources for independent research. Until those lines

[11] Given the institutional make-up of green chemistry and its desire to show the relevance of all fields of chemistry to green chemistry (and vice versa), this has not been difficult.

are established, green chemistry can only be carried out under the auspices of the current structure that it hopes to alter.

Third, despite the difficulties of proponents of green chemistry to establish their own institutional frame within which to work, there has been a great deal more success in securing what Frickel and Gross refer to as “micromobilization contexts” in their efforts to establish a more solid community (2005, pp. 219ff). Drawing on social movement literature,[12] the authors term micromobilization contexts the places where members of the movement community have the opportunity engage in sustained contact with one another and to recruit new members. Proponents of green chemistry have created a myriad of opportunities for this type of organization. The summer of 2006 will bring with it the Tenth Annual Green Chemistry and Engineering Conference as well as the Eighth Green Chemistry Gordon Research Conference. The American Chemical Society (through the Green Chemistry Institute) has also run a number of Green Chemistry Summer School Programs (three as of 2005 with a fourth scheduled for 2006) for introducing graduate students and recent graduates to the field. And many of the core proponents of the field work tirelessly to promote some aspect of the field, whether in speaking engagements, publications, organized symposia at other national meetings, or outreach.

However, while the efforts made to expose new people to green chemistry are extensive, as I indicated in the previous chapter, retention of members may be a larger issue of concern here. The Gordon Research Conferences, for example, have been consistently well attended, but the rate of turnover has been very high. With

[12] See McAdam, McCarthy, and Zald (1996).

the exception of a handful of individuals, people seem to leave these meetings and not return. My experience at the 2004 conference suggests that this is rooted in two problems. First, there seems to be no clear vision for the field. Rather than taking part in cutting edge research, many people seemed to express concern over the level of ordinariness present at the conference. Again, it appeared to me that most people attend because they have a true passion for what they believe the mission of the movement to be. However, this enthusiasm does not carry through the conference. Second, there seems to be little consensus on what the scope of green chemistry ought to be. The principles help hold some things together, but when it comes to making actual decisions about actual cases—for example the Chlorine Sunset debate mentioned above, or the explicit inclusion of environmental endocrine disrupters—no one seems able to commit or comment one way or another. This seems to hint at a larger leadership crisis, as well as a problem of where institutional support comes from for the movement. Should we be surprised if the green chemistry movement does not actively support the Chlorine Sunset Policy or open debate and research into the effects of endocrine disrupting chemicals in the environment?

Frickel and Gross' final proposition also provides hints about some larger issues that green chemistry, viewed as a movement, must struggle with if it is to succeed in mobilizing the masses and maintaining momentum. "As collectives," the authors note, "social movements come together not simply through recognition of grievances arising from objectively similar material or the shared social locations of movement actors, but also around common understandings of the nature and significance of those conditions and locations, as well as shared social values and broader worldviews" (p.

221). Movements require a common and shared identity. In previous chapters, especially chapter 3, I discussed how this process worked in the context of the green chemistry movement, demonstrating, among other things, how proponents of the field shaped the way things appear to those inside and outside the temporarily drawn boundaries. Frickel and Gross claim that these sorts of constructions take place along four lines, many of which have already been explicitly addressed. These include the rhetorical constructions of 1) intellectual identity, shared by individuals in the movement; 2) the movement's collective identity; 3) historical origins; and 4) the movement's relationship to various competitor movements. These rhetorical strategies perform the important function of framing the movement—its motivations, foundations, trajectory, and goals—for a specific audience that it hopes to win over in its struggle.

But the framing of green chemistry, it seems to me, has proven to be the largest impediment to its growth and success. As I showed in chapter 2, proponents of green chemistry frame the historical background of the movement by merging the histories of the environmental movement with the history of the chemical sciences. The history that emerges out of this confluence is not only cumbersome, but also, more importantly, it fails to resonate with those in the movements' target audience—chemists. The "frame-translation"[13] attempts to rethink environmental problems in terms of chemical problems and solutions. But the translation does not work. This could be the consequence of two different problems. Either the story (the frame) needs to be adjusted to more accurately reflect the interests of the target audience,

[13] See Frickel (2004) and Frickel and Gross (2005).

or a serious rethinking of the audience needs to be undertaken. Consider, first, the story frame: green chemists who wish to continue to target other chemists could benefit from a number of strategic shifts. The movement as currently framed does not constitute a radical rethinking of chemistry. Rather it exemplifies what Frickel and Gross call “institutional drift” (2005). That is, the movement does not provide enough of a difference to create any sustained momentum—needed to garner support in the form of new (and lasting) recruits and resources. Furthermore, the history of the movement, which effectively frames the group, operates by internalizing issues from other groups rather than translating them into something that is both familiar and new. Simply retelling the stories told in environmental circles and placing green chemistry as the capstone does not create the necessary grounding from which to operate because it fails to demonstrate a unique frame that constitutes green chemistry.

Yet further, proponents of green chemistry need to understand the larger context within which they happen to be operating right now. The greater chemical enterprise already finds itself in the midst of an identity crisis. Several of the presenters during the “Symposium on Sustainability” at the August 2005 meeting of the American Chemical Society spoke to the disappearance of the discreet identity of the chemist. And just last year, the editor of *Chemical and Engineering News*, the weekly publication of the ACS, suggested that the society change its name to the “Society for Molecular Sciences & Engineering” (Baum 2004b). Baum’s statement reinforces broader shifts within the chemistry communities to change the definition of chemistry to reflect its multidisciplinary nature.[14] Three weeks after Baum's editorial, Stephen Ritter wrote that perhaps chemistry is evolving back into the multi-disciplinary field that it once was (2004). These pieces followed an earlier editorial by Baum in which he expressed alarm about the "disturbing trends" characterizing discussions about the future of chemistry and chemistry departments in major universities across the nation that suggest that many might be considering dividing up what used to be called the chemical sciences into their physical and life science components, thus ending any formal training in what might have once been simply called 'chemistry' (2004a). These ideas, even if exaggerated for effect in these editorials, reflect a greater debate that is taking place within the chemical sciences about where they are headed, and what they should do about it. The problem for green chemists in this case is not that they don't fit within the debate—indeed, they could very well position themselves to take advantage of these shifts. Instead, the problem is that many see green chemistry, with its multi-/inter-/cross-disciplinary research as precipitating these changes within chemistry, and thus accelerating the rate at which chemists will disappear. If proponents of green chemistry are to continue to target this group, they will have to take these features of the current landscape into account.

However, green chemists might also consider rethinking just who their audience ought to be. As a multi-/inter-/cross-disciplinary endeavor, green chemistry has the opportunity to use its focus on the technical aspects of broader environmental problems that involve chemicals (which is nearly all of them) to work in conjunction

[14] See for instance the *ACS Strategic Plan* for 2004-2006.

with (not instead of) other groups working to sort out the complex systems involved in the creation of these problems. The current resistance to discussing extra-technoscientific aspects of environmental issues leaves them out of this debate, does not work with their target audience, and leaves them vulnerable to cooptation into current structures that are able to exert influence and power over them precisely because they have currently failed to present the green chemistry movement as offering a radical departure from the norm. Working to recognize the social, political, and ethical dimensions of the greater problems that we currently face—and not just the naïve economics of the current techno-scientific networks—could create a more formidable (and possibly even successful?) coalition for dealing with and not just discussing current crises.

These considerations, however, all focus on green chemistry *the movement*, and not green chemistry *the community*. This is because the term 'green chemistry' is refers to a fractured idea, applying to both an organizational movement with many of the characteristics of other movements, and also a community of practitioners that practices green chemistry in one form or another in their everyday work as chemists. practices. This division, I believe, might cause scholars to rethink exactly what is meant in their discussion of scientific movements. While the green chemistry case might not fit neatly within the framework offered by Frickel and Gross, the lessons here offer an opportunity to expand and explore the possible connections for using social movement theory within science studies.

What I hope to have provided here in the dissertation is more than a summary of the green chemistry movement. Green chemistry, its problems and promises, exists within a much broader set of issues concerning technocracy, expertise, and relations between society, science, technology, and the environment. It is one of many movements—scientific, political, social, technical—aimed at addressing what has become a set of increasingly difficult to ignore calamities facing our global ecosphere. In this work, I hope to have created an opportunity for further discussion, elaboration, communication and ultimately transformation.

The chemical sciences, while not alone, are an important focal point for change. But to understand what is at stake, we must have a clear idea of how we have arrived at this moment. This is one reason I have placed so much emphasis on the history offered by the green chemistry movement, and why I believe the movement cannot succeed as currently configured. To understand what green chemistry is trying to change, we need a more detailed and in-depth understanding of the evolution of chemical practices. Twenty-first century chemistry is littered with nineteenth century artifacts—technological and otherwise. To re-create chemistry, even if this new chemistry is no longer known by this name, requires the disentangling of old connections, and the careful and purposeful establishment of new ones. This is the path towards a truly green chemistry.

I take up this work because it is of the utmost importance to do so. As a scholar in science studies, I feel an obligation to use the tools of critique to understand the situation of our contemporary world. But I also understand this obligation to include critical interventions into the places where problems reside. As a student of these critical studies, I've learned to crack open boxes—literal, metaphorical, theoretical—to lay bare the contents. But I have also learned that this cannot happen without a cracking open of myself. I exist with, within, and alongside these boxes. My study of green chemistry is as much a study of myself, my field of science studies, and the world within which I live. It is not only an attempt to intervene in green chemistry, but in the world. Working at the limits of ourselves to understand the present requires us to confront the past and the future simultaneously. But it is here, as Foucault (1997, p. 316) reminds us, where change is possible: "I mean that this work done at the limits of ourselves must, on the one hand, open up a realm of historical inquiry and, on the other, put itself to the test of reality, of contemporary reality, both to grasp the points where change is possible and desirable, and to determine the precise form this change should take."

Appendix A: Conferences

The following is a comprehensive list of conferences and workshops found on the Green Chemistry Institute's website, which was compiled in Fall of 2005. Additions and updates can be found at:

http://www.chemistry.org/portal/a/c/s/1/acsdisplay.html?DOC=greenchemistryinstitute\conferences.html.

Note that many of these conferences are not explicitly concerned with Green Chemistry, but have sections, panels, or symposia within them that are related (or said to be related) to the overall project. See Chapter 3 for discussion of these conferences and their relation to the Green Chemistry community.

1996	1st Green Chemistry Gordon Conference, "Environmentally Benign Organic Synthesis"
1997	2nd Green Chemistry Gordon Conference, "Environmentally Benign Organic Synthesis"
1998	Vision 2020 Workshop: Renewables
1998	1998 Florida Environmental Chemistry Conference
1998	OECD Workshop on Sustainable Chemistry
1998	3rd Annual Green Chemistry Gordon Conference
1998	2nd Annual Green Chemistry and Engineering Conference, "Global Perspectives"
1998	Vision 2020 Workshop: The Role of Polymer Research in green Chemistry and Engineering
1998	Vision 2020 Workshop: Supercritical Solvents
1998	The Role of Chemical Industry and Chemical Research for the Eco-Sustainable Development of the Mediterranean Area
1999	SUSTECH 10 Conference, Colloquium on Sustainable Chemistry

1999	Clean Products and Processes II
1999	218th American Chemical Society National Meeting[1]
1999	Towards Sustainable Product Design #4
1999	4th Annual Green Chemistry Gordon Research Conference
1999	3rd Annual Green Chemistry and Engineering Conference, “Moving Towards Industrial Ecology”
1999	Eco-Design and Supply Chain Management
1999	2nd International Workshop on Green Chemistry in China
1999	217th American Chemical Society National Meeting
1999	IFPAC '99: 13th International Forum of Process Analytical Chemistry
2000	Pacifichem 2000
2000	ACS Midwest Regional Meeting[2]
2000	Towards Sustainable Product Design, 5th International Conference
2000	2twentieth American Chemical Society National Meeting[3]
2000	5th Green Chemistry Gordon Conference
2000	4th Annual Green Chemistry and Engineering Conference[4]
2000	ACS New England Regional Meeting (NERM 2000)[5]
2000	Canadian Society for Chemistry National Meeting
2000	2nd Green Chemistry Conference
2000	Green Industrial Applications of Ionic Liquids, A NATO Advanced Research Workshop
2000	219th American Chemical Society National Meeting[6]
2001	CUSTOM (Center for Uncertain Systems: Tools for Optimization and Management) Mini Conference
2001	2nd European Meeting on Environmental Chemistry
2001	12th Annual International Workshop on Solvent Substitution and the Elimination of Toxic Substances & Emissions
2001	The Role of Precaution in Chemicals Policy
2001	3rd Green Chemistry Conference
2001	2nd National Symposium on Green and Sustainable Chemistry

2001	157th 2YC3 Conference (Western)
2001	American Chemical Society Western Regional Meeting[7]
2001	1st International Symposium on Tools of Sustainability
2001	1st meeting of the Green Chemistry Network of Spain
2001	First Baltic Symposium on Environmental Chemistry
2001	IUPAC-OECD Workshop on Green Chemistry Education[8]
2001	Post-Graduate Summer School on Green Chemistry
2001	EuropaCat V, 5th European Congress on Catalysis
2001	222nd American Chemical Society National Meeting[9]
2001	Green Engineering: Sustainable and Environmentally Conscious Engineering
2001	Green Chemistry: the Next Technology Wave
2001	Green Chemistry in Education Workshop
2001	Green Chemistry in Education
2001	World Chemistry Congress
2001	5th Annual Green Chemistry and Engineering Conference, "A New Generation of Professionals: A New Generation of Processes"
2001	DOE Pollution Prevention Conference (P2 '01)
2001	CHEMRAWN XIV World Conference: Toward Environmentally Benign Processes and Products
2001	4th International Green Chemistry Symposium in China
2001	1st Massachusetts Green Chemistry Symposium, "Profiting from Pollution Prevention"
2001	221st American Chemical Society National Meeting
2001	Green Chemistry: Sustainable Products and Processes
2001	International Symposium on Catalysis and Fine Chemicals 2001 (C&FC 2001)
2001	Green Chemistry Workshop Regina
2001	Green Chemistry Workshop Saskatoon
2001	International Symposium on Green Chemistry

2002	Sustainable Construction Practices: Concrete and Asphalt
2002	4th IUCT green Chemistry Conference
2002	ReachOut - Chemicals from Crops: The Green and Sustainable Option?
2002	Green Solvents for Catalysis: Environmentally Benign Reaction Media
2002	Research and Commercial Opportunities for Green Chemistry
2002	Process Innovation and Process Intensification (PI)2 Conference
2002	Gordon Research Conference on Green Chemistry
2002	5th Post-Graduate Summer School on Green Chemistry
2002	Green Chemistry Network Meeting: Oxidation
2002	8th FECS Conference on Chemistry and the Environment
2002	224th American Chemical Society National Meeting
2002	17th Biennial Conference on Chemical Education
2002	Green Chemistry in Education Workshop
2002	IUPAC-ICOS-14, 14th International Conference on Organic Synthesis
2002	6th Annual Green Chemistry and Engineering Conference "Meeting Global Challenges Through Economic and Environmental Innovations"
2002	Responsible Care Conference
2002	223rd American Chemical Society National Conference
2002	National Pollution Prevention Roundtable Spring Conference
2002	Workshop on Sustainability and Industry: Energy, Material Consumption, and Human Behavior
2002	Italian Australian Technological Innovations Conference and Exhibition (IATICE), Workshop on Green and Sustainable Chemistry
2002	Ionic Liquids for Green Chemistry
2002	Application of Analytical Chemistry to Green Chemistry
2003	Indo-US S&T Forum Workshop on Green Chemistry
2003	Crystal Faraday's 3rd Research Workshop: Alternative & Renewable Feedstocks
2003	5th IUCT Green Chemistry Conference
2003	Super Green 2003; The 2nd International Symposium on Supercritical

	Fluid Technology for Energy and Environment Applications
2003	European Chemicals Experts Visit the United States
2003	National Chemistry Week, "Earth's Atmosphere and Beyond"
2003	7th International Conference on Carbon Dioxide Utilization
2003	Second Brazilian Symposium on Environmental Engineering
2003	SETAC Asia/Pacific Conference 2003: Solutions to Pollution
2003	226th American Chemical Society National Meeting
2003	6th Green Chemistry Summer School
2003	54th Annual Meeting of the International Society of Electrochemistry (Role of electrochemistry in the sustained development of modern societies)
2003	EuropaCat VI, 6th European Congress on Catalysis
2003	39th IUPAC Congress and 86th Conference of the Canadian Society for Chemistry (w/ focus on interdisciplinarity)
2003	Green Chemistry in Education Workshop
2003	Green Chemistry Experimental Workshop
2003	Pan-American Advanced Studies Institute on Green Chemistry
2003	First Conference on Green Chemistry in Poland
2003	7th Annual Green Chemistry and Engineering Conference
2003	"Accelerating the Adoption of Sustainable Technologies: The Role of the federal Government"; AIChE, NIST, GCI, EPA
2003	Water and Sustainable Development: Opportunities for the Chemical Sciences
2003	Ionic Liquids: New Materials for Nanotechnology, Electrochemistry and green Chemistry
2003	ACHEMA World Forum for Process Industries; Symposium on a Green and Sustainable Chemistry"
2003	International Symposium on Green Chemistry - Use and Applications of Renewable Materials
2003	ECI Conference, "Green Engineering: Defining the Principles"

2003	Crystal Faraday Partnership (Green Technology for the Chemical and Allied Industries); Workshop: "Heterogeneous Catalytic Hydrogenation for Organic Synthesis"
2003	Responsible Care Conference: Celebrating 15 Years of Excellence
2003	The Green Chemistry and Engineering Conference: Practical Applications in Coatings, Resins, and Plastics
2003	Chemists Celebrate Earthday
2003	6th International Symposium on Catalysis Applied to Fine Chemicals
2003	Crystal Faraday Partnership (Green Technology for the Chemical and Allied Industries); Workshop: "Research Challenges in Speparation Technologies"
2003	AIChE Spring National Meeting and Process Industries Exposition
2003	225th American Chemical Society National Meeting
2003	Advanced Course on Biocatalysis
2003	1st International Conference on Green and Sustainable Chemistry
2003	3rd National Conference on Science, Policy, and the Environment, "Education for a Sustainable and Secure Future"
2004	6th Green Chemistry Conference
2004	Industrial Applications of Renewable Resources
2004	2nd Annual EU Sustainable Chemicals Management Conference
2004	Green Solvents for Synthesis
2004	Profitable Sustainability: The Future of Business
2004	7th Green Chemistry Summer School
2004	9th DCE/FECS Conference on Chemistry and the Environment
2004	EPA Hosted CAPE-OPEN meetings
2004	228th American Chemical Society National Meeting
2004	11th International Symposium on Supercritical Fluid Chromatography, Extraction, and Processing
2004	ACS-PRF Summer School on Green Chemistry
2004	Green Chemistry in Education Workshop

2004	18th Biennial Conference on Chemical Education
2004	13th International Congress on Catalysis
2004	6th International Conference on Catalysis in Membrane Reactors
2004	Gordon Research Conference on Green Chemistry
2004	8th Annual Green Chemistry and Engineering Conference
2004	Chemistry for Water and CHEMRAWN XV
2004	Sustainability and Beyond: Business Leadership Through Innovation and Design
2004	Workshop on Innovative Chemistry in Cleaner Media
2004	18th Canadian Symposium on Catalysis
2004	Responsible Care Conference and Expo, Certifying Our Future
2004	AIChE 2004 Spring National Meeting: Green Chemical Engineering
2004	Ionic Liquids: A Road-map to Commercialisation
2004	The World Congress on Industrial Biotechnology and Bioprocessing
2004	Sustainable Chemistry in the Pharmaceutical Industry (Student Workshop Sponsored by Pfizer)
2004	227th American Chemical Society National Meeting
2004	Ionic Liquids Workshop
2004	6th International Exhibition of Chemistry, Environment, and Water
2005	Ionic Liquids: Background, State-of-the-Art, and Applications
2005	229th American Chemical Society National Meeting
2005	MSI Engineering Sustainability Conference
2005	ACHEMAMERICA2005: Novel Processes for Refining, SynFuels and Petrochemicals
2005	7th International Symposium on Supercritical Fluids
2005	7th International Symposium on Green Chemistry in China
2005	Knowledge-based Materials and Technologies for Sustainable Chemistry
2005	2nd International Conference on Green & Sustainable Chemistry
2005	9th Annual Green Chemistry & Engineering Conference
2005	1st International Symposium on Fluorous Technologies

2005	230th American Chemical Society National Meeting
2005	7th International Symposium on Catalysis Applied to Fine Chemicals
2005	Pacifichem
2006	231st American Chemical Society National Meeting
2006	232nd American Chemical Society National Meeting

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Curriculum Vitae

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Education

Ph.D. Science & Technology Studies. Virginia Polytechnic Institute and State University, Candidate. 2006. Dissertation: "Creating Green Chemistry: Discursive Strategies of a Scientific Movement."

M.S. Science & Technology Studies. Virginia Polytechnic Institute and State University. 2002. Thesis: "Instruments and Domains of Knowledge: The Case of Nuclear Magnetic Resonance Spectroscopy, 1956-1969."

B.S. Chemistry. Saint Vincent College. 1999. Thesis: "The Attempted Synthesis of 3-benzyl-1,5,6,8-tetraphenyl-9,3-oxazatricyclo[3.3.1.0^{2,4}]nonan-7-one."

Professional Experience

Managing Editor. *Perspectives on Science: Historical, Philosophical, Social*. MIT Press. Summer 2002 – January 2006.

Instructor. *Humanities, Technology, and the Physical Sciences*. Spring 2002. Special topic: Creating Chemistry and Chemists.

Graduate Teaching Assistant. *Introduction to the Humanities, Science, and Technology*. Fall 2001.

Graduate Teaching Assistant. *Judaism, Christianity, Islam*. Spring 2001.

Graduate Teaching Assistant. *Asian Religions*. Fall 2000.

Teaching Assistant. *Organic Chemistry Lab*. Spring 1999.

Publications

"Deciding the Future of Nanotechnologies: Legal Perspectives on Issues of Democracy and Technology." In *Discovering the Nanoscale*. Edited by Davis Baird, Alfred Nordmann, and Joachim Schummer. IOS Press: Amsterdam (2004).

"Negotiated Identities of Chemical Instrumentation: The Case of Nuclear Magnetic Resonance Spectroscopy, 1956-1969." In *Chemical Explanation: Characteristics, Development, Autonomy*. Edited by Joseph E. Earley. *Annals of the New York Academy of Sciences*, volume 988. The New York Academy of Science: New York (2003).

Conference Presentations

American Society for Environmental History. "Uncertainty, 'Data Quality', and Regulation: The Curious Case of Atrazine." St. Paul, MN. March 2006.

Society for the Social Studies of Science. "(Green) Washing the Chemical Industries: Regulation, Responsibility, and the Emergence of the Green Chemistry Movement." Pasadena. October 2005.
Society for the Social Studies of Science. "What is a 'Green' Chemist? Searching for Identity within the Milieu of Chemistry." Paris. August 2004.
Science and Technology in Context. "On the Impossibility of Being 'Green': Reflections and Recommendations for Rethinking the 'Green Chemistry Initiative'." American Association for the Advancement of Science. April 2004.
Imaging and Imagining Nanoscience and Engineering. "To See is to Know; To Know is to Control: Virtual Reality, Molecular Modeling, and the Politics of Visualization" (with Brent K. Jesiek). University of South Carolina. March 2004.
History of Science Society. "Selling Science, Constructing Gender: The Role of Chemical Instrument Advertisements in the Construction of Gender in the Laboratory" (with Maria Rentetzi). Cambridge, MA. November 2003.
4th International Conference on the History of Chemistry. "Selling Science, Constructing Gender: The Role of Journal Advertisements in the Reflection and Reification of Gender in the Chemical Laboratory" (with Maria Rentetzi). Budapest. September 2003.
Discovering the Nanoscale. "What's Law Got to Do with It? Why looking at the law might offer an alternative perspective to examining the introduction of nanotechnology into our societies." University of South Carolina. March 2003.
Society for the History of Technology. "Reading Between the Spectral Lines: A Look at the Co-Production of Nuclear Magnetic Resonance Spectrometers by Varian Associates and Organic Chemists, 1956-1969." Toronto. October 2002.
International Society for the Philosophy of Chemistry. "Changing Identities and Shifting Domains: The Development of Nuclear Magnetic Resonance Spectroscopy, 1956-1969." Georgetown University. August 2002.
Mephistos 2002. "Rethinking the Relationship between Theory and Practice: A Metaphorical Structure for Metaphors." Virginia Tech. March 2002.
17th Annual Conference of the National Association for Science & Technology Studies (NASTS). "Against a Model of Diffusion: Using Metaphors to Teach Analytical Chemistry." Baltimore. February 2002.
International Society for the Philosophy of Chemistry. "A Tale of Two Experiments: The French, the Germans, and the Role of Crucial Experiments in the Acceptance of Lavoisier's Chemistry." Loughborough University. August 2001.
Exhibiting STS. "Accepting Lavoisier's Chemistry: The Role of Crucial Experiments." Virginia Polytechnic Institute and State University. April 2001.
American Chemical Society National Convention. "The Attempted Synthesis of a Tropane Alkaloid Analog." Anaheim. March 1999.

Awards and Grants
Gordon Cain Fellowship. Chemical Heritage Foundation. 2006-7.
Charles C. Price Fellowship. Chemical Heritage Foundation. 2005-6.
Cain Research and Travel Grant. Chemical Heritage Foundation. 2004.
Travel Grant. Chemical Heritage Foundation. 2003.

Course Development

Co-Developer (with Steve Gravelle) of a new “chemistry in context” component for use in General Chemistry courses. Saint Vincent College. 2002-present.

Co-Developer (with Benjamin R. Cohen) of *Humanities, Technology, and the Physical Science: Creating Chemists and Chemistry* (HST 2354). 2001.

Co-Author (with Benjamin R. Cohen) of *Interdisciplinary Studies Course Module: “Industry and the Environment”* (IDST 1114). 2001.

Service Activities

Co-chair of STS Thursday Lunch Discussion Speaker Series. 2001-2005.

Organization and Program Committees. *STS (R)Evolutions*. 2005.

Organization and Program Committees. *Technologies/Moralities: the Ethical Grammar of Technological Systems*. 2003.

Organization and Program Committees. *Mephistos 2002*.

Participant in *Choices and Challenges Program*. Virginia Tech. 2001-4.

Graduate Student Representative to Center for Interdisciplinary Studies Steering Committee. 2002-3.

Master’s Representative to the STS Policy Committee. 2001-2002.

Representative to the Graduate Student Association. 2000-2, 2003-5.

Work Experience

Aluminum Company of America (ALCOA). Research Technician. August 1999-August 2000.

Monastery Run Wetlands Restoration Project. Tour Guide. Summers 1999, 2000.

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