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From Radioactive Fallout to Environmental Critique : : Ecology and the Politics of Cold War Science

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From Radioactive Fallout to Environmental Critique: Ecology and the Politics of Cold War Science

A dissertation submitted in partial satisfaction of the requirements for the degree of Doctor of Philosophy

in

Sociology (Science Studies)

by

Brian Sewell Lindseth

Committee in charge:

Professor Charles Thorpe, Chair
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2013

The Dissertation of Brian Sewell Lindseth is approved, and it is acceptable in quality and form for publication on microfilm and electronically:

Chair

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2013

DEDICATION

This dissertation is dedicated to my parents, Maxine and Arnold Lindseth. Their love and support means more to me than I can ever express.

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ABSTRACT OF THE DISSERTATION

From Radioactive Fallout to Environmental Critique:
Ecology and the Politics of Cold War Science

by

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Doctor of Philosophy in Sociology (Science Studies)

University of California, San Diego, 2013

Professor Charles Thorpe, Chair

This work explores the question of the place of science in society by focusing on two cases in which ecology as a science entered into very different kinds of political projects in the cold war period. The first case hinges on the usefulness of ecology to the Atomic Energy Commission's effort to manage radioactive fallout as a problem that was both epistemic and political in nature. In this alliance with the cold war state, ecology benefited from an unprecedented level of external funding as well as access to experimental technology such as radioisotopes and Geiger counters. As a result ecology was introduced to the world of 'big science,' and radiation ecology emerged as a new specialty. Along with access to funding and technology, however, the state was often also interested in asserting a level of control over the research agendas of ecologists, and ecologists devised ways of asserting the autonomy of their discipline in order to maintain control over their research.

The second case centers on the relationship between ecology and environmentalism as a social movement. With the environmental movement came a large

public audience interested in what ecologists had to say about matters of politics and ethics. While many ecologists held this interest at arms length, others saw in it the possibility for a new place for science in society. For these ecologists, science should be useful to the problems of society. Like the tension between different forms of environmentalism, however, ecologists differed on how science should be useful. For many, this usefulness meant providing expert advice to political leaders, while for others, it meant entering into a radical oppositional relationship with the place of technology in cold war culture.

In both of these cases, ecologists challenged norms of value neutrality associated with the organization of academic labor into highly specialized disciplines in the late 19th and early twentieth centuries. In doing so, they confronted challenges to their professional autonomy but also experienced opportunities to redefine both themselves as scientists and the place of science in society.

Chapter 1. Introduction: the Place, and the Politics, of Science

I. Introduction

What is the place of science in society? To what extent is science, or should science be, autonomous from the concerns of the rest of society? Should the professional pursuit of truths be insulated from the conflicting demands of the world—from politics and power and the pursuit of wealth? Or should science be useful to the rest of society? And if science should be useful, to what ends—the welfare of the people, the ends of the state or economic gain—and on what grounds?

The question of the place of science in society is also a question about the proper role of the scientist. If science is something apart from politics, then it follows that scientists should not also be politicians nor engage, as scientists, in the affairs of the world. Perhaps instead they should restrict their research to questions of fact emerging from within their discipline and address their findings to other scientists in their specialty. On the other hand, if the direction of scientific research is handed down by the state or determined democratically, then scientists might be driven to engage in research guided by the goals of the state or public welfare and address their findings to different audiences.

By examining ecology in the U.S. during the period from the early 1950s through the early 1970s, we can explore the ways in which science became useful to nonscientists engaged in two very different political struggles. As we shall see, these political struggles presented opportunities and challenges for specific scientists seeking to define their role as scientists in different ways. The close relationship between ecology and the environmental movement in the 1960s and 1970s provides an opportunity for examining efforts to position ecology as part of an effort to change society and to re-work the relationship between humans and nature. In these years ecologists stepped outside of their roles as academic specialists in order to position their science as offering insight for questions emerging from outside of their discipline. The relationship between ecology as a science and contemporary environmentalism as a social movement provides fertile ground for investigating tensions between the role of the scientist as specialist and the scientist as critic as well as tensions between efforts to define science as apart from the concerns of society or as part of a political project to change society. It also provides an excellent opportunity for exploring questions centering on the relationship between science and social movements more generally.

Although the relationship between ecology and the environmental movement is well known, some ecologists also enjoyed a close relationship with the cold war state. Commissioned by the Atomic Energy Commission to study radioactive matter, these ecologists enjoyed a level of funding and access to specialized tools and knowledge that introduced the young discipline to a new way of practicing research as a form of "big science." As a result a new specialty named radiation ecology was formed, and new scientists and new centers for research developed in the 1950s and early 1960s. Here, ecological research became useful to the Atomic Energy Commission as part of a larger political culture centered on the perceived needs of national security and the cold war conflict with the Soviet Union. In addition to the benefits of unprecedented levels of funding and access to new tools and field sites, this alliance with the cold war state also presented certain challenges to ecologists endeavoring to define the logic guiding their research as the logic of their discipline--autonomous from the concerns of society. In the decades following World War II, the story of the changing political contexts of ecology is one of dramatic contrasts. Few disciplines have been drawn in opposite directions in as few years as ecology was from the early 1950s through the early 1970s. These two cases model very different places for science in society as well as two very different roles for scientists.

This dissertation represents, in part, a response to the call by Scott Frickel and Kelly Moore for a more politically focused sociology of science and the effort to, "seek new answers to an old question: what's political about science?"[1] In her work *Disrupting Science*, Moore addresses this question by foregrounding the ways that alternative scientific roles have challenged a strict division between science and politics or fact and value.[2] Against the cold war backdrop of science that often served the military and a state focused on war, Moore investigates three case studies in which scientists questioned the military industrial complex and explored ways of being scientists that went beyond a commitment to the pursuit of truth in highly specialized professional communities of fellow scientists. In engaging with "the moral and political problems of their day, not only as 'experts' whose authority is based on technical knowledge, but as moral individuals and/or movement activists" these scientists were also "redefin[ing] relationships between fact and value, between politics and science, and between expert and citizen."[3]

Here I will explore the politics of science by building on Moore's emphasis on how specific scientists can embody and improvise on scientific roles. In addressing

1 Scott Frickel and Kelly Moore, "Prospects and Challenges for a New Political Sociology of Science," in *The New Political Sociology of Science: Institutions, Networks, and Power,* (Madison: University of Wisconsin Press, 2006), 3. See also Daniel Kleinman, *Politics on the Endless Frontier: Postwar Research Policy in the United States* (Durham, NC: Duke University Press Books, 1995), chapter 1.

2 Kelly Moore, *Disrupting Science: Social Movements, American Scientists, and the Politics of the Military, 1945-1975,* (Princeton: Princeton University Press, 2008), 193-8.

3 Moore, *Disrupting Science,* 198 and 2.

Frickel and Moore's call for a "political sociology of science," I will draw on Max Weber's classic essay "Science as a Vocation," which focuses attention on the role of the scientist and embeds this role in larger scale social and political contexts in which individuals constitute themselves as scientists over the course of their careers.[4] Weber's essay—delivered as a presentation nearly a hundred years ago—has experienced a resurgence of interest and come to occupy a central position for scholars interested in exploring the role of the scientist and the place of science in relation to the nature of late modernity.[5] My analysis will draw on the themes in Weber's essay and contribute to this growing dialogue about the continuing relevance of Weber's ideas for understanding the scientific role in the 20th century.

Counterbalancing Weber's emphasis on the insulation of science from the rest of society, Norbert Elias' notion of "figuration" provides an analytical tool for investigating the ways that science became useful to non-scientists.[6] As I will discuss below, the relationships between ecologists and the cold war state on the one hand and

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4 In positioning my work as building on Frickel and Moore's work, my work implicitly argues for the ongoing relevance of sociological tools and concepts in approaching the practice of science. Frickel and Moore, "Prospects and Challenges for a New Political Sociology of Science," 9. See also Daniel Lee Kleinman, "Science and the World/Science in the World." *Contemporary Sociology* 41, 4 (July 2012): 430-1.

5 Moore, *Disrupting Science*, 2. Paul Rabinow, *Anthropos Today: Reflections on Modern Equipment,* (Princeton, NJ: Princeton University Press, 2003), 96-102. Paul Rabinow, *French DNA: Trouble in Purgatory*, (Chicago: University Of Chicago Press, 1999), 7-10. Steven Shapin, *The Scientific Life: A Moral History of a Late Modern Vocation*. (Chicago: University of Chicago Press, 2008), 11, 45-6, 250-1. Charles Thorpe, *Oppenheimer: the Tragic Intellect,* (Chicago: University of Chicago Press, 2006), xii-xiii, xvi and 4-6. Charles Thorpe, "Violence and the Scientific Vocation." *Theory, Culture and Society* 21, 3, (2004): 60-4. Charles Thorpe, "Disciplining Experts: Scientific Authority and Liberal Democracy in the Oppenheimer Case," *Social Studies of Science*, 32, 4 (2002): 525–562. Charles Thorpe, "Science Against Modernism: The Relevance of the Social Theory of Michael Polanyi," *The British Journal of Sociology* 52, 1 (March 1, 2001): 19, 20- 22, 29 and 33. Shapin draws on "Science as a Vocation" to define the terms of his analysis and mark a shift in the moral status of scientists. See *Scientific Life*, 21, 47, 93, 127, 269, and 305. See also Hackett, Edward J. "Science as a Vocation in the 1990s." *The Journal of Higher Education* 61, 3 (May-June, 1990): 241, 268, 273, and 276.

6 Norbert Elias, "Scientific Establishments," in *Scientific Establishments and Hierarchies* ed. N. Elias. (Dordrecht, Holland: D. Reidel, 1982), 4 and 40-1.

environmentalism on another introduced opportunities, such as funding for research and an increased readership, but also tensions that ecologists had to navigate on a concrete level.

In this chapter, I will introduce the literatures I will draw on and the debates which the rest of the dissertation addresses and to which it contributes. First I will introduce the role of the scientist in terms of Weber's classic work as well as the tools I will draw on to analyze the individual scientist in relation to the politics of the cold war state and environmentalism. Next I will sketch an alternative role of the scientist as an intellectual and argue that Elias' notion of figuration provides a way of conceptualizing the opportunities and challenges that can accompany the political engagement of science. Then, I will provide tools for examining each of my two cases here by reviewing literature on the place of science in relation to the cold war state and on the relationship between social movements and science.

II. The Role of the Scientist

a. Max Weber and the Role of the Scientist as Specialist

In a lecture delivered on November 7th 1917, sociologist Max Weber described the proper place of science in terms of its insulation from the rest of society.[7] Science, he

[7] Although H. H. Gerth and C. Wright Mills date Weber's presentation of "Science as a Vocation" to 1918 in their well read compilation *From Max Weber: Essays in Sociology*--and Lassman and Velody date the talk to 1919, Wolfgang Mommsen as well as David Owen and Tracy Strong date the presentation to November 7, 1917. Gerth, H.H. and C. Wright Mills, *From Max Weber: Essays in Sociology*, (New York: Oxford University Press, 1978), 129. Mommsen, Wolfgang J. *Max Weber and German Politics, 1890-1920*. Translated by Michael Steinberg. Chicago: University of Chicago Press, 1990) 268 n292. Peter Lassman and Irving Velody, "Introduction," in *Max Weber's "Science As a Vocation* edited by Peter Lassman and Irving Velody, xiii-xvii. Boston: Unwin Hyman, 1989), xiii. David S. Owen and Tracy B. Strong. "Introduction: Max Weber's Calling to Knowledge and Action." In *The Vocation Lectures: Science As a Vocation, Politics As a Vocation*, edited by David S. Owen and Tracy B. Strong, (Indianapolis, IN: Hackett Publishing Co, 2004): xix.

argued in “Science as a Vocation,” should be separate from politics and religion and other spheres of society, and scientists should restrict themselves to questions of fact emerging from within their own disciplines. They should avoid approaching their work as providing insight into the question of how people should live, since this is a question of value and cannot be answered scientifically.[8] Nor can a scientist scientifically answer the question of what he or she should be researching or why. A branch of science might be based on a given value—medicine valuing life, for example—but that value must remain outside of the scope of scientific inquiry. It should not be up to a doctor to determine *which* lives to value or *why*. These questions are questions for ethics, not science.[9]

This insulation of science from the rest of society is a key element of Weber's theory of the nature of modernity. While religion might have once provided over-arching narratives promising a meaningful existence, it has been increasingly relegated to one sphere of society among others, such as law, the economy, and science. Each of these "life spheres," Weber argues, "is governed by different laws."[10] While science has played

8 He asked, “Who—aside from certain big children who are indeed found in the natural sciences—still believes that the findings of astronomy, biology, physics, or chemistry could teach us anything about the *meaning* of the world?” Weber, "Science," 142, 150 [emphasis in original].

9 Weber, "Science," 144-5. See David Owen on the importance of science's inability to "ground the presupposition of its own value" to Weber's vision of the place of science in modern society. Owen argues that Weber transfers the problem to the level of the individual whose commitment to become a scientist despite the fact that the value of the practice of science cannot be rationally grounded resolves what otherwise would have been, and was for Nietzsche, a much broader problem. Owen, David, *Maturity and Modernity: Nietzsche, Weber, Foucault and the Ambivalence of Reason,* (New York: Routledge, 1994), 90-1. While the literature on Weber is vast, Bruun offers an influential interpretation of Weber's emphasis on value freedom and the way, for Weber, science cannot scientifically address the values on which it is based. Hans Henrik Bruun, *Science, Values and Politics in Max Weber's Methodology,* (Ashgate Publishing Company, 2007), chapters and 2 respectively. David Owen and Tracy Strong provide a much more concise argument on the centrality of value neutrality to Weber's vision of the proper place of science. Owen and Strong, "Introduction," xxx-xxxii.

10 Max Weber, "Politics as a Vocation." In *From Max Weber: Essays in Sociology*, edited by H.H. Gerth and C. Wright Mills, 77-128. (New York: Oxford University Press, 1978), 123. See Brubaker and Goldman for accessible accounts of the "clash of the value spheres" and Bruun for coverage of the "fundamental conflict between different spheres of ultimate values" in the context of a discussion on Weber's relation to Heinrich Rickert. Rogers Brubaker, *The Limits of Rationality: An Essay on the Social and Moral Thought of Max Weber,* (Boston: Allen & Unwin, 1984), 69-90. Harvey Goldman,

a particularly important role as a “motive force” of disenchantment, it can nonetheless not provide the meaning that religion once did.[11] Efforts to bridge these value spheres—like efforts to find a deeper significance or use for science—represented, for Weber, an immature inability to adjust to the reality of an increasingly fragmented social world.[12] For such reasons, Weber opposes the figure of the scientist to the figure of the prophet:

> Science today is a 'vocation' organized in special disciplines in the service of self-clarification and knowledge of interrelated facts. It is not the gift of grace of seers and prophets dispensing sacred values and revelations, nor does it partake of the contemplation of sages and philosophers about the meaning of the universe. This, to be sure, is the inescapable condition of our historical situation.[13]

This contrast between the scientist and the prophet highlights Weber's belief that questions of value—of the larger significance of life or even of science—had no place in science.[14] Scientists should avoid using their positions as an opportunity to engage in political polemics or “imprint” their political views on others.[15]

While Weber's essay is known as a source for his reflections on the nature of modernity, it also represents a meditation on the changing conditions of the university as

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Politics, Death, and the Devil: Self and Power in Max Weber and Thomas Mann (Berkeley: University of California Press, 1992), 56-60. Bruce Bruun, "Weber on Rickert: From Value Relation to Ideal Type," *Max Weber Studies* 1, 2 (2001): 101-3.

11 See Weber's assertion that, “This process of disenchantment, which has continued to exist in Occidental culture for millennia, and, in general, this 'progress,' to which science belongs as a link and motive force.” Weber, "Science," 139. See also Thorpe, "Science Against Modernism," 29.

12 Weber invokes the language of value spheres in his demarcation of the limits of the scientist's role: “The impossibility of 'scientifically' pleading for practical and interested stands except in discussing the means for a firmly given and presupposed end--rests upon reasons that lie far deeper. 'Scientific' pleading is meaningless in principle because the various value spheres of the world stand in irreconcilable conflict with each other.” Weber, "Science," 147.

13 Weber, "Science," 153.

14 “[P]olitics," Weber asserted, "is out of place in the lecture-room.” Ibid., 145.

15 For the full quote see Weber's assertion that, “The task of the teacher is to serve the students with his knowledge and scientific experience and not to imprint upon them his personal political views.” Weber, "Science," 146. By contrast, politicians should avoid letting considerations external to politics—such as religious conviction or a bureaucratic commitment to impartiality. See Harvey Goldman for more on these features of “Politics as a Vocation” in the context of a broader argument of Weber's emphasis on asceticism as a mode of self-formation. Goldman, Harvey, *Politics, Death, and the Devil: Self and Power in Max Weber and Thomas Mann,* (Berkeley: University of California Press, 1992), chapter 6.

a place for the pursuit of science. In the essay, it is this focus on the "external conditions" for the pursuit of science that leads to his discussion of the extent to which the pursuit of science can still provide meaning and function as a vocation.[16] He opens the essay with a brief consideration of "the academic career" and the university positions that an aspiring scientist might inhabit in Germany in contrast with the United States. This contrast is significant for Weber as he sees in the bureaucratic nature of the university system in the United States the future of German universities.[17]

In an essay entitled "Max Weber's Calling to Knowledge and Action," David Owen and Tracy Strong ask why Weber chose to begin "Science as a Vocation" with this focus on the external conditions of scientific work. They answer that Weber was emphasizing that "a significant aspect of what it means to engage in scientific work (or to embark on a scientific career) is to work within a set of university institutions that are subject to the processes of rationalization and bureaucratization characteristic of European cultural life at this time."[18] Here, Owen and Strong contextualize Weber's focus on the conditions of university in terms of two of the larger themes running throughout Weber's work--rationalization and bureaucratization. They continue, "Here Weber is responding to the slow collapse of the Humboldtian vision of the university. In 1810, Wilhelm von Humboldt laid the basis for a university that would be oriented to research and teaching, funded from public coffers and committed to advancing the frontiers of knowledge for its own sake."[19] Jürgen Habermas provides a similar account of the

16 Weber, "Science," 129.
17 Ibid., 129-31, esp. 129.
18 Owen and Strong, *The Vocation Lectures*, xxi-xxii.
19 Ibid., xxii. See Altbach for a similar account of sociologist Edward Shils' nostalgia for the Humboldtian university--and the influence of Max Weber. Philip G. Altbach, "Edward Shils and the American University" in *The Order of Learning: Essays on the Contemporary University*. Edited by Philip G. Altbach, ix-xx. (New Brunswick, NJ: Transaction Publishers, 1997), ix-x, xiv, and xviii.

founding of the modern research university as a place designed to insulate science from society. He argues that Wilhelm von Humboldt (1767-1835) based many of his ideas for the reform of universities on the work of philosopher and theologian Friedrich Schleiermacher (1768-1834) and that both men were

> concerned with the problem of how modern science, freed from the supervision of religion and the church, can be institutionalized without endangering its autonomy--whether through the authority of the government which secures the external existence of science, or through pressures from the side of the occupational and economic system, with its interest in the useful applications of scientific work. Humboldt and Schleiermacher see the solution to the problem in a governmentally organized autonomy of science which would protect the university from both political interventions and economic imperatives.[20]

If science is valued for its political or economic utility, in other words, its autonomy from the rest of society might be compromised. Where Humboldt and Schleiermacher answered this problem by securing the autonomy of science in a state funded university, roughly a century later Weber found the answer at the level of the individual's obligation to adjust to the fragmentation of value spheres.[21]

In addition to the insulation of science from society, the new German university model approached deep engagement with a field of learning as a form of self-formation. For Humboldt, the students could engage in a process of self-formation referred to as

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20 Jürgen Habermas, "The Idea of the University - Learning Processes." *New German Critique* 41, (Spring / Summer, 1987): 5

21 A discussion of the nature and scope of the Prussian university reforms and the emergence of the 'Humboldtian university' in itself and as a model for the contemporary research university lies outside the scope of the current study. For a sampling of secondary accounts of Humboldt and the move to integrate research and teaching, see William Clark, *Academic Charisma and the Origins of the Research University* (Chicago: University Of Chicago Press, 2007), 444-471; Christophe Charle, "Patterns," in *Universities in the Nineteenth and Early Twentieth Centuries (1800-1945),* edited by Walter Rüegg, 33-80. (New York: Cambridge University Press, 2004), 47-53; Robert Proctor, *Value Free Science? Purity and Power in Modern Knowledge* (Cambridge, MA: Harvard University Press, 1991), 70-4; Rüegg, Walter. "Themes." In *Universities in the Nineteenth and Early Twentieth Centuries (1800-1945),* edited by Walter Rüegg, 3-32. New York: Cambridge University Press, 2004), 4-6.

Bildung.[22] It was through intense engagement with a branch of scholarship (or *Wissenschaft*) that one could develop oneself as a person.[23] Scholarship provided the means for self-formation. In this new kind of university, it was important that professors not only transmit existing knowledge to students in their role as teachers but also to add to this knowledge by researching, publishing the results and, where possible, making new discoveries.[24] Importantly, research was also an important part of being a student at the university. Schleiermacher argued that students should develop "mastery. . .in the particular field of knowledge to which they wish to devote themselves, so that it becomes second nature for them to view everything from the perspective of scholarship." For Schleiermacher, this mean that students should "acquire the ability to carry out research, to make discoveries, and to present these, gradually working things out in themselves."[25] The place of science in society should, at least for Humboldt's idea of the university, be isolated in the service of self-formation.[26]

Owen and Strong's assertion of the importance of this "Humboldtian vision of the university" to "Science as a Vocation," however, raises the question of how the university had changed in the years between the Prussian university reforms and the writing of "Science as a Vocation."[27] In approaching this question, we can not only see the centrality

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22 Goldman, *Politics, Death, and the Devil*, 27.
23 Ibid., 38 and 25. Owen and Strong, "Max Weber's Calling to Knowledge and Action," xx.
24 Turner, "Reformers and Scholarship in Germany," 505-31.
25 Quoted in Charle, "Patterns," 48.
26 Education as *Bildung* was understood in opposition to the service of external ends. Goldman, *Politics, Death, and the Devil*, 27-8. Habermas, "The Idea of the University," 5.
27 Given my use of Weber's essay to organize discussion and the widespread influence of the German model of the research university, here I will frame my discussion on transformations in the university as a setting for the practice of science with reference to the German and not the comparatively hierarchical French model for the research university. For a concise introduction to the differences between French and German models of research universities--as well as helpful references--see Rüegg, "Themes," 9-13. See Charle for the importance of the French model as a foil in the design of the Prussian model. Charle, "Patterns," 47.

of the university in the professionalization of science during these years but also provide the necessary context to understand Weber's essay as a reaction to these trends.[28]

Reviewing changes in the ways that scientists and scientific work have been described provides one way of providing a sense of the transformation in the practice of science that occurred during the 19th century. It is often noted that the word "scientist" was coined in 1834 by English natural philosopher William Whewell. Before "scientist" entered common use, people practicing science were commonly known as "men of science" or natural philosophers.[29] Ultimately, with this new word would come a new role for people interested in practicing science in what would be very different social

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28 Charles Rosenberg, Paul Forman, and Ruth Barton have rightly pointed out the ways in which speaking of science as a profession can obscure the differences between the practice of science and of professions such as law and medicine. Paul Lucier meanwhile has critiqued efforts to approach 19th century science as a profession as anachronistic and often misleading. In response to these critiques, here I will foreground the professionalization of science as a way of understanding significant - and far ranging - changes in the practice of science over time. By relying on Lucier's use of "professionalization" as an analytical category, I will also be building on the work of scholars such as Joseph Ben-David, Norbert Elias, Stephan Fuchs, Arthur Jack Meadows, Walter Rüegg, Robert S. *Westman, and Richard Whitley.* Joseph Ben-David, *Scientist's Role in Society: A Comparative Study*. (Prentice Hall, 1971), 108. Ruth Barton, "'Men of Science': Language, Identity, and Professionalization in the Mid-Victorian Scientific Community," *History of Science* 41 (2003): 78-9. Robert V. Bruce, *The Launching of Modern American Science 1846-1876*, (Ithaca, NY: Cornell University Press, 1987), 4. Elias, "Scientific Establishments," 40. Paul Forman, "Modernity Entails Disciplinarity Postmodernity Entails Antidisciplinarity." *Osiris* (Forthcoming): 3-4. Stephan Fuchs, *The Professional Quest for Truth: A Social Theory of Science and Knowledge,* (State University of New York Press, 1992), 9, 15, and 145-62. Konrad Jarausch, *"Graduation and Careers," in Universities in the Nineteenth and Early Twentieth Centuries (1800-1945),* edited by Walter Rüegg, 363-392. (New York: Cambridge University Press, 2004), 369-74. *Paul Lucier, "The Professional and the Scientist in Nineteenth-Century America." Isis* 100, 4 (2009): 699–732, esp. 704. Arthur Jack Meadows, *The Victorian Scientist: The Growth of a Profession*. (London: British Library, 2004), 1. Charles Rosenberg, "Toward an Ecology of Knowledge: On Discipline, Context and History," in *The Organization of Knowledge in Modern America, 1860-1920*, edited by Alexandra Oleson and John Voss, (Baltimore: Johns Hopkins University Press, 1979), 441-4. Walter Rüegg, "Themes," 7. Robert S. *Westman,* "The Astronomer's Role in the Sixteenth Century: A Preliminary Study," *History of Science* 18 (1980): 105. Richard Whitley, *The Intellectual and Social Organization of the Sciences*. (New York: Oxford University Press, 1984), 43. Richard Whitley, "Changes in the Social and Intellectual Organization of the Sciences: Professionalization and the Arithmetic Ideal," in *The Social Production of Scientific Knowledge*, ed. E. Mendelsohn et al. (Boston: D. Reidel Publishing Company, 1977), 145-7.

29 Though "men of science" were predominantly men, Barton provides examples of how women could occasionally become visible as "philosophers." Much more commonly, however, women *were* excluded. Barton, "'Men of Science': Language, Identity, and Professionalization," 80-90, esp. 83, 90, 107 [on women]. Lucier, "The Professional and the Scientist," 726. Sydney Ross, "Scientist: the Story of a Word," *Annals of Science* 18, 2 (June 1962): 71 and 76.

circumstances than those surrounding natural philosophers and a different understandings of what constituted proper behavior. Where the ability to participate in and to contribute to scientific research in settings such as elite scientific societies like the England's Royal Society depended on an external source of income and preferably also the ability to adhere to norms of gentlemanly conduct,[30] scientists would often instead come to work in increasingly standardized university settings where they were *employed* by a department[31] and dedicated to a comparatively very specialized field of knowledge.[32] While income was still important ingredient to becoming a scientist,[33] it would be mediated by the completion of a Ph.D. and a dissertation as more or less necessary "rite of passage" in order to be able to work as scientists at universities.[34]

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30 In her account of the ways in which scientists described themselves in 19th century, Barton notes that "men of science" often "emphasized the nature of the person rather than the activity undertaken; it alluded to the qualities of mind and character supposedly needed for and formed by the practice of science." In *A Social History of Truth,* Steven Shapin provides a well cited account of "gentlemanly science" and the importance of following the norms and expectations associated with proper gentlemen to the ability to have one's scientific contributions accepted as credible. And with *Leviathan and the Air-Pump* Steven Shapin and Simon Schaffer provide a classic account of the formation of the Royal Society and expectations about what constituted proper scientific research. While I emphasize the figure of the gentleman scientist above for contrast, it is important to note that the 19th century ushered in many of changes, described below, that distinguish it from the elite settings described in *Leviathan and the Air-Pump* and *A Social History of Truth.* Barton, "'Men of Science': Language, Identity, and Professionalization," 81. Steven Shapin, *A Social History of Truth: Civility and Science in Seventeenth-Century England*, (Chicago: University Of Chicago Press, 1995), xvii-xxxi. And for a classic account of the formation of the Royal Society and expectations about what constituted proper scientific research, see Shapin, Steven, and Simon Schaffer, *Leviathan and the Air-Pump: Hobbes, Boyle, and the Experimental Life.* Princeton, NJ: Princeton University Press, 1985.

31 Here I use "department" in its contemporary sense, indicating the organizational unit into which scholars are hired at universities and not, as might have been more common in the Victorian period, as a discipline, as in "departments of science." Barton, "'Men of Science': Language, Identity, and Professionalization," 100.

32 I will discuss specialization and the proliferation of disciplines below

33 See Weber's note of the "plutocratic prerequisites" of the scientific vocation. Weber, "Science," 129.

34 William Clark, *Academic Charisma and the Origins of the Research University* (Chicago: University of Chicago Press, 2007), chapter 6 and 30 [quote]. See also R. L. Geiger, *To Advance Knowledge: the Growth of American Research Universities, 1900-1940* (New York: Oxford University Press, 2004), 20.

Another difference, if one unfolding over a larger time period than that discussed here, is covered in Shapin's *The Scientific Life*. Scientists are generally considered ordinary people, whereas men of nature often enjoyed an elevated status people interpreting nature as the work of God. Shapin, *The Scientific Life*, 14-5.

As Weber discusses in "Science as a Vocation," the trajectory of would be scientists differed in Germany and the United States. Where promising graduates can hope to be hired as assistant professors

While Whewell coined the term "scientist" in 1834, these changes in what would constitute proper training or work environment for scientists would emerge much later.[35] In the secondary literature on the history of the university, it is clear that the years between the 1870s and World War I, especially, were accompanied by widespread changes in the organization and role of universities as a setting for the practice of science. Historian of universities William Clark notes that the University of London granted its first Ph.D. degrees in the late 1860s and Cambridge University in 1882. Oxford would not grant a Ph.D. until 1917.[36] Although Yale would grant the first Ph.D. in the United States in 1861,[37] the opening of Johns Hopkins University in 1876 is more often seen as a signal event in the emergence of the modern research university in the United States partly because it was built on the model of the research university introduced by Humboldt.[38] Shortly after Johns Hopkins was formed on the German model, Clark University and the University of Chicago followed suit, and by the 1890s graduate

who earned a salary in the United States, in Germany they would generally aspire to working as a *Privatdozenten*, working as a lecturer earning a much smaller amount of money from students' contributions and not a university salary, before becoming a professor. Weber, "Science," 129-34. See also C. E. McClelland, *State, Society, and University in Germany, 1700-1914,* (New York: Cambridge University Press, 1980), 164-74; and *Clark, Academic Charisma*, chapter 7; and *Steven R. Turner, "University Reformers and Professorial Scholarship in Germany, 1760-1806," in The University in Society, Volume II: Europe, Scotland, and the United States from the 16th to the 20th Century*, edited by Lawerence Stone, 495-531. (Princeton, NJ: Princeton University Press, 1974), 507.

35 Lucier notes, however, that it would not be until after the late 1860s that the word "scientist" would emerge from obscurity and in new form to eventually enter more common use. Lucier, "The Professional and the Scientist," 726-7

36 Clark, *Academic Charisma*, 183.

37 Ibid.

38 Owen Hannaway, "The German Model of Chemical Education in America: Ira Remsen at Johns Hopkins (1876-1913)," *Ambix* 23 (November, 1976): 145-64. Robert Kohler, “The Ph.D. Machine: Building on the Collegiate Base.” *Isis* 81, no. 4 (1990): 639. Edward Shils, *The Calling of Education: “The Academic Ethic” and Other Essays on Higher Education*. Edited by Steven Grosby, (Chicago: University Of Chicago Press, 1997). 237. Edward Shils, *The Order of Learning: Essays on the Contemporary University,* ed. Philip G. Altbach. (New Brunswick, NJ.: Transaction Publishers, 1997), 13-4. Laurence R. Veysey, *The Emergence of the American University* (University Of Chicago Press, 1970), 158-73.
For a discussion of the sometimes unrealized differences, see Ben-David, *The Role of the Scientist*, 139 and 144-5; and Veysey, *The Emergence of the American University*, 160-1 and 166.

education had become an organizationally autonomous presence at Harvard, Columbia and Wisconsin as well.[39] Situated as the highest degree offered by these newly defined graduate programs, the Ph.D. degree "became in effect a certification that the candidate was an academic specialist."[40]

At the same time as divisions and schools dedicated to graduate education were emerging, the university was witnessing "a bewildering and ever-increasing variety of new disciplinary specialties."[41] From the late medieval period, natural philosophy was considered as a part of a philosophy faculty that would train students in law, medicine, or theology.[42] In the mid to late nineteenth century however, it became increasingly common for faculty in natural philosophy to be hired into departments that were organized according to the logic of emerging disciplines. Historian John Higham reports that, before the U. S. Civil War, a natural philosophy professor might teach all the sciences in smaller colleges. At larger colleges, science instruction might be divided among several faculty, each specializing in a different science. Yale, for example, created a separate mathematics professorship in 1836, a chemistry position in 1853, and in 1864 positions in biology and geology.[43] As the 19th century progressed, the trend towards increasingly specialized disciplines accelerated and played a dominant role in defining what constituted proper scholarship.[44] Nor were new positions and disciplines restricted to the sciences. Psychology, anthropology, economics, sociology, and political science began to form as

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39 Veysey, *The Emergence of the American University*, 165-73; Kohler, "The Ph.D. Machine," 649.
40 John Higham, "The Matrix of Specialization," in *The Organization of Knowledge in Modern America, 1860-1920*, edited by Alexandra Oleson and John Voss, 3-18. (Baltimore: Johns Hopkins University Press, 1979), 11.
41 Konrad Jarausch, "Graduation and Careers," in *Universities in the Nineteenth and Early Twentieth Centuries (1800-1945),* ed. Walter Rüegg (New York: Cambridge University Press, 2004), 370.
42 Proctor, Value-Free Science," 76; Rüegg, "Themes," 4.
43 Higham, "The Matrix of Specialization," 4.
44 Ibid., 4-5.

distinct disciplines in the U.S. context with the expansion of universities in the 1870s and 1880s.[45] The addition of newly coined words provides a sense of the proliferation of areas of study in the 19th century--bacteriology (1884), biology (1819), climatology (1843), criminology (1890), egytology (1859), embryology (1859), epistemology (1846), ethnology (1842), gynecology (1847), limnology (1895), methodology (1800), morphology (1830), opthalmology (1842), phrenology (1815), and toxicology (1839).[46] Where the proliferation of disciplines is evident in the emergence of a widening array of more or less standardized departments at the level of the university,[47] it can also be seen in the emergence of societies, journals and conferences that allowed scholars employed at different universities to come together with colleagues in their discipline. While historian Ronald Geiger documents only two scholarly societies (The American Oriental Society and the American Association for the Advancement of Science) forming in the U.S. in the first half of the 19th century, there were twenty two that formed in the second half of the 19th century.[48]

In Germany, this proliferation of disciplines went along with a demand for

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45 Dorothy Ross. "The Development of the Social Sciences." In *The Organization of Knowledge in Modern America, 1860-1920*, edited by Alexandra Oleson and John Voss, 107-138. (Baltimore: Johns Hopkins University Press, 1979), 107 and 113. Proctor, *Value-Free Science*, 99.

46 Proctor, who constructed this list, notes that biology was coined in its modern sense in 1819. Proctor, *Value-Free Science*, 66.

47 Shills, *The Order of Learning*, 43; Laurence R. Veysey, "The Plural Organized Worlds of the Humanities." In *The Organization of Knowledge in Modern America, 1860-1920*, edited by Alexandra Oleson et al. (Baltimore: Johns Hopkins University Press, 1979), 41; and Veysey, *The Emergence of the American University*, 356.

48 The list includes the American Social Science Association (1865), the American Philological Association (1869), the American Chemical Society (1876), the Archaeological Institute of America (1879), American Society of Naturalists (1883), the Modern Language Association (1883), the American Historical Association (1884), the American Economic Association (1885), the American Mathematical Society (1888), the Geological Association of America (1888), the American Academy of Political and Social Science (1889), the American Society of Zoologists (1890), the American Psychological Association (1892), and the Botanical Society of America (1893). Geiger also documents the emergence of a variety of discipline's journals. Geiger, *To Advance Knowledge*, 22-4 and 32-3. See also Veysey, "Plural Organized Worlds of the Humanities," 70-1.

practical training and increased enrollments that led to a crisis in the university system. Fritz Ringer has shown that from around 1870 the expansion of the German economy dramatically increased the demand for graduates with scientific and technical education.[49] This demand saw increased enrollments in both German research universities and the less elite technical schools, which subsequently rose in status and began granting advanced degrees.[50] In addition to the strain introduced by such a rapid rise in enrollment, many saw the demand for a more instrumental education as a challenge to a research university built on the notion of *Bildung*.[51] For this reason Harvey Goldman has described the crisis of the German university system as also a "crisis of *Bildung*."[52] The call for "pure" science or *Wissenschaft* marked one response among an educated elite who wanted to prevent the Humboldtian university from being remade in the image of the technical school.[53] Another response came in the call, especially among students, for a different place for science in society. These students--including many in Weber's audience listening to him deliver "Science as a Vocation"--were looking for alternatives to the rise of mechanistic approaches to science that had come to serve the forces of industrialization

49 Ringer, "The German Academic Community," 413-9.

50 Ibid., 419-21. Jarausch, "Graduation and Careers," 369-380

51 Goldman, *Politics, Death, and the Devil*, 36-43. Jarausch, "Graduation and Careers," 370-3. As Goldman and Ringer note, the notion of Bildung was losing its resonance for other reasons as well. The secularization of German society over the 19th century undermined the notion of Bildung insofar as it was a secular concept of self-improvement that was defined in largely religious terms and against the foil of religious re-making of the self. "Fully secularized," Ringer notes, "the language of Bildung in fact became a rhetoric of privacy. . . .a privileged retreat rom ordinary life." He goes on to note that, "Along with the 'unpolitical' stance, the language of *Bildung* fostered a particularly dangerous blindness to social realities." Ringer, Fritz K. "[untitled]." *Central European History* 11, no. 1 (March 1, 1978): 108-10, esp. 109 and 110. Ringer, "The German Academic Community," 409-10. Goldman, *Politics, Death, and the Devil*, 33-6.

52 Goldman, *Politics, Death, and the Devil*, chapter 2, esp. 25-6 and 47-50. McClelland has characterized the changing status of the research university in relation to the technical university as the "erosion of the line between university *Bildung* (education) and technical-school *Ausbildung* (training)." C. E. McClelland, *State, Society, and University in Germany, 1700-1914* (New York: Cambridge University Press, 1980), 24. Thorpe, "Science against Modernism," 21.

53 Ringer, "The German Academic Community," 421 and 412. See also Proctor's more general argument on the defensive nature of calls for value free science. Proctor, *Value Free Science*, 72-3 and 7-8.

more readily than the project of self-formation. In place of this "machine science," they sought out more holistic efforts to bridge the emerging gaps between areas of study and to position science as capable of providing answers to the question of how to live.[54] For Goldman, these responses make sense when approaching the crisis in *Bildung* as also the "crisis of the sciences" insofar as many were beginning to question the relevance of the sciences.[55]

In "Science as a Vocation," Weber was addressing efforts to redefine the place of science in society in the context of an increasingly specialized academy that had fallen in prestige and moved away from the effort to help students shape themselves. Speaking to a crowd searching for a science capable of bridging specialized areas of study and of providing meaning and hope, Weber described specialization as inevitable and meaning as outside the sphere of science.[56] The scientist that Weber described in "Science as a Vocation" is someone who must accommodate this trend towards science as an

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54 As Lassmen and Velody note, however, it was not only students interested in fashioning a new place for science in German society. They summarize Erich von Kahler's call for a "new science" as "an understanding of the world which would rejuvenate an exhausted and crippled society." Harrington approaches biophysicists' efforts to explain biological phenomena with the principles of physics as emblematic of the trend towards mechanism and reductionism in late 19th century Germany. In "Science as a Vocation," Weber invokes Hermann von Helmholtz, the scientist Harrington locates as a leading member of the "biophysicist program" and at the center of the move towards reductionism and mechanism, three times in "Science as a Vocation." A. Harrington, *Reenchanted Science: Holism in German Culture from Wilhelm II to Hitler*, (Princeton, NJ: Princeton University Press, 1999), xv-xvi, 7-19, and 118. Lassman and Velody, introduction, xiv-xvii, esp. xv. Weber, "Science," 133 and 136. Goldman, *Politics, Death, and the Devil*, 44-50 and 64-5.

55 In his discussion of "the question of the sciences," Goldman argues that "The crisis of the sciences as experienced in the early part of the century was actually a crisis in the relationship of society and the individual *to* the sciences and to their worth and significance, a crisis of faith in the sciences stemming from questions about what would, at a much later time, be called their "relevance." In his reading of Weber as working in the lineage of Friedrich Nietzsche, Weber's response to "the question of science" represents a key part of David Owen's interpretation of Weber as working in the lineage of Friedrich Nietzsche. He maintains, ""Weber accepts Nietzsche's diagnosis of modern culture as one in which the value of truth is called into question and therefore one in which science requires justification." Goldman, *Politics, Death, and the Devil*, 43-4. Owen, *Maturity and Modernity*, 89.

56 Harrington, *Reenchanted Science,* xv-xvi, 7-19, and 118. Lassman and Velody, introduction, xiv-xvii. Owen and Strong, "Max Weber's Calling to Knowledge and Action," xiii-xiv. Proctor, *Value-Free Science*, 82. Weber, "Science," 134-5.

increasingly specialized affair. Science, he notes, "has entered a phase of specialization previously unknown and that this will forever remain the case."[57] In order to become a scientist and to succeed as a science, the student must become a specialist: "the individual can acquire the sure consciousness of achieving something truly perfect in the field of science only in case he is a strict specialist."[58] He went on to maintain that "Only by strict specialization can the scientific worker become fully conscious, for once and perhaps never again in his lifetime, that he has achieved something that will endure. A really definitive and good accomplishment is today always a specialized accomplishment."[59] The role of the scientist that Weber described, then, represents a figure who has adjusted--and who must adjust--to these trends in the organization of science at the university.

Put another way, Weber addressed a crisis in the university system and the "crisis of the sciences" by endorsing a particular, and comparatively recent, vision of the pursuit of knowledge as highly specialized.[60] Mirroring the timing of the acceptance of the term "scientist," the term "specialist" similarly came into use in the mid to late 19th century.[61] As noted above, although William Whewell coined the term "scientist" in 1834, the word would not enter common use until the 1860s.[62] The *Oxford English Dictionary* reports that the first recorded use of "specialist" in English came in 1856 and indicated a Medical practitioner focusing on particular diseases.[63] In a few short years, however, the term was

57 Weber, "Science," 134.
58 Ibid.
59 Ibid., 135. In chapter 7, I will introduce literature on intellectuals as similarly focused on increasing specialization in the university context. Although intellectuals are often characterized as resisting specialization, they are also seen to be an increasingly rare given the degree and demands of specialization in the university setting.
60 On "the crisis of the sciences" see discussion above and Goldman, *Politics, Death, and the Devil*, 43-50, esp. 43-5.
61 See discussion above on "scientist."
62 Lucier, "The Professional and the Scientist," 726-7.
63 In 1856, E. K. Kane noted that "The recital might edify a specialist who was anxious to register the

applied in more general form to those focusing on one branch of knowledge by Herbert Spencer and soon many others.[64] Where 19th century men of science could make contributions in multiple fields, by the late 19th and early twentieth centuries, this kind of accomplishment was rendered progressively more difficult by the separation of fields of knowledge into disciplines with distinct career trajectories and territories over which its members could contribute.[65] Nonetheless, in the years surrounding Weber's "Science as a Vocation" speech, disciplines were still in formation.[66]

Despite what he saw as the collapse of the Humboldtian university, Weber nonetheless offer the possibility that the aspiring scientist can find a meaningful life, if in a limited way. For Weber, Humboldt's ideal of *Bildung* was no longer tenable.[67] While value freedom in the Humboldtian university had meant freedom from state interference (the freedom to allow scholarship to serve self-formation), for Weber value freedom meant that scientists, or scholars, had to restrict themselves to matters of truth that had no larger significance.[68] "Inwardly as well as externally," Weber noted, "the old university

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Protean indications of scurvy." "specialist." Oxford English Dictionary 2nd edition, 1989; online version June 2012. For this point I am indebted to Peter Burke, "Norbert Elias and the Social History of Knowledge." *Human Figurations* 1, no. 1 (January 2012), section III.

64 Burke also notes that "spécialisation" was coined in French by Auguste Comte in the mid 19th century. Burke, "Norbert Elias and the Social History of Knowledge," section III. "specialist." Oxford English Dictionary

65 Burke, "Norbert Elias and the Social History of Knowledge," section III. On the territorial nature of disciplines, see Norbert Elias' use of the metaphor of statehood and Andrew Abbott's similar emphasis on professions' struggle for jursidiction. Elias, "Scientific Establishments," 25. Andrew Abbott, *The System of Professions: An Essay on the Division of Expert Labor* (Chicago: University of Chicago Press, 1988), 86-91. See also Veysey, *The Emergence of the American University,* 317.

66 Maintaining that disciplines are "peculiar to modernity," historian of science Paul Forman argues that disciplines would not become fully formed until decades later when they reached their high point in the mid 20th century. Paul Forman, "On the Historical Forms of Knowledge Production and Curation: Modernity Entails Disciplinarity Postmodernity Entails Antidisciplinarity," *Osiris* 27 (2012), 59-60, esp. 60.

67 Ibid., 267. Owen and Strong, "Max Weber's Call to Knowledge and Action," xxii-xxiii.

68 See the discussion above on the fragmentation between value spheres. In his work entitled Value Free Science? Robert Proctor offers a much more critical assessment of Weber's notion of value freedom. Proctor, *Value-Free Science*, 137-140 and 85-98.

constitution has become fictitious."[69] However, the scientist could nonetheless find personal meaning by applying him or herself to science with a secularized form of ascetic devotion.[70] In the place of *Bildung*--and in an increasingly bureaucratic university defined by specialization, this devotion provided the only path to a meaningful existence.[71] The aspiring scientist must ignore the very likely chance that he or she will not succeed, and "find and obey the demon that holds the very fibers of his very life."[72]

For Weber, the inability of science to provide meaning or to answer questions of how to live was a necessary accommodation to a research university that had become increasingly specialized from the mid 19th century to the time of Weber's speech in 1917. While the insulation of science, or *Wissenschaft*, for Humboldt served the ends of education as self-cultivation, for Weber it was part of a resigned response to a view of modernity as increasingly fragmented and rationalized. As I will address below, in "Science as a Vocation" there is little sense that this could change--that science could be anything other than specialized, value neutral, apolitical.

In *The German Ideology* Karl Marx provided a counterpoint to Weber's emphasis on the insulation of science from the rest of society. Here he argued that

> Feuerbach speaks in particular of the viewpoint of natural science. He mentions secrets disclosed only to the eye of the physicist and chemist. But where would natural science be without industry and commerce? Even the 'pure' natural science receives its aim, like its material, only through

69 Weber, "Science," 131.
70 Goldman, *Politics, Death and the Devil*, 81.
71 Goldman argues that a "life of service is an absolute necessity, and to Weber there is no other path to meaning." This in spite of Nietzsche's earlier critique of asceticism. Ibid., 178-9 and 270-1, esp. 179. Weber, "Science," 130-1 on bureaucratization.
72 Speaking of aspiring academics' prospects of achieving a secure position, Weber notes that "Certainly chance does not rule alone, but it does rule to an unusually high degree. I know of hardly any other career on earth where chance plays such a large role." Weber, "Science," 132 on chance and 156 on the demon.

commerce and industry, through the sensuous activity of men.[73]

Other scholars have similarly argued that science has proven especially useful to the goals of commerce.[74] How can we approach scientists who do not fit into Weber's description of the scientist as value neutral specialist?

b. Scientist as Intellectual

Literature on the figure of the intellectual describes a critical role for academics and others that contrasts with Weber's description of the scientist as a value neutral specialist.[75] Where Weber's scientist restricts him or herself to engaging matters of fact before a narrow audience of fellow professionals, the intellectual engages in value concerns and speaks to a broad public audience. Literature on intellectuals agrees with Weber's description of the demands of the contemporary academic setting. For both Weber and scholars of intellectuals, the academy asks for specialized work that is value neutral. The key difference, then, is how intellectuals react to this setting. Where Weber's scientist should accommodate trends toward specialization and value neutrality, the intellectual resists these trends. The intellectual is a figure who represents, to a significant degree, a negative image of Weber's scientist as specialist. For this reason--and for the insights that this literature can bring to my characterization of critical ecologists and

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73 Karl Marx and Friedrich Engels, *The German Ideology*, (New York: International Publishers, 1967), 418.

74 By investigating the greater acceptance of atomistic theories that so appealed to Galileo in England, Margaret Jacob and Larry Stewart show how "science was made practical and put into the service of industry and empire." David Noble similarly emphasizes the usefulness of science to industry, or the "systematic application of scientific knowledge to the process of commodity production." Margaret C. Jacob and Larry Stewart. *Practical Matter: Newton's Science in the Service of Industry and Empire, 1687-1851* (Harvard University Press, 2006), 3. David F. Noble, *America by Design: Science, Technology, and the Rise of Corporate Capitalism*, (Oxford University Press, 1979), 5.

75 As I will describe below, there are at least two strong alternatives to the figure of the intellectual--the citizen-scientist and the prophet.

environmentalists, I will draw on literature on intellectuals in order to focus on the scientist as intellectual over and above the figures of the prophet and of the citizen-scientist.

In “Science as a Vocation,” Weber contrasts the scientist as specialist with the prophet, a figure for whom he clearly has little patience. While Weber's sketch of the prophet in this essay functions primarily as a foil, it provides a suggestive way of understanding the work of ecologists I have described in previous chapters. Viewing these figures as a species of prophet resonates with descriptions of the religious elements of environmental critiques. The strongest example of this has involved noting the ways that environmental critiques invoke a rhetoric associated with the Biblical prophet Jeremiah. The introduction to chapter 5 introduces the environmental jeremiad.[76] Despite this connection between Weber's prophet and the characterization of leading voices of the environmental movement as doing the work of the prophet, there is little literature on the figure of the prophet when compared to the figure of the intellectual.[77]

In their descriptions of the "citizen scientist," Jack Stilgoe, James Wilsdon, and Brian Wynne describe another way of characterizing critical ecologists and environmentalists. Stilgoe describes the citizen scientist:

> All scientists are citizens, but not all scientists are Citizen Scientists. Citizen Scientists are the people who intertwine their work and their citizenship, doing science differently, working with different people, drawing new connections and helping to redefine what it means to be a

76 For an example, see "Fighting to Save Earth From Man." *Time Magazine* 95, 5 (February 2, 1970): 60-70. Accessed July 28, 2009, http://www.time.com/time/magazine/article/0,9171,878179,00.html.

77 Although GIl Eyal's work provides a salient example of a contemporary application of Weber's notion of the prophet, in his argument the figure plays a comparatively small role in modeling a position in a theoretical framework for describing contrasts between kinds of experts. Gil Eyal, *The Disenchantment of the Orient: Expertise in Arab Affairs And the Israeli State* (Stanford, CA: Stanford University Press, 2006), 27-30, esp. 29.

> scientist.[78]

A citizen scientists is a person who "can't draw a line between her professional activities as a scientist and her responsibilities towards society as a citizen."[79] This blurring of lines between one's scientific research and one's engagement as a citizen marks a willingness to approach science in political terms. Stilgoe asserts that "Citizen scientists typically find themselves engaging intimately with the politics of science." Further, this kind of engagement is often at odds with trends towards increasingly specialized research. Stilgoe quotes epidemiologist Carolyn Stephens' critique of specialization:

> Stephens is damning about the effect of publishing on science. According to her, 'the culture of science is getting worse and worse in terms of quantity of publication and citation'. Pressure to 'publish or perish' is creating a system she calls 'incredibly myopic', in which most science is judged, or possibly ignored, only by the tiny subculture who also practise it: You publish as much as you can for a very specific audience... So science becomes narrower and narrower, not just because science is about specialisation but because science is politically dominated by a particular model.[80]

For Stilgoe, this kind of engagement defines an important way of being a scientist. He argues that "one of the arguments of this pamphlet is that there are countless alternative ways [in theory] to run scientific careers, many of which embrace citizenship." Although the model of being a scientist that Stilgoe describes contrasts with Weber's emphasis on specialization, value neutrality and the insulation of science from the rest of society, focusing on the figure of the intellectual provides a way of characterizing critical ecologists that fits more easily with Weber's emphasis on the importance of changing external characteristics in his description of the role of scientists.

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78 Jack Stilgoe, *Citizen Scientists: Reconnecting Science with Civil Society* (London: Demos, 2009), 11.
79 Ibid.
80 Ibid., 44.

In his introduction to an edited volume on public intellectuals, Amitai Etzioni reviews the central features of intellectuals. They are known as "generalists rather than specialists, [they] concern themselves with matters of interest to the public at large, and they do not keep their views to themselves." And they are often, but not always, critical.[81] The account of Russell Jacoby, a prominent historian of intellectuals, is very similar. Intellectuals write for a broad and educated audience. They are not professional specialists speaking to narrow audiences.[82] Their "commitment [is] not simply to a professional or private domain but to a public world--and a public language, the vernacular."[83] By contrast to this broad engagement, Weber's scientist as specialist is restricted to precisely the narrow professional domain--speaking to small audiences of fellow professionals and avoiding matters of general concern.

One of the central focal points of work on the intellectual, however, is the seeming disappearance of the intellectual in contemporary society. This often pessimistic concern with the fate of the intellectual in contemporary society is evident in even a cursory review of the titles of recent work on intellectuals.[84] Jacoby's work on intellectuals is titled *The Last Intellectuals* and opens with the mystery of "missing

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81 A. Etzioni, "Are Public Intellectuals an Endangered Species?" In *Public Intellectuals: An Endangered Species?* ed. A. Etzioni et al. (New York: Rowman and Littlefield Publishers, 2006), 1-2.

82 Russell Jacoby, *The Last Intellectuals: American Culture in the Age of Academe* (New York: Basic Books, 1987), x, 5-8.

83 Quoted in Etzioni, "Are Public Intellectuals Endangered," 2.

84 While work on the disappearance of intellectuals often takes on a pessimistic tone centered on the disappearance of the public sphere, Medvetz rightly emphasizes that intellectuals can come from the right as well as the left. From the perceived movement of left leaning intellectuals into the university, right leaning intellectuals often approach the theme of the disappearance of the intellectual in favorable terms or as a decline in quality of intellectual work. See Posner's negative assessment of the "decline" of intellectuals and Jacoby's response to the attack, by conservative intellectuals, on left leaning intellectuals. Thomas Medvetz, "'Scholar as Sitting Duck': the Cronon Affair and the Buffer Zone in American Public Debate." *Public Culture* 24, 1 (2012): 48-51. Richard A. Posner, *Public Intellectuals: A Study of Decline* (Cambridge, MA: Harvard University Press, 2003) 1-14. R. Jacoby, "Why Intellectuals Are All Bad," *The Chronicle of Higher Education* (February 14, 2010). Accessed August 28, 2011, http://chronicle.com/article/Skewering-Intellectuals/64113/.

intellectuals."[85] In a follow up work, Jacoby addresses "the eclipse of utopia among intellectuals."[86] Amitzai Etzioni and Alyssa Bowditch subtitled their edited volume on intellectuals with the question, "An Endangered Species?" that Etzioni addresses in the introductory essay, titled "Are Intellectuals an Endangered Species?[87] And in an article whose title begins "Scholar as Sitting Duck," Thomas Medvetz has addressed the "marginality and ineffectiveness of intellectuals in American public debate."[88] Intellectuals have disappeared, and where they have not, they have stepped into more restricted roles and addressed more circumscribed audiences and topics.[89]

Again and again in this literature, the intellectual's engagement with the broader public has disappeared before increasingly specialized conditions of academic work--the same trend demanding accommodation in Weber's "Science as a Vocation." While literature on intellectuals includes a focus on a variety of settings in which contemporary intellectuals might work, the academy receives pride of place in literature on intellectuals. Charles Lemert, for example, has focused his work on intellectuals in the academy as the place "where intellectuals are usually bred and frequently housed."[90]

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85 One of the "last intellectuals" that Jacoby examines is Murray Bookchin, an anarchist who saw revolutionary potential in ecology and Lewis Mumford, whose work I briefly explored in the last chapter. Jacoby, *The Last Intellectuals*, chapter 1, 96-9 on Bookchin, and 191-4 on Mumford.

86 In this work, Jacoby is interested in the eclipse of "the utopian spirit" as the "sense that the future could transcend the present." Russell Jacoby, T*he End Of Utopia: Politics And Culture In An Age Of Apathy* (New York: Basic Books, 1999), 103 and xi.

87 Etzioni, "Are Public Intellectuals Endangered," 14-8.

88 Thomas Medvetz, "'Scholar as Sitting Duck': the Cronon Affair and the Buffer Zone in American Public Debate." *Public Culture* 24, 1 (2012): 49.

89 An important exception is scholarship that counts as intellectuals the members of a "new class" of technical and knowledge workers. Alvin Gouldner's *The Future of Intellectuals and the Rise of the New Class* represents a classic expression of this position and one that locates in the new class the possibility for bringing about large scale social change. In Carl Boggs' response to Gouldner we encounter a similar technical intellectual but one whose ability to effect any meaningful change has been circumscribed. Gouldner, Alvin Ward. *The Future of Intellectuals and the Rise of the New Class* (New York: Seabury Press, 1979), 57-73. Boggs, Carl. *Intellectuals and the Crisis of Modernity*. State University of New York Press, 1993), 90-7.

90 For Lemert, the efforts of left-leaning work on intellectuals to keep academy and politics separate while incorporating 1960s era activists into disciplines such as sociology has revealed "sociology's spectacular

In Jacoby's account of the disappearance of intellectuals, the mystery of the missing intellectuals is accounted for by their entry into specialized professions such as technical professions, consultants, and--most alarmingly for Jacoby--academics.[91] While 1960s era activists entered the academy with an outpouring of radical theory that challenged the academic disciplines as they found them. Yet even this reaction against academic conventions failed to reach the larger concerns and audiences that define the work of intellectuals precisely because of the ways that it fit into academic conventions. The scholarship of these former activists "look[ed] more and more like the work it sought to subvert." It was "largely technical, unreadable and--except by specialists--unread."[92] While Jacoby clearly has little sympathy for scholars choosing narrowly specialized topics over ones that are broadly relevant, he acknowledges the fact that the process of becoming an academic generally involves specialization and "depoliticization." "Academic professionalization," he argues, "leads to privatization and depoliticization, a withdrawal of intellectual energy from a larger domain to a narrow discipline."[93]

Jacoby's clear sense of the failing of scholars unwilling or unable to speak outside their academic specialties is inverted by scholars antagonistic to contemporary

stodginess." Charles C. Lemert, "The Politics of the Academy and the Limits of the Academy," in *Intellectuals and Politics: Social Theory in a Changing World*, ed. Charles C. Lemert (Newbury Park, CA: Sage Publications, 1991), 177-187, esp. 177 and 184.

91 Jacoby, *The Last Intellectuals*, xii-xiii, 6-8, and 160-190 on Marxist academics specifically, esp. 179. See also Eric Bronner on the "deadening scholasticism" of critical theory in the academy. Quoted in Brulle, *Agency Democracy, and Nature*, 10.

92 Jacoby, *The Last Intellectuals*, 141.

93 See also Jacoby's characterization of the withdrawal of the intellectual as a "generational shift." Jacoby, The Last Intellectual, 149 and ix and 179 on generational shift. In the introduction to the 2000 edition of the book, Jacoby adds the categories of academics who speak to broader audiences in more critical terms after they have established their reputations on more specialized works and of science writers such as Stephen Jay Gould as potential intellectuals. With his later turn to more popular writing about the implications of ecological research, Odum fits both categories. Russell Jacoby, "Introduction to the 2010 Edition." *The Last Intellectuals: American Culture in the Age of Academe* by Russell Jacoby (New York: Basic Books, 2000), xix.

intellectuals. In his account of the "decline" of intellectuals, Richard Posner takes intellectuals to task for speaking outside of their areas of specialty.[94] While Posner's celebration of the restriction of intellectuals is in stark tension with Jacoby's yearning for more broad intellectual engagement, both scholars' accounts of the fate of intellectuals center on the increasing specialization of the settings in which intellectuals work.

In addition to the increasing specialization of academic work, work on intellectuals also highlights the way that norms encouraging value neutrality also impinge upon efforts to research work that is explicitly political. In his account of 1960s era activists entering the academy, Medvetz argues that

> it was not the mere fact of academic employment that tempered their [New Left intellectuals] critique of technocrats, but also a culture of academic professionalism that elevated value-neutrality over civic engagement as the primary regulative norm.[95]

The value neutrality that Weber called for in "Science as a Vocation" here functions to transform intellectuals into academics. Following Wacquant, this emphasis on value neutrality imposed a heavy toll in the form of the "self-inflicted irrelevance" of the American academy.[96]

> the sickly self-absorption of the university microcosm, its closing onto itself, its palace wars (or muggings) and intestinal controversies whose sound and fury are matched only by their inconsequentiality--in all senses of the word.[97]

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94 A page after Posner--in his "taxonomy" of intellectuals--describes academics speaking outside their areas of specialization as "self popularizing," he notes the "debilitating impact. . .on the public intellectual of academization and specialization of knowledge." Posner, *Public Intellectuals: A Study of Decline,* 6 and 7. See also Jacoby, "Why Intellectuals Are All Bad."

95 Medvetz, "Scholar as Sitting Duck," 51.

96 Ibid. Loïc Wacquant, "The Self-Inflicted Irrelevance of American Academics," *Academe* 82, no. 4 (1996): 21.

97 It is clear where the sympathies of Wacquant, as those of Jacoby, lie. Wacquant, "The Self-Inflicted Irrelevance of American Academics," 21. See also Steven Shapin's critique of "self referentiality, self-absorption, and a narrowing of intellectual focus" as symptoms of a "pathological form of professionalism" that Shapin calls "hyper-professionalism." Steven Shapin, "Hyperprofessionalism and the Crisis of Readership in the History of Science." *Isis* 96, 2 (2005): 238.

Not only do norms of value neutrality discourage research that is political engaged, but they can also render the scholar who does decide to assume a political position particularly vulnerable to attack from opposing positions. In his recent article, Medvetz has shown how the political writing of even such a renowned scholar such as environmental historian William Cronon was met with political censure.[98] Less established scholars have less incentive to expose themselves in this way.[99]

In scholarship on academic science and the university setting more generally, graduate school plays a central role in socializing scholars into the role of value neutral specialist that Jacoby and Wacquant deplore. For Ben-David, the principal effect of requiring a PhD degree for the pursuit of research "was to create a professional role that implied a certain ethos on the part of the scientist as well as his employer."[100] To a large degree this has meant commitment to a highly specialized field of study.[101] Historian John Higham has also commented on the role of graduate school in producing specialized scholars. Within a few short decades of the opening of Johns Hopkins, the Ph.D. degree had come to serve as "a certification that the candidate was an academic specialist."[102]

In their work on the ways graduate education socializes students into communities of academic specialists, Sharon Traweek and Joseph Hermanowicz show how graduate

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[98] Medvetz notes that Cronon had, by the time of the controversy, been a Rhodes scholar and recipient of the Macarthur "genius" grant and history's Bancroft Prize. Medvetz, "Scholar as Sitting Duck," 53. See also Jacoby, "Introduction to the 2000 Edition," xix.

[99] Medvetz, "Scholar as Sitting Duck," 53.

[100] Ben-David identifies the scientific identity, of "intellectuals conceiving of themselves as scientists--with the motivations and obligations entailed in that," as crucial to the development of science in early modern Europe and the "importation of the European model" of training scientists in graduate schools as crucial to the development and rise of science in America. Ben-David, *The Scientist's Role in Society*, 155 on professional role, 45 on motivations, and 139 on the European model.

[101] Ibid., 155-6.

[102] In Germany, by contrast, the degree also indicated a broad education and love of "pure" science. Higham "Matrix of Specialization," 10-11. For more on the trend of increasing specialization in the academic context, see the discussion in the previous section.

school can form the expectations and identities of scientists as specialists. Traweek emphasizes the ways that grad school sorts students into specialties and the familiarity with the experimental technology that each specialty demands,[103] As the graduate student becomes linked with a professor as an adviser, the adviser trains the student in his or her specialty and later uses his or her professional network to locate a postdoc for the student.[104] While the success of graduate students is attributed to characteristics such as diligence, Traweek shows that such attributions belie the important role of less examined features of graduate education, such as family support and the ability of the graduate student to affect a confident, aggressive and even abrasive style in interactions.[105] Hermanowicz as well emphasizes the ways that graduate students are trained "how to be" scientists, often through informal interaction with advisers.[106]

As graduate students become junior academics, their ability to adhere to the norms attending the role of the specialist is judged in an ongoing way in a series of career-related rituals. Sociologists of science Harriet Zuckerman and Robert Merton have

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103 Sharon Traweek, *Beamtimes and Lifetimes: The World of High Energy Physicists* (Cambridge, MA: Harvard University Press, 1992), 81. See also Whitley, "Changes in the Social and Intellectual Organization of the Sciences," 146.

104 In addition to being trained in the scientific specialty, Traweek argues that students are also "receiving training in aesthetic judgments as well as in the emotional responses appropriate to those judgments." Ibid., 82. See also Jacoby, *The Last Intellectuals*, 144.

105 Traweek, *Beamtimes and Lifetimes*, 83-4 and 89-90. These examples show how expertise often involves a social actor meeting the expectations for what is taken as expertise in given social settings. For a sometimes very critical review of the notions of performance and performativity in science studies, see Nancy D. Campbell, “Credible Performances: The Performativity of Science Studies,” *Social Studies of Science* 34, no. 3 (June 1, 2004): 433–442.

106 Interestingly, Hermanowicz also found that the disparity between the values and expectations inculcated in graduate school and the reality of working as elite scientists often left the faculty feeling as if they were the victims of a con game. In her review of Hermanowicz's work in *Nature*, Rachel Ivie draws attention to this phenomenon as a "con game." By contrast with elite scientists, scientists who worked in positions emphasizing teaching over research experienced greater satisfaction by the end of their careers because they had experienced the collapse of the lofty expectations inculcated in graduate school and located goals and aspirations outside of science many years prior. Ivie, Rachel. “Playing the Con Game of Academe.” *Nature* 460, no. 7256 (August 5, 2009): 690. Joeseph C. Hermanowicz, *Lives in Science: How Institutions Affect Academic Careers,* (Chicago: University of Chicago Press, 2009), 150 and 223-9.

commented on the fact that the peer review process judges "role-performance" as well as the quality and appropriateness of scholarship for a given audience:

> The referee system in science involves the systematic use of judges to assess the acceptability of manuscripts submitted for publication. The referee is thus an example of status judges who are charged with evaluating the quality of role-performance in a social system.[107]

And historian Steven Turner has made a very similar argument focusing on the ways that academics' job searches and efforts to get promoted "define and sustain professional duties and values."[108] If a junior academic does not conform to expectations of appropriately specialized work, he or she will likely experience difficulties publishing that work in respected journals and presses and securing a job as an academic.[109]

Alvin Gouldner's work on intellectuals specifies a way that scientists can be socialized into specialist roles but nonetheless engage in broader critiques and effect larger scale social transformation.[110] As science and technology play an increasingly important role in society, a "new class" comes into an increasingly prominent role as a "cultural bourgeoisie" made up of a variety of knowledge workers--engineers and accountants but also university professors, government officials, and others.[111] As part of

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107 Harriet Zuckerman and Robert K. Merton, “Patterns of Evaluation in Science: Institutionalisation, Structure and Functions of the Referee System,” *Minerva* 9, no. 1 (1971): 66.

108 Turner highlights the tension between expectations of teaching and specialized research on the one hand and departmental and disciplinary identities on the other. See also Rosenberg and Ben-David on the primacy of disciplinary identity. Turner, "University Reformers and Professorial Scholarship in Germany, 1760-1806," 505. Rosenberg, "Toward an Ecology of Knowledge: On Discipline, Context and History," 444-5. Ben-David, *Scientist’s Role in Society*, 158.

109 Shukaitis, Graeber, and Schmidt offer significantly more critical views of the functioning of graduate school that nonetheless complement the emphasis on norms of specialization and value neutrality here. Stevphen Shukaitis and David Graeber, "Introduction," in *Constituent Imagination: Militant Investigations, Collective Theorization* ed. Stevphen Shukaitis et al. (Oakland, CA: AK Press, 2007), 16. J. Schmidt, *Disciplined Minds: A Critical Look at Salaried Professionals and the Soul-Battering System That Shapes Their Lives* (Lanham, Md: Rowman and Littlefield, 2000), 2, 4, and 218-9.

110 I will explore Gouldner's work more fully in chapter 7.

111 Gouldner, *Future of Intellectuals and the Rise of the New Class*, 18-27 on cultural bourgeoisie, 8 and 21-7 on cultural capital, 19 on professionalism, and 15 on new class membership.

their professional training, these knowledge workers are socialized into a "culture of critical discourse" in which interlocutors are dedicated to securing assent without reference to factors external to dialogue, such as the speaker's social status.[112] In excluding references to the privileged position of the bourgeoisie and in approaching the culture of critical discourse as the means to securing the truth, the culture of critical discourse functions to position the new class in tension with the bourgeoisie. The new class's support of science and technology further places it in tension with the bourgeoisie. Gouldner argues that its

> critique of the state. . .takes the mystified form of asserting the dominance and autonomy of impersonal technology.
>
> The new ideology holds that productivity depends primarily on science and technology and that the society's problems are solvable on a technological basis, and with the use of educationally acquired technical competence.[113]

Both the culture of critical discourse and the promotion of science and technology provide ways that the new class can promote its own interests and put it in tension with the more powerful bourgeoisie. This tension with the bourgeoisie makes the new class "the most progressive force in modern society" and makes it "a center of whatever human emancipation is possible in the foreseeable future."[114] In its commitment to self-

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[112] Gouldner argues that "the culture of critical speech forbids reliance upon the speaker's person, authority, or status in society to justify his claims. As a result, CCD [culture of critical discourse] de-authorizes all speech grounded in traditional social authority, while it authorizes itself. . .as the standard of *all* 'serious' speech." See also Gouldner's claim that the "culture of critical speech requires that the validity of claims be justified without reference to the speaker's *societal position or authority.*" Further, the culture of critical discourse unites knowledge workers despite their commitment to specialized areas of study and professional expertise. Ibid., 28-44, esp. 29 on speaker's person, 28 on validity of claims, and 30 on uniting knowledge workers.

[113] Gouldner notes that "Presenting technology as an impersonal and autonomous societal resource, the New Class conceals itself and its own role in the process" of strengthening its claims "*within the status quo*." As I will explore in the concluding chapter, this position introduces a point of contrast with works that position intellectuals as critiquing efforts to locate science and technology at the center of modernity. Gouldner, *Future of Intellectuals and the Rise of the New Class*, 24 on critique of the state and 25 on presenting technology.

[114] Ibid., 83-5, esp. 83.

promotion and its potential for large scale social change, the new class is, for Gouldner, a "flawed universal class."[115]

While Gouldner identifies the new class as a form of intellectual who identifies with science and technology, other scholars describe an alternative form of intellectual who critiques the place of science in society. Carl Boggs has identified Gouldner's intellectuals as technocratic intellectuals.[116] The authority of their position emerges from their professional expertise and their identification with the central position of science and technology in society. Drawing on the critical theory of Herbert Marcuse, Boggs contrasts the technocratic intellectual with the figure of the critical intellectual. Where the technocratic intellectual identifies with science as a central cultural institution (and as part of an effort of professional self-promotion), the critical intellectual is far more oppositional and diagnoses science and other core institutions as a key part of the *problem* of contemporary society.[117] In addition to critical theorists such as Horkheimer, Boggs locates the critical intellectual in the new social movement mobilization of the 1960's New Left and in the ecology movement.[118] These figures critiqued the central

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115 Ibid., 83-5. In taking issue with the leadership roles that that Gouldner assigns to intellectuals as drivers of large-scale social change, Carl Boggs' work prefigures many of the themes that would find wider circulation in the "post-Marxist" work of Michael Hardt and Antonio Negri. In Hardt and Negri's *Empire* as in Boggs' *Intellectuals and the Crisis of Modernity*, we find a greater emphasis on popular mobilization 'from below' rather than the leadership of individuals (such as Karl Marx or Vladimir Ilyich Lenin whom Gouldner characterizes as intellectuals) as causing or precipitating the mobilization that might lead to large-scale social transformation. See, for example, Hardt and Negri's characterization of new social movements and their discussion of the importance of the refusal to work in the transition to post-Fordist modes of accumulation Carl Boggs, *Intellectuals and the Crisis of Modernity*, (Albany, NY: State University of New York Press, 1993), 89-96, esp. 96. Michael Hardt and Antonio Negri, *Empire*, (Cambridge, MA: Harvard University Press, 2001), 204, 261, and 274-6.

116 Carl Boggs, *Intellectuals and the Crisis of Modernity* (Albany, NY: State University of New York Press, 1993), chapter 6, esp 145-6 on Gouldner and 153 and 162-4 on the contrast between technocratic and critical intellectuals.

117 Ibid., esp 162

118 Ibid., 164-79, esp 172 on ecology. I will discuss new social movements in greater detail below in the section on science and social movements in this chapter and in chapter 7.

place of science and technology in relation to the Vietnam War and as an engine of ecological destruction.[119] Further, both the New Left and the ecological movement explicitly attacked the technocratic authority of Gouldner's new class.[120] Although the larger point in invoking literature on intellectuals is to describe a scientific role that contrasts with Weber's scientist as specialist, contrasts between kinds of intellectuals can similarly be useful in describing the different ways in which ecologists became critical of contemporary society.

While scholars of intellectuals generally agree with Max Weber's argument that specialization and value neutrality have become central features of academic work, their assessment of these trends is far more critical. Jacoby's grim assessment of the "unreadable," and "unread," work of activists-turned-scholars and Wacquant's description of the "sickly self-absorption of the university microcosm" leave little doubt as to how these scholars feel about specialization, for example. Weber's reaction to specialization is harder to decipher. While the sense of resignation pervading the essay suggests that he would have preferred things to be otherwise, Weber also valorizes the ability to accommodate changes in the setting and practice of science and willingly step into a circumscribed role of scientist as specialist. Further, Weber's resignation is written into the proper role of the scientist. "Whoever wishes to serve science has to resign himself to this fact" of the limited relevance of academic work.[121] Later in the essay when Weber argues that “To the person who cannot bear the fate of the times like a man, one must say: may he rather return silently, without the usual publicity build-up of renegades, but

[119] Ibid.
[120] Ibid., 166 and 170-1.
[121] Weber, "Science," 138.

plainly and simply," he deploys a masculinist language to valorize defeat--or at very least uneasy accommodation.[122]

c. The "Figuration" of Science: The Problems of Usefulness and Autonomy

Where Weber described the proper place of science and the proper role of the scientist as isolated from the rest of society, scholars such as Jacoby and Wacquant see the proper role of the intellectuals as actively engaging the concerns of the larger society. The figure of the scientist as an intellectual provides a stark contrast with Weber's vision of the scientist as a specialist who is isolated from the rest of society. Although scholarship on intellectuals provides a vocabulary for describing how scientists can enter into a relationship with a larger public and engage questions of value, clearly there are many different kinds of relationships scientists can enter with many different kinds of non-scientists. The figure of the scientist as intellectual will be particularly helpful in exploring, in the second half of this dissertation, ecologists who chose to orient their research around the goals of environmentalism. As I show in the section titled "Science and the Cold War State," scholarship on cold war science can similarly provide tools for exploring the politics of ecology—in this case in relation with the state. But how can we bring together these two very different relationships—and areas of scholarship—into the same analytical space?

Norbert Elias provides an answer with his concept of "figuration." Elias explains

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[122] Ibid., 155. See Anderson on Weber's "scornful dismissal." Lassman and Velody, however, find Weber's admonition innovative. Anderson, Perry. "The World Made Flesh." *New Left Review* 39 (May - June 2006): 138. Lassman and Velody, "Science, Disenchantment, and the Search for Meaning," 168. See also Sheldon S. Wolin, "Max Weber: Legitimation, Method, and the Politics of Theory," *Political Theory* 9, 3 (Aug., 1981): 420. See Goldman on Weber's invocation of "manliness" here and as a key part of his nationalism. Goldman, *Politics, Death, and the Devil*, 66 and 192.

the term using the metaphor of a game: “If four people sit around a table and play cards together, they form a figuration. Their actions are interdependent."[123] The players’ actions form “a flexible lattice-work of tensions. The interdependence of the players, which is a prerequisite of their forming a figuration, may be an interdependence of allies or opponents."[124] If one player engages in a strategy to win a game, that strategy unfolds in relation to other players and their reactions to this strategy in the context of their own efforts to win the game.

When Elias applies the notion of figuration to science in a later essay, he foregrounds the tensions between scientists who are established in a given field and social actors—the public, the state, scientists working in adjacent disciplines, the state, and others—who are outsiders to the scientific establishment.[125] He argues that "established and outsider groups form a highly variable figuration with an uneven balance of power as its main axis."[126] The dynamic relationship between scientists and outsiders who find their work useful forms "a flexible lattice-work of tensions" such that scientists and various other groups of non-scientists become interdependent—similar to the players in Elias’ game metaphor.[127] Further, he argues that scientific establishments

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123 Elias, *What is Sociology*, 130. Elsewhere, Elias explains figuration using the metaphor of dance. Norbert Elias, *The Civilizing Process: The History of Manners* (New York: Blackwell Publishers, 1978), 261-2.

124 Elias, *What is Sociology*, 130.

125 Elias, "Scientific Establishments," 4 and 40-1. Joseph Soeters and Ad van. Iterson trace Elias' emphasis on the relation between established and outsider groups from a 1935 paper on Huguenots to his reworking of John Scotson's MA thesis, which would be pushed in 1966 as *The Established and the Outsiders.* In his reworking of Scotson's analysis of working class suburbs in England, Soeters and Iterson argue that Elias' emphasis on the established and outsiders came into greater focus. Joseph Soeters, and Ad van. Iterson, "Blame and Praise Gossip in Organizations: Established, Outsiders, and the Civilizing Process," in *The Civilized Organization: Norbert Elias and the Future of Organization Studies*, ed. Ad van. Iterson, et al. (Philadelphia: John Benjamins Publishing Company, 2002), 27. Norbert Elias and John Scotson, *The Established and the Outsiders,* New York: Humanities Press, 1966), introduction.

126 Elias, "Scientific Establishments," 40-1.

127 Elias, *What is Sociology*, 130.

"are establishments only in so far as there are not-established people, of outsiders, who need the resources monopolized by them [scientists] and who depend on them for access to, or use of, them."[128] In relationships with non-scientists, "Members of an establishment usually are very careful to maintain and, if possible, to increase the high dependence ratio of their outsider groups and thus the power differentials between these and themselves."[129]

Thus, while figurations can be approached in general form as a game or a web of inter-relationships between the players, in the case of science Elias' notion of figuration brings a more specific emphasis on the relationships between scientists, or members of the scientific establishment, and non-scientists. Further, this "main axis" that divides scientists from non-scientists plays a significant role in defining the nature of the relationship between the players of this game. While both non-scientists and scientists in a given figuration are dependent on each other, Elias' scientists are always attempting to minimize their dependence on non-scientists and increase the dependence of non-scientists on them.[130] Although Elias acknowledges the importance of a measure of autonomy in order to realize innovations, in the bulk of his essay autonomy is approached in relative and comparative terms. He notes, for example, that most contemporary scientific establishments in the West enjoy far greater autonomy than scientific

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128 Elias, "Scientific Establishments," 40.

129 Ibid.

130 Confronted with their dependence, or potential dependence on non-scientists in a given figuration, scientists are always concerned with efforts of "preserving and enhancing their power ratio." From the higher level perspective of a given figuration, the back and forth efforts of scientists and non-scientists both attempting to assert their autonomy and make the other party dependent on them forms a "balance between dependence and independence." He goes on to note that "The power tensions and conflicts, potential or actual, which are generated by balance problems of this kind, form part of a wider set of standing tensions and conflicts which have their roots in the social situation of scientific establishments and in the figuration of interdependencies within which they have their place." Ibid., 51 and 4.

establishments working under the Church in the medieval university or under the Soviet state during the cold war.[131] Phrased in terms of this dissertation, Elias' notion of figuration describes the social relationships in which science can be useful and also assert its own autonomy.

Further, the usefulness of a given science can play a significant role in the transformation of the status of a given scientific establishment and the resources available to it. Significantly, Elias emphasizes the usefulness of chemistry during World War I and physics during World War II. In both cases, the usefulness of these scientific establishments played a key role in providing these disciplines with greater funding and greater status both during and after the two world wars.[132] Nonetheless, the transformation of these scientific establishments comes with the risk of greater dependence on the state. Despite the greater autonomy of contemporary scientific establishments in the West then, they are still in a position in which the autonomy that they do enjoy is threatened by the state. In this context, one of the central questions of Elias' essay—and of the current dissertation—is "whether and how far the relative independence of scientific establishments can be maintained in the face of growing dependence of their work on non-scientific establishments, bureaucratic, military, industrial or whatever."[133]

In responding to the threat to their autonomy, scientists can engage "boundary work" in order to separate their work from the work of non-science and to assert their

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131 In addition to this level of autonomy, the figuration of most contemporary scientific establishments is also defined by a level of professionalization, which I described in the previous section, and as providing the primary "means of orientation" through which people understand their place in the world. Ibid., 4, 37 and 43 on the church, 38 on professionalization and the church, 45-8 on the Soviet Union, and 37-45 on means of orientation.

132 Ibid., 46-7.

133 Ibid., 48.

control over science. In defining boundary work in terms of the efforts of scientists as professionals, sociologist of science Thomas Gieryn provides an analytical tool that fits well with Elias' account of the figuration of contemporary scientific establishments. Gieryn describes scientists' use of boundary work as part of a larger effort to establish and maintain control over the ability to provide legitimate interpretations of nature by distinguishing science from non-science:

> Construction of a boundary between science and varieties of non-science is useful for scientists' pursuit of professional goals: acquisition of intellectual authority and career opportunities; denial of these resources to 'pseudoscientists;' and protection of the autonomy of scientific research from political interference.[134]

Scientists' efforts to secure state funding raise the possibility that scientists could simply become state employees and subject to the close controls and bureaucratic working environment associated with the state.[135] In Elias' terms, the figuration of scientists in a relationship with the state comes with the risk that the state will encroach upon the autonomy of scientists such that the scientists will become overly dependent on the state. As Gieryn notes,

> Once scientists accumulate abundant intellectual authority and convert it to public-supported research programs, a different problem faces the profession: how to retain control over the use of these material resources by keeping science autonomous from controls by government or industry.[136]

In this context, boundary work functions to separate the ends of the state from the ends of the scientist. It functions, in other words, to make scientists more autonomous and less

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[134] Gieryn, "Boundary-work and the Demarcation of Science from Non-Science," 781.

[135] See Thorpe for a discussion of how the tension between the bureaucratic mode of state management resulted in the disciplining of one of the period's most prestigious scientists, Robert Oppenheimer. Charles Thorpe, "Disciplining Experts: Scientific Authority and Liberal Democracy in the Oppenheimer Case," *Social Studies of Science* 32, 4 (2002): 549-52.

[136] Gieryn, "Boundary Work and Demarcation," 789.

dependent on the state. Boundary work, Gieryn argues:

> Boundary-work is an effective ideological style for protecting professional autonomy: public scientists construct a boundary *between* the production of scientific knowledge and its consumption by nonscientists (engineers, technicians, people in business and government). The goal is immunity from blame for undesirable consequences of *non-scientists'* consumption of scientific knowledge.[137]

Here, as in the case of ecologists and other prominent cold war scientists whom I examine in chapter 3, scientists deploy a distinction between basic and applied science as a core part of their boundary work. Scientists separate their work from the state—and seek to avoid being supervised and controlled—by asserting the difference between their own university-based science as basic science from what the state is interested in as applied science and technology. But in order to secure the funding the state, the scientists assert that "university-based science is essential for technological progress."[138] University-based science, in other words, should be supported by the state (because it leads to the technology that the state desires) but it should also be autonomous (because technological innovation flows from basic research, which must be unrestricted in order to be effective).[139]

In this dissertation, I will focus on the figurations formed by the scientific establishment of ecology and the cold war national security state and specifically the Atomic Energy Commission on the one hand and the environmental movement on the

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137 Gieryn, "Boundary-work and the Demarcation of Science from Non-Science," 789.

138 Ibid., 791.

139 Kelly Moore has rightly criticized applications of Gieryn's notion of boundary work that reduce scientists to "monodimensional identities as professionals or experts." Although I rely on Gieryn's notion of boundary work as an analytical tool, I have incorporated Moore's point by emphasizing the ways that scientists such as Eugene Odum can move from a scientific role using boundary work to maintain professional autonomy to a more critical scientific role built on engagement with a broad public. Moore, *Disrupting Science*, 204.

other. In the first half of the dissertation, I will show that the funding and resources that the Atomic Energy Commission provided for the discipline of ecology played a role in transforming the practice of ecology. Radiation ecology emerged as a new specialty, and centers of research focusing on radiation ecology (such as the University of Georgia and the Oak Ridge National Lab) came to occupy a central position in the larger discipline.[140] While the scale of this external funding was unprecedented in the history of ecology, it also challenged the degree of autonomy enjoyed by the ecologists benefiting the most from the funding.[141] And these ecologists performed boundary work of the kind that Gieryn describes. They distinguished basic ecology from applied ecology in order to maintain autonomy when confronted with the demands of the state. As I will show, boundary work was only one way in which scientists endeavored to maintain their autonomy while drawing on the resources of the state.

In the case of the environmental movement (chapters 5, 6, and 7), ecologists entered a very different kind of figuration. Instead of funding and access to new forms of experimental technology, ecologists gained access to a broad public readership. Particularly from the 1960s, the discipline of ecology became, for many, a source of insight on how we should relate to the natural world. With this readership and this elevated status, however, came demands on the discipline of ecology to address itself in a more thorough way to the goals of environmentalism. In a figuration that included broad public support, some ecologists began exploring the role of the scientist as intellectual. While disciplinary reward structures favored the more specialized work of Weber's scientist as specialist, the broad public interest of the environmental movement provided

[140] See chapter 2.
[141] See chapter 3.

a context in which many ecologists broke out of the role of scientist as specialist by addressing their research to this larger public.[142]

Elias' notion of figuration is helpful in another way as well. It—along with the model provided by the work of Charles Thorpe, Erving Goffman and Howard Becker—provides analytical approach that fits neatly with an empirical emphasis on the choices and roles that individual scientists explored and elaborated upon.[143] Although this focus on the individual is most commonly found in biographies as a form sometimes still associated with the notion of great men driving historical change,[144] here I will approach the career of individual scientists as providing a lens into the larger relationships and tensions defining the figurations in which ecologists worked in the cold war period.[145]

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[142] Elias' notion of figuration easily incorporates the fluidity and complexity in Robert Merton's notion of "role-sets." Merton argues that instead of thinking of each position as primarily made up of one role or one relationship (a student in relation to a teacher), we should think of each position as made up of "an array of associated roles" (a student in relation to a teacher but also in relation to fellow students, librarians, archivists, administrative personnel, and so forth). Not only does this analytical focus a more realistic level of complexity, it also allows for the investigation of tension between different roles. A student might want to impress a teacher but also not want to seem, to other students, like the kind of student who is only or even primarily interested in the approval of a teacher. Borrowing from Elias' language, these tensions between roles play out in different ways depending on who is present in a given interaction. Robert K. Merton, "The Role-Set: Problems in Sociological Theory," *The British Journal of Sociology* 8, 2 (June, 1957): 110-3.

[143] The emphasis on Goffman and Becker here draws heavily on Steven Shapin's use of these scholars' work in approaching Robert Boyle. Steven Shapin, *A Social History of Truth: Civility and Science in Seventeenth-Century England*, (Chicago: University of Chicago Press, 1995), 126-192, esp. 128 on Becker and 129-131 and 151 on Goffman. Steven Shapin, "Personal Development and Intellectual Biography: the Case of Robert Boyle," *British Journal for the History of Science* 26 (1993): 335-345, esp. 338.

[144] In this narrative form, the biographical subject often comes across as a maverick, a loner operating at the fringes of social convention, whose discoveries are simply too radical for the relevant social group to appreciate.

[145] To be certain there are other sociologists who have employed biographical approaches or spoken to the sociological relevance of attending to biographical details. In his introduction to his well-read 1959 work *The Sociological Imagination*, C. Wright Mills lays the theoretical groundwork for the sociological analysis of individuals. Here, Mills encourages sociologists to view the links between individuals' actions and much larger scale social forces. Just as larger cultural and scientific trends can represent concrete dilemmas to individuals, so can individual's choices matter in important ways in shaping such trends. Here we can see that the image of an individual confronting society reveals an impoverished view of society *and* the individual. Neil Gross offers a prominent recent example of a sociological biography of Richard Rorty. There have also been a number of historians of science who have offered interesting considerations of the place of the biographical form in the history of science. In 2006, *Isis* published an issue that centered on the subject of biography and included essays by Mary Jo

In addition to providing a tool for analyzing the usefulness of science, Elias' notion of figuration is also helpful in addressing the relation between the individual and society. Elias notes that, “It is rather unusual nowadays for a book dealing with the problems of society to probe deeply into the notion of the individual, the single person."[146] Sociologists, he argues, should not restrict their analysis to societies and theories about societies as this approach relies on the “[c]ontemporary usage” of these terms that, “would lead us to believe that the two distinct concepts, 'the individual' and 'society', denote two independently existing objects, whereas they really refer to two different but inseparable levels of the human world.”[147] He proposes the neologism of “figuration” to describe the approach of, “thinking of people as individuals at the same time as thinking about them as societies.”[148] In examining the lives of cold war ecologists,

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Nye, Theodore Porter, Joan L. Richards, and Mary Terrall. And *Science in Context*, in 2003 published an issue based on a conference on scientific persona that included essays by Lorraine Daston, Gadi Algazi, William Clark, Paula Findlen, Myles Jackson, Otto Sibum, Anne Secord, Janet Browne, Michael Hagner, Silvan S. Schweber, and Cathryn Carson. Porter and Michael Shortland and Richard Yeo's 1996 edited volume provides another example. C. Wright Mills, *The Sociological Imagination* (New York: Oxford University Press, 2000) introduction. Neil Gross, *Richard Rorty: The Making of an American Philosopher,* (Chicago: University of Chicago Press, 2008), xv-xvii and 11-16. Theodore M. Porter, “Is the Life of the Scientist a Scientific Unit?” *Isis* 97, no. 2 (June 1, 2006): 314–321. Joan L. Richards, “Introduction: Fragmented Lives.” *Isis* 97, no. 2 (June 1, 2006): 302–305. Mary Jo Nye. “Scientific Biography: History of Science by Another Means?” *Isis* 97, no. 2 (June 1, 2006): 322–329. Mary Terrall, “Biography as Cultural History of Science.” *Isis* 97, no. 2 (June 1, 2006): 306–313. Gadi Algazi “Scholars in Households: Refiguring the Learned Habitus, 1480–1550.” *Science in Context* 16, no. 1–2 (2003): 9–42. Janet Browne, “Charles Darwin as a Celebrity.” *Science in Context* 16, no. 1–2 (2003): 175–194. Cathryn Carson, “Objectivity and the Scientist: Heisenberg Rethinks.” *Science in Context* 16, no. 1–2 (2003): 243–269. William Clark, “On the Professorial Voice.” *Science in Context* 16, no. 1–2 (2003): 43–57. Lorraine Daston, and H. Otto Sibum. “Introduction: Scientific Personae and Their Histories.” *Science in Context* 16, no. 1–2 (2003): 1–8. Paula Findlen, “Becoming a Scientist: Gender and Knowledge in Eighteenth-Century Italy.” *Science in Context* 16, no. 1–2 (2003): 59–87. Michael Hagner, “Skulls, Brains, and Memorial Culture: On Cerebral Biographies of Scientists in the Nineteenth Century.” *Science in Context* 16, no. 1–2 (2003): 195–218. Myles Jackson, “Harmonious Investigators of Nature: Music and the Persona of the German Naturforscher in the Nineteenth Century.” *Science in Context* 16, no. 1–2 (2003): 121–145. Silvan S. Schweber, “J. Robert Oppenheimer: Proteus Unbound.” *Science in Context* 16, no. 1–2 (2003): 219–242. Anne Secord, “: Samuel Smiles, Thomas Edward, and the Making of a Working-Class Scientific Hero.” *Science in Context* 16, no. 1–2 (2003): 147–173.

146 Norbert Elias, *What is Sociology?* (New York: Columbia University Press, 1978), 128.

147 Ibid., 129.

148 Ibid. See also Harry Collins' argument that "Individuals should be thought of as the sum of the forms of

we are also examining the society in which ecologists were employed by the cold war state and were approached for research that could back radical critiques of the cold war state and of consumer capitalism.

In his biography of J. Robert Oppenheimer, Charles Thorpe similarly provides a model for a sociological approach that foregrounds the individual as providing a lens for exploring the larger society.[149] Here, Oppenheimer's dilemmas in how to construct himself as a scientist and as a person open into tensions between different visions of the place of science and learning in society. As a physicist and administrator leading the Manhattan Project, Oppenheimer worked at the center of the alliance between science and the state. Thorpe shows that Oppenheimer

> occupied a nodal position in the emergence of late modern technoscientific culture and in the compact between science and the state that developed from World War II. To trace to the constitution of Oppenheimer's wartime and postwar scientific identity is to trace the key struggles over the role of the scientist in relation to nuclear weapons, the state and culture.[150]

To a significant degree, he was also working in a bureaucratic environment and played an important role in bringing compartmentalized, and highly complex, sets of tasks together into a completed bomb at the appropriate time. Yet he also sought to present himself as having the taste and breadth of learning of a cultivated man. And when he stepped too far outside the role of the scientist as specialist, a security hearing stripped him of his status. Through a sociological analysis of Oppenheimer, not only do we gain an insider's view into the shape of science state relations at a crucial period in their intensification, but we

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life in which they play a role." Harry Collins, *Changing Order: Replication and Induction in Scientific Practice* (Thousand Oaks, CA: SAGE Publications, 1985), 148.

149 For explicit discussion of his approach, see Thorpe, *Oppenheimer*, 15-20.

150 Thorpe, *Oppenheimer*, 1.

also see how these larger social contexts provided opportunities and constraints for Oppenheimer's attempts to fashion his own identity at different points in his life and before different audiences.

Erving Goffman's interactionist sociology represents an important influence in Thorpe's sociological biography. Famous for applying a dramaturgical metaphor to everyday social interactions, Goffman is also popular for emphasizing the role individuals play in managing others' impressions of them. In works such as *The Presentation of Self in Everyday Life*, identity formation is an ongoing process but also one that takes into the account the nuances of concrete social settings. Once an individual has committed him or herself to a certain line of action, maintaining consistency before a given audience represents a way of maintaining one's moral integrity in the audience of another. Here the maintenance of a coherent identity is approached as an accomplishment in and across interactions.[151]

Howard Becker, with Anselm Strauss and James Carper, has written on the implications of this constructionist approach when considering changes across the course of an individual's life.[152] In place of the effort to explain adult behavior through values or stable personalities that are formed in early childhood, there is an emphasis on continuity of identity as an achievement.[153] For Becker, one mechanism that can account for

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151 Goffman's work also represents an important influence in Stephen Hilgartner's analysis of the performative dimensions of expert position-taking. I will discuss Hilgartner's work in greater detail in chapter 2. Stephen Hilgartner, *Science on Stage: Expert Advice As Public Drama* (Stanford, CA: Stanford University Press, 2000), 7-16.

152 Howard S. Becker, “Notes on the Concept of Commitment,” *American Journal of Sociology* 66, no. 1 (July 1, 1960): 32–40. Howard S. Becker, “Personal Change in Adult Life,” *Sociometry* 27, no. 1 (March 1, 1964): 40–53. See also Steven Shapin's and Barry Barnes' use of Becker. Shapin, *Social History of Truth*, 14 and 128. Barry S. Barnes, “Making Out in Industrial Research.” *Science Studies* 1, no. 2 (April 1, 1971): 163-5 and 174-5.

153 Howard S. Becker and Anselm L. Strauss, “Careers, Personality, and Adult Socialization,” *American Journal of Sociology* 62, no. 3 (November 1, 1956): 262-3.

consistent behavior over time is the "side bet." By expressing one's commitment to a given line of action (or identity or set of cultural expectations) that person can constrain his or her future options on otherwise unrelated decisions.[154] If someone commits to (or makes a side bet on) an identity as a reliable employee but is offered a superior job weeks after accepting the terms of a job, his or her decision to take the better new job is constrained by his or her commitment to being a reliable employee.[155] Like changes in one's self-presentation at the conversational level, here changes in an individual's life course represent efforts to construct and maintain one's identity relative to larger scale and generally more persistent social environments.[156]

For Goffman, Becker and Thorpe, it is important to consider the ways individuals construct their identities in different social settings as an ongoing accomplishment. In contrast to the conventions of many biographical treatments, this implies an analytical openness to a lack of coherence in the subject's actions. Instead of considering the subject's identity as the more or less stable—and often more or less coherent—values established in early childhood, here attention centers on the ways a subject has constructed his or her identity in an ongoing way and often in different ways in different settings and at different points in time.[157] This attention to the importance of self construction provides a way of understanding how and why a given scientist might approach his or her role in different ways while engaged in different political projects.

c. The Role of the Scientist in the Career of a Cold War Ecologist

[154] Becker, "Notes on the Concept of Commitment," 35-6.
[155] Ibid., 36.
[156] Becker makes this comparison himself albeit as an example of commitment. Ibid., 37-8.
[157] Historian of science Joan Richards captures the importance of paying attention to these kinds of shifts in her work on scientific biography. Richards, "Fragmented Lives," 302–304.

Eugene Pleasants Odum (1913-2002) is known as one of the most prominent 20th century American ecologists. In promoting the notion of ecosystem ecology from the early 1950's he furnished postwar ecology with a specialty that would become dominant within academic ecology by the mid 1960s and influential among environmental activists and policy makers long after. Successive editions of his textbook, *The Fundamentals of Ecology*, which was first published in 1953 and would provide an early definition, for several generations of ecologists, of what ecology was. Further, he was perhaps the most important figure in this period in introducing ecology to the benefits of large scale funding—primarily from the Atomic Energy Commission but also the National Institute of Health, and NASA—and practices of team-based and equipment-intensive research that went along with it. Both his textbook and his success in securing outside funding enabled what, for Odum, was a larger project—to build ecology as a discipline and a mature science. While discipline building efforts of this kind are often approached as a form of epistemic activity—in elaborating the principles of ecological theory—Odum's gifts as an organization-builder were a central part of his success in his success in backing ecosystem ecology.

One of the things that makes Eugene Odum such a compelling object of analysis is the prominence, length, and varied nature of his career. Between enrolling in graduate school at the University of Illinois in 1937 and retiring from the University of Georgia in 1984, Odum's professional path crossed a surprising amount of territory. Odum came to his position of a junior faculty member at a peripheral state university with a preponderance of ambition and more than a bit of ambivalence. Although the saw the small town location of the University of Georgia as fitting in with his early desire to establish himself as a public figure, he simply was not sure that the university could accommodate his professional ambition.[158]

Despite this initial ambivalence—or perhaps partially because of it, Odum was fully prepared to leverage the opportunity he saw in the initially modest Atomic Energy Commission interest to survey the grounds for what would become a factory for producing plutonium and tritium for the hydrogen bomb. With this backing we see Odum establish a successful ecology program from scratch at a peripheral state university and play an important role in setting the agenda for postwar ecology. Odum was a central player in the figuration in which ecology entered a relationship with the cold war state.

In successfully garnering the funding of the Atomic Energy Commission from the early 1950s, we see Odum navigating one of the central tensions of cold war science—the tension between the research goals of ecology as a discipline and the goals driving the state's decision to fund his research, between the autonomy and the usefulness of science. In chapter 3, I will explore the ways Odum drew on existing tropes and employed a form of "boundary work" to distinguish the aims of ecology as basic science and the aims of the AEC as applied science.[159] I will also explore how Odum experimented with organizational solutions to the problem of maintaining his autonomy as a scientist.

During these years, the specter of radioactive fallout assumed more public prominence, and the Atomic Energy Commission found itself spending more and more resources attempting to contain the problem of fallout in order to support the political vision of the national-security state. These developments transformed the AEC's initially

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158 Craige, *Eugene Odum*, 31-3.

159 T. F. Gieryn, "Boundary Work and the Demarcation of Science from Non-science: Strains and Interests in Professional Interests of Science," *American Sociological Review* 48 (1983): 782.

modest interest in ecology, and Odum was there—eager to apply the funding—but also the connections, tools, and even the momentum of the AEC research agenda—to establish himself as an ecologist, his approach to ecology as a legitimate specialty within the larger field of biology, and the University of Georgia as a center of ecological research. In doing so, Odum became a different kind of ecologist. His primary research specialty shifted from ornithology to radiation ecology. Although much of his graduate training and the majority of his early publications were the work of an ornithologist—an interest that he had had from the awkward years of his youth—radioisotopes provided a near ideal way of researching the movement of matter and energy and matter through the ecosystem. Odum turned from measuring the heart rates and fat content of birds using comparatively simple tools to organizing teams of ecologists to working on AEC land using geiger counters and a source of radioactive cobalt worth $6,000 in 1957.[160] From the early 1950s to the early 1960s, in other words, Odum took on a leading role not only in radiation ecology but also in ushering in a new form of ecological practice as a "big science."

Further, in exploring the ways Odum positioned the principles of ecology for a larger public audience, he provides a lens for investigating the relationship between ecology and the American environmental movement as well as larger scale shifts in the legitimacy of science in the mid twentieth century. Despite the distance between the politics of the cold war national-security state and the environmental movement, both represented an effort to approach ecology as a source of utility. Both the patronage of the cold war state and the attention of the environmental movement presented certain kinds of opportunities and difficulties for scientists interested in maintaining the professional

[160] Letter from Eugene Odum to Clyde E. Connell, no date. UGA 97 044, box 1, folder 49. Memo from John E. Bowyer, dated June 16, 1959. UGA 97 044 box 2.

autonomy of their research. As historian and ecologist Daniel Botkin and sociologists Abby Kinchy and Daniel Kleinman have shown, there were often significant tensions between the goals of ecology as a science and the goals of environmentalism as a social movement.[161]

In representing an audience looking to established ecologists for insights, the environmental movement presented new professional possibilities for academic ecologists. Suddenly they could speak to much larger audiences on social problems of wide interest. At the same time, the environmental movement represented, for some ecologists, a threat to the some ecologists who were interested primarily in maintaining the autonomy of their research. In this context, ecologists such as Odum often performed a delicate form of boundary work in order to navigate the tensions between these competing demands.[162]

This is what makes Odum such an interesting subject for exploring the politics of ecology. He navigated the tension between academic ecology and the ecology of radioactive fallout on the one hand but *also* between academic ecology and the ecology of the environmental movement on the other. In navigating the tensions between the uses of ecology—to manage radioactive fallout, to provide insights for the environmental movement, or to perform research aimed at other professional ecologists, Odum was also navigating the tensions between different answers to the question of what is the proper place for science in society. Should science seek to answer questions emerging from its own research—science for the sake of science? Or should science be used as an

[161] Abby Kinchy and D. L. Kleinman. "Organizing Credibility: Discursive and Organizational Orthodoxy on the Borders of Ecology and Politics," *Social Studies of Science*, 33, 6 (2003), 869-70, 872-4, 877-8, and 890-1. Daniel Botkin, *Discordant Harmonies: A New Ecology for the Twenty-first Century* (New York: Oxford University Press, 1992), introduction.

[162] Gieryn, "Boundary Work and Demarcation," 782.

instrument to answer larger social problems? And , if so, who gets to decide what those larger social problems are? Is it a prestigious—and insulated—group of experts working for the state, as in the case of the Atomic Energy Commission? Or is it the larger populace, people without formal qualifications who have come together in order to question the existing social order? Should science perform a role supporting the existing structures of state power or should science perform a critical role—or perhaps neither. Perhaps science should be troubled principally or only with the goals set internally, by other scientists, and enforced by a reward structure determined internally.

By focusing on Eugene Odum and, to a lesser extent, other ecologists, I hope to provide an intimate view into the concrete problems introduced by larger scale tensions between different answers to the question of what is the place of science in society. Given Odum's involvement with radiation ecology and the environmental movement, focusing on Odum also provides a narrative thread that runs throughout the work. It should be emphasized, however, that, even though I will be examining episodes in the life of one man, this dissertation is not a biography. I will not be examining Eugene Odum's childhood development or training as important factors in how he came to be the person who he was. The focal point is not Eugene Odum as a person but rather how his engagement with radiation ecology and his engagement with environmental critique provide opportunities to explore, in an empirically grounded way, the politics of ecology and the role of the scientist from the early 1950s through the early 1970s. Further, I will be examining other professional ecologists as well as those whose work drew on ecological research. In exploring the relationship between ecology as a science and the environmental movement, I will discuss Paul Sears and Marston Bates as well as Rachel

Carson, Murray Bookchin and others.

The appreciation for self construction and discontinuity in the work of Goffman, Becker, and Thorpe provide important resources for understanding changes in Eugene Odum's professional trajectory as an ecologist. In the first half of his career, Eugene Odum constructed his role as a scientist in a way that fits with the vocational ethos that Weber describes in "Science as a Vocation." Between the early 1950s and the early to mid 1960s, Odum was primarily concerned with building the respectability and coherence of ecology as a distinct academic specialty with the notion of the ecosystem at its center. During these years, he felt that science should be autonomous from society and that the questions driving ecological research should emerge from within the discipline. He established himself in ornithology before moving on to radiation ecology in the early to mid 1950s. However, at the same time as Odum was asserting the autonomy of ecology as an independent discipline, he was benefiting from funding from the Atomic Energy Commission. As importantly, in modeling how ecologists could benefit from outside funding and still assert their autonomy, he was also modeling the role of the academic ecologist in the discipline's transition to "big science."[163] When we find Weber's ethos exemplified in Odum's early work, we also find it exemplified in an extremely successful academic. At least in the case of Odum, the academic context proved receptive to the narrowly focused, professionally circumscribed role that Weber described.

Later, however, Odum eschewed a strict emphasis on specialization and began approaching ecology as a normative science. Here, Odum addressed himself to much

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[163] Galison, "The Many Faces of Science," remains a helpful introduction to the large scale changes in the funding and practice of twentieth century science. But see also Thomas Hughes on the precursors of this transformation. Thomas P. Hughes. *American Genesis: A Century of Invention and Technological Enthusiasm, 1870-1970* (Chicago: University of Chicago Press, 2004), 96-9.

larger, public audiences and situated the relevance of ecological insight in relation to cultural problems—not the work of other ecologists.[164] Ecology became a source of insight on questions of how to live. In challenging the role as defined by Weber, Odum's later career models a different way of being a scientist. Here Odum was modeling a role that was new for ecology, a role in which ecology was drawn on for an environmental critique that was aimed at targets well outside of the scholarly pursuit of ecology.[165] If Odum's critique began to challenge—and in many cases transgress—the limits that Weber identifies for the role of scientists, then much of the science practiced under the aegis of human ecology fell far outside the ethos outlined in Weber's essay.

In chapter 5, I will explore how Odum came to situate the relevance of his

[164] The contrast between the ways that Odum situates the larger relevance of ecosystem ecology provides the clearest lens into the shift between Odum's earlier and later career. As I will describe in chapter 4, Odum's initial promotion of ecosystem ecology was intended of providing ecology with the principles and coherence it needed to be recognized as a legitimate science that was autonomous from other approaches to biology--both at the University of Georgia and among biologists more generally. The place of ecosystem ecology in Odum's later career can most easily be seen in a video interview taped in the final years of his life. Here, Odum situated ecosystem ecology as an approach particularly suited for approaching environemental problems in all of their complexity. In the interview, Odum acknowledged the extent to which the ecosystem approach had come under fire among the more specialized audience of professional ecologists.

My emphasis on the discontinuity in Odum's career contrasts markedly with the emphasis on continuity in Betty Jean Craige's biography of Odum. The richness of this biography and the insights it provides into Odum's character benefits in no small degree from the close friendship that Craige shared with Odum and his wife Martha. It is difficult to escape the sense when reading this work that we often are hearing Odum's voice speak through Craige. The ease of his explanations and fondness for parallels come through in her prose, and this is a good thing. She brings his voice to life in a way that no other biographer could. But the biography also relies upon the characterization of his earlier career from the vantage point of his later career. Although we see important turning points in his career—significantly in his role as activist trying to save the marshes of Georgia, we also hear that Odum was an environmentalist all along. While there is a sense in which this is true, it is also true that Odum—like many, many others—did not always approach his career in the same terms throughout his life. E. P. Odum, P. Williams, D. A. Silvian, S. Culpepper, G. Gilland, M. Smith, and M. L. Barrett. *Eugene Odum [videorecording] : an Ecologist's Life,* Writer-producer, Phil Williams ; Producer-director, David Allen Silvian. Athens, GA : University of Georgia, 1996. Betty Jean Craige, *Eugene Odum: Ecosystem Ecologist and Environmentalist* (Athens, GA: University of Georgia Press, 2001), xvii-xxii.

[165] Odum targeted the impacts of population growth and the incompatibility of an aggressively acquisitive ethos with people's place in nature. While people acted as if they were in a youthful or immature stage of ecosystem development, in actuality they were in a mature stage and so had to be much more mindful of the way they approached nature in terms of raw material and dumping ground.

research in relation to the question of how to value, and act in relation to, the environment. In chapter 6, I will address how other ecologists went further than Odum and approached their science as the basis of a critical theory of modern society. After exploring how these scientists broke with the role of scientist as specialist, in the concluding chapter I will explore how the figure of the critical intellectual provides an alternate model for understanding these ecologists' critical stances.

III. Science and the Cold War State

What uses has the state found for science in the 20th century U. S. context and what impacts has their use of science brought to the content and practice of science? In the early cold war period, the American state found a use for ecology and began funding the discipline at levels that were unprecedented until that time. To a significant degree, the experience of ecology was one shared by many other sciences that the state also found useful. Although the relationship between science and the state has had a long history,[166] this relationship intensified significantly with World War II. And after the war was over, scientists were credited as having played an important role in the defeat of Nazi Germany and Imperial Japan--particularly with the development of radar and the atom bomb.

World War II marks an important turning point in the relationship between science and the state for several reasons. During World War II, many disciplines saw an influx of state funding that was unprecedented in scope and that gave rise to widespread and

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[166] Patrick Carroll, for example, offers a compelling account of the longstanding relationship between science and the state in which science and technology form an integral role in the formation of the modern state. Patrick Carroll, *Science, Culture, and Modern State Formation*, (Berkeley: University of California Press, 2006), 3-6, 26-7, and 171-4.

lasting changes in the practice of science. While science was also mobilized during World War I, it did not see the extent of mobilization that occasioned World War II. Further, science was for the most part demobilized at the end of the World War I. While many scientists left state laboratories at the end of World War II, the escalation of cold war tensions in the late 1940s and early 1950s saw a renewal of the World War II science-state alliance. In his 1961 farewell address, President Eisenhower famously warned of the "unwarranted influence" of the nation's new "military industrial complex." He also found science-state relations troubling and warned of the "prospect of domination of the nation's scholars by Federal employment, project allocations, and the power of money" as well as the "equal and opposite danger that public policy could itself become the captive of a scientific-technological elite."[167]

While this relationship gave scientists unprecedented funding and political access, it also raises the question of the extent to which science funded by the state can be considered autonomous from the rest of society. For individual scientists, and particularly for scientists receiving state funding in this period, the larger question of the place of science in cold war society was also a concrete question of how to approach their own role as scientists in relation to the tension between the view that science should be autonomous from society and the view that science should be useful to the state. In this section, I will draw on secondary historical literature on science-state relations in order to provide a sense of both the distinctiveness of state funding of science in this period and the impact that this funding often had on the content of science and practice of scientists. Here the central question of the historiography of cold war science (what was the impact

[167] Dwight Eisenhower, "Farewell Address to the Nation," Accessed July 1, 2010, http://mcadams.posc.mu.edu/ike.htm.

of state funding on the content of science) will be addressed as an effort to understand the nature and impacts of the political engagements of cold war science.

a. State Uses for Science from World War I through the Early Cold War

In this section, I will provide a brief history of state funding for science from World War I through the early cold war in order to provide a sense of the scale and distinctiveness of state patronage of science that came with World War II. It is my implicit argument here that understanding the dimensions of state involvement with science in this period provides an important context in which the case of ecology's involvement with the politics of the state can be approached as a case study of a much more general phenomenon. More specifically, by understanding the scale of state funding for science during this period and its impacts on science, we can better understand the importance of looking at Eugene Odum's efforts to position ecology as a science in relationship to the Atomic Energy Commission.

The close relationship between science and the state during the early cold war era would have been difficult to imagine in an earlier context in which efforts to see the state as a patron for science were met with suspicion. This atmosphere of suspicion played an important role in defining the character of mobilization of science for World War I. It characterized the efforts of industrialists and scientists, and their contributions often took the form of recommendations and voluntary cooperation. While leading scientists such as Robert Millikan and George Ellery Hale played a role in mobilizing scientists under the National Research Council (and gaining President Woodrow Wilson's recognition of the body), the role of scientists was that of the volunteer expert adviser for specific military projects.[168] Mobilized through the War Industries Board, industry suspicion over federal intervention shaped a preference for private initiative over the formation of the kind of powerful administrative bodies that dominated the mobilization for World War II and the early cold war.[169]

Importantly, however, both critics and supporters of the role of science and industry in World War I saw in it a model for the future. Bernard Baruch, the chairman of the War Industries Board, saw in World War I an important lesson in the importance of a strong alliance between the military and industrialists.[170] Essayist Randolph Bourne, meanwhile, saw in the mobilization a dark expression of the affinity between the state and militarism. Further, "he saw how militarism and the state defined one another, how each required the other for its strength and legitimacy, and how together they threatened at home the very democratic values that the nation claimed to be fighting for abroad."[171] After the war, however, the wartime coalition demobilized, and universities turned to industry and philanthropic organizations.

While suspicion of state funding of science played an important role in defining science-state relations in the interwar period, the scarcity of funds during the Great Depression nonetheless provided a context in which many scientists welcomed the sharp increase in funding that came with American involvement in World War II. As Rebecca Lowen shows, scientists were wary of federal funding in the interwar period because they were afraid of the loss of autonomy that it might bring.[172] In this context there was a

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168 Leslie, *The Cold War and American Science,* 4.
169 Ibid. See also R. L. Geiger, *To Advance Knowledge: the Growth of American Research Universities, 1900-1940* (New York: Oxford University Press, 2004), 48.
170 Leslie, *The Cold War and American Science,* 3-4.
171 Ibid., 3.
172 Lowen, *Creating the Cold War University,* 8.

widespread turn to private sources of funding, particularly among scientists in astronomy and physics and scientists able to position their work as benefiting causes of social reform favored from the late nineteenth century.[173] The 1930s saw a return to the funding patterns of the 1910s, with smaller grants provided to individual researchers--instead of scientific communities--and on a smaller overall scale.[174] In this atmosphere of pared down funding, universities and scientists both welcomed the state funding that earlier they would have treated suspiciously.[175] But how did this funding come about?

By most accounts, electrical engineer turned science administrator Vannevar Bush represented a central figure in convincing politicians of the promise of funding scientists as part of the effort to prepare for and fight World War II. In 1939 Bush moved from his role as engineering dean and vice president of MIT to Washington to serve as the president of the Carnegie Institute in Washington and head its National Advisory Committee on Aeronautics.[176] By the spring of 1940 Bush was convinced that the nation was not prepared for the coming war and, with the help of influential Washington insiders, petitioned Roosevelt to create an agency, the National Defense Research Committee (NDRC) that would assist in the mobilization of science for the duration of

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173 The fields of chemistry and agriculture served as two exceptions if in different ways. Robert Kohler describes the state funding of agricultural sciences during the 1920s and 1930s as one of the primary exceptions of the suspicion and reluctance that characterized the relationship between scientists and the state. Chemistry was also exception to the larger pattern of private philanthropic patronage of science insofar as it received funding from industry during these years. In Edmund Russell's work we gain a view of the effect of World War I on the chemical industry itself. As the export of German chemical products was blockaded and, later, the American chemical industry was helped by protective tariffs, the industry emerged as a leader after the war. Robert Kohler, "Science, Foundations, and American Universities in the 1920s," *Osiris* 3 (1987): 140, 135, and 150-2. See also Geiger, *To Advance Knowledge*, 140-9. Edmund Russell, *War and Nature: Fighting Humans and Insects with Chemicals from World War I to Silent Spring* (New York: Cambridge University Press, 2001), chapter 2.

174 Kohler, "Science, Foundations, and American Universities," 162.

175 Lowen, *Creating the Cold War University,* 42 and 45.

176 Leslie, *The Cold War and American Science*, 6-7. Daniel Kevles offers another source for Bush's trajectory and importance in these years. Daniel Kevles, *The Physicists: The History of a Scientific Community in Modern America,* (Cambridge, MA: Harvard University Press, 1995), 294-340.

the war and would report directly to the president. Frustrated by the restriction of the committee to scientific research--not development--and its distance from military planning of weapons development, Bush maneuvered a year later for the creation of the more powerful Office of Scientific Research and Development in which the NDRC would play an advisory role. One of the first priorities in the wartime mobilization of science was radar. A committee on microwave research was formed and decided to locate its lab at MIT on the model of the interwar Research Laboratory of Electronics.[177]

Before 1943, the Rad Lab represented the most prominent concentration of physicists involved in the war effort. The lab's development of the radar would cost some $1.5 billion and would be treated a major accomplishment during and after the war.[178] Despite an early 1939 letter from Albert Einstein to President Roosevelt and much preparatory maneuvering by Bush, physicist Leo Szilard and others, it was not until June 1942 that Roosevelt would authorize Bush for a full scale effort to develop the atom bomb.[179] Thorpe summarizes the unprecedented scale of the project: "Employing at its peak nearly 129,000 workers and costing $2 billion, the Manhattan Project was the largest technoscientific project to that time."[180] When Los Alamos opened in March 1943 as the central node of the Manhattan Project it "absorbed physicists like a sponge"--even from the Rad Lab.[181] Of course, the Manhattan Project and the Rad Lab were only two of many war-related technoscientific projects. Other prominent projects included the

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177 Kevles, *The Physicists*, 291-301 and Leslie, *The Cold War and American Science*, introduction.

178 Kevles, *The Physicists*, 307-8.

179 Ibid., 326. Philip L. Cantelon, Richard G. Hewlett, and Robert C. Williams, eds. *The American Atom: A Documentary History of Nuclear Policies from the Discovery of Fission to the Present*. Philadelphia: University of Pennsylvania Press, 1992), 9-11.Richard Rhodes, *The Making of the Atomic Bomb* (New York: Simon and Schuster, 1986), 1, 20-45.

180 Thorpe, *Oppenheimer*, 1. See also Cantelon, Hewlett, and Williams, *The American Atom*, xiv. Kevles, *The Physicists*, 308.

181 Kevles, *The Physicists*, 329.

construction of solid fuel rockets at California Institute of Technology and the proximity fuse at Johns Hopkins.[182]

Put in perspective, the scale of projects like the Rad Lab and the Manhattan Project dwarfed state funding of science during World War I. As historian of science Stuart Leslie reports, science during World War II was funded to the tune of"billions instead of millions of dollars."[183] Another difference was the extent to which the money went to universities (for research and development) over industry, the primary benefactor of state funding during World War I. One of the innovations--and windfalls, from the perspective of universities--that World War II brought was the funneling of federal funds into overhead expenses and not the narrower conception of relevant funding targets that had accompanied contracts.[184] Most importantly, however, the role of science in devising and developing the weapons of World War II would become an enduring feature of the cold war. This was far from predetermined at the close of World War II, however.

In the years immediately following World War II, the proper place of science--and its relation to the military--was contested.[185] An immediate struggled ensued over the May-Johnson bill, in which control of atomic energy would be dominated by military control and characterized by strict security regulations. Many atomic scientists--interested in pushing for international control of atomic energy--reacted strongly against this bill.[186] While these scientists garnered support for the McMahon bill, a series of international

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[182] Ibid., 308.

[183] S. W. Leslie, *The Cold War and American Science: The Military-Industrial-Academic Complex at MIT and Stanford,* (New York: Columbia University Press, 1994), 6. See also R. S. Lowen, *Creating the Cold War University: The Transformation of Stanford*, (Berkeley: University of California Press, 1997), 1.

[184] Lowen, *Creating the Cold War University*, 58-66.

[185] Jessica Wang, *American Science in an Age of Anxiety: Scientists, Anticommunism, and the Cold War*, (Chapel Hill: University of North Carolina Press, 1999), 10-43, esp. 12-25 and 38-43.

[186] Wang, *American Science in an Age of Anxiety*, 14, 18, and 26.

developments made its passage less likely.[187] The role of the military was a key issue in debates and the bill's passage ultimately came to depend on a provision for a significant military role in order to satisfy House conservatives.[188]

While Bush had provided a blueprint for postwar science-state relations in his 1945 *Science: The Endless Frontier*, the nature of the agency that was to provide much of the funding was being fought over in Congress.[189] Senator Harley Kilgore sponsored the Science Mobilization bill that attempted to establish a postwar science that would be politically accountable to the larger public and could address itself to a range of technical and social issues.[190] While some prominent New Dealers supported the bill, industry, the military and members of the conservative scientific elite such as Bush, James B. Conant, Frank B. Jewett and Karl T. Compton opposed the bill.[191] Senator Warren G. Magnuson introduced an alternative bill that was drafted by Oscar Ruebhausen at the OSRD and Carroll L. Wilson who was Bush's top assistant at the OSRD.[192] In Magnuson's bill, the director would be internally appointed.[193] In contrast to the Magnuson bill, the Kilgore bill outlined an agency that would contribute, on the model of the New Deal, to other

187 Ibid., 21.
188 Ibid., 29.
189 There are many valuable accounts of Bush's efforts to define the place of science in the years following World War II. See, for example, M. A. Dennis, "Reconstructing Socio-Technical Order: Vannevar Bush and US Science Policy." In *States of Knowledge: The Co-Production of Science and Social Order*, edited by Sheila Jasanoff, 225-253. (New York: Routledge, 2004); D. S. Greenberg, *Science, Money, and Politics: Political Triumph and Ethical Erosion, (*Chicago*:* University of Chicago Press, 2001), chapter 3; D. S. Greenberg *The Politics of Pure Science*. Chicago: University Of Chicago Press, 1999), chapter 4; Zachary Karabell, *Architects of Intervention: The United States, the Third World, and the Cold War, 1946-1962,* (Baton Rouge, LA: Louisiana State University Press, 1999), chapters 13-15; Kevles, *The Physicists*, 347-61; D. Kevles, "The National Science Foundation and the Debate over Postwar Research Policy, 1942-1945: A Political Interpretation of Science--The Endless Frontier," *Isis*, 68*,* 1 (1977): 5–26; Kleinman, *Politics on the Endless Frontier*, chapters 4-6; Pielke, Roger, *"*In Retrospect*:* Science - The Endless Frontier*." Nature* 466 (August 19, 2010): 922-3; and Wang, *American Science in an Age of Anxiety*, chapter 1.
190 Wang, *American Science in an Age of Anxiety*, 28.
191 Ibid., 29-30.
192 Ibid., 27.
193 Ibid., 28.

government agencies and whose director would be appointed by the president. Further, patents of government-funded research would be public.[194]

At stake in the struggle between Kilgore bill and the Magnuson bill was the proper place of science in society. These bills represented very different ideas about whether science should remain insulated from society or accountable to the larger society.[195] In Kilgore's bill, science would serve the public and other branches of the state as needed.[196] By contrast, in the Magnuson bill, scientists funded by the agency would remain more autonomous from other branches of government as well as the needs of the people, however determined.[197] Kilgore's leader would be appointed by the U.S. president and so also answerable to the political stance of the president and, by extension, the voting public.[198] By contrast, Magnuson's leader would be appointed internally, by scientists, such that the research funding that the agency controlled could be distributed to research deemed important by scientists, not by the president or other officials elected by the public.[199]

In the end, neither side won out.[200] The direction of state funded science would not be left for scientists to determine or the American public but, instead, the military. When the National Science Foundation was finally formed in 1949, after years of effort, it turned out to be much less significant patron of science than many had anticipated.[201] After the conclusion of World War II, the Office of Naval Research stepped in to provide

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194 Ibid., 26-9 and 32.
195 Ibid., 10-12.
196 Ibid., 28 and 32.
197 Ibid., 28.
198 Ibid.
199 Ibid..
200 Dennis, “Reconstructing Socio-Technical Order," 225-7.
201 Greenberg, D. S. *Science, Money, and Politics*, 45 and 51 on the NSF and the National Institute of Health. Kevles, *The Physicists*, 353-5 on the role of the Office of Naval Research.

much of the funding that had been curtailed with the end of World War II.[202] Wang notes that during this period "well over 90 percent of funding for research in the physical sciences came from agencies devoted to military needs."[203] With America's loss of a monopoly on atomic weapons in 1949 and particularly the beginning of the Korean War in mid 1950, funding for science doubled.[204] Truman's announcement, on January 31st 1950, of efforts to build the hydrogen bomb would herald a significant expansion and revitalization of the infrastructure of the AEC as the agency that had inherited from the Manhattan Project.[205]

Within months, plans were underway to construct the Savannah River Site as a production facility for plutonium and tritium. With the construction of a new production facility, the AEC determined that it was in a position to conduct a baseline environmental survey of the land on which it would be constructed. The agency would contact the University of South Carolina and the University of Georgia, where a young Eugene Odum worked as an Associate Professor, with the possibility of a modest, one-time $10,000 grant.[206] In a very real sense, Odum's involvement in radiation ecology depended on the expansion of the cold war state's investment in the science and technology of weaponry.

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202 Kevles, *The Physicists,* 353-5.
203 Wang, *American Science in an Age of Anxiety*, 38-41, esp. 38.
204 To $1.3 billion. Leslie, *The Cold War and American Science*, 8.
205 See the discussion, in chapter 2, on the cold war national-security state for a discussion of how this time saw a marked intensification of the effort to mobilize society for war. For more complete coverage, see Paul G. Pierpaoli, *Truman and Korea: The Political Culture of the Early Cold War*, (Columbia: University of Missouri Press, 1999), Introduction and chapter 1; Steven Casey, "Selling NSC-68: The Truman Administration and the Politics of Mobilization, 1950-51." *Diplomatic History,* 29, (September, 2005): 655-90; Melvyn P. Leffler, "National Security." *The Journal of American History* 77, 1 (June 1990): 143-152; and Melvyn P. Leffler, "The American Conception of National Security and the Beginnings of the Cold War, 1945-48." *The American Historical Review* 89, 2 (April 1984): 391-400.
206 Craige, *Eugene Odum*, 49-50.

b. State Funding of Science and the Autonomy of Science

The distinctiveness of the scale and breadth of military-driven state funding of science during and after World War II raises the question: what was the impact of this funding on the content of science?[207] If scientists often define their work as driven by the pursuit of knowledge for its own sake, how do we account for the ends to which their work was often put, as in the dramatic and oft-cited case of the atom bomb? This section will provide a brief review of historians' efforts to understand the impact of militaristic state funding on the content of science. Historians and sociologists are not the only ones who have confronted these issues, however. The relation between a militarized state and science that emerged out of World War II posed a dilemma for scientists and politicians as well.

What was the nature of the relationship between the cold war state and science during these years? This is one of the central questions of the historiography of cold war science. Despite the straightforwardness of the question there are many ways of trying to answer it. One way of approaching this relationship involves addressing the nature of the impact of military funding on the content of science.

Looking at science in the university setting, Leslie focuses on military funded labs at MIT and Stanford as two model 'cold war universities' and makes a strong case that the military funding of science strongly impacted the content of science. While Leslie includes accounts of scientists and the university taking advantage of military funding to further their own (scientific) research, the picture Leslie provides emphasizes the ways in

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[207] It is important to note that this question of the impact of funding on the content of the science takes on further significance when examined in light of longer term transformations that science has undergone over the course of the twentieth century. In this section, I provide a brief account of these developments that focuses on prominent examples of state funded science.

which this funding was, above all else, funding for military ends. Significantly, at MIT the influence of the labs that served as a central link between the university and the military filtered down to the core of the university's 'educational mission' in the formation of a "curriculum structured by the more pressing demands of the applied electronics at the heart of post-war military systems."[208] Julius Stratton, a former RLE director reflected in retrospect that MIT's labs, "[p]erhaps more important than other development in recent years. . .have contributed to the special intellectual character and environment of M.I.T."[209] And in 1962 Alvin Weinberg wondered whether MIT "is a university with many research laboratories appended to it or a cluster of government research labs with a very good educational institution attached to it."[210]

As he announces in the introduction, Leslie is also very much concerned with the long-term implications of this influence. In fact, one of the reasons that attention to the militaristic values accompanying the large scale infusion of state money into science is important is precisely because science becomes imprinted with these values on a number of levels--from undergraduate instruction, to scientists' choice of problems and the shape that disciplines and even universities take.[211] Leslie concludes his work with a strong emphasis on the impact that state funding had on science:

> [p]ostwar events largely proved out the fears of Cornell (and later MIT) physicist Philip Morrison and others that the military would end up buying American science and engineering "on the installment plan." But the full costs of mortgaging the nation's high technology policy to the Pentagon can only be measured by the lost opportunities to have done things differently. No one can go back to the beginnings of the Cold War and follow those paths not taken."[212]

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208 Leslie, *Cold War and American Science*, 31.
209 Ibid., 16.
210 Ibid., 14 on Weinberg's quote.
211 Ibid., introduction.
212 Ibid., 256.

Nor is Leslie alone in emphasizing the impact of state funding on the content of cold war science.

In Rebecca Lowen's work on the cold war university and Paul Edwards' work on computing and psychology, we get a similar sense of the importance of transformative effects of cold war patronage. For Lowen, this patronage played a significant role in changing the structure of higher education at places like Stanford by devaluing the importance of undergraduate education at the expense of research and particularly externally funded research.[213] Given that the university is her focal point, however, she does not see the influx of funding from the state as unique so much as one chapter in a larger story of the funding of science.[214]

Paul Edwards' account focuses on the impact of military funding on computer science, cybernetics and strands of psychology.[215] While one the goals of *Closed World* is to unite two types of accounts in the history of computing--one focusing on hardware or device history and the other on software and logic--another of his goals is to situate the history of computing firmly in the cold war context.[216] For Edwards, an approach looking for the ways in which military funding shaped computing research would miss the larger picture--the way that military funding gave birth to computer science. He also traces the emergence and influence of cybernetics from its inception with Norbert Wiener's interest in anti-aircraft fire--the same problem for which ENIAC, the first fully electronic computer, was the answer--to its influence in artificial intelligence modeling and

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213 Lowen, *Creating the Cold War University: The Transformation of Stanford*, chapter 8.
214 Ibid., chapters 1 and 2.
215 Edwards, *Closed World*, chapters 2 and 3 on computer science, chapter 6 on cybernetic psychology, chapter 7 on cognitive psychology, and chapter 8 on artificial intelligence.
216 Ibid., x-xiii

cognitive psychology.

Chandra Mukerji analyzes the effects of state patronage of science even in cases where the effects of patronage are not obvious. In *A Fragile Power*, she asks why the state would fund scientific research with “no immediate or even obvious long term benefit to the state.”[217] She answers that state funded scientists can serve as an “elite reserve labor force” for the state insofar as their highly developed skill set and knowledge will be available to the state in times of need.[218]

Mukerji's analysis foregrounds an interplay between dependence and autonomy. Scientists are often dependent on state funding, or the tools that state funding can provide, and so are often interested in exercising autonomy from the state. While this autonomy can come in the form of prestige and confer a level of power to scientists, it is a 'fragile power' insofar as it remains dependent on the patronage of the state. Often, however, the state has encouraged scientists' efforts to assert the autonomy of their work as this autonomy adds to the value of science. Mukerji summarizes this dynamic: “Science gains value to the state because of its claims to 'independence' and 'detachment.' The voice of science is authoritative to the extent that it seems objective and above politics even when applied to policy.”[219] Although it is often limited in indirect ways, even the autonomy of scientists can serve a political function.

In her article on cold war era oceanography, Naomi Oreskes emphasizes theoretical approaches that can account for “the complexities of military-scientific collaborations” in specific cases.[220] On the one hand, historians such as Daniel Kevles

217 Chandra Mukerji, *A Fragile Power: Science and the State* (Princeton: Princeton University Press, 1990), 5.
218 Ibid., 6.
219 Ibid., 190.
220 N. Oreskes, N. "A Context of Motivation: U.S. Navy Oceanographic Research and the Discovery of

have emphasized scientists' ability to maintain autonomy over their work despite extensive state patronage, and on the other historians such as Paul Forman have called attention—like Leslie, Lowen, Edwards, and Mukerji—to the effects of state patronage on science and the directions that scientific research has taken. Oreskes is interested in bringing together scientists' recollections of cold war science as a golden age of science with historians accounts of the effects of military funding on science.[221]

Oreskes' analysis, like that of Mukerji, highlights the interplay between the autonomy and dependence of cold war scientists. In speaking to each other in private, scientists often invoked "the ideology of pure science, of 'independent scientific exploration,' as a lever to wrest some measure of autonomy from their patrons."[222] Importantly, however, these narratives do not account for the ways in which the discoveries of sea-floor hydrothermal vents were, "also an engineering accomplishment made possible by a novel technology" that was a tool in the context of cold war politics and that answered, "the U.S. Navy's desire to monitor the movements of Soviet submarines and be prepared for deep-sea rescue and salvage of its own."[223] Oreskes brings together this emphasis on the importance of the military context of deep sea research—in providing the necessary technology to explore the bottom of the ocean—with the accounts of scientists—and their efforts to assert their autonomy and experience of the cold war as a special time to be a scientist—by considering military interests as part of a context in which some scientific projects might be selected above others. She notes, "Like a lens, military pertinence brought certain subjects into clear sight while

Sea-Floor Hydrothermal Vents." *Social Studies of Science* 33, 4 (2003), 698.

[221] Ibid., 699 on the golden age, 698 on Kevles, Forman and Mukerji.

[222] Ibid., 728 and 725.

[223] Ibid., 699-700.

others remained on the edges of the field of view."[224]

In his account of Lloyd Berkner, historian Allan Needell similarly endeavors to include the perspective of scientists when addressing the nature of the relation between the cold war state and science. Instead of approaching the science and the state, for example, as unproblematically monolithic, he approaches them in the terms of the struggles within which they were navigated and by which they came to be defined by a historical actor, Lloyd Berkner, who straddled the gaps that sometimes separated military, scientific, and political actors.[225] When Berkner was tapped to work on a paper on the role that science could play for the State department for example, he tactfully leveraged his recent appointment to the Academy of Sciences to engage important scientists' opinions and, at the same time, create the beginnings of an alliance that would find expression in the report and provide an ongoing source of information for the State department.[226] Here science performs a dual role, serving both the research interests of scientists and the national-security state that funds the scientists. We see Berkner bridging science and the state in other contexts as well--in implementing the military's summer study model for the State Department's Project Troy, for example.[227] Berkner illustrates the often tangled alliances that emerged during and after World War II and the importance of behind the scenes work in making these alliances function in practice.

Here I will emulate the use of a biographical level of analysis in Thorpe and Needell to unpack the relation between science and the state at the level of the individual. In these case studies, historians have shown how the larger relation between science and

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[224] Ibid., 697
[225] Allan Needell, *Science, Cold War and the American State* (New York: Routledge, 2000), 3.
[226] Ibid., 131-48.
[227] Ibid., chapter 6.

the cold war state was navigated and constructed in part by scientists who were often eager to assert the autonomy of their research in the face of their dependence on the patronage of the state.

IV. Science and Social Movements

In the previous section, I addressed how the relation between science and the cold war state has often been addressed in terms of the impact of state funding on the content of science. In this section I will address how the relationship between science and social movements has often been addressed by exploring the impact of social movement mobilization on the practice of science. In reviewing relevant literature on social movements and science, I hope to lay the groundwork for addressing, in the body of the dissertation, the question of how the political engagement of ecologists with the environmental movement has changed the practice of ecology.

Many scholars have noted the distinctive relationship between the environmental movement and science and particularly the dependence of environmentalism on the claims and the credibility that science provides.[228] At the same time, scholars have emphasized the ways that environmentalism has challenged postwar efforts to locate science and technology at the center of society.[229] How did environmentalism both rely on

[228] Frank Fischer, *Citizens, Experts, and the Environment* (Durham: Duke University Press, 2000), 47 and 50. M. Killingsworth, Jimmie Palmer and Jacqueline S. Palmer, *Ecospeak: Rhetoric and Environmental Politics in America* (Carbondale, IL: Southern Illinois Press), 51-3. Sylvia Noble Tesh, *Uncertain Hazards: Environmental Activists and Scientific Proof* (Ithaca, NY: Cornell University Press, 2000), 82. Steven Yearley, *The Green Case: Sociology of Environmental Issues, Arguments and Politics* (New York: Routledge, 1991), chapter 4. Steven Yearley, *Cultures of Environmentalism: Empirical Studies in Environmental Sociology* (New York: Palgrave Macmillan, 2005), chapter 8..

[229] Alberto Melucci, *Challenging Codes* (Cambridge: Cambridge University Press, 1996), 127, 163-6, and 309. Michael Egan, *Barry Commoner and the Science of Survival: The Remaking of American Environmentalism* (Cambridge, MA: MIT Press, 2007), 5-9. Fischer, *Citizens, Experts, and the Environment*, chapter 6. Andrew Jamison, *The Making of Green Knowledge: Environmental Politics and Cultural Transformation* (Cambridge: Cambridge University Press, 2002), 16.

and challenge science? Here I will answer this question by bringing together literature on environmentalism as a "new social movement" with literature foregrounding the reflexive character of modernity. While sociological literature on new social movements enables us to understand how environmentalism challenged postwar efforts to locate science and technology at the center of society--and introduces language for describing collective identity formation and framing of issues, literature on reflexive modernization introduces the question of the extent to which environmentalism as a social movement or ecology as a science has rendered the hazards of industrial civilization visible.

In his work *Impure Science*, Steven Epstein provides a well-read example of a social movement affecting the practice of science. AIDS activists challenged the conventions by which randomized clinical trials were considered to be a necessary step in the FDA approval of drugs as being safe and efficacious. People infected with AIDS simply could not afford to wait for the lengthy process of testing and approval and demanded access to drugs that had passed Phase I of the trials. And this demand for access came to problematize conceptions of AIDS trials.[230] Further, in being seen as representatives of people infected with AIDS by the biomedical establishment, activists became active participants in the science of AIDS.[231] And the social movement of AIDS activists played a key role in determining the route by which these lay people became experts.[232]

230 Steven Epstein, *Impure Science: AIDS, Activism, and the Politics of Knowledge* (Berkeley: University of California Press, 1996), 196-214

231 Ibid., 264

232 In documenting social movement activists who become recognized by the scientific establishment as possessing a form of expertise about AIDS, Epstein draws attention to the weaknesses in Harry Collins' emphasis on elite scientists. Contra Collins a priori emphasis on the "core set" of insider scientists, Epstein asks, "[h]ow can science be studied without assuming in an a prior fashion which groups at which social locations create scientific knowledge?" Ibid., 18.

There are many ways in which the environmental movement has challenged the practice of science and its use in industry. Phil Brown has documented a form of "popular epidemiology" that provides a form of scientific evidence prepared by nonscientists who are exposed to harmful pollutants.[233] At the same time as this process provides scientific evidence of the effects of pollutants, it confers a level of lay expertise and provides a collective identity centered around the health risks from exposure to toxic chemicals.[234] Brown outlines multiple "stages of citizen involvement" in cases of toxic waste.[235] First, community residents individually start to notice health problems and the presence of pollutants and then start to wonder about a possible link. As the residents begin to share information, they begin to develop a shared outlook based on the link between pollution and health problems. With time and action, the group becomes more cohesive and begins to share a collective identity. The group then becomes more active as it begins to organize groups to accomplish goals and to pressure for government intervention. As official studies often find no correlation between health and pollutants, the community group often calls in its own experts and attempts to conduct its own study before engaging in litigation and pressing for corroboration of their own findings.

In her work on residents of of Louisiana's “chemical corridor,” Barbara Allen provides another example of local mobilization that comes to contest official narratives about the presence and harmfulness of industrial pollutants.[236] The setting in Allen's work is the corridor extending from New Orleans to Baton Rouge that hosts a number of

233 Phil Brown, “Popular Epidemiology and Toxic Waste Contamination: Lay and Professional Ways of Knowing,” *Journal of Health and Social Behavior* 33, no. 3 (1992): 267–281.
234 Phil Brown and Edwin J. Mikkelsen. *No Safe Place: Toxic Waste, Leukemia, and Community Action* (University of California Press, 1997), chapter 4.
235 Brown, “Popular Epidemiology and Toxic Waste Contamination," 269-70.
236 Barbara Allen, *Uneasy Alchemy: Citizens and Experts in Louisiana’s Chemical Corridor Disputes* (Cambridge, MA: MIT Press, 2003).

petrochemical companies with histories of illegal dumping.[237] She argues, “identities come together by sharing experiences, creating new networks of stories and constructing an alternative vision of an unjust present and a promising future in toxic communities.”[238] As residents incorporate health problems into their narratives about their homes and share these narratives with their neighbors, they are also doing the work of creating a shared identity and mobilizing against the companies pumping pollutants into the ground.

Kelly Moore's work provides another example of the impact of social movement mobilization on science and the changing role of the scientist. Looking at three cases of critical scientists, Moore explores the ways that these scientists' social movement involvement facilitates the emergence of alternative scientific identities.[239] Scientists who were Quakers formed the Society for Social Responsibility in Science to promote a scientific role in which scientists as moral individuals avoided scientific work with unethical consequences.[240] Moore also examines Barry Commoner's science information movement and the Science for the People movement associated with the New Left. In each of these cases, social movement activity enabled scientists to explore new ways of being scientists--as moral individuals, as providers of scientific information to the public, and as political radicals. In different ways, these scientists attempted to "redefine relationships between fact and value, between politics and science, and between expert and citizen."[241] Where Epstein, Brown, and Allen focus on the emergence of forms of lay expertise and counter narratives, Moore's example focuses on the ways that social

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237 Ibid., chapter 1.
238 Ibid., 21.
239 Moore, *Disrupting Science*, 207-11.
240 Ibid., chapter 3.
241 Ibid., 2, chapter 3 on the Society for Social Responsibility in Science, chapter 4 on the scientists' information movement, and chapter 5 on Science for the People.

movements can provide a kind of laboratory in which scientists can explore new scientific roles.

Alongside these scholars' work on the impacts that social movements can have on the practice of science, it has often been noted that the contemporary environmental movement[242] relies on science to provide credible evidence of the existence and toxicity of pollutants.[243] Steven Yearley, for example, has asserted that environmentalism is "very profoundly. . .scientific."[244] The claims of late 20th century environmentalism "are all based in a distinctively scientific perception of the world" and depend on the training and technology of scientists. As something that is relatively remote from everyday human experience, awareness of the ozone layer--and the danger of the hole in the ozone layer--are mediated by scientists with years of training and access to specialized equipment.[245]

At the same time as environmentalism relies on science, it critiques science. Alberto Melucci and Andrew Jamison, for example, have similarly pointed out that environmentalism represented a critique of the place of science and technology in cold war culture.[246] And in his biography of Barry Commoner, Michael Egan shows that one of the central threads running through Commoner's activism is the critique of approaches to

242 For ease of reference, I use ""the modern environmental movement," the contemporary environmental movement," "contemporary environmentalism," and sometimes just "the environmental movement" and "environmentalism" to signify the environmental movement of the late 20th century--and specifically from the early 1960s--in the American context. Although this phrasing might be taken to convey a sense of coherence in the various positions staked out by environmental activists, below I discuss some of the central tensions between different forms of environmentalism. For a recent history of environmental activism that ranges from the late 19th century through to contemporary environmental justice movements--and emphasizes tensions between different strains of environmentalism--and particularly from the 1960s, see Robert Gottlieb, *Forcing the Spring: the Transformation of the American Environmental Movement.* Washington D.C.: Island Press, 2005).

243 Fischer, *Citizens, Experts, and the Environment,* 47 and 50. Killingsworth, Palmer and Palmer, *Ecospeak*, 51-3. Tesh, *Uncertain Hazards*, 82. Yearley, *The Green Case*, chapter 4. Yearley, *Cultures of Environmentalism*, chapter 8..

244 Yearley, *Cultures of Environmentalism*, 115.

245 Ibid., 116.

246 Melucci, *Challenging Codes*, 163-6. Jamison, *The Making of Green Knowledge*, 16.

risk assessment in terms of value neutrality and expert judgment.[247] In a 1980 article, Commoner took aim at precisely this target in attacking cost benefit approaches as providing a seemingly value neutral language that functions to veil corporate interests and the risks that technology poses to people and to the environment.[248]

How can we make sense of environmentalism's reliance on and critique of science? In approaching environmentalism as a "new social movement," scholars such as Alberto Melucci draw attention to the ways that environmentalism (along with civil rights, gay rights, and women's rights but also the peace movement and anti-nuclear movements) does not follow the logic of classical Marxism but, along with other new social movements, targets cultural change. In doing so, these activists attempt to take control over their ability to fashion their own identities (gay pride) instead of inhabiting identities emerging from the dominant terms often associated with "technoscientific apparatus" (homosexuality as pathology).[249] The environmental movement aimed to redefine the context of human action in terms of the larger framework of nature.[250] Jürgen Habermas famously defined these social movements "as resistance to tendencies to

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[247] Egan, *Barry Commoner and the Science of Survival*, chapter 6.

[248] Barry Commoner, "The Risk of Cost / Benefit Analysis: Of lollipops and meteorites." *Science for the People* 12, 3, (May-June, 1990): 9.

[249] Alberto Melucci, "A Strange Kinds of Newness: What's 'New' in New Social Movements?" In *New Social Movements: From Ideology to Identity* ed. Enrique Larana et al. (Philadelphia: Temple University Press, 1994), 101.

[250] For social movement scholars Benford and Snow, framing involves an active process of sorting and grouping events in order to make them meaningful. Frames allow members of social movements to "negotiate a shared understanding of some problematic condition or situation they define as in need of change, make attributions regarding who or what is to blame, articulate an alternative set of arrangements, and urge others to act in concert to affect change." Framing, then, can be understood as a set of inter-related steps—diagnosing a problem, proposing a solution, and attempting to get others involved by constructing "vocabularies of motive." Robert D. Benford and David A. Snow. "Framing Processes and Social Movements: An Overview and Assessment." *Annual Review of Sociology* 26 (2000):611-639, esp. 615 and 617. On the environmental movement, see Melucci, *Challenging Codes*, 163; and Sylvia Tesh, *Uncertain Hazards: Environmental Activists and Scientific Proof* (Ithaca, NY: Cornell University Press, 2000), chapter 7.

colonize the life-world."[251] Similarly, Dorothy Nelkin has approached new social movements as "challenging the instrumental reason that underlies science."[252] The cost benefit approach to to risk assessment that Commoner takes issue with is precisely the kind of logic that, for Habermas, is colonizing everyday existence.[253]

At the same time, any effort to reduce the questions posed by the contradictory tendencies of the environmental movement by asserting a single theory of social movements would be missing out on the significance of the multiplicity of the environmental movement. Scholars of environmentalism have asserted that the understanding the contradictory impulses of the environmental movement form an important step in approaching the history of environmentalism. Robert Gottlieb and Mark Dowie, for example, have traced how many of the often radical grassroots mobilizations of the 1960s and 1970s gradually transformed into large scale environmental organizations focused on lobbying-based reform fueled with corporate donations and membership fees.[254] Philip Sutton has similarly contrasted the more radical grassroots strains of environmentalism with the comparatively conservative efforts of large environmental organizations such as the Sierra Club.[255]

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[251] Jürgen Habermas, "New Social Movements." *Telos* 49 (1981): 35.

[252] Dorothy Nelkin, *Controversy: Politics of technical decisions* (Thousand Oaks, CA: Sage Publications, 1979), x.

[253] I will approach this dynamic in more detail in the concluding chapter.

[254] Mark Dowie, *Losing Ground: American Environmentalism at the Close of the Twentieth Century* (MIT Press, 1996), Preface**.** Gottlieb, *Forcing the Spring*, chapter 4.

[255] Philip W. Sutton, *Explaining Environmentalism: In Search of a New Social Movement* (Burlington, VT: Ashgate, 2000), chapter 1, esp. 2-6. As I will suggest in more detail in chapter 7, different currents of the environmental movement can be best described with different social movement theories. While the larger, professionalized organizations resemble the social movement organizations of McCarthy and Zald's resource mobilization approach, the more radical claims of less organized grassroots groups more closely resemble new social movements. John D. McCarthy, and Mayer N. Zald, “Resource Mobilization and Social Movements: A Partial Theory,” *American Journal of Sociology* 82, no. 6 (May 1, 1977): 1218–23.

Science, the Environment, and Modernity

What can the cases of the political engagement of ecology with the cold war national security state and the environmental movement tell us about the place of science in relation to modernity? And how does the relationship between social movements and science--between environmentalism and ecology--figure into the more general question of the place of science in modernity? Although I will explore these questions in more detail in the concluding chapter, here I will provide a brief overview of how these questions are answered in different ways by different scholars of modernity. As Weber's work provides a central theoretical resource in this dissertation, I will begin with his theory of modernity.

Weber foregrounded the role of science in driving rationalization as a process that defined modernity in terms of disenchantment and the retreat of overarching values.[256] Importantly here, Weber considers science as a "motive force" of disenchantment.[257] He notes that,

> Wherever. . .rational empirical knowledge has consistently carried out the disenchantment of the world and its transformation into a causal mechanism, there appears to be the ultimate challenge to the ethical postulate, that the world is a divinely ordered cosmos with some kind of ethically meaningful direction.[258]

When we encounter something such as the functioning of a streetcar that we do not

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256 In phrasings such as "The fate of our times is characterized by rationalization and intellectualization and, above all, by the 'disenchantment of the world'" and "Wherever. . .rational empirical knowledge has consistently carried out the disenchantment of the world and its transformation into a causal mechanism" rationalization appears beside and as the cause of disenchantment as central features of contemporary life. Weber, "Science," 155. Weber, "Religious Rejections of the World and Their Directions," 350.

257 Weber, "Science," 139. I will address these points in much more depth in the concluding chapter.

258 Max Weber, "Religious Rejections of the World and Their Directions," in *From Max Weber: Essays in Sociology*, edited by H.H. Gerth and C. Wright Mills, 323-359. (New York: Oxford University Press, 1978), 350.

understand, we do not need to “implore the spirits, as did the savage” or resort to “mysterious incalculable forces."[259] Instead we know that this and other questions can be answered in a rational and mundane manner by attending to the workings of the streetcar as a mechanism.

For Weber, the advance of rationalization and the inability to engage in "ultimate and most sublime values" marks the victory of a certain kind of rationality--what he calls formal rationality.[260] In his well-read exposition of Weber's ideas, Rogers Brubaker explains Weber's approach to rationality as relational in nature. Something can only be rational from a specific point of view.[261] Formal rationality compares and assesses a set of means from the point of view of their ability to realize a goal that is already determined.[262] Where formal rationality refers to the "calculability of means and procedures," substantive rationality by contrast assesses values (also from a specific point of view). For Weber, rationalization as a larger process marks the enlargement of the sphere over which formal rationality holds and the shrinking of areas in which substantive rationality, or appeal to and discussion over values, holds.[263] Science is the not only the driver of rationalization (as the defining process of modernity), it is also the sphere that deals in facts. It is important to note, however, that although science is a driving force of modernity and the territory over which matters of fact hold is ever expanding, that science is also limited to its own value sphere and cannot provide a new set of overarching values.

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259 Weber, "Science,"139.
260 Brubaker, *The Limits of Rationality*, 37 and 43-5.
261 Ibid., 35-6.
262 Ibid. 35-6.
263 Ibid., 37 and 43-5. Habermas described the spreading logic of formal rationality as "the extension of the areas of society subject to the criteria of rational decision." Jürgen Habermas, "Technology and Science as 'Ideology,'" 81.

Many theorists who take up and modify Weber's theory of modernity similarly position science as a central and often defining force of modernity. This is the case, if in different ways, in efforts to theorize modernity as "post-industrial" or as a "risk society." Daniel Bell's landmark 1973 work *The Coming of Post-Industrial Society* provides an example of the first case. The title refers to the eclipse of the manufacturing or industrial sector of the economy by the service sector.[264] For Bell, this shift is accompanied by the rising importance of science and technology in driving the automation of extractive and industrial sectors of the economy. With the rising importance of science and technology, scientists and technical workers and professionals begin to overtake the blue collar factor worker both in terms of percentage of total workers and cultural salience.[265]

Alvin Gouldner's discussion of the potentially transformative role of the "new class" similarly foregrounds their allegiance to science as well as professionalism and technology. As I noted above, Gouldner argues that the new class's belief that "productivity depends primarily on science and technology and that the society's problems are solvable on a technological basis, and with the use of educationally acquired technical competence."[266] Further, the new class's identification with science and technology provides one of the bases for its tension with the bourgeoisie--itself the basis

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264 Bell, as other theorists of post-industrial society, is careful to emphasize that the service sector is not replacing the manufacturing sector so much as emerging as a statistically more dominant sector that comes to assume a more central position in the culture. Daniel Bell, *The Coming of Post-Industrial Society: A Venture in Social Forecasting* (New York: Basic Books, 1976), chapter 2, esp 125 and 162. For more on how Bell's post-industrial society thesis was actually about post-industrial culture, see Malcolm Waters, *Daniel Bell* (New York: Routledge Press, 1996), 172.

265 Ibid., chapter 3.

266 Gouldner notes that "Presenting technology as an impersonal and autonomous societal resource, the New Class conceals itself and its own role in the process" of strengthening its claims "*within the status quo*." As I will explore in the concluding chapter, this position introduces a point of contrast with works that position intellectuals as critiquing efforts to locate science and technology at the center of modernity. Gouldner, *Future of Intellectuals and the Rise of the New Class*, 24 on critique of the state and 25 on presenting technology.

of the new class's world-historical significance.

Science plays a similarly central role in Ulrich Beck's work on modernity. Beck's vision of modernity is centered on the transition from industrial to risk society. This transition signals the emergence of a political reflexivity focused on the hazards that emerge as a part of the process of industrial society.[267] For Beck, science is a key institution of both industrial society and risk society. On the one hand, science has brought about hazards such as radioactive waste and a proliferating array of toxic chemicals and transgenic organisms, as well as the terms for a future eugenics.[268] But science is also the primary way in which often invisible hazards can be detected and their effects made known.[269] The central place that science enjoys in Beck's work can be seen in his assertion that it "drives [the] transformation of the world."[270]

Anthony Giddens has countered Beck's emphasis on science and argued that environmentalism as a form of "life politics" has played a key role in rendering contemporary hazards visible.[271] For Giddens it is environmentalism, or "the ecology movement," that brings "heightened awareness of high-consequence risks which industrial development, whether organized under the auspices of capitalism or not, brings in its train."[272] Further, Giddens emphasizes that environmentalism is a movement

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[267] On Beck's distinction between reflexivity as "more of the same" and reflection as "a process of critical self-engagement" see the summary in Welsh, *Mobilising Modernity*, 23-5, esp. 23; and Beck, "The Reinvention of Politics: Towards a Theory of Reflexive Modernization, " 5-6 and 12.

[268] Beck, *Risk Society*, 35, 42, 66, and 72. Ulrich Beck, *World at Risk* (New York: Polity, 2009), 25, 118. Beck, *Ecological Enlightenment*, 104. Ulrich Beck, *Ecological Politics in an Age of Risk* (New York: Wiley-Blackwell, 1995), 2. Beck, *Ecological Politics in an Age of Risk*, 28-32.

[269] On the central role of science in making the hazards of industrial society known, see Beck, *Risk Society*, 27; Beck, *Ecological Politics in an Age of Risk*, 115. On the invisibility of these hazards, see Beck, *Risk Society*, 22 and 72-5.

[270] Beck, *Ecological Enlightenment*, 101. I will address the place of science in Beck's vision of modernity in more detail below.

[271] Anthony Giddens, *The Consequences of Modernity* (Stanford: Stanford University Press, 1990), 158-162.

[272] Ibid., 161 on heightened awareness and 146-7 on high-consequence risks in the context of reflexive

oriented around "life politics" and not the "emancipatory politics" of class-based struggles.[273] Elsewhere, he contrasts these two forms of politics further: "While emancipatory politics is a politics of life chances, life politics is a politics of lifestyle. Life politics is the politics of a reflexively mobilized order--the system of late modernity."[274] Here, Giddens asserts life politics are the political form of late modernity as a period defined by an unprecedented level of reflexivity, or constant re-examination of social practices.[275] In bringing attention to the risks of industrialism, environmentalism brings a re-examination or reflexive awareness to the social practices associated with industrialism.[276] He argues that

> The question 'how shall we live?' is raised by any attempt to decide what to preserve--of nature or of the past--short of problems that bear in a brute way on global survival. Ecological problems disclose just how far modern civilization has come to rely on the expansion of control, and on economic progress as a means of repressing basic existential dilemmas of life."[277]

For Giddens, the environmental movement is significant in part because it challenges answers to the question of how to live, or lifestyle, that emerge from industrial society.[278]

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modernity.

273 Giddents defines emancipatory politics as "radical engagements concerned with the liberation from inequality or servitude." Ibid., 156 on radical engagements and 156-7 on the contrast between emancipatory and life politics.

274 Anthony Giddens, *Modernity and Self-Identity: Self and Society in the Late Modern Age* (Stanford, CA: Stanford University Press, 1991), 214. Elsewhere he makes the same point: "Life politics is a politics, not of *life chances*, but of *life style*. It concerns disputes and struggles about how (as individuals and collective humanity) we should live in a world where what used to be fixed either by nature or tradition is now subject to human decisions." Anthony Giddens, *Beyond Left and Right: The Future of Radical Politics*, (Stanford, CA: Stanford University Press, 1994), 14-15 emphasis in original. He describes "An 'ethics of the personal'" as "a grounding feature of life politics, just as the more established ideas of justice and equality are of emancipatory politics." See also his assertion that "Life politics refers to radical engagements which seek to further the possibilities of a fulfilling and satisfying life for all, and in respect of which there are no 'others.'" Giddens, *Consequences of Modernity*, 156.

275 Giddens argues that "The reflexivity of modern social life consists in the fact that social practices are constantly examined and re- formed in the light of incoming information about those very practices, thus constitutively altering their character." Ibid., 38.

276 Ibid., 161.

277 Giddens, *Beyond Left and Right*, 212.

278 Although Giddens' emphasis--like that of Beck--is on mid to late 20th century developments, he acknowledges "[a]ntecedent forms of todays' 'green movements.'" Giddens, *Consequences of*

In arguing that environmentalism plays an important role in the emergence of reflexive awareness of the hazards of industrialization, Giddens stakes out a position very close to that of theorists of new social movements such as Alberto Melucci and Jürgen Habermas.[279] Just as Giddens defines "life politics" in opposition to "emancipatory politics," so do both Melucci and Habermas define new social movements in contrast with the class-based movements of the Marxist "old" left.[280] New social movements and life politics also both center on the question of how to live. Habermas, for example, famously described new social movements (Giddens' "life politics") as resisting "the colonization of the life-world."[281] Giddens' assertion that life politics are the "politics of lifestyle" echoes Habermas' description of the project of new social movements as centered on questions of "how to reinstate endangered lifestyles" or "how to put reformed life styles into practice."[282] For Melucci as well, new social movements target "cultural models which orient behavior and on which daily life, production, exchange, and consumption structure themselves."[283]

Put another way, new social movements target precisely the question that Weber considered science as incapable of addressing. In "Science as a Vocation," Weber quoted

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Modernity, 161.

279 To a significant degree then, Giddens' account of "life politics" represents a theorization of "new social movements." After introducing "life politics" in Consequences of Modernity, Giddens goes on to describe the same phenomena using the more common term "new social movements." Giddens, *Consequences of Modernity*, 156.-63. Kelly Moore's argument that scientists became unbounded "moral claims-making about science from scientists" and "'re-bound' it into networks of citizens, intellectuals, and government" provides a historically grounded mechanism for understanding the gap between the position of Beck (that science has rendered industrial hazards visible) and that of Giddens (that it was environmentalists and new social movements more generally). As I will explore in more detail in chapters 5, 6, and 7, both ecologists and new social movement activists made claims that rendered the hazards of industrial society--and, crucially here, of science itself--visible. Moore, *Disrupting Science*, 15-6 and 202-5, esp. 15 and 16

280 Ibid., 33. See the discussion of Melucci in the above section on social movements and science.

281 Habermas, "New Social Movements," 37 and 35.

282 Giddens, *Modernity and Self-Identity*, 214. Habermas, "New Social Movements," 33.

283 Melucci, *Challenging Codes*, 163.

Russian writer Leo Tolstoy as saying "Science is meaningless because it gives no answer to our question, the only question important for us: 'What shall we do and how shall we live?'" Weber continued, "That science does not give an answer to this is indisputable."[284] Scientists should not try to be prophets and answer questions of meaning or of how to live in contemporary society.[285] Significantly, Melucci invokes Weberian language in opening *Challenging Codes* by asserting that "Movements in complex societies are disenchanted prophets."[286] Like the prophet in "Science as a Vocation," Melucci's social movements assume a prophetic voice in actively engaging large public audiences in matters of value, of how to live. But they are also disenchanted. To a degree, they inhabit the same modernity that Weber describes in "Science as a Vocation."

Weber's future (in "Science as a Vocation") was defined by progressive rationalization and bureaucratization, and it was also defined by existing institutions. It is difficult to avoid the sense in “Science as a Vocation” that Weber's modernity is closed off from the possibility of a significant intervention. It is as pessimistic as it is predetermined. Although "Science as a Vocation" is centered on this vision of modernity, his philosophy of history recognizes another possibility. Social critic Lewis Mumford describes this possibility when he asserted that “[w]e must allow, when we consider the future, for the possibility of miracles."[287] For Weber, this potential was captured in the kind of charismatic social relations that could counterbalance, if not defeat, bureaucratization.

In this context, it is instructive to compare the view of modernity we encounter in

284 Weber, "Science," 143.
285 See above discussion on Weber's characterization of the figure of the prophet in the section on scientists as intellectuals.
286 Melucci, *Challenging Codes*, 1.
287 Mumford, "Prospect," 1143.

"Science as a Vocation" with the view of modernity in *The Protestant Ethic and the Spirit of Capitalism*, written twelve years earlier. Initially we see a similarly pessimistic view of modernity in Weber's concluding remarks. He notes that the “rosy blush” of the Enlightenment “seems also to be irretrievably fading and the idea of duty in one's calling prowls about in our lives like the ghost of dead religious beliefs.”[288] While the protestant ethic played a significant role in giving birth to capitalism—in informing the ethos of early capitalists, now we are simply pursuing wealth. The meaning that the protestant ethic lent to business—in finding evidence of spiritual approval, for example—has left us, but “capitalism, since it rests on mechanical foundations, needs [religious asceticism's] support no longer.”[289] However, he proceeds to note that,

> No one knows who will live in this cage in the future, or whether at the end of this tremendous development, entirely new prophets will arise, or there will be a great rebirth of old ideas and ideals or, if neither, mechanized petrification, embellished with a sort of mechanical self-importance.[290]

While Weber's optimism is far from overwhelming here, the fate of modernity is an open ended in a way that it is not in “Science as a Vocation.” Here the prophet still harbors the possibility of social change--in the same way that Melucci's social movements hold on to the possibility of change. Borrowing Weber's language, and so also the language of Melucci, we can explore the extent to which the environmental movement served a prophetic role as a charismatic challenge to ways of living that emerged with industrialism and the promise of limitless economic growth.

But environmentalism as a social movement also changed the figuration of

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[288] Max Weber, *The Protestant Ethic and the Spirit of Capitalism* translated by Talcott Parsons (New York: Dover, 2003), 182.

[289] Ibid., 181-2.

[290] Ibid., 182.

ecologists and so the shape and the texture of the scientific role. Working in a social environment that recently included a public interested in social change, ecologists began to step outside the role of scientist as specialist that Weber describes and into a different role--the more prophetic role of the scientist as intellectual. But, as Carl Boggs has asserted, obviously not all intellectuals are the same. Chapter 5 describes how Eugene Odum came to approach his research as a source of insight on precisely the question of how to live. In identifying himself and his voice as that of scientific expertise, he models the figure of the technocratic intellectual. Chapter 6 describes how other ecologists approached ecology as a science capable of subverting dominant values and describing new ways of living that accounted for the Earth's limited supply of natural resources. These ecologists modeled the role of the critical intellectual.

The environmental movement changed the figuration of ecology but so did the cold war national security state. When the state became interested in the usefulness of ecology, ecologists such as Eugene Odum entered a new figuration that brought with it unprecedented levels of funding and powerful new experimental tools but also the dilemma of how to assert autonomy from the interests of the state. In chapters 2 and 3 I will explore this figuration, the birth of radiation ecology, and the ways that ecologists attempted to distinguish their discipline from the goals of the state.

Chapter 2. The Cold War National Security State, Radioactive Fallout and Radiation Ecology

> Recently we brought an ecologist to the staff. The first question asked by several people is why is [the] AEC interested in ecology.
> - Dr. Charles W. Schilling, Advisory Committee for Biology and Medicine, November 30th, 1955.[1]

I. Introduction

Why *would* the Atomic Energy Commission be interested in employing an ecologist? What use for ecology did Charles Schilling see in relation to the goals of the Atomic Energy Commission's Division of Biology and Medicine or the cold war state more generally? How did ecology enter into a figuration with the cold war state and what opportunities and challenges did this present for individual ecologists?

The Advisory Committee for Biology and Medicine was made up scientists who met regularly in order to provide advice for the Atomic Energy Commission's Division of Biology and Medicine. The relation between this group and the AEC's Division of Biology and Medicine was analogous to the relation adhering between the more prestigious General Advisory Committee and the AEC as a whole.[2] By the time of this meeting, the mission of the Division of Biology and Medicine had taken on a larger public role with the emergence of radioactive fallout as a problem that had the potential to destabilize the practices and political and cultural legitimacy of the Atomic Energy Commission.

The 1955 meeting where Dr. Schilling raised the question of why the AEC would

1 "53rd Meeting of the Advisory Committee for Biology and Medicine," RG 326, Entry 73B – Records relating to fallout studies, 1953-64, Division of Biology and Medicine, Box 50.
2 See Richard Sylves' *Nuclear Oracles: a Political History of the General Advisory Committee of the Atomic Energy Commission, 1944-1977*. Brian Balogh's *Chain Reaction: Expert Debate and Public Participation* provides a theoretical framework for understanding the place of scientific expertise in relation to public participation in an environment increasingly dominated by large-scale government bureaucracies such as the Atomic Energy Commission.

employ an ecologist came shortly after the International Conference for Peaceful Uses of the Atom, which was held in Geneva and which followed the directives that President Dwight Eisenhower laid out in his 1953 "Atoms for Peace" address to the United Nations.[3] In opening the meeting, the Chairman of the Advisory Committee of Biology and Medicine, Gioacchina Failla noted that, "We are very fortunate in having Mr. Strauss this morning. He was in Geneva. He was very active there."[4] When the floor was handed over to Lewis Strauss, whom President Eisenhower had appointed as the chairman of the AEC in 1953, he tried to impress the significance of nuclear power upon those gathered. He told them that "On Sunday afternoon, about half past six, I went aboard the Nautilus. By 6:45 or 7 we were submerged and about half past two Monday we surfaced." During this time, many of those on board were "only a few, I started to say, inches, a few feet away from an atomic reactor that was driving us through the water silently at an impressive and classified speed."[5] Here and elsewhere, it was important to Strauss to assert nuclear weapons and nuclear power as both secret and central to the continued security and prosperity of the United States and--given this centrality--also to assert the secrecy.

As Strauss was zooming through the ocean at a classified speed, we can imagine a young and nervous ecologist, John W. Wolfe, preparing his remarks for his new employers. Although Wolfe had just recently earned his PhD in plant ecology from Ohio

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3 Eisenhower uses this as an opportunity to draw attention away from the use of the atom in building atomic and nuclear weapons: "the United States pledges before you—and therefore before the world—its determination to help solve the fearful atomic dilemma—to devote its entire heart and mind to find the way by which the miraculous inventiveness of man shall not be dedicated to his death, but consecrated to his life " (Quoted in Cantelon 1992, 96-103).

4 "53rd Meeting," 2.

5 Ibid., 3-4. See Hewlett and Holl for more on Strauss and Eisenhower. Richard G. Hewlett and Jack M. Holl, *Atoms for Peace and War*, 17-34.

State University and was a junior ecologist by any measure, he would soon become a central, if often overlooked, figure in the history of postwar American ecology. In serving as the expert voice guiding the flow of an unprecedented level of funding into ecology, he would play a significant role in the transformation of American ecology in these years.

Although the AEC funded a variety of ecologists engaged in different forms of research, the majority of this work falls into one of two camps—research on the effect of radioactive matter on the environment and research on the movement of radioisotopes through the environment. Research on the effect of radioactive matter tended to be performed in places where there was a lot of radioactive matter –AEC laboratories such as Hanford and Oak Ridge as well as sites (in Nevada and the South Pacific) used for testing atomic bombs and hydrogen bombs. This work was generally carried out by scientists working for the AEC directly or, more often, for contractors responsible for running the AEC labs at Hanford and Oak Ridge. The second form of radiation ecology tended to be more loosely connected with the AEC. Here ecologists, often working as academics in university settings, used radioisotopes procured from the AEC to detect the movement of matter and energy through the environment. While radioisotopes were not visible, they could be easily detected often through the use of Geiger counters. In both cases, radiation ecology represented the closest thing that ecology had seen to "big science" until that time and would set the tone for later, large scale research projects in ecology such as the International Biological Program and the Long Term Ecological Research Network.

Odum would quickly move into a central position in the relation between the AEC and the field of ecology. Further, this relationship would play an important role in establishing not only Odum's own prominence in the larger field of ecology but also the prominence of the University of Georgia as a center for ecological research. In raising the broad question of the usefulness of ecology to the cold war national security state, then, Schilling's 1955 question also introduces for us the context in which the Atomic Energy Commission would contract Odum to perform an environmental survey of a stretch of land in south east South Carolina. From the beginning, Odum had an ambitious eye to the ways external funding could facilitate his hopes to establish himself as a respected ecologist and to establish ecology as a discipline at the University of Georgia and beyond. The political context I describe in this chapter provided the conditions in which Odum was able to turn an initially modest and circumscribed AEC project into the basis of the long-term source of funding for a wide variety of ecological research. As he noted much later in his career, this success in securing outside funding proved to be a central component of his later success.[6] In this chapter I will examine Projects Gabriel and Sunshine in order to understand the political context in which it made sense for the Atomic Energy Commission to hire an ecologist. In the following chapter, I will turn to Odum's point of view and his efforts to render ecology useful to but also autonomous from the ends of the Atomic Energy Commission. In this chapter I will privilege the point of the view of the cold war state (and proceed to a disciplinary-level account of radiation ecology) by exploring what use it had for ecology.

II. Project Gabriel

6 Eugene Odum, "Turning Points in the History of the Institute of Ecology," in *Holistic Science: The Evolution of the Georgia Institute of Ecology (1940-2000)*, ed. Barrett, Gary W., and Terry Lynn Barrett. (New York: Taylor and Francis, 2001) 13-37.

> The less wise among the magi counseled the prince according to his pleasure, saying 'The weapons may be used, only do not exceed such-and-such a limit or surely all will perish' (Walter M. Miller, *Canticle of Liebowitz* 1960, 171).

> It is with some trepidation that we present in a preliminary report of this nature an estimate of the number of nuclear detonations which will contaminate the world.
> (Atomic Energy Commission, *Worldwide Effects of Atomic Weapons: Project Sunshine*, R-251-AEC, 1953, 5).

The Atomic Energy Commission (AEC) invoked the archangel Gabriel in a project designed to answer the question of how many atomic bombs it would take to render the world uninhabitable. The project began in 1949 when AEC staffer Nicholas M. Smith determined—and the head of the AEC's Division of Biology and Medicine agreed—that it would take three thousand kiloton size bombs to make the earth uninhabitable. In 1951 Smith revised his earlier estimate upwards and "concluded it would require the detonation of one hundred thousand weapons of the Nagasaki type to reach the 'doomsday' level."[7] Although it had begun as a small operation staffed only by Smith, Project Gabriel began to assume more and more importance in the early 1950s as radioactive fallout became a larger and more pressing issue.

In these years Project Gabriel gave way to Project Sunshine that grew quickly through the 1950s to become an umbrella project centered on better understanding and managing the problem of radioactive fallout. And, as the scientific studies funded as a part of Project Gabriel and then Project Sunshine assumed more importance, estimates of the amount of fallout required to make the earth uninhabitable increased. By 1953, the

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7 Richard G. Hewlett and Jack M. Holl, *Atoms for Peace and War, 1953-1961: Eisenhower and the Atomic Energy Commission*, (Berkeley: University of California Press, 1989), 265. Stafford Warren was the head of the AEC's Division of Biology and Medicine at this time.

estimate was revised upwards once again. This time it was concluded that it would take 25,000 megatons worth of damage in order to render the earth uninhabitable.[8] Although 'sunshine' might have provided a more palatable euphemism for discussing calculations of this level of destruction, the name of the initial project was in many ways more fitting as many Christians envision Gabriel to be the angel who will herald the beginning of the end times with the sound of his horn.[9]

Why was the Atomic Energy Commission so intent on imagining an inhabitable future in the late 1940s and early to mid 1950s? If many understand the archangel Gabriel as responsible for heralding the beginning of the end times, then how are we to to understand the meaning and role of the Atomic Energy Commission's visions of the irradiated futures? How can this project serve as a case for understanding the relationship between science and the state in the years following World War II? What *was* the role of ecology in this state-run project?

III. The Cold War National-Security State

Project Gabriel and Project Sunshine emerged from a period in the cold war—the late 1940s and early 1950s—when the notion of the national-security state and the ongoing mobilization for war with the Soviet Union became central features of cold war politics. For advocates of the cold war national-security state, the development and

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8 Arnold Kramish, Ed., *Worldwide Effects of Atomic Weapons: Project Sunshine*, R-251-AEC, August 6, 1953, U. S. Department of Energy OpenNet Project, accessed August 28, 2010, https://www.osti.gov/opennet/advancedsearch.jsp.

9 *See S. Vernon McCasland on the belief that it is Gabriel who is referenced in I Thessalonians chapter 4:16-7,* "For the Lord himself will come down from heaven, with a loud command, with the voice of the archangel and with the trumpet call of God, and the dead in Christ will rise first. After that, we who are still alive and are left will be caught up together with them in the clouds to meet the Lord in the air. And so we will be with the Lord forever." S. Vernon McCasland, "Gabriel's Trumpet," *Journal of Bible and Religion* 9, 3 (August 1941): 159-161.

testing of atom bombs and later hydrogen bombs were considered necessary to "contain" communism.[10] But the possibility that radioactive fallout created significant negative health effects posed a problem to a state that was committed to building an arsenal of atomic and nuclear weapons. In this context, the question of the negative health effects of radioactive fallout was both epistemic and political in nature. It was a question that could be addressed by scientists working in laboratories as spaces set aside from the pressures of the world. But it was also a political problem insofar as it could, and did, undermine the legitimacy of the cold war national-security state and efforts to mobilize for war in a time of peace.

Projects Gabriel and Sunshine represent the state's effort to employ scientists in order to assert that radioactive fallout, and therefore weapons testing, were safe. In attempting to provide an authoritative answer to the epistemic question of the health effects of fallout, the AEC was also attempting to prevent fallout from undermining the political legitimacy of the cold war national-security state. In its early years especially, Project Gabriel modeled a fascination with a future rendered uninhabitable by the very weapons it would later be used to justify. Atomic Energy Commission elites would deploy knowledge gained from Sunshine's sampling program in order to try to close the debate by assuring the public that radioactive fallout—and weapons testing—was safe. The process of imagining an uninhabitable world was used to justify the development of weapons that threatened to make that scenario real.

Although Project Sunshine was launched in the early 1950s, it would not be until much later that the nature of its practices would come under public scrutiny. While the

10 Charles E. Nathanson, "The Social Construction of the 'Soviet Threat': a Study in the Politics of Representation." *Multilingua* 7, 3 (January 1988): 241-4.

project began as the efforts of one man, it grew quickly to encompass theoretical studies, experiments, and a sampling network that spanned the globe. Specimens of soil, plants and film were collected and returned to laboratories that were funded by the Atomic Energy Commission in order to determine the spread of fallout from weapons tests. Decades later the public would realize that, in addition to samples of soil and plants, the AEC had been collecting cadavers and body parts often of people who had not given consent. As macabre as these practices were, they fit with how the AEC had treated people as unwitting subjects of dangerous experiments on other occasions. One notable set of experiments involved injecting radioisotopes of plutonium into the bloodstream of people who were not informed that they were being injected with plutonium or that it was at levels that the AEC itself had deemed dangerous.[11] It is my contention that these practices, as a troubling intersection between science and the state, made sense according to a logic defined by a political culture centered on war.

The centrality of war, and especially nuclear war, to this political culture entailed a way that humans could act on themselves, that was considered problematic and opposed by people subscribing to an ecological vision of life. This perspective went along with a very different form of ethics that included not only humans but also non-human animals. From this perspective, the AEC's uncertainty about and investigation into the health effects of fallout transformed these Engebi rats and people all over the world into the objects of an experiment into the effects of radioactive matter on living organisms.

Project Gabriel was initiated in 1949 after the discovery of the first USSR atom

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[11] Eileen Welsome, *The Plutonium Files: America's Secret Medical Experiments in the Cold War,* (New York: Random House, 1999), chapter 13.

bomb test, and took root in the years that saw the emergence of the national-security state as one of the dominant political visions of the early years of the cold war. When America saw its monopoly over the atom bomb vanish, President Truman responded within a few short months to announce the development of the hydrogen bomb, the 'superbomb.' This announcement would be followed by a significant revitalization and expansion of the infrastructure that the Atomic Energy Commission had inherited from the Manhattan Project after the end of World War II. New laboratories and production facilities would emerge—such as Lawrence Radiation Laboratory in Livermore, California and the Savannah River Site in South Carolina—along with efforts to re-enlist scientists, many of whom had returned to the academy at the close of World War II. If the mushroom clouds above Hiroshima and Nagasaki lent credence to the characterization of World War II as 'the physicist's war,' they would also come to symbolize the power of a modern state armed with science as "a central instrument of violence."[12] Although this alliance had begun to weaken with the demobilization following World War II, it would be reanimated with the mission to build larger and more destructive weapons such as the hydrogen bomb.

These mobilization efforts would become significantly more widespread and permanent with the outbreak of the Korean War and then The People's Republic of China's entry into the war. When President Truman declared a state of national emergency, there was a dramatic increase in mobilization efforts, defense spending, and the creation of new organizations such as the powerful Office of Defense Mobilization and its Defense Production Administration.[13] In her account of cold war strategist Herman

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[12] Charles Thorpe, *Oppenheimer: the Tragic Intellect*, (Chicago: University of Chicago Press, 2008), xi.

[13] Paul G. Pierpaoli, *Truman and Korea: The Political Culture of the Early Cold War*, (Columbia:

Kahn, Sharon Ghamari-Tabrizi provides a view into public reactions to these events when she notes that many Americans believed that "U.S. involvement in the Korean War meant that World War III had already begun."[14] It is in this context—a context defined by the mobilization of society for war—that Project Gabriel, later folded into Project Sunshine, made sense. America was remaking itself according to the image of the vision of the national-security state. It was remaking itself, in other words, according to the logic of war.

IV. Project Sunshine and the Voice of Science

Recommendations emerging from a summer 1953 conference at RAND, a think tank that served as a hub for cold war strategizing, played an important role in sketching out the dimensions that Project Sunshine would later assume.[15] When the report from the conference was released the August following the RAND conference, it announced that "Its purpose is to inquire into the nature of various large-scale disasters which conceivably might result from the detonation of large numbers of nuclear and/or thermonuclear weapons. By 'large scale' we imply areas many magnitudes larger than the immediate destruction area." The conference's recommendations for a worldwide

University of Missouri Press, 1999). Michael J. Hogan, *The Iron Cross: Harry S. Truman and the Origins of the national-security state, 1945 – 1954*, (Cambridge: Cambridge University Press, 1998). Steven Casey, "Selling NSC-68: The Truman Administration and the Politics of Mobilization, 1950-51." Diplomatic History 29, September, (2005): 655-90. Melvyn P. Leffler, "National Security." *The Journal of American History* 77, 1, Jun., (1990): 143-152. Melvyn P. Leffler, "The American Conception of National Security and the Beginnings of the Cold War, 1945-48." *The American Historical Review* 89, 2, Apr., (1984): 391-400.

14 Sharon Ghamari-Tabrizi, *The Worlds of Herman Kahn: The Intuitive Science of Thermonuclear War* (Cambridge, MA, Harvard University Press, 2005), 87, emphasis in original).

15 Started as a small operation in 1949, Project Gabriel would be folded into Project Sunshine by the end of this 1953 RAND conference and continue the effort to calculate the effects of nuclear war. This was, for example, the conference where the scientists of the AEC determined that it would take twenty five thousand megatons worth of destruction in order to render the world uninhabitable.

sampling network would become a reality as film, along with a wide variety of other 'indicators'—soil, plants, milk, and biological specimens—would be sent to labs such as the AEC Health and Safety Laboratory in New York, Columbia's Lamont observatory, and Willard Libby's lab in Chicago to determine the level of radioactive fallout that settled from the sky in various parts of the world.

As Sunshine grew in size, it also grew in importance. The project's budget serves as one indicator of its perceived importance. Sunshine's budget after the 1953 conference represented a significant increase—at $140,000 and fifteen man-years of labor—over Project Gabriel. By the end of 1956, Sunshine had grown significantly and come to encompass a range of projects that had been created in the intervening years and that were budgeted at over $1.5 million dollars a year.[16]

Project Sunshine was also seen to be very important by many in the AEC. Historian Barton Hacker notes that when John Bugher replaced Stafford Warren as the head of the Division of Biology and Medicine in 1953, Bugher "learned how highly the commissioners now valued the project. Accordingly he quickly upgraded the effort. 'The project known as Gabriel is to be accelerated and given a priority status,' he [Bugher] ordered."[17] Four years later in February 1957, Willard Libby, then an AEC commissioner, asserted that, behind the production of nuclear weapons, Project Sunshine was AEC's most important mission.[18] Nor was he alone in thinking this was the case as the growing

16 This account of Project Gabriel and Sunshine draws from Hacker *Elements*, 180-4. Richard T. Sylves *Nuclear Oracles: a Political History of the General Advisory Committee of the Atomic Energy Commission, 1947-1977*, (Ames, IA: Iowa State University Press, 1987), chapter 7; Hewlett and Holl *Atoms for Peace and War*, particularly 264-266, and Welsome, *Plutonium Files,* chapter 3.

17 Quoted in Hacker, *Elements*, 182.

18 Welsome *Plutonium*, 300. Willard Libby was a member of the AEC's prestigious General Advisory Council from 1950 through 1954--at which time he was appointed to the Commission itself--and again from 1960 through 1962.

importance of Sunshine provided the impetus for the reorganization of the Division of Biology and Medicine in 1957.[19]

Although the agency was concerned to manage the problem of fallout from at least the 1949 beginning of Project Gabriel, the Castle Bravo test in 1954 propelled the problem of fallout into the public eye. At the Castle Bravo test on March 1st, 1954 fallout unexpectedly rained down over a Japanese fishing vessel, over two hundred Marshall islanders and a handful of American servicemen. Despite their efforts to contain and then to downplay the news about the incident,[20] fallout would become an international controversy when the Associated Press picked up Japanese news stories that their citizens had radiation poisoning and that the test could have compromised one of the nation's primary food sources.[21] It was then that the AEC scrambled against its critics to contain credibly the epistemic and political uncertainty posed by fallout. For both sides of this controversy, the stakes were high as the question of the health effects of fallout took on a political significance that threatened to undermine the politics of the national-security state as a political vision centered on war.

As the question of the health effects of fallout became progressively more public, and more pressing, many were alarmed to learn that the issue could not be resolved by

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19 Hacker *Elements*, 182-184.

20 See Hacker, Hines and Caulfield on the AEC's initial reaction. Hacker, *Elements*, 147; Hines, *Proving Ground*, 169; Catherine Caufield, *Multiple Exposures: Chronicles of the Radiation Age* (Chicago: University of Chicago Press, 1990), 112-116. Laura Harkewicz, "*The Ghost of the Bomb": The Bravo Medical Program, Scientific Uncertainty, and the Legacy of the Cold War, 1954 – 2005* (PhD diss., University of California, San Diego, 2010).

21 When Strauss reacted by publicly maintaining that the vessel must have been within the restricted zone, the Japanese embassy replied that Strauss' claim was "not. . .entirely consistent with information officially received here." In private, Strauss told Eisenhower Press secretary James Hagerty that the vessel was a "Red spy ship" (Hacker *Elements*, quote from 150-1). At a press conference a month after Bravo, Strauss unintentionally stoked the flames of public concern in describing the hydrogen bomb as "large enough to take out a city." "Text of Statement and Comments by Strauss on Hydrogen Bomb Tests in the Pacific" *New York Times* April 1, 1954, 20 and William T. Laurence, "Vast Power Bared" *New York Times,* April 1, 1954, 1 and 20.

consulting scientific experts. Many geneticists took issue with the claims of AEC scientists that fallout was safe. Here, Hermann Muller's Nobel prize winning work on the mutagenic effects of x-ray radiation in the 1920s became a common reference point. If even very small amounts of radiation could cause mutations, some argued there was no safe—or "permissible" or "acceptable"—level of radiation as the AEC claimed. AEC Division of Biology and Medicine chief John Bugher responded by maintaining that "discussion of the genetic implications in man of radiation exposure. . .has all been speculative."[22]

In 1957 and again in 1959 the controversy took public stage in Congressional hearings. In both cases the hearings were held in the Joint Committee on Atomic Energy's Subcommittee on Radiation and focused on understanding the nature and effects from a scientific perspective. Formed for the occasion of preparing for the 1957 hearings, the subcommittee reported an effort to bring together a group of scientists that would be both "representative" of prevailing opinions and "balanced" with respect to positions on weapons testing.[23] While the hearings include the voices of a number of scientists working for and affiliated with the AEC, they do include the strongly dissenting views of Barry Commoner.[24] After the conclusion of the 1957 hearings, Chet Holifield, a

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22 Carolyn Kopp, "The Origins of the American Scientific Debate over Fallout Hazards." *Social Studies of Science* 9, 4, (November 1979): 408.

23 Chet Holifield, "Congressional Hearings on Radioactive Fallout." *Bulletin of the Atomic Scientists* (January 1958): 52-4. Balogh provides partial coverage of the hearings in the context of a struggle by sanitary engineer Abel Wolman and the U. S. Public Health Service to gain authority over the health effects of fallout. Balogh, *Chain Reaction*, 154-7 and 297.

24 Meanwhile, the activist organization that Commoner played a leadership role in - the Committee for Nuclear Information - charged the work of Edward Teller, staunch advocate of the safety of weapons testing, with "fail[ing] to conform to the standards of validity which are customary in scientific work." See also Egan's, Lutt's and Moore's coverage of the organization's effort to collect baby teeth to establish how much Strontium 90 that they contained and to raise awareness about the distribution and effects of radioactive fallout. These authors also provide excellent sources on Commoner's opposition to weapons testing on the grounds that the health effects of radioactive fallout were unknown. Michael Egan, *Barry Commoner and the Science of Survival: The Remaking of American Environmentalism*.

Democratic representative from California and chair of the Subcommittee on Radiation, reported that the hearings were a

> scientific seminar to lay a basic groundwork of knowledge by the public and for more intelligent policy decisions. Had we departed from this basic approach, I am sure that our hearings would have lost their scientific informational value. We would have been caught up in emotionalism, propaganda, and controversy, and would have found ourselves debating moral, philosophic, and religious opinions and convictions. I do not mean to suggest that such debates are inappropriate, only that an impartial fact-finding and fact-sifting job had to be done first.[25]

The fact-finding efforts of the hearings apparently did not come without some struggle, however, as Holifield also reported that he had to "squeeze the [fallout] information out of the agency."[26] His summary of the conclusions and future questions of the hearings nonetheless provide the picture that a range of views were heard but that the health effects of fallout were being addressed and did not yet constitute a major issue.[27]

The following year (1958) fallout was the subject of a televised debate between two prominent scientists—physicist Edward Teller and chemist Linus Pauling. One of focal points for the debate was the role that Pauling had played in drafting a petition that called for an end to nuclear weapons testing on the grounds that the radioactive fallout that it generated was unsafe.[28] Signed by Barry Commoner, Edward Condon and over

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(Cambridge, MA: MIT Press, 2007), 37-8, 48-53, 62-75, esp. 64 [quote]. Ralph Lutts, "Chemical Fallout: Rachel Carson's Silent Spring, Radioactive Fallout and the Environmental Movement," *Environmental Review* 9, 3 (Fall 1985): 210-225. Moore, Disrupting Science, chapter 4. Barry Commoner, “The Fallout Problem.” *Science* 127, no. 3305. New Series (May 2, 1958): 1023–1026. Joint Committee on Atomic Energy. *The Nature of Radioactive Fallout and Its Effects on Man. Hearings Before the Special Subcommittee on Radiation of the Joint Committee on Atomic Energy Congress of the United States Eighty-Fifth Congress First Session on the Nature of Radioactive Fallout and Its Effects on Man. May 27, 28, 29, and June 3, 1957.* U.S. Government Printing Office, 1957.

25 Holifield, "Congressional Hearings," 52-3.

26 Hewlett and Holl, *Atoms for Peace and War*, 454.

27 Although Holifield cited ongoing concern for the fear that fallout can cause genetic mutation, his report also seemed to be optimistic about the prospects of a "clean" bomb and indicated that it was "clearly shown" that the effects of pasts tests was minimal. Holifield, "Congressional Hearings," 53-4.

28 "'Fallout and Disarmament,' a televised debate between Linus Pauling and Edward Teller." 1958. Ava

9,000 other scientists, the petition garnered widespread attention including President Eisenhower's comment that "I noticed that in many instances scientists that seem to be out of their own field of competence are getting into this argument about bomb testing."[29] In the televised debate between Pauling and Teller, Pauling opened the debate with the simple statement "I am a scientist" and proceeded to frame the attack of his position as full of the kind of untrue statements more characteristic of a politician than a scientist. He noted that "It is of course an old trick of a politician to attribute to his adversary an untrue statement that he has not made and then to demolish it."[30]

While Teller still emphasized his identity as a scientist, he also emphasized nuclear weapons as a necessary part of the struggle with the Soviet Union. After opening by acknowledging the importance of Pauling's scientific work, Teller framed his disagreement with Pauling in terms of the need for debate.[31] He then characterized Pauling's position as an unrealistic approach to an enemy who, citing Soviet leader Nikita Khrushchev, "wants to bury us." By contrast to the effort to obtain peace "by wishing for it," Teller cast himself as capable of facing the ugly reality of politics.[32]

Helen and Linus Pauling Papers, Digital Collection Accessed February 15, 2010, http://osulibrary.oregonstate.edu/specialcollections/coll/pauling/peace/papers/1958p2.1.html.

In his coverage of the Pauling-Teller debate in the pages of *Bulletin of Atomic Scientists*, Malcolm Sharp carefully covers the disagreement between the scientists while emphasizing their credibility as "responsible" scientists. While Teller "minimizes the ill effects of the tests" and Pauling "maximizes their ill effects," Sharp emphasizes that "It should be understood that each is a responsible scientist, and neither finally depends on figures, estimates or doubts that are without foundation." Malcolm Sharp, "No More War!" *Bulletin of the Atomic Scientists* 15, 1 (January 1959): 44-46, esp. 44. Shapin, “Cordelia's Love," 255-75; Epstein, *Impure Science*, Introduction.

29 "The Right to Peititon," Ava Helen and Linus Pauling Papers, Digital Collection Accessed March 15, 2011, http://osulibrary.oregonstate.edu/specialcollections/coll/pauling/peace/narrative/page27.html. See also Christopher J. Jolly, "Linus Pauling and the Scientific Debate Over Fallout Hazards," *Endeavour* 26, 4 (2002): 149-153; and Kopp, "Origins of the Scientific Debate Over Fallout," 418.

30 Later in the debate Pauling buttressed his estimate of the ill effects of fallout by citing the agreement of "one of the world's leading geneticists, a distinguished authority in this field and conservative in all of his statements."

31 Later in the debate, Teller did dispute Pauling's scientific argument by arguing that there is no proof for "the alleged damage which the small radioactivity is causing."

32 "'Fallout and Disarmament,' a televised debate between Linus Pauling and Edward Teller," Ava Helen

In 1959 the Joint Committee on Atomic Energy's Subcommittee on Radiation hosted another set of hearings. Where Holifield characterized the 1957 hearings as a more open ended attempt to establish the current state of the facts of radioactive fallout, the 1959 hearings were more focused on the issue of whether weapons tests should be limited.[33] Scientists' dissenting positions, the activism of groups like the Committee for Nuclear Information, and the widespread publicity of radioactive fallout as problem were undermining the Atomic Energy Commission's efforts to assure the public that fallout was safe.[34] In a brief article published in the *Bulletin of Atomic Scientists* the month following the hearings, the AEC's General Advisory Committee continued to maintain that exposure to fallout was small compared to natural sources of radiation, but it also adopted a more cautious and almost defensive tone. The committee reported that they had "reviewed carefully the available facts and opinions" and "released all significant fallout

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and Linus Pauling Papers.

33 Hewlett and Holl, *Atoms for Peace and War*, 555-6. Joint Committee on Atomic Energy, *Fallout from Nuclear Weapons Tests: Hearings Before the Special Subcommittee on Radiation of the Joint Committee on Atomic Energy, Congress of the United States May 5, 6, 7, and 8, 1959*. U.S. Government Printing Office, 1959.

34 In addition to Pauling and Commoner, the mid to late 1950s also saw the increasing prominence of former Manhattan Project physicist Ralph E. Lapp as a dissenting voice to AEC approaches to fallout. See the increasing number of his critical publications and the statement of Thomas Shipman, AEC head of health physics for Los Alamos, that Ernest Sternglass, might be a “trouble maker[s] of the Ralph Lapp-Barry Commoner type.” Ralph E. Lapp, "Strontium Limits in Peace and War." *Bulletin of the Atomic Scientists* (October 1956): 287-9; *Ralph E. Lapp, The Voyage of the Lucky Dragon*. New York, NY Harper & Brothers, 1958; Ralph E. Lapp, "Local Fallout Radioactivity," *Bulletin of the Atomic Scientists* (May 1959): 181-6; *Ralph E. Lapp, "Fallout and Home Defense." Bulletin of the Atomic Scientists* (May 1959): 187-91; *Ralph E. Lapp, "What is the Price of Nuclear War?" Bulletin of the Atomic Scientists* (October 1959): 340-3. *Ralph E. Lapp, "A Criticism of the GAC Report. " Bulletin of the Atomic Scientists* (September 1959): 311-2. *Hacker, Elements of Controversy*, 252.

Later, the AEC would encounter other scientists that dissented from its official position on fallout. Geographer Scott Kirsch details Harold Knapp's efforts to draw attention to the risks posed by radio-iodine in the early 1960s, and historian of science Ionna Semendeferi has described John Gofman's work on the effects of low levels of radiation. While these scientists were not as prominent as Pauling or Libby, their critiques gained attention and weight from the fact that both were scientists working for the AEC. Scott Kirsch, “Harold Knapp and the Geography of Normal Controversy: Radioiodine in the Historical Environment.” *Osiris* 19 (2004):167-181. *Ioanna Semendeferi “Legitimating a Nuclear Critic: John Gofman, Radiation Safety, and Cancer Risks.” Historical Studies in the Natural Sciences* 38, 2, (*2008): 259–301.*

data to other agencies and to the public." Further, the committee acknowledged that the "present state of knowledge does not permit a full evaluation of the biological effects of fallout."[35] Behind closed doors, the Atomic Energy Commission had already begun considering limiting weapons testing to underground tests in order to limit fallout as early as May, 1958.[36]

Despite impressive efforts on both sides of the larger fallout debate to locate and to marshall a scientific position credible and conclusive enough to close the controversy, concern over the effects of fallout would persist into the 1960s era concern over the uptake of Iodine 131 into the thyroid and ongoing concern about the impact of radiation from nuclear power plants.[37] In this context, the findings of Project Sunshine became a key resource for assuring the public that weapons testing could continue because fallout was safe. In January of 1956, Willard Libby would deploy data from Project Sunshine to assert that, “On the basis of the information [we have] attained. . . it is possible to say unequivocally that nuclear weapons tests carried out at the present time do not constitute

35 General Advisory Committee to the U. S. Atomic Energy Commission, "Problems Presented by Radioactive Fallout," *Bulletin of the Atomic Scientists* (June 1959): 258-259, esp. 258.

36 "Atomic Energy Commission Meeting 1377, May 28, 1958," in *The American Atom: A Documentary History of Nuclear Policies from the Discovery of Fission to the Present* ed. Philip Cantelon, Richard G. Hewlett, et al. (Philadelphia: University of Pennsylvania Press, 1992), 174-9.

37 There are many rich histories of various aspects of the fallout debate. See, for example, Catherine Caufield, *Multiple Exposures: Chronicles of the Radiation Age* (Chicago: University of Chicago Press, 1989). Robert A. Divine, *Blowing on the Wind: The Nuclear Test Ban Debate, 1954-1960*, (New York: Oxford University Press, 1978). Robert P. Crease, Robert P. "Fallout: Issues in the Study, Treatment, and REparations of Exposed Marshall Islanders" in *Science and Other Cultures: Issues in Philosophies of Science and Technology* edited by Robert Figueroa, et al. (New York: Routledge, 2003), 106-25. Hacker, *Elements of Controversy*. J. Christopher Jolly, “Linus Pauling and the scientific debate over fallout hazards.” *Endeavour* 26, 4, (2002): 149-153. Kirsch, “Harold Knapp and the Geography of Normal Controversy," 167-181. Kopp, “Debate Over Fallout.” George T Mazuzan and J. Samuel Walker.. *Controlling the Atom: The Beginnings of Nuclear Regulation 1946-1962*. (Berkeley: University of California Press, 1985). Semendeferi “Legitimating a Nuclear Critic," 259–301. J. Samuel Walker, *Permissible Dose: A History of Radiation Protection in the Twentieth Century*. **(**Berkeley: University of California Press, 2000). J. Samuel Walker, 1994. “The Atomic Energy Commission and the Politics of Radiation Protection, 1967-1971.” *Isis* 85(1, Mar.): 57-78.

a health hazard to the human population"[38]. Further, Libby's statement, like those of Edward Teller but also Linus Pauling and Barry Commoner, came with impressive scientific credentials. The facts that he was an AEC Commissioner and leading chemist (he had not yet been awarded the Nobel Prize) could have only bolstered the credibility of his calm assurances that fallout was safe.

While Libby and Edward Teller might have been among the more prestigious scientists assuring the public that fallout was safe, they were not the only ones. In fact scientists at all three of the primary laboratories that processed the samples collected in Project Sunshine's worldwide network would become vocal advocates of the position that fallout was safe. Libby headed the Chicago lab and was perhaps the most vocal. At the AEC's Health and Safety Laboratory in New York, Merril Eisenbud was lead author on a series of articles that reported the levels of fallout that had turned up in different parts of the world. At the same time as the articles helped establish Eisenbud as an expert in fallout, they were also deploying this credibility to assure the public that the amount of fallout from weapons tests was safe. In one such paper Eisenbud with coauthor John Harley—who also worked at the AEC's New York lab—assured the reader that, "Unfortunately, the calm presentation of the facts, usually many months after the incident, does not erase from people's minds the more sensational statements that have appeared in the press as a result of either pure speculation or superficial and incomplete information."[39] In a publication the following year, Eisenbud and Harley maintained that geneticists' "concern" for fallout as out of proportion to the fact that radiation from from

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[38] Hewlett and Holl *Atoms for Peace and War*, 328-30, esp. 330 [quote].

[39] Merril Eisenbud and John H. Harley, "Radioactive Fallout in the United States" *Science* May 13, 1955: 680.

weapons test "is small when compared to gamma radiation received from natural sources."[40] In this article and one Eisenbud published as a solo author in 1959, it was acknowledged that Strontium 90 from weapons tests would become a part of our skeletons, but it would be an acceptably small amount.[41]

Meanwhile, J. Laurence Kulp was the lead author on a series of articles coming out of the Lamont Geological Observatory—another lab processing Sunshine data. His message was the same. The amount of fallout from weapons tests is small compared to natural sources of radiation. He went further in rendering explicit what Eisenbud's articles conveyed in the impressive tables of fallout sampling locations, world maps, and graphs. Radioactive fallout "is being carefully monitored"[42]. The message was that, although the uncertainty from the fallout debate might make fallout seem like a problem, fallout from weapons tests is at safe levels and being monitored by experts. With the samples of plants and soil and exposed film collected from all over the world, Atomic Energy Commission scientists could assume a confident tone in assuring the public that fallout was not a problem.

The question of the health effects of fallout was in many ways an epistemic question—a question that could be answered by scientists working in laboratories, free of

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40 Merril Eisenbud and John H. Harley, "Radioactive Fallout Through 1955" *Science* August 10, 1956: 254.

41 Ibid. and Merril Eisenbud, "Radioactive Fallout Through 1958" *Science* 3367, July 10, 1959: 76-80. See also Merril Eisenbud and John H. Harley, "Long Term Fallout," *Science* 128, 3321, August 22, 1958: 399-402.

42 "The increase in normal gamma background is very small, so far, and it is being carefully monitored." J. Laurence Kulp, Walter R. Eckelman and Arthur R. Schulert, "Strontium-90 in Man" *Science* February 8, 1957: 219. The articles followed in progression and were appended with roman numerals designating their place in the series. Walter R. Eckelman, J. Laurence Kulp, and Arthur R. Schulert, "Strontium 90 in Man II," *Science*, February 2, 1958. J. Laurence Kulp, Arthur R. Schulert and Elizabeth J. Hodges, "Strontium 90 in Man III," *Science*, May 8, 1959. J. Laurence Kulp, Arthur R. Schulert and Elizabeth J. Hodges, "Strontium 90 in Man IV" *Science*, August 19, 1960. J. Laurence Kulp and Arthur R. Schulert, "Strontium 90 in Man V," *Science*, May 18, 1962.

political concerns. AEC scientists asserted their detachment from the political concerns from fallout at the same time as they assert their reliance on science and the "calm presentation of the facts."[43] Further, this characterization of the importance of science as a way of addressing fallout fits in with Representative Chet Holifield's emphasis on the importance of "impartial fact-finding and fact-sifting" in organizing the 1957 congressional hearings on fallout. The detached tone that Libby, Eisenbud, and others assumed came together with their scientific credentials and emphasis on a fact-based approach to fallout.

These scientists are clearly presenting their stance on fallout employing the voice of science. Unlike the scientists Mukerji discusses in *Fragile Power*, however, many of the Project Sunshine scientists worked directly with the state.[44] Nonetheless, the AEC's public position on fallout was, to a significant degree, defined by an attempt to marshall the credibility of prominent scientists to present the question of the health effects of radioactive fallout as an epistemic question that was being managed by experts. Although these scientists worked for the state - and so could not claim the added legitimacy conferred by a visibly autonomous stance, Mukerji's basic insight into the nature of science-state relations applies. By marshaling the voice of science as (ostensibly) operating above or outside politics, the state was able to bolster its political position and better manage fallout.

By carefully controlling the information it was presenting on fallout, the AEC was able to present this problematic new entity as an epistemic, and not a political, concern on which there was broad agreement of experts. Libby, Kulp, and Eisenbud employed a form

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43 Eisenbud and Harley, "Radioactive Fallout in the United States," 680.

44 Mukerji, *A Fragile Power* chapter 10. See the chapter 1 for more explicit discussion of Mukerji's work.

of stage management that controlled the information being disclosed to the public. In asserting very similar messages--that fallout was safe or within safe levels and that fallout was being monitored by experts--these scientists could attempt to bring closure to fallout as a controversy.[45] Hilgartner has argued that by selectively disclosing the information that they want their audiences to here, the public performances of scientists and others are also actively engaged in withholding or enclosing other information. In this case, information about the ongoing uncertainty of the health effects of fallout was being enclosed along with the nature of many of the samples that informed their analysis of the distribution and effects of fallout.[46] By defining fallout as a problem that was epistemic, and not political (or value laden), in nature, they were also defining it as the kind of technical problem for which they were uniquely suited to address with the unprecedented cadre of nuclear expertise that it had assembled as advisers, employees, and consultants.

V. Samples of Sunshine

Plants and soil and exposed film were not the only things that the project collected. It also collected dead humans, many of whom had not given their permission for their remains to be combed over for the presence of fallout. Welsome provides an additional sense of the project's activities: “approximately 9,000 samples of human

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45 On stage management as a technique to bring about closure see Stephen Hilgartner, *Science on Stage: Expert Advice As Public Drama* (Stanford, CA: Stanford University Press, 2000), 11-13, 19-20, and 149.

46 On enclosure see Hilgartner, *Science on Stage*, 20 and 83-5. By employing the techniques that Hilgartner describes, the AEC was also performing what science studies scholar Sheila Jasanoff has termed "ontological surgery," or "deciding how to describe and characterize the problematic entities whose natures must be fixed as a prelude to ethical analysis." Only, in this case, the AEC was proposing an ethics of inaction. Sheila Jasanoff, *Reframing Rights: Bioconstitutionalism in the Genetic Age* (Cambridge, MA: MIT Press, 2011), 61.

bones, entire skeletons, and nearly 600 fetuses were collected from around the world."[47] In a meeting of the General Advisory Committee—the elite group of scientists chosen to advise and guide the Atomic Energy Commission—scientists spoke openly about stealing human corpses. In a 1955 meeting, Willard Libby lamented that getting bodies was so difficult. "If anyone knows how to do a good job of body snatching, they will really be serving their country." He added, "I don't know how to snatch bodies."[48] Houston, apparently, was an exception. Laurence Kulp, a scientist from the Lamont Laboratory—one of the key labs for Project Sunshine, assured Libby that, "Down in Houston they don't have all these rules. . . .They claim that they can get virtually every death in the age range we are interested in that occurs in the city of Houston. They have a lot of poverty cases and so on." Unlike other sites, medical technicians there "don't have to worry how the individual looks when they get through."[49]

As problematic as it was, this project unfortunately fit in with longer term practices of treating humans as the unwitting subjects of experiments on the effects of radioactive matter. Eileen Welsome has told how America's atomic project has injected plutonium into the bloodstream of Americans, fed radioactive oatmeal to children under the care of the state, and fed radioactive cocktails to pregnant poor women. One such

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47 Welsome *Plutonium Files*, 300.

48 "The Importance of 'Body Snatching' to Project Sunshine," George Washington University National Security Archive On-line, Accessed February 20, 2012, http://www.gwu.edu/~nsarchiv/radiation/dir/mstreet/commeet/meet15/brief15/tab_d/br15d2.txt. Libby's statement has since been reproduced in several sources including the book based on the Department of Energy based investigation of the Atomic Energy Commission's experiments on humans. Advisory Committee on Human Radiation Experiments, United States. *Human Radiation Experiments (*New York: Oxford University Press, 1996), 404. See also Welsome, *Plutonium Files*, chapter 32.

49 "The Importance of 'Body Snatching' to Project Sunshine," George Washington University National Security Archive. Houston journalist Debbie Nathan also quoted Libby - and deployed Libby's language in the title of her article on how Houston was viewed as prime territory for stealing corpses as there were fewer legal issues there. Debbie Nathan, "Bayou City Body Snatchers: How cold war fears fueled a hot market for Houston's human parts business," *Houston Press*, November 1, 2001, accessed August 28, 2010, http://search.houstonpress.com/2001-11-01/news/bayou-city-body-snatchers/print.

victim of atomic politics, Elmer Allen was diagnosed as schizophrenic, for thinking that someone had “guinea-pigged” him—by the same physician sending tissue samples to an AEC laboratory for testing[50]. Elmer Allen's experience as a guinea pig for the Atomic Energy Commission's investigations into the effects of radioactive matter has also been the experience of over two hundred Marshall Islanders exposed as the result of Castle Bravo. While there is debate as to whether their exposure was deliberate, the Marshall Islanders were nonetheless approached by the AEC as the subjects of a long term experiment on the effects of fallout.[51]

Two years before Willard Libby decried the absence of good, patriotic body snatchers, he presented to the AEC's prestigious General Advisory Committee the early results of the kind of sampling that would become the hallmark of Project Sunshine. In a chart on the levels of activity of Strontium 90, a radioisotope at the center of the 1950s debate on fallout, we see beside clam shells from Long Island (.04 disintegrations per minute per gram of calcium) and month old Wisconsin cheese (3 +/- .03 disintegrations per minute per gram of calcium), a stillborn baby (3.6 disintegrations per minute per gram of calcium).[52] The archives of the Atomic Energy Commission contains numerous tables like this one. Another example centered on the detonation of Ivy Mike in theSouth Pacific in 1952. Here the average level of radioactive 'wet' tissue across islands--Biijiri,

50 Welsome *Plutonium Files*, prologue. See also Amy Goodman, "Plutonium Files: How the U.S. Secretly Fed Radioactivity to Thousands of Americans," *Democracy Now,* May 5, 2004. Accessed March 1, 2009, http://www.democracynow.org/2004/5/5/plutonium_files_how_the_u_s

51 For more on the Marshall Islanders and differing perspectives on the extent to which their exposure was deliberate, see Dennis O'Rourke, *Half-Life: A Parable for the Nuclear Age*. Cairns - Queensland, Australia: Camerawork Lrd., 1986. Videocassette (VHS), 86min; Crease, "Fallout: Issues," 109; Harkewicz, *The Ghost of the Bomb*.

52 “Thirty Sixth Meeting of the General Advisory Committee to the U. S. Atomic Energy Commission.” August 17-19, 1953, U. S. Department of Energy OpenNet Project, accessed August 28, 2010, https://www.osti.gov/opennet/advancedsearch.jsp.

Enjebi and Rojoa-- was .0052 disintegrations per minute per gram (or dmg), 0 for bone tissue, and .017 for "gut and contents." After the Mike test, rats from Biijiri had averages of 9.2 dmg in skin tissue, 17 in bone tissue, and 12 in gut and contents.[53]

The tissue from human bodies, and parts of bodies, that were gathered and processed in the AEC labs would occupy a place beside tissue from rats in the South Pacific.[54] If the rats in Engebi and the humans whose bodies and bones were collected were not in an actual laboratory at the time of their exposure to fallout, they would soon be transported to an AEC laboratory, whether in Washington state, Chicago, New York or elsewhere. In a significant sense, however, this practice of collecting bones from across the world enlarged the scope of the laboratory to include the entire world. Once—with megaton level hydrogen bomb tests—the fallout entered the stratosphere, it would circle the world and be deposited globally. Although the world population was not experimented on explicitly, it was knowingly exposed to the unmanageable and uncertain effects of weapons testing. The AEC's determined insistence on the safety of fallout and weapons testing, their repeated characterizations of larger public concerns about fallout as hysterical and susceptible to PR campaigns, and their ongoing efforts to undermine the credibility of any scientist who publicly disagreed with their claims cast a shadow on the

53 *Radiobiological Studies at Eniwetok Atoll Before and Following the Mike Shot of November 1952 testing Program, UFL-33* (United States Atomic Energy Commission, 1953), 66. Rats were collected after the Mike test only from Biijiri. Rats on other islands were thought to have been destroyed by the test. Although Ivy Mike was too large physically to be deployed as a bomb, it represented for many the first test of the workings of the hydrogen bomb. The detonation was registered as 10.4 megatons, or 10.4 million tons of TNT—roughly eight hundred times larger than the explosion in Hiroshima—and provided enough force to destroy completely the island on which the detonation took place. Richard Rhodes *Dark Sun: The Making of the Hydrogen Bomb*, (New York: Simon & Schuster 1996), 510.

54 While the scientists of project Sunshine were well positioned to provide knowledge claims about the distribution of fallout, they went further than this in claiming that fallout was safe. They deployed their scientific credentials—which the articles were helping to establish—to make assurances that spoke directly to the political legitimacy of the politics of the national-security state. See Welsh on the ways prestigious cold war scientists deployed their scientific credentials to bring closure to controversies surrounding nuclear power plants in England. Welsh, *Mobilising Modernity*, 4, 91-2.

sometimes narrower epistemic claims of the scientists in Project Sunshine[55]. Nonetheless, the precise dimensions of the health effects of radioactive fallout were unknown. Given this level of uncertainty, weapons tests constituted what Wolfgang Krohn and Peter Weingart term an 'implicit' or 'social' experiment. For these science studies scholars, the implementation of complex technologies such as nuclear reactors and, we could add nuclear weapons tests, turned society itself into a field of experimentation[56].

VI. What is Radiation Ecology?

The practices of Project Sunshine demonstrate the extent to which fallout constituted a problem for the state and the extent to which the state went in order to assure the public that fallout was not a problem. Next I will examine radiation ecology itself to provide an overview of the field in the remainder of this chapter before approaching radiation ecology as an example of cold war science in the following chapter. My emphasis on the place of fallout for the state forms a backdrop for discussion for the remainder of this chapter and the following chapter insofar as the state's desire to manage fallout informed its decision to fund ecologists. Nonetheless, as I will discuss, this funding and the logic driving it did not predetermine the shape that the field of

[55] There is rich and disturbing documentation of the lengths to which the AEC went to preserve the authority of their claims that fallout was safe. High profile examples include the AEC's efforts to silence and sometimes to attack scientists such as Nobel laureate Herman Muller, Harold Knapp, John Gofman, Arthur Tamplin, and Thomas F. Mancuso. Kopp, "Debate Over Fallout," Kirsch, "Harold Knapp," Semendeferi "Legitimating a Critic." Gayle Greene. *The Woman Who Knew Too Much: Alice Stewart and the Secrets of Radiation*. (Ann Arbor, MI: University of Michigan Press, 2001), 147-54. See also Hacker, on the repeated approach to fallout in terms of PR and as an effort to silence, in the words of Thomas Shipman, AEC head of health physics for Los Alamos, "trouble maker[s] of the Ralph Lapp-Barry Commoner type." Hacker, *Elements of Controversy*, 252.

[56] Wolfgang Krohn and Peter Weingart, "Nuclear Power as Social Experiment: European Political 'Fall Out' from the Chernobyl Meltdown," *Science, Technology, and Human Values* 12, 2, Spring (1987): 52. As noted in the introductory chapter, we can also see Krohn and Weingart taken up in the work of Ullrick Beck. Beck, *Ecological Enlightenment*, 104-6; Beck, *Ecological Politics in an Age of Risk*, 122-4; Beck, *World at Risk*, 111.

radiation ecology would take.

Radiation ecology can be roughly divided into two different forms of research. One follows the logic of the AEC more closely as it was research conducted by ecologists working as AEC employees. Here the focal point of research was on analyzing the impact of radioactive matter on the environment directly or on people with the environment as a mediating term. Another form of research was still funded by the AEC but operated with more autonomy from the concerns of the AEC. Here, radioisotopes functioned as an important new research tool to conduct experimental field studies of a variety of ecological processes. In this chapter I will use this distinction to organize discussion. First, I will describe an example of research conducted by ecologists who worked for the AEC and investigated the impact of radioactive matter on the environment. Then I will describe examples of radiation ecology research that was conducted in academic settings and that used radioisotopes as a new research tool to investigate ecological principles.[57] Through both of these kinds of research, radiation ecology could serve a dual role as part of a larger effort to contain the problem of radioactive fallout and as an example of how the products of atomic physics—funded by the state—could serve the peaceful function of advancing scientific knowledge in other disciplines.

Much of Eugene Odum's empirical work in radiation ecology involved the use of radioisotopes as a new research tool.[58] Although radioisotopes were occasionally used in

57 This distinction in kinds of radiation ecology is also important in setting up discussion, in the following chapter, on radiation ecology as a cold war science. The distinction is not meant to be taken to indicate a non-permeable boundary so much as a way of emphasizing (and organizing discussion according to) significant differences in the practice of radiation ecology. That said, clearly there was a fair amount of trafficking across this kinds of work this distinction points to. One example, mentioned below, is the role that academic ecology programs (where radioisotopes were an important part of research and graduate education) played in training ecologists who would later research the impact of radioactive matter on the environment while working at AEC facilities.

58 Given his early prominence in the field of radiation ecology and close relationship with the AEC, Odum

ecology research before the 1950s,[59] this kind of work was rare and did not yet have a title designating a distinct area of research. It would be earn this distinction in 1955 when Odum coined the term "radiation ecology" in his contribution to the First International Conference for the Peaceful Uses of Atomic Energy held in Geneva, Switzerland in 1955[60].

Although this conference is more commonly associated with Eisenhower's 1953 “Atoms for Peace” address than the AEC's more hands on work with atomic energy and atomic bombs, the president's speech emerged from the political climate as the AECs radioisotope distribution program, and it was similarly concerned with containing potentially negative accounts of a political trajectory centered on war. By focusing attention on the peaceful promise of atomic energy, Eisenhower hoped to draw attention away from the negative sentiment often associated with the destructive potential of atomic and nuclear weaponry.[61]

The vision Odum presented for radiation ecology at the International Conference for the Peaceful Uses of Atomic Energy differed significantly—and in telling ways—

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would also work as a consultant to the ecology program at Oak Ridge from 1956 through 1965. UGA 97 045, box 54.

59 See G. E. Hutchinson and Vaughan Bowen's 1947 article “A Direct Demonstration of the Phosphorus Cycle in a Small Lake” for an oft cited early work of the kind that would come to be known as radiation ecology (1947).

60 Historian of ecology Chunglin Kwa also asserts that this article marked the coining of the phrase (1993, 213). Interestingly—as I will explore in the following chapter, Odum's original vision for what would constitute the practice of radiation ecology differed in telling ways from the bulk of the work that would later be called radiation ecology

61 This is a point I will discuss below in covering the distribution of radioisotopes and Eisenhower's "Atoms for Peace" initiative in more detail. See, however, Chernus, *Eisenhower's Atoms for Peace*, 79-84; Angela Creager, “Nuclear Energy in the Service of Biomedicine: The U.S. Atomic Energy Commission’s Radioisotope Program, 1946-1950,” *Journal of the History of Biology* 39, no. 4 (December 1, 2006): 649–684; Angela Creager, and María Jesús Santesmases, “Radiobiology in the Atomic Age: Changing Research Practices and Policies in Comparative Perspective.” *Journal of the History of Biology* 39, no. 4 (December 1, 2006): 637–647; John Krige, “Atoms for Peace, Scientific Internationalism, and Scientific Intelligence.” *Osiris* 21, 1 (January 1, 2006): 161–181; and Weart, *Nuclear Fear*, 163.

from the bulk of the work that would later be called radiation ecology. His 1955 paper also included a distinctive role for radiation ecologists. Trained in radiation biology and ecology, radiation ecologists could staff atomic power plants and determine “tolerance levels for entire ecological systems.”[62] Here we can already see Odum link the ecology, and particularly the academic training of biologists in radiation ecology, with the state's desire to manage the ill effects of atomic energy.[63] While radiation ecology programs would not train ecologists to work at nuclear power stations as Odum foresaw in 1955, they would train ecologists to work in positions for the AEC. Further, when Odum asserted, in this 1955 article, the importance of measuring the impact of radiation on living organisms and not just specific tissue samples, on the metabolism of communities in addition to the metabolism of individual organisms, and on the structure of communities of organisms, he was, to a significant degree, describing the kind of work that ecologists working at the AEC would perform.[64]

From Odum's vision—and the research conducted by Yale ecologist G. Evelyn Hutchinson and AEC staff ecologists—radiation ecology would grow quickly in the 1950s. As historian of ecology Chunglin Kwa notes, by the end of the decade radiation ecology “was being practiced at several National Laboratories and at up to fifty

62 Eugene Odum, "Consideration of the Total Environment in Power Reactor Waste Disposal," Paper presented at the International Conference on the Peaceful Uses of Atomic Energy, Geneva, July 12, 1955, 350.

63 And, in doing so, link the two forms of radiation ecology as described above. This kind of move will enter the foreground of discussion in the following chapter.

64 It is interesting to note that Odum deployed the analogy of testing a drug on an organism to make his point. Just as we should test a drug on a living organism instead of only a tissue sample, so should we study the effects of radiation on living nature, or organisms and communities of organisms in situ. Odum's use of the analogy of the organism recalls his desire to study living nature and not the 'dead' nature found in a natural history museum (as discussed in the introductory chapter) but also his desire to avoid the reductionism he saw in more dominant fields of biology (as I will discuss in the concluding chapter). Odum, "Consideration of the Total Environment," 350.

universities, sponsored by the AEC."[65] In the discussion of different kinds of radiation ecology in this chapter, we will begin to gain a sense that the specialty of radiation ecology meant very different things for different actors.[66] For the remainder of this chapter, I will describe the emergence and early years of of radiation ecology as a specialty. Although Eugene Odum coined the phrase "radiation ecology" in 1955, ecologists working for the state had by that point been investigating the impact of radioactive matter on the environment for more than ten years. As part of the wartime effort to produce an atom bomb, the Manhattan Project established the Hanford Site in 1943 in eastern Washington in order to produce plutonium to be used in the bombs. As part of what was then a very early concern for the effects of radioactive matter that was being produced, the Manhattan Project formed what would become known as the Applied Fisheries Laboratory that would employ ecologists to study the impact of radioactive fallout from atom bomb and hydrogen bomb tests in the Pacific as well as the radioactive waste from Hanford reactors.[67]

VII. Radioactive Rats, or The Impact of Radioactive Matter on the Environment

> You would swear that that the whole world was on fire. It was really something I'll never forget.
> - Unnamed sailor commenting on the detonation of Ivy Mike, quoted in Hansen (1988), 59

When scientists of the Applied Fisheries Laboratory surveyed the effects of the

[65] Chunglin Kwa, "Radiation Ecology and Systems Ecology and the Management of the Environment," in *Science and Nature: Essays in the History of the Environmental Sciences,* edited by Michael Shortland, 213-250, (Oxford: Alden Press. 1993), 218.
[66] Again, this theme will be foregrounded in the following chapter.
[67] Neil Hines, *Proving Ground: An Account of the Radiobiological Studies in the Pacific, 1946-1961 (*Seattle: University of Washington Press, 1963), 3-10.

world's first thermonuclear explosion, they were overwhelmed with the level of destruction wrought by the explosion.[68] The destructive power of the test, named Ivy Mike, was registered as 10.4 megatons, or 10.4 million tons of TNT—roughly eight hundred times larger than the explosion in Hiroshima (Rhodes 1996, 510). It was enough force to destroy completely the island (Elugelab) on which the detonation took place. Observers positioned 35 miles away at sea first experienced the light and the heat from the blast, and then the “tremendous fireball appear[ed] on the horizon like the sun when half risen.” By the time the shock wave hit, with a “sharp report” followed by “an extended, broken, rumbling sound,” a couple of minutes later, the mushroom cloud was 100,000 feet high. Within thirty minutes it would span 60 miles.[69]

When the Applied Fisheries Laboratory scientists visited the island of Engebi - a neighboring island located just a few miles from the blast, the island appeared to be wiped clean of all life.[70] In their official report of their survey, the team noted that they found no rats that had survived and that “the sole bird found on Engebi post shot had been blown to pieces by the shock wave.”[71] In his history of the Applied Fisheries Laboratory scientists, team member Neil Hines noted that the island of Bogombogo, which was farther from the test site than Engebi, “had been stripped of vegetation by the force and heat of the blast. Palm trees had been burned down to the roots. All animal life, so far as members of the team could tell, had been snuffed out."[72]

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[68] Even though the device was too large to be deployable as a bomb, here I refer to Ivy Mike as a weapon test partly for ease of reference and partly because Ivy Mike was a test of the principles that would result in the development of a deployable weapon.

[69] Witness account of Major A. S. Knauf, quoted in Hacker. *Elements of Controversy*, 57-8.

[70] Engebi was part of the Eniwetok atoll, a coral atoll that was made up of a number of islands roughly in the shape of a ring.

[71] “Radiobiological Studies," 62.

[72] Hines, *Proving Grounds*, 143.

While the scientists found no rats when they surveyed Engebi in the days following the blast, they were bewildered to discover on later trips to the island that some rats had somehow survived the devastation wrought by Ivy Mike. By 1954, the scientists saw that enough rats had survived to rebuild their numbers. The ability of these Polynesian rats to live through the test represented an ongoing puzzle to these ecologists. The conditions to which their habitat had been subjected were unprecedented. The blast alone would have been devastating enough, but these rats also survived waves of incredible heat and radiation blanketed the island in addition to a surge of radioactive water that was blown over the island.[73] How could they possibly have survived?

Perhaps, these scientists mused, the original rat population *had* been wiped out, and rats from some neighboring island swam to Engebi once the post blast levels of radioactivity had died down. But this could not have been the case. The strength of the ocean currents and the distance between the islands would have been too great. Ecologists concluded that some rats must have survived the Ivy Mike test on Engebi.[74]

Opinions differed as to how the rats survived. Team scientist Frank Lowman believed that some of these rats must have been sheltered from the blast by structures built as a part of the testing program. Some of them must have been in portions of bunkers and in cable tunnels that were far enough underground to afford protection. Over two and a half decades after the Ivy Mike test, biologist William Jackson would revisit the question of the survival of these rats. Based on the reports of the Applied Fisheries Laboratory and his own experience performing field research in the Pacific Islands,

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[73] Ibid., 141-152 . William, “Survival of Rats at Eniwetok Atoll,” *Pacific Science* 23, (July 1969): 265-275.

[74] Hines, *Proving Grounds*, 141-152. William, "Survival of Rats," 265-8.

Jackson argued, contra Lowman, that the Polynesian rats were not alone on Engebi at the time of the blast. The more common roof rat (*rattus rattus)* had joined the native Polynesian rat (*rattus exulans*) on the island by the time of the Ivy Mike test. As they are more prone to burrowing, it was roof rats who had successfully found cover in the built structures. By contrast "the Polynesian rat was exterminated by the Mike test." The continued survival of rat colonies was far from assured, however, as their primary sources of food—the island vegetation—would have been destroyed in the blast. Most likely, the survivors would have to have fed on beach debris, beach invertebrates, and by cannibalism.[75]

Efforts to understand *how* they survived would be recognized as a significant contribution of the Applied Fisheries Laboratory to the research sponsored by the AEC's Division of Biology and Medicine. From an organizational perch high above the scientists who surveyed the Pacific proving ground, the Chief of Biology Branch Paul B. Pearson commented in an advisory committee meeting in 1955 on the important insights coming from the "studies made on re-populations out in the Pacific in the case of rats on one of the islands" and then, more simply, "the rat project."[76]

When the AEC Division of Biology and Medicine chief John Bugher visited the ecologists working on the rat project in 1953, he came bearing good news. The Atomic Energy Commission had come to appreciate their work more and more at higher levels. This appreciation—and the urgency behind it—motivated the construction of a new laboratory facility, the Marine Biological Laboratory, on Eniwetok for these scientists.[77]

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75 William, "Survival of Rats," 268-9.

76 "Fifty Third Meeting of the Advisory Committee for Biology and Medicine," November 30, 1955, page 78 in Record Group 326, Entry 73B - Records relating to fallout studies, 1953-64, Box 50.

77 Hines*, Proving Grounds*, 154 and 162.

The study of the rats on Engebi represented a form of radiation ecology that focused on the effects of radioactive matter on the environment. As I noted, this research was often conducted by scientists working for the AEC or for AEC contractors and conducting research on AEC facilities and land.

VIII. Radioisotopes

Another strain of radiation ecology focused on the use of radioisotopes to render ecological processes visible and was more often conducted by ecologists working in university settings. Some, like Eugene Odum, would be funded by the Atomic Energy Commission—though few at the level of Odum's funding—and all of them would using radioisotopes provided by the Atomic Energy Commission. Before describing this research, however, perhaps it first makes sense to introduce radioisotopes.

The Department of Energy has defined isotopes are defined as versions of an element that differ in the number of neutrons they have in their nucleus. They do, however, have the same number of protons and so share the chemical behavior of the element. Radioactive isotopes are often called radioisotopes or radionuclides and represent less stable isotopes whose presence could be detected with a Geiger counter.[78] In an article coauthored with Frank Golley, an ecologist who headed Odum's Savannah River Ecological Laboratory for a number of years, Odum maintained that, “we may think of radioactive tracers as one kind of label” that can be useful “to detect or to measure some event or process not easily detected or measured directly."[79]

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78 Advisory Committee on Human Radiation Experiments, United States. *Human Radiation Experiments* (New York: Oxford University Press, 1996), Introduction section 9.4 “Radioisotopes: What Are They and How Are They Made?” Accessed May 19, 2011, http://www.hss.energy.gov/HealthSafety/ohre/roadmap/achre/intro_9_4.html.

79 Eugene P. Odum and Frank Golley, "Radioactive Tracers as an Aid to the Measurement of Energy Flow

Often, radioisotopes were approached as a revolutionary new tool for ecology but also biological research more generally.[80] Stanley Auerbach, a staff ecologist at Oak Ridge from 1954, maintained that, "Radioactive tracers offer almost unexplored opportunities for investigating ecological processes in the landscape."[81] By the early 1960s the ranks of researchers interested in radiation ecology had grown significantly, and Odum's role as a leader in the field was becoming more established. As a moderator on a panel on education and training in radiation ecology, which was part of the First National Symposium on Radio-ecology in 1961, Odum declared that, "use of tracers is revolutionizing thinking and procedures in these two fields [ecology and geochemistry]."[82] Later he would compare radioisotopes to the microscope in "extend[ing]our powers of observation of function"[83] Both the microscope and radioisotopes provided visibility to the previously unseen functioning of nature. In the same article, Odum characterized tracers as "an 'atomic meter.'"[84] But where did radioisotopes come from and how can we account for the sudden rise of radiation ecology?

at the Population Level in Nature," in *Radioecology; Proceedings of the First National Symposium on Radioecology held at Colorado State University, Fort Collins, Colorado, September 10-15, 1961,* edited by Vincent Schultz and Alfred W. Klement, 403-410. (New York, Reinhold Publishing Corporation, 1963), 403.

80 See discussion of Patrick Carroll's notion of scopes in the introduction. Carroll, *Science, Culture, and Modern State Formation,* 7, 23-7, 45-51.

81 Bocking (1997, 83). In this work, Bocking describes the development of the ecology group at Oak Ridge as well as some of the challenges that faced this group.

82 Eugene Odum, "Panel Discussion on Education and Research Training," in *Radioecology; Proceedings of the First National Symposium on Radioecology held at Colorado State University, Fort Collins, Colorado, September 10-15, 1961,* edited by Vincent Schultz and Alfred W. Klement, 643-645. (New York, Reinhold Publishing Corporation, 1963), 643.

83 Eugene Odum, "Relationship Between Structure and Function in the Ecosystem" *Japanese Journal of Ecology* 12, 3 (1962): 115-6. From the attention following the 1956 translation of his textbook *Fundamentals of Ecology* into Japanese, Odum would be invited to Japan in the spring of 1962 to lecture at the ten imperial universities. Craige, *Eugene Odum*, 80-4.

84 Ibid., 118.

By many accounts, the flood of radioisotopes that would emerge from the laboratory system that the Atomic Energy Commission inherited from the Manhattan Project could be dated from the "Atoms for Peace" address that President Eisenhower delivered to the United Nations on December 8th, 1953. In this speech, Eisenhower announced, "I feel impelled to speak today in a language that in a sense is new – one which I, who have spent so much of my life in the military profession, would have preferred never to use. That new language is the language of atomic warfare." Although this language and "the awful arithmetic of the atom bomb" represent a dire threat to all nations, the science behind it offers the possibility for hope as well.[85] He continued,

> My country wants to be constructive, not destructive. It wants agreements, not wars. . . .So my country's purpose is to move out of the dark chamber of horrors into the light, to find a way by which the minds of men, the hopes of men, the souls of men everywhere, can move forward toward peace and happiness and well-being.[86]

Eisenhower identified "one new avenue of peace which has not yet been explored" in a General Assembly call for a Disarmament Commission the previous month.[87] He went on to maintain that,

> the United States. . . is instantly prepared to meet privately with other countries as may be 'principally involved' to seek 'an acceptable solution' to the atomic armaments race which overshadows not only the peace, but also the very life, of the world.
>
> The United States would seek more than the mere reduction or elimination of atomic materials for military purposes. It is not enough to take the weapon out of the hands of the soldiers. It must be put into the hands of those who will know how to strip it of its military casing and

[85] Chemus reproduces the speech in its entirety. After emphasizing the danger the bomb represents, Eisenhower links this danger with hope: "I know the American people share my deep belief that if a danger exists in the world, it is a danger shared by all; and equally, that if hope exists in the mind of one nation, that hope should be shared by all." Chernus, *Eisenhower's Atoms,* xii and xiv.

[86] Ibid., xiv-xv.

[87] Ibid., xvi.

adapt it to the arts of peace.[88]

Eisenhower proposed that the US, the Soviet Union and other countries "begin now and continue to make joint contributions from their stockpiles of normal uranium and fissionable materials to an international atomic energy agency" that would watch over the material and make sure it could be used "begin now and continue to make joint contributions from their stockpiles of normal uranium and fissionable materials."[89] The First International Conference for the Peaceful Uses of Atomic Energy where Odum laid out his vision for radiation ecology brought together a wide range of scholars in different disciplines as a way of making good on the promise of Eisenhower's speech.

While the conference addressed a wide range of issues, one of the unifying themes centered on the use of the insights and products of atomic physics in other branches of science, including the use of radioisotopes for biological research and medical diagnostics and research[90]. Despite Eisenhower's anger over what he saw as the lapse of security surrounding the atomic and nuclear weapons project, including Henry D. Smyth's 1945 report on the Manhattan Project and the release of information to the press about the 1952 Ivy Mike test, he approached the sharing of "x kilograms" of fissionable

88 Ibid., xvi-xvii.

89 Ibid., xvii. The International Atomic Energy Agency, established in 1957, traces its roots to Eisenhower's speech. David Fischer, *History of the International Atomic Energy Agency: the First Forty Years*, (Vienna: International Atomic Energy Agency Division of Publications, 1997), Introduction and Chapter 1.

90 In his history of Project Plowshare, Scott Kirsch details another legacy of Eisenhower's initiative. The idea underlying this project was that nuclear weapons could be used as tools in earthmoving projects or 'geographical engineering.' A new Panama Canal and a harbor in Alaska represented two of the opportunities that Teller and others saw for peaceful applications of nuclear explosions. The matter of fact tone of Edward Teller's pronouncement that, "If anyone wants a hole in the ground, nuclear explosions can make big holes," only adds to the retrospective strangeness of this failed project. Kirsch deploys this strangeness to great effect as a way of defamiliarizing the technocratic optimism that permeated the atomic energy establishment in these years. Scott Kirsch, *Proving Grounds: Project Plowshare And the Unrealized Dream of Nuclear Earthmoving* (New Brunswick, NJ: Rutgers University Press, 2005), xiv.

material through an international agency as a key part of his “Atoms for Peace”[91]. Eisenhower's discussion of the importance of "x kilograms" as an idea “which he did not think anyone had yet thought of" provides one window into the political strategy behind what he was widely characterized as a peace offering. In a memorandum from September, 1953, Eisenhower explained the idea and hints at its strategic importance: “Suppose the United States and the Soviet Union were each to turn over x kilograms of fissionable material. The amount x could be fixed at a figure which we could handle from our stockpile, but which it would be difficult for the Soviets to match”[92]. Predating his speech to the United Nations, Eisenhower's comment strongly suggests that the initiative had a political function from the beginning. In one move, the United States could demonstrate both its peaceful intentions and its superiority over the Soviet Union in the realm of atomic energy.

Further, The AEC's efforts to distribute radioisotopes as a research tool fit perfectly into Eisenhower's “Atoms for Peace” initiative. As AEC historians Richard Hewlett and Jack Holl note, “No commission activity held greater promise for the peaceful uses of nuclear energy than did research in biology and medicine.[93] If atomic physics could be credibly seen as creating a new technology to advance knowledge in other scientific disciplines, this provided an important example for a peaceful, non military use of atomic energy[94].

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91 On the language of “x kilograms,” see Hewlett and Holl, *Atoms for Peace and War,* 62; Chernus, *Eisenhower's Atoms*, 79-84. On Esienhower's anger over perceived lapses in security, see Hewlett and Holl, *Atoms for Peace and War,* 13-16 and 37-4.

92 Here already we can see Eisenhower's proposal was not without politically strategic intent, a fact that Chemus explores and contrasts with Hewlett and Holl's emphasis on Eisenhower's optimistic personality. Chernus, *Eisenhower's Atoms*, 80-1.

93 Hewlett and Holl, *Atoms for Peace and War,* 262.

94 Historian Spencer Weart similarly emphasizes the role that scientists can play in lending credence to initiatives that are primarily political in nature in noting that, “The Atoms for Peace crusade broke

Even before Eisenhower's speech, however, the breakthroughs of physics promised to revolutionize medicine. Paul Boyer's *By the Bomb's Early Light* chronicles a host of wonders that populated the cultural landscape in the months after the bombings of Hiroshima and Nagasaki. Atomic energy was imagined to one day powere automobiles and control the weather - even provide an artificial sun. Another, sometimes more sober minded strain of optimism about the peaceful potential of the atom centered on the research potential of radioisotopes[95]. A 1947 *Collier's* article announced that research with radioisotopes would provide "cures for hitherto incurable diseases" and lead to a "golden age of atomic medicine."[96] In 1948, *Coronet* magazine predicted that "isotopes would soon yield. . . amazing medical applications such as a possible cure for diabetes, 'a basic understanding of the heart and its disorders,' 'the control of one or more types of cancer,' and ultimately 'a real cure that will eradicate [cancer] or even eliminate it before it appears.'"[97]

Focused on often very imaginative popular speculation on the promise of physics, Boyer's account raises the question of how physicists themselves might have approached the potential biomedical impact of their work. In *Lawrence and his Laboratory*, historians of science John Heilbron and Robert Seidel tell of how Ernest Orlando Lawrence created with the Berkeley Rad Lab a model for many of large, multidisciplinary labs that would play such an important role during and after World War II.[98] In a later article, Seidel

through to a new level of credibility at an international conference proposed by the United States and convened in Geneva in 1955." S. R. Weart, *Nuclear Fear: A History of Images* (Cambridge, MA: Harvard University Press, 1988), 163. I will approach this theme more explicitly below, along with Chandra Mukerji's analysis of 'the voice of science.'

95 Paul Boyer, *By the Bomb's Early Light: American Thought and Culture at the Dawn of the Atomic Age* (Chapel Hill, NC: The University of North Carolina Press, 1994), chapter 10.

96 Ibid., 119.

97 Ibid., 120.

98 J.L. Heilbron, and Robert W. Seidel, *Lawrence and His Laboratory: A History of the Lawrence*

provides a stark behind the scenes glimpse into the nature of early promises of the biomedical breakthroughs that physics could bring. Confronted with the high costs of building his cyclotron, Lawrence

> had to develop a rationale for high-voltage X-ray and neutron therapy that would appeal to private and, ultimately, federal patrons. Confessing privately that there was 'not much point in X rays above half a million volts for therapy purposes,' Lawrence continued to publicize the million volt X-ray tube his laboratory his laboratory developed as a 'high voltage X-ray machine which alone is as effective as all the radium in the world for the treatment of cancer.' Neutron therapy was promoted in a similar fashion with results that were at best disappointing and at worst disastrous. In this way, Lawrence responded to the opportunities provided by the Research Corporation's desire to raise funds for research through patents on academic science inventions and the growing philanthropic support for cancer research and therapy in the 1930's.[99]

Importantly, Seidel characterizes this somewhat alarming funding strategy as an enduring feature of cold war science. He notes in somewhat ambiguous terms that, “This adaptation of scientific to cultural and political values was to become characteristic of big science."[100]

While radioisotopes from Lawrence's cyclotron were distributed as a new kind of tool for biomedical research, it would not be until the conclusion of World War II that the ability to produce much larger volumes of radioisotopes would be in place. In a series of articles focusing on the use of tracers in biomedical research, historian of science Angela Creager provides an overview of the beginnings of the Atomic Energy Commission's radioisotope distribution program.[101]

Berkeley Laboratory, Volume I (Berkeley: University of California Press, 1989), xvii-xviii.

99 Robert Seidel, "The Origins of the Lawrence Berkeley Laboratory," in *Big Science: The Growth of Large-Scale Research*, edited by P. Galison, 21-45, (Stanford, CA: Stanford University Press, 1994), 27.

100 I will return to scientists' efforts to secure funding as part of my discussion of radiation ecology as a cold war science in the following chapter. Seidel, "The Origins of the Lawrence Berkeley Laboratory," 27.

101 See especially Creager, “Nuclear Energy in the Service of Biomedicine;" and Creager and Santesmases,

Predating the Atomic Energy Act of 1946, the distribution of radioisotopes initially emerged out of an effort of Oak Ridge scientists to assert a rationale for the postwar existence of their laboratory. Although Oak Ridge was primarily a production facility, many working at the laboratory feared that it would be shut down long before Hanford, which produced plutonium for weapons on a much larger scale. The graphite reactor at Oak Ridge had served primarily as a model for the much larger plutonium producing reactors at Hanford, so it was no longer in use. This anxiety was compounded by changes in the entity responsible for running the lab - from University of Chicago to Monsanto in 1945, briefly back to University of Chicago in 1947, and then to Union Carbide by the beginning of 1948 - and the fact that the prestige of the lab as a place for research was undermined by the fact that it had generally been run by a contractor in industry from the end of the war.[102] The coming together of scientists' concern for the future of their lab with public concern over cancer and a tradition of using radioactive matter for cancer therapy would provide a future trajectory for work at Oak Ridge. They would re-purpose the graphite reactor to produce radioactive matter for biomedical, and particularly cancer-centered, research and treatment. By 1950, this program had entered high gear as an "atomic pharmacy" that put "radio-isotope processing, packaging and shipping on an assembly-line basis, eliminating for the most part the time consuming method of handling radio-isotope shipments manually."[103]

"Radiobiology in the Atomic Age."

[102] Westwick, *National Labs*, 54-5. Creager, "Nuclear Energy in the Service of Biomedicine," 657.

[103] Quote is from John Krige, "Atoms for Peace, Scientific Internationalism, and Scientific Intelligence." *Osiris* 21, 1 (January 1, 2006): 168. The account here draws on the recent work of Angela Creager and Maria Santesmases. Angela Creager, "Nuclear Energy in the Service of Biomedicine: The U.S. Atomic Energy Commission's Radioisotope Program, 1946-1950," *Journal of the History of Biology* 39, no. 4 (December 1, 2006): 649–684; Angela Creager and María Jesús Santesmases, "Radiobiology in the Atomic Age: Changing Research Practices and Policies in Comparative Perspective." *Journal of the History of Biology* 39, no. 4 (December 1, 2006): 637–647.

Interestingly, this effort to use the distribution of radioisotopes after the war to redefine (and assert the ongoing usefulness of) the Oak Ridge laboratory succeeded in a large measure because it provided the AEC with a way of redefining the militaristic nature of the state's investment in atomic physics. In the minutes of a 1950 meeting for the Advisory Committee on Isotope Distribution, Henry DeWolf Smyth expressed this sentiment clearly:

> He said that the Atomic Energy Commission is especially interested in isotope distribution because when it is asked, 'What are the peacetime uses of atomic energy?' it can reply 'Isotopes.' Not that they will be useful sometime but that they are already useful. The isotope distribution program is enormously valuable because it reveals the Atomic Energy Commission as more than just a weapons organization.[104]

For Creager then, radioisotopes provided a scientific tool but also a political instrument for legitimacy.[105] While the political function of the distribution of radioisotopes predated Eisenhower's “Atoms for Peace” address, the shipment of radioisotopes—and the political import of these shipments—took on greater importance with Eisenhower's initiative.

Although radiation ecology provided an example of peaceful application of atomic energy (in the production of radioisotopes as a research tool), it was born out of an earlier—and, one could argue, more encompassing—effort to manage the problem posed by radioactive fallout. Historian of science John Krige has argued, and Angela Creager agrees if in somewhat less pointed terms, that Eisenhower's "Atoms for Peace" initiative "was intended to divert attention from Eisenhower's commitment to the use, expansion,

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104 Creager, “Nuclear Energy in the Service of Biomedicine," 650.

105 The importance, for Creager, of the political purpose of distribution of radioisotopes is indicated by its pride of place as part of her title of her articles on the biomedical uses of radioisotopes, “Radioisotopes as Political Instruments, 1946-1953.”

and improvement of increasingly lethal nuclear weapons."[106] Nonetheless, whether we frame Eisenhower's atoms for peace program in the organizational trajectory of Oak Ridge National Lab or in the larger story of the state's efforts to manage the problem of radioactive fallout, it is clear that these narratives come together both analytically and in the emergence of radiation ecology as a field.

In asserting the political function of the radioisotope as a research tool, Creager's argument resonates with my analytical claim that the question of the health effects of radioactive fallout was both epistemic and political in nature. In both cases the reliance of the cold war national-security state on atomic and nuclear weapons compelled the AEC and Eisenhower to draw on the voice of science in addressing, and attempting to ameliorate, the problem of negative sentiment associated with radioactive fallout and atomic power.[107] In both cases the epistemic authority of science provided the state with an avenue for addressing problems emerging from its commitment to atomic weapons.

Many questions remain, however. How were these radioisotopes used by ecologists and who were the ecologists involved in this kind of research? We could ask if there were any differences in the kind of research conducted by ecologists working for the AEC or laboratories run by industrial contractors on the one hand with ecologists working in university settings, some with and some without AEC funding.

IX. The Early Years of Radiation Ecology

I think there is a question I am supposed to answer. I have answered it

[106] John Krige, "Atoms for Peace, Scientific Internationalism, and Scientific Intelligence," 162. Angela Creager, "Nuclear Energy in the Service of Biomedicine," 651. See also, Chernus, *Eisenhower's Atoms for Peace*, 79-84; and Weart, *Nuclear Fear*, 163.

[107] See discussion of "the voice of science" in the introduction. Mukerji, *Fragile Power,* 190-203.

> partly. Why is the AEC interested in ecology? This question you [members of the Advisory Committee for Biology and Medicine] will have to answer. I think that they should be interested in ecology because of the point of view, because ecologists are trained in studying relationships, because the ecologists of North America represent a. . . scienti[fic] resource that we have not tapped adequately.
> -John Wolfe, Advisory Committee for Biology and Medicine, November 30th, 1955.[108]

Although Eugene Odum coined the term 'radiation ecology' in his 1955 presentation at the International Conference for the Peaceful Uses of Atomic Energy in Geneva, the meaning and fate of the term was far from settled. In the mid 1950s, the field of radiation ecology was still very young. Despite this indeterminacy and the youth of the field, research by botanists, zoologists, environmental biologists and ecologists implementing radioisotopes as a research tool and research on the environmental effects of radioactive matter predated this coinage by many years. In his introduction to the Atomic Energy Commission's Advisory Committee on Biology and Medicine, John Wolfe summarized to the committee some of this work. Not surprisingly, the work he described was funded by the Atomic Energy Commission and much of it was conducted by scientists working full time at AEC labs such as Hanford and Oak Ridge. He also covered Eugene Odum's work. Interestingly, Wolfe did not cover research that has since become some of the most well cited early research in this area—the work of G. Evelyn Hutchinson and Vaughan Bowen on the phosphorus cycle in Linsley pond, an inland lake near Yale University where Hutchinson taught for many decades. In order to provide a context for understanding the place and nature of Odum's contribution to this field, first I

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108 "53rd Meeting of the Advisory Committee for Biology and Medicine," RG 326, Entry 73B – Records relating to fallout studies, 1953-64, Division of Biology and Medicine, Box 50. The original quote reads: "the ecologists of North America represent a group of scientists resource that we have not tapped adequately."

will introduce the state of the rest of the field of radiation ecology from 1943 through the mid 1950s.

The earliest cluster of work by ecologists and biologists emerged from within the Manhattan Project. Neal Hines details the emergence of the Applied Fisheries Laboratory that was affiliated with both the University of Washington in Seattle and the AEC's Hanford facility for the production of plutonium.[109] Hines' account opens with the beginning moments of the Manhattan District and its decisions to build plutonium production facilities at Clinton Engineer works in the Tennessee valley and Hanford in Washington. Leslie Groves raised the question of the effect of using water from the Columbia River for cooling with Stafford Warren who was a colonel in the Army medical corps who held a position at the University of Rochester's medical school and had experience researching the effects of radiation on animals. Lauren Donaldson, a professor of fisheries at the University of Washington, was approached to head the effort. While the lab--to be called the Applied Fisheries Lab--was cloaked in secrecy from its inception, its work on the effects of radiation on salmon was joined by research, directed by Chicago Met Lab's Robert Stone, on the effect of radiation on animals. Historian of ecology Chunglin Kwa notes that it would not be until after the war that the work of the Applied Fisheries Lab would take on a more ecological character with the beginning of environmental surveys of the Pacific and Columbia Rivers in 1946.[110]

Hines shows that the Pacific Proving ground became a field site for the Applied Fisheries Lab as it became the object of continued attention with the resurveys of the Marshall Islands area in the late 1940s. With the 1946 Crossroads tests in the Bikini atoll

[109] Hines, *Proving Ground*, 3-10.
[110] Ibid., 218.

we see members of the Applied Fisheries Laboratory become a part of a much larger effort to understand the impacts of the test shots. Following Crossroads, the lab became a part of later surveys of the test area—including a 1947 resurvey and Bikini-Eniwetok resurvey of 1948-1949. With the 1952 Ivy Mike test, these ecologists were introduced to the level of destruction described in the previous chapter. As we saw, Hines saw their work on the Engebi rats as some of the lab's most important work. He notes that the "case [of the rats' survival] was important because it seemed to bear so directly on one of the broadest unanswered question of the nuclear age, the effect on warm-blooded vertebrate animals of continued exposure to low level irradiation."[111]

One of this lab's most influential findings centered on the principle of biomagnification.[112] Biomagnification describes the concentration of radioactivity as it progresses through the food chain. Although the Columbia River might have comparatively safe levels of radioactivity, radioactive matter would become more concentrated, first in plankton then in the fish eating the plankton. Richard (Dick) Foster, one of Hanford's ecologists, recounts the groups' early discovery of this principle:

> So we wondered at the outset very briefly, 'Why are the Columbia River fish so much more radioactive than the fish in the laboratory?' Of course, we only had to think of this for a matter of minutes or hours to recognize that the major thing which was different was that the fish in the laboratory were being fed on food which was uncontaminated whereas the fish in the river had to get their food from natural sources. So there you had the food chain mechanism which was obvious and also the reconcentration of some

[111] Ibid., 297.

[112] See also Kwa and Robert Rudd on the origin of the notion of biomagnification, introduced here in the previous chapter. Kwa, "Radiation Ecology and Systems Ecology," 219-20; Robert L. Rudd, *Pesticides and the Living Landscape* (Madison: University of Wisconsin Press, 1964), 241-64. In an article reviewing the danger posed by radioactive waste, Elmer Higgins cites oceanographer Harald Sverdrup in noting that, "The ability of aquatic organisms to concentrate particular ions in their tissues by selective absorption from the surrounding water is well known." Elmer Higgins, "Radiation Hazards for Fish," *The Journal of Wildlife Management*, 15, 1, Jan., (1951), 7.

of the elements.[113]

In addition to Dick Foster, Hanford ecologists such as Wayne C. Hanson, Harold (Harry) A. Kornberg, and Royal E. Rostenbach recognized this was an important principle, but they did not refer to it as biomagnification. Instead they often simply referred to the principle of the variable “concentration” of radioactive matter in fish, plankton, and the river water.[114] Ironically, the principle of biomagnification would later be invoked by members of the environmental movement as providing a scientific basis for a more cautious approach to pesticides and radioactive matter.[115]

Another early center of radiation ecology was Oak Ridge, originally a production site for uranium during World War II. Although Oak Ridge would quickly become a center for the practice of radiation ecology and eclipse Hanford as a center for ecology research more generally, the program there started over a decade after the program at Hanford.[116] Stephen Bocking provides an account of the emergence of the ecology program at Oak Ridge as a component of the facility's health physics program.[117] In his account of radiation safety practices of the Atomic Energy Commission, historian Barton

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113 Richard F. (Dick) Foster, interviewed by J. Newell Stannard, June 11, 1979, U.S. Department of Energy OpenNet Project, accessed August 28, 2010, https://www.osti.gov/opennet/advancedsearch.jsp, 11. Kwa, "Radiation Ecology and Systems Ecology," 219.

114 See, for example, J. J. Davis and R. F. Foster, “Bioaccumulation of Radioisotopes Through Aquatic Food Chains,” *Ecology* 39, no. 3 (July 1, 1958): 530–535; Foster, R. F. and R. E. Rostenbach. "Distribution of Radioisotopes in the Columbia River," *Journal of American Water Works Association* 46 (1954): 663-640; and W. C. Hanson and H. A. Kornberg. "Radioactivity in Terrestrial Animals Near an Atomic Energy Site," *Proceedings of the International Conference on the Peaceful Uses of Atomic Energy* 13 (1955): 385-388.

115 As I will discuss in chapter 6, Rachel Carson invoked the need for caution when dealing with "biological magnifiers" and the, "progressive buildup of chemicals." Carson, *Silent Spring*, 21, 108, and 173.

116 See Stephen Bocking's assertion that, “By 1968 the Oak Ridge radiation ecology section was one of the largest ecological research groups in the United States." Bocking, *Ecologists and Environmental Politics*, 82.

117 Ibid., chapters 4 and 5.

Hacker notes that the term "health physics" was “coined in the early days of the Manhattan Project at Chicago” and came to refer to a profession focused on radiation physics and radiation biology.[118] Health physicist Karl Morgan played a particularly important role in bringing a focus on the environment to Oak Ridge. Assisted by the emphasis on atomic energy development in the 1954 Atomic Energy Act, Morgan brought in Edward Struxness to head a study on waste disposal. Struxness and Morgan, in turn, decided to bring an ecologist on borad as part of the study. When they asked Orlando Park, a prominent ecologist at the University of Chicago, Park recommended one of his former students, Stanley Auerbach. Although Auerbach's research at Oak Ridge fell under the shadow of the much larger health physics program, in 1956 it began taking on more of the traditional trappings of ecological work as he moved from the lab into the field to study White Oak Lake.

Similar to Hanford ecologists' research on the concentration, distribution, and effects of radioactive matter in the Columbia River, Oak Ridge ecologists studied radioactive matter locally, at White Oak Lake. The lake had served as a dumping site for low-level radiation since 1943. By the time it was drained in 1955, the lake was very contaminated. The Lake provided a visible opportunity for Oak Ridge ecologist Stanley Auerbach to move his research out of the lab and gather valuable data many health physicists prized as being more realistic. Another site of research at Oak Ridge was focused on the seepage of Ru-106 from waste pits. Auerbach tested nearby trees for radionuclides to see if the radioactive material had traveled through the environment.[119]

[118] Hacker, *Elements of Controversy,* 19**.**

[119] On White Oak Lake see Bocking, *Ecologists and Environmental Politics*, 68-9; and Stanley I. Auerbach, “The Soil Ecosystem and Radioactive Waste Disposal to the Ground,” *Ecology* 39, no. 3 (July 1, 1958): 528. For more on the early years of Auerbach's ecology program, see Bocking, *Ecologists and Environmental Politics*, 65-71.

In the context of Bocking's argument about the challenges facing the ecology group at Oak Ridge, it is significant that Eugene Odum would serve as a consultant to the Oak Ridge ecology program from 1956 through 1965. In Bocking's account, the ecology program at Oak Ridge faced the ongoing problem of establishing themselves in a context dominated by the prestige of physics.[120] The initial organizational position of ecologists, then working under the organizational and research direction of health physics, provides one indicator of how their work fit into a hierarchy of scientific approaches at the lab[121]. While Auerbach's lab work represented, in part, an effort to bring to ecological research a level of rigor that physicists might find reassuring, his move to the field to study White Oak Lake was seen as a more realistic study of the uptake of radioactive fallout. Bocking describes this work, "In 1957 he [Auerbach] and his colleagues planted corn, legumes and other crops on the lake bed to measure their uptake of radionuclides and the effect of radiation on their growth." Lab director Alvin Weinberg was impressed.[122] In addition to added legitimacy that Odum's positive report of Auerbach's program brought, Odum's input also played a role in shaping the Oak Ridge ecology program. Bocking reports that Auerbach decided to base his then-fledgling program around the ecosystem approach to ecology.[123]

Odum's consulting work at Oak Ridge also provided a level of legitimacy for the young ecology group.[124] In a March 1957 report, he reassured Weinberg, "Excellent

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[120] Bocking, *Ecologists and Environmental Politics*, 68.

[121] Even after Auerbach had started building an ecology program at Oak Ridge, it remained under the Health Physics division, headed by Karl Morgan. Struxness would be appointed to head the Environmental Studies division under Morgan with Auerbach heading a Radiation Ecology group under Struxness. UGA 97 045, box 54.

[122] Bocking, *Ecologists and Environmental Politics*, 69.

[123] Stephen Bocking, "Ecosystems, Ecologists, and the Atom: Environmental Research at Oak Ridge National Laboratory," *Journal of the History of Biology* 28, no. 1 (1995): 8.

[124] Based on interviews with Odum and Auerbach, Kwa notes that Wolfe seems to have favored Odum's

progress has been made since the organization of a long range ecology project in the two phases [administrative work setting up the program and the publication of preliminary work] which must go hand in hand in the development of difficult new fields." Odum went further to assert the importance of the group's "training as ecologists and biologists," which would be useful for them "to plan and carry out experiments and analyses."[125] In addition to providing an endorsement of Auerbach's group, he was also asserting the importance of having ecologists on staff at a laboratory that was dominated by the natural sciences.

In addition to the research that the AEC sponsored and that took place on AEC sites such as Hanford and Oak Ridge, the agency also formed a more centralized Environmental Sciences Division in 1955 with ecologist John Wolfe brought on initially as a consultant.[126] In his comparative work on the AEC ecology programs, Chunglin Kwa has noted that it was at this time—in the middle of the fallout controversy following the Castle Bravo shot—that the AEC ramped up its support for ecology.[127] By 1958, Wolfe had been brought on full time, and he would soon head a staff that would include Vincent Schultz as a Program Manager and Alfred W. Klement.[128] This group would play a significant role in determining how AEC funding would be distributed to ecology projects, managing the projects that received funding, and planning and funding a series

group over that of Auerbach. Kwa, "Radiation Ecology and Systems Ecology," 229.

125 UGA 87 045, box 54. I will return to the importance of Odum's consulting work in the framework of the autonomy of cold war science in the following chapter.

126 See Bocking, *Ecologists and Environmental Politics*, chapter 4; and Kwa, "Radiation Ecology and Systems Ecology," 218 and 229.

127 Kwa, "Radiation Ecology and Systems Ecology," 218.

128 Stanley I. Auerbach and David E. Reichle, "U.S. Radioecology Research Programs Initiated in the 1950s: History of the Atomic Projects, The 50s Years: Sociopolitical, Environmental, and Engineering Lessons Learned," Oak Ridge National Laboratory (September 22, 1999), 18. Bocking, *Ecologists and Environmental Politics*, 66-7.

of conferences for radio-ecology.[129]

So far I have discussed the AEC ecology programs at Hanford, Oak Ridge, and the Environmental Sciences Division in the agency's Division of Biology and Medicine. But not all radiation ecology shared such a close relationship with the AEC. At Yale, G. Evelyn Hutchinson and Vaughan Bowen took advantage of the newly available radioisotopes to study Linsley Pond, one of Hutchinson's favorite field sites, in the summer of 1946.[130] The ecologists released twenty four samples of radio-phosphorus along two lines crossing the lake. A week later they returned to the lake and collected water samples from four different levels. Then they evaporated the water and measured the radioactivity of precipitates on filter paper with a Geiger counter.[131] Hutchinson and Bowen found the experiment to confirm previous work in which seemingly mysterious variability in phosphorus levels in lakes by season, for example, is accounted for by the existence of a phosphorus cycle. The cycle describes the movement of phosphorus that is liberated from mud at the bottom of the lake, consumed by phytoplankton, and later sedimented to the bottom of the lake in the form of dead phytoplankton and the feces of

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129 The First International Symposium on Radioecology was held in 1961 in Fort Collins, Colorado and represented an unprecedented gathering of radiation ecologists. Kwa, "Radiation Ecology and Systems Ecology," 229. As we shall see in the following chapter, AEC efforts to manage Odum's ecology program at the Savannah River Site represented a source of ongoing tension for Odum.

130 G. Evelyn Hutchinson and Vaugham T. Bowen. “A Direct Demonstration of the Phosphorus Cycle in a Small Lake.” *Proceedings of the National Academy of Sciences of the United States of America* 33, no. 5 (May 15, 1947): 148–153. Nancy Slack describes this research in her biography of Hutchinson. Nancy Slack, *G. Evelyn Hutchinson and the Invention of Modern Ecology*. (Yale University Press, 2011), 159-62.

131 Interestingly, Hutchinson and Bowen's article and Slack's account of the article report there were difficulties with the Geiger counter. In their article Hutchinson and Bowen note that, “The voltage stabilizer of the only Geiger counter circuit available was not sufficiently good to prevent alterations in the background count which completely obscured the increases in single two-minute counts, due to the radioactivity of the samples." Hutchinson and Bowen, “A Direct Demonstration of the Phosphorus Cycle," 150.

zooplankton feeding on the plant cells. The lower concentration of phosphorus in lake water in the summer can be seen to be a steady state, “maintained at low levels by the activity of phytoplankton, the rate of development of which depends rather on the rate of supply of phosphate ions from the mud.”[132] For Hutchinson and Bowen, the radio-phosphorus provided a way to measure the distribution of phosphorus in the lake more easily, and, in doing so, it rendered the cyclical movement of matter through the pond visible.[133]

Other than Odum's work at the Savannah River Site, which I will cover in the next two chapters, the ecological work at Hanford and Oak Ridge formed the two largest centers for the practice of radiation ecology into the late 1950s. Despite the early start of Hanford affiliated ecologists, it would be the program at Oak Ridge, along with Odum's program at the University of Georgia, that would emerge as two new centers for the practice of ecology in the postwar period. As we shall see, to a significant degree, the ecology program at Oak Ridge and at the University of Georgia were formed around the nucleus of their earlier work in radiation ecology[134].

While comparing these ecology programs, we could ask what were some of the

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132 Ibid.,149.

133 At roughly the same time as Hutchinson's experiment, F. Ronald Hayes was leading a similar experiment with graduate students and other professors from Dalhousie University. While technically much more complex, this experiment had a much simpler goal—to see if the radio-phosphorus would change the “nutrient economy” of the lake. They found it did not. Although Hayes would consult with Hutchinson after completing his experiment, his experiment was conducted independently of Hutchinson's and was published after Hutchinson's later 1950 paper. Slack, *G. Evelyn Hutchinson*, 162-3.

134 I have not included Hutchinson's “Yale school” of ecology in this comparison as Hutchinson himself would soon turn away from the use of radioisotopes. Compared to Georgia, Oak Ridge, and certainly Hanford, his research and the research of his many students would nonetheless play a decisive role in setting the agenda for ecological research in the decades following World War II. Kwa, "Radiation Ecology and Systems Ecology," 216. In her biography of Hutchinson, Barbara Slack speculates that Hutchinson did not pursue radiation ecology because he was "uneasy with government-funded big science." Slack, *G. Evelyn Hutchinson*, 169.

other differences between these programs. We can detect one important difference in the kind of research that made up radiation ecology. In the case of the research initiated by Hutchinson and Hayes, radioisotopes were used as part of an effort to trace the presence and functioning of ecological principles such as biogeochemical cycles. As we shall see, Hutchinson's use of radioisotopes also describes Odum's radioecology research as well as his philosophy of the relation between applied and basic research.

For the Oak Ridge ecologists investigating White Oak Lake as for the Hanford ecologists investigating the Pacific Proving Ground and the Columbia River, the primary object of analysis was the impact of radioactive matter on the environment. To a significant degree, in this research, the environment itself functioned as the object of experiments with uncertain outcomes. Hanford ecologists Jared Davis and Dick Foster express precisely this idea in the opening section of their contribution to the 1955 International Conference on the Peaceful Uses of Atomic Energy. They note that, "organisms living in the Columbia River which have picked up radioactive substances from the reactor effluent may be utilized as a large-scale experiment in which the isotopes serve as tracers."[135]

In addition to the different place of radioactive matter, the working environments of these programs differed significantly. Chunglin Kwa has argued that the Applied Fisheries Lab at Hanford operated in a more constrained environment than the program at Oak Ridge and Odum's program at the Savannah River Site, which enjoyed the greatest degree of autonomy. Funded out of operating and not research funds, ecological research at Hanford was kept to a higher standard of direct relevance by contractor General

[135] Jared Davis and Richard Foster. "Bioaccumulation of Radioisotopes," 364.

Electric. By contrast, Eugene Odum had successfully built an ecology research center at Savannah that was able to leverage its affiliation with nearby University of Georgia in order to order to maintain more discretion over how AEC funding was distributed. Between these two poles was the position of ecological research at Oak Ridge. Although officially held to the same level of stringency as at Hanford, the Oak Ridge contractor Union Carbide did not enforce them in practice, and ecology research there enjoyed a level of discretion over how AEC funds were distributed[136].

X. Conclusion

In this chapter I have addressed the question of why the AEC would have been interested in funding ecology as a way of addressing the larger question of the place of ecology in relation to the cold war state. The state's commitment to a political vision centered on atomic and nuclear weapons provided a context in which radioactive matter came to represent a destabilizing force that needed to be managed. In their efforts to manage this problem, however, the Atomic Energy Commission began collecting dead human and animal bodies and body parts to serve as experimental matter in the effort to assure the public that radioactive fallout was not a problem. Considered against the backdrop of these practices, the uses of ecology were clear. It provided a way of managing the problem of radioactive fallout.

In contrast with working for the state and studying the impact of radioactive matter on the environment, ecologists like Odum and Hutchinson used radioisotopes as an exciting new way of studying the movement of energy and matter through the

[136] Kwa, "Radiation Ecology and Systems Ecology," 220.

environment. In 1961, Odum noted that the use of radioisotopes was playing a role in revolutionizing ecology.[137] And during his 1962 trip to Japan, Odum noted enthusiastically, “Tracers do extend our powers of observation greatly. Just as the microscope improved our powers of observation of biological structure, so tracers have extended our powers of observation of function."[138]

Like the microscope, radioisotopes rendered new phenomena in nature visible to the senses and played a role in extending and structuring the practice of certain forms of biological research.[139] In his discussion of the role of science in state formation, Patrick Carroll has argued that "scopes" are a kind of "epistemic engine" that "frame, target, and augment phenomena for the senses."[140] Like Odum's radioisotopes, they augment ecologists' ability to see ecological processes such as the movement of energy through the environment. Further, they have helped to "generate objects of inquiry, institutionalize and structure practices of inquiry, and drive the research agenda."[141] Radioisotopes augmented perception, but they also played a role in stabilizing the postwar ecological emphases on the movement of energy and matter through the environment.

This dual role is evident in the practice of referring to radioisotopes as "labels" or "tags" for processes that might not otherwise be easily visible. In an update to Chief of

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137 Eugene Odum, "Panel Discussion on Education and Research Training," in *Radioecology; Proceedings of the First National Symposium on Radioecology held at Colorado State University, Fort Collins, Colorado, September 10-15, 1961,* edited by Vincent Schultz and Alfred W. Klement, 643-645. (New York, Reinhold Publishing Corporation, 1963), 643.

138 Eugene Odum, "Relationship Between Structure and Function in the Ecosystem" *Japanese Journal of Ecology* 12, 3 (1962): 115-6. From the attention following the 1956 translation of his textbook *Fundamentals of Ecology* into Japanese, Odum would be invited to Japan in the spring of 1962 to lecture at the ten imperial universities. Craige, *Eugene Odum*, 80-4.

139 See Creager and Santesmases on the role radioisotopes played in other forms of biological research. Creager, "Nuclear Energy in the Service of Biomedicine," 649-684. Creager and Santesmases, "Radiobiology in the Atomic Age," 637-47.

140 Carroll, *Science, Culture, and Modern State Formation*, 47.

141 Ibid., 23.

Radiation and Health Branch at the Savannah River Site on SREL research, Golley noted that

> The most notable experiment completed during the period concerned tagging old-field vegetation with Phosphorous-32. Preliminary analyses support previous findings that clear differences in uptake and transfer occur where different plant species are *tagged*. The most rapid uptake in animals occurred in the ant and tree cricket populations.[142]

In the same period, radioisotopes were also approached as "labels." The relative interchangeability is evident in Odum's revisions of an essay on the use of Zinc 65 to trace the excretion rate of "the salt marsh snail."[143] On an early draft, Odum crossed out "tagging" and wrote in "labeling."[144] Further, Odum taught the use of radioisotopes as "tags" and "labels" in the seminar that he helped to design to teach radiation ecology to other ecologists at Oak Ridge.[145] And in the paper he co-authored with Frank Golley for the 1961 Radioecology conference, radioisotopes "labeled" processes at the level of individual, population, metabolism.[146]

The language of radioisotopes as "labels" and "tags" implies their more or less passive role in rendering the functioning of nature visible, but this visibility was of the "function" of nature.[147] However, not only were the movement of energy and matter through the environment generally not visible to the unassisted--and certainly not the

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142 Correspondence from Frank Golley to Karl Herde, dated August 2, 1963. UGA 97 049, box 1 [emphasis added].

143 Jiro Mishima and Eugene P. Odum, “Excretion Rate of Zn65 by Littorina Irrorata in Relation to Temperature and Body Size,” *Limnology and Oceanography* 8, no. 1 (January 1, 1963): 39.

144 Working draft of an article Odum wrote with Jiro Mishima that would be titled "“Excretion Rate of Zn65 by Littorina Irrorata in Relation to Temperature and Body Size." "Use of Zn65,"1-2. UGA 97 045, box 40. Jiro Mishima and Eugene P. Odum, “Excretion Rate of Zn65 by Littorina Irrorata in Relation to Temperature and Body Size,” *Limnology and Oceanography* 8, no. 1 (January 1, 1963): 40.

145 UGA 97 045, box 54.

146 Odum, Eugene P., and Frank Golley. "Radioactive Tracers as an Aid to the Measurement of Energy Flow," 3.

147 Odum, "Relationship Between Structure and Function," 115-6.

untrained--eye, they were also novel focal points in ecology. Just as Odum's *Fundamentals of Ecology* placed these principles at the center of ecosystem ecology, and in front of students training to become ecologists, so did his use, and promotion, of radioiostopes helped to stabilize their existence as objects of inquiry in ecology.

Despite Odum's enthusiastic characterization of the revolutionary potential of radioisotopes, clearly radioisotopes could not revolutionize ecology in isolation. The language of "tagging" and "labeling," as well, suggest that radioisotopes were only one element in the restructuring of practices of ecological research in the field of radiation ecology. In addition to radioisotopes, there needed to be geiger counters as ways of indicating the presence of radioisotopes and, in Odum's case, an AEC production facility as a field site for their use. Further, their proper use required training and practice--hence the 1961 discussion over how to incorporate radiation ecology into the training of ecologists and the seminar Odum organized in the use of radioisotopes at Oak Ridge. Not only, in other words, did the radioisotopes render processes in nature visible, but they restructured ecological research, at least in the emerging field of radiation ecology. Like Carroll's scopes, radioisotopes augmented perception and structured experimental practice and helped stabilize objects of inquiry.[148]

To a significant degree, Odum's leadership in the field of radiation ecology depended on the availability of radioisotopes and geiger counters as well as AEC land and money. The state provided access to the funding, technology, and training that allowed Odum to distinguish himself as an expert in radiation ecology. Borrowing the language of Chandra Mukerji, Eugene Odum was in a position of "technological

[148] Carroll, *Science, Culture, and Modern State Formation*, 23 and 47-8.

dependence" on the state. Mukerji argues that "[t]he same instruments that allow scientists to make reputations for themselves, promote their labs, and stimulate scientific debate also tie them to" the state and the funding that the state provides. Further, "scientists' work is circumscribed by technological limits imposed by these outsiders. . .as a consequence of the structural relationship between scientists and people in the military or industry who develop equipment of potential use to the researchers."[149] On a material level, the radioisotopes that Odum depended for his research in radiation ecology tied Odum's work in a very real way with the AEC's efforts to contain the problem of radioactive fallout and to bolster both the prestige of nuclear physics and a political vision in which nuclear physics played a central role in preparing for war with the Soviet Union.

However as I will address more explicitly in the following chapter, I do not intend to argue that Odum's research using radioisotopes can be understood through the lens of the state alone. He used the tools the state provided in order to address research goals he associated with the discipline of ecology. As we shall see, he fought to protect the space that would allow him to determine the goals of his research. The world of Eugene Odum was separate from but also linked to the state's efforts to contain the problem of fallout.

In this sense, radioisotopes served as a form of boundary object that linked academic ecology with the cold war state as social worlds with very different customs and concerns. In their well cited article on boundary objects Leigh Star and James Griesemer describe how plant and animal specimens served as "boundary objects" that linked the social worlds of people involved in the natural history research museum.[150]

[149] Mukerji, *A Fragile Power*, chapter 6, esp. 105.
[150] Susan Leigh Star, and James R. Griesemer, "Institutional Ecology, 'Translations' and Boundary Objects:

Similarly, radioisotopes linked ecology to the AEC. The concerns separating philanthropists from amateur naturalists and museum administrators from professional biologists were similar to the concerns separating the AEC and Eugene Odum. And like the specimens of furs and plants that linked amateur collectors, philanthropists, administrators, and biologists, radioisotopes linked Odum with the AEC. In this chapter, I have used Project Sunshine as a case study to provide a sense of the concerns animating the social world of the AEC. And we have gained a preliminary sense of the relative autonomy that Odum enjoyed from the AEC's concerns and the way that this autonomy allowed Odum to use radioisotopes to explore a wider range of research questions than those pursued by ecologists at Oak Ridge or Hanford. In the following chapter, I will explore the tension that Odum's reliance on the tools and the funding of the AEC introduced for Odum and the ways he navigated this tension.

Amateurs and Professionals in Berkeley's Museum of Vertebrate Zoology, 1907-39," *Social Studies of Science* 19, no. 3 (1989): 393, 408-13.

Chapter 3. Radiation Ecology as a Cold War Science

I. Introduction

As we have seen, Atomic Energy Commission funding for ecology was driven by the need to manage the epistemic and political problem that radioactive fallout posed to the national-security state as a political vision centered around the logic of war. While this funding was administered by the Atomic Energy Commission, the distribution of radioisotopes by the AEC came together with President Eisenhower's efforts to put a peaceful face on atomic energy and provided the primary tools used in the field of radiation ecology. With this funding and readily available radioisotopes, a new field of ecology emerged and flourished in the 1950s and 1960s. The last chapter discussed the early history of this new form of ecology and how Eugene Odum was a leader positioned himself as a leader in the field.[1]

In this chapter, I will address how Odum and radiation ecology as a case study for understanding a key question in the historiography of science. Did the often militaristic ends of scientific funding affect the content of science? Odum's situation presents a valuable opportunity for exploring larger questions about the nature of cold war science. One of the central issues of the historiography of cold war science involves the nature of the relationship between science and its sources of funding. Did the often militaristic ends of scientific funding in this period affect the science that was being funded and—if so—how?

There have been a wide range of attempts to answer this question, often by

[1] In a sense the previous chapter approaches the same problem as this chapter but from a different angle. Chapter 2, 'Mobilizing Ecology,' attempts to capture the reasons for funding ecology from the perspective of the state, and the previous chapter begins to approach the question of why ecologists would be interested in this funding and what they did with it. Put more simply, it describes a viewpoint closer to that of ecologists, such as Odum, who were seeking AEC funding. In this chapter, I will attempt to bring these two viewpoints into the same space by using the questions of cold war historiography as a framework and cold war historians as a set of interlocutors.

focusing on the ways that funding impacted the content of the science that received funding. In an article on oceanographers' cold war investigation of sea-floor hydrothermal vents, Naomi Oreskes outlines two contrasting answers to this approach.[2] One position could be represented by Daniel Kevles' findings that, "despite pervasive military patronage, US physicists retained control of their intellectual agenda."[3] By contrast, much more critical positions can be found in the work of Paul Forman and many others who argue that military patronage has played a significant role in determining the content of cold war sciences.[4]

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2 Naomi Oreskes, 2003. “A Context of Motivation: U.S. Navy Oceanographic Research and the Discovery of Sea-Floor Hydrothermal Vents,” *Social Studies of Science*, 33, (4, Oct.): 697-642. See also Naomi Oreskes, "Introduction," in *Nation and Knowledge: Science and Technology in the Global Cold War*, ed. Naomi Oreskes and John Krige, (Cambridge, MA: MIT Press, forthcoming).

3 Oreskes "Context of Motivation," 698.

4 Paul Forman, "Behind Quantum Electronics: National Security as Basis for Physical Research in the United States, 1940-1960," *Historical Studies in the Physical and Biological Sciences* 18, 1 (1987): 149-229.

Much of the scholarship I reviewed in the introduction on the relationship between the state funding of science and its impact on the content of science has focused on the level of a field of study or the kinds of questions investigated at a specific research site. Instead of addressing state funding primarily in terms of its impact on the content of science, here I propose to follow in the footsteps of work approaching the science-state relation by foregrounding the details of particular scientists as illustrating not only the way larger scale tensions can present themselves to individuals but also the how individuals' responses matter in modeling a way of navigating these tensions for others. Phrased a different way, I am proposing to leverage the level of detail provided by a biographical level of engagement in order to address the ways larger scale social trends and tension can interact in a dynamic way with the particulars of one person's biography[5]. I will ask,

- What does radiation ecology tell us about the place that ecology took in relation to the cold war state from the mid to late 1940s to the early 1960s?
- What kinds of expectations or demands, if any, accompanied the funding that the Atomic Energy Commission provided to ecologists?
- If science 'should,' for Weber, be value neutral, then how were ecologists as scientists able to conduct research that was motivated by political ends of the cold war national-security state?
- How did ecologists position their research in relation to the need to understand and to manage radioactive fallout on the one hand or the ends of furthering the discipline of ecology on the other?
- What strategies did ecologists use during this period to assert the autonomy of ecology, even though it was funded by the state?

It would be difficult to find a scientist more central in bringing the funding of the

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5 Here, I am pointing to the insights that can be gained by employing the sociological biography approach that I described in the introductory chapter. Thorpe discusses and models this approach to Oppenheimer's life (2006) and in a less explicitly sociological way, Allan Needell does so as well with Lloyd Berkner's life (2001). C. Wright Mills' introduction to *The Sociological Imagination* provides a much earlier and more theoretical description of this kind of approach (1959). See the introduction for a more detailed description of this approach.

cold war state to the discipline of ecology than Eugene Odum. In successfully navigating the funding landscape of the early cold war years, he also modeled for future ecologists how to secure outside funding. As we shall see, however, this funding often came with expectations as to the nature of the research it would be used to fund. The historiographical question of the impact of militaristic sources of funding on science was a concrete problem for Odum and one that he answered in a very sociological way. His response was to create an organizational 'filter' in order to keep the strings attached to AEC money separate from his research goals. He created an organization dedicated to research on the AEC site (the Savannah River Ecological Laboratory, or SREL) and carefully managed the connections between this laboratory and the ecologists working at the University of Georgia. While this resolution was effective in buffering his research goals at the University of Georgia from the research goals of the AEC, it created tensions among ecologists hired to work at the SREL who aspired to professor positions at UGA. For Odum this organizational solution went along with efforts to distinguish radiation ecology from basic research. In his textbooks but also in his conference presentations and elsewhere Odum engaged in a form of boundary work to hold the research goals intrinsic to ecology apart from the research goals of the Atomic Energy Commission.[6] By drawing on the patronage of the state but also distancing himself from the research it funded, Odum found a new place for ecology in society in the early cold war period.

II. The Tensions of Cold War Science in Eugene Odum's Work

[6] Thomas F. Gieryn, "Boundary-work and the Demarcation of Science from Non-Science: Strains and Interests in Professional Ideologies of Scientists," *American Sociological Review* 48 (1983): 781-2 and 791–3. Thomas Gieryn, *Cultural Boundaries of Science: Credibility on the Line*, (Chicago: University of Chicago Press, 1999), 4-5, 15-8.

The First National Symposium on Radioecology in 1961 represented an important moment in the young field of radiation ecology. Although it was not the first time ecologists working with radioisotopes had gained an organizational foothold to present their work at a conference of professional scientists, it was both the largest assemblage of radiation ecologists to date and the first conference dedicated to radiation ecology as a specialty.[7] Given the importance of this conference, it was all the more striking that Odum as a leader in the field of radiation ecology chose this venue to distinguish radiation ecology from the broader field of ecology.

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7 Before the 1955 International Conference on the Peaceful Uses of Atomic Energy contained a handful of radiation ecology papers. In addition to the one introduced above by Odum, Hanford ecologists Richard Foster, J. J. Davis, W. C. Hanson, and H. A. Kornberg delivered papers. Held in January the following year. the AEC-sponsored Conference on Radio-Isotopes in Agriculture was dominated by radiobiologists working in AEC labs and agricultural researchers. By comparison with the 1956 conference, the 1961 Radioecology was much larger, centered on radioecology and brought together a wider range of participants. In addition to AEC staff scientists and a few agricultural scientists, there was a wide array of biologists and ecologists. Eugene Odum, ""Consideration of the Total Environment in Power Reactor Waste Disposal." *Proceedings of the International Conference on the Peaceful Uses of Atomic Energy* 13 (1955): 350-8. Foster, R. F. and J. J. Davis "The Accumulation of Radioactive Substances in Aquatic Forms." *Proceedings of the International Conference on the Peaceful Uses of Atomic Energy* 13 (1955): 364-367. W. C. Hanson and H. A. Kornberg, "Radioactivity in Terrestrial Animals Near an Atomic Energy Site," *Proceedings of the International Conference on the Peaceful Uses of Atomic Energy* 13 (1955): 385-388. Eugene Odum, "Ecological Aspects of Waste Disposal." In *A Conference on Radioactive Isotopes in Agriculture: Held on January 12, 13 and 14, 1956, at Michigan State University, East Lansing, Michigan*. Argonne National Laboratory, 95-104. U. S. Atomic Energy Commission, 1956. Argonne National Laboratory. *A Conference on Radioactive Isotopes in Agriculture: Held on January 12, 13 and 14, 1956, at Michigan State University, East Lansing, Michigan* (U. S. Atomic Energy Commission, 1956), v-vi. Vincent Schultz and Alfred W. Klement eds. *Radioecology; Proceedings of the First National Symposium on Radioecology held at Colorado State University, Fort Collins, Colorado, September 10-15, 1961, (*New York, Reinhold Pub. Corp, 1963), ix-xii.

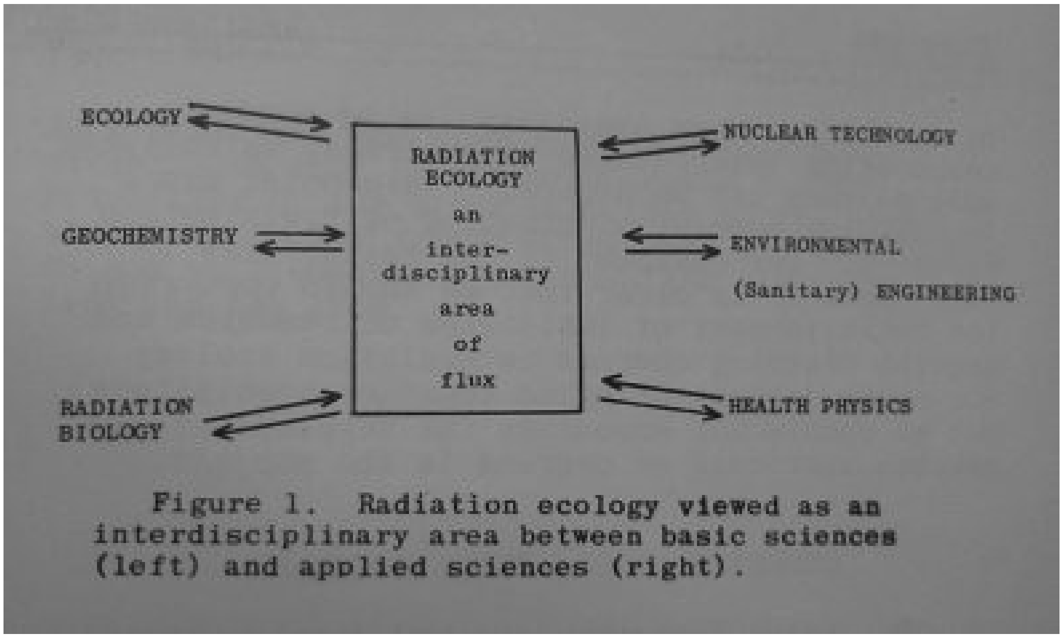

Figure 3.1 - Radiation ecology as an inter-disciplinary area of flux. Odum's position was summarized in a diagram that served to organize discussion and that separated off ecology from radiation ecology as "an inter-disciplinary area of flux."[8]

In a panel discussion that Odum led on "Education and Research Training," he was careful to frame discussion by distinguishing ecology as a field from radiation ecology. Odum characterized radiation ecology as an applied science but also as a field that was outside the field of ecology.[9] As the comparatively informal panel began, Odum drew a diagram on the blackboard. In the center was a box labeled "Radiation Ecology." On the left he wrote "Ecology" and under that "Geochemistry" and "Radiation Biology." On the right of the box, Odum wrote "Nuclear Technology," Environmental (Sanitary) Engineering," and "Health Physics." He explained the diagram in terms of the position of radiation ecology in relation to the distinction between basic and applied research. On the

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8 This diagram was reproduced in the conference proceedings. See Vincent Schultz and *Alfred W. Klement* eds., *Radioecology; Proceedings of the First National Symposium on Radioecology held at Colorado State University, Fort Collins, Colorado, September 10-15, 1961,* (New York, Reinhold Pub. Corp., 1963), 643.

9 As I will discuss below, Odum's characterization of the place of radiation ecology would shift as Odum addressed different audiences at different points in time.

left side of the diagram are "investigators and students from at least three vigorous and well-established basic areas" and on the right side of the diagram are "three major fields of applied science"[10]. What was Odum doing here? If radiation ecology served as one of the key bases of Odum's expertise as a research ecologist, why would he go to such trouble to separate radiation ecology off from "basic" ecology at the largest gathering of radiation ecologists to date?

The gap between AEC goals and Odum's research goals represented an ongoing source of tension for Odum and for many of the ecologists working with him in affiliation with the University of Georgia. Odum attempted to resolve these tensions in two ways. He performed a complex form of boundary work that both asserted a close link between academic ecology to radiation ecology but also qualified that link in important ways.[11] Another resolution was organizational in nature. Odum maintained parallel organizations —one at the university and another on the AEC site. On both an individual and an organizational level, Odum modeled for later ecologists how to be an academic ecologist in the cold war setting—how to secure outside funding but also use it towards the pursuit of research problems that were ecological in nature.

III. Odum's Boundary Work and the Place of Radiation Ecology in Relation to the Larger Field of Ecology

The puzzle of what Odum sought to achieve through his demarcation of radiation ecology at this Radioecology conference becomes more understandable when considered

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10 A transcript of Odum's presentation is included in the proceedings of the conference. Eugene P. Odum, "Panel Discussion on Education and Research Training." In *Radioecology; Proceedings of the First National Symposium on Radioecology held at Colorado State University, Fort Collins, Colorado, September 10-15, 1961,* ed. Vincent Schultz et al. (New York, Reinhold Publishing Corporation, 1963), 643.

11 See discussion of boundary work in the introduction.

in the framework provided by sociologist of science Thomas Gieryn. As I have discussed in the introductory chapter, Gieryn describes scientists' use of boundary work as part of a larger effort to establish and maintain control over the ability to provide legitimate interpretations of nature by distinguishing science from non-science:

> Construction of a boundary between science and varieties of non-science is useful for scientists' pursuit of professional goals: acquisition of intellectual authority and career opportunities; denial of these resources to 'pseudoscientists;' and protection of the autonomy of scientific research from political interference.[12]

This emphasis on boundary work as a way of distinguishing what should count as science goes a long way in explaining what Eugene Odum was up to in the First National Symposium on Radioecology in 1961. This was the first scientific conference devoted to radiation ecology and so an important one in determining the professional trajectory of the subfield in relation to academic ecology. In separating ecology from radiation ecology, Odum was performing a kind of boundary work that separated the two areas and implicitly privileged ecology as a 'basic' science.

At the same time, Odum had a lot to lose by casting off the work of radiation ecology entirely. By 1961, his Savannah River Ecological Laboratory alone was taking in $54,165 a year from the Atomic Energy Commission—five times more than the agency's original ten thousand dollar contract. By the time Odum's diagram would be published in 1963, the laboratory would be bringing in $202,062[13]. Odum's star was on the rise in this

12 Thomas F. Gieryn, "Boundary-work and the Demarcation of Science from Non-Science," 781.

13 "Budget History of the SREL," UGA 97 045, box 59. Although such calculations embed theoretical assumptions and are never as clear cut as they may presume to be, two websites translate the 1961 amount of $54,165 translates into approximately $395,000 of funding in 2010 dollars. The 1963 amount of $202,062 translates into approximately $1,465,000 in 2010 dollars. While this amount of funding was dwarfed by AEC funding for the Atomic Bomb Casualty Commission and, certainly, for the production of weaponry, it represented an unprecedented level of external funding for ecology at the time. See websites such as http://www.measuringworth.com/ppowerus/ or

period, and in no small part due to the success of this laboratory, which served as the basis of his prominence in the field of radiation ecology. Odum, in other words, would have had plenty of motivation *not* to sever the link between ecology and radiation ecology fully.

Instead he separated the fields but also re-connected them using a familiar rhetoric centering on the distinction between basic and applied science.[14] Ecology was a basic science while radiation ecology was closer to the applied sciences of Nuclear Technology or Environmental Engineering but was less stable, "an inter-disciplinary area of flux."[15] In the diagram he drew for the panel on "Education and Research Training" at the Radioecology conference, Odum positioned radiation ecology *between* the basic and applied sciences.

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http://www.buyupside.com/calculators/purchasepowerjan08.htm for translating monetary equivalency across time.

14 The work of Peter Galison, Benoit Godin, and Ronald Kline all provide a broader historical contexts for understanding the way the distinction between basic and applied research was deployed during World War II and the cold war era. Peter Galison, "Ten Problems in History and Philosophy of Science," *Isis* 99, 1 (2008): 113-4. Benoit Godin, "The Linear Model of Innovation: The Historical Construction of an Analytical Framework," *Science, Technology, & Human Values* 31, 6 (2006): 640, 644-5, 649-54. Ronald Kline, "Construing 'Technology' as 'Applied Science': Public Rhetoric of Scientists and Engineers in the United States, 1880-1945," *Isis* 86, 2 (June 1, 1995): 197, 216, 218-220. Roger Pielke, "In Retrospect: Science - The Endless Frontier," *Nature* 466 (August 19, 2010): 922-3. I approach the familiarity of the basic-applied distinction in the following section ("Boundary Work and the Tensions of Cold War Science More Generally").

15 Schultz and Klement, *Radioecology,* 643.

Elsewhere, he approached radiation ecology as an applied science. In the same presentation in which Odum coined "radiation ecology," he envisioned radiation ecology as an applied science that would be practiced at atomic energy installations.[16] Here, ecologists would use their training in the principles of ecology to help solve the problems posed by radioactive waste disposal[17]. By contrast, ecologists employed in academic settings worked on problems set internally by the discipline of ecology—doing basic research furthering ecological knowledge.

In one of many news clippings covering the Geneva conference, Odum was quoted: “Successful peacetime use of atomic energy calls for a 'new breed' of scientist, says Eugene P. Odum, University of Georgia professor of biology.” The article proceeds, “Dr. Odum. . . points out that disposal of radioactive waste and the effect of that waste upon man's environment pose basic problems and, at present, barriers to effective peacetime use of atomic energy.”[18] In the context of Odum's careful boundary work—and the analytic of the role of the scientist, it is significant that Odum sees the radiation ecologist as a new "breed" of scientist. Not only is radiation ecology a new field, but it is also a hybrid field—drawing off of the insights of basic research in ecology but also more of an applied area, and one in 'flux.'

With the inclusion of radiation ecology in the second (1959) edition of his college level textbook, Odum had an opportunity to position radiation ecology before a much

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16 Eugene Odum, "Consideration of the Total Environment in Power Reactor Waste Disposal." *Proceedings of the International Conference on the Peaceful Uses of Atomic Energy* 13 (1955): 350-8.

17 Given the AEC's role in blocking geneticist Hermann Muller's talk on the effects of radiation on genetic mutation, it is interesting to note here that Odum invoked uncertainty over the impact of radiation as part of the rationale for staffing ecologists at nuclear power plants. Ibid., 350. Kopp“The Origins of the American Scientific Debate over Fallout Hazards,” 407-12.

18 UGA 97 045, box 50. The article, titled “New Scientist Breed Held Atom Age's Need” is dated July 22, 1955.

wider audience of ecologists in training.[19] Odum's textbook represented several firsts for the field of ecology. In a context in which the discipline of ecology was experiencing growth from the influx of college students after World War II and later from a surge of interest in the environment, Odum's textbook would become a standard part of ecology education in the U. S.[20] The textbook was also novel in its promotion of ecosystem ecology as a way of uniting the field of ecology.

In the organization of the textbook, Odum once again separated basic ecology from radiation ecology, here again as an applied form of ecology. The textbook's organization went along with its effort to promote ecosystem ecology. Discussion proceeded from general, ecosystem level principles in Part 1 to the application of these principles in different habitats in Part 2 and, finally to applied areas of ecology in Part 3. It is significant here that radiation ecology falls into the category of "applied ecology" in Part 3. In the textbook, he reserved the term "basic ecology" for the "principles and concepts" that hold across the field of ecology. Instead of locating "basic" ecological research at the forefront of research conducted within given specialties--and so possibly differing in content between botany and zoology, for example, Odum identified basic ecological research in terms of the principles that applied to all areas of ecology

[19] We can detect something of the tension of cold war science in Odum's efforts to position the importance of radiation ecology with respect to the 'fundamental problems' of ecology as a basic science in the preface to the revised edition of his textbook: “In this revision a new section entitles 'Radiation Ecology' has been added to Part III. It should be emphasized that this new hybrid field is becoming an area of applied science of the greatest importance but also is bringing with it exciting new techniques, which may be expected to contribute to better understanding of fundamental problems, as outlined in Part I” (1959, viii).

[20] See discussion in the "Fundamentals of Ecosystem Ecology" section in the following chapter. Burgess, "The Ecological Society of America," 3. Craige, *Eugene Odum*, 39. Hagen, "Teaching Ecology During the Environmental Age," 704 and 713. Kwa, "Radiation Ecology and Systems Ecology," 222 [emphasis in original]. Orians, “A Diversity of Textbooks,” 1238-39. Philip G. Altbach, "Edward Shils and the American University." In *The Order of Learning: Essays on the Contemporary University* ed. Philip G. Altbach (New Brunswick, NJ: Transaction Publishers, 1997), xiv.

(biogeochemical cycles, the movement of energy through the environment, population dynamics, limiting factors, and organization at the level of species and community).

Despite the fact that Odum characterized radiation ecology as an applied area of ecology in Fundamentals of Ecology, he also seemed to be struggling with how to place the field. In addition to characterizing radiation ecology as an applied area of ecology (his most dominant characterization), he also characterized it as a "borderline" and "hybrid" field. Significantly, one element of his characterization of the relationship between radiation ecology and basic ecology that was constant was its place in the career trajectory of an ecologist.[21]

Odum consistently approached radiation ecology as an area in which trained ecologists could work. Odum's textbook played a role in early stages of the professionalization of ecologists at the level of undergraduate or early graduate study,[22] and it emerged as part of Odum's effort to include ecology as an important part of the curriculum for biology majors at the University of Georgia in the late 1940s and early 1950s. The discussion over the proper relationship between ecology and radiation ecology at the 1961 Radioecology symposium explicitly took place with reference to the goal of the training of future ecologists.[23] In pondering the implications of this workshop, Frank Hungate was careful to emphasize that radiation ecology should be taught in the form of "special training courses" but not be implemented in the form of college courses:

> At that time there seemed to be general agreement that radiation ecology should not be thought of as a new discipline in the academic sense but rather is best considered as an interdisciplinary field between established

[21] Odum, Fundamentals of Ecology 2nd ed., vii-viii and 419.

[22] See the general discussion of professionalization of science in the introduction and a more specific discussion of boundary work and professionalization below.

[23] The name of this panel was “Education and Research Training.” Odum, "Panel Discussion on Education and Research Training," 643.

> basic fields such as ecology, geochemistry and radiation biology on the one hand, and important applied fields such as health physics, environmental engineering and nuclear technology on the other. For this reason it was recommended that the establishment of research programs, institutes and special training courses be encouraged, but that the establishment of special curricula and college courses be discouraged.[24]

The message in both examples is clear. The extent to which radiation ecology should be incorporated into the training of future ecologists should be limited. In both cases, however, people trained in ecology could consider radiation ecology as a potential area in which to work.

IV. Boundary Work and the Tensions of Cold War Science More Generally

The rhetoric centering on the distinction between basic and applied science would have been familiar to Odum as it was prevalent in science policy discussions during and after World War II.[25] Vannevar Bush's call to fund science in *Science: The Endless Frontier* provides a centerpiece in these discussions.[26] In this 1945 report, the wartime head of the Office of Scientific Research and Development called for the need for the state to continue funding science after the war in order to insure "[p]rogress in the war against disease" as well as "[n]ew products, new industries, and more jobs."[27] For Bush,

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[24] From a letter from Frank Hungate to Odum dated March 3rd, 1965. UGA 97 -45, box 2.

[25] Galison, "Ten Problems in History and Philosophy of Science," 113-4. Godin, "The Linear Model of Innovation: The Historical Construction of an Analytical Framework," 640, 644-5, 649-54. Kline, "Construing 'Technology' as 'Applied Science': Public Rhetoric of Scientists and Engineers in the United States, 1880-1945,"197, 216, 218-220. Pielke, "In Retrospect: Science - The Endless Frontier," 922-3.

[26] Godin, "The Linear Model of Innovation," 639-40.

[27] Bush maintained that, "Progress in the war against disease depends upon a flow of new scientific knowledge. New products, new industries, and more jobs require continuous additions to knowledge of the laws of nature, and the application of that knowledge to practical purposes. Similarly, our defense against aggression demands new knowledge so that we can develop new and improved weapons. This essential, new knowledge can be obtained only through basic scientific research." Vannevar Bush, *Science: The Endless Frontier*, (National Science Foundation, 1945), 5.

these things were dependent on the knowledge that came from scientific research. In his account of Bush's report, Benoit Godin shows how Bush's position in this report builds on the "linear model of innovation." This model specifies that "innovation starts with basic research, is followed by applied research and development, and ends with production and diffusion."[28] In the report, Bush argued that basic research, as research "performed without thought of practical ends," provided the "fund from which the practical applications of knowledge must be drawn" and allowed for the "further progress of industrial development."[29] According to this kind of logic, Bush's tract has come to embody the linear model of innovation whereby the insights from basic research are seen as fueling applied research and, in turn, technological development.[30]

There are other highly visible cases of scientists' efforts to mobilize the distinction between basic and applied research. In fact, Oppenheimer deployed the distinction to characterize his state sponsored work as applied or technological. In his biography of Oppenheimer, Charles Thorpe notes that Oppenheimer had to negotiate the tension between two very different views of physics—physics as a field of scientific research that should be accorded a level of autonomy and physics as a source of insight and technology central to the cold war national-security state:

> A distinction between science and technology, and the definition of the war's legacy as merely technological, was essential to Oppenheimer's

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28 Godin, "The Linear Model of Innovation," 639.

29 Bush quoted in Godin, "The Linear Model of Innovation," 644. While Kline has argued that, in fact Bush supported basic and applied research," Pielke has argued that Bush's "basic research" represented an effort to realize scientists' goal of pure research with politicians' interest in meeting the needs of the nation. Kline, "Construing 'Technology' as 'Applied Science,'" 218–221. Pielke, Roger, "In Retrospect: Science - The Endless Frontier," 923. See also Naomi Oreskes (2010) 'Science, Technology and Free Enterprise', Centaurus 52:297-310.

30 Bush linked basic research with advances in technology in a variety of places throughout his work. See, for example, "Today, it is truer than ever that basic research is the pacemaker of technological progress." Bush, *Endless Frontier*, 19.

> negotiation of, on the one hand, academic autonomy and, on the other, control of atomic energy for national security. The science of the atom would be autonomous. The technology of atomic energy would be controlled and directed by the government.[31]

In making this distinction, Oppenheimer aims to restore the purity of a science stained by its role in building the atom bomb.[32] Physicists' work on the bomb was applied, or technological, and should not be considered a core part of what physics was. Atomic physics as a profession was—or, we could add, should be—autonomous from the state's concern for national security. Just as Odum was eager to distinguish his (basic) ecological research from (the more applied) radiation ecology, so was Oppenheimer eager to distinguish the pursuit of physics from his work for the Manhattan Project and Los Alamos as technological. The atom bomb was merely a "gadget."[33]

Bush's 1945 work not only represents an influential example of the distinction between basic and applied science, it also envisions an organizational strategy for

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31 Thorpe, *Oppenheimer*, 174.

32 See also the discussion of the way Oppenheimer viewed the link between science and the atom bomb as a "paradox." We can see Oppenheimer performing boundary work in order to separate his work on the bomb from science (and the state): "The bomb was spawned by science, but its nature was alien to science.' Even when he [Oppenheimer] described the atomic bomb as an instrument of power, he distanced both his profession and his nation from the bomb's violence." Thorpe, *Oppenheimer*, 184.

33 See also Rebecca Slayton, "Discursive Choices: Boycotting Star Wars Between Science and Politics," *Social Studies of Science* 37, no. 1 (February 1, 2007): 27-8; Jane Calvert, "What's Special About Basic Research?" *Science, Technology, & Human Values* 31, no. 2 (March 1, 2006): 199–220. See also Woods Hole Oceanographic Institution Director Paul Fye's characterization of the imbalance in the Office of Naval Research's funding for "applied research projects" or oceanographer Allyn C. Vine's appeal: "WHOI [Woods Hole Oceanographic Institution] normally cooperates with the Navy on applied problems and would do so again but we would not sign our basic interests away before the fact." Oreskes, "Context of Motivation," 731, 704. Scholars such as Gieryn might read Fye's and Vine's appeals as performing boundary work to maintain the professional autonomy of oceanography in the face of the expectations accompanying military funding. For Oreskes, discussion of 'basic' and 'applied' research are important primarily in the context of the primary question of cold war historiography: "'Applied' projects often led scientists to learn about the natural world. That point seems pretty obvious. Less obvious, and therefore more important, is the way in which the military context shaped 'basic' scientific investigation. . . . scientific topics that gained the attention of the oceanographers. . . .were questions that came into focus in the crosshairs of national security." Oreskes, "Context of Motivation," 730.

protecting the autonomy of science while still securing the patronage of the state.[34] In order to protect basic or "pure" science, Bush proposed the creation of an agency that would be autonomous from other concerns of the state and devoted to the goal of scientific research:

> A new agency should be established, therefore, by the Congress for the purpose. Such an agency, moreover, should be an independent agency devoted to the support of scientific research and advanced scientific education alone.[35]

He continued, "Basic scientific research should not, therefore, be placed under an operating agency whose paramount concern is anything other than research."[36] As historian Jessica Wang and others have pointed out, however, Bush was careful to try to place scientists in control of the agency that would funnel government money to particular scientific projects.[37] Positioning scientists and not elected officials in charge of determining what projects government money would fund would provide an organizational buffer whereby scientists could benefit from government funding but maintain a level of professional autonomy.[38] The same principle applied at the level of the

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[34] In addition to the discussion of Bush's vision for what would become the National Science Foundation in the introduction, see Dennis, "Reconstructing Socio-Technical Order," 225-53; Greenberg, *Science, Money, and Politics*, chapter 3; Greenberg, *The Politics of Pure Science*, chapter 4; Karabell, *Architects of Intervention*, chapters 13-15; Kevles, "The National Science Foundation," 5–26; Kevles, *The Physicists*, 356-61; Kleinman, *Politics on the Endless Frontier,* chapters 4 and 5; Pielke, *"In Retrospect: Science--the Endless Frontier,"* 922-3.

[35] See also Bush's statement in *Science: The Endless Frontier*:

> The responsibility for the creation of new scientific knowledge rests on that small body of men and women who understand the fundamental laws of nature and are skilled in the techniques of scientific research. While there will always be the rare individual who will rise to the top without benefit of formal education and training, he is the exception and even he might make a more notable contribution if he had the benefit of the best education we have to offer.

Bush, *Science: The Endless Frontier*, 23.

[36] Ibid., 32.

[37] Jessica Wang, *American Science in an Age of Anxiety: Scientists, Anticommunism, and the Cold War,* (Chapel Hill: University of North Carolina Press, 1999), 30-1.

[38] See also Chandra Mukerji, *A Fragile Power: Science and the State* (Princeton: Princeton University Press, 1990), 52-61.

specific scientific projects selected for funding.

> Support of basic research in the public and private colleges, universities, and research institutes must leave the internal control of policy, personnel, and the method and scope of the research to the institutions themselves. This is of the utmost importance.[39]

In Bush's scheme, scientists should be funded by the government, but they would not become civil servants nor would their work be dedicated to democratically determined ends. Historian of science Michael Dennis has argued that, despite Bush's efforts, the hybrid character of the National Science Foundation represented (contra Daniel Kevles' interpretation) "a profound defeat" for Bush in relation to his hopes for an agency that could protect basic research.[40]

V. Odum's Organizational Response to the Tensions of Cold War Science

Although he would not enjoy Bush's prominence or access to policy elites, Eugene Odum also had an organizational strategy for managing the tension between his desire to secure external funding on the one hand with his desire to maintain professional autonomy on the other. While Bush was describing a hypothetical organization to handle state funding for a wide variety of scientific projects, Odum's response was driven by a much more immediate effort to avoid what he saw as the counter productive micro management of the Atomic Energy Commission's Savannah River Operations Office. Throughout his involvement with the Atomic Energy Commission, Odum was careful to separate the bulk of AEC funded research from the rest of the ecology research conducted

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39 Bush, *Science: The Endless Frontier*, 32.

40 Michael Aaron Dennis “Reconstructing socio-technical order," 225-7, esp. 226. Kevles, *The Physicists*, 361-6; Kevles, "The National Science Foundation and the Debate," 25-6. See also Oreskes on the inherent tensions in Bush's position. Oreskes, "Science, Technology and Free Enterprise," 297-310.

at the University of Georgia. He did this by establishing a laboratory (the Savannah River Ecological Laboratory) on the AEC's Savannah River Site and carefully managing the connections between this laboratory and the ecology units at the University of Georgia.

While Odum's organizational strategy arguably provided a level of autonomy that he might not have otherwise enjoyed, it created other problems among ecologists seeking to move between the organizational units of what health physicist Paul Dunway referred to as Odum's “'empire' at Athens”[41]. These problems are most easily visible in the early 1970s in the transition from Robert (Bob) Beyers' tenure in charge of the Savannah River Ecological Laboratory (SREL) to Michael Smith. While many of the details in this seemingly bumpy transition remain unknown, it is clear that one of the primary issues at stake was the lack of mobility between SREL and UGA. The challenges that Beyers—and, later, Smith—encountered in their efforts to move from SREL leadership to faculty positions at UGA illustrate the unintended consequences of Odum's efforts to limit the connections between UGA and the SREL. In their frustration at their inability to move from the SREL to university positions, Beyers and Smith found themselves blocked from the path taken by earlier SREL head Frank Golley. Hired to work on AEC research in 1958, Golley would become the resident director of SREL in 1962. Although it would not be for many years that he would move into a faculty position at the University of Georgia, his move would have provided a model for this possibility for Beyers and Smith.[42]

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[41] In a letter to Odum dated March 20th 1961, Health physicist Paul Dunway indicated his desire to, "have the opportunity to see your 'empire' at Athens." UGA 97 044. box 2.

[42] Eugene Odum, “Turning Points in the History of the Institute of Ecology.” In *Holistic Science: The Evolution of the Georgia Institute of Ecology (1940-2000)*, ed. Gary W. Barrett, et al. (New York: Taylor and Francis, 2001), 13-37.

It would take a number of years before Odum's organizational answer to the tensions of cold war science became settled, however. As we saw in the last chapter, Odum's first contract with the AEC started in 1951 in modest terms before growing into a more stable operation in the period from the mid 1950s though the early 1960s. From 1951 through 1954, the funding that Odum secured for what would become the SREL increased slowly from $10,000 to $14,796.[43] For the remainder of the 1950's, funding would continue this steady increase from $18,400 to $23,000.[44] During this period, Odum's AEC-funded ecology research would secure their first full time resident ecologist and an office on Savannah River Site land that they would share with the U. S. Forest Service.[45]

In this period, one of the primary links between the University of Georgia and Odum's Savannah River ecology research—other than Odum himself—was provided by graduate student labor. In the sumer of 1951, Odum recruited three graduate students, William Cross, Edward (Ed) Keunzler, and Leslie Davenport, to perform much of the grunt work of the ecology research at the Savannah River Site.[46] In the beginning, these students were often enrolled in other graduate programs.[47] Ed Keunzler, for example, was

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43 "A Proposal to the United States Atomic Energy Commission for the Expansion and Reorganization of the Savannah River Ecological Laboratory," UGA 97 045, box 59.

44 In an early record of quarterly balances "as of Nov. 1955" we can gain a sense of how funding was divided up in this period. Out of the total (1520.05), 15.6% went to travel, 27.8% went to "supplies," and 44.3% went to "equipment." UGA 01 019, box 1.

45 "A Proposal to the United States Atomic Energy Commission for the Expansion and Reorganization of the Savannah River Ecological Laboratory," UGA 97 045, box 59. Odum, "Turning Points in the History of the Institute of Ecology," 13-37. Frank Golley, "Establishing the Network." In *Holistic Science: The Evolution of the Georgia Institute of Ecology (1940-2000)* edited by Gary W. Barrett and Terry Lynn Barrett, 38-68. New York: Taylor and Francis, 2001.

46 Craige, *Eugene Odum*, 50.

47 This hybrid arrangement would later be replicated with professors (some former graduate students) seeking to continue ecological research at the Savannah River Plant. Odum set up an arrangement such as this with Frank McCormick, whose summer salary would be paid (out of AEC funding) based on his salary during the academic year (UGA 01 019, box 1).

a graduate student at the University of Florida where he had been recommended to Eugene by his brother H.T., who was a professor at Florida at the time. Odum later recollected that he had envisioned that the prospect of funded research opportunities at the Savannah River Plant would not only attract graduate students to enroll at the University of Georgia, and work under Odum or one of the professors he had brought to Georgia, but also enhance the University of Georgia's reputation as a place to do ecological research.[48]

By 1962, Odum's AEC funded Laboratory of Radiation Ecology became the Savannah River Ecological Laboratory, and Odum had formed a separate Institute of Radiation Ecology on the University of Georgia campus. By this time, the scale of Odum's ecology operation at the Savannah River Site had expanded considerably. The budget had nearly doubled from 1959 to 1960 and again from 1961 to 1962. The 1962 – 1963 budget of $91,736 would more than double in the following 1963 – 1964 academic year to $202,062.[49] From the establishment in the 1955-56 academic year of a more permanent headquarters and the hiring of Robert Norris as the first full time on-site ecologist, the Ecological Laboratory would take on more and more staff members (ecologists and administrative support) and establish a larger presence on the Savannah River Plant. In 1962, the newly appointed SREL head Frank Golley recruited Richard

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48 To a significant degree, this plan worked. But retrospectively pointing out the success of the arrangement should not obscure the ways in which Odum planned, or remembered himself as planning, to build the early reputation of the program on the labor of graduate students who were contributing to projects whose success was to be first attributed to Odum and the University of Georgia program in Ecology. Robert Merton's work on the "Matthew effect" describes how the insights, and any ensuing symbolic capital, of Odum's graduate students' work could easily become attributed to Odum himself as the more senior, and more established, scientist. Robert K. Merton, "The Matthew Effect in Science The Reward and Communication Systems of Science Are Considered." *Science* 159, no. 3810 (January 5, 1968): 56–63.

49 "A Proposal to the United States Atomic Energy Commission for the Expansion and Reorganization of the Savannah River Ecological Laboratory," UGA 97 045, box 59.

Wiegert, Carl Monk, Frank McCormick, David Coleman and Robert Beyers. Golley joined Odum in Athens after completing his dissertation at Michigan State University under Don W. Hayne. In a letter to Odum dated September 14th, 1956 Golley wrote, "My doctorate problem involves the study of the energy turnover in the grass-meadow mouse-weasel food chain of the pasture community. . . . As far as I know, your team in Georgia are the only other investigators doing this type of study in a terrestrial environment". It is interesting to note Odum's earlier appointment for the position of an ecologist to reside and conduct research at the Savannah River Site in the 1955-1956 academic year was fellow "bird man" Robert Norris. Norris would garner attention and a prestigious Mercer Award (in 1961) for his work in ornithology. By the early 1960s, the specialties of subsequent appointees would follow Odum's trajectory from ornithology to more theoretically driven work in ecosystem ecology and radiation ecology.[50]

Craige describes the informality that dominated the early years of the university-based Institute of Radiation Ecology. Although the 'institute' was founded with Odum as its director in 1961, it initially represented a loose gathering of UGA professors interested in ecological research. For the organization's first five years, it was not even recognized by university's Board of Regents. Shortly after it was, the scientists requested to have the

[50] UGA 97 044, box 1. See also Frank Golley, *A History of the Ecosystem Concept in Ecology: More Than the Sum of the Parts,* (New Haven: Yale University Press, 1993) xiii; and Odum, "Turning Points in the History of the Insitute of Ecology," 16-27. Norris had been in contact with Odum from at least 1952 when he asked Odum for data on "Savannah sparrow specimens." We can also see Odum mentioning his plans for appointing Norris in January, 1954 in an attempt to fish for information from the University of South Carolina as to their plans for further research on the Savannah River Site. UGA 97 044, box 1. Unfortunately, Norris would not find as supportive an environment after leaving the Savannah River Site. In a 1961 letter to John Cantlon, then in the Botany Department at Michigan State, Odum noted that, "Bob has had a hard time since leaving us in that he has resigned from three Universities in succession and is now essentially a free-lance working a menial job by day and science by night. Bob is a one track mind inverted semi-genius wich [sic] does excellent work on his own when given a free hand, but is unable to cope with the multi-pressures of University life. The Mercer Award will be a great stimulus to his and will help insure that an excellent man does not drop out of science." UGA 97 045, box 3.

“Radiation” removed from its title and secured a three story building south of the football stadium where the university was locating new science buildings. This university-based ecology organization benefited from the patronage of the AEC but also other forms of state patronage. In 1967, UGA Biology head Donald Scott brought in a multi-million dollar National Institute of Health grant, and in 1968 the Institute of Ecology secured another NIH grant to help recruit new ecology faculty whose salaries would, after their first year, be paid for by their home departments (Zoology for Bernard Patten, Entomology for Deyree A. (Dac) Crossley, Microbiology for William Wiebe, and Geography for Howard Dougherty). In 1970 the interdisciplinary institute established a Ph.D. in ecology, and in 1974 they institute moved into a new facility.[51]

To a significant degree, the Savannah River Ecological Laboratory provided an organizational buffer to limit AEC management of university professors' research that was funded by the AEC. In addition to funding university-based ecologists' research directly, AEC money paid for grad students to work on university based research conducted on AEC land. Despite the fact that UGA-based ecologists would benefit from AEC funding, they could rely on the ecologists working full time at the SREL as well as graduate students and post-doctoral scholars and the SREL administrative staff to answer the need to provide the AEC with reports detailing the research and research infrastructure they were paying for.[52]

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51 Odum would serve as director of the Institute through 1984 when Golley would be appointed director. UGA 01 019, box 1. Craige, *Eugene Odum*, 75-8. Golley, *A History of the Ecosystem Concept*, preface.

52 In correspondence dated November 28th 1972, Frank Golley explains to several SREL staff ecologists the administrative arrangements for their employment. Although they have appointments at the University of Georgia as Research Associates, their salary is paid to the state by the AEC and so their affiliation with UGA has to be renewed every year pending AEC funding for their positions. As I will discuss below, this limited connection with the Institute of Ecology did little to assist senior SREL researchers and administrators in gaining professor positions at the university. UGA 97 045, box 59.

Having the Savannah River Ecological Laboratory serve as an organizational buffer between AEC and Odum's university-based 'basic' ecological research did not always work, however. AEC demands sometimes overwhelmed SREL personnel and required Odum's attention, despite his efforts to avoid dealing with the details of administering the SREL. Frank Golley reported that Odum, “by self admission, was not interested in day to day administration."[53] Hired to work directly for the AEC in ecologist John Wolfe's Environment Services Branch of the Division of Biology and Medicine, ecologist Vincent Schultz wrote to Odum, "the [AEC] research Committee was not too pleased with your proposal and progress report." In a follow up remark, he added, "Just consider this a friendly rap on the knuckles by a friend.”[54] Odum wasted no time in firing off an indignant reply to Schultz:

> We are now being increasingly 'managed', well intentioned for the most part, by the Savannah River Plant administration whose policies are set up for the operation of an industrial complex not a research program. We are quite willing, indeed anxious to justify our program by preparing stronger annual reports but we cannot do this if we have to justify our every action on a weekly and monthly basis. . . .Our very small staff, selected for their creative potential and not their administrative experience, has been so tied up with excessive paperwork on equipment purchases, weekly reports, almost daily inspections, unannounced reviews originated by someone unknown to us in the vast SRP organization, that they had little time to spend on the 1963 annual report and still do research and publish papers.[55]

Odum's resisted the AEC's efforts to manage the SREL as if it, too, were part of the 'industrial complex' of the AEC's Savannah River Plant. For Odum, this effort not only

53 Craige, *Eugene Odum*, 76.
54 Odum would have most likely found this condescending remark, from a junior ecologist and AEC staff member, to represent a violation of decorum and lack of awareness, on Schultz's part of Odum's stature in the field of ecology and among Schultz's superiors at the AEC and senior level ecologists working as staff at the AEC facilities. Throughout his professional life, Odum maintained a keen awareness of his stature in the field of ecology, in the university community, and in Athens more generally. Correspondence dated November 5th, 1963. UGA 97 049, box 1.
55 Correspondence date November 13th, 1963. Underlined in original. UGA 97 049, box 1.

misses the importance of the fundamental difference between research and the production, but it also represents a poorly conceived effort to extend the bureaucratic management style of the AEC over the realm of research.[56] A staff of scientists selected for their "creative potential" were being used in "administrative" roles. To make matters worse, Schultz's impolitic admonishment (in Odum's view) threatened to support “political pressure which would have the University of Georgia eliminated from the plant.” In his reply, which came nearly a full month later, Schultz focused his most of his attention on the question of whether purchases for the on site ecology lab should go through the university contract and then acknowledged curtly that his superior, Environmental Sciences Branch head John Wolfe, would discuss the issue with Odum directly.[57]

Odum's dual organizational structure would generally filter the impact that these kinds of AEC demands would have on the work of ecologists based at the University of Georgia and provide a model for future ecologists of how to manage the tension between securing state funding while preserving professional scientific autonomy. In using this flare up of tensions as an opportunity to re-negotiate what he saw as the inappropriately bureaucratic demands the AEC was placing on the SREL, Odum was also attempting to re-negotiate the terms of both his organizational response to cold war tensions and his

56 In "Against Time" Charles Thorpe has captured the tension between norms of scientific research and the state's effort to manage scientists according to a more instrumental logic towards the end of producing an atomic weapon at the Los Alamos laboratory. Here, the laboratory's schedule functioned as an instrument of "social control that tied both the daily lives and the consciousness of the scientists to the overall goals of the institution." Thorpe, *Oppenheimer*, chapter 5, esp. 129.

57 Correspondence dated December 10th, 1963. UGA 97 049, box 1. The tension between the AEC management of the Savannah River Plant and the ecologists working there reappeared in comparatively minor form over the years. A few years after this confrontation between Odum ad Schultz, for example, tensions rose briefly over the AEC effort "to strengthen the control and use of contraband items at SRP." Correspondence dated June 14, 1966 from P. J. Hagelston Director of Safety and Technical Services Division of Savannah River Plant to Dr Robert J Beyers. UGA 01 019, box 1.

role as a cold war scientist.

Although it helped to solve certain problems, this dual organizational structure introduced constraints in the work environments and career trajectories of scientists hired into Odum's 'empire' in Athens. Just as the first graduate students were hired on a contract basis to work on the AEC funded environmental survey, so were later hires dedicated to working on the AEC funded research. From the time Odum established separate organizations—the SREL and the interdisciplinary Institute of Radiation Ecology (later the Institute of Ecology) from 1961 on the University of Georgia campus, there was less and less mobility between his AEC funded research and his academic organization. Although some of the early hires, such as Richard Wiegert, Carl Monk, and David Coleman were able to earn professorial positions at the University of Georgia, with time this kind of mobility would become the exception that would prove the rule. Further, this mobility came to emphasize to other ecologists hired into the SREL (often but not always later hires) their lack access to the corridors of academia.

The career trajectory of Robert Beyers provides a visible example of the unintended problems that accompanied Odum's dual organizational setup. Recruited by Frank Golley to work at the SREL in 1963, ecologist Robert (Bob) Beyers worked at the SREL as a staff ecologist until 1967 when he was appointed to be the director of the SREL.[58] Before joining the SREL Beyers would have been well placed to receive a favorable recommendation as he had worked under Eugene's brother Howard Odum at the Institute of Marine Science in Port Arkansas, Texas. After working at the SREL for

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[58] Although Beyers was appointed director in 1967, he had been serving as an acting director of the SREL from at least July, 1966. See letter from Nathaniel Stetson, the manager of the AEC's Savannah River Operations Office to "Dr. R.J. Beyers" dated July 11th, 1966. UGA 01 019, box 1.

around a decade, Beyers was itching for a position as a professor at the University of Georgia.[59] Clearly he would have been aware of his predecessor Frank Golley's move from being an administrator of the SREL to being a tenured faculty member at the University of Georgia. When Gollley was hired in 1958, his research on the Savannah River Site came with an appointment at the University of Georgia. The appointment was as an instructor in Zoology, however, and only lasted through 1962, when Golley was appointed full time director of the SREL. In 1966 Golley moved to the main campus as Executive Director of the Institute of Ecology and faculty member. With Odum's support, Golley would later secure a tenured position at Georgia partially on the basis of his work administering the SREL and partially on the basis on his publications while working at the SREL and the time surrounding his efforts to make the transition from the AEC facility to Athens.[60]

Unfortunately, however, Beyers efforts to become a professor at the University of Georgia would not meet with the success that had rewarded Golley's efforts. Because of a very incomplete archival record, it is impossible to reconstruct with any precision the series of events that led to Beyers' resignation.[61] It appears that Beyers was removed from

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59 Correspondence from Beyers to Odum dated May 28, 1973. UGA 97 045, box 59.

60 See Odum on the trajectory of Golley's career. Odum, "Turning Points," 21-2. There is a series of correspondence between Eugene Odum and Beyers on the details of Beyers' move to the Savannah River Ecological Laboratory from working under Howard Odum at the Insitute of Marine Science. UGA 97 044, box 3. There is a letter from Golley, Beyers and John P. Kerr to Odum dated March 6th, 1966 that alludes in vague terms to a “three step process” for what appears to have been a plan to transition SREL leadership from Golley to Beyers. This came two days before an Institute of Ecology meeting. UGA 01 019, box 1.

61 Correspondence from Frank Golley to Nathaniel Stetson, the manager of the AEC's Savannah River Operations Office, dated April 11th, 1973 indicates the AEC had safety concerns centering on SREL operations: “I was distressed to learn today that Dr. Beyers will not be in town for my proposed visit to the SREL tomorrow. Since my purpose was to review the state of his safety program. I have decided to cancel my visit and reschedule it next week. Rest assured that we are equally concerned that this research program is conducted in a safe and effective manner.” In a letter dated the following day, Golley apologized to Beyers for canceling their meeting as he [Golley] “was given an inaccurate message that you would not be on site.” UGA 97 045, box 59.

the position of director of SREL and replaced by a younger ecologist, Michael Smith in June, 1973. Although Beyers continued working at SREL under his replacement for another year in a research capacity, his replacement consistently provided Odum and Golley negative performance reviews of Beyers.[62] Whatever prompted the removal of Beyers from his position as director of SREL, he made his dissatisfaction with the terms of Odum's dual organization clear in a letter addressed to Odum and dated May 28th, 1974:

> When it becomes necessary for an individual to terminate an association of ten years standing, in simple fairness it is obligatory on that individual to give some explanation for the termination. I shall not go into the reasons which deal with me as an individual as they are personal, perhaps controversial, and you know or can guess most of them. I will dwell therefore only on the defects of the system which can be remedied in the hope that my leaving will be of some benefit to the Institute of Ecology, the University of Georgia, and the SREL.
>
> Many years ago I told you that I thought SREL could not fulfill its function as an ecological center for the southeastern United States if it was nothing other than a postdoctoral mill. The pattern of hiring young scientists just out of graduate school, keeping them for a few years, and then replacing them as they move on is detrimental to long term research and understanding of the ecosystems on the Savannah River Plant. . . .Every person on the senior staff here knows that his chances of making full professor (even with the dubious word adjunct in front of it) is nil. Tenure is impossible. . . .as one dissatisfied staff member recently remarked, 'there is no future here for anyone after two or three years unless he goes into laboratory administration.' Since my services are no longer required in any administrative capacity, this same situation applies to me now. Therefore, I have found it necessary to follow in the footsteps of Frank McCormick, Carl Monk, Claude Boyd, and Bill Lewis and seek employment elsewhere.[63]

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62 Correspondence from Robert Beyers to Odum dated June 21, 1973. In this letter—one day after Golley notified the UGA administration and the AEC that Smith would be moving into Beyer's position–Beyers indicated his desire to resign from the remainder of his administrative responsibilities and continue working as a researcher for SREL; correspondence Michael Smith to Robert Beyers dated August 27th, 1973; correspondence Michael Smith to Odum and Golley dated November 19th, 1974. UGA 97 045, box 59.

63 In correspondence dated July 3rd, 1973, Frank Golley would provide an ambiguous acknowledgement of Beyers' frustrations: “Your tenure has often been arduous and frustrating and we all appreciate the time

In highlighting the range of career opportunities at the SREL, Beyers' letter also points to the obstacles facing even senior SREL researchers and administrators hoping to secure tenure or tenure track positions at the University of Georgia. As Beyers was not able to follow Golley's trajectory and gain a tenured professor position at UGA, he saw himself as following the model of earlier ecologists who had also faced the gap between the SREL and the Institute of Ecology and left the SREL. Beyers saw his problem in organizational terms as an organizational problem that others (McCormick, Monk, Boyd and Lewis) also experienced.

Michael Smith, the SREL administrator who followed in Beyers' footsteps, would also experience this problem. On May 9, 1973, Michael Smith had informed Odum that he had received an offer from Battelle Memorial Institute. As Beyers and others familiar with the SREL had noted, turnover was a problem. A month after receiving Smith's letter, Odum would receive a very similar, if more demanding, letter from SREL staff ecologist Whitfield (Whit) Gibbons. Within a few days, Golley was requesting for Gibbons a new Associate Director position along with management of a thermal ecology group and an increased salary. Smith would similarly be offered a new position--the directorship of the SREL--which he accepted in June 1973.[64]

Smith would soon learn, however, that the directorship would not bring him any closer to a tenure or tenure track position at the University of Georgia. On November 27, 1973, Smith wrote to Odum and Golley:

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and attention you've given to the common effort." UGA 97 045, box 59.

64 Correspondence from Michael Smith to Eugene Odum dated May 9th 1973; correspondence from Whitfield Gibbons to Odum dated June 6th, 1973; correspondence from Frank Golley to S.W. Pelletier, Provost of the University of Georgia's Old College, dated June 11th 1973; correspondence from Frank Golley to William Pelletier dated June 20th 1973. UGA 97 045, box 59.

> As you can see the position is for a research associate and director of SREL. This is not consistent with our discussions during my negotiations last summer. I am personally not interested in the titles associated with academic affiliations, but I realize that many of my colleagues and administrators recognize the subtle differences in title. In addition, I feel the title of associate professor gives the position a degree of permanence and independence that may at some time be valuable for the SREL. Since Dr. Beyers held this position before me, I do not feel that we should lose this precedent at this time. . . .I still feel that my best security is in my own satisfaction with my professional development. However I do feel it is best for SREL if the director has a tentative commitment of tenure from the university administration, so that dismissal for a slight difference in opinion is not possible.[65]

What Smith did not realize when he wrote this letter was that Beyer's affiliation with the University of Georgia was as an adjunct.[66]

These cases of senior level SREL researchers and administrators' efforts to secure tenure or tenure track positions at the University of Georgia illustrate the lack of mobility between SREL and the university. While Odum's dual organizational structure generally functioned to buffer AEC management of the research they funded, it was not the only way in which Odum's professional activities speak to the central tension of cold war science. As discussed above, Odum also performed a form of boundary work in which his AEC funded research in radiation ecology was considered an applied form of the more basic ecological research conducted by ecologists stationed at the University of Georgia.

Odum modeled other resolutions to the tension between cold war scientists and their patrons. As a consultant to the health physics (and later ecology) program at Oak

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65 UGA 97 045, box 59.

66 Smith must have known that his association with the University of Georgia before becoming a director was as an adjunct as Frank Golley had informed him of as much a year earlier. See the letter from Frank Golley to Michael Smith, Rebecca Sharitz, I. Lehr Brisbin, and Whitfield Gibbons dated November 28, 1972. Despite the fact that he might he encounter the same lack of mobility that Beyers experienced, Smith clearly had no sympathy for Beyers, Michael Smith correspondence to Robert Beyers dated August 27th, 1973 and Michael Smith to Odum and Golley dated November 19th, 1974. UGA 97 045, box 59.

Ridge, he served as an outside expert who advised the AEC without occupying the role of AEC employee on the one hand or recipient of research funding on the other. In this capacity, Odum helped shape the Oak Ridge seminar on radiation ecology in the early 1960s as well as conducting performance reviews and provided recommendations for the ecology program. From his work with Oak Ridge in the mid to late 1950s would bud a long term friendship with Stanley I. Auerbach, the laboratory's first ecologist and later head of their ecology program. Odum fought for the professional autonomy of these ecologists. In a report titled "Impressions and Broad Evaluations, March 1957," Odum noted,

> The ecology group . . . must not be reduced to the level of technicians . . . . To be really effective in the long run . . . ecologists must be able to plan and carry out experiments and analyses in which their training as ecologists and biologists can be fully utilized.[67]

Odum's consultant position with Oak Ridge would extend from 1956 through 1965 and bring added legitimacy to his work in radiation ecology and in ecology more broadly. Odum, in turn, brought legitimacy to a program struggling to establish itself in an AEC laboratory dominated by the prestige of physics.[68] Writing to Oak Ridge Director Alvin Weinberg in 1966, Odum indicated that with his increasing responsibilities, no doubt including his 1965 presidency of the Ecological Society of America, he was going to have to step down from much of his work at Oak Ridge, "I am afraid I have accepted too many committee assignments during the past two years in my zeal to spread the gospel of ecology!" He went on to note graciously that, "My five years on the advisory committee

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[67] UGA 97 045, box 54.

[68] UGA 97 045, box 54. See discussion of discussion of the Oak Ridge ecology program in chapter 2.

has been one of my most valued activities."[69]

VI. The Voice of Ecology

The fact that Odum's boundary work and his efforts to establish an organizational buffer represented his efforts to assert his autonomy from the concerns of the cold war state raises the question of what we are to make of the moments in which he and his colleagues positioned the relevance of ecosystem ecology before the AEC and even offered to speak on behalf of the state? In seeing how Odum and other ecologists positioning the relevance of ecology before the AEC, we can begin to gain a sense of how they saw the political salience of the 'voice' of ecology.[70]

Odum exercised caution in presenting his work given “the political situation on atomic energy.” While preparing for his trip to Japan, he wrote with deference and tact to the AEC's John Wolfe,

> If I can be of service in any way in Japan, or Alaska, please let me know. I shall, of course, be emphasizing the use of isotopes as tools and other peaceful uses of atomic energy without making a special point of it (since political situation on atomic energy will be touchy if weapons testing is resumed in the Pacific).[71]

Odum was careful here to ask if he can help Wolfe as a representative of the AEC while at the same time maintaining the need for treating the topic of atomic energy and, implicitly, radioactive fallout cautiously while in Japan.

Almost a decade later, SREL veteran Frank McCormick exhibited a similar level

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[69] Correspondence from Odum to Weinberg dated April 5th, 1966 (UGA 97 045, box 54). See UGA 97 044, box 2, and UGA 97 045, box 54, for more details about the radiation ecology class Odum led at Oak Ridge.

[70] See discussion of the relevance of Chandra Mukerji's notion of the voice of science in the introduction. Mukerji, *A Fragile Power: Scientists and the State*, chapter 10.

[71] Correspondence Odum to John Wolfe dated March 3rd 1962. UGA 97 045, box 3.

of care in positioning the political relevance of ecology before the Atomic Energy Commission. While making a case to establish a National Environmental Research Park at the Savannah River Site, he wrote as Secretary of the Ecological Society of America,

> The nation, especially the environmental fanatics armed with emotion and fear rather than facts and dedication, need to witness the successful operation of the nuclear industry over two decades without degradation of the environment. The Savannah River Plant provides an excellent model.
>
> As you well know the science of Ecology has benefited more from research in environmental radiation than any other endeavor in recent decades. . . .No agency has provided more financial support to ecological research than the U.S. Atomic Energy Commission. We have a chance to make this pay off at the Savannah River Plant. . . . The public must realize that because of our growing population, our foolish rate of energy consumption, and the finite reserves of fossil fuels, we <u>must</u> (not may) seek electrical power from nuclear reactors. The public must also realize that reactors are the safest and cleanest power source. . . . These several goals may be accomplished with the establishment of a National Environmental Research Park at the Savannah River Plant. This is what I strongly recommend. . . . I recently conducted a three week tour of major cities and universities in the midwest. I presented to audiences of university faculty, students and townspeople, the story of ecological research, landscape management, timber production, and atomic industry at the Savannah River Plant. They were amazed at the maintenance and improvement of environmental quality at a reactor site.[72]

McCormick here positioned the voice of ecology in opposition to the "environmental fanatics armed with emotion and fear." Interestingly, he does this at the same time as he draws attention to "our growing population, [and] our foolish rate of energy consumption," a core component of many environmentalists' critiques. It is because of the urgency of our growing population and the finite supply of fossil fuels that we need to shed the "emotion and fear" of "environmental fanatics" and "realize that reactors are the safest and cleanest power source." The AEC can help people realize this—and help make

72 Correspondence from Frank McCormick to William Daub dated December 17th 1971 (UGA 97 045, box 59).

its investment in ecology pay off—by investing more money in ecology at a newly designated 'Environmental Research Park.'

In letter to the newly appointed AEC Commissioner Dixy Lee Ray, Odum exerted a similar level of caution in positioning ecology in relation to the environmental movement on the one hand and the AEC on the other. Ray is an interesting historical figure for multiple reasons. She was an ecologist who was appointed to chair the AEC by Richard Nixon in 1973 and also the only woman to chair the AEC. She was also a strong advocate of nuclear energy. Although it is surprising that Nixon would appoint an ecologist to chair the AEC, it fits in with his support for the National Environmental Policy Act and the Clean Air Act of 1970. Copying the director of the AEC's Division of Biology and Medicine, Odum wrote to Ray,

> We are delighted to have someone of your integrity who takes a rational view of environmental problems undertake this important post. We know that the AEC is not the 'bad guy' in regard to the environment as is often pictured, because no federal agency has supported as many good, long-range ecological studies as the AEC. However, AEC's public relation's efforts have sometimes been strangely inept. You have a golden opportunity to rectify this by getting behind the First Environmental Research Park at the AEC Savannah River Plant. . . .No time should be lost in appointing a strong director. . .and a strong steering committee.[73]

Interestingly, Odum framed his plea for more funding as an opportunity for the AEC to shake the bad press it has received in the past. While somewhat more open to interpretation, Ray's "rational view of environmental problems" seems to align with Odum's rational view and the rational view of ecology as a discipline.[74]

Shortly after Odum sent this letter, Ray submitted an introduction to a SREL

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[73] Correspondence from Odum to Dixy Lee Ray dated February 8th 1973 (UGA 97 045, box 59).

[74] For more on Ray, see Oreskes and Conway, *Merchants of Doubt*, 130-4, 231-2, 252, and 257.

sponsored symposium on thermal ecology held in Augusta, Georgia outside the Savannah River Plant in May of 1973. She wrote,

> I appreciate the opportunity to help launch this effort in the field of thermal ecology. The results of comprehensive and diverse thermal ecology studies will not only help us to protect the environment but will also contribute to growing public acceptance of nuclear power.
>
> Research on thermal ecology is far from a crash effort in response to the awakened environmental awareness of the 1960s. For the last quarter of a century, the Atomic Energy Commission has conducted programs aimed at reconciling the nation's growing demand for energy with the quality and stability of the environment.
>
> The Columbia River Study at Hanford was begun toward the end of World War II when the first two production reactors went into operation. Over the years this river system has become the site of thorough ecological research on the responses of natural ecosystems to thermal and radionuclide stresses and on the recovery of these ecosystems when reactor operations cease.[75]

Although Ray positions AEC funding of ecology as part of their concern for the environment, concern for thermal pollution would have been relatively recent at the time of the symposium. Historian Samuel Walker has charted the emergence of concern for the thermal pollution created by nuclear power stations against the backdrop of increasing demand for energy in the late 1960s (1989). Although Ray is not speaking for the ecologists at the symposium—or AEC ecologists at Hanford or AEC funded ecologists at the SREL—she invokes their work as part of an argument intending to legitimize AEC governance.

Chandra Mukerji's work on 'the voice of science' provides a framework for understanding what Ray was proposing at this symposium.[76] By funding scientists and

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[75] UGA 97 045, box 10. It is interesting that Ray cites the Hanford ecologists' work on the Columbia River. Her effort to deploy this ecological research as evidencing the AEC's concern for the environment contrasts sharply with the account of Hanford's approach to radioactivity in the river found in Michele Gerber's 1992 work *On the Home Front: the Cold War Legacy of the Hanford Nuclear Site*.

[76] Mukerji, *Fragile Power*, chapter 10.

providing them with a level of autonomy, the state can reap the benefits from the added legitimacy that this autonomy confers to scientists. By invoking a legacy of AEC funding for ecology that outstripped the concerns of thermal ecology or even as a reaction to the "awakened environmental awareness of the 1960s," Ray's plea represents an effort to invoke the voice of ecology as also the voice of the AEC.

This is a particularly significant move given the subject of the conference—thermal ecology. While ecologists were not as outspoken as geneticists in the radioactive fallout controversy of the 1950s, they did become much more contentious in speaking to the concerns of the environmental movement and in raising awareness about the thermal pollution that atomic energy introduced to lakes and rivers.[77] At this time, the voice of ecology was a powerful one, and Ray's effort to invoke this voice also represented an effort to mollify critics drawing attention to the AEC's troubled history in introducing radioactive fallout, radioactive waste, and thermal pollution into an already overburdened environment.[78]

VII. Conclusion

In this chapter I have approached one of the central problems of cold war historiography—the relation between state funding of science and the nature of the science funded—as also a concrete problem for scientists who were funded by the state in

77 See Walker on the role that ecology played in relation to thermal pollution and the AEC's response. Samuel J. Walker,"Nuclear Power and the Environment: The Atomic Energy Commission and Thermal Pollution, 1965-1971." *Technology and Culture* 30, no. 4 (October 1, 1989): 964-71 and 975-9.

78 One could extend this argument to Nixon's appointment of Ray as a professional ecologist in a time when ecology was often associated with the criticisms of the environmental movement. In the second half of this dissertation, I will approach the ways that ecology came to inform many environmental critiques emerging in the 1960s and 1970s and the ways that professional ecologists such as Odum engaged in and reacted to these critiques.

this era. Odum navigated this tension in a variety of ways. He asserted the autonomy of ecology from the Atomic Energy Commission with a form of boundary work that relied on the distinction between basic and applied science. He also attempted to maintain his autonomy by carefully managing the links connecting the Savannah River Ecological Laboratory on AEC land and the University of Georgia. On at least one of the occasions when the SREL did not function to hold the AEC's efforts to manage ecological research at arm's length, Odum approached the conflict as an opportunity for renegotiating the terms of the interaction between the AEC and the SREL—to convince the AEC that it should not overburden the SREL with its demand for "excessive paperwork" and increasingly fine grained management. In addition to asserting his autonomy, Odum also expressed his dependence on and debt to the AEC in offering his voice as a prominent ecologist to speak on behalf of the concerns of the agency.

Odum's efforts to assert the autonomy of his own research interests and the autonomy of ecology as a discipline also represented an effort to protect the territory over which he and other ecologists could claim professional authority. The way that asserted his professional autonomy as a scientist through the distinction between pure and applied science fit in with the way the salience and use of this distinction by other, more prominent scientists and science administrators in this period. In fact, scientists' efforts to protect their autonomy in determining research questions in contexts of state patronage represented one of the primary examples in Gieryn's 1983 article. Commenting on the tensions introduced by scientists' success at garnering state funding, Gieryn notes that,

> Once scientists accumulate abundant intellectual authority and convert it to public-supported research programs, a different problem faces the profession: how to retain control over the use of these material resources

> by keeping science autonomous from controls by government or industry.[79]

Scientists' efforts to secure state funding raises the possibility that scientists could simply become state employees and subject to the close controls and bureaucratic working environment associated with the state.[80] Boundary work, Gieryn argues, represents a possible response, "an effective ideological style for protecting professional autonomy."[81]

In Gieryn's example of state funded scientists, scientists deploy the distinction between basic and applied science as a core part of their effort to distance themselves from the state, By asserting the difference between their own university-based science as basic science from what the state is interested in as applied science and technology, scientists endeavor to avoid close supervision and management by the state. Gieryn asserts, however, that scientists' boundary work can come into question when scientists ask for more money (to deliver work they have characterized as technological in nature) and even when they deliver the results.[82]

Gieryn's emphasis on boundary work as a strategy for scientists as professionals, it is important to note that, in the two cases discussed above, Odum's boundary work took place as part of an effort to define the proper training for future ecologists. One of the spaces in which Odum distinguished radiation ecology from basic ecology was the textbook that would become a standard part of the education of several generations of ecologists, and another was a workshop on the place of radiation ecology in the training

79 Gieryn, "Boundary Work and Demarcation," 789.
80 See Thorpe for a discussion of how the tension between the bureaucratic mode of state management resulted in the disciplining of one of the period's most prestigious scientists, Robert Oppenheimer. Charles Thorpe, "Disciplining Experts: Scientific Authority and Liberal Democracy in the Oppenheimer Case," *Social Studies of Science* 32, 4 (2002): 549-52.
81 Gieryn, “Boundary Work and the Demarcation of Science from Non-science," 789.
82 Ibid., 789-93.

of ecologists.[83]

Despite Odum's efforts to distinguish basic ecological research from the interests of the AEC, much of Odum's research was dependent on the money, land and tools such as radioisotopes that the AEC provided.[84] Odum's efforts to create a boundary between himself and his research and the AEC operated in tension with his dependence on and material links with the AEC.[85] As we shall see in the following chapter, Odum's efforts to protect ecology from the interests of the AEC were part of a larger effort to promote ecology as a legitimate discipline in the larger field of biology.

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83 See the discussion of the widespread adoption of Odum's *Fundamentals of Ecology* in the following chapter. The fact that the training of future ecologists was the site of much of Odum's boundary work resonates with the place of education in Vannevar Bush's effort to insulate basic science in *Science: The Endless Frontier*. Bush opened a chapter titled "Renewing Our Scientific Talent" by positioning the science agency he proposed as linked with an educational response to the need for more scientists--and quoting famed Harvard administrator and science policy insider James Bryant Conant. While "there will always be the rare individual who will rise to the top [to understand the fundamental laws of nature], he is the exception and even he might make a more notable contribution if he had the benefit of the best education we have to offer." He then quoted Conant's statement that, "In every section of the entire area where the word science may properly be applied, the limiting factor is a human one. We shall have rapid or slow advance in this direction or in that depending on the number of really first-class men who are engaged in the work in question. . . .So in the last analysis, the future of science in this country will be determined by our basic educational policy." Bush, *Science: The Endless Frontier*, 23.

84 See Chandra Mukerji's discussion of the dependence of scientists on the technology that the state provides in order to establish their reputations as scientists. Mukerji, *A Fragile Power*, 105.

85 See the discussion in the previous chapter on the way that radioisotopes functioned as boundary objects linking, on a material level, Odum's research with the AEC's efforts to manage fallout as an epistemic and political problem.

Chapter 4. Ecosystem Ecology and Ecology as a Discipline

I. Introduction

In the last chapter I covered Odum's leading role in the field of radiation ecology. In leading ecology into a new era of funding, he also faced the same dilemma that confronted many scientists in the cold war period—how to balance the demands of one's patron with the demands of one's discipline. Not only was he successful in securing outside funding, he was also successful in navigating the tension between the AEC and his own research goals. These successes together occupy one of the cornerstones of Odum's later prominence.

The other cornerstone followed from the success and widespread adoption of his textbook, *Fundamentals of Ecology*. First published in 1953, the textbook became a standard part of the education of an increasing number of graduate and undergraduate students enrolling in ecology courses in the years following World War II.[291] With the text's heavy emphasis on an ecosystem approach to ecology, these students were introduced to Odum's use of the notion of the ecosystem as an organizing concept for ecology as an emerging discipline.

In this chapter, I will explore how Eugene Odum positioned his work, and the significance of his work, in relation to the end of furthering ecology as an academic discipline. In ecology and the broader field of earth sciences, Odum is best known for his promotion of ecosystem ecology, the influence of successive editions of his textbook, *Fundamentals of Ecology*, and his role in creating a center of post-World War II

[291] Historian of ecology Joel Hagen shows that *Fundamentals of Ecology* was "the dominant textbook in the 1960s" and cites ecologist Gordon Orians in noting that "“Until recently, the appropriate unit of measure of ecology textbooks was the odum, and the problem of selection of a text for a course was a simple one.” Joel Hagen, "Teaching Ecology During the Environmental Age, 1965-1980," *Environmental History* Issue 13 No 4 (October 2008): 704 and 713. Craige, *Eugene Odum*, 39. Burgess, "The Ecological Society of America," 3. Gordon H. Orians, “A Diversity of Textbooks: Ecology Comes of Age,” Science 181 (1973): 1238-39.

ecological research at the University of Georgia In this chapter I will argue that all of these accomplishments come together as different parts of Odum's effort to promote the ecosystem ecology. In doing so, Odum chose to promote ecology *as a discipline*. Historically, the disciplinary formation emerged as an institutional setting for the practice of science in the late 19th and early twentieth centuries and entered, for historian Paul Forman, a high point in the mid twentieth century.[292] Nonetheless, for historian of ecology Robert McIntosh--and arguably for Odum himself, by the time Odum enrolled in a Ph.D. program at the University of Illinois in 1937, ecology still had an uncertain status as a discipline.[293] Although there was an established scholarly society (the Ecological Society of America) and journals, the discipline was fragmented along the lines of specialization and was not institutionalized at the level of academic departments.[294]

By examining his influential textbook in the context in which Odum became motivated to write it, I will argue that his promotion of ecosystem ecology was also an effort to provide ecology with the principles and coherence it needed in order to be recognized as a legitimate discipline. Although Odum did not coin "ecosystem ecology,"

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[292] Forman, "On the Historical Forms of Knowledge Production," 59-60. See chapter 1 for more on the emergence of the discipline as a central unit in the organization of academic science.

[293] Robert P. McIntosh, "Ecology Since 1900." In *History of American Ecology*, Frank N. Egerton, ed. (New York: Arno Press, 1977), 353-372. Robert P. McIntosh, *The Background of Ecology: Concept and Theory* (Cambridge: Cambridge University Press, 1985), 66-8.

[294] The Ecological Society of America (or ESA) was founded and had its first annual meeting, attended by around 125, in 1916. The description of the meeting dominated the first issue of the *Bulletin of the Ecological Society of America,* published a month later in January 1917. "The New York Meeting." *Bulletin of the Ecological Society of America* 1, no. 1 (January 1, 1917). Initially published by the Brooklyn Botanical Garden, the ESA first published *Ecology* as its first journal devoted to reporting scholarly research in January, 1920. "Front Matter." *Ecology* 1, no. 1 (January 1, 1920). Eleven years later Ecology would be joined by another ESA journal *Ecological Monographs*. "Front Matter." *Ecological Monographs* 1, no. 1 (January 1, 1931). The British Ecological Society, meanwhile, had formed in 1913 out of the Central Committee for the Survey and Study of British Vegetation, and initiated the publication of the *Journal of Ecology* in 1913 and the *Journal of Animal Ecology* in 1932. Tansley, A. G. "The Aims of the New Journal." *Journal of Ecology* 1, no. 1 (March 1, 1913): 1–3. "Foreword." *Journal of Animal Ecology* 1, no. 1 (May 1, 1932): 1–2.

he did not hesitate to rework the term and expand its meaning as a part of his vision for ecology--and his efforts to define ecology in relation to other disciplines. By tracing the trajectory of this term below, I will inserting Eugene Odum into a context of fellow ecologists and highlighting how his vision of ecosystem ecology represented one of his contributions to ecology.

By the mid 1960s, Odum occupied a prominent position in ecology. In 1964 he was elected to serve as the President of the Ecological Society of America and published an article announcing the arrival of the "new ecology."[295] In the article, he described ecosystem ecology and the novelty of the new ecology in terms of an increasing focus on the "function" of nature. While ecologists and natural historians had long described and classified nature, he saw the role of the new ecology as emphasizing the importance of the functional relationships that defined the interrelationships of nature. Key among these were the movement of energy and matter through the environment.[296] Interestingly, for Odum a functional emphasis promised to unite ecology in the same way that the relationships it described held together the various parts of nature.

At the same time as Odum defined the focus and coherence of ecology as a discipline in terms of the ecosystem and the function of nature, he distinguished this discipline from other biological disciplines in terms of the notion of levels of organization and the centrality of a holistic approach. Ecology studied levels of organization such as populations of species and interactions between populations of species while other molecular biologists studied genes and cells and physiologists studied

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[295] "President Eugene Odum." *Bulletin of the Ecological Society of America* 45, 4 (December, 1964): 129-30. Eugene Odum, "The New Ecology," *BioScience* 14 (1964): 14-16.

[296] Odum, "The New Ecology," 14-15.

organs and organisms.[297] Below I will argue that the notion of levels of organization provided Odum with a vocabulary for describing a division of labor among biologists and protecting the autonomy of ecology as a discipline from the much more dominant disciplines such as molecular biology.

Odum elaborated and defended the contribution of ecology in terms of holism, which he positioned as being in tension with the reductionist approach of molecular biology.[298] Although much of this dissertation focuses on the larger contexts in which, or in relation to which, ecologists worked (the cold war national-security state and the environmental movement), this chapter provides more attention to what might be called the 'internal' history of ecology. Importantly, however, this chapter is also an account of how Odum attempted to make ecology into an autonomous discipline.

Odum's effort to promote the discipline of ecology in the first half of his professional career fit with the vocational ethos Max Weber describes in "Science as a Vocation." Despite the fact that he benefited from AEC funding and played a leading role in the field of radiation ecology, Odum defined himself and his role as a scientist in relation to ecology as a discipline that should be autonomous from the politics of the state. Here and in his promotion of ecosystem ecology as a way of establishing ecology as a discipline, Odum positioned his role as a scientist and the place of ecology in society

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[297] Eugene Odum, *Fundamentals of Ecology,* 3rd edition (Philadelphia: WB Saunders Company, 1971), 4. Odum, "The New Ecology," 14-5. Eugene Odum, *Fundamentals of Ecology,* 2nd edition (Philadelphia: WB Saunders Company, 1959), 4-5. Talk Odum delivered to NASA sponsored conference on theoretical biology. UGA 97 045, box 3. See discussion below for more detail.

[298] Odum, "A New Ecology," 14-5. As I will discuss below, Odum later elaborated this position as part of an effort to position ecology as a meta discipline.

Eugene Odum, "The Emergence of Ecology as a New Integrative Discipline" *Science* 195*,* 4284 (1977): 1289-1293. Eugene Odum, "Diversity and the Emergence of Integrative Disciplines in Universities," Paper presented at the Forty-first Annual Meeting of the Southern University Conference, Birmingham, AL, 1978.

in a way that fit in with the role of the scientist and the place of science in society in Weber's essay. Like Weber's scientist, in the first half of his career Odum approached the primary relevance of his work in relation to the ends of ecology as a discipline in isolation from politics. Ecology, in other words, was not at this point a resource in answering the broader question of how to live. Promoting ecology as a discipline and pursuing the research goals that emerged from within that discipline (and not, say, the politically inflected goals emerging from outside the discipline of ecology), Odum was working in the university's disciplinary organization of science as he found it. As I will explore in the following chapter, Odum would question this way of approaching the relevance of ecology and break with the effort to approach science as an enterprise that should be value free.

II. The Notion of the Ecosystem

Although Eugene Odum did not invent the notion of the ecosystem, he promoted ecosystem ecology from the 1953 publication of his *Fundamentals of Ecology* to the end of his professional career. In this section I will provide a brief history of the notion of the ecosystem before focusing on the historical context in which Odum would pick up the term and make it *the* central element in his vision for ecology as a discipline. Here I will distinguish between the notion of the ecosystem as a theoretical term in the work of earlier ecologists (Arthur Tansley on the one hand and Raymond Lindeman and G. Evelyn Hutchinson on the other) and ecosystem ecology as a program—Odum's program—for ecology. In order to understand Odum's role in promoting ecosystem ecology, I will first introduce the coining of "ecosystem" by Arthur Tansley in the 1935 as part of a debate with Frederick Clements, one of the leaders of American ecology in this period. Less than a decade later, the notion entered greater prominence, and took on a new set of meanings, in Raymond Lindeman's 1942 article titled "The Trophic-Dynamic Aspect of Ecology."[299] Despite the broad influence of Lindeman's paper, here it will provide a prelude to examining how Odum picked up the notion of the ecosystem and built around it a program for ecology, to unify ecology and provide it with the principles it needed to be recognized as an independent discipline. Here the attention will shift to the concrete context in which Odum decided to write a that would be used to educate the increasing number of students interested in ecology in the postwar period.[300]

By most accounts Frederic Clements (1874-1926) was one of the most prominent ecologists in the U.S. context in the first half of the 20th century. He is known for bringing new, more quantitative methods to the study of succession in the grasslands and for his emphasis on communities of plants as a kind of organism.[301] For Clements, stages of succession could be understood in terms of a move towards a stable, or "climax," state

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299 Lindeman, "The Trophic-Dynamic Aspect of Ecology."

300 The rise in the number of Ecological Society of America (or ESA) members after World War II and then much more rapidly from the early 1960s provides one indicator of the increasing interest in ecology, here in the context of higher education. While the number of ESA members hovered under 1,000 from the 1920s through the early 1950s. In the 1950s membership doubled, and it doubled again in the 1960s, growing to almost 4,000 members by the end of the decade and approaching 6,000 members in the mid to late 1970s when Robert L. Burgess' history of the association appears to have been written. Robert L. Burgess, "The Ecological Society of America: Historical Data and Preliminary Analysis," (Oak Ridge, TN: Oak Ridge National Laboratory), accessed January 15, 2009, www.esa.org/history/docs/BurgessHistory.pdf, 3. *Craige, Eugene Odum*, 39..

301 Given his prominence in early twentieth century ecology there are a number of accounts of Clements. See Kohler and Bowler, particularly, for emphasis on Clements' new and more quantitative methods. See, for example, Peter J. Bowler, *The Earth Encompassed: A History of the Environmental Sciences* (W. W. Norton & Company, 2000), 370-8, 521-4, esp. 374; Hagen, *Entangled Bank*, 20-49; Sharon Kingsland, *The Evolution of American Ecology, 1890-2000* (Baltimore: Johns Hopkins Press, 2005),126-55; Robert Kohler, *Landscapes and Labscapes: Exploring the Lab-Field Border in Biology* (Chicago: University of Chicago Press, 2002), 74-7 and 100-7; Robert P. McIntosh, *The Background of Ecology: Concept and Theory* (Cambridge: Cambridge University Press, 1985), 34-46 and 68-84; Ronald C. Tobey, *Saving the Prairies: The Life Cycle of the Founding School of American Plant Ecology, 1895-1955* (Berkeley: University of California Press, 1981), chapter 2.

that fit with the characteristics of a given environment.[302] In implementing the tools of the laboratory, Clements drew on the work of his mentor at the University of Nebraska, Charles Bessey (1845-1915), and the work of an influential German plant geographer, Oscar Drude (1852-1953).

In Clements' training at the University of Nebraska he learned from Bessey's emphasis on laboratory methods and physiology. In 1884, Bessey became a professor of botany at the University of Nebraska and quickly began advocating the laboratory method in the botany textbooks he wrote for college and high school. In historian of ecology Ronald Tobey's account, Bessey offers an example of the ways that the trends toward graduate education and the emphasis on the centrality of the lab could come together. In addition to serving as a locus of research, the lab could also serve an important role in education. Bessey combined his advocacy for the new botany with a concern for conservation of the grassland prairies that he studied.[303]

Clements was also influenced by Oscar Drude.[304] In 1896, Drude published a book on the plant geography of Germany that would inspire Clements and fellow graduate student Roscoe Pound to perform a similar study of Nebraska. The joint study served as the doctoral dissertations of Clements and Pound and was published as *Phytogeography of Nebraska* in 1898. Clements and Pound's work was influential in introducing Drude's quantitative measure of abundance or quantity of plant life to

302 For more on Clements' "climax state," see Bowler, *The Earth Encompassed*, 370-8; Mitman, *The State of Nature*, chapter 2; Tobey, *Saving the Prairies*, 81-2 and 164-5; and Nicolson, "Humboldtian Plant Geography After Humboldt," 306.

303 See Tobey for an account of Bessey that factors in Clements' development and Tobey and Kohler for an emphasis on the importance of new quantitative methods. Toby, *Saving the Prairies*, chapter 2. Kohler, *Landscapes and Labscapes*, 74-7 and 100-107.

304 Bowler, *Earth Encompassed*, 370-7.

ecologists in America.[305] Previously, abundance had often been considered not measurable or was estimated in very rough terms from a view of the area. Clements and Pound used measured off ‘quadrats’ or variably sized square plots to provide a much more exact estimate of the number and locations of certain species of plants. In smaller, one meter, square plots the exact number of plants could be counted such that their density over much larger areas could be estimated. The smaller plots were also helpful in charting the succession of plants, a topic that would become a focal point for Clements and much early twentieth century ecology. With the recognition from *Phytogeography of Nebraska* and his 1905 textbook *Research Methods in Ecology* that popularized the quadrat method, Clements was quickly becoming a central figure in ecology. He taught briefly at the University of Nebraska before being recruited away by the University of Minnesota and then the Carnegie Institute of Washington.[306]

In addition to being known for his use of methods such as quadrats, Clements was also known for his approach to communities of plants as organisms.[307] Here, the ecologist took Herbert Spencer's approach to society as an organism and applied it to plants. The field of biogeography had long mapped groupings of plants and approached them as 'associations' and 'communities.' Clements’ primary innovation was to approach these associations or communities of plants as a larger organism. In this context, stages of succession could be treated as stages in an organism’s development. Further, for Clements there was an optimum relation between

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[305] Hagen, *Entangled Bank*, 22. Kohler, *Landscapes and Labscapes*, 74-7 and 100-7.

[306] Bowler, *The Earth Encompassed,* 374. Kohler, *Landscapes and Labscapes*, 100-111.

[307] See Nicolson and Bowler for precursors. Malcolm Nicolson, “Alexander von Humboldt, Humboldtian science, and the origins of the study of vegetation,” *History of Science* 25, 2 (June 1987): 167-94; Bowler, *The Earth Encompassed,* 272-6.

communities of plants and their environment.[308] He characterized this state as a "climax" towards which stages of succession would develop.[309] Odum would later incorporate this emphasis on stages of succession in his work on natural ecosystems and, later still, on his work on ecosystems containing people and nature.[310]

When John Phillips, one of Clements' followers, invited engagement with Clements' work, a prominent British ecologist named Alfred George Tansley (1871-1955) obliged.[311] Tansley framed his response, published in 1935 as "The Use and Abuse of Vegetational Concepts and Terms," as an attack on Phillips' treatment of Clements. Although Tansley was careful to emphasize Clements' contributions to ecology, he was less generous with Phillips' treatment of Clements. Tansley argued that "Phillips' articles remind on irresistibly of a creed--of a closed system of religious or philosophical dogma. Clements appears as the major prophet and Phillips as the chief apostle, with the true apostolic fervor in abundant measure."[312] Nonetheless, Tansley was clearly dissatisfied with Clements' practice of referring to groupings of plants in a given environment as "biotic communities" and as "complex organisms." While Tansley thought the notions of communities and organism could function as effective

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308 See Mitman for coverage of Spencer's influence as well as a more general account of the overlap between biological theory and social theory. While the side of Clements' ideas that leaned towards vitalism and the rigid application of the organism concept were sometimes controversial in the US, they were much more so abroad. Gregg Mitman, *The State of Nature: Ecology, Community, and American Social Thought, 1900-1950* (Chicago: University Of Chicago Press, 1992), 25-34 and 62-74.

309 Bowler offers a concise summary of Clements' notion of climax, and Worster provides a more detailed account. Bowler, *The Earth Encompassed*, 523-4. Donald Worster, *Nature's Economy: A History of Ecological Ideas* (New York: Cambridge University Press, 1994), chapter 11.

310 See chapter 5 for a detailed discussion of how the incorporation of Clements' emphasis in mid 1950s era research, with his brother Howard, would later find expression at the heart of Odum's later and more critical work.

311 Historian of ecology Peder Anker offers a richly detailed account of this often summarized episode. Peder Anker, *Imperial Ecology: Environmental Order in the British Empire, 1895-1945*. (Cambridge, MA: Harvard University Press, 2002), 58-77.

312 A. G. Tansley, "The Use and Abuse of Vegetational Concepts and Terms," *Ecology* 16, 3 (Jul., 1935), 285.

analogies, they should not be read into nature itself.[313] One of the problems with both of these terms is that they implied a degree of organization that did not exist in nature. Both represented, for Tansley, "a confession of the holistic faith."[314] Instead of a community or an organism, Tansley argued that groups of plants could be considered as an ecosystem.[315] Not only did the notion of the ecosystem avoid imputing order to nature that did not exist, it also included the inorganic parts of nature that were relevant to the functioning of groups of plants.[316]

In 1942 Raymond Lindeman, then a postdoctoral student of G. Evelyn Hutchinson, took up Tansley's notion of the ecosystem and used it as a framework for discussing the movement of matter and energy through the environment--two principles that were central to Hutchinson's "Yale school" of ecology.[317] Both moves--reintroducing the notion of the ecosystem and focusing on the movement of energy and matter through the environment--were important elements of the article's influence. It would be difficult to overestimate the influence of this article on the course of postwar ecology. Historian of ecology Joel Hagen, for example, has argued that Lindeman's paper was "one of the great intellectual watersheds in the history of ecology" and "set the course" for much of postwar ecology.[318] In an article about the publication of

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313 Ibid., 290-1 and 295-9.

314 Ibid., 286. Environmental sociologists John Bellamy Foster and Brett Clark have characterized Tansley's work as a progressive materialist reaction to the tendency toward idealism in South African ecologist Jan Smuts' commitment to holism. They argue that "The materialist/realist view. . .was superior in both its ontological realism and its constructionist tendencies." John Bellamy Foster, and Brett Clark, "The Sociology of Ecology: Ecological Organicism Versus Ecosystem Ecology in the Social Construction of Ecological Science, 1926-1935," *Organization Environment* 21 (2008): 313.

315 Tansley, "The Use and Abuse of Vegetational Concepts and Terms," 299-303.

316 Ibid., 299.

317 Hagen, *Entangled Bank*, 75-80. The tension between the approaches of Clements on one hand and Tansley--and later Lindeman and Hutchinson--on the other found another expression in Hutchinson's critical review of Clements' and Shelford's 1939 work *Bio-Ecology*. Hutchinson, [untitled], review of *Bio-Ecology*, 267.

318 Hagen, *Entangled Bank*, 94 and 87. See also historian of ecology Nancy Slack's comment that the

Lindeman's paper, Robert Cook has similarly noted that the paper "became the foundation for much future work."[319] And in 1968, Eugene Odum noted that Lindeman's essay did more than any other single contribution to bring concepts of energy flow to focus at the level of the ecosystem."[320]

In his 1942 article, Lindeman defined the "basic process" of his trophic dynamic approach as "the transfer of energy from one part of the ecosystem to another" and describes the ways that plants use energy from the sun to produce organic substances that represent stored energy and are consumed by animals.[321] It is important to emphasize here that the object of interest—the movement of energy through the environment—could be easily abstracted from the details of a given ecosystem. In a significant departure from longer standing practices of field-based research centering around documenting the kinds and distributions of organisms, plants and animals were examined for the part they played in the movement of energy.[322]

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publication "marks the beginning of ecosystem ecology." Slack, *G. Evelyn Hutchinson*, 149.

319 Cook, "Raymond Lindeman and the Trophic-Dynamic Concept," 22.

320 Eugene Odum, "Energy Flow in Ecosystems: a Historical Review," *American Zoologist 8*, 1 (1968): 17. In rejecting Lindeman's paper for publication, one of the referees advised that Lindeman "put this paper aside for ten years" in order to develop more empirical basis for his generalizations. G. Evelyn Hutchinson responded by writing a letter backing Lindeman and asserted that "My own view is that, if the work is published, after the ten years or so suggested by Referee 2 have elapsed, Lindeman will feel that he has played a very considerable part in a healthy reorientation of ecological research." Although Hutchinson's plea resulted in the publication of Lindeman's article without a ten year delay, his sense of the article's influence proved prescient. Both referee and Hutchinson quoted in Robert E. Cook, "Raymond Lindeman and the Trophic-Dynamic Concept in Ecology" *Science* 198, 4312 (October 7, 1977): 23-4.

321 Lindeman, "The Trophic-Dynamic Aspect of Ecology," 400. We can additionally see Hutchinson's regard for Vernadsky's work in his role in having it translated, by Vernadsky's son George, into English. Margulis, L., Ceruti, M., Golubic, S., Guerrero, R., Ikeda, N., Ikezawa, N., Krumbein, W.E., Lapo, A., Lazcano, A., Suzuki, D., Tickell, C., Walter, M., and Westbroek, P., "Forward" in *The Biosphere: Complete Annotated Edition*, M. A. S. McMenamin ed. (New York: Springer-Verlag, 1998), 16-9. Lindeman further notes, in his article on "The Trophic-Dynamic Aspect of Ecology," that the "trophic-dynamic viewpoint" is "closely allied to Vernadsky's 'biogeochemical' approach." Raymond L. Lindeman, "The Trophic-Dynamic Aspect of Ecology," *Ecology* 23, 4 (1942): 399-400.

322 We can see the tension between the level of abstraction in the work of Lindeman - and Hutchinson - and norms emphasizing greater emphasis on field data in the referee's reactions to Lindeman's paper, which was initially rejected. Cited in Cook's account of Lindeman's paper, Chancey Juday at the University of

Both of these focal points signal influences that can be traced, along with an emphasis on thermodynamics, in the earlier work of Alfred J. Lotka and Vladimir Vernadsky.[323] In tracing the impact of Lotka and particularly his 1925 book *Elements of a Physical Biology*, historian Sharon Kingsland notes that “Lotka wanted to reformulate biology as a branch of physics, where biological relationships would be related back to physical principles, specifically to the laws of thermodynamics."[324] For Lotka, the organic world operated as an "engine" that transformed energy that could be accumulated and stored (in plants for example) and later dissipated or released by animals consuming these plants. While it differed in important ways from Lotka's work, Vernadsky's vision was similarly influenced by thermodynamics and encompassed emphases on energy flow and his "biogeochemical approach."[325]

Wisconsin asserted that "A large percentage of the following discussion and argument is based on 'belief, probability, possibility, and imaginary lakes' rather than on *actual* observation and data. The chances are that the author's beliefs and imaginary lakes would be very different entities had he had a background of observations on fifty or a hundred of the 10000 lakes claimed by the state of Minnesota instead of on only one, and that a special type." Cook, "Raymond Lindeman and the Trophic-Dynamic Concept in Ecology," 23. Kohler's 2002 work, *Landscapes and Labscapes: Exploring the Lab-Field Border in Biology*, foregrounds this tension. Kohler, *Landscapes and Labscapes*, chapter 1.

323 Sharon Kingsland, *Modeling Nature* 2nd ed, (Chicago: University of Chicago Press, 1995), chapter 2. Alfred J. Lotka, *Elements of Mathematical Biology* (New York: Dover Publications, 1956), 331-340

324 Kingsland, *Modeling Nature*, 233. We can see the importance of thermodynamics clearly in Lota's formulations such as the following, “The great world engine—in which each of us is a most insignificant little wheel—has its energy source, its firebox, so to speak in the sun, ninety-eight million miles away from the working substance (the 'boiler'). From an engineer's standpoint this would be an incredibly bad design, if high efficiency alone were the aim in view.” Lotka also focused on “the circulation of the elements” including phosphorus and nitrogen—some of the same elements Hutchinson focuses on in his 1940s work on biogeochemical cycles. Alfred J. Lotka, *Elements of Mathematical Biology* (Dover Publications, 1956), 331 [for quote], 256-51 [circulation of phosphorus], and 229-45 [circulation of nitrogen]. G. Evelyn Hutchinson, “Nitrogen in the Biogeochemistry of the Atmosphere,” *American Scientist* 32, no. 3 (July 1, 1944): 178–195. Hutchinson, G. Evelyn, and Vaugham T. Bowen, “A Direct Demonstration of the Phosphorus Cycle," 148–153.

325 Other important influences on Hutchinson, not discussed above, include the uptake of notions from cybernetics and economics. Although it would not be until 1973 that ecologist Bruce Hannon would explicitly import economist Wassily Leontief's input output analysis into ecology, Kingsland notes Lotka's debt to economic thought in his attempts to quantify the conversion of energy. From the perspective of exploring these kinds of inter-disciplinary exchanges, language such as Howard and Eugene Odum's description of the “balance sheet” of the Eniwetok reef community in their award winning 1955 article and the much earlier 'producer' and 'consumer' organisms of August Thienemann's “language of community economics” (Lindeman 1942: 400) become particularly suggestive. Kingland,

Importantly, the focus on biogeochemical cycles and the movement of energy through the ecosystem dissolved the traditional separation of living organisms and nonliving matter and so called for a new ecological unit. The approach of Frederick Clements but also Victor Shelford and others focused on plants and animals and excluded matter.[326] Not only were Hutchinson and Lindeman calling to foreground nonliving matter, they were also arguing that organisms can and should be approached as conduits through which matter and energy moved. To provide an example described in the previous chapter, phosphorus in the mud at the bottom of a lake can be released into the water, taken into phytoplankton and then passed along the food chain, into

Modeling Nature, 41. Bruce M. Hannon, "The role of input–output analysis of energy and ecologic systems in the early development of ecological economics—a personal perspective," *Annals of the New York Academy of Sciences* 1185 (2010): 30-8; Bruce Hannon "An Energy Standard of Value." *Annals of the American Academy of Political and Social Science* 410 (November 1, 1973): 139–153. Odum, Howard T. and Eugene P. Odum. "Trophic Structure and Productivity of a Windward Coral Reef Community on Eniwetok Atoll." *Ecological Monographs* 25, 3, (July 1955): 317 [balance sheet]. Lindeman, "The Trophic-Dynamic Aspect of Ecology," 400 [on Thienemann]

Another influence for Hutchinson came from his involvement with the Macy Conferences in which the notion of cybernetics emerged and was applied to a wide variety of phenomena. In drawing on the considerably more general language of cybernetics, ecologist G. Evelyn Hutchinson's description of biogeochemical cycles (the cycles through which matter moves through the environment) as self regulating can be approached as an early effort to find cybernetic systems in nature. He described these 'circular causal systems' in a talk that was delivered at a New York Academy of Science conference that was themed on cybernetics and took place immediately after the second Macy Conference in 1946. Organized by Lawrence Frank to take advantage of the fact that the Macy participants would be in New York at the time, the conference included cybernetics luminaries such as Norbert Wiener and Warren McCulloch. See Taylor on Hutchinson's involvement with the Macy Conferences and Heims for more on this and other meetings. Peter J. Taylor, "Technocratic Optimism, H.T. Odum and the Partial Transformation of the Ecological Metaphor after World War II," *Journal of the History of Biology* 21 (1988):220-6. Steve J. Heims, *The Cybernetics Group* (Cambridge, MA: MIT Press, 1991), 80.

326 Craige provides a concise description of the biome as the notion that Clements and Shelford backed during this period and which was featured in their 1939 work *Bio-Ecology.* Craige, *Eugene Odum*, 24-5. Frederic Edward Clements and Victor Ernest Shelford, *Bio-ecology* (New York: J. Wiley & Sons, Incorporated, 1939), chapter 2. Hutchinson's attacks on *Bio-Ecology* for being "mainly classificatory" and "descriptive" went along with the work's "neglect of the biogeochemical approach." Hutchinson seems to be dumbfounded in the brevity of the treatment of photosynthesis as a process in which plants convert inorganic matter and that plays a definitive role in the production and self regulation of the biosphere. Hutchinson, [untitled], 267-8. See also Lindeman's definition of his "trophic dynamic viewpoint" in opposition with Clements and Shelford's "'bio-ecological' species--distribution approach." Lindeman, "The Trophic-Dynamic Aspect of Ecology," 399.

insects and carnivorous insects, such as spiders, or larger animals, or into smaller and then larger fish. Eventually, however, as the phytoplankton plankton and other organisms die, their remains and the phosphorus return to the mud at the bottom of the lake.[327]

Although the notion of the ecosystem provided a way of accommodating these principles, it was the principles themselves that were the most important for Lindeman. After quoting Tansley's much lengthier definition of the ecosystem, Lindeman asserts that "the ecosystem may be formally defined as the system composed of physical-chemical-biological processes active within a space-time unit of any magnitude, i.e. the biotic community plus its abiotic environment."[328] In seventeen pages of text devoted to underscoring the importance of the movement of matter and energy through the ecosystem, Lindeman devotes half of a paragraph—less than half of a page to the notion of the ecosystem.[329] Although Lindeman picked up Tansley's term, he redefined it in terms of what he clearly considered to be the most important focal points of his article—the movement of matter and energy through the environment.

III. The Fundamentals of Ecosystem Ecology

Odum similarly redefined the notion of the ecosystem. He took up the notion of the ecosystem and began promoting it as a way of establishing ecology as a coherent and autonomous discipline. Given the fact that Odum is known as both a dedicated promoter of ecosystem ecology and as the author of a series of textbooks entitled *Fundamentals of*

[327] Hutchinson and Bowen, "A Direct Demonstration of the Phosphorus Cycle," 148-53.
[328] Ibid.
[329] Lindeman, "The Trophic-Dynamic Aspect of Ecology," 400.

Ecology, perhaps it should not be surprising that these two elements of Odum's reputation should be so closely intertwined.

Odum published the first edition of this textbook in 1953, just as the discipline of ecology was growing with an influx of students in the years following World War II.[330] With the widespread adoption of his textbook in these years to train incoming students in ecology, Odum's text would familiar to several generations of ecologists.[331] The textbook would become a cornerstone in the prominence he would later enjoy. Because of its success and widespread adoption as a textbook, the work came to be known as "the Odum," and, as historian of ecology Chunglin Kwa notes, “For several generations of students, 'the Odum' was the textbook.”[332] It is important to note that his decision to write the textbook emerged from his effort to establish ecology as a discipline locally, at the University of Georgia. Although this link may seem coincidental or unimportant, I will argue that it provides a key to understanding Odum's career. His success as a discipline-builder—in promoting the theory of ecosystem ecology—was intimately tied to his savvy as an organization-builder.

In his later years, Odum often reported that the impetus for writing the textbook originated in a faculty meeting of the University of Georgia's biology professors. In the meeting, Odum suggested that ecology be a required class of all biology majors. The bulk of the professors at the meeting rebuffed the idea as absurd.[333] Writing of the incident much later—and referring to himself in the third person, he notes “Odum's suggestion

[330] Burgess, "The Ecological Society of America," 3. Craige, *Eugene Odum*, 39.
[331] Hagen, "Teaching Ecology During the Environmental Age," 704 and 713. Craige, *Eugene Odum*, 39. Orians, “A Diversity of Textbooks,” 1238-39.
[332] Kwa, "Radiation Ecology and Systems Ecology," 222 [emphasis in original].
[333] Eugene Odum, "The Emergence of Ecology as a New Integrative Discipline." *Science* 195, 4284 (1977): 1289. On the other biology professors' "mockery" of Odum's suggestion, see Craige, *Eugene Odum*, 39.

that ecology be a part of the core [curriculum or set of required classes] was rejected on the basis that the subject had no basic principles. Responding to this and other challenges, Odum began writing 'Fundamentals of Ecology.'"[334]

While ecology had been in existence in one form or another since at least the mid to late 19th century, it was not institutionalized as a department and seldom as a distinct specialty in biology departments. In the U. S., many self designated ecologists were employed in botany and zoology departments.[335] Ecologist and historian of ecology Robert McIntosh reports that "by 1915 a body of scientists had arisen in America who regarded themselves as ecologists, although their areas of interest in biology ranged widely over plants, insects, aquatic organisms, and terrestrial vertebrates."[336] The Ecological Society of America was formed in 1914 with Victor Shelford serving as the first president in 1916.[337] First published in 1917, the first issue of the *Bulletin* of the Ecological Society was three pages long and focused on the recent meeting of the society at Barnard College. The article reported that, although only 125 members attended the meeting, the society currently had members 307 members and that annual dues were

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334 Odum, "Turning Points in the History of the Institute of Ecology," 16. See also Craige, *Eugene Odum*, 37-8.

335 McIntosh provides a summary of the coming together of ecologists working primarily in botany and zoology departments and quotes ecologist Henry Chandler Cowles' 1904 assessment of the state of ecology: "the field of ecology is chaos. Ecologists are not agreed even as to the fundamental principles or motive; indeed no one at this time. . . is prepared to define or delimit ecology." Robert P. McIntosh, "Ecology Since 1900." In *History of American Ecology*, ed. Frank N. Egerton, (New York: Arno Press, 1977), 353-7, esp. 354.

336 McIntosh dates the rise of "self conscious ecology" in the U. S. from the formation of the formation of the Ecological Society of America. McIntosh, "Ecology Since 1900," 353-6, esp. 355. While McIntosh has described the institutionalization of ecology as lagging in the U. S. context in comparison to Europe, Peter Bowler argues instead that the development of ecology in the U. S. was by comparison "more secure" than in Britain and elsewhere. Robert P. McIntosh, "Ecology Since 1900." In *History of American Ecology*, ed. Frank N. Egerton, (New York: Arno Press, 1977), 353-5. Bowler, *The Earth Encompassed*, 519.

337 See Burgess for a view into the formation of the Ecological Society of America. Burgess, "The Ecological Society of America," 1-2. Bowler, *The Earth Encompassed*, 518-21. McIntosh, "Ecology Since 1900," 353-6.

$1.00.[338] *Ecology*, the primary journal of the society was established in 1920.[339]

The institutional affiliations of early leaders in the field provides a sense of the degree of institutionalization of ecology at the level of the university department. Victor Shelford, the first president of the Ecological Society of America, for example, specialized in animal ecology but earned his Ph.D. from Chicago in a Zoology department and would then work as a professor in the University of Illinois' Zoology department.[340] Gregg Mitman and Peter Bowler both describe the work emerging from the Zoology department and particularly that associated with Shelford's adviser Henry Chandler Cowles (1869-1939), who earned his Ph.D. from the same department where he taught.[341] As I have noted, another prominent figure in ecology in this time was Frederic Clements. Clements earned his Ph.D. in a Botany department working under Charles Bessey (1845-1915), himself a botany professor who had not earned a Ph.D. but who studied intermittently under Harvard's eminent Asa Gray after graduating from Michigan Agricultural College.[342] Although Clements worked as a professor in botany at the University of Nebraska and then the University of Minnesota, his research was funded by the Carnegie Institute of Washington for the remainder of his professional career.[343] In sum, the discipline of ecology, such as it existed in the U. S. in the opening decades of the 20th century, was fragmented into pre-existing specialties.[344]

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338 Ecological Society of America, "The New York Meeting," *Bulletin of the Ecological Society of America* 1, 1 (January 1917): 1-3.
339 Burgess, "The Ecological Society of America," 2.
340 Bowler, *The Earth Encompassed*, 527.
341 Ibid., 527-9. Mitman, *State of Nature*, 16-19,
342 Tobey, *Saving the Prairies*, 6, 21-3, and 121.
343 Kingsland, *The Evolution of Modern Ecology*, 144-51. McIntosh, "Ecology Since 1900," 354.
344 Bowler and McIntosh show that although botany was initially a more established specialty in ecology, by the 1930s animal ecology was becoming a more established specialty. Bowler, *The Earth Encompassed*, 519. McIntosh, "Ecology Since 1900," 356-7.

Odum's training in ecology reflects the fragmentation of ecology at the level of the department. Working in a department dominated by animal ecologist Victor Shelford, he earned his Ph.D. in zoology in 1939 and was hired as a professor of zoology in 1940 just as plant ecologists were often hired as professors of botany.[345] Although the Ecological Society of America and their journal Ecology served as forums that brought together ecologists, there was seldom much—if any—organizational basis for the discipline at the level of the university.

Odum wanted to change that—to provide an organizational basis for ecology at the University of Georgia. This took the form of his ongoing efforts to influence the biology curriculum throughout the 1950s, and it took the form of writing a textbook that could provide principles to unite the field of ecology and provide it with respect it deserved.

In no small sense, the birth of this textbook was a family affair. In January 1944—well before Eugene had anything to show publishers, he received a letter from the Macmillan publishing company expressing interest in his textbook. A prominent sociologist who focused on the South, Odum's father Howard Washington Odum (1884-1954) had solicited the interest of publishers when the possibility of writing an ecology textbook was just an idea for his son Eugene.[346] His father not only probed the interest of prospective publishers, he also encouraged Eugene to write a textbook just a few years after starting to work as a professor. Although Eugene hesitated in reacting to his father's encouragement, certainly the son did not suffer from a lack of ambition. Although he was not yet thirty when he began the work, he was ready to hear his father's encouraging

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345 Craige, *Eugene Odum*, 22-37, and 170.
346 Ibid., 37-42.

words. Much later, he remembered this interaction with his father, “'What if I don't know enough yet?' 'You'll learn as you write,' his father responded. 'What if I make mistakes?' 'You'll correct them in the second edition.'”[347]

His response to the letter from Macmillan provides an indication of how Odum saw the significance of his textbook. The book would be “suitable for college courses” but also those “who should find in ecology a basic discipline.” From the beginning, Odum saw his textbook as an effort to bolster ecology as a discipline. The effort to write a textbook that brought together different specialties in the discipline required some justification, however. He noted that his book would fill a current gap. While there are “good reference books” on specialty areas, there is “no book that covers the whole field of ecology in a comprehensive scientific manner."[348] Tellingly, in the effort to establish himself as a credible candidate for writing such a textbook, he asserted that he would be capable of bringing together the various specializations that defined the level of fragmentation of ecology as a field. He asserted that "I have had a rather broad training in both botany and zoology and have been subjected to several rather different 'schools of thought' in [the] field."[349] In 1944, when he wrote this letter, Odum was already considering his textbook as something that would be not only scientific in nature but also of interest to people who belonged to ecology as a discipline.

Although the book would eventually be printed by W. B. Saunders, there were a number of different publishers who expressed interest in the project. The courting period took place in the middle months of 1951. Here we see Hugh W. Handsfield of McGraw

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[347] Ibid., 38.
[348] Craige, *Eugene Odum*, 37-42, esp. 38.
[349] Ibid.

Hill writing Odum in June that he will send the proposed outline to “our consultant.” A couple of months later Alden H. Clark of Henry Holt and Company wrote Odum to see if he was planning to attend an upcoming American Institute of Biological Sciences conference in order to schedule a meeting. Clark wrote, “I should be delighted to have you as my guest for lunch or some less formal refreshment on any of the three days of the meetings.” Odum was interested in scheduling a meeting as well. “How about Monday at noon?”[350]

Although the bulk of the exchange between Odum and prospective publishers came in the middle of the year, it is clear that Odum had solicited interest, evidently in a more tentative fashion, earlier in the year. As early as February publishers were replying to Odum and expressing interest. James B. Lackey wrote, “Can you send me any information at all on it at this time, especially a tentative table of contents and the approximate size of the book? I understand of course that all of this is tentative.”[351] It would be interesting to know more about what transpired in these months—if these were the months that saw the struggle between Odum's awareness of his young age and his ambition to establish ecology as its own discipline guided by its own principles.

When it came time to decide on publishers, Odum went with W. B. Saunders. Tipped off as to Eugene's plans to write a textbook, Tyler Buchenau, the college editor contacted Eugene in August 1951 to express his interest in the book and began a decades-long association. In the letter, Buchenau noted that prominent ecologist W. C. Allee had “expressed confidence in your ability and your serious intention to go ahead with the

[350] Hugh W. Handsfield to Eugene Odum, June 21, 1951; Alden H. Clark to Odum, August 21, 1951. UGA 97 045, box 61.
[351] James B. Lackey to Odum, February 14, 1951. UGA 97 045, box 61.

project." Despite opening with Allee's recent recommendation, the letter betrays a longer term interaction between the editor and Odum. Buchenau continues by reminding Eugene that "I wrote you last spring conveying our interest in the book after our representative, Jim Rose, had made an enthusiastic report of his visit with you." He concludes the letter by asking to meet with Odum at the AIBS meeting in Minneapolis.[352] It is difficult to avoid the sense here that Odum, in the gap between Buchenau's letters—and in the elapsed time between Lackey's February letter and the ones arriving in the late summer, was buying time. Further, although Buchenau had met with Allee in Woods Hole—and we can see elsewhere that Eugene had been in direct contact with Allee in this period, it is nonetheless interesting to note that Allee was at the time spending the twilight of his career (1950-1955) at the University of Florida, where Eugene's brother Howard T. (or H.T.) Odum was before leaving for Duke University and then the University of Texas. Perhaps H. T. had, with Gene's father, played a role in eliciting interest in his brother's textbook.[353] In either case, he did help his brother writing the *Fundamentals of Ecology*. In a letter to Eugene, H. T. expressed concern, however, that his contribution went unrecognized, "I am wondering whether the way the acknowledgement was written anybody can tell if it was primarily my chapter--not that it matters." Eugene replied, "perhaps we can arrange some other method of acknowledgement [sic]. People get us mixed up so generally anyhow we shall probably continue to get credit for the wrong things. . .A second printing has come out. . .your name was added to chapter on [energy] where it got left out on the first printing."[354] The notation to the copies reprinted in 1954

352 Tyler Buchenau to Odum, August 24, 1951. UGA 97 045, box 61.
353 H.T. Odum to Eugene Odum, n.d. UGA 97 044, box 1.
354 Correspondence HT Odum to Eugene Odum, n.d. UGA 06-032, box 1.

bore a note that “The author wishes to acknowledge the substantial contributions made by Howard T. Odum to the preparation of this chapter”.

Nor did his father's advice or his brother's input end with the writing of this textbook. In addition to helping Eugene write the textbook's chapter on energy, the brothers would remain in close contact personally but also professionally and collaborate on a number of projects.[355] To a significant degree, Eugene's father provided the elder brother with a model of what it meant to be an academic. When he advised his son to stay in a fancy hotel in Athens while arranging for his much less impressive, and more permanent, apartment, he was giving his son a lesson in impression management and the importance of status in the role of the academic. Eugene's stated preference for working in a small town--where college professors play a more prominent role in the community--similarly linked the role of the professor with status in the local community. For the Odums, academia was the Odum family business.[356]

Eugene Odum's textbook was also reviewed by a sociologist for the pages of Social Forces, a journal that his father Howard Odum had helped to start in 1922.[357] One of the things that is striking in this review is the way that the reviewer, Rupert Vance—an established sociologist, positions the textbook and ecology more generally as a source of insights for sociologists.[358] He writes, “Certainly ecology, as Eugene Odum here presents

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355 In the following chapter, I will be exploring one of these collaborations—the brothers' work in Eniwetok—in detail.

356 Although Eugene and Howard's sister Mary Frances would not become an academic, she would marry Phil Schinham, who was the son of musician and academic, Jan Philip Schinhan. Mary Frances told Craige in an interview that, “H.T. was the gifted one.” Craige, *Eugene Odum*, 17.

357 Ibid., 5-6.

358 Vance was the President of the American Sociological Association in the mid 1940s. American Sociological Association. “Rupert Bayless Vance.” Accessed January 27, 2011 from http://www.asanet.org/about/presidents/Rupert_Vance.cfm. Rupert B. Vance, “[untitled],” review of *Fundamentals of Ecology* by Eugene Odum, *Social Forces* 32, no. 4 (May 1, 1954): 375–376.

it, in its latest manifestations, still offers a mine of theories and leads for demographers and sociologists looking for systematic analysis."[359] In finding, with other reviewers, the strength of Odum's work in its synthetic approach, Vance goes on to note that, “this synthesis in biology continues to furnish analogies, models, and strong scientific underpinning for sociological analysis. The organization of topics and relationships in Odum's book-one of its strongest contributions-makes this clear."[360] Vance goes further in locating ecology as a source for sociological insights as part of a larger, and distinguished, trajectory in sociology: “Things have gone far since R. E. Park developed his first insights from reading Eugene Warming and F. E. Clements.”[361]

Assessing the reviews as a whole, it is easy to detect the first glimmerings of the book's later impact. In *The Quarterly Review of Biology*, L. C. Birch called the book a “very successful venture,” and argued that, “On the whole this book can be warmly commended to college students as one of the best modern texts on ecology.”[362] In his review in the pages of *Evolution,* Richard S. Miller named the book, “the first attempt in several years at a concise, introductory treatment of the fundamentals of ecology.” It represented a “radical and refreshingly dynamic approach”[363]. In his review in *Ecology*, Edwin Moul noted that the Fundamentals of Ecology was a “well organized, readable, basic text”[364]. And on the pages of Science, Joel Hedgpeth noted that, “Odum has done an

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359 Vance, review of *Fundamentals of Ecology*., 376.
360 Ibid.
361 Ibid.
362 L. C. Birch, “[untitled],” review of *Fundamentals of Ecology* by Eugene Odum, *The Quarterly Review of Biology* 29, no. 2 (June 1, 1954): 152.
363 Richard S. Miller, “[untitled],” review of *Fundamentals of Ecology* by Eugene Odum, *Oikos* 5, no. 1 (January 1, 1954): 134–136.
364 Edwin T. Moul, “Two Reviews of Odum’s Fundamentals of Ecology,” *Ecology* 35, no. 2 (April 1, 1954): 297.

excellent job in conciseness, and his title is fully justified."[365]

Not surprisingly, Odum exulted in this kind of reception. In a letter to his brother, he commented that, "It was most gratifying that the first two letters came from men who might be the most critical, Huthinson and Redfield. I don't believe it is possible to get a nicer letter than the one from Redfield!" Confident in the success of the book, Odum told his brother—then working at the University of Florida, "don't worry about it getting adopted at Florida."[366]

Of course, some of the reviews of the textbook were not without a critical edge. Richard S. Miller alternated criticism and praise when he noted that, "Although the general tone of the book seems often rather elementary, even for the most retarded freshman, some chapters are exceptionally good". He continued, however, to argue that, "this book suffers from inconsistent writing and an unfortunate style of presentation—each topic numbered and discussed under the subheadings statement, explanation, and example. It is difficult to believe that students and general readers need such a crutch."[367] Odum's "introductory approach," which he praises elsewhere in his review, was evidently too introductory for his taste. L. C. Birch, meanwhile, saw issues that were characteristic of Odum's efforts to explain "subtle problems which are difficult to deal with in an elementary text."[368] Despite these criticisms, the bulk of the textbooks reviews were positive.

It is significant that most of the books' reviews comment on the on the level of synthesis that Odum's text brought to ecology. C. H. Baer, for example, notes that,

365 Joel W. Hedgpeth, "[untitled]," review of *Fundamentals of Ecology* by Eugene Odum, *Science* 120, no. 3108. New Series (July 23, 1954): 134.
366 Letter from Eugene Odum to H.T. Odum. UGA 06 32, box 1.
367 Miller, review of *Fundamentals of Ecology,* 134–136.
368 Birch, review of *Fundamentals of Ecology*, 151-2.

“Odum's text should be a welcome change for animal ecologists as well as for biologists in universities and colleges where ecology is not divided into plant and animal corrals.”[369] And Rupert Vance noted that, “the synthesis of ecological principles. . . .this is Odum's major love.”[370]

Several reviewers, as well, commented on the way that this synthetic approach was embedded in the organization of the text. Richard S. Miller noted that first the text provided the “groundwork of governing principles” before delving into the specialty areas of ecological research.[371] Birch as well noted the movement in the text, “from general to particular and back again.”[372] In order to understand one of the defining features of Odum's hope for ecology in this period, this synthetic approach should be examined in the context out of which the textbook emerged.

For Odum, the notion of the ecosystem would give ecology coherence as the theoretical core of the discipline and furnish the principles that would legitimate it as a field for the other University of Georgia biology professors. The two goals emerged from the same context and were two sides of the same coin. In order to have ecology courses as a part of the core biology curriculum at the University of Georgia, Odum was told, the discipline needed principles. For Odum this meant that it needed to be united under a coherent theoretical approach.

The acceptance of ecology in this meeting and its incorporation as an organizational unit depended on the properties of the discipline's theory. As we shall see, at the core of the ecosystem approach were the emphasis, drawn from G. Evelyn

369 C. H. Baer, “[untitled],” review of *Fundamentals of Ecology* by Eugene Odum, *Castanea* 19, no. 1 (March 1, 1954): 41.
370 Vance, review of *Fundamentals of Ecology*, 376.
371 Miller, review of *Fundamentals of Ecology*, 178.
372 Birch, review of *Fundamentals of Ecology*, 151.

Hutchinson and his student Raymond Lindeman, on the movement of energy and matter (termed biogeochemical cycling) through the environment. Although he borrowed their use of the term 'ecosystem,' which they had borrowed from ecologist Arthur Tansley, in Odum's hands the analytical term became a way of providing theoretical coherence and thus legitimacy to the field.[373]

Odum's backing of the notion of the ecosystem in this early period in his career was, to a significant degree, an effort to make ecology into a science that was credible. In order to be credible, the fragmented areas of research had to be brought together and united around common theoretical principles. Odum's textbook represented an effort to provide the field with theoretical principles but also coherence—something the text's reviewers commented on as well. In being widely used to train new generations of ecologists, the textbook would play a significant role in spreading Odum's hopes for the discipline of ecology.

What was the fate of these ambitious efforts of Odum in the 1940s and 1950s? How would Odum characterize these goals and the significance of his work a decade later? Would he still be as determined to provide ecology with the principles and coherence it needed to be recognized as a discipline? In more general terms we could ask, what did Odum see as the core of his work?

IV. The 'New Ecology'

In a 1964 article, Eugene Odum proudly proclaimed the arrival of a 'new ecology.'

[373] As I will note below, the context for the ecosystem switched in Odum's earlier and later career. Later, it became the center of an approach to environmental problems that drew on ecological expertise. While I have emphasized Hutchinson and Lindeman's contribution to Odum's notion of the ecosystem (an emphasis that reflects the emphasis in Odum's own accounting), he also drew on the notion of the biome in Frederic Clements' and Victor Shelford's 1939 work *Bio-ecology*.

In the postwar years there were many ecologists—and scientists of other stripes—proclaiming the novelty of their work. These claims of novelty offer a view of how ecologists perceived--and endeavored to position--the significance of their work in relation to larger trends and tensions in their field. Further, reading these claims in relation to the authors' work allows us to foreground the work that these claims might be doing.

In the mid 1960s, Odum was becoming a more and more central figure in ecology. With hisleadership position in radiation ecology and the influence of *Fundamentals of Ecology*, ecosystem ecology was gaining more adherents, and Odum himself was becoming more prominent in the field. He was invited to Japan to lecture at multiple imperial universities in 1962—an honor he would cherish for many decades, and in 1965 he would serve as the President of the Ecological Society of America.[374] His efforts, begun in the late 1940s, to establish ecology as a recognized field united around the notion of the ecosystem, had, by the mid 1960s, played a significant role in positioning Odum as a central figure in the field of ecology. From the initially humble perch of a peripheral state university, Odum had established himself as a major figure in ecology. This success reinforced the confidence with which he would chart the course of ecology as a whole in his 1964 article.

While Odum's centrality in 1960s ecology can not be discounted as a factor in his sense of reassurance in his assessment of the state of ecology, it would be overly simplistic to reduce Odum's proclamation to his increasing prominence alone. Other ecologists were saying similar things. Yale's G. Evelyn Hutchinson—another ecologist

[374] Craige, *Eugene Odum*, 81-4.

whose work was enjoying greater prominence in this period—issued similar pronouncements from the mid 1940's. It is significant that these claims of novelty often defined the future of the discipline against its past, effectively performing a kind of internal boundary work.[375] Despite obvious similarities between Hutchinson's and Odum's claims of novelty, it would be wrong to assume that these ecologists were of similar minds about what made postwar ecology distinctive. For Hutchinson, ecology was becoming more scientific insofar as it was becoming less descriptive and more quantitative and centered on problems such as the movement of matter and energy through the environment and population ecology. Although Odum shared Hutchinson's disregard for ecology that was purely, or primarily, descriptive, his vision of what constituted the new ecology differed in important respects from that of Hutchinson.[376]

Although ecology had made progress on both counts, it still needed more of a unifying theory and needed to become more coherent. After providing a review of different approaches in ecology, Odum lamented,

> Until quite recently, these widely divergent approaches remained largely separate fields with little general theory to connect them. Worst of all, specialists have too often attempted to extend narrow approaches into 'general theories' that differ as widely as do the approaches, much to the confusion of those who look for some kind of unity of thinking among ecologists that might be comparable, for example, with that found among geneticists.[377]

In the place of the misguided generalizations of the theories guiding a given specialty or branch of ecology, Odum recommended ecosystem ecology as an approach that could

[375] See introduction for discussion of Thomas Gieryn's notion of boundary work. Gieryn, “Boundary Work and the Demarcation of Science from Non-science," 782.
[376] See discussion below for more on the distinctiveness of Odum's new ecology.
[377] Eugene Odum, "The New Ecology." *BioScience* 14 (1964): 14.

unite ecologists:

> In my opinion, the ecosystem concept brings together all ecologists, because the ecosystem is the basic unit of structure and function with which we must ultimately deal. Ecologists can rally around the ecosystem as their basic unit just as molecular biologists now rally around the cell, another important basic unit of structure and function.[378]

Although he began this quote by noting that "the ecosystem concept brings together all ecologists," he went beyond this and introduced us to his language of the "structure" and "function" of nature as well. He also introduced the question of the place of ecology in relation to other biological disciplines, a topic I will explore in more depth below. What does Odum mean, though, when he said that "the ecosystem is the basic unit of structure and function"?

In order to answer this question and explore Odum's reflections on the significance of his 1960s era work in more detail, I will introduce his use of the terms "structure" and "function" before examining their meaning in relation to the "new ecology" and the place of ecology in relation to other disciplines. When Odum equated ecology with "the study of the structure and function of nature," he was also announcing the importance of this language to his approach.[379] In order to make sense of this language, I will examine its emergence in the context of his promotion of ecosystem ecology, beginning with his 1953 textbook. In providing a longer term context for these terms, I will also be addressing the question of the extent to which Odum's promotion of—and definition of—ecosystem ecology changed between the early 1950s and the mid 1960s.

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378 Ibid., 15.
379 Ibid.

V. The Structure and the Function of Nature

From the opening pages of the first edition of the *Fundamentals of Ecology*, Odum emphasized the interrelationships between different organisms and between organisms and their natural environment. Odum quickly added, however, that ecology was as concerned with groups of organisms as with individual organisms. He offered one definition of ecology as “the study of structure and temporal processes of populations, communities, and other ecological systems, and of the interrelationships of individuals composing these units.”[380] It is worth noting that this definition introduces part of what would, for Odum, be a more lasting definition of the focus of ecology—the “structure” of individual organisms and groups of organisms. Nonetheless, Odum emphasized interrelationships again in introducing the ecosystem as the primary focus of the book: “its [the concept of the ecosystem] main function in ecological thought being to emphasize obligatory relationships, interdependence, and causal relationships.”[381] If the structure of nature would be one component of Odum's definition of the focus of ecology, this recurring emphasis on interrelationships presages the second component. With this in mind, an earlier title for his textbook, *Ecology: the Science of Environmental Interrelations*, takes on greater significance.[382]

In the second (1959) edition of his textbook, Odum introduced how he expressed this component for the remainder of his career—the 'function' of nature. He noted with more confidence than in the first edition that

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[380] Odum, *Fundamentals of Ecology*, 4.
[381] Ibid., 10.
[382] Correspondence with Hugh W. Handsfield, McGraw-Hill, June 21, 1951. UGA 97 045, box 61.

> Because ecology is concerned especially with the biology of *groups* of organisms and with functional processes on the lands, in the oceans and in fresh waters, it is more in keeping with the modern emphasis, to define ecology as the study of the structure and function of nature.[383]

By 1959, the attention to the interrelationships in nature in the 1953 edition found expression in the pithy--and lasting--expression, “the structure and function of nature.” Since the 1959 text is the first place we see Odum deploying this definition, it is worth quoting in length his narrative account of the importance of this emphasis on function in the preface to the second edition:

> In working with the literature over the past few years, I have been more impressed than ever with the fact that ecology has emerged from a primarily descriptive subject to one which is also functional in approach. Until comparatively recently, ecologists were content to describe how nature 'looks' (sometimes by means of fantastic terms!) and to speculate on what she may have looked like in the past or might look like in the future. Now an equal emphasis is being placed on what nature 'does,' and rightly so, because the changing face of nature can never be understood unless her metabolism is also studied![384]

In the first edition of his textbook, Odum had not yet formulated the expression "function" instead preferring the wordier, “temporal processes of populations, communities, and other ecological systems, and of the interrelationships of individuals composing these units”[385].

During the first half of Odum's career, his emphasis on the function of ecosystems

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383 Odum, *Fundamentals of Ecology* 2nd ed., 4. These definitions of the focal point of ecology come in the same place in Odum's text—in the opening pages just before discussing the basic divisions or 'layers' of biology.

384 Odum, *Fundamentals of Ecology* 2nd ed., ix. In implicitly equating the function of nature with its metabolism in the last sentence we are also introduced here to the lasting importance of Eugene's study, with his brother Howard, of the coral reef of the Eniwetok atoll in the mid 1950s. As we shall see this study built on the work of Eugene's brother Howard T. Odum in measuring the 'productivity' and 'respiration' of springs in Florida. This study will receive more attention in the chapter on Odum's environmental critique.

385 Odum, *Fundamentals of Ecology*, 4.

became increasingly mapped onto the emphasis on the movement of matter and energy through the environment. In a 1962 address delivered during his stay in Japan, Odum maintained that,

> By function, we mean the rate of biological energy flow through the ecosystem, that is rates of production and rates of respiration of the populations and the community; (2) the rate of material or nutrient cycling, that is, biogeochemical cycles; (3) biological or ecological regulation including both regulation of organisms by environment (as for example in photoperiodism) and regulation of environment by organisms (as for example in nitrogen fixation by micro organism[386].

This kind of emphasis on function has come along with an increase in the, "use of experimental methods, both in the field and in the laboratory" and contrasted with ecologists' focus "[u]ntil recently" on " structure, or what we might call the descriptive approach"[387].

This 1962 essay is important in combining a re-worked and more fully specified notion of just what 'function' is. In doing so it provides a partial answer to the question of what the "new ecology" meant for Odum. Not only did the new ecology—and ecosystem ecology—focus on "relationships, interdependence, and causal relationships"[388] or "what nature 'does,'"[389] but it also involved the use of "experimental methods" to study

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386 Odum, "The New Ecology," 108. We see much the same emphasis in his 1968 work "Energy Flow in Ecosystems." Eugene Odum, "Energy Flow in Ecosystems: a Historical Review," *American Zoologist* 8, 1 (1968): 11-18.

387 Ibid., 108. In an article co-authored with Clyde Connell and Leslie Davenport, Odum notes that, "The functional approach to the study of ecological systems is being followed by an increasing number of investigators working in a variety of different habitats. Such an approach may consider either or both of the two major areas of ecosystem dynamics, namely energy flow and nutrient cycles" Eugene P. Odum, Clyde E. Connell, and Leslie B. Davenport, "Population Energy Flow of Three Primary Consumer Components of Old-Field Ecosystems," *Ecology* 43, no. 1 (January 1, 1962): 88.

388 Odum, *Fundamentals of Ecology*, 10.

389 Odum, *Fundamentals of Ecology* 2nd ed., ix.

biogeochemical cycles, the movement of energy through the ecosystem, and biological regulation."[390] Odum linked the use of experimental methods and "improved analytical, mathematical, and experimental procedures" with the new ecology in his 1964 essay.[391]

One of the most striking examples of the importance Odum assigned to the emphasis on the function of the ecosystem comes in his characterization of his 1958-9 sabbatical year.[392] After a series of warm letters leading up to the portion of the time he spent with Charles Elton,[393] Odum would cast the thrust of Elton's work in a less than rosy light. In a leter to Peter Frank, a professor of Biology at the University of Oregon, Odum admits, "I am glad to give you my impressions" from "My visits to Elton's 'Bureau.'"[394] He continues,

> As you know I went there specifically to see what has really been accomplished by the long term descriptive approach on a relatively small area of land. Essentially, Elton's approach has been descriptive and taxonomic although, of course, he feels that many processes can best be elucidated in this manner. I enjoyed presenting our functional approach and comparing it with his. I came away with the very definite impression that the functional approach will break many bottlenecks which can never be solved in the Eltonian manner. . . .As far as I could see, he has become completely bogged down in this cataloging. One thing which has come out of this work, however, is the question as to the functioning of the numerous rare species of the community. . . .
>
> In summary, Elton's approach consists very simply enumerating animals and stimulating various students to study the details of the natural history of populations. His building is completely devoid of any modern

390 Odum, "The New Ecology," 108.

391 Odum, "The New Ecology," 14. In *Landscapes and Labscapes*, Robert Kohler provides a compelling account of the tension between the tools and conventions of field based research and laboratory based research in ecology. Although he approaches each set of conventions and the "borders" separating them, he is very much interested in the moments in which there are "border crossings" and the techniques of the lab find their way into the field and vice versa. Kohler, *Landscapes and Labscapes*, 11-8.

392 Craige, *Eugene Odum*, 68-75.

393 Their correspondence dates from at least 1954. UGA 97 044, boxes 1 and 2.

394 From May 7, 1959. UGA 97 044, box 2.

> equipment but it does contain an excellent library.[395]

Odum clearly had little patience for what he saw as Elton's overly "descriptive" and "taxonomic" approach. Odum saw Elton as "very simply enumerating animals" and engaging in "the natural history of populations." One of the things that is striking in this characterization is the degree to which, by Odum's own accounting, Elton was a central figure in twentieth century ecology. In his 1964 article, for example, Odum included Elton with Henry Chandler Cowles, Frederic Clements, and Victor Shelford as figures central to community ecology.[396] For Odum, Elton was a central figure in ecology, but the value of his primarily descriptive approach was in the past.

Although Thomas Gieryn originally defined the notion of 'boundary work' to designate efforts to distinguish the work of science from non-science, it can also designate efforts to distinguish the kind of science that ecologists should practice from the science of the past.[397] Here, Odum's claim that Elton was “bogged down” with the structural approach—with descriptive cataloging—meant that Elton was relegating himself to the ecology of the past. Not only was Elton's ecology “devoid of modern equipment” it also cannot answer the very questions on which it centered.

In a March, 1956 letter to Odum, Elton thanked Odum for his reprints,

> of which I particularly enjoyed the coral reef and the radiation ecology. You have certainly added anew and urgent reason for studying productivity paths. My view is that ecologists have been rather hypnotised by interest in natural control mechanisms, forgetting that it is necessary to see the whole picture of what there is to be controlled.[398]

[395] UGA 97 044, box 2.
[396] Odum, "The New Ecology," 14.
[397] Gieryn, “Boundary Work and the Demarcation of Science from Non-science," 782.
[398] UGA 97 044, box 1.

Elton here recast the trends of ecology as a form of distraction. Ecologists have been "hynotised" by "natural control mechanisms." What was Elton taking issue with here? In the 1955 article that Eugene Odum had sent Elton, Eugene and his brother H. T. had applied Lindeman and Hutchinson's emphasis on measuring energy flow to a coral reef in the South Pacific.[399] Based on their measurements of the amount of energy that algae living on the coral produced and how much energy that the coral required, the brothers discovered that the coral and the algae living on the coral formed a symbiotic relationship. Applying the theoretical approach that H. T. had studied under Hutchinson, who had been his adviser, the brothers argued that the relationship between the coral and the algae should be approached as an instance of a much broader phenomenon of self regulating systems. Where Clements might have characterized the relationship between the algae and coral as having achieved a climax or a lasting state of balance between a biotic community and its environment, the Odum brothers described the coral as a "steady state system."[400]

Elton was taking issue with the rise of precisely this kind of work - the desire to locate in nature examples of "natural control systems" such as the one that the brothers had located in the South Pacific. Of course, Elton's disregard for what Odum and others considered new and scientific did not mean that Odum's assessment of his work as out of date was correct. As we shall see in the discussion of ecology as a "subversive science" in chapter 7, Elton's 1950s era emphasis on conservation would prove a valuable resource to Rachel Carson and other environmental critics interested in engaging ecology in a very

399 Howard T. Odum and Eugene P. Odum. “Trophic Structure and Productivity of a Windward Coral Reef Community on Eniwetok Atoll.” *Ecological Monographs* 25, 3, (July 1955): 291-320. I will discuss this work in more detail in the following chapter in the section entitled "Eniwetok and the Ecology of Productivity."

400 Odum and Odum, “Trophic Structure and Productivity," 319.

different kind of political project than that represented by radiation ecology.

The language of the structure and the function of nature is important because the study of the function of nature occupied such a central part of Odum's approach but also how he defined the "new ecology." Importantly, this emphasis on function also provided an avenue for uniting ecology. In his 1964 essay, Odum argued that,

> A shift in emphasis from the descriptive to the functional has also been very important in bringing together the widely divergent roots of ecology. As long as a purely descriptive approach was emphasized, there was little in common between the sea and the forest or between higher plants and higher animals and, therefore, little exchange of ideas between marine and terrestrial ecologists or between plant and animal ecologists. Now, however, studies on energetics, nutrient cycling, species diversity, functional niches, ecological regulation, etc.[401]

In foregrounding the connections between different parts of nature, the functional emphasis also brought together groups of ecologists whose work had traditionally been segmented by their focal point in nature—zoologists focusing on animals and botanists focusing on plants, for example.[402] In conceptualizing the similarities and differences between ecology and zoology or botany—in his 1964 essay and elsewhere, Odum relied on the language of "the levels of organization concept."[403]

VI. Levels of Organization

In this section I will explore what Odum meant by levels of organization and how he used this notion to position ecology in relation to other disciplines. In many of Odum's

401 Odum, "The New Ecology," 14.
402 It would be interesting to approach this assertion as an example, if one that would be at least partly hypothetical in nature, of Sheila Jasanoff's notion of co-production (2006).
403 Odum, "The New Ecology," 14.

discussions of this concept, he was using this concept to perform two kinds of work. He was specifying the kinds of topics that should be studied in the discipline of ecology. And he was specifying topics that other, more successful, areas of biology—such as molecular biology—could *not* explain. He was using this concept, in other words, to define and protect the turf of professional ecologists.

It should be noted, as well, that Odum also saw an important role for the levels of organization concept within ecology by helping to bring the different specialties of the discipline together into a coherent whole. In his 1964 essay on the new ecology, he argued that,

> The levels-of-organization concept, which is not new but which has only recently achieved wide acceptance by biologists, has played an important part in uniting these diverse roots into something resembling a trunk of central ecological theory.[404]

How did Odum see this working? And, more importantly, how was this notion of levels of organization supposed to help define and protect the territory of ecology[405]?

Odum provided an answer to these questions with his “biology 'layer cake'” in the opening pages of *Fundamentals of Ecology*.[406] Each layer of the cake represented one way of dividing the larger field of biology, as the larger “science of life.”[407] The layers signify “basic” divisions of biology “because they are concerned with fundamentals common to all life or at least are not restricted to particular organisms.”[408] In Figure 4.1 below, ecology was represented next to genetics, physiology, and morphology.

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404 Ibid.
405 See the discussion of the themes of the sociology of professions literature cited in the introduction.
406 Odum, *Fundamentals of Ecology* 2nd ed., 4; and Odum, *Fundamentals of Ecology* 3rd ed., 4.
407 Odum, *Fundamentals of Ecology* 2nd ed., 5.
408 Ibid.

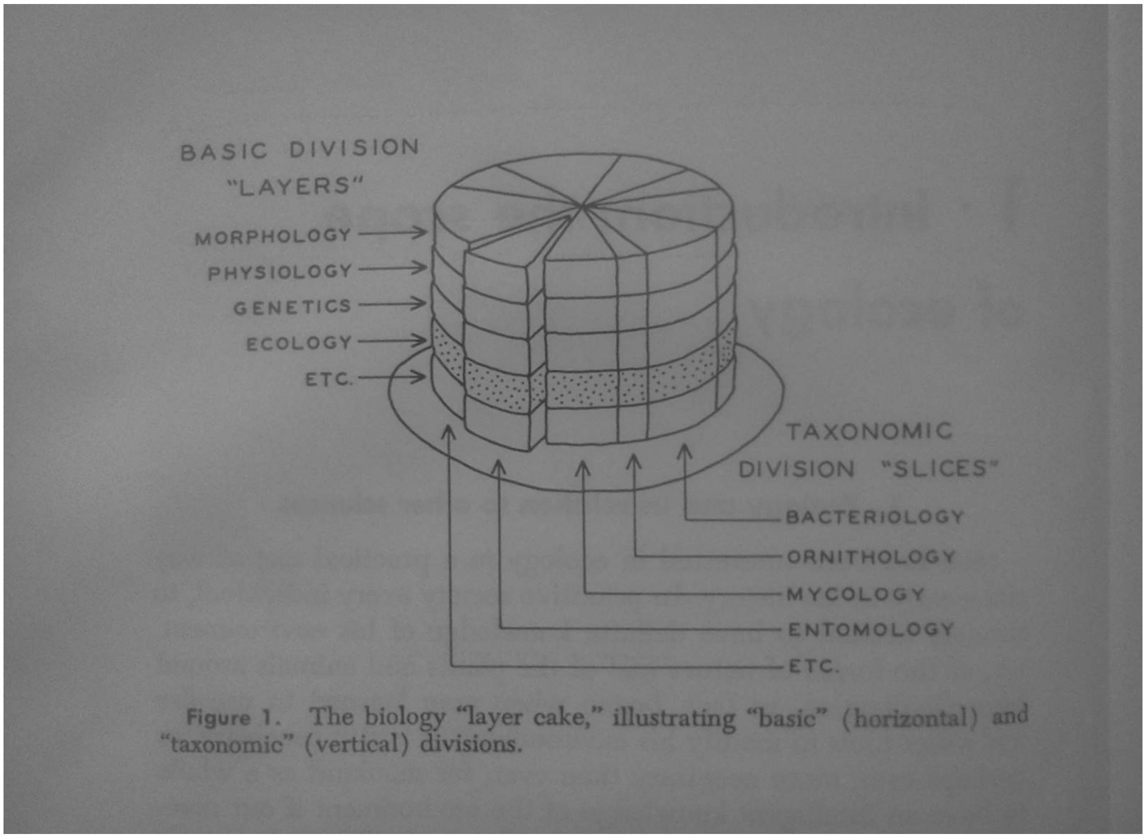

Figure 1. The biology "layer cake," illustrating "basic" (horizontal) and "taxonomic" (vertical) divisions.

Figure 4.1 - Odum's biology layer cake, with original caption.[409]

Vertical "slices" of the cake represented a way of dividing biology by the taxonomic characterization of objects of study—bacteria, birds, fungi, insects, and so on. In Odum's textbooks, this cake metaphor introduced his discussion of levels of organization. Though these levels shift somewhat with successive editions (the "protoplasm" level in the 1959 edition is expressed as "genes" in his 1971 edition), they were relatively constant and consistently arranged in order of increasing scale. The level of genes was followed by the levels of cells, organs, organisms, populations, and communities. Although ecology was represented as one layer of the biology layer cake, it actually covered several levels of organization—populations of species and communities of multiple kinds of organisms

[409] Odum, *Fundamentals of Ecology* 2nd ed., 4.

living in a given area. How did the ecosystem fit into this portrayal of levels of organization? Odum answered, “The community and the nonliving environment function together as an ecological system or *ecosystem.*”[410]

We have seen how Odum described the new ecology—and ecosystem ecology—in terms of an increasing emphasis on function and how Odum described ecology as the focus on higher levels of organization such as populations and communities. This begs the question of how these definitions come together. How did Odum's use of the notions of “structure” and “function” fit in with his description of layers of organization? The study of structure and function proceeded at each level of organization. Odum emphasized that,

> the findings at any one level aid in the study of another level but never completely explain the phenomenon occurring at that level. This is an important point because persons sometimes contend that it is useless to try to work on complex populations and communities when the smaller units are not fully understood. If this idea was pursued to its logical conclusion, all biologists would concentrate on one level, the cellular , for example, until they solved the problems of this level; then they would study tissues and organs. Actually this philosophy was widely held until biologists discovered that each level had characteristics which knowledge of the lower level explained only in part.[411]

There was no one level to which all of biology could be reduced. He expressed a similar sentiment in asserting that, “in the long run, no one level [of organization] is any more or less important or any more or less deserving of scientific study than any other level.”[412]

In his 1964 essay on the new ecology, Odum provided a key to understanding the importance of his emphasis on levels of organization as an effort to delineate the borders

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410 Odum, *Fundamentals of Ecology* 3rd ed., 5.

411 Odum, *Fundamentals of Ecology* 3rd ed., 4. For very similar formulations, see also Odum, *Fundamentals of Ecology* 2nd ed., 7; and Odum, "A New Ecology," 14.

412 Odum, *Fundamentals of Ecology* 3rd ed., 5.

of ecology from the encroachment of scientists studying lower levels of organization. In this essay, Odum explained how each level of organization included different kinds of entities that interact in distinct ways.[413] While biological regulation at the cellular level took place through enzymes, biological regulation at the level of the ecosystem generally involved multiple organisms separated in space. In the place of chemicals, regulation occurred by the interaction of populations of predators and prey.[414] Another factor that distinguished the levels of organization approached by ecosystem ecology was the sheer diversity of species or kinds of entities in consideration. While functioning at the cellular level should be approached in terms of genetic code, functioning at the ecosystem level must take into account a wide diversity of species. Given the differences between the kinds of entities that exist on each level as well as the differences between how these different kinds of entities interact, it would be absurd to expect the functioning of one level to account for the functioning of all levels.[415]

By this logic, efforts to reduce the functioning of higher levels of organization (such as organisms, communities, or ecosystems) with reference to the functioning of lower levels (such as genes) were fundamentally flawed. Odum's ambivalence towards—and efforts to curb—reductionist approaches are clearly evident in his 1964 essay. Here he cited an essay written by famed microbiologist Rene Dubos on “the shortcomings of

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[413] We can also see Odum performing a very similar move in his presentation for a NASA sponsored conference on theoretical biology (UGA 97 045, box 3)

[414] When Odum notes, in this 1964 essay, “At least, if anyone thinks that bird or human behavior can be understood by reducing the population to macromolecules, I would like to learn how this might be done,” it is easy to miss the tone of bafflement that Odum adopts here as this is precisely how human behavior has come to be approached in more recent years with efforts to find genetic markers for all manner of disease and undesirable behavior. Odum, "A New Ecology," 15.

[415] Odum does not rule out the possibility for explanatory mechanisms to operate across levels although he clearly treats the search for such mechanisms—and particularly searches biased towards the accounts emerging from one particular level—with suspicion. Nonetheless, the exceptions he points to are telling—homeostasis, thermodynamics, and metabolism. Ibid., 14-15.

'the reductionist philosophy.'"[416] Although Dubos positioned his comments about reductionism in the context of an appeal for environmental biology, he did admonish,

> biologists [who]. . . assume that the purely reductionist approach is the only scientific way to study life processes, yet it is certain that most biological problems, and probably the most important, cannot be dealt with exclusively by the scientific methods based on the reductionist philosophy.[417]

For Dubos, the successes of molecular molecular biology obscured the need for greater emphasis on and respect for environmental biology as the study of living organisms in situ and, "the complexity of natural phenomena, especially those involving life."[418] He concluded his essay by noting that,

> the time has come to give to the study of the responses that the living organism makes to its environment the same dignity and support which is being given at present to the study of the component parts of the organism. Exclusive emphasis on the reductionist approach will otherwise lead biology and medicine into blind alleys. Unless a program of environmental research is vigorously prosecuted, medicine will remain a two-legged structure, unable to support the loads placed on it by the health problems arising from the new environmental forces created by modern life.[419]

Dubos' essay was published just months before Odum's essay on the new ecology and was greeted by Odum's praise. In a letter to Dubos dating from February 4th, 1964, Odum asserted that,

> I was pleased that you have added your voice to that of other distinguished biologists who are beginning to cry out against 'reductionist' philosophy (I refer, of course to your article in Bioscience). As you may know I have stressed the 'levels of organization' approach in orienting students to both editions of my (1953; 1959) "Fundamentals of Ecology" text and again in

[416] Ibid., 15.
[417] Ibid., 13.
[418] Ibid., 12-4, esp. 13.
[419] Ibid., 14.

> recent paperback. . . . I have always thought it strange that molecular biologists have been so reluctant to admit that not all problems can be solved on one level only.[420]

Here Odum explicitly tied his levels of organization concept, and its use in the first two editions of his textbook (the third edition would not be published until 1971) to his disregard for reductionist approaches and molecular biologists' tendency to reduce many levels of organization to their level of organization.

Nor were Odum's fears about molecular biology's imperialism in relation to the rest of biology unrealistic. No less than Francis Crick, one of the scientists credited for co-discovering the structure of DNA, noted in a 1966 publication that, “Eventually, one may hope to have the whole of biology 'explained' in terms of the level below it, and so on right down to the atomic level.”[421] Invited before the prestigious Royal Society of London the same year, Crick closed his lecture by asserting that "We can now confidently look forward to placing increasing areas of biology on a molecular basis."[422] In her account of the emergence of molecular biology, historian Lily Kay's points out that, in the 1930's, it was far from predetermined that molecular biology would become such a “dominant disciplinary trend” within the larger field of biology.[423] The disparity of scale between ecologists' efforts to understand interactions between different populations of species, say, and microbiologists' efforts to define “the locus of life in the submicroscopic region between 10^{-6} and 10^{-7} cm” is striking.[424] Further, it is not difficult to imagine ecologists'

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420 Letter from Eugene Odum to Rene Dubos, dated February 4, 1964. UGA 97 044, box 3.
421 Francis Crick, *Of Molecules and Men*, (Seattle: University of Washington Press, 1966), 17.
422 Francis Crick, “The Croonian Lecture, 1966: The Genetic Code.” *Proceedings of the Royal Society of London. Series B, Biological Sciences* 167, no. 1009 (April 18, 1967): 346.
423 Lily Kay, L. E. *The Molecular Vision of Life: Caltech, the Rockefeller Foundation, and the Rise of the New Biology* (New York: Oxford University Press, 1993), 3.
424 Kay, *The Molecular Vision of Life*, 5.

discomfort when someone such as Francis Crick, who had just received the Nobel Prize four years prior, asserts a reductionist approach to biology that would, if taken seriously, render the research of ecologists superfluous.

Sociologists of science Joseph Spear and Stefan Fuchs offer an interpretation of reductionist claims as an effort of some scientists to colonize the domain of other scientists. Both Fuch's work and Spear's work on the growth of neuroscience oppose their sociological treatment of reductionism to the work of philosophers of science attempting to arrange an ontological hierarchy.[425] In place of this kind of effort, Spear offers a reading of reductionism as an effort to expand the boundaries over which a discipline holds sway. Here scientists are approached as professionals attempting to invade and to control the territory of other scientists. Applying this approach to the case of molecular biology and ecology, we can read molecular biologists' efforts to assert the primacy of activities occurring at a submicroscopic level of analysis as a play of one group of professionals attempting to exert power over the terrain previously controlled by another group of professionals. Further, we can interpret Odum's elaboration of his notion of levels of organization as, at least in part, an effort to hold the colonizing claims of molecular biologists at bay.

VII. 'The Whole is Greater Than the Sum of its Parts'

In addition to wanting to preserve the territory—and autonomy—of ecology, Odum approached the discipline with an approach that differed in significant ways from

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[425] Stephan Fuchs, *Against Essentialism: A Theory of Culture and Society* (Cambridge, MA: Harvard University Press, 2005), 199-200. Joseph H. Spear, *The Sociology of Reductionism: A Case Study of the "Neuroscience Explosion."* (PhD diss, University of Virginia, 2000), 1-15.

the reductionist vision he associated with molecular biology. Central to Odum's definition of his ecosystem approach was the tenet that 'the whole is greater than the sum of the parts.' Despite the changes between the different ways that Odum positioned himself and the relevance of ecosystem ecology across the course of his career, this tenet remained constant. Institute of ecology colleague Karen Porter went so far as to call Odum "a proselytizer of holism." She added that, "his message of interconnectivity inspired a generation of ecologists."[426] In this section I will illustrate Odum's commitment to holism and focus on how holism (for Odum) both distinguished and protected ecology as a discipline from more dominant and reductionist disciplines in biology.

The constancy of Odum's commitment to holism throughout his career is evident in often repeated formulations such as 'the whole is greater than the sum of its parts' or, in briefer form, 'whole-before-parts.' In the textbook Odum wrote to establish the principles of ecology as a discipline, Odum equated ecosystem ecology with the 'whole-before-parts' approach to ecology when explaining the layout of the text:

> Principles are arranged in a logical sequence based on the theory that the whole environmental complex and its functional aspects are best presented first, and then followed by ideas and concepts which deal with smaller units. I am more convinced than ever that the 'ecosystem' or 'whole-before-parts' approach with its functional emphasis is sound because it avoids several stumbling blocks.[427]

Odum rendered the implicit association here between holism (or ecosystem ecology) and ecology as a discipline in more explicit terms elsewhere. He notes in 1977 that, “Among academic subjects, ecology stands out as being one of the few dedicated to holism”[428].

426 Quoted in Craige, *Eugene Odum*, xiii.
427 Odum, Fundamentals of Ecology 2nd ed., vi.
428 Odum, "The Emergence of Ecology as a New Integrative Discipline," 1291. As I shall explore in the following chapter, Odum came to position ecosystem ecology in relation to environmental issues in his later work. When he did so, he characterized the benefits of a holistic approach as uniquely suited to

Odum's commitment to ecology as a holistic discipline also informed his emphasis on the levels of organization both in his early and later work. Instead of paying attention only to the lower levels of organization studied by molecular biologists, we should include as well higher levels of organization that approached the variety of nature—of various populations of species but also variations in environmental context, inorganic matter, and so forth. In his later work, Odum's discussions of levels of organization would be accompanied with reference to the importance of "emergent properties" that only come into view when the whole of a given level of organization is taken into view. He noted that,

> **an emergent property** of an ecological level or unit cannot be predicted from the study of the components of that level or unit. **Nonreducible properties**, that is, properties of the whole not reducible to the sum of the properties of the parts, is another way to express the concept.[429]

One of the example she provides here came from the research he did with his brother Howard on Eniwetok in 1954. Although found in sea water with low levels of nutrients, algae and coral can combine to form a larger system with a high level of productivity.[430] The behavior of the coral reef that the brothers examined could not have been determined from knowledge of the coral or the algae alone but can only be understood by approaching the coral reef holistically.

In how his descriptions of holism, Odum often opposed it to reductionist approaches in biology that had become more dominant. In a 1977 essay, Odum noted that,

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addressing the scale and complexity of environmental issues.

429 Eugene Odum, *Basic Ecology*. (Fort Worth, TX: Harcourt Brace College Publishing, 1983) 5 [emphasis in bold in original].

430 Ibid., 5-6.

> It is self-evident that science should not only be reductionist in the sense of seeking to understand phenomena by detailed study of smaller and smaller components, but also synthetic and holistic in the sense of seeking to understand large components as functional wholes. . . .Science and technology during the past half century have been so preoccupied with reductionism that supraindividual systems have suffered benign neglect. We are abysmally ignorant of the ecosystems of which we are dependent parts. As a result today we only have half the science of man.[431]

Here and elsewhere, we can detect Odum's realization that his commitment to holism positioned him in a minority position in the larger field of biology[432]. Interestingly, in this essay Odum reflects on his 1964 proclamation of a 'new ecology' as, in part, "a response to the need for greater attention to holism in science and technology."[433] Here, Odum is approaching holism in a larger framework—in terms of kinds of approaches that make up science—than that of ecology as a discipline. By the time Odum authored this article, he had already begun to reposition ecosystem ecology, and so holism as well, within a broader framework[434].

In other works, the complementary (or at least potentially complementary) relationship between holism and reductionism is approached instead in dialectical terms. Drawing on an article written by Henry Margenau and Ervin László and published in *Philosophy of Science* in 1972, Odum later represented the tension between holism and

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431 Odum, "The Emergence of Ecology as a New Integrative Discipline," 1289.

432 See Craige for more on Odum's characterization of his support of holism as a minority position. In the concluding chapter I shall return to this theme in the context of authors - Craige but also UK Green Party founder Edward Goldsmith and others - who have posited a larger significance for Odum's holism as opposing many of the defining trends of modernity. Craige, *Eugene Odum*, 116 [minority position], xiv [modernity]. Craige, B. J. *Laying the Ladder Down: the Emergence of Cultural Holism*. Amherst, MA: University of Massachusetts Press, 1992. Edward Goldsmith, *The Way* (Boston: Shambhala, 1993), chapter 4.

433 Odum, "The Emergence of Ecology as a New Integrative Discipline," 1289.

434 The following chapter will explore this shift in some detail.

reductionism as alternating emphases in the history of science. In the article, Odum proposed to bridge the gap between reductionism and holism by focusing study on “mesocosms,” which he defined as “bounded and partially enclosed outdoor experimental setups” that brought together the strength of laboratory techniques with more realistic field-based research[435].

Of course, Odum was not the first ecologist to approach ecology as holistic. Odum himself provided a roadmap for the trajectory of holism in ecology in his description of community ecology as a branch of ecology indebted to Karl Möbius' work on oyster beds, Eugenius Warming's work on 'communities' of plants, Henry C. Cowles' work on succession, Charles Elton and Victor Shelford on communities of animals and Frederick Clements on plant communities as super-organisms.[436] While there were many such ecologists whose work could be described as holistic, the word “holism” was coined by South African Jan Christian Smuts in 1926, *after* some of these ecologists had already defined their contribution to ecology. The work, entitled, *Holism and Evolution*, centers on, "The tendency in nature to form wholes that are greater than the sum of the parts

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[435] Eugene Odum, "The Mesocosm." *BioScience* 34*,* 9 (1984): 558. See Kohler for a treatment of the tensions and occasional “border crossings” between these approaches in the context of the history of the early years of ecology in the U.S. Kohler, *Landscapes and Labscapes*, 11-8.

[436] Odum, "The New Ecology," 14. For more on the figures Odum mentioned, see McIntosh, *The Background of Ecology*, 37-43, 52, 71, and 186; Tobey, *Saving the Prairies*, chapters 1, 4, and 5; and Bowler, *The Earth Encompassed*, 368-77. Unlike many of these other ecologists, however, Odum's support of holism—like his support of ecosystem ecology—took on a programmatic character. The question of the actual or specific origin of Odum's support of holism is an interesting one although difficult to settle due to an abundance of reasonable possibilities. In addition to the uptake of holism in ecological work on communities of plants and animals, Odum's father also emphasized a holistic approach to his sociology of regionalism. This is an influence which receives a great deal of emphasis by Craige. She notes, for example, that, “Underpinning all of Gene Odum's ideas about the world is a holism he received from his father, Howard Washington Odum." In addition, famed American zoologist Victor Shelford was on Odum's dissertation committee at the University of Illinois although Charles Kendeigh played a much more direct role in mentoring Odum and guiding his research. Shelford's uptake of holism can be seen in his emphasis, with co-author Frederick Clements, on the biome in their 1939 work *Bio-Ecology*. Craige, *Eugene Odum*, 2 [quote] and 24-7.

through creative evolution."[437] A British Association for the Advancement of Science session held a few years later in South Africa and the ensuing discussion would serve as one of the flash points of a larger debate on holism versus mechanism.[438]

Ironically, in coining the term "ecosystem," Arthur Tansley was reacting against precisely the kind of holistic approach that Odum would later locate at the center of ecosystem ecology. Tansley's critique of Clements' description of communities of plants super-organisms included a critique of Smuts' holism.[439] In the 1935 article in which Tansley coins the word "ecosystem," he targets John Phillips' work as particularly problematic. He notes that, "Phillips' articles remind one irresistibly of a creed—of a closed system of religious or philosophical dogma. Clements appears as the major prophet and Phillips as the chief apostle, with the true apostolic fervour in abundant measure."[440] Of three Phillips article that Tansley singles out, he notes that, "the greater part of the third article [the third part in a larger article entitled "Succession, Development, the Climax, and the Complex Organism: An Analysis of Concepts"] is mainly concerned with the relation of the last concept [complex organism] to the theory of 'holism' as developed by General Smuts and others and is really a confession of apostolic faith."[441] Tansley noted that, while Smuts' notion of holism was "acceptable" on the level of philosophy, it fell short "on the scientific as opposed to the philosophic

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437 J. C. Smuts, *Holism and Evolution* (New York: The MacMillan Company, 1926), 88. As Anker has shown, Smuts was a complicated figure. He jailed Mahatma Gandhi, opposed labor unions and supported racial segregation in South Africa yet he was also a supporter of the League of Nations and human rights and assisted in the writing of a United Nations statement on human rights in 1945. Anker, *Imperial Ecology*, chapters 2 and 4.

438 Anker, *Imperial Ecology*, chapters 2 and 4. Foster and Clark. "The Sociology of Ecology," 333-9.

439 Tobey, *Saving the Prairies*, 185-90.

440 A. G. Tansley, "The Use and Abuse of Vegetational Concepts and Terms." *Ecology* 16, No. 3. (July 1935): 285.

441 Ibid., 286.

plane," where he felt "a good deal of fuss is being made about very little."[442] Tansley, it seems, would not have approved of the way Odum turned his notion of the ecosystem into a program for ecology as a discipline.

VIII. Contesting Odum's "New Ecology"

At the same time that Odum was serving as President of the Ecological Society of America and writing about the arrival of the "new ecology" in the mid 1960s, ecosystem ecology was at the height of its influence in the discipline of ecology. Ecosystem ecology became a major influence to people interested in applying ecology to environmental problems from the late 1960s into the present. As a force in the corridors of academic ecology, however, its influence began to fade in the late 1960s and, particularly, early to mid 1970s as Darwinian approaches foregrounding competition and critiquing approaches, such as ecosystem ecology, emphasizing balance in nature.

Although there were earlier attacks on holistic approaches and even ecosystem ecology specifically, one article has come to signal this shift in ecology. In 1973—almost a decade after Odum's proud declaration of the arrival of a 'new ecology,' William Drury and Ian Nisbet published an article titled simply "Succession."[443] In this article, the authors attacked the notion that plants, for example, should be approached in a holistic way as members of a larger community of plants that have stable attributes. Although the authors singled out Odum in their article, their argument undermined a larger tradition of ecological research of which Odum was only a prominent recent example. The authors'

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[442] Ibid., 297.

[443] Drury, William H., and Ian C. T. Nisbet. "Succession." *Journal of the Arnold Arboretum* 54 (1973): 331-368.

argument applied as well to Clements' super-organism and even Warming's communities of plants as it did to Odum's ecosystems.

Drury and Nisbet went further in attacking longstanding ecological approaches to succession. For ecologists such as Frederick Clements and Eugene Odum, succession was understood as an orderly progression from one community of plants (or plants and animals and non-organic matter) to another until a more stable relation was established. By studying succession in different kinds of environments, ecologists could understand regularities in the stages of succession for given environments. By contrast, Drury and Nisbet maintained that there were no consistent stages in succession and no stable and enduring climax state. Instead, ecologists should recognize that succession is a much messier process in which individual plants and kinds of plants are constantly struggling with other plants and animals to establish themselves in different environments.

Their argument was clearly Darwinian but also drew on the earlier ecological arguments of Henry A. Gleason. In an influential 1926 article entitled "The Individualistic Concept of the Plan Association," Gleason argued against Frederick Clements' approach to communities of plants as super-organisms, Gleason argued that, "an association [of plants] is not an organism, scarcely even a vegetational unity, but merely a coincidence."[444] Gleason replaced Clements' notion of a durable balance between communities of plants and their environment in a climax state with an emphasis on competition.[445] It is easy to see why Drury and Nisbet saw in Gleason's work an important precedent. In its attack on communities of species and on the order in

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[444] Craige, *Eugene Odum*, 89.

[445] For more on Clements' "climax state," see Bowler, *The Earth Encompassed*, 370-8; Mitman, *The State of Nature*, chapter 2; and Nicolson, "Humboldtian Plant Geography After Humboldt," 306.

ecosystems made up of the interactions between various species of plants and animals and their environment, Drury and Nisbet's 1973 article represents a major shift in what many ecologists would take as their object of analysis.

Ecology was changing in other ways as well in these years. If Drury and Nisbet's 1973 article signals a change in the focus of research that emerged from within the discipline, there were other reasons why ecologists might change the focus—and significance—of their research that were external to ecology as an academic discipline. Even before ecosystem ecology had come under attack in the work of Drury and Nisbet and others in the early 1970s, the environmental movement had provided a new audience for ecologists interested in stepping outside of their roles as specialists. Instead of working to further the discipline by researching problems set from within the discipline and by speaking to comparatively narrow professional audiences of fellow ecologists, many ecologists chose to address environmental problems that came into prominence on a public stage that extended far beyond ecology as a discipline. Further, these ecologists addressed themselves and their science to broad, public audiences.

IX. Conclusion

In this chapter I have examined Odum's promotion of ecosystem ecology in terms of his vision for ecology as a discipline and his effort to protect the territory of ecology from the encroachment of reductionist approaches of molecular biology. While radiation ecology provides an opportunity for examining how ecologists such as Odum entered a relationship with the cold war state--and asserted his autonomy from the goals of the state, in this chapter I have foregrounded Odum's efforts to assert the autonomy of ecology as a discipline. As I asserted in chapter 2, the funding, technology, and know how of the Atomic Energy Commission played a significant role in Odum's ability to become a leader in the field of radiation ecology. By foregrounding in this chapter Odum's vision for ecology as a whole, we can see how Odum's largely defensive efforts to counter this position of "technological dependence" (examined in chapter 3) fit into his more general and programmatic efforts (examined in this chapter) to assert the autonomy of ecology as a discipline.[446]

Put another way, this chapter focuses on the autonomy pole of my figurational analysis of the politics of ecology. In his efforts to unify ecology and to provide ecology with the principles it needed to count as a real science--both at the University of Georgia and more broadly, Odum was asserting ecology as an autonomous discipline. Further, in defining ecology as a holistic discipline that investigated the structure and function of nature at certain levels of organization, Odum intended to protect the territory--and autonomy--of ecology in the face of what he saw as the increasing power of molecular biology and of reductionist approaches to science.

In the following chapter, I will foreground how ecology as a science entered into a figuration with the environmental movement. In speaking to broad public audiences motivated to realize a more sustainable society, many ecologists began to reposition the relevance of their work as providing a source of insight on the question of how to live.

[446] For more on technological dependence see Mukerji, *A Fragile Power*, chapter 6, esp. 105.

Chapter 5. From Fact to Value: Ecology as a Normative Science

I. Introduction

The 1960s saw a resurgence in interest in people's place in the natural environment as well as a host of environmental critiques that charged that our relationship with nature was unsustainable, was driven by valuing economic growth over all else, and had toxic health effects that were only beginning to become visible.[447] This position is most commonly associated with the publication of Rachel Carson's *Silent Spring* in 1962, a work that is often credited as the opening shot of the modern environmental movement.[448] Clearly, however, Carson's voice was not the only one intent on drawing public attention to these problems--nor the only one looking to ecology to provide a way of understanding our relationship with our natural world. Motivated to make our relations with the natural world more sustainable, many people turned to ecology in these years for answers to the environmental problems that began to occupy the headlines in newspapers and the covers of magazines. Meanwhile, many professional ecologists had long been interested in the goal of realizing a more sustainable society. In this context, ecology entered into a figuration with the environmental movement, and ecologists began exploring new scientific roles as they addressed themselves and their work to the ends of the environmentalism.

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447 Although this concern with people's place in relation to their natural environment--and environmental social movements--certainly predated the 1960s, here the focus will be on environmentalism from the early 1960s in the U. S. context. For ease of reference, I will refer to this as the "modern" or "contemporary" environmental movement" For a more inclusive history--if one still favoring the U. S. context, see Gottlieb, *Forcing the Spring.*

448 Robert J. Brulle, *Agency, Democracy, and Nature*, 182-3. Riley E. Dunlap and Angela G. Mertig (eds.). *American Environmentalism*, 14 and 19. Jamison and Eyerman, *Seeds of the Sixties*, 66. Lutts, "Chemical Fallout: Rachel Carson's Silent Spring, Radioactive Fallout," 211. David S. Meyer and Deana A. Rohlinger, "Big Books and Social Movements: A Myth of Ideas and Social Change," *Social Problems* 59, no. 1 (February 1, 2012): 136–153. Mark Stoll, "Rachel Carson's Silent Spring, a Book that Changed the World, " Environment and Society Portal. Accessed May 25, 2012, http://www.environmentandsociety.org/exhibitions/silent-spring/overview.

A cover story in the February 2, 1970 edition of *Time* identified "a tiny band of ecologists [who have] achieved sudden prominence" as leading voices in the environmental movement. These "once sheltered ecologists have become ardent advocates of seemingly radical views." In addition to Barry Commoner, the article identified Lamont Cole, Rene Dubos, Paul Ehrlich, Eugene Odum, and Kenneth Watt. The article named these ecologists and biologists "new Jeremiahs" and went on to note that "They do not hesitate to predict the end of the world, or at least the end of a life with quality. Yet they hold out hope too. 'We are in a period of grace,' says Commoner. 'We have the time—perhaps a generation—in which to save the environment from the final effects of the violence we have done to it.'"[449]

In his biography of Barry Commoner, Michael Egan devotes a chapter to the figure of the environmental Jeremiah. Named after the Biblical prophet Jeremiah, environmental Jeremiahs such as Commoner spoke of the dark consequences of our unsustainable relationship with nature:

> Just as the original Jeremiah's dire predictions warned of the destruction of Jerusalem, the new Jeremiahs warned of the ongoing destruction of the Earth's ability to sustain life; both lamented the human fall from grace and saw the human condition and attempts at redemption as almost hopeless.[450]

These environmental Jeremiahs, however--like the Biblical prophet--also provided hope. If we follow the insights provided by ecology and implement a sustainable relationship with nature, we can avoid the doomsday visions of the state of life on a polluted earth.[451]

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[449] "Fighting to Save Earth From Man." *Time Magazine* 95, 5 (February 2, 1970). Accessed July 28, 2009, http://www.time.com/time/magazine/article/0,9171,878179,00.html.

[450] Egan includes Odum as an environmental Jeremiad. Egan, *Barry Commoner*, 99 [quote], 100 [Odum].

[451] Ibid., 99-107. For more on the Jeremiad as an American rhetorical form and "ritual designed to join social criticism to social renewal," see Sacvan Bercovitch, *The American Jeremiad* (Madison: University of Wisconsin Press, 1978) xi.

Historian of ecology Sharon Kingsland has approached the ability of ecologists to provide meaning for our times in significantly more general terms. Ecology, she argues, has become "the natural theology of the twentieth century. It is the way we impose order on the world, an order that helps us to understand our place and role in nature as well."[452] For both Kingsland and Egan, ecologists began, by the 1960s, occupying a role that allowed them to draw on the insights of their science to inform impassioned pleas to convince their audience members to change their relationship with their planet

Clearly, this image of the ecologist as environmental Jeremiah exists in tension with the role of the scientist described in Weber's "Science as a Vocation." For Weber, science is and should remain insulated from the concerns of society, and scientists should avoid looking to their work as a source of meaning or insight about how people should live. The concern for matters of fact that drives science is and must be distinct from concerns over meaning that occupy the religious sphere or concerns over justice that occupy the legal sphere.[453]

Sociologist of science Kelly Moore has summarized her recent work on the politics of scientists such as Barry Commoner and others as focusing on the "efforts of scientists to redefine relationships between fact and value, between politics and science, and between expert and citizen."[454] She argues that by "respond[ing] to the moral and political problems of their day, not only as 'experts' whose authority is based on technical

452 Sharon Kingsland, "The History of Ecology," *Journal of the History of Biology* 27, no. 2 (July 1, 1994): 353. See also Levy Van Sant, *Representing nature, Reordering Society: Eugene Odum, Ecoystem Ecology, and Environmental Politics*. (MA thesis, University of Georgia, 2009), 2.

453 See discussion of Weber's value spheres in the section on "the role of the scientist" in chapter 1.

454 Moore, *Disrupting Science,* 2. See also Thorpe's analysis of the Oppenheimer security hearing as an effort to discipline Oppenheimer according to the bureaucratic logic of the state: " In place of a distinction between loyal and disloyal motives, the Board substituted a distinction between the technical and the moral, limiting the authority of the scientific advisor to the technical." Thorpe, "Disciplining Experts: Scientific Authority and Liberal Democracy," 544.

knowledge, but as moral individuals and/or movement activists."[455] The scientists in her study strayed from Weber's vision of the place of science in society and defining science in a new way--as speaking to questions of value.[456]

The moral and political problems that ecologists responded to in the 1960s and 1970s centered on the state of the environment. And in the process of addressing environmental issues, ecologists such as Odum came to approach ecology as part of a normative effort to establish the value of the environment in order to convince people to protect it. What are we to make of the tension between Weber's insistence on the value neutrality of science and these ecologists willing engagement with questions of value?

From the perspective of academic ecologists, the environmental movement brought with it an up swelling of interest in the work of professional ecologists. Suddenly there was a wide public audience interested in ecologists willing to apply their ecological insights and credentials to speak to these broader issues. Ecology became useful to the environmental movement and became more culturally salient as an academic discipline that could contribute to the solution of highly visible problems such as natural resource scarcity and the health effects of pollution. While this public provided a new readership and an increased sense of public salience for their work, the demands of environmentalists also presented certain challenges to ecologists by asking them to step outside of their traditional role of academics focused on conducting research for a narrow range of fellow academics in the setting of specialized journals and conferences. As ecology entered into a figuration with the environmental movement, it became more

[455] Moore, *Disrupting Science,* 198.
[456] Although Weber does not represent a central theoretical reference for Moore, she does invoke Weber in framing the importance of the scientists she examines. Ibid., 2.

prominent, but the autonomy of ecology was challenged.

This tension is part of what makes the relationship between ecology and the environmental movement such an interesting case study for examining larger questions about the place of science in society and the role of the scientist. Despite the many differences between the politics of the Atomic Energy Commission and the politics of the environmental movement, engagement with the environmental movement also represented a way in which ecologists chose to position their work in relation to a political project in the cold war period. Further, the novelty and distinctiveness of the environmental movement—not only in relation to the AEC but also other social entities in the working environment of academic ecologists (the research university, the changing features of the discipline of ecology, amateur conservationists and ornithologists, and so forth)--made its entry into the setting for academic ecology a significant one.

Employing Norbert Elias' term, the environmental movement changed the *figuration* of ecology as a science in this period.[457] In his description of figuration, Norbert Elias relies on the metaphor of a game. If a new player enters a poker game, say, the game (or figuration) can change as each player has to change his or her strategies to account for and deal with the new player. Applied to the current case, we could say that the environmental movement was a new 'player' operating in relation to ecology as a discipline. Just as the availability of Atomic Energy Commission patronage allowed ecology to become a "big science" and to enter into the field of tensions described by the historiography of cold war science, so did modern environmentalism as a broad social movement alter the possibilities for ecologists, if in a very different way. From the

[457] Elias, *What is Sociology?*, 128-33.

perspective of many ecologists the advent of the environmental movement meant that there was, for much of the 1960s and into the 1970s, a large, public audience interested in the broader significance of their work. While some ecologists viewed this audience as a threat to the professional autonomy of ecology as a discipline, others saw this as an opportunity to extend the readership of ecology and, for some, even a chance to play a role in contesting dominant values. The environmental movement represented more than a large public audience interested in ecology, however, as many environmentalists questioned the value neutrality of science and saw the culture surrounding science and technology as contributing to an unsustainable relationship with the natural world. Instead of approaching environmentalism in search of a coherent message, it is important to realize that the tension between different strains of environmentalism--and between these strains and science--represented an important dynamic in the figuration of environmentalism and science in the 1960s.[458] Eugene Odum provides a case for exploring one way in which ecology entered into a relationship with the environmental movement--and how this relationship presented opportunities for exploring new ways of being a scientist. The changes in the figuration of academic ecologists as well as the novelty of these changes raises important questions for an investigation into the politics of ecology that foregrounds the individual scientist.

To a significant degree, Odum's 1969 essay, “The Strategy of Ecosystem Development” signals a major shift in how Odum was coming to situate the broader significance of ecosystem ecology and to navigate his role as a scientist. In much of Odum's career in the 1950s and early 1960s, ecosystem ecology provided ecology with

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[458] I will return to these tensions in more general form in the concluding chapter.

the principles and coherence it needed to be a distinct discipline. The place of ecosystem ecology was to further the science of ecology in the context of the cold war, and the way to do this was to carve out a niche in which ecologists could work as specialists researching the topics of 'basic' research while receiving funding for 'applied' research. By contrast, science in Odum's 1969 essay has a function that escapes the stricture of specialization. Science here addresses larger social problems. In Odum's essay—and throughout much of his later career, he drew upon the ecological principles he researched and the credibility he acquired while occupying the role of scientist as specialist during the first half of his career in order to critique the relation between humans and nature.

Odum's Atomic Energy Commission funded research at the Savannah River Site provided the basis of his prominence in radiation ecology and a source of funding that he used to build an ecology program at the University of Georgia. But the Atomic Energy Commission was not the only source of external funding that Odum secured. He was also funded by a tobacco heir Richard J. Reynolds to research the coastal marshes of Georgia. In this work Odum began to explore the larger significance of ecological approaches to nature as he began to justify the value of the marshes with reference to their productivity.

Odum's work on the marshes can be roughly divided into four different stages. During the first stage, from the mid to late 1950s, Odum and George Boyd, then head of the University of Geogia biology division, established a research station on Sapelo Island where a small group of ecologists, initially with no heat or phone line, began a tradition of research on the salt marshes of Georgia. In the second stage, from the early to mid 1960s, Odum began exploring the larger significance of his approach to the marshes as a particularly productive part of nature.

This research and initial exploration of the larger value of the marshes positioned Odum to play a significant role in efforts to mobilize a social movement to save the marshes from phosphate mining and real estate development in the late 1960s. The experience Odum gained in this third stage of his work on the marshes would be crucial in Odum's trajectory towards his later, more critical work. It is in this period Odum explored the environmental significance of ecological principles before larger audiences in the format of invited lectures. Before an assembly of activists and wealthy landowners in 1968, for example, he tried out the argument that would re-appear in much more finished form a year later as “The Strategy of Ecosystem Development.” This third stage culminated with the publication of this 1969 article in which Odum's approach to the marshes had become fully generalized as an approach to all of nature, including agricultural areas and cities.

In the fourth stage—from the early 1970s to the early 1980s, Odum began asserting that the value of the marshes and other parts of nature can be conveyed in economic terms. Throughout the development of Odum's normative position, the marshes provided a model for components of nature that were undervalued but ecologically necessary. It is interesting that, in this period, the economic value of the marshes came to mediate between questions of fact and questions of value. The effort to understand the movement of energy through ecosystems such as the coral reef at Eniwetok had transformed into an effort to establish the general (non ecological) value of marshes in order to convince people to protect the marshes and other undervalued components of the environment. In providing a model for components of nature that were undervalued but ecologically necessary, Odum's work on the marshes provides an excellent focal point in tracing the emergence of Odum's environmental critique.

In exploring Odum's research at Eniwetok and the marshes as well as his later politically engaged role, I hope to trace the trajectory by which he came to approach ecosystem ecology as a normative science--as providing answers to questions of value that were emerging from outside of ecology as a discipline. In exploring the contexts in which Odum first researched the ecological principles he would later deploy as a part of his critique, we can see how the place and meaning of ecosystem ecology changed for its most important promoter. Instead of providing an answer to the problems of ecology as a discipline (as I explored in the previous chapter), it would provide an answer to larger scale environmental dilemmas. Odum's audience would change as well. Instead of addressing fellow professional ecologists and ecologists-in-training, Odum began to address broader and more public audiences in an effort to convince them of the importance and sources of environmental issues as well as ways to resolve these issues.[459]

II. The Strategy of Ecosystem Development

In 1969 Odum published an article in *Science* that would become far and away his most-cited work.[460] In the article, titled "The Strategy of Ecosystem Development" Odum

459 While focusing this chapter on the shift in Odum's thinking leverages one of the strengths of investigating one scientist's career in some detail, in this case it necessarily does so at the expense of exploring Odum's later critiques in detail. In concluding the chapter, I will provide a sense of some of the important directions these later critiques would take. Here we will see the way Odum drew off of the vocabulary of a comparatively brief encounter he had NASA in the mid 1960s to provide the vocabulary for describing natural resources as a "life support system" on which our lives depend. We will also see how Odum came to characterize his critical work as "human ecology." In the following chapter, I will explore other professional ecologists' earlier critiques. There, efforts to establish human ecology as a field within academic ecology in the 1950s reveals a more thoroughgoing effort to redefine the place and significance of ecology as a way of addressing large scale environmental issues.

460 As of May 2, 2012, Thomson Reuter's Web of Science database indicated that Odum's "Strategy of Ecosystem Development" article has been cited 2,050 times, while "Trophic Structure and Productivity of a Windward Coral Reef Community on Eniwetok Atoll," which he co-authored with his brother Howard, has been cited 457 times, closely followed by a 1985 article "Trends Expected in Stressed

adopted a position that stood in contrast with much of his earlier writing, much of which was aimed at locating ecosystem ecology, and the principles of ecosystem ecology, at the center of ecology as a coherent and distinct discipline. The subtitle of this article named a different goal: “An understanding of ecological succession provides a basis for resolving man's conflict with nature.” Here, 'resolving man's conflict with nature' provides an alternative goal for the development and understanding of ecological research—a goal set not by the discipline of ecology but by an increasing public awareness of human's dependence on the environment for continued survival.

A largely implicit, but very important feature of this article is in the way it situates the principles of ecology as a science in relation to larger environmental problems. In order to do this, Odum outlines an approach to succession in terms of energy.[461] While traditional approaches to succession emphasis the patterns of plants and animals that come to re-inhabit disturbed ecosystems in a series of more or less distinct stages, here Odum defines two stages—young and mature ecosystems—using the technical terms 'productivity' and 'respiration.' After outlining this theory of succession in the terms of

Ecosystems,” cited 448 times. While the use of citation indices have come under fire as a way of indicating communities of scholars sometimes termed 'invisible colleges,' here these numbers are intended as a rough guide of the extent to which Odum's “Strategy” was taken up and discussed in relation to his other work. Of course, the index does not register the uptake and influence of successive editions of Odum's *Fundamentals of Ecology*, which by all accounts, has been considerable. Accessed August 1, 2011, http://apps.webofknowledge.com. Howard T. Odum and Eugene P. Odum, “Trophic Structure and Productivity of a Windward Coral Reef Community on Eniwetok Atoll,” *Ecological Monographs* 25, 3, (July 1955): 291-320. Eugene Odum, "Trends Expected in Stressed Ecosystems," *BioScience* 35, 7 (1985): 419-422.

461 Although he was clearly drawing on early twentieth century ecologist Frederic Clements' notion of stages in succession proceeding towards a “climax state,” he redefined succession in quantitative and 'bioenergetic' terms, as being driven by the ratio of productivity to respiration. Odum summarizes Clements' more traditional approach to succession in plain language in his 1963 introductory book on ecology, titled simply *Ecology*, “One of the most dramatic and important consequences of biological regulation in the community is the phenomenon of ecological succession. When a cultivated field is abandoned in the eastern part of North America, for example, the forest that originally occupied the site returns only after a series of temporary communities have prepared the way. The successive stages may be entirely different in terms of structure and function from the forest that eventually develops on the site.” Eugene Odum, *Ecology*, (New York: Holt, Rinehart and Winston, 1963), 77.

academic ecology, Odum proceeds to apply it to 'man's conflict with nature.' Like young ecosystems, humans' relation to the environment is largely defined by short sighted efforts to approach nature with the goal of maximizing productivity—in maximizing agricultural yield, for example. For Odum, however, these efforts are problematic because humans are no longer in this stage of development. The current stage of human development is more akin to mature ecosystems. Large cities, for example, require proportionally much more energy to keep functioning than small towns. Humans need to realize that, as is the case in mature ecosystems, more attention and more energy needs to be devoted to upkeep—and engaging in a sustainable relationship with nature. By modeling the relation between cities and undeveloped nature on mature ecosystems, Odum was using the voice of ecology as a science to provide a rationale for establishing a more balanced relationship with nature. And what, for Odum, should we do about this crisis? The answer was more enlightened land use zoning.

This article is remarkable for a number of reasons. In addition to being the most widely cited of Odum's publications, the article blended ecological theories and environmental criticism. They are so tightly woven together, in fact, that it would be difficult to draw a line between where the science ends and the critique begins. This is significant, I argue, because it indicates a shift in Odum's approach to ecology. The main point of the article—and a significant percentage of Odum's publications after this point—is not to add to ecological theory but to apply this theory to environmental problems unfolding on a much larger, and more public, stage than that of the discipline of ecology.

The essay is significant as well in heralding many of the elements that would become regular features in many of Odum's later critiques. Central among these is

Odum's emphasis on productivity and more specifically his emphasis on the ratio of productivity to respiration and his use of this ratio as an index of an ecosystem's place in succession. For Odum, this emphasis on productivity followed the emphasis in the work of G. Evelyn Hutchinson, and subsequently as a central part of his ecosystem ecology, on energy as one of the core focal points of postwar ecology.[462] In this essay, Odum approaches succession in terms of energy.[463] He defines succession, a well worn topic in American ecology, as "an orderly process of community development that is reasonably directional and, therefore, predictable." Proceeding according to an interaction between a community of plants and animals and the environment, the process "culminates in a stabilized ecosystem" or a community of plants and animals that are in a state of balance with their environment.[464]

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462 See the previous chapter for more discussion on the movement of energy and matter through the environment.

463 Although he was clearly drawing on early twentieth century ecologist Frederic Clements' notion of stages in succession proceeding towards a "climax state," he redefined succession in quantitative and 'bioenergetic' terms, as being driven by the ratio of productivity to respiration. Odum summarizes Clements' more traditional approach to succession in plain language in his 1963 introductory book on ecology, titled simply *Ecology*, "One of the most dramatic and important consequences of biological regulation in the community is the phenomenon of ecological succession. When a cultivated field is abandoned in the eastern part of North America, for example, the forest that originally occupied the site returns only after a series of temporary communities have prepared the way. The successive stages may be entirely different in terms of structure and function from the forest that eventually develops on the site." Odum, *Ecology*, 77.

464 Odum, "Strategy of Ecosystem Development," 262. As many scholars have noted, this notion of balance was an important ingredient in ecologist's theories about nature from the beginning of the 20th century through the 1960s. But it also a crucial of environmentalists' claims about how we should relate to nature—ie,in a more balanced way. Worster and Craige make much of the ways in which ecological theories can enable and constrain environmentalists' claims. For both Craige and Worster, notions of balance in the work of Eugene Odum but also Paul Sears, whose work we will be exploring in more detail in the following chapter, provided a key resource to the claims of the environmental movement. In contrast, the emergence of schools of ecology, such as population ecology—and particularly from the early 1970s, emphasizing competition seemed to run counter to the end of a balanced relation with nature as portrayed by many environmentalists. If nature is defined by competition and there are no lasting climax states, then attempts to establish lasting order in nature can be read as misguided efforts to fix nature in the image of 'man.' Joel Hagen approaches the tension between these positions in a larger framework. Both competition and balance are embedded, he argues, in Darwin's work, and the tension between the emphases can be traced throughout the history of ecology up to the present day. In "The Strategy of Ecosystem Development" Odum invoked an ecological notion of balance (in terms of energy, or the ratio of productivity to respiration) to provide a reason why the larger public must achieve

More specifically, he argues ecosystems that are young (at an earlier stage in the process of succession) are very productive—effective at transforming the energy of the sun into biomass. Put in simple terms, these ecosystems produce more energy than they need to survive. And this makes sense because, as young ecosystems they are in a greater state of competition and need to be effective in using available energy in order to establish themselves. Using the more technical terms of professional ecology, rate of production (P) of young ecosystems exceeds their rate of respiration (R), or the energy required to maintain themselves. The ratio of productivity to respiration (or P/R) is high in young ecosystems.[465]

As ecosystems age or become more 'mature,' their "strategy" changes. The amount of energy they produce decreases, and the amount of energy they require to survive increases. The ratio of production to respiration (or P/R) decreases. While there were other indicators that went along with changes in stages of succession—nutrient conservation, decrease in entropy and increase in information , for example—the ratio of production to respiration was "an excellent functional index of the relative maturity of the system."[466]

This energetic approach to succession informs Odum's assertion that people need

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a more balanced relation with nature. As I will discuss more below, the insights of ecology were being applied to the ends of environmentalism. Donald Worster, "The Ecology of Order and Chaos," *Environmental History Review* 14, 1/2 (1990), 1–18. Worster, *Nature's Economy*, chapter 13. Craige, *Eugene Odum*, 91-8. Hagen, *Entangled Bank*, chapters 1 and 8.

465 Ibid., 263.

466 Ibid.. As I will explore below, one of the earliest places we see this focus in Eugene's work is in his research, with his brother Howard, on the respiration of a coral reef in Eniwetok—research that was funded by the AEC and published in 1955 as "Trophic Structure and Productivity in a Windward Coral Reef Community on Eniwetok Atoll." The paper won the brothers the prestigious Mercer award a year later in operationalizing Hutchinson and Lindemann more theoretical emphasis on energy transfer. In this work the Odum brothers approached increases in levels of oxygen as the productivity of algae on coral polyps through photosynthesis. They used night time measurements of oxygen levels—when there was no photosynthesis—to indicate respiration. Hagen, *Entangled Bank*, 101-6. Craige, *Eugene Odum*, 58-66, esp. 61-2. "The George Mercer Award for 1956," 2-3.

to change how they relate to the environment. In a section entitled "Relevance of Ecosystem Development Theory to Human Ecology," Odum argued that humans tend to attempt to maximize (ecosystem) productivity as part of an effort to be more economically productive, and earn more money.[467] This tendency is in "a basic conflict" with the ecological principle by which ecosystems tend towards a balanced relationship with their environments.[468] While our emphasis on productivity fits in better with ecosystems in younger stages of development, our survival on earth depends on the things that mature ecosystems provide (such as an atmosphere with a balance of carbon dioxide and oxygen).[469] In mature ecosystems the balance of productivity and respiration, energy spent to apply energy to produce things and energy spent for maintenance, signals a state of balance or homeostasis.[470] It is also the “climax” state that represents a lasting fit between a community of organisms and that community's environment.[471]

Although our continued survival on earth depends on the continued functioning of the many mature ecosystems surrounding us, we nonetheless favor the productivity-centered characteristics of a young ecosystem. In order to address this problem, humans need to realize that "the landscape is not just a supply depot but is also the *oikos* - the

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467 Odum, "Strategy of Ecosystem Development," 266-7.

468 Ibid.

469 Odum's example of human's effort to make the earth more productive is through monoculture, or the agricultural effort to constrain diversity of plants and animals that might have lived in a given environment in order maximize productivity of one plant. Ibid., 266.

470 Homeostasis represents an interesting focal point in Odum's work. Craige argues that Odum first applied physiological notions of homeostasis from Walter Cannon's 1932 work, *The Wisdom of the Body*, to his early ornithological work on the heart rate and fat content of birds. When his research and writings came to emphasize a larger scale focus on ecosystems, he came to apply homeostasis to the level of the ecosystem. In Cannon's work homeostasis represents a central analytic applied to a variety of physiological processes (blood sugar, blood proteins, blood fat, blood calcium, blood neutrality, and the sympathico-adrenal system). Walter B. Cannon, *The Wisdom of the Body*, Second ed. (New York: W.W. Norton and Company, Inc, 1939), chapters 6-9, 11, 16, and epilogue, esp 287-306. Craige, *Eugene Odum*, 60-6 and 110-23.

471 Odum, "Strategy of Ecosystem Development," 263.

home - in which we all must live."[472] Humans, in other words, should act according to the principles that ecology as a science has made apparent.

Odum argued that an ecological form of land use zoning provided an effective response to the environmental crisis. It is important to note here that Odum is not approaching zoning in the usual sense of zoning areas of a city for residential or commercial purposes. Instead, Odum proposes a much broader kind of zoning that attempts to approach components of nature in ecological terms—as sources of energy or consumers of energy.[473] Areas, or "compartments," such as undomesticated nature (receiving energy only from the sun) should be protected as they provide the energy needed for intensive agriculture and for cities, which depended almost entirely on energy (whether in the form of food or more basic services such as oxygen) coming from undomesticated nature and, to a lesser extent on areas used for agriculture.[474] On a basic level, land use planning represented an effort to draw attention to the ecological value of undeveloped areas in order to achieve a more sustainable relationship with the environment. By developing more and more of the undomesticated environment for agricultural uses or for suburban housing, say, we are rendering our continued existence on earth progressively more precarious. In addition to landscape zoning to control the

[472] Ibid., 266.

[473] Although this emphasis on land use zoning would not be a lasting feature of Odum's later critical work, it nonetheless provides an opportunity to explore the way that Odum attempted to base a regulatory response to environmental issues on the principles of ecosystem ecology.

[474] Odum, "Strategy of Ecosystem Development," 268-9. In a 1972 publication, the Odum brothers extend this argument by maintaining that the amount of energy required to maintain developed areas, such as cities, increases *disproportionately* to the increase in the size of the developed areas themselves. They go further in drawing on Claude Shannon's work to formalize this relationship between developed systems, such as cities, and natural systems that receive no energy inputs: "Developed systems generate economic wealth, but *the economic cost of maintenance increases as a power function of the intensity of development.*" Eugene P., Odum, and Howard T. Odum, "Natural Areas as Necessary Components of Man's Total Environment," in *Ecological Vignettes: Ecological Approaches to Dealing with Human Predicaments*. Amsterdam: Harwood Academic Publishers, 1998), 134 [emphasis in original].

conversion of undomesticated nature, for Odum the education of the populace in ecological principles would be necessary so that they too could understand the need for action.[475] Based on the insights of ecology, people should realize the importance of undomesticated nature and start acting accordingly.

III. Eniwetok and the Ecology of Productivity

In the summer of 1954, Eugene Odum and his brother Howard T. Odum spent several weeks paddling around the coral reefs surrounding the coral reef of Japtan in the Eniwetok atoll. Based out of a military base, the brothers would be dropped off with their sandwiches each day by helicopter and wade in the water pushing around a raft full of equipment and samples.[476] The research they were doing garnered the brothers a prestigious Mercer award for "for an outstanding ecological research paper published by a younger [under 40] researcher" in 1956, and provided the central terms that would inform Eugene Odum's later environmental critique.[477]

Here I will explore the research leading to this publication in terms of the emphasis, in Eugene Odum's later critique, on productivity of ecosystems and the ratio of productivity to respiration as a way of gauging the relative maturity of an ecosystem.[478] In the context of this later article, the contrast between young and mature ecosystems was

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475 Odum, "Strategy of Ecosystem Development," 269.

476 Although Odum's log provides a terse account of the development of the research, Eugene indicated in his correspondence with his wife Martha, that it would be an exciting, if very busy, summer. UGA 06 032, box 1. See also Craige's intimate account of the research. Craige, *Eugene Odum*, 58-66.

477 The 1955 article that would come from this research would be Eugene Odum's second most cited article at--according to Thomson Reuter's Web of Science database—433 times as of August 1, 2011. See Jonathon Levine's description of the award from Ecological Society of America website here http://www.esa.org/aboutesa/awards.php. "The George Mercer Award for 1956." *Bulletin of the Ecological Society of America* 38, no. 1 (March 1, 1957): 2–3.

478 Odum, "Strategy of Ecosystem Development," 263.

important as a way of talking about a mismatch between how we should relate to nature and how we relate to nature in practice. Before the brothers' much earlier research on Eniwetok, this ratio was not yet a part of Eugene Odum's scientific vocabulary. Here, I will introduce this principle in the context of the original research in order to provide a sense of the place it held for Eugene Odum in the 1950s. In juxtaposing this place with the place it held in his 1969 article, we can gain a comparative sense of the different ways Eugene Odum framed the central importance of his scientific research.

One of the most innovative features of the Odum brothers' research at Eniwetok was the way it operationalized emerging focal points in ecological research. From the 1940s G. Evelyn Hutchinson and his students were successfully positioning the movement of energy and the movement of matter (or biogeochemical cycling) at the forefront of the research agenda for academic ecology in the United States. Eugene Odum assisted in this effort by placing these terms at the center of his definition of ecosystem ecology in his widely used 1953 textbook *The Fundamentals of Ecology.*[479] At this time, however, there were still few studies that modeled a way for ecologists to study these principles in an empirical way.[480] The Odum brothers' research paper did precisely this for ecologists interested in studying the flow of energy through aquatic ecosystems.

In order to make sense of the Odum brothers' contribution in this article, it will be necessary to review the way their work fit into the comparatively novel emphasis on approaching trophic levels, or the segmentation of species by their place in the food chain, in terms of energy and productivity. By the 1950s, establishing the food chains

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479 See the previous chapter for a discussion of the writing and publication of *Fundamentals of Ecology* and the influence of Hutchinson and Lindeman's work.

480 Odum, *Fundamentals of Ecology*, 83-6.

linking together specific species of plants and animals as predators and prey had long been a goal for ecologists. In his widely read work *Animal Ecology*, the eminent British ecologist Charles Elton captured this focus in his effort to represent food chains or trophic levels in the form of a “pyramid of numbers."[481] The base of a pyramid is made up of whatever occupies the base of the food chain. Generally this would be organisms—such as algae or phytoplankton on water or plants on land—that do not feed on another organism but instead convert inorganic molecules into organic compounds through the process of photosynthesis. The next trophic level or level of the pyramid would be made up of organisms, such as insects, that feed on species at the lowest level of the pyramid. At each progressive level of the pyramid, there are fewer and fewer species feeding on the much more abundant species at lower levels of the pyramid.

Hutchinson's post-doctoral student Raymond Lindeman famously re-interpreted Elton's pyramid of numbers in terms of the flow of energy through the ecosystem in a 1942 article entitled “The Trophic-Dynamic Aspect of Ecology.”[482] Here, the organisms on the base of the pyramid are “*producer* organisms, employing the energy obtained by photosynthesis to synthesize complex organic substances from simple inorganic substances.”[483] As species occupying higher levels of the pyramid feed on the species occupying the lower levels, the energy from the sun is transferred to higher levels of the pyramid. At each level, however, there is a significant loss of energy. Just as the insects and animals do not make full use of the organic matter produced by phytoplankton or

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[481] Elton, Charles S. *Animal Ecology* (Chicago: University of Chicago Press, 2001), 68-70.

[482] The “trophic dynamics” in the title refers to, “the transfer of energy from one part of the ecosystem to another.” For an account of the influence of this article, which Hagen has referred to as "one of the great intellectual watersheds in the history of ecology,” see the discussion in chapter 4 on "The Notion of the Ecosystem." Lindeman, "The Trophic-Dynamic Aspect of Ecology," 408-9, 400 [quote]. Hagen, *The Entangled Bank*, 94.

[483] Lindeman, "The Trophic-Dynamic Aspect of Ecology," 400 [emphasis in original].

algae, so does the algae not make full use of the energy provided by the sun. This focus on energy allowed each trophic level or species to approached in terms of the transfer of energy from lower to higher trophic levels (or levels of the pyramid) but also in terms of productivity.[484] For historian of ecology Joel Hagen, Lindeman's 1942 paper served as a "promissory note" that was then cashed by the Odum brother's study of Eniwetok.[485] The paper was the first published analysis of an entire ecosystem in the terms laid out by Lindeman.

In their research on Eniwetok, the Odum brothers implement the "trophic dynamic" approach described by Lindeman and elaborated by Eugene's brother Howard, who had also been a student of G. Evelyn Hutchinson.[486] On the coral reef of Japtan, the brothers approach the existence of such a complex biological community in

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[484] As much of Lindeman's argument, this emphasis on productivity can be traced to the influence of his mentor, G. Evelyn Hutchinson—here citing Hutchinson's then forthcoming work *Recent Advances in Limnology*. Interestingly, we can detect the novelty of Hutchinson's emphases and approach in established limnologist Juday's negative reaction to Hutchinson's forthcoming book. In private correspondence, Juday noted that, "Deevey [Hutchinson's student Edward S. Deevey] tells us that H. [Hutchinson] is writing a book on limnology and it is to be chiefly mathematical. So you can look forward to the worst." In correspondence the following year, he provides a similarly critical account of Hutchinson's methods: "In a short time I shall expect them [Deevey and Hutchinson] to tell all about a lake thermally and chemically just by sticking one, perhaps two, fingers into the water, then go into a mathematical trance and figure out all of its biological characteristics." Elsewhere, he noted of this trend in ecology that, "it will not be necessary to go to visit a lake at all in order to get its complete chemical, physical, and biological history." The fate of Hutchinson's then forthcoming work is uncertain as Slack's bibliography of Hutchinson's work does not contain a work titled *Recent Advances in Limnology* published in 1942. Hutchinson did publish four volumes of *A Treatise on Limnology* across thirty six years (1957, 1967, 1975, and 1993). Hutchinson published the first and second volume of *A Treatise on Limnology*. The first (1957) volume was subtitled *Geography, Physics and Chemistry*, and the second (1967) volume was subtitled *Introduction to Lake Biology and the Limnoplankton*. Lindeman, "The Trophic-Dynamic Aspect of Ecology," 402. Slack, *G. Evelyn Hutchinson*, 149 [quotes] and 434-7. G. Evelyn Hutchinson, *A Treatise on Limnology, Vol. 1: Geography & Physics of Lakes* (New York: John Wiley and Sons Inc, 1957); G. Evelyn Hutchinson, *A Treatise On Limnology, Vol. 2 - Introduction To Lake Biology and The Limnoplankton,* (New York: John Wiley and Sons, 1967). G. Evelyn Hutchinson, *A Treatise On Limnology, Vol. 3 - Limnological Botany,* (New York: John Wiley and Sons, 1967). G. Evelyn Hutchinson, *A Treatise on Limnology, Vol. 4: The Zoobenthos*. Edited by Yvette H. Edmondson. Volume 4 (New York: John Wiley and Sons, 1993).

[485] Hagen, *TAn Entangled Bank*, 101.

[486] This account is built on Odum's personal log from the Eniwetok research and fills in the gaps with the accounts provided by Craige and the Hagen. UGA 06 032, box 1. Craige, *Eugene Odum*, 58-66. Hagen, *An Entangled Bank*, chapter 6.

the middle of the ocean as a mystery. Sampling the sea water in the ocean surrounding the reef, the brothers determined that it had too little plankton and nutrients to support the coral (that would use tentacles to try to catch free floating zooplankton) or the organisms living in and under the coral.[487] This indicated to the brothers that the coral must have been dependent on the algae that had bored into the exterior of the coral's outer skeleton.[488]

In order to get a sense of the productivity of the algae, the Odum's implemented a “diurnal flow” method. As the seawater flowed over the Japtan reef, the brothers were able to measure the oxygen content of the water simultaneously on each side of the reef—as it flowed into and out of the reef—in order to develop a sense of how the oxygen level was changing because of the reef and the algae. An increase in oxygen during the day signified the net of photosynthetic activity during the day while a decrease in oxygen during the night indicated the total respiration of the community, or the amount of energy needed for maintenance.[489]

In determining that the productivity (or P) of the coral ecosystem roughly matched the amount of energy, or oxygen, needed to maintain itself (respiration or R), the Odum brothers concluded that they had discovered not only a mutualistic relation but also an ecosystem in equilibrium. The productivity of the algae provided the nutrients on which the coral could live as a species on a higher trophic level. Interestingly, the Odum brothers interpret the relatively balanced ratio of production and respiration in terms of traditional ecological theory—as a stable state towards which areas in succession trend.

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487 Odum and Odum, "Trophic Structure and Productivity," 291-2. Craige, *Eugene Odum*, 59.

488 Odum and Odum, "Trophic Structure and Productivity," 297-9. Craige, *Eugene Odum*, 59. Hagen, *An Entangled Bank*, 103-4.

489 Odum and Odum, "Trophic Structure and Productivity," 314. Craige, *Eugene Odum*, 60. Hagen, *An Entangled Bank*, 105.

Here the emphasis in Frederick Clements and others on the move of unstable environments to a stable "climax" state is described as a "steady state."[490] They note, for example, that,

> The gains and losses [of energy or production and respiration] are only 4% apart. In view of the rough nature of some of the estimates it is not certain whether this is a significant difference or whether the community is in a perfect steady state with losses matching gains.[491]

The brothers go on to conclude, tentatively, that this rough balance in the ratio of production and respiration indicates that the Japtan coral reef, "is a true climax community, in the ecological sense."[492] Not only was the ratio of productivity to respiration an important focus of this research at Eniwetok, the ratio was also approached as an indication of the successional stage of the coral ecosystem. Because the ratio was more or less balanced, the brothers concluded that the coral was in balanced and stable relationship with its environment. It was in a climax state.

Although the study was collaborative and benefited from the experience and work of both brothers, this method, as well as the larger focus on energy, came from Eugene's brother Howard. In correspondence to Dr Sidney Galler in the Biology Branch of the Office of Naval Research, Howard noted in August, 1953 that,

> Last spring my brother, Dr EP Odum, ecologist at the University of Georgia who has been working with the AEC in connection with a project on the H bomb area on the Savannah river indicated that there might develop an opportunity to make use of a sort of a biological station that the AEC has at the moment at Enewetok [sic]. At that time I made some suggestions that we needed to extend our production measurements to a

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490 Odum and Odum, "Trophic Structure and Productivity," 293. For more on Clements' "climax state," see Bowler, *The Earth Encompassed*, 370-8; Mitman, *The State of Nature*, chapter 2; Tobey, *Saving the Prairies*, 81-2 and 164-5; and Nicolson, "Humboldtian Plant Geography After Humboldt," 306.

491 Odum and Odum, "Trophic Structure and Productivity," 317.

492 Ibid., 318.

> coral atoll using methods we have been developing in the springs.[493]

The springs that Howard refers to was his study site after joining the faculty at the University of Florida, the Silver Springs. Here, he built on the emphasis in Hutchinson and Lindeman to approach the Springs in terms of energy and productivity. As in the 1955 study, he measured the oxygen and organic matter in the water at different places and points in time.

Given the significance of this emphasis on ecological productivity in Eugene Odum's more explicitly normative later work, it bears emphasizing that the approach, and Odum's application of it, were motivated by the desire to further ecology as a science. The approach itself bears the stamp Hutchinson and Lindeman's emphasis on trophic structure as a key to understanding the metabolism of an ecosystem.[494] Eugene's brother—and Hutchinson's student—Howard was first author on the paper and was responsible for bringing his interest in energy as a primary research focus (an interest that would define his work for decades) and his methods from his Silver Springs work, which predated the Eniwetok collaboration.[495] In this connection, it is significant that the chapter on energy in

493 UGA 06 032, box 1. Correspondence dated August 15, 1953.

494 Odum and Odum, "Trophic Structure and Productivity," 297-318.

495 We can see this in correspondence from Howard to Eugene providing updates on his work as the brother were planning for their Eniwetok research. See, for example, Howard's note that, "I almost have finished constructing a pyramid of number and weight for Silver Springs including bacteria." In another letter to Eugene, Howard notes that he has, "turned up a couple of shocking surprises." He was alarmed to find that, "Sargent and Austin (Austin the Limnology and Oceanography secretary who was knoked [sic] out of the picture for the time by polio paralysis last year---former Hutchinson student) had done exactly the thing I was thinking of. That is they found a place on the reef where the water flowed over regularly and measured the oxygen at the inflow and outflow day and night and subtracted just as I do in Silver--thus my basic method was scooped and I did not even know it. They made estimations of production which look good. " UGA 06 032, box 1 [both letters undated]. We can see the pyramid in his 1957 article summarizing his work at Silver Springs. Howard T. Odum, "Trophic Structure and Productivity of Silver Springs, Florida," *Ecological Monographs* 27, no. 1 (January 1, 1957): 84. The accounts of the Eniwetok study in Hagen and Craige as well as Taylor's account of Howard T. Odum's work in Silver Springs, Florida provide further support for Howard's role in setting the agenda for the Eniwetok research. Hagen, *An Entangled Bank*, 102-3; Craige, Eugene Odum, 59; Taylor, "Technocratic Optimism, H.T. Odum and the Partial Transformation," 226-8.

the 1953 edition of Eugene's textbook was coauthored by his brother.[496] Further, this researched earned the brothers the Mercer Award because of its importance in pointing to new lines of research within the field of ecology as an internally directed research enterprise.[497]

As we have seen, however, this research would take on broader significance for Odum as he began situating ecosystem ecology as providing answers to environmental problems that extended beyond the discipline of ecology. In fact the ratio of productivity to respiration would provide one of the central pillars of Odum's 1969 essay "The Strategy of Ecosystem Development." In a later retrospective account of the Eniwetok research, Odum would ask in a rhetorical tone, "Do these coral reef discoveries have any significance for urban industrial man? Perhaps they do."[498]

IV. Tidal Marshes and the University of Georgia Marine Institute

After Eugene Odum returned to Georgia from Eniwetok, he applied a similar emphasis on productivity to the coastal marshes of Georgia. However, when it came to his work on the marshes, Odum's assertions about the ecological productivity of the marshes would soon become part of an argument to the larger public about the *value* of marshes as a part of nature that was traditionally not valued. Although his rationale relied on ecological principles, he would come to make this argument to audiences that extended far beyond the discipline of ecology and included business people, activists, property owners, college students and a Georgia governor. In these moments, ecology—

[496] UGA 06-032, box 1. For more on this textbook including the correspondence between Eugene and his brother on this chapter, see the section of the previous chapter entitled "The Fundamentals of Ecosystem Ecology."

[497] Hagen, *An Entangled Bank*, 101-6. "The George Mercer Award for 1956," 2.

[498] Odum, "The Emergence of Ecology as a New Integrative Discipline," 1290.

and particularly the ecological approach to energy—would provide the logic for a general argument about how people should relate to their environment. Odum did not begin his research on the marshes in the mid 1950s with this goal in mind. Nor did this position emerge in a fully elaborated and internally consistent way in the form of a book or a journal article. Instead, Odum explored different ways of talking about the value and even the productivity of the marshes from the early 1960s into the early 1980s and beyond.

Here I will approach these shifts in term of what they can tell us about how Odum was beginning to position ecosystem ecology in these years. As we shall see, from the early 1960s, Odum would try on a number of different ways of conveying the ecological value of the marshes and before wider and wider audiences. As his audience broadened, so did the ecological rationale for the value of the marshes assume new forms. In the 1970s and early 1980s, Odum would continue this movement as he devised ways of assigning economic values to the marshes and then other undervalued components of nature. And in the 1980s and 1990s Odum stepped up his efforts to reach a broad, public audience with the successive editions of popular books such as *Ecology and our Endangered Life Support Systems* in 1989 and 1993—republished in revised form as *Ecology: A Bridge Between Science and Society* in 1997—and *Ecological Vignettes: Ecological Approaches to Dealing with Human Predicaments* in 1998.

When approaching the trajectory of Odum's work on these marshes, it is possible to divide his work into five periods. From the mid to late 1950s Odum was in the beginning stages of researching the marshes and was busy with the work of setting up a research station on land that he gained access to on the Georgia coast. This period would culminate with the formation of the University of Georgia Marine Institute in the late

1950s and the publication of early research findings on ecological functioning of populations of species *within* the marshes. From the early to mid 1960s, Odum would begin reflecting, if in a somewhat tentative way, on the larger (and unrecognized) value of the marshes, often in comparison to other parts of nature that were valued, such as agricultural land or land for real estate development. In the late 1960s, this move towards asserting the value of the marshes would intensify as Odum became involved with activist efforts to save the coastal marshes of Georgia. Importantly, it was during this period that Odum's approach to the marshes became generalized to all of nature, a position modeled in his 1969 essay "The Strategy of Ecosystem Development." Later, in the early 1970s into the early 1980s, Odum began asserting the economic value of marshes and other areas. From the early 1980s and into the 1990s Odum would elaborate on the positions he was assuming from the late 1960s in books aimed squarely at the larger public. During this time, the marshes would become one of many examples all directed towards a much more general effort to institute a more balanced relationship with nature, and more implicitly to position ecology as providing answers to environmental problems. Phrased another way, by this time the historical importance of the marshes in Odums formulation of his critique would become effaced as Odum had become comfortable with his approach to ecology as a normative science.

For the remainder of this chapter, I will focus on Odum's progression through these stages of his work on the marshes - and particularly through the fourth stage.[499] This trajectory highlights how Odum came to situate the relevance of his scientific work in

499 I choose to foreground the first through fourth stages because they witness the largest shifts in Odum's approach towards ecology as focused on matters of fact to being focused on matters of value. While the fifth stage saw Odum generalizing his approach to marshes to the rest of nature, by this time the terms of his normative stance were largely established.

terms of problems that extended beyond the boundaries of ecology as a discipline. The progression is important as an index, in other words, of Odum's move towards approaching ecology as a normative science.

Attending this shift towards ecology as a science capable of adjudicating matters of value, Odum explored a scientific role that diverged in significant ways from the vocational ethos described in Weber's essay “Science as a Vocation.”[500] In contrast with the role that Weber describes, the second half of Odum's career models a scientific role that included the possibility of public critiques and asserted a broader significance for scientific research as a way of making life on earth more sustainable and better.[501]

Odum's introduction to what would be a long term research program focusing on coastal marshes began in a somewhat haphazard 1948 meeting while on a bird watching trip with a fellow professor and a prospective graduate student.[502] The three were on the hunt for a Mexican bird, the Chachalaca or *Ortalis vetula*, that had been introduced to a coastal island by the island's previous owner. When the current owner and tobacco heir Richard J. Reynolds learned of the scientists' presence, he was intrigued. At the time, he was entertaining guests as well as medical doctors looking after his pregnant wife. He ducked out with a bottle of expensive scotch and spoke with the scientists about his plans for the island. Using it to raise cattle and as a dairy farm was not working, so he was planning on building an exclusive resort, the "Sapeloe Plantation Inn." The scientists,

500 Particularly from the mid to late 1960s.

501 Although I will provide examples of this shift below, Odum's oft repeated injunction that humans need to stop growing bigger and start growing better provides one example. His essay “What We Learn From Ecology About Growth” in his 1998 book *Ecological Vignettes* provides an example of this theme.

502 The account in this and the following paragraphed represents a synthesis of the coverage provided by Craige, Eugene Odum, 54-8; Odum, “Turning Points in the History of the Institute of Ecology,” 13-37; and particularly L. R. Pomeroy and Donald C. Scott, "The University of Georgia Marine Institute: The First Decade," In *Holistic Science: The Evolution of the Georgia Institute of Ecology (1940-2000)* ed. by Gary Barrett, et al. (New York: Taylor and Francis, 2001), 128-142.

meanwhile, asserted the value of the island as a place to research wildlife. In fact, Reynolds' plan for the resort would later fail for lack of an attraction, such as a golf course or beach.[503] But in 1952--four years after his meeting with Odum, Reynolds contacted University of Georgia President O.C. Aderhold to send a delegation of scientists to visit the island to consider the possibility of using it for research in agriculture, forestry or biology. With Aderhold and the deans of forestry and agriculture, Odum visited the island. However, when the delegation returned to the university, Odum was the only one to submit a proposal for research.[504]

With funding from Reynolds and backing from the University of Georgia, Odum was able to build a research center on Reynolds' island that would focus on the study of salt marshes. Odum and Biology Department head George Boyd chose recent Robert Ragotzkie, who had just received his PhD at the University of Wisconsin, to head the lab beginning in the early months of 1954. Shortly after Ragotzkie would be joined by Theodore Starr, a microbiologist, and Lawrence Pomeroy, an invertebrate zoologist.[505] By 1955 Reynolds' funding of $25,000 a year would be supplemented with $12,000 a year from the National Science Foundation's environmental biology program.[506] In a way that resembled Odum's use of the Savannah River Ecological Laboratory to draw and fund graduate and postdoctoral students, the young marine laboratory would draw resident graduate students beginning with Alfred E. Smalley as a graduate student and, notably,

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[503] Pomeroy and Scott, "The University of Georgia Marine Institute," 128-9. Craige, *Eugene Odum*, 55-6.

[504] Odum's eagerness to secure external funding for his work on marshes recalls his eagerness to secure external funding from the Atomic Energy Commission. In both cases, Odum asked for much more funding than he would receive. Pomeroy and Scott, "The University of Georgia Marine Institute," 129-30.

[505] Ibid., 132.

[506] Craige, *Eugene Odum*, 56.

John Teal as a postdoc.[507] Despite Reynolds' and NSF funding, the research on Sapelo was run on a tight budget. At first the resident researchers' quarters had no heat, and there was no phone or quick way of getting to laboratory for years. An early conference was held in the hastily renovated second floor of a barn. By the late 1950s, however, the research station on Sapelo Island had become more established and would be named the University of Georgia Marine Institute.[508]

In a preface to a 1981 collection of essays written about the Georgia salt marshes, Odum provided a retrospective summary of the trajectory of the research of the University of Georgia Marine Institute.[509] First, the group researched “general patterns of food chains and other energy flows” and “the nature of imports and exports to and from the system and its subsystems. Next, a number of general hypotheses were formulated and subsequently tested by detailed studies of key components.”[510] Lastly, the key investigators prepared a synthesis, *The Ecology of a Salt Marsh* edited by Lawrence Pomeroy, one of the Institute's first hires and Richard Wiegert, who had initially been hired to do research at the Savannah River Ecological Laboratory in the early 1960s.

The early emphasis on energy and productivity is clear in two early surveys of the research coming out of the Marine Institute in the 1950s and early 1960s. Both Odum's 1961 article, “The Role of Tidal Marshes & Streams in Estuarine Production,” and John Teal's 1962 article, “Energy Flow in the Salt Marsh Ecosystem of Georgia,” provide a sense of the importance of energy and productivity in the work of the Marine Institute. In summarizing his article provides a visual representation of “community energy flow,”

507 Pomeroy and Scott, "The University of Georgia Marine Institute," 132-5.
508 Ibid., 135-8.
509 Eugene Odum, "Preface," in *The Ecology of a Salt Marsh* ed. by L. R. Pomeroy et al. (New York: Springer-Verlag, 1981).
510 Ibid., v. Correspondence from Odum to Alvin B. Biscoe dated June 20, 1963 (UGA 97 044:3).

reproduced below in Figure 5.1, that was not uncommon in postwar research on the movement of energy through the environment.

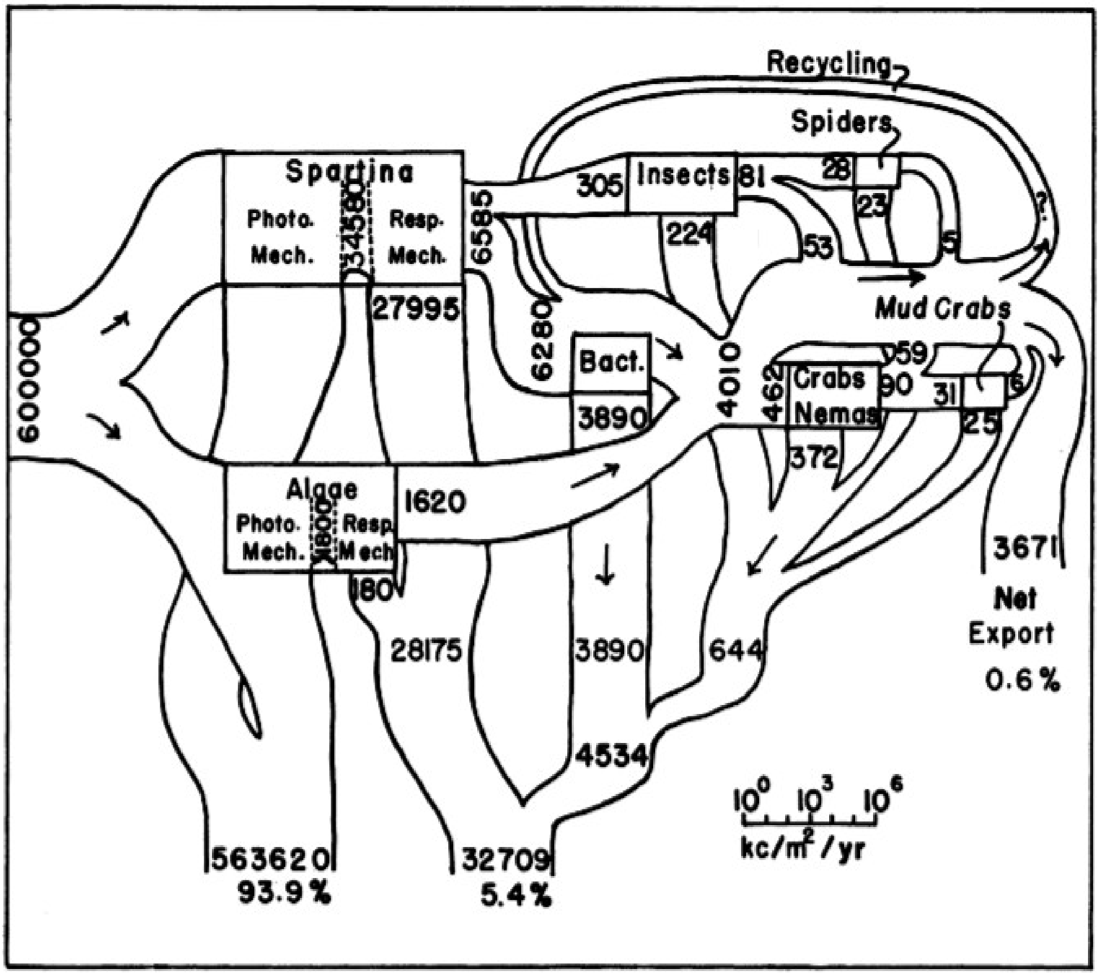

Figure 5.1 - Teal's energy flow diagram. Teal's original caption reads “Energy flow diagram for a Georgia salt marsh.”[511]

In a popular work on energy, Howard Odum and his wife Elisabeth provided an accessible introduction to energy diagrams such as this one (Figure 5.1).[512] The numbers

[511] John M. Teal, “Energy Flow in the Salt Marsh Ecosystem of Georgia.” *Ecology* 43, no. 4 (October 1, 1962): 622..

[512] It should be noted that, by the mid 1970s, Howard Odum was advocating for energy diagrams using a standard set of symbols and notations. This kind of diagram would have been familiar to ecologists of the time interested in the movement of energy through the ecosystem. In a chapter on energy written by Eugene and Howard for Eugene's 1959 textbook, there is another accessible introduction to this kind of diagram. Interestingly, in 1962, the same year that Teal published his summary of the Georgia Marine Institute work on energy flow, Odum and two of his students—Clyde Connell and Leslie Davenport—

on these diagrams represented units of energy flowing into and out of each component of the diagram—or nature. Teal's diagram mapped the flow of energy from the sun (coming from the left of the diagram) to the algae and *spartina*, or cord grass, in the marshes to insects feeding on the grass, spiders feeding on the insects and so on. In the bottom right there was an indication of the units of energy, kilocalories per square meter per year.[513]

Odum's article summarizing the group's research on the coastal marshes of Sapelo provided a broader and comparative sense of the productivity of the marshes.[514] The article also exemplified the second stage in Odum's work on the marshes. Instead of mapping out, with Teal, the flow of energy of energy through the marshes, Odum applied a comparatively coarse grained approach and ascertained the productivity of the marshes in relation to moderately productive ecosystems (grasslands, forests, some lakes, and "ordinary" or non-intensive agriculture) and less productive ecosystems (land deserts and oceans). While the productivity of estuaries, coral reefs and intensive agriculture fell in range of thousands grams of biomass per square meter per year, the productivity of grasslands and forests fell in the range of hundreds and oceans and deserts in the range of tens of grams of biomass per square meter per year.[515]

Why were the coastal marshes so fertile? Odum's answer contrasts with earlier understandings of the fertility of the marshes in terms of agricultural runoff or the role of freshwater entering the marshes from streams. Instead, Odum asserted that the mix of

published an article summarizing a subset of the work on energy flow at the Savannah River Ecological Laboratory. Odum and Odum, " Natural Areas as Necessary Components," 16-22. Odum, *Fundamentals of Ecology*, 47. Odum et al., "Population Energy Flow," 88-96.

513 Unfortunately unpacking Teal's diagram would involve summarizing large parts not only of his article but also of the articles that he is summarizing. For his account, see Teal, "Energy Flow in the Salt Marsh Ecosystem," 621-7.

514 Eugene Odum, "The Role of Tidal Marshes in Estuarine Production," *New York State Conservationist* (June - July 1961): 12-5.

515 Ibid., 12.

freshwater and saltwater creates a "nutrient trap" in which nutrients are not swept out to sea but are kept in the marshes.[516] At the same time, the movement of the tide did provide a source of new nutrients and removes the waste. Contributing an unexpected amount of biomass to the phytoplankton operating in deeper water was algae in the mud of the marsh. In addition to these factors, the total productivity of the marshes derived in part from the fact that they produced biomass year round.

V. The Productivity and the Value of Marshes

While Odum's efforts to explain the productivity of the marshes and provide a comparative sense of its scale are significant on their own, they are even more so as part of an early effort to assert the value of the marshes. In considering Odum's efforts to convince his audience—here and elsewhere—of the value of the marshes, it is important to consider the attitude he was arguing against. As he notes in this 1961 essay, "When the average citizen looks at the vast green marshes of the southeast. . .he is likely to regard them as wastelands because he sees no direct use by man."[517] In addition to being seen as "wastelands," marshes are also seen, "as convenient sewers."[518] Just as his 1969 essay attempted to provide a sense of the importance and value of nature as a source of energy needed to maintain civilization, here Odum is bringing attention to the importance of the marshlands. In both cases, he is trying to convince his reader that an undervalued and neglected part of nature is valuable.

How did Odum characterize the importance and value of the marshes in this

[516] Ibid., 13.
[517] Ibid., 14.
[518] Ibid., 12.

essay, and how did this characterization change over the years? We have already seen how Odum characterized the marshes in comparative terms as an extremely productive part of nature. While this productivity answered the question of how Odum would assert the value of the marshes, it was often less clear exactly how ecological productivity would translate into value that a non-ecologist could understand.

For example, Odum argued that we need to learn how to approach marshes in terms of utilizing their productivity instead of attempting to make them productive. “Emphasis on management,” he argues, “must be on utilization."[519] Later he noted that, “the principle theme of this article. . .[is] the need to learn more about the utilization of natural estuarine fertility."[520] Odum suggested that instead of re-making the marshes into a productive system in the way of intensive agriculture, we should utilize the productivity that is already in place there. In the article, however, Odum provided little sense of how we might do this. He notes that the productivity of the marshes in relation to people must be approached as “potential” as the marshes do not produce food that people can eat or anything else that people use directly.[521] Interestingly, the vagueness that we meet in this article would be complemented, in some of Odum's later stances, with concrete suggestions as to how we can utilize the natural productivity of the marshes. As I will explore below, in finding specific ways that we can value marshes—and better ways of explaining this value—Odum was also becoming more familiar in a scientific role that addressed itself to wide, non-specialist audiences.

In this 1961 article, it seems that Odum was struggling to find a way of talking

519 Ibid., 12.
520 Ibid., 15.
521 Ibid., 13.

about the value of the marshes that could be understood by non-ecologists. He noted, for example, that,

> Too often we justify the existence of non-economic forms only on the basis that they provide food for economic animals (raccoons eat mussels, for example). Often such forms may be more *valuable in a less direct way*, as is the mussel, *in the maintenance of a biogeochemical cycle!*[522]

While the emphasis, at the beginning of this quote, on justifying the existence of "non-economic forms" of life might make sense to a broad audience, he proceeded to invoke biogeochemical cycles as providing an example of a justification that is non-economic. Further, Odum did not define the phrase "biogeochemical cycle" but instead proceeded directly to a discussion of the components of the marsh ecosystem as "production units," also without much in the way of introductory explanation.[523] Given the fact that this would have been a relatively new term even among professional ecologists, it is difficult to imagine a broader readership making much sense of how something called a biogeochemical cycle might render marshes valuable. The editor seemed to acknowledge as much in his warning that, "This is a challenging article," that "requires close attention and thought."[524] The absence of an introduction to these terms is all the more significant because Odum's ability to explain technical terms in an accessible way was long taken to be one of his strengths and contributions as an ecologist.[525]

[522] Ibid. [emphasis in original].
[523] Ibid.
[524] Ibid., 12.
[525] We can see this talent in the pages and success of Odum's textbook, *The Fundamentals of Ecology* but also in his 1963 work, *Ecology*, his 1983 work *Basic Ecology*, and in later and more explicitly critical positions such as the various editions of *Ecology and Our Endangered Life Support Systems* (1989, 1993, 1997) and *Ecological Vignettes: Ecological Approaches to Dealing with Human Predicaments* (1998). More tellingly, however, other ecologists recognized Odum's gift to provide accessible explanations. The Ecological Society of America commemorated Odum's ability to introduce new students to ecology through accessible accounts with the Eugene P. Odum Award. In this context, Odum's lack of explanation stands out as a significant indicator of the early and tentative nature of Odum's remarks. Eugene Odum, *Ecology and Our Endangered Life Support System* (Sunderland, MA:

Although it does not receive as much emphasis as biogeochemical cycles, Odum does provide a more accessible justification for the value of the marshes. In a passage that invokes an image curiously similar to that governing "The Strategy of Ecosystem Development," Odum notes that,

> Unfortunately, too many so-called conservationists and engineers also view these estuarine environments as would a dry land farmer. On land, production and harvest occurs all on the same spot; in tidal estuaries, there is a constant transport system which results in the separation of production and utilization in both time and space. By analogy, we could think of the marshes and probably also the mud and sand flats, as the great 'wheat fields' which feed the teeming 'cities' of fish and other organisms living in the creeks and sounds. The point of all this is that if we decide to spend a lot of money to dike off the marshes and make lettuce fields out of them, then we must figure on the loss of much of the energy which supports the sea food. In America I believe we need high quality, protein-rich seafood more than we need more lettuce, grown at heavy tax payer expense![526]

There are several things that are striking about this passage. The less important point is that Odum's image of marshes, "as the great 'wheat fields' which feed the teeming 'cities' of fish and other organisms," he is invoking an image remarkably similar to that which informs his 1969 essay, with agricultural areas feeding cities and undomesticated nature 'feeding' both agricultural areas and cities.

A more important feature of this passage in the context of my argument is that Odum provides a clear justification for the marshes as a source of food for the seafood that we eat. Odum goes further in asserting the value of "high quality, protein rich seafood." Given that this article was published in 1961, it is perhaps unsurprising that we

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Sinauer Associates Inc., 1989). Eugene Odum, *Ecology and Our Endangered Life-Support Systems,* 2nd ed, (Sunderland, MA: Sinauer Associates Inc, 1993). Eugene Odum, *Ecology: A Bridge Between Science and Society*, 3rd ed. (Sunderland, MA: Sinauer Associates, 1997. Originally published as *Ecology and Our Endangered Life Support System*. Sunderland, MA: Sinauer Associates Inc., 1989). Eugene Odum, *Ecological Vignettes: Ecological Approaches to Dealing with Human Predicaments* (Amsterdam: Harwood Academic Publishers, 1998).

[526] Odum, "The Role of Tidal Marshes in Estuarine Production," 14-5.

encounter a similar justification in Odum's 1959 textbook where he notes that,

> The potential high productivity of estuaries has often not been appreciated by man, who has frequently classed them as 'worthless' areas suitable only for the dumping of waste materials or useful only if drained or filled and planted with some terrestrial crop. When the high costs of such changes are considered, it may well be that utilization in the natural state is preferable, especially since seafood is a dietary item that vegetables cannot replace.[527]

Although Odum's illustration of how marshes help produce things we value (such as seafood) is clear, it occupies an uncertain relation to the primary justification that Odum provided (biogeochemical cycles).

The clarity or accessibility of Odum's two candidate justifications (seafood and biogeochemical cycles) went along with the degree to which they were expressed in the specialized language of ecology as a science. As I noted above the term “biogeochemical cycles” would have been a comparatively new term even among ecologists in the late 1950s and early 1960s. However, even if it were a commonplace among ecologists, it would be difficult to then make the leap that it would also be known more generally by people outside ecology or the earth sciences. Seafood, by contrast, would have been a category familiar to a much larger swath of the population. This difference in terminology and familiarity goes along with a difference in proximity. Seafood is something that most people would have come into contact with or at least heard of, while biogeochemical cycles is not. Particularly when contrasted with the much more complex and evenly argued justifications Odum would provide later in the 1960s and which I will explore below, the awkwardness of Odum's two very different ways of justifying the marshes stands out as tentative or at least unpracticed.

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[527] Odum, *Fundamentals of Ecology* 2nd ed., 366.

In a 1963 conference presentation to the International Congress of Zoology that was titled "Primary and Secondary Energy Flow in Relation to Ecosystem Structure," Odum was still struggling to find the terms with which to establish the value of marshes.[528] In this presentation, Odum approached marshes in contrast with grasslands and other ecosystems in which energy flows from the sun to "autotrophic" plants, such as grass, and then through large mammals who graze on the grass.[529] Generally, autotrophic plants are ones that convert the energy of the sun and inorganic matter into organic matter (itself as a plant) through the process of photosynthesis. Another version of this kind of "grazing" ecosystem is in the ocean, where energy flows from the sun to phytoplankton to fish who graze on the phytoplankton. In both cases, the bulk of the energy passes through the grazing animals to higher levels of each ecosystem's food chain.[530] By contrast, the tidal marshes represent a detritus ecosystem where only a small percentage of energy is passed to grazers and species occupying higher levels of the food chain. In these environments, most of the energy flows from plants or animals that are dead and decaying into species occupying higher levels of the food chain. In the case of marshes, the energy can come from decaying *spartina*, or cord grass, but more often from mud algae and smaller scale species.[531]

In this presentation, Odum couched the significance of the marshes in terms of this contrast between grazing and detritus ecosystems. He noted that,

So far man has depended almost entirely on the grazing or granivorous

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[528] Eugene Odum, "Primary and Secondary Energy Flow in Relation to Ecosystem Structure." (Paper presented at the International Congress of Zoology, Washington D. C., August 20-7, 1963). In *Proceedings of the 16th International Congress of Zoology, 1963.* Vol. 4, Specialized Symposia. Edited by John A. Moore, 336-8. Washington, D. C.: National Academies, 1963.
[529] Ibid., 336.
[530] Ibid.
[531] Ibid., 336-7.

> type food chains for his food; all of his highly developed agricultural systems are of these types. Since detritus systems seem to have greater buffering effect on fluctuations in the physical environment, and, thus, greater inherent stability it might be well for man to consider the possibility of developing cultural systems of the detritus type. Detritus might be used directly by man in two ways: (1) cellulose and other undigestable materials might be converted into metabolizable energy by suitable enzymes, (2) or by the culture and harvest of detritus-feeding animals such as is already done in some types of tropical fish and shellfish culture. Or perhaps better still, the large particulate material could be converted for direct use and the bacteria-rich small particles fed to animals.[532]

In this passage, Odum followed the logic he laid out in his 1961 article. Because of their productivity, marshes might be able to provide food that people can eat. Here, however, Odum imagined this process as operating in a more direct way and in more concrete terms. People can culture and harvest shellfish in the tidal marshes. He also allowed that we may be able to convert the inedible products of the marshes into food. In this presentation, Odum bypassed the harder to imagine links that might or might not connect decaying plant matter with a fish swimming many miles away in the ocean. In this presentation, by contrast, the ecological (and unvalued) productivity of the marshes was translated into valuable seafood products in the space of the marsh itself.

These tentative efforts to find and assert the ecological terms by which value of marshes would be realized characterize Odum's work on the marshes in the early to mid 1960s. Some of the elements of his 1969 critique are already in place here—the attempt to assert ecological productivity as a basis for a more general form of value and, in more tentative form, doing this with reference to food chains that link tidal marshes with people. However, Odum's reflections on the larger significance of his research on the

[532] Ibid., 338.

marshes was still a long way from the argument we see in “The Strategy of Ecosystem Development” where we see Odum expressing, in a confident way, a larger theory about the links between people and all kinds of undervalued natural areas.

VI. Mobilization to Save the Marshes and the Generalization of Their Value

In the mid to late 1960s, Odum's efforts to justify the value of marshes—and explore a more outspoken and critical role as a scientist—intensified when he joined efforts to resist the mining of a large a swath of Georgia's marshes. In 1967, the Kerr-McGee Corporation determined that there was a rich load of phosphate under a section of the Georgia marshes. Although the company was planning to mine under some 12,000 acres the company had recently purchased, in May of the following year the company also petitioned Georgia Governor Lester Maddox to gain permission to mine under state owned land. A social movement quickly formed to oppose the mining and succeeded not only in preventing the mining of the proposed state land but also instituted a Coastal Marshlands Protection Agency to monitor and regulate future efforts to mine or to develop the coastal marshes with the passage of the Coastal Marshlands Protection Act in the beginning of 1970.[533]

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[533] The account of the formation of the “Save Our Marshes” campaign and the events that surrounded it relies on the accounts provided in a 1969 article in *Life* magazine entitled “The Threatened Marshes of Glynn,” the Advisory Committee on Mineral Leasing's report for Georgia Governor Lester Maddox, a National Park Service monograph entitled An Ecological Survey of the Coastal Region of Georgia that included two investigators from the University of Georgia's Institute of Natural Resources and built on the earlier work of that Institute and the Institute of Ecology, David Maney's edited volume entitled *The Future of the Marshlands and Sea islands of Georgia*, a 1968 article from UGA's student newspaper *Red and Black* (“Conservancy”), James Kundell report entitled Management of Georgia's Marshlands, and Craige. Advisory Committee on Mineral Leasing, University System of Georgia. *A Report on Proposed Leasing of State Owned Lands for Phosphate Mining in Chatham County, Georgia*, 1968. Sydney A. Johnson, Hilburn O. Hillestad, Sheryl Fanning Shanholtzer, G. Frederick Shanholtzer. *An Ecological Survey Off the Coastal Region of Georgia*. National Park Service Scientific Monograph Series, 1974. Accessed January 15, 2011, http://www.nps.gov/history/history/online_books/science/3/index.htm. "Conservancy." *Red And Black:*

When Kerr-McGee petitioned to mine state owned marshes in addition to the areas they had purchased, Governor Lester Maddox appointed an Advisory Committee on Mineral Leasing to review the request. Due to his research on marshlands and his prominence in the field of ecology,[534] Odum was tapped to be a part of the Advisory Committee on Mineral Leasing along with E.L. Cheatum, the newly appointed director of the University of Georgia's new Institute of Natural Resources. In addition to Odum and Cheatum, Frederick Bellinger, the chair of the Chemical Science and Materials Division at Georgia Institute of Technology, Vernon J. Hurst, the head of the University of Georgia's Geology Department and Chairman of the Physical Sciences Division, and Thomas Jackson, Director of the University of Georgia's Skidaway Institute of Oceanography were also on the committee.[535]

Published in 1968, the committee's report to the governor provided a multi-faceted analysis of the value of the marshes and the impact of several scenarios of mining. Although the text of the report stood a scant twenty pages long, it contained lengthy appendices detailing the relevant legal context, the process of mining, environmental effects and an economic analysis of the benefits and costs that the mining would pose to the state of Georgia. It considered three scenarios—to mine the marshes, to

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the University of Georgia's Student Newspaper. (January 16, 1968): 8. Craige, Eugene Odum, 98-103. Kundell, James E. *Management of Georgia's Marshlands Under the Coastal Marshlands Protection Act of 1970*. Governmental Research and Services Division, Carl Vinson Institute of Government, University of Georgia, 1988. David S. Maney., Frederick C. Marland, Clifford B. West, *The Future of the Marshlands and Sea Islands of Georgia,* Conference on the Future of the Marshlands and Islands of Georgia at The Cloister on Sea Island, October 1968. "The Threatened Marshes of Glynn." *Time* (November 14, 1969): 88-93.

534 In addition to the prominence Odum enjoyed from his leading role in radiation ecology and as the author of successive editions of the widely used *Fundamentals of Ecology* textbook, Odum also gained visibility to people outside of the discipline in serving as President of the Ecological Society of America in 1964-5 and in being elected Georgia Scientist of the Year for 1967 (awarded by the Georgia Science and Technology Commission). Craige, *Eugene Odum*, 171.

535 Advisory Committee on Mineral Leasing, *A Report on Proposed Leasing* , vi-x.

mine the marshes and attempt to restore the marshes, and to mine the marshes and then create raised areas with the processed materials for later real estate development. One of the primary concerns—and one that applied in all of the plans—was whether mining would puncture the Coastal Plain aquifer and contaminate one of the state's key supplies of water.[536]

Largely written by Odum, a separate section entitled "Environmental Effects" focused on the impact of each plan in terms of its biological and hydrological effects as well as the pollution it would generate. Perhaps unsurprisingly, the bulk of the biological effects covered in the report focused on the impact of the proposed mining on the productivity of the marshes. The productivity would be lowered by the replacement of shallow water areas with a mix of deeper water areas and high ground areas. In addition, the plans that did not include restoring the marshes would remove around half of shrimp nursery grounds and oyster and crab growing waters. Further, not only would the changes negatively impact sport fishing and wildlife recreation but it would also generate mosquito control problems by creating areas of standing water behind dykes that had reduced levels of salinity.[537] Interestingly, this section shares with Odum's 1961 and 1963 positions, discussed above, a mixed emphasis on general productivity and the role of the marshes in providing seafood for the state of Georgia.

When Governor Maddox denied the Kerr-McGee Corporation their petition, the controversy spread as opponents of Maddox's decision came together to back a developer's plans to create a resort on the southern coast of Georgia.[538] Odum did not

[536] Ibid., 9-10 and B 21-9.
[537] Ibid., 10-4 and C 1-15.
[538] Craige, *Eugene Odum*, 100-1.

remain satisfied with his role as Advisory Committee member but instead got involved with students' efforts to mobilize a "Save Our Marshes" campaign, which aimed to raise awareness about the value of the marshes and prevent the destruction of another part of Georgia's tidal marshes in the future. Odum delivered a "Conservation Teach In" about the marshes for students and others at the University of Georgia and wrote up a fact sheet that student activists handed out across the state.[539] Throughout these and other efforts, Odum helped students by providing an ecological rationale for the preservation of the marshes. He later reported that his experience in this social movement played a role in his efforts to effect change by mobilizing popular opinion.[540] Nor did he wait to apply this lesson. It was in this period Odum began formulating the elements of the critique that would be published as "The Strategy of Ecosystem Development" as he was delivering public lectures.

In addition to providing an ecological rationale for the value of the marshes, Odum also provided a credible voice for the small social movement. At this time in his life, Odum was a prominent ecologist but also a respected member of the University of Georgia community and a recognized figure among Georgia scientists. In 1968, the year that the Advisory Committee released its report, *Life* magazine published an article covering the struggle that quoted Odum as asserting the value of the marshes in the name of science: "It is no longer a luxury item to save our estuaries. It is a scientific necessity."[541] Odum would also champion the cause of the marshes before the audiences gathered at the events of the Georgia Conservancy, an environmental organization formed

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539 Ibid., 101.
540 Craige, *Eugene Odum*, 102.
541 "The Threatened Marshes of Glynn," 93.

in 1967.[542]

On the other side of the debate, State representative George Harrison Jr. led efforts to oppose Maddox's decision and assert the ability of private landowners to develop their land in whatever way they saw fit. Harrison and other supporters of development invoked the frame[543] of private property rights and the importance of economic development. In a 1969 interview, Harrison opined, “I feel the attorney general should tell us how much of the salt marsh acreage is state-owned. The rest is privately owned and belongs to private people. They should be allowed to do with their land what they want. . . .We can conserve and preserve without telling people just what they can and can't do.” He went on, “Let's live and let live for a bit. We've got to have development. People are going to have all this recreation—but they've got to have jobs first."[544] Despite Harrison's efforts to protect private property rights, activists who mobilized to “save our marshes” would prevail in their efforts to promote legislation. By the time the vote for the Coastal Marshlands Protection bill came around in February 1970 it faced little resistance in the Georgia house and none in the senate.

Odum's experience with the effort to save the marshes of Georgia would be an important one in his move toward a more outspoken and critical position. Decades later, he would remember this time as an important one in convincing him that public sentiment could function as a driver of change and that providing economic valuations of nature was effective.[545] A change in orientation is evident in Odum's public lectures. One of the most striking of these lectures was one he delivered in October 1968, a month before the

542 "Conservancy," 8.
543 Robert D. Benford and David A. Snow. "Framing Processes and Social Movements: An Overview and Assessment," *Annual Review of Sociology* 26 (2000):613-8.
544 "The Threatened Marshes of Glynn," 93. See also Crige on Harrison's role. Craige, *Eugene Odum*, 100.
545 Craige, *Eugene Odum*, 102.

publication of the Advisory Committee's report. The setting was the Conference on the Future of the Marshlands and Sea Islands of Georgia. Although Odum focused on the marshes of Georgia in this presentation, he began to approach the marshes as part of a larger problem when he formulated, in the opening moments of the talk, one of his central questions: "what strategy do we need to devise for utilizing our environment and preserving it at the same time?"[546] The question called for "a little ecological framework" within which to approach and value parts of nature such as the marshlands.[547]

Before Odum introduced his fledgling framework, he first explained in accessible prose the differences between young and mature ecosystems and the similarities between ecosystems and organisms. He noted that, "A natural system including man and nature resembles an organism in that it is subject to a natural developmental process."[548] Just as an organism can be different in youth and maturity, so could parts of nature be different:

> the whole environment develops in a way similar to the development of an organism. As such it has both youth and maturity, just as an organism develops from youth to maturity. It is convenient then to talk about 'young' nature and 'mature' nature.[549]

In young nature, "quantity and production are the predominant characteristics." He went on to note that, "In general language we may speak of the 'young nature' as the *productive environment.*" Mature nature, by contrast, is "the *protective environment.*" Unfortunately, Odum did not explain exactly what he meant by calling mature nature protective. He provided the example of "a forest on the slopes" as mature nature because

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546 Eugene Odum, "A Proposal for a Marshbank and the Statewide Zoning of Estuarine, Georgia," in *The Future of the Marshlands and Sea Islands of Georgia,* edited by David Maney et al. (paper presented at the Conference on the Future of the Marshlands and Islands of Georgia at The Cloister on Sea Island, October 1968), 74.

547 Ibid., 74.

548 Ibid., 75.

549 Ibid.

it had a “protective function in providing oxygen and water for any wood we might harvest from it." Later in the essay, however, protective environments were environments that should be protected.[550]

Odum proposed to approach all of nature in terms of this distinction between young and mature in order to regulate our relation to the environment so that, “we will have some of both.” In addition to young and mature parts of nature, Odum proposed that multiple use areas be approached as part of the “compromise environment.” Areas such as streams and lakes have natural functions, such as purifying waste materials, but also provided for other kinds of uses, such as recreation and transportation. Other areas that were “covered with concrete and steel and houses” should be known as parts of the “urban-industrial environment.” Unlike the productive, protective, and compromise environments, the urban industrial environment “yields no biological necessities” such as “food or oxygen.”[551]

In this talk, marshes became one case--if a key case--in a more general framework or approach to nature in terms of the larger ecosystem. In the framework, marshes were examples of compromise environments and should be regulated as such. They could be used as productive environments—by culturing and harvesting oysters for example, but they also should be protected from being converted entirely to productive ends. Over-emphasis on approaching marshes as a source of production would, “endanger the large and more important value of the marshes as a protective landscapes."[552] The danger of allowing multiple uses for natural areas such was that the most lucrative use would

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550 Ibid. [emphasis his].
551 Ibid.,76.
552 Ibid.

dominate the approach to those areas. In the case of the marshes, mining the marshes for phosphate would dominate efforts to approach the marshes “for seafood harvest, recreation, transportation, mineral regeneration and other needs of human society.”[553] By zoning different areas of nature according to their ecological function, we can regulate nature according to the services they provide over the long term and not how much profit they could return in the short term.

The overlap between Odum's argument here and his argument in his 1969 essay “The Strategy of Ecosystem Development” is striking. In both cases, he approached the environment in terms of an ecological theory of succession—in terms of productive young and mature, or 'protective,' ecosystems. Nature was zoned according to this distinction but also included urban-industrial areas and mixed use or compromise areas, and this zoning provided the basis for regulation of how we treat different parts of the environment. In his 1969 essay, the framework is more filled out and explained in a more accessible fashion. In this context, it is not surprising that the title of this 1968 presentation, “A Proposal for a Marshbank and the Strategy of Ecosystem Development for the Estuarine Zone of Georgia,” contained the title of his 1969 essay. By the time of his 1968 presentation, however, Odum's assertion of the value of the Georgia marshes had morphed into a broader effort to assert the value of parts of nature that are like the marshes in relation to other parts of nature, such as the urban-industrial environment.[554]

Further, Odum positioned ecosystem ecology in this talk as part of an effort to

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553 Odum, "A Proposal for a Marshbank and the Statewide Zoning," 77.

554 Odum tried out the framework he proposed in “The Strategy of Ecosystem Development in other places as well. See, for example, a presentation entitled “The Watershed as an Ecological Unit” that Odum delivered in 1968 at Kent State University. Eugene Odum, “The Watershed as an Ecological Unit,” in *The Cuyahoga River Watershed; Proceedings of a Symposium Held at Kent State University, Kent, Ohio, November 1, 1968*, edited by Dennis G, Cooke. Kent, Ohio: Kent State University Institute of Liminology, 1969.

manage environmental problems. Approaching and valuing natural areas like marshes for the less financially lucrative but still very valuable services they can provide provided “an example of thinking and acting in terms of the big Eco-system.” He continued, “We must plan in terms of large areas so each unit is a part of the whole and can be considered together."[555] For Odum, ecosystem ecology provided not only a way of approaching nature but also a way of *valuing* nature.

VII. The Financial Value of Marshes

In his recollections about his engagement with the mobilization against the mining of Georgia's marshes, Odum reported that one of his chief lessons was the importance and effectiveness of assigning economic values to the marshes.[556] In addition to reporting on the possible impacts of the proposed mining on the productivity of the marshes and the state's water supply, the report of the Advisory Committee on Mineral Leasing also provided an economic analysis of the possible impacts of the mining operations. This analysis was dominated, however, by an account of the benefit that phosphate mining would bring the state, there was little to no financial information on the negative impacts on the seafood industry or contamination of the Coastal Plain aquifer or even the surface water.[557] While the exact circumstances attending the lesson Odum learned about the importance of providing financial estimates are unclear, it is difficult to

555 Odum, "A Proposal for a Marshbank and the Statewide Zoning," 82.

556 Craige, *Eugene Odum*, 102.

557 The disparity between the wealth of financial figures of the benefit to the state of mining and the lack of figures of the cost of mining for the state suggests that the financial figures might have been prepared or at least provided by the Kerr-McGee corporation. Whether or not this is the case, the disparity of financial data on the environmental costs of phosphates mining represented part of the setting in which Odum became convinced of the importance of estimating a financial value for the ecological services that the environment provides. Advisory Committee on Mineral Leasing, *A Report on Proposed Leasing*, A 1-15

avoid the sense that this disparity in data, if not the political economy informing it, might have been a factor.

The report on the economic impacts of phosphate mining provided the terms with which the financial benefits of the mining for the state and citizens of Georgia—of increase in property taxes, job creation, increased retail sales, and so forth—could be weighed against the costs to the state. The appendix providing some of the details of the economic analysis contained sections on the economy of the area to be mined, financial data on the mining operation, economic cons or costs to the state, economic benefits for the state, a summary of the factors limiting a more complete analysis, and a summary of the findings.[558] The report summarized that the state might expect roughly two million dollars per year for the first twenty years and more if the mining was followed by marsh restoration and land development.[559]

One of the things that stands out in this report is the lack of economic estimates of the costs to the state of mining. There is discussion of the possibility that mining would puncture the Coastal Plain Aquifer, cause a level of pollution in surface water and on beaches, negatively impact the seafood industry as well as area recreation and land development. There are four tables full figures detailing potential negative impacts on land development, but there are no comparable figures on the impact to the seafood industry or surface water contamination. In this report, the productivity of the marshes

558 The section on the economy of the area to be mined included figures on population trends, income and employment. The section on factors relating to the mining operation included information on the market for phosphate and related minerals and the real estate market and employment trends in the area. The section on the economic costs of the operation included a consideration of the water supply, the seafood industry, ground water pollution, recreation, and land development. The section on the economic benefits of the operation included estimates changes to the job market, tax revenue, royalties paid to the state, increased income of area businesses.

559 Advisory Committee on Mineral Leasing, *A Report on Proposed Leasing*, 15.

did not yet have any financial worth.

Odum would endeavor to change this during the 1970s and early 1980s in the fourth stage of Odum's engagement with the marshes. Even during the period of Odum's activism, he oriented himself around the need to financially value various parts of nature. In the 1968 presentation I introduced above, Odum asserted that, "Some day very soon society must find a way to put an economic value on protective functions."[560] Further, he positions the effort to assign economic value to nature as a logical replacement of the regulatory zoning framework he introduces in the presentation:

> Until environmental quality can come to have an economic value competitive with quantity we can only rely on regulations and legal restrictions as a means of keeping balance between short term needs and long term human survival. In other words, our present strategy must be to try to determine in some logical way, how to compartmentalize or zone the landscape so that we will have some of both, - that is youth and maturity.[561]

Although the exact circumstances attending this impulse are uncertain, it is difficult to avoid the sense that it would have involved the gap between the financial figures describing the benefits of the mining operation and the lack of figures describing the impact of the mining.

Given the centrality of ecological productivity in Odum's valuation of the marshes through the 1960s, it should not be surprising that, when he began to assign financial value to the marshes, he would do so in terms of the marshes' ecological productivity. In 1972, Eugene and his brother Howard co-authored an article entitled "Natural Areas as Necessary Components of Man's Total Environment" that introduced an effort to assign

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560 Odum, "A Proposal for a Marshbank and the Statewide Zoning," 75.
561 Ibid., 75-6 [emphasis his].

economic value to nature in terms of productivity. The article contains many of the same terms that Eugene laid out in his 1968 talk and his 1969 article. He suggested that nature was divided up into areas such as cities and the natural environment. Here, however, the zones or compartments of nature are decoupled from the stages of the ecosystem, and the primary contrast is between the "developed environment," epitomized in cities and industrial areas, and the "natural environment," which "operates without energetic or economic input from the power flows directly controlled by man."[562]

The article also introduced a way of assigning financial value to nature. Based Howard Odum's 1971 work *Environment, Power, and Society*, the brothers propose that, "a ratio of Gross National Product (GNP) to National Power Consumption can be used to convert calories to dollars."[563] A dollar value of energy measured in calories could then be applied to the results of ecological studies of natural areas in terms of energy. Interestingly, the brothers do not illustrate this method and assign any financial values to nature. In his book, Howard Odum noted that, "Although potential energy [from natural sources] has no dollar value, there is an average amount of work equivalent to the work done in the economy."[564] In order to illustrate this point, he graphed energy consumption by GNP. On the bottom left of the graph (low GNP and low energy consumption), we see countries such as Nigeria, India, and Pakistan. On the top right of the chart we see the United Kingdom, then Canada, then the United States.

The brothers introduced a second approach as well. They propose finding the economic value of the treatment and recycling of wastes that nature provides for free.

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562 Odum and Odum. "Natural Areas as Necessary Components," 133-4.
563 Ibid., 138-9.
564 Howard T. Odum, *Environment, Power, and Society (*New York: Wiley-Interscience, 1970), 182.

Based on others' research, they estimate that an acre of natural environment could be valued at $400 per year based on the treatment work it does alone.[565] Although the first method built on Howard's work, both it and the second technique would become a lasting presence in Eugene's work in this period.

As Odum continued his efforts to assign financial values to parts of nature, he built on the more this 1972 article and provided multiple ways in which value could be calculated, sometimes with a discussion of the relative benefits of each method. In a 1973 article entitled "The Pricing Mechanism" Eugene adopted a much more critical tone in taking aim at the pricing system as a mechanism that was central to capitalist economies. He noted that,

> The pricing system, which is at the heart of a supply-and-demand free economy, is ineffective when it comes to preserving natural environment as long as life support and other values of environment in its natural condition are not considered in making land-use decisions.[566]

We also see a renewed emphasis on preservation at a pragmatic level. Although the co-authored 1972 article opened with an assertion of the importance of preserving the natural environment, preservation quickly faded from view.[567] By contrast preservation was clearly a higher priority in Eugene Odum's 1973 article. He repeatedly contextualized the importance of pricing the natural environment as a tool for efforts to preserve the natural environment. He noted, for example, that, "Demonstrating that marshlands and estuaries have a substantial dollar value in their natural state certainly provides a big boost to preservation of such areas that are in public ownership."[568]

565 Odum and Odum. "Natural Areas as Necessary Components," 139.
566 Eugene Odum, "The Pricing System," *Georgia Conservancy Magazine* (Fourth quarter 1973): 8.
567 Odum and Odum. "Natural Areas as Necessary Components," 133.
568 Odum, "The Pricing System," 10.

Both this 1973 article "The Pricing Mechanism" and another 1973 article Odum co-authored with R.M. Pope and James Gosselink of Louisiana State University, provided actual estimates of the financial value of marshes using different methods, a step that was not taken in the 1972 article Eugene co-authored with his brother Howard[569]. In contrast with the 1972 article, the 1973 articles generalize the assignment of financial values to the "services" that nature provides. By the time of these 1973 articles Eugene Odum had expanded the focus on waste treatment (the only service mentioned in the 1972 article) to include the value of commercial and sport fishing and potential for creating intensive and moderate oyster cultures. Both 1973 articles also included estimates of the financial value "for total life support" by dividing the productivity of Georgia and Louisiana's marshes (in kilocalories) by the ratio of Gross Energy Consumption to Gross National Product. Interestingly, the 1973 article that Odum co-authored with Gosselink and Pope would be taken up into policy conversations and appear in the 1974 Council on Environmental Quality Report and Senate hearings on the Federal Water Pollution Control Act.[570]

The article would also spark a debate with unconvinced economists. In a 1979 article entitled "Economic Value of Natural Coastal Wetlands: a Critique," Leonard Shabman and Sandra Batie took aim at the article's efforts to provide financial estimates of the worth of nature. The authors found the calculation of "life support values" by a ratio of GNP to energy consumption particularly problematic and set about the work of discrediting the approach by comparing its estimates for hay land in rural Virginia ($6960

[569] Although the estimates are not identical, it seems likely that the estimates in "The Pricing System" were based on the estimates established in the article Odum co-authored with Pope and Gosselink. He also reproduces some of the estimates in a presentation, also in 1973, entitled "A Description and Value Assessment of South Atlantic and Gulf Coast Marshes and Estuaries."

[570] Leonard Shabman and Sandra S. Batie, "Economic Value of Natural Coastal Wetlands: A Critique," *Coastal Zone Management Journal* 4, no. 3 (1978): 232.

per acre) to the market value for this land ($556 per acre). While estimates of the value of marshes using the GNP to energy consumption ratio bear the brunt of Shabman and Batie's attack, the authors also take issue with problems in the way the article estimated economic value of marshes from the current economic value generated from commercial and sport fishing, oyster cultures, etc. The conclude by asserting that Pope, Odum and Gosselink's article represented an, "illegitimate marriage of the principles of systems ecology with economic theory."[571]

In his reply, Odum emphasized that Shabman and Batie's article misunderstood the original article as endeavoring to provide an accurate assessment of the economic value of the marshes using an economic that would externalize the value of the marsh (and so, for Odum, its natural productivity) to begin with. He argued that, "The principle aim of our article was to point out, using specific illustrations, how the natural environment's goods and services are grossly undervalued in conventional economic accounting."[572] He went on to argue that their original article did not intend to undermine economics as a whole so much as point out a problem with how current market valuation fails to take the value of natural goods into consideration. Citing an economist who made a similar point, Odum argued that

> What we are talking about is market failure. . . . Economist Georgescu-Roegen (1977) in his discussion of economics of food and energy states: 'We cannot possibly rely on the market mechanism to avoid ecological catastrophes because the market is the parameter of demand ans supply only of current generations, whose horizon is just a brief spell in comparison with the life span of the whole species. Prices can never be ecologically right simply because future generations are not present to bid

571 Eugene Odum, "Rebuttal of 'Economic Value of Natural Coastal Wetlands: A Critique." *Coastal Zone Management Journal* 5 (1979): 243..
572 Ibid., 231.

> on scarce resources side by side with current generations.'[573]

Despite the success of Odum's original article, by the early 1980s Odum began to move away from his efforts to assign financial value to undervalued parts of nature.

In a short 1983 essay entitled “Wetlands and Their Values,” Odum instead invoked a legal argument that interior marshes should be counted as part of the nation's water resources and so be approached and protected as public property.[574] A year later, Odum made a similar argument. Here he asserted that,

> Wetlands are not isolated habitats, as many people seem to regard them. Rather, wetlands are extensions of estuaries, rivers, and lakes, and, therefore, are vital components of the nation's water resources. Accordingly, wetlands that are closely coupled with water bodies should be considered a part of the public domain to be valued and legally protected just as are navigable and other larger bodies of water.[575]

On one level this move could be interpreted as a return to the basis of the success of the “Save Our Marshes” campaign of the late 1960s. In this case, the state rejected Kerr-McGee's petition to mine under state owned lands. In order to prevent the issue from being addressed on a parcel by parcel basis, the Coastal Marshlands Protection Act instituted a legal framework in which to consider efforts to develop marshlands against the need to preserve the state's marshes. It offered a legislative resolution, in other words, that favored efforts to preserve marshes. After a decade of assigning financial values to marshes and forests and other parts of nature, Odum began to move away from this

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573 Odum, "Rebuttal of 'Economic Value,'" 234.
574 Eugene Odum, “Wetlands and Their Values,” *Journal of Soil and Water Conservation* 38, no. 5 (September 1, 1983): 380.
575 Eugene Odum, "Wetlands as Vital Components of the Nation's Water Resources." In *The Water Resources of Georgia and Adjacent Areas*, ed. Ram Arora et al. (Georgia Geologic Survey Bulletin 99, Atlanta: Georgia Department of Natural Resources, 1984), 88.

strategy and attempted to invoke a legal argument to preserve a wider category of marshes more thoroughly.

VIII. Conclusion

With his move away from asserting the financial worth of nature, Odum was not signaling a retreat from his efforts to assert the value of nature. Far from it. In the 1980s, he would turn to authoring a series of books that targeted a broad public audience and provided ecological accounts of environmental problems and sometimes even social problems. Odum wrote a 1989 work entitled *Ecology and Our Endangered Life Support Systems* as “a citizen's guide to the principles of ecology as they relate to today's threats to earth's life-support systems.”[576]

It is interesting to note that the history of this work bears a striking resemblance to the history of Odum's emphasis on productivity and the ratio of productivity to respiration. From the early 1960s, Odum would begin pitching the relevance of both the insights of these books and his research on productivity to wider audiences and as a way of approaching larger scale environmental problems. Both his emphasis on productivity and the ratio of productivity to respiration began in earnest with his research at Eniwetok but morphed throughout the 1960s and came to serve, as we have seen, as the ecological principles informing Odum's environmental critique in “The Strategy of Ecosystem Development.”

Similarly, *Ecology and Our Endangered Life Support Systems* began as a different work aimed at a different, and narrower, audience. Odum notes in the preface to the first

[576] Eugene Odum, *Ecology and Our Endangered Life Support System,* (Sunderland, MA: Sinauer Associates Inc., 1989), ix.

(1989) edition of this work that large parts of it were based on his 1963 work *Ecology*, which was written as a part of a “Modern Biology” series of books intended “to introduce the beginning student in college biology—as well as the gifted high school student and all interested readers—both to the concepts unifying the fields of biology and to the diversity of facts that give the entire field its unique texture.”[577] When he was still writing the work, in 1962, Odum characterized his book in very similar terms as, “captur[ing] the minds of freshmen and high school students” and thus generating “more enrollees for the junior-senior course” that would use his *Fundamentals of Ecology* text.[578] The 1963 work, in other words, could function to interest people in the early stages of the professional training for ecologists. By contrast, the 1989 work was primarily, as we have seen, “a citizen's guide to the principles of ecology as they relate to today's threats to earth's life-support systems.” Odum then admits that, “I have also kept in mind specialists from fields such as engineering, environmental design and planning, environmental education, economics, sociology, agriculture, law, public health, and politics.”[579]

In the period from beginning of Odum's work on marshes in the 1950s through the early 1980s, ecology became, for Odum, a normative science. Clearly, by 1989 Odum was interested in engaging a broad audience in the effort to convince people of the value of the environment so that they would be interested in protecting it. In approaching ecology as a normative science, Odum also innovated on his role as a scientist based on the figuration that ecology entered with a larger public in the 1960s.

Odum's effort to understand the productivity of nature provides a basis for

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[577] Eugene Odum, *Ecology*. Modern biology series. New York: Holt, Rinehart and Winston, 1963), i.
[578] June 1962 correspondence from Odum to Tyler Buchenau. UGA 97 044, box 3.
[579] Odum, *Ecology and Our Endangered Life Support System,* ix.

understanding the transformation in his approach to ecology. Odum's early research on the productivity of marshes drew on the research he performed with his brother in Eniwetok in 1954. The emphasis in this work on the productivity of ecosystems can be traced to G. Evelyn Hutchinson and Raymond Lindeman's work. This work at Eniwetok was, like Hutchinson's and Lindeman's work on trophic structure and bioenergetics, and was concerned with uncovering the truth of the functioning of ecosystems.

When Eugene Odum returned to Athens, Georgia, he began applying the emphasis on measuring the productivity of ecosystems to the coastal marshes of Georgia--a research he had only recently gained access to through the largesse of tobacco heir Richard J. Reynolds, Jr. Over time, the emphasis on the ecological productivity of the marshes provided a way of asserting the *value* of the marshes and their need to be protected. When developers proposed mining marshes for phosphate and later developing a resort on the marshes, Odum's research on the marshes placed him in a prominent position to take part in efforts to mobilize in order to save the marshes from development. It was at this time, in the final years of the 1960s, that Odum drafted his most cited article, "The Strategy of Ecosystem Development." In it, Odum's effort to base the general value of the marshes based on their ecological value provides the basis for approaching--and zoning--all of nature in terms of its level of productivity. By the late 1960s, Odum had staked a position for ecology as a normative science capable of providing guidance for re-orienting how people understood and acted in relation to the natural environment.

From Odum's efforts to save the marshes he learned that assigning a financial value to nature could provide an effective way of convincing people that the environment should be protected. In this later stage of Odum's career, economic value becomes a mediator between factual questions about the working of ecosystems and moral claims about the need to protect ecosystems. His emphasis on the ecological productivity of nature provided, from the beginning of Odum's move to approaching ecology as a normative science, the basis of his assertions of the value of nature. In this later period, Odum gave ecological productivity an economic value. In approaching ecology as providing insight into questions of value, Odum stepped outside the role of the scientist as described by Weber.

Further, this implicit challenge to the Weberian scientific role was accompanied by another, more explicit challenge. From the 1970s, disciplinary specialization would come to represent a problem for Odum. The proliferation of disciplines and departments, narrow specialties did little, he thought, to resolve real world problems, which generally assumed a much broader scale and crossed the boundaries separating scientists into disciplines and specialties.[580] By contrast with overly specialized departments filled with professors capable of addressing very narrow areas of expertise, ecology was an "integrative discipline" and could offer to answer the problems introduced by disciplinary specialization.[581] Odum returned to this position many years into his retirement when he renamed *Ecology and Our Endangered Life Support Systems* to *Ecology: A Bridge Between Science and Society* in its third (1997) edition.[582] The shift in Odum's effort to approach the significance his work in terms of the goals of environmentalism had

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[580] Eugene Odum, "Diversity and the Emergence of Integrative Disciplines in Universities," (paper presented at the Forty-first Annual Meeting of the Southern University Conference, Birmingham, AL, 1978), 31. A year earlier, Odum tackled the same problem, and named ecology as "a new integrative discipline"

[581] Odum, "The Emergence of Ecology as a New Integrative Discipline," 1289-90.

[582] Significantly, Odum would rename his 1963 work *Ecology* in 1975 to *Ecology: the Link Between the Natural and the Social Sciences.*

redefined his conception of the kind of science that ecology could and should be.

The moves by which Odum would oppose ecology to norms of specialization described by Weber were also the moves by which he would position ecosystem ecology and more generally as a normative science providing answers to larger scale environmental and social problems. In contrast with Weber's view of science as a narrowly specialized domain insulated from society, Odum's ecology had assumed a much more public role. With the increased public interest in ecology in the 1960s, ecology entered into a figuration with a broader public that Odum asserted as proper for the rest of his life. As a science that was normative and integrative, ecology was capable of providing answers to real world environmental problems in a way that other disciplines could not. Academic specialists were limited by their specialties in the same way that they were limited to questions of fact. In contrast to his efforts to locate ecology as useful to but also distinct from the concerns of the cold war state (in chapter 3) as well as his efforts to provide ecology with the principles and coherence it needed to be a legitimate discipline (in chapter 4), by the late 1960s Eugene Odum had found a new place for ecology in society.

Chapter 6. The 'Subversive Science': Ecology, Environmental Critique and Alternative Scientific Roles

I. Introduction

In the 1960s, ecology became associated with the emergence of a new form of critique of modern society. The critique charged that our ability to control nature is a myth, and that through modern industry and technology we are filling our environment--and ourselves--with toxic chemicals. And our unsustainable use of natural resources is endangering our ability, and the ability of future generations, to live healthy and happy lives. This kind of position is most commonly associated with the publication of Rachel Carson's *Silent Spring* in 1962, a work that is often credited as the beginning of the contemporary environmental movement.[583] *Silent Spring* targeted the unreflective application of pesticides, often as part of US Department of Agriculture eradication campaigns, as undemocratic and toxic. Clearly, however, Carson's voice was not the only one intent on drawing public attention to these problems. In the same year as *Silent Spring*, Murray Bookchin published a more polemical work on the pervasiveness and negative health effects of “our synthetic environment."[584] Barry Commoner was another prominent figurehead in the emergence of an environmental critique. Commoner is interesting partly because his environmental critiques in the 1960s and 1970s were

583 Brulle, *Agency, Democracy, and Nature*, 182-3. Lutts, "Chemical Fallout: Rachel Carson's Silent Spring, Radioactive Fallout," 211. Dunlap and Mertig, *American Environmentalism*, 14 and 19. Jamison and Eyerman, *Seeds of the Sixties*, 66. Meyer and Rohlinger, “Big Books and Social Movements: A Myth of Ideas and Social Change,” 136–153. Stoll, "Rachel Carson's Silent Spring, a Book that Changed the World."

584 Bookchin asserts that, "The problems of our synthetic environment can be summed up by saying that nonhuman interests are superseding many of our responsibilities to human biological welfare. To a large extent, man is no longer working for himself. Many fields of knowledge and many practical endeavors that were once oriented toward the satisfaction of basic human wants have become ends in themselves, and to an ever-greater degree these new ends are conflicting with the requirements for human health. The needs of industrial plants are being placed before man's need for clean air; the disposal of industrial wastes has gained priority over the community's need for clean water. The most pernicious laws of the market place are given precedence over the most compelling laws of biology." Murray Bookchin, *Our Synthetic Environment*, (New York: Knopf, 1975), chapter 1, esp. 26 [under "Man and the Natural World"].

preceded by 1950s critiques on the health effects of radioactive fallout. In chapter 2 we saw how efforts to manage fallout as an epistemic and political question unraveled as these kinds of critiques propelled the issue of radioactive onto a larger public stage. As Laura Bruno, Ralph Lutts and others gave argued, debates on the health effects of fallout were linked in many ways with 1960s era debates on our treatment of the environment. The movement of radioactive matter, such as Strontium 90 through the environment provided a model—for critics such as Rachel Carson but also the public and scientists—for understanding the movement of pesticides and pesticide derivatives through the environment.[585] Nor were these the first works engaging in this kind of environmental critique. In 1948, Henry Fairfield Osborn, Jr. published *Our Plundered Planet* and William Vogt published *Road to Survival.*

Although all of these works drew on an ecological framework to draw attention to the negative effects of our treatment of our environment, and ourselves, Rachel Carson's work is often noted for the effective use of accessible and often lyrical prose to bring the dangers of synthetic pesticides to life for a broad audience. Instead of overwhelming the reader with a survey of changes in our use of technology or cancer statistics, Carson opens her work with “a fable for tomorrow” in which she describes an idyllic town “in the heart of America."[586] The town was full of variety of animals and plant life until,

> a strange blight crept over the area and everything began to change. Some evil spell had settled on the community: mysterious maladies swept the flocks of chickens; the cattle and sheep sickened and died. Everywhere was a shadow of death. The farmers spoke of much illness among their families. In the town the doctors had become more and more puzzled by

[585] Egan, *Barry Commoner and the Science of Survival*, 1-14; Moore, *Disrupting Science*, chapter 4, esp. 108-118; Bruno, “The Bequest of the Nuclear Battlefield: Science, Nature, and the Atom," 237–260; Lutts, "Chemical Fallout: Rachel Carson's Silent Spring, Radioactive Fallout," 216;

[586] Carson, *Silent Spring*, 1-3.

> new kinds of sickness appearing among their patients. There had been several unexplained deaths, not only among adults but even among children, who would be stricken suddenly while at play and die within a few hours.[587]

Her imagination of a small town living under “a shadow of death” invites the reader to imagine the threat in a familiar setting.

Interestingly, the early 1960s and late 1950s would see the publication of a number of novels that described fictional landscapes similar in many ways to the one described by Carson. Often in these books the source of blight would be nuclear war instead of pesticides. In books such as Nevil Shute's 1957 novel *On the Beach* (turned into a popular film in 1959 film), Pat Frank's 1959 novel *Alas Babylon*, and somewhat less explicitly in Walter M. Miller's 1960 work *Canticle for Liebowitz* and Richard Matheson's 1954 work *I Am Legend,* the source of blight was nuclear war instead of pesticides. Ralph Lutts and Laura Bruno have argued that efforts to imagine and understand radioactive fallout in the 1950s played a role in helping the public but also scientists understand, in the early 1960s, how pesticides pose a threat to human health as it moved through the ecosystem.[588] While these linkages form part of the background of this dissertation, in this chapter I will focus on environmental critiques and especially environmental critiques coming from professional ecologists.

It would be difficult to disentangle critiques drawing on the framework and insights of ecological research and research emerging from ecology as a scientific discipline in this period.[589] This is evident in the practice of referring to the environmental

[587] Ibid., 2.

[588] Lutts, "Chemical Fallout: Rachel Carson's Silent Spring, Radioactive Fallout," 212. Bruno, “The Bequest of the Nuclear Battlefield," 237-8.

[589] Further, in some ways it would represent a misguided effort for a sociologist of science to attempt to disentangle environmental critiques from ecological science. As I will describe below, the scientific

movement as “the ecology movement.” In 1970, the year that brought us the first Earth Day and the enacting of the National Environmental Policy Act, *Life Magazine* captured the proximity implied by this phrasing in an article heralding ecology as “the new mass movement.”[590] “Ecology,” the article argued, “is one major political issue on which the country may be united.”[591] Previously the name of a scientific discipline, ecology came to designate the politics of the environment. Many environmental critics as well came to name their efforts to change our relationship with the earth as “ecology.” In one camp Norwegian philosopher Arne Næss has spoken of the “deep ecology movement,” and, in another camp, anarchist Murray Bookchin has developed an intellectual and political project under the banner of “social ecology.”[592]

Although lines between ecology and the environmental movement often became blurred in these years, I will be building on the arguments of Abby Kinchy, Daniel Kleinman and Daniel Botkin foregrounding the tensions between the environmentalism as a social movement and ecology as a science.[593] For these scholars, the differences

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credentials of Rachel Carson's critique came under explicit attack in the controversy following *Silent Spring*. To rule that Carson was not a scientist without attending to the details of such a controversy would miss the importance of the indeterminacy of what counts as science and who can be called a scientist. This dissertation focuses, nonetheless, on scientists working in the academic environment, and although Carson was working as a science writer for the Department of the Interior's Fish and Wildlife Service before focusing on her own writing projects full time, she was not employed as an ecologist in an academic setting at the time she wrote *Silent Spring*.

590 "Ecology, the New Mass Movement." *Life* (January 30, 1970): 23.

591 Ibid.

592 See Næss' 1973 essay “The Shallow and the Deep, Long Range Ecology Movement” as well as Bookchin's more recent essay “What is Social Ecology?” There are many compelling histories of the environmental movement that speak of “the ecology movement” and efforts to draw on the name and credibility of ecology as a science to bolster, capture and convey the ends of environmentalism. Arnne Naess, "The Shallow and the Deep, Long-Range Ecology Movement. A Summary," *Inquiry* 16(1973): 95-100. Murray Bookchin, "What is Social Ecology?" In *Environmental Philosophy: From Animal Rights to Radical Ecology*, edited by M.E. Zimmerman. Englewood Cliffs, NJ: Prentice Hall, 1993. Accessed August 1, 2011, http://dwardmac.pitzer.edu/anarchist_archives/bookchin/socecol.html. Kingsland, Sharon. *The Evolution of American Ecology, 1890-2000* (Baltimore: Johns Hopkins Press, 2005), chapter 7. Gottlieb, Robert, *Forcing the Spring: the Transformation of the American Environmental Movement* (Washington D.C.: Island Press, 2005), chapter 3.

593 Kinchy and Kleinman. "Organizing Credibility: Discursive and Organizational Orthodoxy on the

between academic ecologists and environmental activists has made the perceived proximity of their views and their work a problem for many ecologists. Although the findings of ecology have often been useful for environmentalists, this usefulness has introduced problems for ecologists wanting to assert the autonomy of ecology as a science.[594] For ecologists constructing the identity of their discipline as "value-free science," environmentalism represents "controversial 'value-laden' politics."[595] To a large degree *Discordant Harmonies* represents an effort to disentangle environmentalism from ecology from the perspective of an ecologist wanting to preserve the value freedom of his science.[596] This emphasis on the distinctiveness of environmentalism and ecology raises a number of questions centering on how environmentalism and ecology interacted in these years and the impacts of these interactions on what it meant to be an ecologist.

II. Rachel Carson's Critique

> Can anyone believe it is possible to lay down such a barrage of poisons on the surface of the earth without making it unfit for all life? They should not be called 'insecticides,' but 'biocides.'[597]

Borders of Ecology and Politics," 869-70, 872-4, 877-8, and 890-1. Botkin, *Discordant Harmonies*, introduction.

594 Kinchy and Kleinman open their article by noting "Since the beginning of the environmental movement in the early 1960s, ecologists have struggled to maintain a distinction between their work and the efforts of environmental activists." Kinchy and Kleinman, "Organizing Credibility," 869, 872-4, esp. 869.

595 In responding to this tension, ecologists engage in precisely the kind of boundary work I described in chapter 3. As President of the Ecological Society of America, Odum distinguished ecology from environmentalism by noting that increased interest in the environment created a demand on ecologists to provide a factual basis for action. Ibid., 878-80 and 891, esp 891. Eugene Odum, "President's Report." *Bulletin of the Ecological Society of America* 47, 1 (March 1966): 10.

596 Botkin's work, however, often relies on simplistic characterizations of the science of ecology as triumphing over environmentalists' myths and "prescientific" ideas about nature. Here, I draw on Botkin's argument distinguishing ecology as a science from environmentalism with the important caveat that tensions between environmentalism as a social movement and ecology as a science will be approached as much more variable and complicated than Botkin's argument would have us believe. Botkin, *Discordant Harmonie*s, 188.

597 Carson, *Silent Spring*, 7-8.

In 1957 and 1958, a set of Long Island residents were reacting to a US Department of Agriculture campaign against the mosquito, gypsy moth and tent caterpillar. The USDA had sprayed a mixture of DDT and fuel oil over these residents' land and provoked a storm of protest linking a range of citizens concerned with the effects of the pesticides. In addition to the formation of a 'Committee Against Mass Poisoning,' a lawsuit was filed that was scheduled to begin in the early months of 1958. A friend of some of the plaintiffs, an organic gardener named Beatrice Hunter wrote an angry letter to the *Boston Herald* describing the effects of the pesticides on wildlife. Despite this protest and a law suit against the USDA based on it, the USDA planned on expanding their spraying campaign.[598]

Hunter's letter provoked Olga Owens Huckins to join the struggle. She forwarded Hunter's letter along with a personal letter to Rachel Carson with whom she had been friends since the early 1950s,[599] and, when another letter dismissed Hunter's concerns as "hysterical," Huckins fired off her own letter to the *Herald*. For her part, Carson contacted the USDA's Agriculture Research Service for information on the pesticides in use as well as available research bulletins. In addition to Huckins efforts to get Carson involved, Carson's literary agent Marie Rodell and her former coworker at the US Fish and Wildlife Service Clarence Cottam similarly encouraged Carson to expose the negative effects of indiscriminate pesticide use.

In Carson's acknowledgements in *Silent Spring*, she recalls the letter Olga Owens

598 This account relies heavily on Linda Lear's account of the events leading up to Carson's decision to write *Silent Spring*. Lear, *Rachel Carson: Witness for Nature*, chapter 14.

599 Huckins' friendship with Rachel Carson stemmed from her positive review of Carson's *The Sea Around Us* in 1951. Upon reading the review, Carson wrote Huckins a letter of thanks, and the two became friends and correspondents. Lear, *Rachel Carson: Witness for Nature*, 314.

Huckins had written to her about “a small world made lifeless” by a Massachusetts insecticide campaigns targeting mosquitoes.[600] In the letter to the *Boston Herald* that Huckins sent along with a more personal letter to Carson, she noted that this unwanted campaign and a similar one in Long Island wiped out populations of fish, bees, songbirds, and grasshoppers that were not the intended targets.[601]

This Long Island campaign against the gypsy moth was followed by an even more intense effort to exterminate the fire ant in the American South. Despite negative reactions to the gypsy moth campaign that had preceded it, the US Department of Agriculture was determined to wipe out the fire ant menace. When their offensive was met with resistance, the USDA redoubled their efforts to portray the fire ants as invading hordes of a foreign army, ravaging the agricultural base of the region.[602]

For people like Rachel Carson and Olga Huckins, campaigns to wipe out the fire ant and the gypsy moth were a dark new feature of postwar America and modeled an arrogant and shortsighted view of nature as something that was apart from people and that can, and should, be manipulated in order to increase people's comfort and profit. Armed with chemicals like DDT that were both powerful and poorly understood, this attitude suddenly became much more dangerous.[603] When she turned to write a book about insecticides and their effects—a book she felt *had* to be written—she had no idea

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[600] Rachel Carson, *Silent Spring*, iix. Linda Lear and Paul Brooks provide fuller accounts of Carson's decision to write *Silent Spring*. Lear, *Rachel Carson: Witness for Nature*, chapter 14; Paul Brooks, *House of Life: Rachel Carson at Work*, (Boston: Houghton Mifflin, 1972), chapter 19.

[601] Brooks, *House of Life*, 231-3.

[602] Lear, *Witness for Nature,* chapters 14 and 15, and Brooks, *House of Life*, 231-3.

[603] See Carson, *Silent Spring*, 161-172 as well as Daniel and Buhs on the fire ant campaign and Lear, *Witness for Nature*, chapters 14 and 15 on Carson's opposition to the campaign. Pete Daniel, “The USDA Fire Ant Campaign of the Late 1950s,” *Agricultural History* 64, 2, Spring (1990). Joshua Blu Buhs, *The Fire Ant Wars: Nature, Science, and Public Policy in Twentieth-Century America*, (Chicago: University of Chicago Press, 2004), 112-23.

how influential the book or the ecological approach it championed would become in shaping the contemporary American environmental movement.

Because of this influence, it would be difficult to speak of the politics of ecology in the 1960s and 1970s without some coverage of her argument and its reception. Given the volume of coverage her work has received,[604] here I will rely upon a summary of her argument that focuses on the following question: what was the relationship between ecology as a science and Carson's critique?[605]

At the time that Carson was researching and writing *Silent Spring*, she was living on the proceeds of her earlier best-selling work *The Sea Around Us*. Significantly, she was in a position outside a reward system for enforcing conventions of disciplinary specialization. She did not have to take into consideration the reaction of tenure review or promotion committees as she formulated her far reaching argument.[606]

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604 There are many excellent works on the environmental movement and Rachel Carson's place in it. See for example, Brulle, Agency, *Democracy and Nature*, 182-3. Mark Dowie, *Losing Ground: American Environmentalism at the Close of the Twentieth Century,* (Cambridge, MA: MIT Press, 1995). Dunlap and Mertig, *American Environmentalism*, esp. 2-4, 19, 28, and 65 on Carson. John Bellamy Foster and Brett Clark, “Rachel Carson's Ecological Critique,” *Monthly Review* (2008):1-17. Robert Gotlieb, *Forcing the Spring: the Transformation of the American Environmental Movement*, (Washington D.C.: Island Press 2005 [1994]), esp. chapter 3 on Carson. Gould, Kenneth, David Naguib Pellow and Allan Schnaiberg. *The Treadmill of Production: Injustice and Unsustainability in the Global Economy,* (Boulder, CO: Paradigm Publishers, 2008), xiii. Andrew Jamison and Ron Eyerman, *Seeds of the Sixties* (Berkeley: University of California Press, 1995), 92-100. Gary Kroll, “Rachel Carson's Silent Spring: A Brief History of Ecology as a Subversive Subject” from here: http://www.onlineethics.org/cms/9174.aspx. Mark H. Lytle, *The Gentle Subversive: Rachel Carson, Silent Spring and the Rise of the Environmental Movement*, (New York: Oxford University Press, 2007). David Pellow and Robert Brulle, editors, *Power, Justice, and the Environment: A Critical Appraisal of the Environmental Justice Movement*, (Cambridge, MA: MIT Press, 2005), esp. 1-4 on Carson.

605 This is a more restricted version of the question framing this chapter—namely, what is the relationship between ecology as a science and environmental critique? By appreciating the distinctiveness of ecology as an academic specialty and environmental critiques that drew off of the findings of ecological research, we can then appreciate the distinctiveness of the role modeled by ecologists—like Paul Sears, Marston Bates and others—who were willing to engage in environmental critiques directly.

606 Lear, *Witness*, chapter 10. In some of her earlier work, she commented explicitly on specialization: "As the frontiers of science expand, there is an increasing trend towards specialization. . . .But fortunately there is a counter-tendency, which brings different specialists together to work in cooperation." Rachel Carson and Linda Lear, *Lost Woods: the Discovered Writing of Rachel Carson*, (Boston: Beacon Press, 1998), 165.

Although Carson was not a scientist practicing within an academic setting and subject to its norms of disciplinary specialization, her argument was built on and synthesized the findings of professional ecologists whose work was considered credible. Carson's ecological perspective combined insights from academic research in ecology but also extended beyond a purely academic approach in treating ecology as a broad framework within which the insights from a variety of academic fields could be incorporated. Her argument brought together the work of economic entomologists studying insects, accounts of the chemical structure of the chlorinated hydrocarbons and organophosphates that were used as pesticides, occupational medicine research on carcinogens, and toxicological work. In many ways, this range made her work more compelling in providing a single framework that could incorporate such a diversity of scientific findings.

The argument of the book strongly relied upon a perspective built on the insights of postwar ecology. As we have seen, G. Evelyn Hutchinson is often associated with principles accounting for the movement of matter and energy through the environment. And Eugene Odum played no small role in pushing these principles into the mainstream of ecological research due to the influence of *Fundamentals of Ecology*, which placed these principles at the heart of ecosystem ecology. For these ecologists, the pathways through which matter moved through the environment were termed biogeochemical cycles, and often focused on food chains connecting plants with insects with smaller and then larger animals.

For Carson, these pathways pulled together different kinds of plants and animals and people into a seamless whole, a “web of life.” An insect that feeds upon grass might become food for a small animal that might, in turn, become food for a larger animal. And if the grass had been peppered with a toxic chemical such as DDT or dieldrin or heptachlor, that chemical travels up the food chain connecting grass, insects, animals, and humans. To make matters worse, toxins can often become more concentrated as they move up through the food chain. Supposedly safe levels of pollutants put in the category of 'the environment' become more and more toxic as they move towards humans and come to occupy, with DDT, a place in people's fatty tissue—or, with radioisotope Strontium 90, in the human skeleton.[607]

Because people are a part of nature, our practices, e.g. industrial farming and weapons testing, should be considered in terms of their impacts on nature and, therefore, their impacts on people as a part of nature. In 1956, for example, Carson maintained that, "neither man nor any other creature may be studied or comprehended apart from the world in which he lives." She continued on to argue that this approach necessarily impacts how we should approach problems: "[we] cannot understand the problems that concern us in this, our particular moment of time, unless we first understand our environment and the forces that have made us what we are, physically and mentally."[608] The troubling insight following this ecologically driven point of view is that the

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[607] Carson, *Silent Spring*, 22, 107, and 110 on food chains; Carson, *Silent Spring*, 64 and 75 for "web of life" or 67 for "fabric of life." It is important to note that Carson also saw her arguments in Silent Spring as being based on ecology. In a letter to Clarence Cottam, one of her former bosses at the Fish and Wildlife Service and famed conservationist, she writes, "my current writing project is a book dealing with the basic problem of chemical pesticides in present use on all living things and on their fundamental ecological relationships." Lear, *Witness for Nature*, 336.

See Lutts on the way the fallout debate of the 1950s prepared the public for Carson's argument and Bruno on the ways that following the movement of fallout through the environment laid the groundwork for following pesticides like DDT though the environment. Lutts, "Chemical Fallout: Rachel Carson's Silent Spring, Radioactive Fallout," 212. Bruno, "The Bequest of the Nuclear Battlefield," 237-8.

[608] Carson, *Lost Woods, 165*

unreflective use pesticides has altered the physical make up of our bodies.

Although this use of pesticides constituted Carson's primary target, she noted that nuclear weapons testing created the same kind of effects. She argues that,

> The most alarming of all man's assaults upon the environment is the contamination of air, earth, rivers, and sea with dangerous and even lethal materials. The pollution is for the most part irrecoverable; the chain of evil it initiates not only in the world that must support life but in living tissues is for the most part irreversible. In this now universal contamination of the environment, chemicals are the sinister and little recognized partners of radiation in changing the very nature of the world—the very nature of its life. Strontium 90, released through nuclear explosions into the air, comes to the earth in rain or drifts down as fallout, lodges in soil, enters into the grass or corn or wheat grown there, and in time takes up its abode in the bones of a human being, there to remain until his death. Similarly, chemicals sprayed on croplands or forests or gardens lie long in soil, entering into living organisms, passing from one to another in a chain of poisoning and death. Or they pass mysteriously by underground streams until they emerge and, through the alchemy of air and sunlight, combine into new forms that kill vegetation, sicken cattle, and work unknown harm on those who drink from once pure wells.[609]

This invocation of Strontium 90 is significant as the scientific and public controversy over radioactive fallout preceded the controversy that Carson's work would initiate in the early 1960s. Ralph Lutts has argued that the highly visible nature of the fallout controversy prepared the public for the controversy over the use of pesticides. Carson's argument following the movement of pesticides through the environment resonated with earlier arguments focusing on the ways that Strontium 90 moved through the environment and came into contact with people indirectly through the food chain.[610] Laura Bruno has similarly argued that efforts to study the movement of radioisotopes "changed the environmental sciences by revolutionizing the possibilities for studying and

[609] Rachel Carson, *Silent Spring*. Boston: Houghton Mifflin (2002 [1962]): 6.
[610] Lutts, "Chemical Fallout: Rachel Carson's Silent Spring, Radioactive Fallout," 211-2 and 220-3.

researching our environment in new ways."[611] She goes on to argue that, "Knowledge about the pathways of fallout isotopes became instrumental in the understanding of the pathways of other pollutants in the environment such as DDT."[612]

Although pesticides targeted populations of fire ants, and gypsy moths, and mosquitoes, their effects spread out over the boundaries of these biological categories and followed the logic of ecological relationships that brought together what taxonomy had kept apart. In terming insecticides and pesticides as, instead, 'biocides,' Carson is pointing to this lack of specificity and its impacts.[613] In addition to targeted organisms like the fire ant, populations of opossums, meadowlarks, blackbirds, armadillos, quail, cattle, wild turkeys, and domestic pets were affected along with the milk coming from cows grazing on land that had been poisoned from aerial spraying.[614]

The fact that there were so many unintended targets indicated, for Carson, that bodies such as the USDA were often acting based on dangerously partial knowledge. In the case of their campaign against the fire ant, the "chemicals to be used were dieldrin and heptachlor, both relatively new. There was little experience or field use for either and no one knew what their effects would be on wild birds, fishes or mammals when applied

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611 Bruno, "The Bequest of the Nuclear Battlefield," 237-8, esp. 237.

612 Ibid., 238. While Bruno's argument is compelling on many levels, it would be stronger with a fuller sense of work in radiation ecology and if it could account for the differences between Carson's work and radiation ecology.

613 Carson was not the first to coin the word 'biocide.' In 1947, E. M. Greenberg wrote the *Saturday Review of Literature* and suggested that, in addition to the newly coined word 'genocide' should be added a term to designate "another kind of murder going on all the time all about and within us." E. M. Greenberg, Letter to the Editor, *Saturday Review of Literature*, August, 1947. "Biocide." Oxford English Dictionary, 2nd ed. OED Online. Accessed August 1, 2010, http://dictionary.oed.com/cgi/entry/00337225.

614 See Carson, *Silent Spring*, (New York: Mariner Books 2002[1962]), 161-172 as well as Daniel and Buhs on the fire ant campaign and Lear 2009, chapters 14 and 15 on Carson's opposition to the campaign. Pete Daniel, "The USDA Fire Ant Campaign of the Late 1950s," *Agricultural History* 64, 2, Spring (1990). Joshua Blu Buhs, *The Fire Ant Wars: Nature, Science, and Public Policy in Twentieth-Century America*, (Chicago: University of Chicago Press, 2004).

on a massive scale."[615] Because the USDA was acting on such incomplete knowledge, their campaign took on the form of an experiment—but one conducted in the world, outside the laboratory. In her famous denunciation, Carson notes the experimental character of the fire ant campaign,

> It is an outstanding example of an ill-conceived, badly executed, and thoroughly detrimental *experiment* in the mass-control of insects, an *experiment* so expensive in dollars, in destruction of animal life, and in loss of public confidence in the Agriculture Department that it is incomprehensible that any funds should still be devoted to it.[616]

Carson is here formulating a critique of real-world experiments that anticipates later discussions in science studies. Wolfgang Krohn and Peter Weingart, for example, later comment on the experimental character of nuclear energy. Because of its complexity—and the complexity of safety programs—nuclear energy is tested in an 'implicit' or 'social' experiment. "Society," they argue "has become an experimentation field for complex technologies."[617]

Carson's application of an ecological perspective led her to adopt a political stance that was critical of mainstream politics. Ecology provided a source of disciplinary academic insights but also as a larger framework that incorporated the insights of a variety of disciplines and highlighted the ways that the use of synthetic pesticides was mainstream but also had deadly effects.

The way in which Carson went beyond existing scientific disciplines became a feature of attacks on Carson's credibility. The controversy that followed the publication of

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[615] Carson, *Silent Spring*, 165.
[616] Carson, *Silent Spring*, 162, emphasis added.
[617] Wolfgang Krohn and Peter Weingart, "Nuclear Power as Social Experiment: European Political 'Fall Out' from the Chernobyl Meltdown," *Science, Technology, and Human Values* 12, 2, Spring (1987): 52.

Silent Spring was defined, to a large degree, by efforts to undermine or establish the scientific credibility of Carson's argument. Velsicol, a company selling pesticides, the USDA, economic entomologists and others attacked the book as the alarmist and non scientific work of a woman.[618] Former Secretary of Agriculture Ezra Taft Benson wondered publicly "Why a spinster with no children is so concerned with genetics?" His answer was that Carson was "probably a Communist."[619] Efforts to undermine Carson's credibility commonly portrayed her as an overly emotional woman with a fondness for cats and birds and a "mystical attachment to the balance of nature."[620] She was not a scientist.[621] Although her undergraduate record studying biology at the Pennsylvania College for Women earned her a place studying zoology and genetics at Johns Hopkins in 1929, she left the university in 1934 with the Master's degree she had earned two years earlier in order to support her family by working at the U.S. Bureau of Fisheries (later the Fish and Wildlife Service).[622] Whether or not Carson's educational background, her work with the Fish and Wildlife Service, and her familiarity with scientific research qualified her as a scientist and someone and someone whose work could be counted as credible was very much at stake.

A year later, however, Kennedy's prestigious Presidential Scientific Advisory Committee (or PSAC) vindicated Carson's arguments and silenced many of the critics

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618 Lear, *Rachel Carson: Witness for Nature*, 429-33. Lear addresses the question of why the U. S. Department of Agriculture would attack Carson in her 1992 article, “Bombshell in Beltsville." Linda J. Lear, “Bombshell in Beltsville: The USDA and the Challenge of ‘Silent Spring’.” *Agricultural History* 66, no. 2 (April 1, 1992): 151–170.

619 Lear, *Rachel Carson: Witness for Nature*, 429

620 Ibid. 429-32, esp. 430.

621 Ibid. 428-31

622 In the context of a detailed treatment of Carson's educational trajectory, Lear reports that during the time that Carson enrolled at Johns Hopkins "the ruling assumption of the faculty of Philosophy was that most graduate students would continue on for the Ph.D.." Ibid. chapters 2 and 3, esp. 67.

who attacked the scientific validity of her claims.[623] In vindicating the claims of her work, PSAC lent the credibility of one of the cold war's most prestigious group of scientists behind the weight of her argument. Science, in this case, agreed with the environmental critique. If, as so many have claimed, *Silent Spring* inaugurated the contemporary environmental movement, it also set the terms for its often troubled reliance on the findings, and prestige, of scientists to bolster its claims.[624]

III. Paul Sears' Critique

Born twenty two years before Eugene Odum, Paul Bigelow Sears (1891 – 1990) was a professional ecologist who engaged in a number of public critiques throughout his professional career. One of the most remarkable critiques came in an article published in *Science* in 1958. Speaking as the retiring president of American Academy for the Advancement of Science, Sears addressed himself to America's "present hysteria" surrounding the launch of Sputnik I, in October 1957. The Soviet Union had taken many Americans by surprise—and punctured the nation's sense of technological dominance—by launching the world's first artificial satellite. Less than a month later—while many Americans were still grappling with the implications of Sputnik, the Soviet space program launched a second satellite, Sputnik II, sending famed space dog Laika into orbit and certain death. In his recent account of America's reaction, Paul Dickson

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[623] See Linda Lear, *Rachel Carson: Witness for Nature*, chapter 18; Zuoye Wang 's *In Sputnik's Shadow: The President's Science Advisory Committee and Cold War America* (New Brunswick: Rutgers University Press, 2008), chapter 12.

[624] Steve Epstein's *Impure Science* provides a theoretical framework that draws off of Steven Shapin's emphasis on credibility but positions this emphasis in a field of struggle in which credibility can be both an outcome and a target of attack. Epstein, Impure Science, 3, 19, and 330. Shapin, "Cordelia's Love," 255-75.

characterized Sputnik as "the shock of the century."[625]

Amid this frenzied reaction, Sears adopted an exceptional position. He rebuked the readers of *Science* for what he saw as an escapist obsession with outer space. Instead of facing the very real dilemmas posed by resource scarcity and increasing population, people instead are falling back onto a childlike faith in technology—the "belief that technology will solve any problems that confront humanity."[626]

Sears went further to describe the lives of contemporary humans as analogous to the lives of factory farmed chickens. He provides an evocative description of these chickens living in "ultra-modern apartment[s]" and their powerlessness and dependence on "an elaborate technological mesh":

> From New Jersey to Oregon, one sees great egg factories, where highly selected strains of poultry are confined at maximum density and with maximum efficiency. Every need—nutritive, environmental, psychological—is taken care of. These gentle, stupid birds have no responsibility but to stay alive and do their stuff. Yet they are at the mercy of any break in an elaborate technological mesh that keeps them going. And should a stranger burst abruptly into their quarters, the ensuing panic would pile them up in smothering heaps of their ultra-modern apartment.[627]

While he admits "People, of course are not poultry," he argues that analogy is "one of the most powerful tools of the scientist."[628] Like the chickens, we have become used to being

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[625] Paul Dickson, *Sputnik: The Shock of the Century* (New York: Walker and Company, 2007), 1-10. Dickson opens his work with the striking juxtaposition of the launch of Sputnik and the premier of the quintessential postwar sitcom Leave it to Beaver.

[626] Paul Sears, "The Inexorable Problem of Space," in *The Subversive Science: Essays Toward an Ecology of Man*, ed. Paul Shepard et al. (New York: Houghton Mifflin, 1969), 79. Other critics similarly characterized the often obsessive focus on space travel during this period—along with the more general treatment of science and technology as ends in themselves—as a form of escape from the complexity of more pressing social problems. See for example Arendt and Mumford. Hannah Arendt, *The Human Condition*, (Chicago: University of Chicago Press, 1998), Prologue, esp. 1-2. Lewis Mumford, *Pentagon Of Power: The Myth Of The Machine, Vol. II* (New York: Harcourt Brace Jovanovich, 1974), Figure 14-15 and 304..

[627] Sears, "The Inexorable Problem of Space," 80,

[628] Ibid., 81.

treated through the logic of "maximum efficiency" and profit. We have become used to it, Sears argues, because these are lenses we have grown accustomed to using in viewing the rest of nature. Instead of addressing questions about the quality of life on earth, we are instead addressing—in a narrow technical mode—the conditions of necessity and asking questions such as how can we meet the most basic of human needs in the most cost efficient manner possible. Instead of being a mean to the ends of human happiness, technology has become an end in itself.

Sears' critique did not begin in the postwar years, however. For many, he best known for the early outspoken position he took in reaction to the Dust Bowl years of the 1930s. First published in 1935 *Deserts on the March* covers the way that short sighted agricultural practices, especially, have stripped the productive top soil and turned formerly rich land into deserts. The book opens with a dark image that sets the tone for the remainder of the work. He opens the work by announcing, "The face of the earth is a graveyard, and so it has always been."[629] On one level, this image sets a dark tone for the work but perhaps one that would have made sense to an audience still gripped in the midst of "the Dust Bowl years" and facing the very real dilemmas posed by the loss of their land's agricultural productivity.[630] On another level however, the dark overtones of the image provide Sears with an opportunity to redefine people's perspective on the Dust Bowl by foregrounding the perspective of the earth. Immediately after calling the earth a "graveyard," he notes,

> To earth each living thing restores when it dies that which has been borrowed to give form and substance to its brief day in the sun. From earth, in due course, each new living being receives back again a loan of

[629] Sears, *Deserts on the March*, 1.
[630] Gus Speth, "Introduction." In *Deserts on the March,* (Washington D. C.: Island Press, 1988), xi-v.

> that which sustains life. What is lent by earth has been used countless generations of plants and animals now dead and will be required by countless generations in the future.[631]

The earth is a graveyard, but it is also the source of life. Here and throughout this work, Sears endeavors to broaden people's focus by highlighting the negative effects of short sighted efforts to wrest as many crops from a given plot of land as quickly as possible. Sears points to the circumstance of the Dust Bowl but also many similar instances of desertification as evidence of the need to take a longer term and ecological perspective. Although the mode of his argument is ecological, he returns time and time again to the fact that it is people's approach to nature that is to blame.

Despite scientific and technological advances that have promised increased well being often by enlarging people's control over nature, over a longer time range these advances have instead backfired and resulted in tragedies such as the Dust Bowl.[632] Sears summarizes one of the primary themes of the work in announcing that, “Nature is not to be conquered save on her own terms.”[633] Throughout the book, ecology provides a framework in which to interpret the interaction between people and their natural environment.[634] The tone set by the opening image of the work is driven home, however, as the reader realizes that, time and time again, the lesson is the same. Humans' efforts to conquer nature have often initially led to increased agricultural returns and the

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631 Sears, *Deserts on the March*, 1.

632 Sears asserts that, “Mechanical invention plus exuberant vitality have accomplished the conquest of a continent [North America] with unparalleled speed, but in doing so have broken the gentle grip wherein nature holds and controls the forces which serve when restrained, destroy when unleashed.” Sears, *Deserts on the March*, 11.

633 Ibid., 3.

634 Sears' use of ecology as a broad framework in which to interpret the relation between and mutual constitution of people's activities and the environment provides an early example of the use of ecology that would find a wide popular audience in Rachel Carson's *Silent Spring* twenty seven years later.

blossoming of cities and civilizations, but when considered in a larger scope that includes their effects on the natural environment—desertification, floods, and other natural disasters—these efforts have proven far from successful. In his wide ranging survey of failed attempts to control nature, he writes, “the story of man's destruction upon the face of his own Mother Earth.”[635]

In Sears' postwar work, we see Sears' commitment to the critical potential of ecology become more explicit. Most dramatically, in a 1964 article, Sears announced that ecology was “subversive.” He argues that, “By its very nature, ecology offers a continuing critique of man's operations within the ecosystem,” in part because it affords a “unifying philosophical point of view."[636] What were the targets of the critical perspective that ecology afforded?

Above we saw that one target was the space program.[637] Sears, however, saw the “almost hypnotic concern with outer space” following the launch of Sputnik as part and parcel of a much larger problem—the widespread legitimacy of science and technology in the postwar years. He saw in the reaction to Sputnik signs of, “the culmination of a new faith—the belief that technology will solve any problems that confront humanity.”[638]

If peoples' relation with science and technology was one target, another was our relationship with the economy. He noted in his 1964 article that, “it is disturbing to hear the current glib emphasis on economic 'growth' as the solution of all ills."[639] A page later, he extended his critique to include the widespread emergence of advertising and marketing following the successes of Fordist mass production:

[635] Sears, *Deserts on the March*, 11.
[636] Sears, “Ecology-A Subversive Subject,” 12.
[637] Sears, “The Inexorable Problem of Space,” 9-16.
[638] Ibid., 10.
[639] Sears, “Ecology-A Subversive Subject," 13.

> Mass production with its steadily increasing drains upon energy and materials is now so efficient that industry has to exert itself to create demand. . . .Meanwhile our efficient industry and domestic sanitation push their wastes into air and water—painful mockery of the quiet recycling of materials in the ancient pattern of nature.[640]

Nor were science and the economy the only problems Sears saw.

He also called for "fundamental reforms in the educational process" as part of a larger imperative to arm citizens with critical reasoning.[641] While the university system, an "instructional juggernaut creaking along in conventional paths" was content to offer highly specialized disciplinary knowledge, Sears saw a need for the kind of unifying perspective that ecology could offer.[642] He noted that, "College science, training as it does both scientist and citizen, should be taught in the context with the rest of human knowledge and experience."[643]

For Sears, this recommendation became all the more meaningful when considering that universities not only trained current students but also future citizens. Armed with a more holistic and critical perspective, citizens would be prepared to see through the hype surrounding the space program as well as widespread faith in technology and the economy. In a 1954 article, Sears noted that, "Of the utmost importance is the need to see that the ecologist's point of view is embodied in elementary science education. This is more than a matter of self-preservation for our discipline—it is a matter of responsible citizenship."[644] Further, this kind of critical, ecological perspective

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640 Sears, "Ecology-A Subversive Subject," 14. See also Sears, "Human Ecology: A Problem in Synthesis," *Science* 120, 3128 (1954): 960.
641 Ibid., 13.
642 Ibid.,12.
643 In a similar vein, he notes that, "No one science by itself can give that balanced view of the world of nature so essential to the citizen in our modern culture." Sears, "The Inexorable Problem of Space," 8.
644 Sears, "Human Ecology: A Problem in Synthesis," 961-2.

could arm citizens to base their political stance on their knowledge of the environments in which they lived and worked.[645] Sears summarizes the critical potential of ecology in suggesting that, if it were "taken seriously as an instrument for the long run welfare of mankind" it could, "endanger the assumptions and practices accepted by modern societies, whatever their doctrinal commitments."[646]

Here, Sears clearly approached ecology as part of a political effort to change our relationship with nature. Sears' student Paul Shepard took his adviser's use of ecology as the basis for critique seriously, and produced a body of work that provided inspiration for many environmental activists and thinkers. Rachel Carson cites Shepard in the second chapter of *Silent Spring* in asking, "[w]hy should we tolerate a diet of weak poisons" and "[w]ho would want to live in a world which is just not quite fatal?"[647] In this 1958 essay Shepard launched a biting critique of the systematic poisoning of the environment with synthetic pesticides and nuclear fallout and the inadequacy of notions of safe thresholds.

Further, Shepard's work was taken up by members of the 'deep ecology' movement and the founders of the radical environmental group 'EarthFirst!'[648] Both deep ecology historian Bill Devall and Arnne Naess, the founder of deep ecology, have

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645 See Sears' comment that, "as a matter of political health, the citizen must face the facts where he lives. . .at the local level" and, ten years earlier, "the long road to constructive statesmanship begins at the local level." Sears, "Ecology-A Subversive Subject," 13. Sears, "Human Ecology: A Problem in Synthesis," 962.

646 In 1964, the "doctrinal commitments" of the world's two largest powers were capitalism and communism. His emphasis on the potential role of ecology in arming citizens with local knowledge takes on greater significance when considered next to his warning that, "Blanket solutions from distant sources of power can seldom be trusted." Although Sears does not name the "sources of power"—nor the practices—that he has in mind, his comments could be read as suggesting his preference for a political order that would be smaller and more local. Sears, "Ecology-A Subversive Subject," 11 and 13.

647 Shepard, "The Place of Nature in Man's World," 86, quoted in Carson, *Silent Spring*, 12.

648 Bill Devall, "The Deep, Long-Range Ecology Movement, 1960-2000--A Review," *Ethics and the Environment* 6, 1 (2001): 18 and 24. Bill Devall and George Sessions, *Deep Ecology: Living as if Life Mattered* (Salt Lake City: G.M. Smith, 1985) 181-5. David Foreman, "Forward." In *Man in the Landscape: a Historical View of the Aesthetics of Nature* by Paul Shepard, (Athens, GA: University of Georgia Press, 2002), xi-xx

asserted Shepard's importance to deep ecology.[649] In his landmark 1973 article defining the tenets of deep ecology--and citing Paul Shepard, Naess defined the deep movement in contrast with efforts of the "shallow" ecology movement, which has its primary goal the "health and affluence of people in the developed countries."[650] Dave Foreman, one of the founders of EarthFirst![651] has called Shepard "the most important thinker of our time," and notes that he became aware of Shepard by reading, in 1971, Shepard and McKinley's edited volume about ecology titled *The Subversive Science.*[652] Deep ecology, social ecology and EarthFirst! represent some of the more radical strains of environmentalism. The uses that these groups found for the work of Sears and his student Shepard underscore the political implications of Sears' critique. While Sears' critique is certainly noteworthy, other professional ecologists drew on the approach and insights of their discipline in adopting critical stances.

IV. Marston Bates' Critique

Marston Bates, closer in age to Odum than the elder Sears, speculated in 1956, "[p]erhaps our Western world, so proud of its technical advantages, is starting a process of suicide."[653] Four years later, Bates published a powerful critique in his popular 1960 work *The Forest and the Sea*. After graduating from the University of Florida in 1927,

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649 Devall, "The Deep, Long-Range Ecology Movement," 18 and 24. Arnne Naess, "The Shallow and the Deep, Long-Range Ecology Movement. A Summary." *Inquiry* 16(1973): 100.

650 Shepard is one of very few citations in this article. Other names include Barry Commoner, Paul Ehrlich, Jacques Ellul, Jacques Meynaud, and Eugene Odum. Naess, "The Shallow and the Deep," 95 and 100.

651 Derek Wall, *Earth First! and the Anti-Roads Movement* (London: Routledge, 1999), chapter 3. Along with Shepard and Naess, Edward Abbey provided an inspiration to the formation of EarthFirst! in his 1975 novel *The Monkey Wrench Gang*. In the novel, the protagonists decide to take the mistreatment of the environment into their own hands and engage in sabotage as a form of protest. Fed up with the perceived failure of mainstream environmental groups, Dave Foreman, Mike Roselle and others founded EarthFirst! and engaged in the kind of direct action that Abbey described in his book.

652 Foreman, "Forward," ix.

653 Marston Bates, "Process." In *Man's Role in Changing the Face of the Earth,* ed. William L. Thomas, Jr. (Chicago: University of Chicago Press, 1956), 1140.

Bates worked for the United Fruit Company in Honduras and Guatemala. In 1931 he would begin his studies in zoology at Harvard, where he would earn his PhD in 1934. After spending a year in the Caribbean on a fellowship, Bates moved to Columbia to study mosquitoes in a laboratory started by the Rockefeller Foundation. In 1952 Bates would leave the foundation to assume a position in zoology at the University of Michigan.[654]

His 1960 work *The Forest and the Sea* is intriguing on a number of levels. Predating Carson's work by two years, Bates provided a similarly compelling combination of evocative science popularization with critique. Bates took aim at some of the same targets as Paul Sears and Rachel Carson. Similarly to Carson, he noted that, although many people use the logic of utility to justify 'selfish' and 'arrogant' actions,

> The danger of complete man-centeredness in relation to nature is like the danger of immediate and thoughtless selfishness everywhere: the momentary gain results in ultimate loss and defeat. 'Enlightened self-interest' requires some thought for the other fellow, for the other nation, for the other point of view. . . .This applies with particular force to relations between man and nature.[655]

And, similar to Sears' critique of the instrumentalization of people (in his image of people as factory farmed chickens), Bates offered a disturbing image of what our food chain might look like if we treat it in purely technical terms as a problem of efficiency:

> The shorter the food chain the more efficient the conversion of solar energy into human food. The logical end result of this process, sometimes foreseen by science fiction writers, would be the removal of all competing forms of life--with the planet left inhabited by man alone, growing his food in the form of algal soup cultivated in vast tanks. Perhaps ultimately the algae could be dispensed with and there would be only man, living

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654 Bates, T*he Forest and the Sea: a Look at the Economy of Nature and the Ecology of Man* (New York: Vintage Books, 1960), 279.

655 Ibid., 260.

> through chemical manipulations.
> Efficient, perhaps; dismal, certainly; and also dangerous.[656]

Bates' argument here began in a similar way to much of Odum's critical work. Both ecologists deployed ecological knowledge about the movement of energy through levels of the food chain. Bates, however, painted the unsettling image of people becoming so rationally instrumental that they shorten the food chain to one link—from algae to people. In another passage, Bates provided a similarly disturbing image of the outcome of then-current trends of population growth and agricultural practices:

> The single crop system is in precarious equilibrium. It is created by man and it has to be maintained by man, ever alert with chemicals and machinery, with no other protection against the hazard of some new development in the wounded natural system. It is man working against nature: an artificial system with the uncertainties of artifacts. Epidemic catastrophe becomes an ever-present threat.
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> This is one of the dangers inherent in man's mad spree of population growth--he is being forced into ever more arbitrary, more artificial, more precarious relations with the resources of the planet. The other great danger is related. With teeming numbers, an ever tighter system of control becomes necessary. Complex organization, totalitarian government, becomes inevitable; the individual becomes a worker ant, a sterile robot. This is surely not everyone's destiny.[657]

From a critical ecological perspective, we can see how people are turning themselves into drones, or robots.

In another chapter of his 1960 work, Bates invited the reader to imagine what the world would look like from an insect's perspective. Here he challenged the reader to imagine how insects such as mosquitoes sensed and responded to the world around them. As humans we primarily rely on vision to navigate our natural and built environments,

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[656] Ibid., 260-1.
[657] Bates, *The Forest and the Sea*, 261.

and many of us are unaware of the rich world of scents that insects and other animals inhabit and the ways that a scent can render visible an attractive mate, a source of food, or the presence of danger. As Bates invited the reader to imagine the interior lives of insects, he also issued a political challenge. Seeing the world through the eyes--or antennae--of insects entailed stepping out of a purely anthropocentric view and seeing the world, and the world's problems, from an ecological perspective.[658]

V. Human Ecology and the Role of the Scientist

> And for those who are never happy without a new pigeonhole it may be that something like a new discipline is needed, which, for want of a better name might be called 'social ecology.' This new discipline would include those branches of the social and natural sciences which have a more or less direct bearing upon the role of man in re-forming his habitat. . . . The goal of social ecology is wholeness and not a mere adding together of innumerable details.[659]

Although E.A. Gutkind's call for "social ecology" never took off as an academic field, there was a flurry of activity among ecologists such as Paul Sears, Paul Shepard and Marston Bates, who pushed for something very similar under the banner of 'human

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[658] It is important to note that Bates attempted to implement the kind of curriculum reforms that Sears described in his work. While Sears was lambasting the general scientific readership for their frenzied reaction to Sputnik, Bates took advantage of the scare to implement biology curriculum reforms as a part of the Biological Sciences Curriculum Study. In his review of Bates' and others efforts to design 'the green book' for instruction in ecology, ecologist Frank Egler announced that, "Our civilization, our cultural heritage, and our richly meaningful individual lives—with or without superfluous material affluence—may or may not survive such multiple threats as exploding human populations, radioactive fallout on the land, polluted waters, loaded atmospheres, and persistent biocides ramifying through the environment. . If our values are to survive, then a science must arise to integrate the now fractionated specialist sciences, whose short-term interests serve the pressure groups within our technologies. . . .Two major prospects are on the horizon: (1) an Environmental Biology, and (2) an Ecosystem Ecology emerging from academic Plant and Animal Ecology. I shall put all of my poker chips on the imminent development of an Environmental Biology" Frank E. Egler, "'Environmental Biology,' or 'Ecosystem Ecology'?" *Ecology* 46, no. 3 (May 1, 1965): 386.

[659] Gutkind, E. A. "Our World From the Air: Conflict and Adaptation." in *Man's Role in Changing the Face of the Earth,* ed. by William L. Thomas, Jr. (Chicago: University of Chicago Press, 1956), 6.

ecology' in the 1950s.[660] In addition to the many articles calling for this kind of work, there was also discipline-level maneuvering at the same 1956 Ecological Society of America meeting where Odum led an early meeting for radiation ecology.[661] What are some of the defining features of human ecology and how did it fit in with Weber's figure of the scientist as academic specialist?

In this section I will explore postwar calls for human ecology as well as work in this vein as modeling a scientific role very different from the one described by Weber in "Science as a Vocation." While human ecology will receive the bulk of the attention here, I will also consider postwar calls for conservation as a potential field that—for academic ecologists such as Marston Bates, Charles Elton, and Frank Fraser Darling—shared a strong resemblance to human ecology.[662] I will also include a brief discussion of some of

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660 In identifying Gutkind as a key influence (with Lewis Mumford) on Bookchin's early works, Damian White's work suggests that the overlap between Gutkind's and Bookchin's calls for "social ecology" is more than mere coincidence. Damian White, *Bookchin: A Critical Appraisal* (London: Pluto Books, 2008), 19.

661 "1956 Annual Meeting, Storrs, Connecticut, August 27-29." *Bulletin of the Ecological Society of America* 37, no. 1 (March 1, 1956): 3–5.

662 Frank Fraser Darling, "Introduction." *Future Environments of North America*, edited by F. Fraser Darling and John P. Milton, 1-7. New York: The Natural History Press.

Professional ecologists Frank Fraser Darling, Paul Sears and Charles Elton--who were all associated with the call for human ecology--all wrote reviews of early ecological critiques. Sears and Darling reviewed Henry Fairfield Osborn, Jr.'s 1948 work *Our Plundered Planet*, and Elton reviewed Vogt's *Road to Survival*, also from 1948. In his coverage of Osborn's work, Darling noted Osborn's emphasis on population as a driver of environmental issues and commented that, "Malthus-at whom there was so much carping in the inter-war period-is now back as an up-to-date prophet." His emphasis on the importance of politics in his concluding remarks is telling:

> The reader of this sincere book feels that the author is still hopeful that man will put his garden in order, but the reviewer thinks that Mr Osborn glosses over one cardinal factor in man's make-up, his political quality, unique in nature. We see quite well the necessity for reducing-or certainly not increasing-the world population of human beings. Yet every government seems convinced that its own population must not decrease and is afraid lest it may. Increase will, in fact, continue; and in the reviewer's opinion, technology and conservation will not catch up. The plague on the planet will eat itself out.

Elton's review of Vogt's work was similarly sympathetic and similarly emphasized the prominence of Malthusian themes in Vogt's book. He concludes, nevertheless, with an emphasis that contrasts with Darling's review: "it is on the population question itself that the future really hangs. Here we find a good deal of divergent opinion, and a great many questions that depend less on scientific research and technical planning, than upon social and religious attitudes. Some beliefs, for instance in eternity and the earlier work by Paul Sears as prefiguring many of the themes of his postwar work and human ecology more generally.

As a proposed area of study, human ecology stood in marked tension with Weber's call for disciplinary specialization and engagement with narrow audiences of professional specialists. As we have seen, Max Weber argues in "Science as a Vocation" that scientists must adjust to the historical circumstances in which they find themselves. In a context in which specialization has become a precondition for scientific achievement, scientists must restrict their work to the goals of their specialty. Similarly, science can no longer provide a pathway to God in a disenchanted world in which "one can, in principle, master all things by calculation."[663] In a modernity defined by the fragmentation of society into distinct value spheres (law, science, religion, etc.), overarching narratives providing meaning no longer hold. Scientists must confine themselves to science—to matters of fact—and avoid engaging questions of values or meaning or happiness. Despite these limitations, a scientist can approach the already given goals of science--goals that cannot be determined scientifically--with a secularized devotion. And as a teacher, a scientist can promote clarity and self-awareness among students by presenting a balanced view that includes facts that might be "inconvenient" for the students.[664]

Advocates of human ecology, however, had a very different vision for the role of

other worlds, may make arguments purely from terrestrial conservation inconclusive to the believers. But with all such limitations, there is emerging to view, with books like Mr Vogt's, a picture of human ecology that needs the impartial study of trained animal ecologists." While Darling concludes with an emphasis on the importance, and unlikeliness, of political action, Elton concludes by emphasizing the importance of more "impartial study." Interestingly, Paul Sears' review of Osborn emphasizes the potential role geology as a discipline might play in raising public awareness about the severity of the problems introduced by our treatment of the environment. Darling F. Fraser, "Malthus." *Journal of Animal Ecology* 17, no. 2 (November 1, 1948): 262 [both quotes]. Charles Elton. "Malthus." *Journal of Animal Ecology* 17, no. 2 (November 1, 1948): 264. Paul Sears, "[untitled]." *The Journal of Geology* 58, no. 1 (January 1, 1950): 87.

663 Weber, "Science," 139.

664 Ibid., 147

the scientist. In a 1954 essay on human ecology, Paul Sears approached the central problem of the field in terms of one of the defining characteristics of Weber's scientist—specialization. Here, however, Weber's problem of how to adapt to specialization as a necessary characteristic of science is turned on its head. In Sears' essay the problem is how to create a field that avoids specialization. He notes that, “Human ecology is not so much a specialty as a scientific activity which must draw on a broad range of specialties” including disciplines contiguous to ecology—other areas of biology, geology, and chemistry—but also history and other disciplines focusing on human activity.[665] Further, Sears saw the audience for the work of human ecology as being much more broad than the narrow professional audience that Weber envisioned. “Our discourse,” he notes, “should be simple. Technical terms should be our servants, not our masters."[666]

Although I have foregrounded Sears here, he was not the only ecologist hoping for the emergence of human ecology as a non-specialist field capable of speaking to large public audiences. Paul Shepard followed in his mentor's footsteps in promoting human ecology explicitly as well as implicitly in a long series of strikingly cross-disciplinary and critical works published from the 1950s into the 1990s.[667] Although Bates did not identify *The Forest and the Sea: A Look at the Ecology of Nature and the Ecology of Man* as a work of human ecology, the subtitle reveals that it is close in spirit.[668] In 1955 ecologist

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[665] Sears, "Human Ecology: A Problem in Synthesis," 961.

[666] Ibid.

[667] Paul Shepard, “Whatever Happened to Human Ecology?” *BioScience* 17, no. 12 (December 1, 1967): 891–911.

[668] As I will briefly explore below, Bates—as well as Rachel Carson in places—follows ecologist Charles Elton (in *Ecology of Invasions*) in positioning this work as one of conservation. See Bates, *The Forest and the Sea*, 259; Charles Elton, *The Ecology of Invasions by Animals and Plants* (Chapman and Hall, 1958), 259; Carson, *Lost Woods*, 167; Carson, *Silent Spring*, 117, 165, and 265; and Lewis Mumford, "Closing Statement." In *Future Environments of North America*, ed. F. Fraser Darling et al. (New York: The Natural History Press), 727-8.

Frank Fraser Darling published *West Highland Survey: An Essay in Human Ecology*, which provided a far ranging account of the ecological environments and effects of people living in the West Highlands in Scotland. The work included a history of the region and an anthropological analysis of the people living there. Although this work draws on an impressive breadth of approaches, it was not as openly critical or directed at as large an audience as many of his later work. Throughout an impressively long list of works, including the 1956 *Pelican in the Wilderness: A Naturalist's Odyssey in North America*, the 1966 conference *Future Environments of North America* in 1966, the 1969 publication of *The Impacts of Man on the Biosphere*, and the 1969 Reith lectures entitled “Wilderness and Plenty,” Darling deployed a synthetic approach of human ecology to examine the effects of humans on the environment.

The extent to which these ecologists' work diverges--often explicitly--from the vocational ethos that Weber describes is often striking. Much of this work is explicitly antagonistic towards specialization and implicitly in tension with Weber's call for scientists to engage only narrow professional audiences and questions of fact. Interestingly, there was a similar plea in the work of critics, such as Rachel Carson and Lewis Mumford, working outside the academic setting. Defining the promise of human ecology in contrast to the specialization characteristic of much scientific work, Sears noted that, “The applications of other sciences are particulate, specialized, based on the solution of individual problems with little if any attention to side effects and practically uncontrolled by any thought of the larger whole."[669] Rachel Carson similarly decried specialization: "As the frontiers of science expand, there is an increasing trend towards

[669] Sears, "Ecology--A Subversive Subject," 12.

specialization. . . .But fortunately there is a counter-tendency, which brings different specialists together to work in cooperation."[670] Entering onto the scene at the comparatively late date of 1972, the journal of *Human Ecology* opened its first journal by similarly defining itself in opposition to "Discipline-oriented approaches to the wide-ranging problems facing researchers in human ecology [which] are not only self-limiting, but also self-defeating."[671] In their degree of specialization and lack of concern for matters outside of their borders, disciplines constrained scientists' attention to internally set questions of fact.

Further, for many of these critics science had lost its broader relevance in the way its disciplinary organization had come to define the practice of science as a profession. Rachel Carson linked two of the issues central to Weber's scientific role—the perceived need to address a narrow audience and the separation between science and other value spheres of modernity

> Many people have commented with surprise on the fact that a work of science should have a large popular sale. But this notion that 'science' is something that belongs in a separate compartment of its own, apart from everyday life, is one that I should like to challenge. We live in a scientific age; yet we assume that knowledge of science is the prerogative of only a small number of human beings, isolated and priest-like in their laboratories. This is not true.[672]

Carson, here, defended her efforts to position the findings of science before a broad public audience a full ten years before the publication of *Silent Spring*. Further, she linked the idea that science belonged in a separate compartment from the rest of life with people's tendency to approach people as somehow apart from nature. She made this point

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670 Carson, *Lost Woods*, 166.
671 "Introductory Statement." *Human Ecology* 1, no. 1 (March 1, 1972): 1.
672 Carson made these comments at her acceptance speech for the National Book Award for Nonfiction for *The Sea Around Us*, a best seller published in 1951. Carson, *Lost Woods*, 91.

in a teachers' reference book in 1956:

> neither man nor any other creature may be studied or comprehended apart from the world in which he lives. . . .In the truest sense there is no separate literature of biology or of any science. Knowledge of the facts of science is not the prerogative of a small number of men, isolated in their laboratories, but belongs to all men, for the realities of science are the realities of life itself. We cannot understand the problems that concern us in this, our particular moment of time, unless we first understand the our environment and the forces that have made us what we are, physically and mentally.[673]

In the form that science has taken as a profession, scientific knowledge is both highly specialized and separated off from the rest of life.

While Carson (like Bates, as we shall see below) was not advancing this critique of overly specialized approaches to biology under the banner of "human ecology," both Carson and Bates Charles Elton's "conservation" in order to describe their critiques. In a 1958 work entitled *The Ecology of Invasions*, a famous British ecologist named Charles Elton addressed the question of how to fix the effects of people's approach to nature as something to be dominated. His answer, explored in the final two chapters of the work, was conservation. He argued that,

> Unless one merely thinks man was intended to be an all-conquering and sterilizing power in the world, there must be… some wise principle of coexistence between man and nature, even if it has to be a modified kind of man and a modified kind of nature. This is what I understand by conservation.[674]

In the place of an unsustainable attitude towards nature, he advocated a "wise principle of

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[673] Ibid., 165. This quote is from a 1956 essay on "Biological Sciences," which Carson wrote for a teachers' reference book. We can see Carson taking a similar position in a 1963 presentation: "Yet again and again , in this whole field of environmental influences in relation to life, and this includes our theme of pollution and its impact on life, we meet a strange reluctance to concede that man is, himself, susceptible to harm . . . . this attitude. . . .seems to me to imply a sort of rejection of our past--a reluctance or unreadiness to accept the fact that man, like all other living creatures, is part of the vast ecosystems of the earth, subject to the forces of the environment." Carson, *Lost Woods*, 165 and 244.

[674] Elton, *Ecology of Invasions*, 145.

co-existence between man and nature."[675] Marston Bates cited this phrase in positioning his 1960 work *The Forest and the Sea: a Look at the Economy of Man and the Economy of Nature* in the tradition of Elton's notion of conservation.[676] Rachel Carson similarly cited Elton's phrase in *Silent Spring*.[677] Further, it is not difficult to see the strong resonance of Elton's call for conservation with Sears' much more sustained call for human ecology. And in a 1964 essay defending conservation, Frank Fraser Darling, a professional ecologist who published widely in human ecology, considered human ecology more or less indistinguishable from the conservationism of his era.[678] Even if we hold human ecology separate from conservation however, the contrast between the role of the scientist as modeled in calls for human ecology *and* conservation stand in sharp contrast to the role of the scientist described by Weber in “Science as a Vocation.” Both areas considered the view that scientists should be narrow specialists addressing themselves to narrow professional audiences not only untenable but also dangerous.

As important as critical ecologists' disregard for norms of specialization was their disregard for the strict separation between matters of fact and matters of value. Just after citing Charles Elton, Marston Bates argued that,

> Ethical, esthetic, and utilitarian reasons thus all support the attempt to conserve the diversity of nature. It is morally the right thing to do; it will provide, for future generations, a richer more satisfying experience than would otherwise be possible, and it provides a needed insurance against

[675] See Elton 1958, chapters 8 and 9 for a sustained exploration of this oft-quoted phrase.

[676] Bates, *The Forest and the Sea*, 262.

[677] Carson, *Silent Spring*, 117. Carson made a similar formulation in 1956 in asserting that, "Here and there awareness is growing that man, far from being the overlord of all creation, is himself part of nature, subject to the same cosmic forces that control all other life. Man's future welfare and probably even his survival depend upon his ability to live in harmony, rather than in combat, with these forces." Carson, *Lost Woods*, 167.

[678] Frank Fraser Darling, “Conservation and Ecological Theory,” *Journal of Animal Ecology* 33 (January 1, 1964): 43.

> ecological catastrophe.[679]

Here, Bates' call for conservation is a moral call. Here, and in the context of his larger work, any effort to separate out the facts from the values of ecological degradation would not only miss the point but also risk contributing. A couple of pages earlier, he makes a similar plea for a “conscience” attuned to the value of people's natural environment:

> We talk about regional planning, diversification, working with the landscape--and we build vast stretches of the new suburbia. The ideas so forcefully developed by Patrick Geddes, Lewis Mumford and others like them fall on deaf ears. We need an ecological conscience.[680]

It is interesting here that Bates cites Lewis Mumford, a social critic who was a leading figure in a 1956 conference, *Man's Role in Changing the Face of the Earth,* filled with calls for the kind of perspective human ecology could offer. Mumford had the following to say in a 1966 follow up to this conference:

> science in the strict sense doesn't really like to deal with. . .the world of values and purposes and meanings. . . .since the scientist has excluded the category of purpose, he is singularly unprepared to recognize or deal with institutionalized purposes that are actually controlling our society: forces such as finance capitalism, bureaucratic organization, mechanization, and automation. All of these form part of the great technological apparatus of war. The sciences have passively accepted these purposes, as if they did no harm as long as they do not interfere with the pursuit of science and technology. Give the scientist his laboratory, give him his budget, give him his assistants, give him his honors, and he'll work for any government or corporation without challenging the objectives or questioning the social results. . . .The result is, therefore, that science has become embrangled with all sorts of negative purposes, like nuclear weapons and rockets."[681]

[679] Bates, *The Forest and the Sea*, 262.
[680] Ibid., 260.
[681] In the same presentation, Mumford noted that, "the real purpose of a Conference like this [Future Environments of North America] is to ensure the existence or the replenishment of sufficiently varied environment to sustain all of life, including human life and thus to widen the ground for man's further conscious development." Here, Mumford situates the transformative potential of human ecology in terms that are remarkably similar to Adorno and Horkheimer's discussion of the radical potential of Enlightenment reason in *The Dialectic of Enlightenment*. Mumford, "Closing Statement," 721 and 722.

This section opened with a quote from E. A. Gutkind's contribution to *Man's Role in Changing the Face of the Earth*. In the same essay he makes a similar argument as Bates and Mumford: "the findings of ecology can and should guide man to a course of action that will prevent disaster."[682] Not only can scientists engage in matters of value, they *should.*[683]

VI. Conclusion: Species of Ecological Critique

There are many overlaps between the positions Odum occupied in the second half

[682] Gutkind, "Our World From the Air," 49.

[683] Interestingly, we see in Sears' earlier work a view of modern society that is, in many ways, resonant with that of Weber. In a statement that resonates with Weber's characterization of society's fragmentation into distinct value spheres, Sears notes that, "Science, religion and government still preserve their respective identities." While science generally and ecology specifically are to play an important role in informing a more balanced relation with nature, there is only much scientists can do —"they cannot. . .take over his [the politician's] task." Science can inform us "but it cannot make our decisions for us." Weber, "Science," 225, 222-3, and 220.

Despite these similarities, Sears advocated a much more engaged and hopeful view of science and society. Where Weber resigned himself to this fragmentation by advocating a form of ascetic devotion to the goals within a given value sphere (the principled pursuit of truth according to the norms of disciplinary specialization in the case of scientists), Sears saw a much more engaged role for scientists as working for a greater social good. While scientists were limited in how they could help solve social problems—they still had to work as scientists and not as politicians, their work should be aimed at reintegrating science into a larger social. This move towards integration stands in marked contrast with Weber's vision of science as separated from the rest of society and only able to pursue research goals emerging from within science as a sphere of society. We can also see that Sears did not share Weber's fatalistic resignation to the problems he saw. Where Weber recommended an individualized response (that "each [person] finds and obeys the demon who holds the fibers of his very life") to a view of modernity that was pessimistic to its core, Sears advocated a socially engaged form of action that brought hope. Weber, "Science," 156.

Along with this view of a socially engaged science came a very different vision for the role of the scientist. While the work of Weber's scientist was constrained and even defined by a trend towards progressive specialization, Sears argued that scientists should, "fight off the effects which specialization has on him as an individual." On a concrete level, Sears envisioned scientists working in much more applied work environments. Ecologists could work at the county level providing the kind of feedback that people trained in agriculture already provided. While specialists trained in the agricultural sciences would provide feedback aimed at increasing crop yield in the short term, the ecologist would be focused on the longer term consequences of agricultural practices in order to make sure agricultural practices could remain productive over a much longer time frame. Sears' antagonism towards norms of specialization in science came with a vision of a professional trajectory that was not closed off to the rest of society. Weber, "Science," 226.

of his career and the positions that Carson, Sears, Bates, Darling and others occupied. In the last section, I described the ways that Carson's, Sears', Bates' and Elton's work was in strong and often explicit tension with the vocational ethos that Weber describes in "Science as a Vocation." And I described in chapters 4 and 5 how Eugene Odum came to approach ecology as a science that was "integrative"--explicitly in tension with disciplinary norms of specialization--and normative--capable of valuing nature and providing insights about how to live in relation to nature.[684] Further, in his later work Odum framed his effort to explore the political implications of ecology as human ecology in the same way as Sears, Shepard, Darling.[685] And Odum came to approach his work in terms of human ecology later. In "The Strategy of Ecosystem Development," he approached human ecology somewhat indirectly, by examining, in the words of a section heading, the "Relevance of Ecosystem Development Theory to Human Ecology."[686] In the 1990s, Odum explicitly categorized his own work as human ecology.[687]

Historian of ecology Eugene Cittadino's argument that human ecology failed as an academic discipline reinforces the image of human ecology as in tension with academic trends that Weber describes.[688] Eugene Cittadino has written of the “failed promise” of human ecology, but his assessment is of the failure of human ecology as an academic

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684 See, particularly the introduction and conclusion of chapter 5 and the section, in chapter 4, titled 'the Whole is Greater than the Sum of the Parts.'

685 Odum's framing of his later more critical work as human ecology resembles as well the framing of conservation in the work of Elton, Carson, and Bates.

686 Odum, "The Strategy of Ecosystem Development," 266-7 and 262.

687 Odum, *Ecology: A Bridge Between Science and Society*, xiv. Odum, *Ecological Vignettes*, chapter 7.

688 Eugene Cittadino, "The Failed Promise of Human Ecology," 251-83. Interestingly, recent years have seen a renewed emphasis on human ecology. Richard York and Philip Mancus, for example, have recently published a work that calls for a renewal on human ecology as an explicitly political project, if one that the authors locate in the social sciences and not ecology. While the interdisciplinary emphasis of their vision of human ecology resonates strongly with the earlier ecological version examined in this chapter, it nonetheless focuses on, and proposes to unite, environmental sociology and “neo-Marxist” historical materialism. York, Richard, and Philip Mancus, “Critical Human Ecology: Historical Materialism and Natural Laws,” *Sociological Theory* 27, no. 2 (May 5, 2009): 122–149.

discipline--of the field's failure to establish itself as an academic discipline with "university chairs, departments, journals."[689] While ecologists such as Sears did use existing professional venues to explore the academic institutionalization of human ecology (in attempts to establish human ecology as a section in the Ecological Society of America in the mid to late 1950s), to approach their work as a failed academic specialty misses the larger relevance of their work, the ways that these ecologists rebelled against norms of specialization and value neutrality and, in so doing, made ecology into a subversive science that fed the environmental movement. Where academic disciplines are defined by specialization, human ecology aimed to extend beyond any one specific discipline. Where scientific work 'should' be value-neutral, human ecology explicitly addressed questions of value and positioned science as a source of insight about how to live. If Cittadino is right--that human ecology failed as an academic discipline--then we need to address the very significant ways in which human ecology defined itself in opposition to the norms that have come to define what disciplines are.

Despite the similarity in these scientists' efforts to reach beyond the role of scientist as specialist, there are also significant differences in their critical positions. Compared to the work of Carson, Sears, and Bates, especially, Odum's critique comes across as more cautious and sometimes also more hopeful of the ability of ecology as a science to provide the answers that could transform our relationship with our

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[689] Cittadino opens his paper, titled "The Failed Promise of Human Ecology," by noting that "The title of this paper is a bit misleading, deliberately so. Human ecology certainly did not fail as a cultural phenomenon. Indeed, it is very much with us. It did, however, fail to materialize as a consistent and coherent field of inquiry. The existence of university chairs, departments, journals, and an imposing body of literature has not placed human ecology any closer to fulfilling the expectations held out for it earlier in the century."Eugene Cittadino, "The Failed Promise of Human Ecology." In *Science and Nature: Essays in the History of the Environmental Sciences* ed. Michael. Shortland (Oxford: BSHS Monographs, 1993), 253.

environment and so also our future. I will focus on the differences in these scientists' critique of specialization as a key feature in the role of the scientist but also in order to demonstrate Odum's comparative caution. Another key difference between Odum and many of the other scholars I have mentioned is their relation to the environmental movement. Odum's critique came much later than that of Carson, Sears, Bates, and Elton and was enabled by the environmental movement rather than the other way around. The question of timing and relation to the environmental movement becomes more important as we consider these scholars in relation to the debate, introduced in the first chapter, on whether scientists or activists play the more important role in rendering the hazards of reflexive modernity visible.[690]

These scholars' critique of specialization provides a basis for comparison of Odum and other critical ecologists that reflects on one of the central features of Weber's description of the role of the scientist.[691] As I discussed in chapter 4, by the mid 1970s Odum had begun defining ecology as an "integrative" discipline.[692] In providing a viewpoint capable of linking together and uniting more specialized disciplines, ecology

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690 See the section in chapter 1 entitled "Science, Social Movements and Modernity."

691 A comparison of Marston Bates' and Eugene Odum's imagination of the suicide of Western civilization provides a striking contrast. When Marston Bates wrote, in 1956, "[p]erhaps our Western world, so proud of its technical advantages, is starting a process of suicide" his speculation was grounded in an assessment of the West's already present pride in its "technical advantages." Compare this to Odum's 1969 statement:

> The most pleasant and certainly the safest landscape to live in is one containing a variety of crops, forests, lakes, and "waste places"-in other words, a mixture of communities of different ecological ages. As individuals we more or less instinctively surround our houses with protective, nonedible cover (trees, shrubs, grass) at the same time that we strive to coax extra bushels from our cornfield. We all consider the cornfield a "good thing," of course, but most of us would not want to live there, and it would certainly be suicidal to cover the whole land area of the biosphere with cornfields, since the boom and bust oscillation in such a situation would be severe.

Odum's speculation of the suicidal application of monoculture comes across by comparison as much more hypothetical--as an extreme that "most of us" already know to avoid. Marston Bates, "Process," 1140. Odum, "The Strategy of Ecosystem Development," 267. This passage was chosen as the only place in Odum's work where I found him describing earth's future using the word "suicide."

692 Odum, "The Emergence of Ecology as a New Integrative Discipline," 1289-90.

could also provide a viewpoint uniquely suited to the complexity of real world environmental problems. While specialization was a limit of other disciplines, this limitation could be countered with the broader, more holistic approach provided by ecosystem ecology. Much later, Odum imagined a very similar role for ecology as a "communication bridge between science and society."[693] Here, Odum positions ecology as answering the dilemma C. P. Snow posed in *Two Cultures*. Interestingly, Snow's focus on the lack of communication between science and the humanities becomes transformed for Odum into a lack of communication between science and society--and as a problem that ecology as a discipline can address.[694]

For Bates, by contrast, specialization represented a far more serious problem. In 1960 he argued that

> More and more, in all areas, we tend to separate the study of man from the study of nature. The separation is one of the basic lines of division in the way we have organized knowledge, in our pattern of specialization. The natural sciences and the social sciences exist in practically complete isolation from one another. Man's body, curiously, has been left with the natural sciences while the social sciences have taken over his mind.[695]

The social circumstances of the professional pursuit of science, in other words, has played a significant role in keeping knowledge about nature apart from knowledge about people. And this separation of knowledge has made it difficult for people to realize the ways that their actions have environmental effects that can impact them in direct and often very negative ways. Unlike Odum, Bates does not envision ecology, or human ecology or conservation, as easily addressing the problems that go along with "our

693 Odum, *Ecology: a Bridge Between Science and Society*, xiii.

694 Trilling offers an analysis of this debate in which Snow's emphasis on lack of communication obscures his real sense of the problem as the humanities' insufficient respect for and literacy in the sciences. Lionel Trilling, "The Leavis-Snow Controversy." In *Beyond Culture*: *Essays on Literature and Learning* by Lionel Trilling (New York: Harcourt Brace Jovanovich, 1978), 126-54.

695 Marston Bates, *The Forest and the Sea*, 250.

pattern of specialization" in the pursuit of knowledge. For Bates, ecology is as much a part of this specialization as other disciplines.[696]

Odum's optimism in the potential of ecology, specifically, to overcome the problems of specialization went along with his hesitation to critique science more broadly. Compare, for example, passages from two essays I have already foregrounded--Sears' 1958 essay critiquing space travel and Odum's 1969 essay on "The Strategy of Ecosystem Development." In his essay, Sears notes that "One hears too frequently for comfort the sober assertion that we need not worry about depletion of natural resources, now that interplanetary space travel is just around the corner!" Sears is clearly incredulous in “the culmination of a new faith—the belief that technology will solve any problems that confront humanity.”[697] Sears goes on to emphasize that, "I do not question the tremendous accomplishments and future possibilities of technology. I yield to no one in my admiration for the cleverness, manual and intellectual, of those who apply science to the needs of mankind." Despite this admiration, Sears goes on to note that "The direction in which science is applied depends upon the values of the culture applying it even while science is in turn modifying the culture."[698] For Sears our faith in technology forms the cultural context in which some uses for science are chosen over others. Instead of applying science to the dilemma of increasing demand for diminishing natural resources, we apply it to "our almost hypnotic concern for outer space."[699]

Odum, by contrast, had a much greater faith in science and our ability to get meaningful direction on how to live from the input of scientists. In "The Strategy of

[696] Bates gives the example the separation of ecology, as a biological discipline, from economics, as a discipline focusing on people. Ibid.
[697] Sears, “The Inexorable Problem of Space,” 10.
[698] Ibid.
[699] Ibid.

Ecosystem Development," he argued that

> Although as individuals we readily recognize that we can have too many dams or other large-scale environmental changes, governments are so fragmented and lacking in systems-analysis capabilities that there is no effective mechanism whereby negative feedback signals can be received and acted on before there has been a serious overshoot. Thus, today there are governmental agencies, spurred on by popular and political enthusiasm for dams, that are putting on the drawing boards plans for damming every river and stream in North America![700]

From an ecological perspective, Odum saw that there were and would be many more dams than needed. In comparatively muted terms, he drew attention to the same technological enthusiasm that Sears critiques in his 1958 article. But for Odum the answer was more efficient communication between governmental agency and, more importantly here, consultation with experts with "systems-analysis capabilities." Scientific expertise, whether in the form of ecosystem ecology or systems analysis, could provide the answers that Sears located in the cultural values guiding science. The following cartoon, from Odum's 1996 *Ecological Vignettes*, provides a very similar sense of the relationship between science and policy.

[700] Odum, "The Strategy of Ecosystem Development," 267.

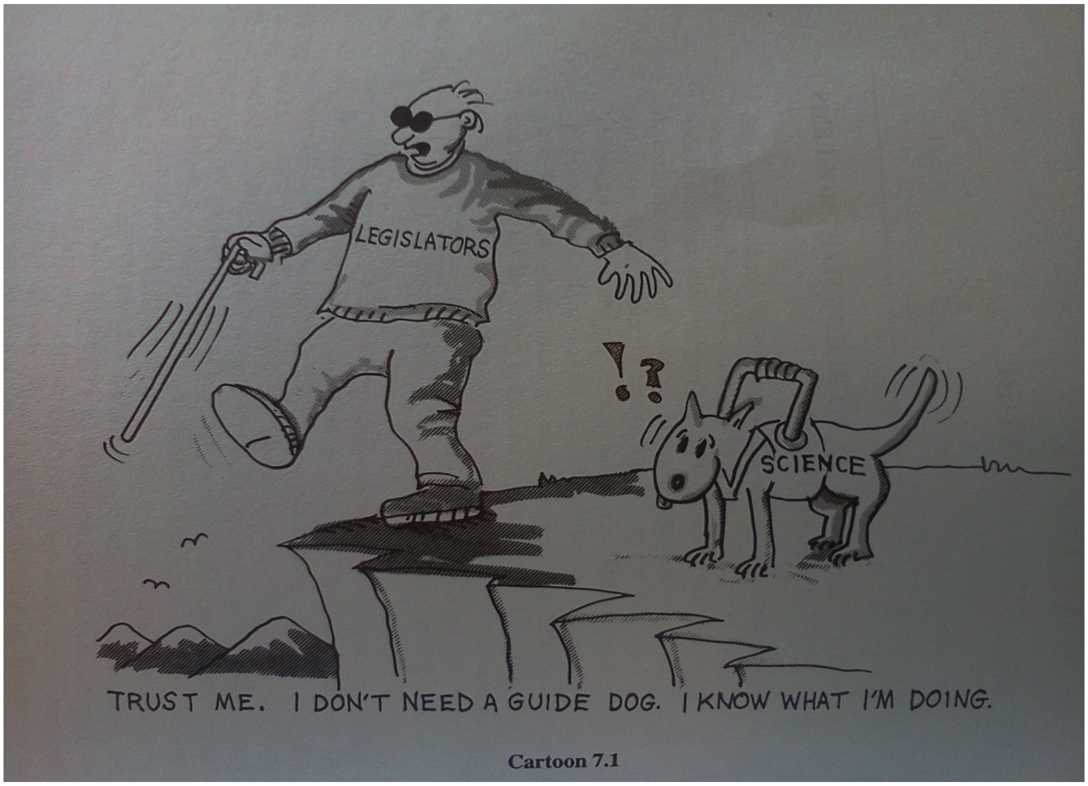

Figure 6.1 - I don't need a guide dog, from Odum's *Ecological Vignettes: Ecological Approaches to Dealing with Human Predicaments*.[701]

Without science to guide legislators, they are likely to walk off a cliff without realizing it. The astonished seeing eye dog in this picture is Odum, not understanding how policy makers could be so self-defeating as to ignore scientists' guidance.

The contrast with Sears is striking. In his 1958 article and elsewhere, he pointed out that technocratic faith in science and technology involved substituting science as a means to larger issues such as the well being of humans with science as an end in itself.[702]

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[701] Odum, *Ecological Vignettes*, 42.

[702] See also "The Steady State: Physical Law and Moral Choice" reprinted in Shepard and McKinley's edited volume. Cold war scientists such as Alvin Weinberg, director of Oak Ridge National Lab, gave expression to the position that Sears attacked. For Weinberg, science, and particularly big science, had the potential to solve any number of problems. Weinberg argued that, "[t]here is a possibility that the technologically oriented research institutions may contribute to an unexpected degree to the resolution of problems that now seem to be primarily social. I refer to the possibility of devising 'cheap technological fixes' that afford shortcuts to the resolution of social problems." Sears, "The Steady State," 2-3, 8. Weinberg, *Reflections on Big Science*, 141.

Further, the spread of this kind of instrumentalizing logic could only result in applying a narrowly instrumental approach to people themselves. On the pages of *Science*—a prestigious and widely read scientific journal, Sears illustrated the endpoint of this kind of logic with the image of people as factory farmed poultry—managed with efficient attention to minimal needs for survival and reproduction.[703]

Another significant difference between Odum on the one hand and Sears, Bates and others centers on the comparatively late timing of Odum's critique and so also the distinctiveness of his relation to the environmental movement. As I discussed in the previous chapter, one of the crucial shifts in Odum's move towards approaching ecology as a normative science came with his involvement in a campaign to save the coastal marshes of Georgia in the late 1960s. It was this involvement that informed Odum's 1969 work "The Strategy of Ecosystem Development" as well as his later turn to assigning financial value to nature. Bates, by contrast, had assumed an outspoken endorsement of conservation by 1960, Elton by 1958, and Darling (endorsing human ecology) by 1964.[704] All of these other scholars' critiques came much earlier than Odum's critique and all but

[703] Sears, "The Inexorable Problem of Space," 10. Bates' image of people living off of algae offers a similar, if somewhat less dire, image of the outcome of "the logical end result" of applying narrow instrumental logic to core human concerns:

> The shorter the food chain the more efficient the conversion of solar energy into human food. The logical end result of this process, sometimes foreseen by science fiction writers, would be the removal of all competing forms of life--with the planet left inhabited by man alone, growing his food in the form of algal soup cultivated in vast tanks. Perhaps ultimately the algae could be dispensed with and there would be only man, living through chemical manipulations.
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> Efficient, perhaps; dismal, certainly; and also dangerous.

In place with an interest in the quality of life, there is an interest in the efficiency of the production of food. Bates, *The Forest and the Sea*, 260-1.

[704] I am using the 1960 publication date of Bates' *The Forest and the Sea* and the 1958 publication date of Elton's *The Ecology of Invasions.* Although I use the 1964 publication date of Darling's "Conservation and Ecological Theory" in order to maintain a standard criteria (explicit backing of conservation or human ecology), one could as easily date his publication of the kinds of critiques later associated with contemporary environmentalism to the 1939 publication of A Naturalist on Rona, given the work's call for "law-making in the interests of wild life." Charles Elton, "The Relation of Man to Animals." *Journal of Animal Ecology* 8, no. 2 (November 1, 1939): 390 [quotes Darling].

that of Darling were published *before* Carson's *Silent Spring*.[705] Clearly, Odum was a comparative latecomer to the concerns that would drive the environmental movement.

In discussing reflexive modernity in the first chapter, I raised the debate over whether social movements or science should be considered the more important actor in raising awareness of the often invisible hazards of industrial society.[706] In his work on the emergence of "risk society" Ulrich Beck, has argued that science is necessary in rendering the bads of industrial society visible.[707] Anthony Giddens, meanwhile, has argued that social movements, and particularly new social movements such as environmentalism, play the more important role.[708] Examining the relation of Odum and other ecologists in relation to the environmental movement provides an opportunity for assessing these contrasting claims. Although Odum's name and involvement would lend weight to the campaign to save the coastal marshes of Georgia, he nonetheless became involved *after* activists had already identified the hazards that would follow phosphate mining on the Georgia coast. Interestingly, the place of social movement mobilization is lost in the above cartoon, where society needs science to render the cliff visible. Elton's 1958 call for conservation, by contrast, would be picked up by Carson as a part of the work credited with beginning the environmental movement.[709] Sears similarly engaged in

705 I emphasize these scholars' relation to the publication date of *Silent Spring* given the importance assigned to this work as the opening shot of the environmental movement. Brulle, *Agency, Democracy, and Nature*, 182-3. Lutts, "Chemical Fallout: Rachel Carson's Silent Spring, Radioactive Fallout," 211. Dunlap and Mertig, *American Environmentalism*, 14 and 19. Jamison and Eyerman, *Seeds of the Sixties*, 66. Meyer and Rohlinger, "Big Books and Social Movements: A Myth of Ideas and Social Change," 136–153. Stoll, "Rachel Carson's Silent Spring, a Book that Changed the World." Carson, *Silent Spring*, 117 on Elton.

706 See the section titled "Science, Social Movements, and Modernity."

707 Beck, *Risk Society*, 27; Beck, *Ecological Politics in an Age of Risk*, 115.

708 Giddens, *The Consequences of Modernity*, 158-62. See also the discussion in Welsh and Wynne. Welsh, *Mobilising Modernity*, 23-5. Wynne, May the Sheep Safely Graze," 47-61.

709 Brulle, *Agency, Democracy, and Nature*, 182-3. Lutts, "Chemical Fallout: Rachel Carson's Silent Spring, Radioactive Fallout," 211. Dunlap and Mertig, *American Environmentalism*, 14 and 19. Jamison and Eyerman, *Seeds of the Sixties*, 66. Mark Stoll, "Rachel Carson's Silent Spring, a Book that Changed

an outspoken critique on the unintended consequences of mainstream agricultural practices decades before Carson's *Silent Spring*.[710]

In these ecologists' lives and work there is a mixed answer to the debate between Beck and Giddens. While Odum endorsed science, the importance of his involvement with the "save the marshes" campaign suggests environmental activism played the more important role in his own move towards ecology as a normative science. The critiques of Bates and Sears, meanwhile, predate *Silent Spring* and so suggest that science plays a more important role. But their critique of the place of science in society suggests that science might not be capable of raising awareness of environmental hazards on its own.[711] Adding to this ambiguity is the fact that the role of the activist and the role of the scientist have often come together in the same person. Despite Weber's objections, Odum participated in the campaign to save the coastal marshes of Georgia as both a scientist and an activist. Rachel Carson's *Silent Spring* can similarly be approached as crystalizing the driving concerns of environmentalism and as a work of science. Recognizing and foregrounding this ambiguity and overlap is crucial in the effort to understand the place of science in Weber's modernity and the place of ecology in the cold war period. While Weber's science counted as science insofar as it was insulated from politics, in the cold

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the World, " Environment and Society Portal. Accessed May 25, 2012, http://www.environmentandsociety.org/exhibitions/silent-spring/overview. Carson, *Silent Spring*, 117 on Elton.

710 Sears, *Deserts on the March*, 9-10 and 56**.**

711 This would particularly be the case for Sears given his emphasis on the larger cultural values guiding science. Sears, "The Inexorable Problem of Space," 10. Peter Kuznick's history of scientists who became political activists in the 1930s nonetheless provides a provides a context in which we can nonetheless re-insert social movement mobilization in Sears' earlier professional environment. Although Sears' involvement with the American Association for the Advancement of Science, a central protagonist in Kuznick's account, reached a peak when he served as the society's president in 1956, it is less clear if the political nature of his 1935 work might have benefited from his connection with other politically minded scientists in this period. Kuznick, P. J. *Beyond the Laboratory: Scientists as Political Activists in 1930s America*. Chicago: University of Chicago Press, 1987), chapter 3.

war period ecology was a science and it was political.

Chapter 7. Conclusion: Environment, Technology, and Modernity

I. Introduction

What is the place of the scientist in society? Is science, or should science be, separated off from the concerns of society or should science be useful to society? In this dissertation, I have addressed this question by exploring ecology as a science in relation to the cold war national security state and environmentalism as a social movement. By analyzing these relationships in terms of Norbert Elias' notion of figuration, I have highlighted the ways that larger social relationships have posed concrete opportunities and challenges to specific ecologists.

Elias' notion of figuration emphasizes the relational and contextual nature of social action. In describing the term, Elias has deployed the metaphor of a game and pointed out how the actions of each player in a game is in tension with the other players and their actions, which form “a flexible lattice-work of tensions" crystallizing into "interdependence of allies or opponents."[712] A player's strategy and actions can only make sense in relation to other players' actions in the context of a given game.

In analyzing the figuration of science, Elias has emphasized scientists' relationship with non-scientists, whether members of the public, the state, scientists in other fields, and others.[713] He argues that "established and outsider groups form a highly variable figuration with an uneven balance of power as its main axis."[714] In this kind of figuration, scientists endeavor to minimize their dependence on non-scientists and increase the dependence of non-scientists on them.[715] Although Elias acknowledges the

[712] Elias, *What is Sociology*, 130. See chapter 1 for a more detailed assessment of Elias' notion of figuration.
[713] Elias, "Scientific Establishments," 4 and 40-1.
[714] Elias, "Scientific Establishments," 40-1.
[715] Ibid., 51 and 4.

importance of a measure of autonomy in order to realize innovations, in the bulk of his essay autonomy is approached in terms of scientists' efforts of “preserving and enhancing their power ratio,” or minimizing their dependence on non-scientists and increasing their dependence on science.[716]

Elias’ notion of figuration describes the social relationships in which science can be useful and also assert its own autonomy. Significantly, for Elias the usefulness of a science can play a significant role in the transformation of the status of that science.[717] Physics provides an excellent example. As physics became useful to the U. S. state during World War II, it received more funding from the state and contributed to innovations such as the radar and the atom bomb, which subsequently provided a kind of proof of the usefulness of physics and so also the postwar status of physics as a science. Nonetheless, the transformation of these scientific establishments comes with the risk of greater dependence on the state. In this context, one of the central questions of Elias’ essay—and of the current dissertation—is "whether and how far the relative independence of scientific establishments can be maintained in the face of growing dependence of their work on non-scientific establishments, bureaucratic, military, industrial or whatever."[718]

Historians of cold war science have approached a very similar question in their attempts to ascertain the impact of the influx of state funding for science from World War II through the cold war. Here the usefulness of science to the state's efforts to secure itself against the perceived threat of the Soviet Union frames questions of the relative autonomy of scientific practice and the impact of that funding on the content of science.

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[716] Ibid.
[717] Ibid., 46-7.
[718] Ibid., 48.

In approaching this question, historian of science Naomi Oreskes has urged an approach that can accommodate the complexities of state-science collaborations and the ways that these collaborations can vary significantly from one case to another. Her analysis of cold war oceanography brings together scientists' invocation of "the ideology of pure science, of 'independent scientific exploration,' as a lever to wrest some measure of autonomy from their patrons" with the fact that oceanographers' discoveries were made possible by technology funded by the state for the purpose of monitoring Soviet submarines.[719] The relationship between oceanography and the state modified but did not determine the kinds of research questions that oceanographers pursued insofar as military interests represented part of a context in which some scientific projects might be selected above others.[720] In this figuration involving oceanography and the cold war military, oceanographers enjoyed a measure of autonomy even as this autonomy was limited by their desire to use the technology that the military funded.

Many cold war scientists have responded to the threat of dependence on the state by engaging "boundary work" to separate their work from the work of non-science and to assert their control over science. Sociologist of science Thomas Gieryn has defined boundary work as the efforts of scientists as professionals to establish and maintain control over their turf as professionals by distinguishing what counts as science (and therefore legitimate accounts of nature) from non-science:

> Construction of a boundary between science and varieties of non-science is useful for scientists' pursuit of professional goals: acquisition of intellectual authority and career opportunities; denial of these resources to

[719] Ibid., 728 and 699-700.
[720] Oreskes notes, "Like a lens, military pertinence brought certain subjects into clear sight while others remained on the edges of the field of view." Ibid., 697

> 'pseudoscientists;' and protection of the autonomy of scientific research from political interference.[721]

Scientists' efforts to secure state funding raise the possibility that scientists could simply become state employees and subject to the close controls and bureaucratic working environment associated with the state.[722] In Elias' terms, the figuration of scientists in a relationship with the state comes with the risk that the state will encroach upon the autonomy of scientists such that they will become overly dependent on the state.[723] Gieryn's notion of boundary work provides an analytical tool for examining how scientists attempt to distance themselves and their work from the ends of the state and other social actors encroaching upon their autonomy.[724]

While Gieryn focuses on boundary work as a strategy exercised by scientists, Chandra Mukerji has shown how the autonomy of science can render that science useful for the state. While scientists working under the patronage of the state can become dependent on the state for the funding and the access to the tools that the state provides, they can also gain a level of prestige and power--and so also autonomy. This power, however, is a "fragile power" insofar as it remains dependent on the patronage of the state. Often, however, the state has encouraged scientists' efforts to assert the autonomy of their work as this autonomy adds to the value of science. Mukerji summarizes this dynamic: "Science gains value to the state because of its claims to 'independence' and

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721 Gieryn, "Boundary-work and the Demarcation of Science from Non-Science," 781.

722 See Thorpe for a discussion of how the tension between the bureaucratic mode of state management resulted in the disciplining of one of the period's most prestigious scientists, Robert Oppenheimer. Charles Thorpe, "Disciplining Experts: Scientific Authority and Liberal Democracy in the Oppenheimer Case," *Social Studies of Science* 32, 4 (2002): 549-52.

723 Gieryn makes a similar point in arguing that "Once scientists accumulate abundant intellectual authority and convert it to public-supported research programs, a different problem faces the profession: how to retain control over the use of these material resources by keeping science autonomous from controls by government or industry." Gieryn, "Boundary Work and Demarcation," 789.

724 Gieryn, "Boundary-work and the Demarcation of Science from Non-Science," 789.

'detachment.' The voice of science is authoritative to the extent that it seems objective and above politics even when applied to policy."[725] Although it is often limited in indirect ways, even the autonomy of scientists can be useful to the state.

In this dissertation, I have explored the question of the place of science in society by deploying Elias' notion of figuration to analyze the politics of ecology in the cold war period. In this period, ecology became useful to the cold war state and to environmentalism as a social movement. In the first case, ecologists entered into a figuration with the cold war state in situating their research as useful to the Atomic Energy Commission's efforts to manage radioactive fallout as a problem that was both epistemic and political in nature. In the second case ecologists aligned their discipline with a social movement and called for a new, more sustainable relationship with the environment. Both cases challenge the view of science as isolated from the workings of society.

In entering a figuration with the cold war state, ecologists benefited from access to funding and new experimental tools. While some ecologists--often working for the AEC or at an AEC facility--studied the impact of radioactive matter on the environment, ecologists such as Eugene Odum employed radioisotopes provided by the AEC to trace the movement of matter and energy through the environment.[726] Atomic Energy Commission funding represented a significant stimulus not only to Odum's organization building efforts at the University of Georgia but also in the development of radiation ecology as a new field of ecology. Further, the distribution of radioisotopes to scientists in

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[725] Ibid., 190.

[726] See chapter 2 for more on the figuration that ecology entered into with the cold war national security state.

ecology and other disciplines legitimated Eisenhower's emphasis on the peaceful potential of atomic physics but also provided the state with access to scientists working at a level of remove from the ends of the state. The state gained access, in other words, to the voice of science. Despite this level of autonomy, however, these scientists depended on the state for access to radioisotopes, which served as a kind of boundary object linking the material practice of research in radiation ecology to the production of atom and hydrogen bombs as central tools of the cold war national security state.

Access to the funding and tools of the AEC, however, also posed a challenge to the autonomy of Odum and other scientists like him. In response, Odum engaged in a form of boundary work and erected an organizational buffer in order to maintain control over the direction of his research at the University of Georgia.[727] He characterized radiation ecology as a form of applied science that depended on ecology as a basic science to provide both the professional training for radiation ecologists and to provide the framework that radiation ecologists could apply to the concerns of the AEC. While the organizational buffer that Odum erected between the University of Georgia and the AEC assisted in his effort to maintain autonomy from the AEC, it also created a barrier in the career trajectory of ecologists who were initially employed at the Savannah River Ecological Laboratory and who aspired to tenured positions at the University of Georgia.

Further, engagement with the political projects of the cold war state and environmentalism presented certain opportunities and challenges to people fashioning themselves as scientists. In seeking out AEC funding for an environmental survey of the land that would become the Savannah River Plant, Eugene Odum entered a relationship

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[727] See chapter 3.

with the cold war state that would last many years and that would serve as one of the pillars of his later prominence in the field of ecology. By taking advantage of AEC funding and access to radioisotopes and knowledge about how to use them, Odum established himself as a leader in the emerging field of radiation ecology and built a successful ecology program at the University of Georgia. Odum's promotion of ecosystem ecology--another pillar of his later prominence--underscores the gap between his own goals (providing ecology with the principles it needed to be recognized as a coherent discipline) and the goals of the AEC.[728] Although his presentation of his own research and that of his program as autonomous from the concerns of the AEC was an accomplishment that required effort, his work and later fame were nonetheless tied to the cold war state on a material level through his use of radioisotopes.

The environmental movement also presented opportunities and challenges for ecologists. It introduced demands on ecologists to produce scientific support for environmental claims that were sometimes based on representations of nature that were foreign to ecological research.[729] However, the environmental movement also provided ecologists with a broad public audience, which enabled scientists such as Odum to explore the normative dimensions of ecological research. Ecosystem ecology came to provide a way of understanding the value of nature--not only for other ecologists but also for the larger public. Further, scientists such as Paul Sears and Marston Bates engaged ecology as the basis for a critical theory of modern society that predated the rise of

[728] See chapter 4.

[729] See chapters 5 and 6. Kinchy and Kleinman, "Organizing Credibility: Discursive and Organizational Orthodoxy on the Borders of Ecology and Politics," 869-70, 872-4, 877-8, and 890-1. Botkin, *Discordant Harmonies*, introduction. In Odum's report as president of the Ecologial Society of America, this tension comes across as the tension between "the need for action, whether real or imagined, by pressure groups in our society" and the need first for the "consolidation and interpretation of data" by ecologists as the basis for action. Odum, "President's Report," 10.

interest in the environment in the early to mid 1960s. Ecology became a normative science with answers to the question of how we should live and a subversive science that challenged our relationship with the environment and sometimes also technocratic approaches to policy making. How are we to understand the scientific role that accompanied ecology as a science that in some hands became normative and even subversive?

The divergence of ecologists from the role of the scientist as specialist introduces a view of modernity in stark tension with that that Weber discusses in "Science as a Vocation." Here I will introduce the broader topic of the place of science in theories of modernity by discussing the role of science first in Weber's theory of rationalization and then in the work of critical theorists who took up and modified Weber's notion of rationalization. Here we encounter a modified, and in some ways much darker, version of Weber's modernity. Significantly, however, it is still a modernity largely without hope for social change or a role for science as a critical force in society. These are theories of modernity, I will argue, that do not fully consider the role that environmentalism as a social movement and ecologists as intellectuals would play in challenging some of the central features of modernity.

II. The Figuration of Science and Social Movements and the Role of the Scientist as Intellectual

How did the figuration in which ecologists entered into a relationship with the environmental movement affect the scientific role that these ecologists modeled? To what extent can ecologists such as Sears, Bates and Odum be characterized as modeling a role of scientists as intellectual? As we have seen, Sears, Bates, and Odum clearly did not share Weber's perceived need to accommodate specialization and value neutrality. All of these scientists engaged broad, non-specialist audiences on the politics of the environment. In doing so, they approached their science as a source of insight for the question of how to act and often explicitly attacked specialization. By approaching Sears, Bates, Odum and other critical ecologists as scientists as intellectuals, we can describe their roles in a way that goes beyond characterizing them as transgressing or as a negative image of Weber's scientist as specialist.

The literature on intellectuals provides tools for understanding these scholars' relationship with the environmental movement and for analyzing these scholars break with the role of scientist as specialist. One of the dominant themes of this literature centers on the disappearance of the intellectual in the face of trends towards increasing specialization in the academy and elsewhere. Other themes that I will draw on include the relationship of intellectuals to social movements and debates on the nature of intellectuals. Interspersed in my review of these themes, I will discuss other scholars' efforts to characterize environmentalists and critical academics as intellectuals.

One of the dominant themes on literature on the intellectual is the disappearance of the intellectual in the increasingly specialized setting of the academy. Although Jacoby's 1987 work *The Last Intellectuals* has been credited with "sounding the alarm" on the disappearance of intellectuals, the theme has become a defining feature of literature on intellectuals.[730] The 2006 essay in which Etzioni cites Jacoby's influence remains centered on the themes that Jacoby introduced nineteen years earlier.[731] Jacoby's 1987 answer to

730 A. Etzioni, "Are Public Intellectuals an Endangered Species," 2.
731 The title of the essay asks the question "Are Public Intellectuals an Endangered Species?"

the question of the missing intellectuals in *The Last Intellectuals* is strikingly similar to Lois Wacquant's 1996 answer. In both accounts, the specialization and self-referentiality that defines academic work leaves little room for academics interested in speaking to a broad public audience about matters outside their specialty.[732] Further, as Medvetz points out, norms of increasing specialization introduce a strong structural motivation for academics to decrease their vulnerability by restricting their claims to the narrow professional field in which they will be recognized as more or less legitimate.[733] Assuming a public position in this way renders academics vulnerable to political attack. When environmental historian William Cronon made a blog post highlighting the role of free market advocacy groups in efforts to restrict Wisconsin state employees to collective bargaining, Republicans responded by demanding access to his email as a state employee. Even with the cultural capital accrued from a very successful career in academics, Cronon was a "sitting duck" whose political engagement left him vulnerable to attack.[734] For Medvetz, the attack on Cronon signifies "the marginality and ineffectiveness of intellectuals in American public debate."[735] Despite the increasing specialization of the academy and increasing vulnerability of academics who break with norms of specialization, scientists sometimes *do* speak out about matters of value to broad public audiences. The ecologists I examined in this dissertation did so, if in different ways and at different times.

The attribution of the beginning of the contemporary environmental movement to

[732] Jacoby, *The Last Intellectuals*, xii-xiii, 6-8, and 160-190. Wacquant, "The Self-Inflicted Irrelevance of American Academics," 21.
[733] Medvetz, "Scholar as Sitting Duck," 53
[734] Cronon had been awarded a MacArthur genius grant and the Bancroft prize and had been a Rhodes scholar. Ibid.
[735] Ibid., 48.

Rachel Carson and Odum's close relationship with a local movement to save the coastal marshes of Georgia raises a second theme in the literature on intellectuals--the question of intellectuals' relationship with social movements.[736] To what extent should intellectuals be understood as a kind of vanguard, laying the groundwork for later popular movements? Alternatively, we could ask: to what extent does intellectuals' ability to address large public audiences presuppose the existence of a social movement? Sociologists Andrew Jamison and Ron Eyerman argue that intellectuals such as Rachel Carson played a vanguard role as they "planted the seeds of the sixties."[737] And Alvin Gouldner has argued that intellectuals form part of a "new class" that has large scale transformative potential.[738] Further, by disaggregating ecologists approaching their scientific role as intellectuals--by paying attention to the differences between Sears on the one hand and Odum on the other, we can better appreciate the fact that sometimes intellectuals (such as Sears) emerge before popular movements and sometimes they emerge after popular movements.

In their work *Seeds of the Sixties,* Andrew Jamison and Ron Eyerman have drawn attention to Rachel Carson as an intellectual who laid the groundwork for the environmental movement.[739] It is a provocative assertion in part because we often think of

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736 For more on Carson's *Silent Spring* as the opening shot of the environmental movement, see chapter 5 and Brulle, *Agency, Democracy, and Nature*, 182-3. Riley E. Dunlap and Angela G. Mertig (eds.). *American Environmentalism*, 14 and 19. Jamison and Eyerman, *Seeds of the Sixties*, 66. Lutts, "Chemical Fallout: Rachel Carson's Silent Spring, Radioactive Fallout," 211. David S. Meyer and Deana A. Rohlinger, “Big Books and Social Movements: A Myth of Ideas and Social Change,” *Social Problems* 59, no. 1 (February 1, 2012): 136–153. Mark Stoll, "Rachel Carson's Silent Spring, a Book that Changed the World, " Environment and Society Portal. Accessed May 25, 2012, http://www.environmentandsociety.org/exhibitions/silent-spring/overview.

737 Jamison and Eyerman, *Seeds of the Sixties*, 1 and 92-100 on Carson.

738 Gouldner, *The Future of Intellectuals and the Rise of the New Class*, 57-73. As I will show, these positions contrast with the pessimism that pervades the work of Max Weber but also critical theorists such as Theodor Adorno, Max Horkheimer, and Herbert Marcuse.

739 Jamison and Eyerman, *Seeds of the Sixties*, 92-100.

Carson in terms of her lyrical prose and as an environmental critic.[740] Jamison and Eyerman also consider Lewis Mumford and Murray Bookchin to be intellectuals who laid the groundwork for the environmental movement.[741] Jacoby notes Lewis Mumford, as a social critic on the periphery of the academic world, is "almost too perfect" as an "exemplar" of "last generation intellectuals."[742] In describing Thorstein Veblen's influence on Mumford, Jacoby notes that "Mumford knew Veblen well, describing him as a fellow 'heretic in the academic world' who, like Mumford himself, refused to 'recognize the no-trespass signs' of specialists."[743] Across a writing career that spanned almost thirty books, Mumford warned of the ways that the centralization and extension of power, often through large scale technological projects, over human needs. He referred to such part social, part technical projects as the "mega machine." "The ideology that underlies and unites the ancient and modern mega-machine is one that ignores the needs and purposes of life in order to fortify the power complex and extend its domination."[744] Like the Egyptian Pharaoh organizing the production of gigantic pyramids, cold war culture erected the space program and nuclear power and nuclear weapons as accomplishments hinging more on the extension of power than satisfying human needs or creating the conditions for better life on earth.[745] Mumford's involvement with *Man's Role in Changing the Face of the Earth* conference in 1955 and with *Future Environments of*

[740] The surprising nature of Jamison's claim may derive in part as well from the fact that sociology as a discipline has been slow to acknowledge the importance of the critiques emerging from the environmental movement. While scholars in social movements include environmentalism as an important 20th century social movement, few outside the somewhat marginalized field of environmental sociology take the issues of environmentalism to be important issues in themselves.

[741] For more on Mumford and Bookchin, see chapter 6. Jamison and Eyerman, *Seeds of the Sixties*, 64-74 and 82-92 on Mumford and 68-9 on Bookchin.

[742] Jacoby, *The Last Intellectuals*, 167-8 and 191-4, esp. 191.

[743] Ibid., 192.

[744] Lewis Mumford, *The Myth Of The Machine: the Pentagon Of Power* (New York: Harcourt Brace Jovanovich, 1974), 260,

[745] Mumford, *The Pentagon Of Power*, 263-73 and 300-12.

North America in 1965 marked two moments in which he crossed paths with Paul Sears, Marston Bates, Frank Fraser Darling, E. A. Gutkind and others drawing on ecology as a source of insight for critiques of modern society.[746] One of Mumford's contributions to the 1955 conference was an article that applied an ecological approach to cities and emphasized the dependence of cities on the surrounding countryside.[747]

Influenced by Lewis Mumford as well as E. A. Gutkind, Russell Jacoby also counts Murray Bookchin as an intellectual who engaged in environmental critique.[748] Two important early works in which Bookchin relied on ecology as the basis of his critique and touted the transformative potential of ecology as a science were his 1962 book *Our Synthetic Environment* and his 1964 essay "Ecology and Revolutionary Thought." Although the book would be eclipsed by Carson's *Silent Spring*, which was published in the same year, Bookchin took aim at a much broader range of targets--synthetic pesticides (chapter 2) but also urban bloat (chapter 3), food additives (chapter 4), pollution and cancer (chapter 5), and radioactive matter (chapter 6). In his 1964 essay, Bookchin approached ecology as having the critical potential of evolutionary theories in the Victorian period, of mechanics and mathematics during the Enlightenment and of astronomy before that.[749] Importantly, few scholars of intellectuals share the optimism

[746] The 1955 conference brought together Mumford with Marston Bates, Paul Sears, Frank Fraser Darling, and E. A. Gutkind. The smaller 1965 conference brought together Mumford with Frank Fraser Darling. In both conferences, Mumford delivered the closing statement of the conference. William L. Thomas, Jr. (ed.), *Man's Role in Changing the Face of the Earth*, ix-xii. F. Fraser Darling and John P. Milton (eds.), *Future Environments of North America*, xi-xiii.

[747] Lewis Mumford, "The Natural History of Urbanization," in *Man's Role in Changing the Face of the Earth,* ed. William L. Thomas, Jr. (Chicago: University of Chicago Press, 1956), 382.

[748] In addition to Jamison and Eyerman, *Seeds of the Sixties*, 68-9. Jacoby, *The Last Intellectuals*, 96-100. On Mumford's influence in Bookchin's early work especially, see Murray Bookchin, *Our Synthetic Environment* (New York: Knopf, 1975), vii, 64 and 254; and Damian White, *Bookchin: A Critical Appraisal,* (London: Pluto Books, 2008), 19 on Mumford's and Gutkind's influence. See the section on human ecology in the previous chapter for more on Gutkind.

[749] Bookchin argued that ecology might "restore and even transcend the liberatory estate" of these sciences. Murray Bookchin, "Ecology and Revolutionary Thought," in *Post-Scarcity Anarchism* (Oakland, CA:

that Bookchin had for ecology in the mid 1960s. Alvin Gouldner represents an important exception.

In *The Future of Intellectuals and the Rise of the New Class*, Gouldner outlined a theory of intellectuals as a "new class" with the potential to realize large scale social change. In opposition to the bourgeoisie as the owners of the means of production, the new class is a "cultural bourgeoisie" made up largely of an assortment of new professions and newly professionalized forms of work--university professors but also accountants, engineers, government officials and journalists.[750] This emphasis on the emergence of a "new class" of cultural workers is often associated with Daniel Bell's work on the emergence of a post-industrial society in which the service sector of the economy assumes the central position that had been occupied by the manufacturing sector.[751] With this shift--and the rise of importance of science and technology in the automation of extractive and industrial sectors of the economy, professionals and technical workers begin to overtake the blue collar factor worker both in terms of percentage of total workers and cultural salience [752]

AK Press, 2004), 20.

750 Gouldner, *Future of Intellectuals and the Rise of the New Class*, 18-27 on cultural bourgeoisie, 8 and 21-7 on cultural capital, 19 on professionalism, and 15 on new class membership.

751 Bell, as other theorists of post-industrial society, is careful to emphasize that the service sector is not replacing the manufacturing sector so much as emerging as a statistically more dominant sector that comes to assume a more central position in the culture. Daniel Bell, *The Coming of Post-Industrial Society: A Venture in Social Forecasting* (New York: Basic Books, 1976), chapter 2, esp 125 and 162. For more on how Bell's post-industrial society thesis was actually about post-industrial culture, see Malcolm Waters, *Daniel Bell* (New York: Routledge Press, 1996), 172.

752 Ibid., chapter 3. As I will discuss below, this kind of theory often informs new social movement theory. In Alain Touraine's approach to social movements, for example the class conflict of industrial society becomes replaced with culturally based social movements. In place of the proletariat, Touraine looks to new social movements to find the central conflict of post-industrial society. See also Alberto Melucci's emphasis on new social movements as "conflicts of culture" and Touraine on "cultural movements" and a succinct reconsideration of the terms of his 1971 work *The Post-Industrial Society*. Steven Buechler, "New Social Movement Theories." *The Sociological Quarterly* 36, 3 (Summer, 1995): 444-5. Alberto Melucci, *Challenging Codes* (Cambridge: Cambridge University Press, 1996), chapter 5, esp. 89-90 and 100-6. Alain Touraine, "On the Frontier of Social Movements." *Current Sociology* 52, 4 (2004): 720-4.

The centrality of science and technology in Bell's post-industrial society carries over into Gouldner's definition of the new class. He argues, for example, that the New class's "critique of the state. . .takes the mystified form of asserting the dominance and autonomy of impersonal technology."[753] Further, the "ideology" of the New Class "holds that productivity depends primarily on science and technology and that the society's problems are solvable on a technological basis, and with the use of educationally acquired technical competence."[754] This "ideology of the autonomous technological process" is significant in capturing, at the level of the new class, the scientific and technological basis of post-industrial society.[755] Gouldner interprets the new class's effort to position science and technology at the center of society as playing a role in "de-legitimi[zing] all other social classes than the New Class."[756]

One of the key ingredients of Gouldner's theory is the socialization of members of the new class into the "culture of critical discourse" (or CCD).[757] The CCD is "a relatively situation-free speech variant" through which interlocutors attempt "to elicit the *voluntary* consent of those addressed solely on the basis of arguments adduced."[758] Importantly,

> the culture of critical speech forbids reliance upon the speaker's person, authority, or status in society to justify his claims. As a result, CCD de-authorizes all speech grounded in traditional social authority, while it authorizes itself. . .as the standard of *all* "serious" speech.[759]

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753 Gouldner, *Future of Intellectuals and the Rise of the New Class*, 24.
754 Ibid.
755 Just below this passage, Gouldner notes that "Presenting technology as an impersonal and autonomous societal resource, the New Class conceals itself and its own role in the process" of strengthening its claims "*within the status quo*." Ibid., 24 and 25 [emphasis in original].
756 Ibid.
757 Although new class members are trained in specialized "sociolects," underlying and uniting these specialized professional languages is the culture of critical discourse. Compare Gouldner's notion of the culture of critical discourse with Jamison and Eyerman's notion of "critical public discourse." Ibid., 28-44, esp. 28 and 30. Jamison and Eyerman, *Seeds of the Sixties*, xii.
758 Ibid., 59 and 28 [emphasis in original].
759 See also Gouldner's claim that the "culture of critical speech requires that the validity of claims be

Through its rise of importance and commitment to the culture of critical discourse, the new class issues a double challenge to the bourgeoisie. The new class challenges the dominance of the bourgeoisie at the same time as the CCD delegitimizes the bourgeoisie's power as external to legitimate policy making decisions.

Further, the CCD contributes to the new class's sense of alienation--one of the key drivers of this group's potential for social change. Not only does the CCD distance new class members from existing languages and cultures, it also enables new class members to claim that the CCD (in maintaining that power and social position should be external to the effort to attain assent) constitutes the pathway to truth.[760] New class members' sense of alienation is compounded by the variety of ways in which their upward mobility and their sense of disparity between their own sense of cultural achievements and comparatively lower access to wealth and power.[761] On the other hand, new class members' interest in pursuing technical problems that are apolitical can be blocked by the emphasis by the bourgeoisie on problems with practical applications.[762]

There is an interesting tension between the New class's potential for large-scale social change and its interest in furthering its own position. On the one hand, the CCD and the professional ideology of the New Class compels its members to appeal to and feel responsible for a broader public.[763] On the other, Gouldner notes that this very appeal is

justified without reference to the speaker's *societal position or authority.*" Ibid., 29 and 28 [emphasis in original].

760 Ibid., 58-9.

761 Gouldner puts special emphasis on the ways that the oversupply of educated workforce can lead to dissatisfaction and alienation--particularly when compared to previous periods of upward ascendance. Ibid., 60-5 on blocked ascendance, 65-6 on status disparity, and 66-7 on overproduction of manpower.

762 Ibid., 66.

763 In addition to the role of professional ideology and the CCD in promoting this broader appeal, Gouldner argues that the "New Class's consciousness is thus not 'economistic.' It is committed to producing worthy objects and services and to the development of skills requisite for these." And, the new class

part of new class members' efforts to further their positions.[764] In fact, one of the important insights of Gouldner's work lies in his recognition of the dual nature of a critique that is posed on a general level and yet emerges from a specific social location. The tension between the particular and situated sources of new class's aspirations and alienation and the class's commitment to the broad public and potential to effect-large scale social change marks them as the "flawed universal class."[765]

What is the relationship between ecologists such as Sears, Bates, and Odum to the environmental movement? To what extent can these ecologists be considered leaders of the environmental movement or as members of Gouldner's new class? Phrased differently, how does the role of the scientist as an intellectual fit into the figuration involving ecology as a science and environmentalism as a social movement? Literature on the intellectual as a vanguard who brings about mobilization and sometimes large scale social change positions the intellectual as chronologically prior to social movement mobilization and as a cause, or playing a causal role, of that mobilization. As we have seen, there have been a number of scholars attributing the contemporary environmental movement to Rachel Carson.[766] By this accounting Carson as an intellectual assumed the role of the vanguard in relation to the environmental movement.[767] This leaves the question of the extent to which Sears, Bates, and Odum should be considered as playing a

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attempts to institutionalize "a distinct principle of distributive justice: 'from each according to his ability, to each according to his work,' which is also the norm of 'socialism.'" Ibid., 19 and 3 on professional ideology, 28-31 on CCD, and 20 on economism and socialism.

764 Ibid., 12, 83-5 and 37.

765 Ibid., 83-5.

766 Brulle, *Agency, Democracy, and Nature*, 182-3. Lutts, "Chemical Fallout: Rachel Carson's Silent Spring, Radioactive Fallout," 211. Dunlap and Mertig, *American Environmentalism*, 14 and 19. Jamison and Eyerman, *Seeds of the Sixties*, 66. Meyer and Rohlinger, “Big Books and Social Movements: A Myth of Ideas and Social Change,” 136–153. Stoll, "Rachel Carson's Silent Spring, a Book that Changed the World."

767 Jamison and Eyerman, *Seeds of the Sixties*, 66.

leadership role in relation to the environmental movement.

Key to the question of the relation of Odum and Sears to the environmental movement is the timing of their critiques. Odum's critique came much later than that of Carson, Sears, Bates, and Elton and was enabled by the environmental movement rather than the other way around.[768] One of the crucial shifts in Odum's move towards approaching ecology as a normative science came with his involvement in a campaign to save the coastal marshes of Georgia in the late 1960s. It was this involvement that informed Odum's 1969 work "The Strategy of Ecosystem Development" as well as his later turn to assigning financial value to nature. Bates, by contrast, had assumed an outspoken endorsement of conservation by 1960, Elton by 1958, and Darling (endorsing human ecology) by 1964.[769] All of these other scholars' critiques came much earlier than Odum's critique and all but that of Darling were published before Carson's Silent Spring.[770] Clearly, Odum was a comparative latecomer to the concerns that would drive the environmental movement. Further, Odum's involvement with the "save the marshes" campaign played an important role in his move towards approaching ecology as a

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[768] It should be noted that the relationship between the critiques of Sears, Bates, and Elton on the one hand and the environmental movement on the other becomes more complicated in shifting to a more inclusive definition environmentalism that incorporates earlier efforts to preserve natural beauty or efficiently manage natural resources.

[769] I am using the 1960 publication date of Bates' *The Forest and the Sea* and the 1958 publication date of Elton's *The Ecology of Invasions.* Although I use the 1964 publication date of Darling's "Conservation and Ecological Theory" in order to maintain a standard criteria (explicit backing of conservation or human ecology), one could as easily date his publication of the kinds of critiques later associated with contemporary environmentalism to the 1939 publication of A Naturalist on Rona, given the work's call for "law-making in the interests of wild life." Charles Elton, "The Relation of Man to Animals." *Journal of Animal Ecology* 8, no. 2 (November 1, 1939): 390 [quotes Darling].

[770] I emphasize these scholars' relation to the publication date of *Silent Spring* given the importance assigned to this work as the opening shot of the environmental movement. Brulle, *Agency, Democracy, and Nature*, 182-3. Lutts, "Chemical Fallout: Rachel Carson's Silent Spring, Radioactive Fallout," 211. Dunlap and Mertig, *American Environmentalism*, 14 and 19. Jamison and Eyerman, *Seeds of the Sixties*, 66. Meyer and Rohlinger, "Big Books and Social Movements: A Myth of Ideas and Social Change," 136–153. Stoll, "Rachel Carson's Silent Spring, a Book that Changed the World." Carson, *Silent Spring*, 117 on Elton.

normative science.

Sears' critique, meanwhile, predates *Silent Spring*. While it is not clear that Sears' critical work played a role in inspiring Carson, the work of his student Paul Shepard inspired Carson and other environmentalists. Rachel Carson cites Shepard in the second chapter of *Silent Spring* in asking, “[w]hy should we tolerate a diet of weak poisons” and “[w]ho would want to live in a world which is just not quite fatal?”[771] In this 1958 essay Shepard launched a biting critique of the systematic poisoning of the environment with synthetic pesticides and nuclear fallout and the inadequacy of notions of safe thresholds. Further, as we have seen, Shepard’s work was taken up by members of the ‘deep ecology’ movement and the founders of the radical environmental group ‘EarthFirst!’[772]

Much more than Odum, then, Sears occupied a vanguard relation to the environmental movement. This does not mean that Odum's contributions to the "save the marshes" campaign or to later efforts to draw on ecology to critique modern society or to solve environmental problems should be neglected. In getting involved with the "save the marshes" campaign, Odum brought the weight of a prominent scientist capable of providing credible scientific reasons to avoid mining the coastal marshes for phosphate.[773] Further, he participated in the movement not only as a scientist but also as an activist. The work of Rachel Carson, as well, did not just inspire environmentalists, it is generally counted as itself a work *of* environmentalism. In this sense, it would be difficult to disentangle the contribution of people such as Odum or Carson as intellectuals from their

[771] Shepard, “The Place of Nature in Man’s World,” 86, quoted in Carson, *Silent Spring*, 12.

[772] Bill Devall, “The Deep, Long-Range Ecology Movement, 1960-2000--A Review,” *Ethics and the Environment* 6, 1 (2001): 18 and 24. Bill Devall and George Sessions, *Deep Ecology: Living as if Life Mattered* (Salt Lake City: G.M. Smith, 1985) 181-5. David Foreman, "Forward." In *Man in the Landscape: a Historical View of the Aesthetics of Nature* by Paul Shepard, (Athens, GA: University of Georgia Press, 2002), xi-xx

[773] See chapter 5.

role as environmentalists.

This question of the relationship between Odum and Sears to the environmental movement opens up into the third theme from literature on intellectuals--different emphases with regard to the nature of the intellectual--as well as the broader question, which I will address in the following section, of the place of science in theories of modernity.[774] In commenting on Alvin Gouldner's work, Carl Boggs raises the question: to what extent should the figure of the intellectual be limited to members of a new class of self-promoting professionals? Alternatively, should more critical figures, often operating at the periphery of the professions, be counted as intellectuals and if so how?

While Boggs does count members of Gouldner's new class as potential intellectuals, he argues that they form one type of intellectual--a technocratic intellectual. The technocratic intellectual follows Gouldner's description of the new class in positioning science and technology as well as professionalized expert knowledge as possessing the answers to society's problems.[775] In addition to the technocratic intellectual, Boggs argues that there is a second kind of intellectual, the critical intellectual. Where the technocratic intellectual identifies with science and technology as part of an effort of gaining more control over society's key institutions, the critical intellectual is far more oppositional and often diagnoses science and other core institutions as a key part of the *problem* of contemporary society.[776] In addition to critical theorists such as Horkheimer, Boggs locates the critical intellectual in the new social movement mobilization of the 1960's New Left and in the ecology movement.[777] These

[774] I will address the place of science in theories of modernity in the following section.
[775] Boggs, *Intellectuals and the Crisis of Modernity*, chapter 6, esp 145-6 on Gouldner and 153 and 162-4 on the contrast between technocratic and critical intellectuals.
[776] Ibid., esp 162
[777] Ibid., 164-79, esp 172 on ecology.

figures critiqued the central place of science and technology in relation to the Vietnam War and as an engine of ecological destruction.[778] Further, both the New Left and the ecological movement explicitly attacked the technocratic authority of Gouldner's new class.[779]

To what extent then should Sears and Odum be considered critical intellectuals or technocratic intellectuals? Compared to the work of Sears, Odum's critique comes across as more cautious and also more hopeful of the ability of ecology as a science to provide the answers that could transform our relationship with our environment and so also our future. Although Odum was critical of science, it was primarily as an enterprise that was highly specialized and reductionist and so incapable of meeting the larger scale and cross-disciplinary problems posed by environmental issues. Yet by the mid 1970s Odum had begun defining ecology as an "integrative" discipline capable of linking together and uniting more specialized disciplines.[780] In doing so, ecology could also provide a viewpoint uniquely suited to the complexity of real world environmental problems.[781] While specialization was a limit of other disciplines, this limitation could be countered with the broader, more holistic approach provided by ecosystem ecology. Much later, Odum imagined a very similar role for ecology as a "communication bridge between science and society."[782] Here, Odum positions ecology as answering the dilemma C. P. Snow posed in *Two Cultures*. Snow's focus on the lack of communication between science and the humanities becomes transformed for Odum into a lack of communication

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[778] Ibid.
[779] Ibid., 166 and 170-1.
[780] Odum, "The Emergence of Ecology as a New Integrative Discipline," 1289-90.
[781] See chapter 4.
[782] Odum, *Ecology: a Bridge Between Science and Society*, xiii.

between science and society--and as a problem that ecology as a discipline can address.[783]

Elsewhere, Odum positioned science--and particularly ecology as an integrative science--as capable of providing the solutions to environmental and even social problems. In "The Strategy of Ecosystem Development" he castigated governments for being "so fragmented and lacking in systems-analysis capabilities that there is no effective mechanism whereby negative feedback signals can be received and acted on before there has been a serious overshoot."[784] Ecologists, by contrast were equipped with the ability to perceive environmental hazards and provide governments with the "negative feedback signals" that they need to govern effectively. Nowhere is Odum's position on the usefulness of science, and particularly ecology, to government than in Figure 6.1.[785] Here science was portrayed as a guide dog capable of keeping the legislators, who are blind, from walking off of a cliff. Without the expertise of scientists, traditional modes of governance are in danger of self destruction. In positioning science as the basis for enlightened governance, Odum came to approach ecology as part of a normative effort to establish the value of the environment in order to convince people to protect it.

By contrast, Sears critiques this kind of effort to position science as an answer to social problems. In his 1958 essay "The Inexorable Problem of Space," Sears notes that "One hears too frequently for comfort the sober assertion that we need not worry about depletion of natural resources, now that interplanetary space travel is just around the corner!" Sears is clearly incredulous in “the culmination of a new faith—the belief that

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783 Trilling offers an analysis of this debate in which Snow's emphasis on lack of communication obscures his real sense of the problem as the humanities' insufficient respect for and literacy in the sciences. Lionel Trilling, "The Leavis-Snow Controversy." In *Beyond Culture*: *Essays on Literature and Learning* by Lionel Trilling (New York: Harcourt Brace Jovanovich, 1978), 126-54.

784 Odum, "The Strategy of Ecosystem Development," 267. See chapters 5 and 6.

785 Figure 6.1 is in the concluding section of chapter 6.

technology will solve any problems that confront humanity."[786] Instead of treating science as a means to an end--managing resource scarcity or improving the quality of life--science is treated as an end in itself.[787] Instead, Sears argued that "The applications of science must be guided, managed, controlled, according to ethical and aesthetic principles and in light of our most profound understanding."[788] Instead, technocratic faith in science and technology resulted in the unreflective application of science.

How can the contrast between Sears' and Odum's positions on science be interpreted in terms of Boggs' contrast between technocratic and critical intellectuals? Odum's faith in science as a form of expertise capable of solving social problems resonates strongly with Gouldner's description of the new class, or Bogg's technocratic intellectual. It is important that Odum's answer to environmental problems is based on ecology as a science. In describing the new class, Gouldner argues that it "assert[s] the dominance and autonomy of impersonal technology" and "educationally acquired technical competence."[789] Odum similarly argued that science, if a holistic and later also a normative science, as a form of professional expertise could solve society's problems.

By contrast, Sears' more radical critique of science resonates with Boggs' description of the critical intellectual. In the midst of concern over the Soviet Union's launch of Sputnik, Sears critiqued "our almost hypnotic concern for outer space."[790] Further, he argued that science in the cold war period had become a form a religion, and that many had the *faith* that science could solve all manner of problems.[791] Instead of

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786 Sears, "The Inexorable Problem of Space," 10.
787 Sears, "The Steady State," 398-9.
788 Ibid., 397.
789 Gouldner, *Future of Intellectuals and the Rise of the New Class*, 24.
790 Sears, "The Inexorable Problem of Space," 10.
791 Cold war scientists such as Alvin Weinberg, director of Oak Ridge National Lab, gave expression to the position that Sears attacked. For Weinberg, science, and particularly big science, had the potential to

being applied as a means to an end such as human happiness, science had become an end in itself. Carl Boggs treats Herbert Marcuse as a model for the figure of the critical intellectual. This raises the question of how Marcuse viewed the place of science and technology in contemporary society. Did he see science as a central social institution and holding the answers to various kinds of problems, including social problems? What does a position that is critical of the place of science in society entail?

The question of how Sears and Odum modeled the role of scientists as intellectuals is also a question of the proper place of science in modern society. A key factor distinguishing critical intellectuals from technocratic intellectuals is the individual's position on the place of science and technology in society (and the extent to which science can be considered a form of professional expertise helpful in addressing social problems.) Should ecology as a science be consulted by politicians interested in expert answers to environmental and social questions or should ecology play a more oppositional role, critiquing the mainstream society? As we shall see, to the extent that scientists as intellectuals can, by engaging their scientific work as normative or subversive, play a significant role in realizing change through social movement mobilization, these scientists break in a decisive way from the place of science in Weber's vision of modernity.

III. The Place of Science and Technology in Modernity

What is the place of science in contemporary society as a place that is

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solve any number of problems. Weinberg argued that, "[t]here is a possibility that the technologically oriented research institutions may contribute to an unexpected degree to the resolution of problems that now seem to be primarily social. I refer to the possibility of devising 'cheap technological fixes' that afford shortcuts to the resolution of social problems." Weinberg, *Reflections on Big Science*, 141.

distinctively modern? To what extent can late modernity (or post-industrial society or reflexive modernity) be characterized as scientific or technological at its core? Given the importance of Weber's "Science as a Vocation" both as a theoretical reference point in this dissertation and in discussions of his view of the nature of modernity, I will open discussion by introducing the place of science in relation to *Weber's* theory of rationalization as one of the central concepts of his view of modernity.

Next I will examine the work of critical theorists who take up and modify Weber's theory of modernity and of rationalization. In this work, the place of science as a central, but also isolated, force in Weber's theory of rationalization came to be approached as a much more pervasive and problematic feature of modern life. Weber's emphasis on value neutrality as a necessary reaction to rationalization is approached instead as part and parcel of the defeated legacy of Enlightenment reason and, for Marcuse, indicative of the central, but not necessary, place of technological rationality in contemporary culture. By extending a consideration of Weber's rationalization into the work of Adorno, Horkheimer, and Marcuse, we can gain a sense of alternative visions of modernity that will be helpful in considering, in the following section, the how ecology as a subversive science and how environmentalism as a social movement figure into the relationship between science and modernity.

In "Science as a Vocation" and elsewhere, Weber foregrounded the role of science as a "motive force" of rationalization and so therefore also of disenchantment and the retreat of "ultimate values:"[792]

[792] Weber, "Science," 139 on motive force and 155 on the link between rationalization, disenchantment, and the retreat of values. See also Weber, "Religious Rejections of the World and Their Directions," 350. In his summary of rationalization, Habermas notes that, "The progressive rationalization of society is linked to the institutionalization of scientific and technical development." Jürgen Habermas, "Technology and Science as 'Ideology,'" in *Toward a Rational Society: Student Protest, Science, and*

> The fate of our times is characterized by rationalization and intellectualization and, above all, by the 'disenchantment of the world.' Precisely the ultimate and most sublime values have retreated from public life either into the transcendental realm of mystic life or into the brotherliness of direct and personal human relations.[793]

Elsewhere he noted that,

> Wherever. . .rational empirical knowledge has consistently carried out the disenchantment of the world and its transformation into a causal mechanism, there appears to be the ultimate challenge to the ethical postulate, that the world is a divinely ordered cosmos with some kind of ethically meaningful direction.[794]

Weber's vision of modernity is largely defined by this process of rationalization, driven by science and banishing values that extend beyond a given "value sphere."[795] It is both ironic and important that, in Weber's modernity, science would be the motive force of a process that would increasingly define modernity but also curtail and limit the role of the scientist.

For Weber, the advance of rationalization marks the triumph of formal rationality as a certain kind of rationality.[796] In his account of Weber's ideas, Rogers Brubaker explains that Weber's rationality implies a point of view from which something could be

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Politics, by Jürgen Habermas, translated by Jeremy J. Shapiro, (Boston: Beacon Press, 1970), 81.

793 Weber, "Science," 155.

794 Weber, "Religious Rejections of the World and Their Directions," 350.

795 So far in this dissertation, Weber's rationalization has been examined primarily in terms of its implications for the role of the scientist and the place of science in society. This was a theme I introduced in the first chapter and which has served as a backdrop for the discussion in many of the other chapters. Clearly, however, the trend towards increasing bureaucratization, as another defining feature of Weber's rationalization, describes changes in the university setting in which the roles of the scientist and the intellectual have become so circumscribed. The emphasis, in the first chapter, on the increasing specialization in the university setting and the discussion, in the last section, on the ways that specialization has curtailed the broad engagement of the intellectual are also the story of the bureaucratization of the university as a setting for knowledge work. Weber, "Science," 130-1 on the bureaucratization of university-based science. Weber, "Bureaucracy," 198-203. But see William Clark's argument of the importance of charisma, beside rationalization and bureaucratization, in the formation of the university and the role of the scholar. *Clark, Academic Charisma and the Origins of the Research University*, 9-21.

796 Brubaker, *The Limits of Rationality*, 37 and 43-5.

rational.[797] While formal rationality assesses means from the point of view of their ability to realize a goal that is pre-determined, substantive rationality assesses values (also from a given point of view).[798] With the process of rationalization, fewer areas are approached in relation to values--or through substantive rationality, and more areas are approached through the lens of formal rationality.[799]

Critical theorists such as Theodor Adorno and Max Horkheimer, meanwhile, have approached the fate of reason in very similar terms as Weber's rationalization.[800] Here, however, reason becomes an instrument of domination over people and nature, and Weber's tone of resigned accommodation is replaced with a tone of outrage. While Weber noted that science was a "motive force" of the process of rationalization, Adorno and Horkheimer locate the dual nature of reason in the work of Francis Bacon, "the father of experimental philosophy."[801] On the one hand, reason was meant "to dispel myths, to overthrow fantasy with knowledge," and, on the other it has brought us a "wholly

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797 Ibid., 35-6.

798 Ibid. 35-6.

799 Habermas would capture the spreading logic of formal rationality in foregrounding "the colonization of the life-world" and "the extension of the areas of society subject to the criteria of rational decision." Ibid., 37 and 43-5. Jürgen Habermas, "New Social Movements," 37 and 35. Jürgen Habermas, "Technology and Science as 'Ideology,'" 81.

800 The following accounts of critical theorists is necessarily very partial--most visibly in focusing on the influence and reworkings of the Weberian notion of rationalization at the expense of considering the importance of Marx's influence. This choice follows my choice of using Weber's "Science as a Vocation" as the key theoretical reference point for this dissertation.

801 Max Horkheimer and Theodor Adorno. *The Dialectic of Enlightenment,* ed. G.S. Noerr, transl. Edmund Jephcott. (Stanford, CA: Stanford University Press, 2002), 1. Jürgen Habermas would later refer to *The Dialectic of Enlightenment* as Adorno and Horkheimer's "blackest book." "On their analysis," he argued, "it is no longer possible to place hope in the liberating force of enlightenment." *See also Carolyn Merchant's classic work Death of Nature*, recent article on Francis Bacon, and edited volume that brings together the work of critical theory and Marx with a variety of voices inspired by environmentalism and ecology--deep ecology, social ecology, ecofeminism, environmental justice, and spiritual ecology. Jürgen Habermas, *The Philosophical Discourse of Modernity: Twelve Lectures*. Translated by Frederick Lawrence (Cambridge, MA: MIT Press, 1996), 106. Carolyn Merchant, *The Death of Nature: Women, Ecology and the Scientific Revolution* (San Francisco: Harper and Row, 1980), chapter 7. Carolyn Merchant, "'The Violence of Impediments': Francis Bacon and the Origins of Experimentation." *Isis* 99 (2008): 731-760. Carolyn Merchant, ed., *Ecology* (New Jersey: Humanities Press), 1994, v-vii, 1-27. Gregg Mitman, “Where Ecology, Nature, and Politics Meet: Reclaiming the Death of Nature.” *Isis* 97 (2006): 496-504.

enlightened earth" that is "radiant with triumphant calamity."[802]

While reason can, or did, have the power to dispel tradition, now it finds primary expression in the domination of people and nature. In "disenchanting" the world, Enlightenment reason rendered the subject as something fundamentally apart from nature. It attacked what is saw as the animistic "projection of subjective properties onto nature."[803] This "distance of subject from object" is the basis of the abstraction of nature as a key process of the Enlightenment and one that allows the subject to relate to nature in a relationship of knowledge of and control over nature as an assembly of lifeless objects.[804]

Reason, for Bacon and for us, means the domination of nature, but in order to subjugate nature we must also subjugate ourselves as an object of reason.[805] The argument, in *The Dialectic of Enlightenment*, that "domination over nature turns against the thinking subject itself" is extended in *The Eclipse of Reason*, where Horkheimer argues that,

> The human being, in the process of emancipation, shares the fate of the rest of his world. Domination of nature involves the domination of man. Each subject not only has to take part in the subjugation of external nature, human and nonhuman, but in order to do so must subjugate nature in himself. Domination becomes 'internalized' for domination's sake.[806]

As reason becomes a tool for knowing and manipulating objects in the world, it

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[802] Horkheimer and Adorno, *The Dialectic of Enlightenment*, 1. In Eclipse of Reason, Horkheimer located the liberatory potential in the prominent place that reason held for "the pioneers of bourgeois civilization, the spiritual and political representatives of the rising middle class, who were unanimous in declaring that reason plays a leading role in human behavior, perhaps even the predominant role." Max Horkheimer, *Eclipse of Reason* (New York: Oxford University Press, 1947), 9.

[803] Ibid., 1-5, esp. 1 and 4.

[804] Ibid., 2, 9, 7, and 148-9, esp. 9 and 2.

[805] In discussing Bacon's work, Horkheimer and Adorno famously note that "Knowledge and power are synonymous." Ibid., 2.

[806] Ibid., 20. Horkheimer, *Eclipse of Reason*, 92 and 43.

becomes restricted to handling and comparing objects in terms of predefined goals.[807] Here again we see the emphasis on the simultaneous advance of reason and retreat of values. As "all life today tends increasingly to be subjected to rationalization and planning" it becomes turned into a tool or a means to an end or a value that escapes discussion:[808]

> If reason is declared incapable of determining the ultimate aims of life and must content itself with reducing everything it encounters to a mere tool, its sole remaining activity is simply the perpetuation of its co-ordinating activity.[809]

Horkkheimer here echoes Weber's emphasis on the retreat of values from public life.[810] More bleakly, however, Horkheimer sees the advance of reason as "The total transformation of each and every realm of being into a field of means" and subsequently "the liquidation of the subject who is supposed to use them."[811]

Despite the sense of outrage we encounter in Horkheimer and Adorno's work, these theorists provide little hope for escaping the advance of reason, the domination of nature, and the "liquidation of the subject."[812] On an individual level, one's "self-preservation presupposes his adjustment to the requirements for the preservation of the system. He no longer has room to evade the system."[813] Horkheimer does recognize, however, the ways in which the advance of reason has been resisted by social movements, from "spontaneous peasant insurrections of the sixteenth century" to the "race riots of our day." However,

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[807] Horkheimer, *Eclipse of Reason*, 3-5.
[808] Ibid. 95.
[809] Ibid., 92.
[810] Weber, "Science," 155.
[811] Horkheimer, *Eclipse of Reason*, 93.
[812] Ibid.
[813] Ibid., 96.

> Typical of our present era is the manipulation of this revolt by the prevailing forces of civilization itself, the use of the revolt as a means of perpetuating the very conditions by which it is stirred up and against which it is directed. Civilization as rationalized irrationality integrates the revolt of nature as another means or instrument.[814]

Although Adorno and Horkheimer's critique radicalizes Weber's vision of modernity, it similarly leaves little hope for the possibility of resistance.[815]

In Herbert Marcuse's work there is a similar emphasis on reason or rationalization (here "technological rationalization") as a form of domination, though he holds out more hope for the possibility of change. While Weber's rationalization stems from the internal orientation of Puritanism which comes to inform early capitalism and science, Marcuse's technological rationality is a more recent phenomenon and stems from the incorporation of technology as part of capitalist's efforts to realize a competitive advantage by relying more heavily on more centralized technology.[816] In an early work, Marcuse describes

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814 Ibid., 94.

815 See also Andrew Feenberg, "Marcuse or Habermas: Two Critiques of Technology," *Inquiry* 39, 1 (1996): 46-7.

816 Weber traces the religious origins of rationalization in *The Protestant Ethic and the Spirit of Capitalism*. Max Weber, *The Protestant Ethic and the Spirit of Capitalism*, 181-2. Herbert Marcuse, "Some Implications of Modern Technology." In *The Essential Frankfurt School Reader*, ed A. Arato et al. (New York: Continuum International Publishing Group, 1978), 141. On the greater importance Weber assigned to *The Protestant Ethic and the Spirit of Capitalism* in relation to rationalization, see Hans G. Kippenberg, "Religious Communities and the Path to Disenchantment: The Origins, Sources, and Theoretical Core of the Religion Section," in *Max Weber's Economy And Society: A Critical Companion*, Charles Camic et al. (Stanford, CA: Stanford University Press, 2005), 165-8.

In many ways, the critical emphasis on the technological nature of modern society reached a high point in the work of Jacques Ellul. In *Technological Society*, Ellul provides a devastating critique of the pervasiveness of "technique" that resonates in many ways with Marcuse's description of technological rationality. Ellul defines technique as "*the totality of methods rationally arrived at and having absolute efficiency* (for a given stage of development) in *every* field of human activity." In his forward to the work, Robert K. Merton explains Ellul's critique: "Ours is a progressively technical civilization: by this Ellul means that the ever-expanding and irreversible rule of technique is extended to all domains of life. It is a civilization committed to the quest for continually improved means to carelessly examined ends." For both Ellul and Marcuse*, the primary object of interest is not machines but their role in the spread of a way of thinking in which an increasing number of phenomena come to be approached as if they were machines.* Jacques Ellul, *The Technological Society,* translated by John Wilkinson (New York: Random House Books, 1964), xxv [emphasis in original]. Robert K. Merton, "Forward," In *The Technological Society,* by Jacques Ellul. Translated by John Wilkinson (New York: Random House Books, 1964), vi-viii, esp. vi.

technological rationality in terms of efficiency and compliance:

> The idea of compliant efficiency perfectly illustrates the structure of technological rationality. Rationality is being transformed from a critical force into one of adjustment and compliance. Autonomy of reason loses its meaning in the same measure as the thoughts, feelings and actions of men are shaped by the technical requirements of the apparatus which they have themselves created. Reason has found its resting place in the system of standardized control, production and consumption. There it reigns through the laws and mechanisms which insure the efficiency, expediency and coherence of this system.[817]

Despite its comparatively recent origin, Marcuse argues that technological rationality has come to pervade thinking in modernity and structure the way we approach not only machines but also other people in terms of "standardized efficiency."[818]

In *One-Dimensional Man*, Marcuse's earlier sketch of technological rationality becomes significantly elaborated into the basis of a scathing critique of modern society. In arguing that contemporary society is defined by "The totalitarian universe of technological rationality," Marcuse signals both the pervasiveness of his object and the extent of its control.[819] This domination is not always easy to detect, however, as it represents a "comfortable, smooth, reasonable, democratic unfreedom" taken as a "token of technical progress."[820] In the context of the rising standard of living in the years following World War II, the purchase of consumer goods is satisfying to the extent that our desire for them was implanted by corporations selling them.[821] And the alliance

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817 Herbert Marcuse, "Some Implications of Modern Technology." In *The Essential Frankfurt School Reader*, ed A. Arato et al. (New York: Continuum International Publishing Group, 1978), 146.

818 Ibid., 142.

819 See also Marcuse's comment that "*By virtue of the way it has organized its technological base, contemporary industrial society tends to be totalitarian." Herbert Marcuse, One-Dimensional Man* (New York: Routledge Press, 2002), 128 and 5.

820 Elsewhere, he notes that "the prevailing mode of freedom is servitude." Ibid., 1 and 92.

821 He argues that "Free choice among a wide variety of goods and services does not signify freedom if these goods and services sustain social controls over a life of toil and fear—that is, if they sustain alienation." Ibid., chapter 1, esp. 5, 7-8, and 10.

between corporations and labor, as a formerly oppositional force, marks "the closing of the political universe" that leaves critics to appear "socially useless," "neurotic and impotent."[822] Without oppositional positions drawing attention to alternative possibilities, there is an inability to distinguish between things as they are and things as they could be. Society becomes "one-dimensional."[823]

In this context of pervasive domination, oppositional thinkers serve a dialectical role that promises the possibility of social change by contradicting the seeming neutrality of technological rationality. As we have seen, for Marcuse both technological rationality and technology are political to their core. He argues that

> In the face of the totalitarian features of this society, the traditional notion of the "neutrality" of technology can no longer be maintained. Technology as such cannot be isolated from the use to which it is put; the technological society is a system of domination which operates already in the concept and construction of techniques.[824]

In this context, oppositional thinking strives to transcend the conditions of existing social order in order to imagine how society might be improved.[825] The tension between the existing social order and the oppositional vision of society represents a dialectic that can propel social change.[826] Efforts to be value neutral on the other hand simply serve the

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822 He argues that "in the contemporary period, the technological controls" that serve as a form of "social control" and provide the logic and enforcement of the current division of labor and mode of production "appear to be the very embodiment of Reason for the benefit of all social groups and interests—to such an extent that all contradiction seems irrational and all counteraction impossible."Ibid., chapter 2, esp. 4 and 12, and 11.

823 Marcuse argues that "the obliteration of the oppositional, alien, and transcendent elements in the higher culture" goes hand in hand with the "liquidation of two-dimensional culture." See also his argument that the now widespread "happy consciousness" reflects "the belief that the real is rational, and that the established system, in spite of everything, delivers the goods." In this context, it is the job of critical theory to draw attention to "the historical alternatives which haunt the established society as subversive tendencies and forces." Ibid., 59 on obliteration, 60 on liquidation, 82 on happy consciousness, xi-xii on subversive forces, and chapter 5 on oppositional or "negative thinking."

824 Ibid., xlvi.

825 Ibid., 17 and 19 on transcendence as oppositional.

826 Ibid., 100-4 and 17. This describes Carl Boggs' critical intellectual.

status quo.[827] For Marcuse, this holds even for value neutrality of science, which simply fits into the larger transformation by which the world is encountered as a world of objects waiting to be manipulated according to ends external to those objects.[828] Trends toward empiricism and operationalism capture this dynamic for Marcuse:

> To the degree to which this operationalism becomes the center of the scientific enterprise, rationality assumes the form of methodical construction; organization and handling of matter as the mere stuff of control, as instrumentality which lends itself to all purposes and ends—instrumentality per se, "in itself."[829]

Although positions opposing this logic have become increasingly incorporated into the logic of technological rationality and sold to consumers as lifestyle products, oppositional positions represent an ongoing force of reason.[830] In this ongoing potential for social change, Marcuse presents a more open-ended and (somewhat) more optimistic view of modernity than characterized the work of Adorno and Horkheimer. While Adorno and Horkheimer described the critical potential of Enlightenment reason in the past tense, Marcuse held out hope for critical reason in the form of oppositional thinkers as expressing the "transcendent, negative, oppositional elements of Reason."[831]

The place of value neutrality as well as the possibility for social change in Marcuse's work provide a stark contrast to the Weber's vision of modernity. While the value neutrality of Weber's scientists represents a necessary accommodation of

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[827] Ibid., 160.

[828] See also Marcuse's description of this shift: "As a technological universe, advanced industrial society is a political universe, the latest stage in the realization of a specific historical project—namely, the experience, trans- formation, and organization of nature as the mere stuff of domination." Ibid., 160 and xlvi.

[829] See also Marcuse's comment that ""Operationalism, in theory and practice, becomes the theory and practice of containment." Ibid., 159 and 19.

[830] Ibid., chapter 1 on the integration of alternatives.

[831] See also Marcuse's statement that "The legendary revolutionary hero still exists who can defy even television and the press--his world is that of the 'underdeveloped' countries" Ibid., 100 and 74

rationalization, for Marcuse value neutrality is a key part of technological rationality as a historically more recent phenomenon. For Weber, scientists' value neutrality represents a mature accommodation of increasingly fragmented value spheres by which science, as a sphere concerned with matters of fact, becomes separated from other spheres. For Marcuse, value neutrality represents not a mature reaction to modernity but part of the very fabric of technological rationality. In choosing to define their work as value neutral instead of oppositional, scientists and others model the logic of technological rationality, which is also the logic of domination. Despite the pervasiveness of this logic in Marcuse's vision of modernity, he nonetheless holds out the hope for social change--a hope that Weber does not share. In "Science as a Vocation" modernity is defined by rationalization as a process that is unavoidable and would only be resisted by fools and children.[832]

More contemporary scholarship in the philosophy of technology and reflexive modernization has taken up Marcuse's critique of the seeming value neutrality of technology, Adorno and Horkheimer's critique of instrumental reason, and Marcuse's hope for change. Langdon Winner and Andrew Feenberg, for example, both revisit Marcuse's sense of the pervasiveness and problematic nature of an unreflective over-reliance on technology. In his 1980 essay "Do Artifacts Have Politics?" Winner poses one of the core concerns of Marcuse's One-Dimensional Man as a question.[833] Winner argues

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832 Weber, "Science," 143. Below, I will raise the question of Weber's treatment of modernity as (somewhat) more open ended in *The Protestant Ethic and the Spirit of Capitalism*.

833 Reprinted as chapter 2 of his 1986 book *The Whale and the Reactor*. For more on Winner's relation to Marcuse, see Langdon Winner, *The Whale and the Reactor: A Search for Limits in an Age of High Technology* (Chicago: University of Chicago Press, 1989), 66-8; Langdon Winner, *Autonomous Technology: Technics-Out-Of-Control as a Theme in Political Thought* (Cambridge, MA: MIT Press, 1978), 6, 40, and 187-8; Edwin T. Layton, "[untitled]," review of *Autonomous Technology: Technics-as-out-of-Control as a Theme in Political Thought*, by Langdon Winner, *Isis* 71, no. 1 (March 1, 1980): 169; and Thomas J. Knight, "[untitled]." Review of *Autonomous Technology: Technics-as-out-of-Control as a Theme in Political Thought*, by Langdon Winner. *Annals of the American Academy of Political and Social Science* 437 (May 1, 1978): 185–186.

that--although we think of them as neutral--technological artifacts embody and render durable the politics attending their creation. He famously illustrates this point with the example of New York city planner Robert Moses, who limited access to Jones beach by constructing overpasses that could not be traversed by public transportation buses of public transportation carrying racial minorities and poor people.[834] As technologies such as these overpasses become an unreflected upon feature of everyday existence, they play a significant role in structuring the practice of everyday life. Winer argues that as technologies "become woven into the texture of everyday existence, the devices, techniques, and systems we adopt shed their tool-like qualities to become part of our humanity "[835] Further, the pervasiveness of technologies makes our unreflective approach to their design all the more urgent.[836] Winner describes this lack of reflexiveness as sleepwalking: "For the interesting puzzle in our times is that we so willingly sleepwalk through the process of reconstituting the conditions of human existence."[837] Further, once in place, technology carries a logic of instrumentality and efficiency that threatens to restructure efforts to resist to fit into the terms of this logic.[838] Nonetheless, in concluding *The Whale and the Reactor* with a description of California's Diablo Canyon Reactor--an

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834 Ibid., 22-9, esp. 22-3. See also similar themes in Donald Norman's "user centered design" and Latour's essay ‘‘Where Are the Missing Masses?" which brings together Winner's and Norman's approaches. In Norman's investigation of the "hidden frustrations" and psychopathology" of everyday things, he assesses, from the perspective of the user and the designer of technologies, how efficiency as a design goal foreign to the user can result in the production of alienating and dysfunctional technologies such as ill-designed doors. Norman, D. A. *The Design of Everyday Things*. New York: Basic Books, 2002) viii-ix on frustrations, chapter 1 on psychopathology, and vii-viii, 3-4, and 87-92 on doors. Latour, Bruno. ‘‘Where Are the Missing Masses? The Sociology of a Few Mundane Artifacts." In *Shaping Technology/Building Society: Studies in Sociotechnical Change*, ed. Wiebe E. Bijker et al. (Cambridge, MA: MIT Press, 1992), 225–258, esp. 227-9 on doors and 234 on Winner.

835 In this way technologies qualitatively transform the forms of life in which we live. Winner, *The Whale and the Reactor*, chapter 1, esp. 12.

836 Winner captures this pervasiveness with the opening sentence of his preface: "The map of the world shows no country called Technopolis, yet in many ways we are already its citizens." Ibid., ix.

837 Ibid., 5-10 on "technological somnabulism," esp. 10.

838 Winner's argument here resonates strongly with Marcuse's technological rationality. Ibid., 171.

object of an anti-nuclear movement protests, Winner raises the possibility of a form of resistance to the logic of technology that Andrew Feenberg explores in more depth in his reworking of Marcuse's critique.[839]

Feenberg situates Marcuse's emphasis on technology in relation to the work of Marcuse's mentor, Martin Heidegger, and suggests that the environmental movement has played a significant role in challenging the central place of technology in modernity.[840] In juxtaposing Marcuse's critical position on technology next to Heidegger's "The Question Concerning Technology," Feenberg emphasizes the ontological role of technology, or technological rationality, in modernity.[841] For Heidegger, the centrality of technology to modernity expresses itself not in the profusion of technological devices as a mode of "revealing" whereby the world appears to us as a collection of raw materials.[842] Similarly, Marcuse's technological rationality renders the world as "the mere stuff of control."[843] As I will explore in the following section, Feenberg along with scholars of reflexive modernization, such as Anthony Giddens and Ian Welsh, have argued that the environmental movement resisted this way of viewing the world and, in doing so, also resisted the centrality of technology to modernity.[844]

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839 Ibid., 164-5 and 174-8 on the reactor and chapter 7 on appeals to nature.

840 In the next section I will explore the role of the environmental movement in challenging the place of technology in modernity. Andrew Feenberg, *Heidegger and Marcuse: The Catastrophe and Redemption of History* (New York: Routledge, 2004), ix-xvi.

841 Andrew Feenberg, *Alternative Modernity: The Technical Turn in Philosophy and Social Theory* (Berkeley: University of California Press, 1995), 188. Feenberg, *Heidegger and Marcuse*, xiii.

842 Feenberg explains Heidegger's contrasting mode of revealing as that of techné, which reveals the inner essences or ends inscribed in nature. Feenberg, *Heidegger and Marcuse*, 12-7 and 21-2. Andrew Feenberg, *Questioning Technology*. New York: Routledge, 1999) 183-4.

843 Feenberg explains this development in terms of the emergence of a mechanistic view of the world expressed in such thinkers as Rene Descartes and Francis Bacon. Feenberg adds that Heidegger's approach similarly approached technology in terms of relations of domination. Marcuse, *One-Dimensional Man*, 159. Feenberg, *Heidegger and Marcuse*, 87 on stuff, 11-12 on Descartes, and 14 on domination.

844 Feenberg, *Questioning Technology*, 93.

Although Ulrich Beck shares critical theorists' pessimistic assessment of the dark nature of modernity, in his work the ambivalence of reason is reinterpreted as both a cause of risks and as a way of rendering these risks visible. Resonating with the epochal shift from industrial to post-industrial society in Daniel Bell's work, Beck's vision of modernity is centered on the transition from industrial to risk society.[845] This transition signals the emergence of a political reflexivity on the hazards that emerge as a part of the process of industrial society.[846] In this sense, industrial society produces the hazards the recognition of which undermines and leads to the destruction of industrial society. Further, the scale and the spreading logic of contemporary disasters--disasters produced from the logic and practice of industrial society--overwhelm our ability to cope with their effects with the institutions of industrial society, with welfare state or insurance.[847] While advances in physics, chemistry and molecular biology have led to the increased ability to

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845 Beck opens his well read 1992 work *Risk Society* by noting, "The theme of this work is the unremarkable prefix 'post.' It is the keyword of our times. Everything is 'post.' We have become used to post-industrialism now for some time." Later in the same work, Beck defines risk as "a *systematic way of dealing with hazards and insecurities induced and introduced by modernization itself*" and notes that, in the shift to risk society, "the unknown and unintended consequences come to be a dominant force in history and society." See also Malcolm Waters' claim that Bell anticipated many of the elements of reflexive modernity. Ulrich Beck, *Risk Society: Towards a New Modernity* (Thousand Oaks, CA: Sage Publications, 1992), 9, 21 [emphasis in original], and 22. Malcolm Waters, *Daniel Bell* (New York: Routledge Press, 1996), 171.

846 On Beck's distinction between reflexivity as "more of the same" and reflection as "a process of critical self-engagement" see the summary in Welsh, *Mobilising Modernity*, 23-5, esp. 23; and Beck, "The Reinvention of Politics: Towards a Theory of Reflexive Modernization, " 5-6 and 12.

847 He states that risks "go beyond rational calculation into the realm of unpredictable turbulence." Beck, "The Terrorist Threat: World Risk Society Revisited," 43. Ulrich Beck*, Ecological Politics in an Age of Risk* (New York: Wiley-Blackwell, 1995), introduction and chapter 4, esp. 1-2 and 75-9; Beck, *Risk Society*, 22. See also Collier and Lakoff's work on catastrophes. Stephen J. Collier and Andrew Lakoff. “Distributed Preparedness: The Spatial Logic of Domestic Security in the United States.” *Environment and Planning D: Society and Space* 26, no. 1 (2008): 7 – 28. Stephen J. Collier and Andrew Lakoff, "On Vital Systems Security," Paper presented at the University of Helsinki Collegium, Helsinki, Finland. June 2008. Stephen J. Collier and Andrew Lakoff, "The Generic Biothreat, or, How We Became Unprepared," *Cultural Anthropology* 23, 3 (2008): 399-428. Stephen J. Collier and Andrew Lakoff, "The Vulnerability of Vital Systems: How Critical Infrastructure Became a Security Problem," in *Securing the Homeland: Critical Infrastructure, Risk and (In)Security* ed. Myriam A. Dunn et al., (New York: Routledge, 2008), 17-39. Andrew Lakoff, "Preparing for the Next Emergency," *Public Culture* 19, 2 (2007): 247-71.

manipulate nature for the ends of profit and state power, they have also yielded radioactive fallout and a proliferating array of toxic chemicals and transgenic organisms, and the terms for a future eugenics.[848] Although these kinds of threats are complemented with terrorist attack and financial risks among others, science and technology have pride of place in Beck's theory.[849] He notes, for example, that "Science and the technology spree, with which the industrial age feeds and irresistibly drives its transformation of the world."[850] As a result of the hazards that science introduces into the world, science itself becomes demystified in the way that the transition from feudal to industrial society involved the demystification of religious worldviews and the privilege of rank.[851] Armed with the tools of science and technology, industrial society is, for Beck, self-destructive.[852]

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848 Beck, *Risk Society*, 35, 42, 66, and 72. Ulrich Beck, *World at Risk* (New York: Polity, 2009), 25, 118. Beck, *Ecological Enlightenment*, 104. Ulrich Beck, *Ecological Politics in an Age of Risk* (New York: Wiley-Blackwell, 1995), 2. Beck, *Ecological Politics in an Age of Risk*, 28-32.

849 Ulrich Beck, "The Terrorist Threat World Risk Society Revisited." *Theory, Culture & Society* 19, 4 (August 1, 2002): 39–55, esp., 43. Beck, *World at Risk*, 202-3.

850 Beck, *Ecological Enlightenment*, 101. I will address the place of science in Beck's vision of modernity in more detail below.

851 In his well read 1992 work *Risk Society*, Beck notes that, "*Just as modernization dissolved the structure of feudal society in the nineteenth century and produced the industrial society, modernization today is dissolving industrial society and another modernity is coming into being*." Because science is implicated in the proliferation (and recognition) of hazards, it has "experience[d] a rapid diminution of its public credibility." Beck, *Risk Society*, 10 on dissolving [emphasis in original] and 161 on credibility..

852 See Beck's comments that the "reflexivity of modernity can lead to reflection on the self-dissolution and self-endangerment of industrial society," that "This new stage, in which progress can turn into self-destruction, in which one kind of modernization undercuts and changes another, is what I call the stage of reflexive modernization," and that "we live on the volcano of civilization." Compare to Adorno and Horkheimer's comment that "the first matter we had to investigate" in *The Dialectic of Enlightenment*, was the "self-destruction of the enlightenment." *Ulrich Beck, "The Reinvention of Politics: Towards a Theory of Reflexive Modernization," in Reflexive Modernization: Politics, Tradition and Aesthetics in the Modern Social Order*, ed. Ulrich Beck et al., (Stanford, CA: Stanford University Press, 1994), 2 on this new stage. Ulrich Beck, "Replies and Critiques," in *Reflexive Modernization: Politics, Tradition and Aesthetics in the Modern Social Order* ed. by Ulrich Beck, et al. (Stanford, CA: Stanford University Press, 1994), 177 on self-dissolution. *Beck, Risk Society*, 76 on volcano. Adorno and Horkheimer, *The Dialectic of the Enlightenment*, xvi. See also Ulrich Beck, *Ecological Enlightenment: Essays on the Politics of the Risk Society* trans. Mark Ritter (Atlantic Highlands, NJ: Humanities Press, 1995), chapter 3.

In addition to playing a central role in producing hazards, science also plays a central role in bringing attention to hazards. For Beck, radiation serves as a paradigmatic example of contemporary risks.[853] Like radiation, many of the hazards created by industrial society are invisible to the naked eye.[854] Further, the links between radiation or toxic chemicals and their health effects require scientific training such that they can be linked in a credible way.[855] The threats posed by radioactive matter and toxic chemicals are "threats that require the sensory organs of science--theories, experiments, measuring instruments--in order to become visible and interpretable as threats at all."[856]

The dual role of science in producing and bringing attention to the hazards of industrial society resonates with the ambivalent role of reason in Adorno and Horkheimer's work. This is all the more apparent if we interchange their use of "reason" with Beck's use of "science." For Beck as for Adorno and Horkheimer, science/reason played a central role in the wiping away of feudal traditions and in the transition to modernity. And for Adorno and Horkheimer as for Beck, the current state of reason/science and our reliance on it pose serious problems for the fate of our times.

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853 In his 1992 work, Beck noted, "By risks I mean above all radioactivity, which completely evades human perceptive abilities, but also toxins and pollutants in the air, the water and foodstuffs, together with the accompanying short- and long-term effects on plants, animals and people." Beck, *Risk Society*, 22. See also Welsh, *Mobilising Modernity,* 2.

854 Beck, *Risk Society*, 22 and 72-5.

855 Risks are "based on *causal interpretations,* and thus initially only exist in terms of the (scientific or anti-scientific) *knowledge* about them." Beck also addresses the tension between efforts to establish causal and statistical links between hazards and health effects. He summarizes by noting that "By turning up the standard of scientific accuracy, the circle of recognized risks justifying action is *minimized,* and consequently, scientific license is granted for *the multiplication of risks.* To put it bluntly: insisting on the *purity* of *the scientific analysis leads to the pollution and contamination* of air, foodstuffs, water, soil, plants, animals and people." Ibid., 23 on causal interpretations [emphasis in original] and 62-7, esp. 62 on causal versus statistical links [emphasis in original].

856 Ibid., 162. Beck's emphasis on the place of science in rendering the hazards visible puts his work at odds with the emphasis on new social movements in Anthony Giddens' work. I discussed this point briefly in chapter 1 and will return to it in the following section. Giddens, *The Consequences of Modernity*, 158-162. Welsh, *Mobilising Modernity*, 23-5. Beck, *Risk Society*, 90 and 161-3.

Here, however, reflexive modernization diverges from Adorno and Horkheimer's critical theory. Scott Lash, another theorist of reflexive modernization, has argued that that the approach provides "a new positive twist to the Enlightenment's dialectic." Instead of Adorno and Horkheimer's vision of modernity, "in which 'system' advances inexorably to destroy the 'life-world'. It [reflexive modernization] points instead to the possibility of a new positive twist to the Enlightenment's dialectic."[857] Reflexive modernization, in other words, holds out the hope that progress towards a new social order can be realized based on growing critical awareness of the hazards of industrial society.[858]

Importantly, in the work of Beck, Winner, Feenberg, Marcuse, Adorno, Horkheimer, and Weber--but also Daniel Bell and Alvin Gouldner, science and technology represent a core feature of modernity, if in different ways. For Bell, the post-industrial society was largely defined by our increased reliance on science and technology.[859] In Gouldner as well, the relationship between the emerging new class and the bourgeoisie is largely defined by the reliance of the new class on science and technology.[860] For Weber, rationalization is one of the defining features of modernity and marks the triumph of formal rationality and the difficulty of engaging overarching values. Although science has served as a motivating force of rationalization, the place of science and the role of scientists has become more circumscribed in modernity as a result of the

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857 Scott Lash, "Reflexivity and its Doubles: Structure, Aesthetics, Community," in *Reflexive Modernization: Politics, Tradition and Aesthetics in the Modern Social Order* ed. Ulrich Beck et al. (Stanford, CA: Stanford University Press, 1994), 112.

858 For more on the influence of Adorno and Horkheimer on reflexive modernization theory, see Beck, *World at Risk*, 230-1 and 226; and Beck, Ecological Politics in An Age of Risk, 28-32, esp. 28.

859 Bell, *The Coming of Post-Industrial Society*, chapter 2.

860 For Gouldner, the new class has an "ideology of the autonomous technological process." In holding that "productivity depends primarily on science and technology and that the society's problems are solvable on a technological basis," the new class is "asserting the dominance and autonomy of impersonal technology" as an ideology that puts them in conflict with the bourgeoisie. Gouldner, *Future of Intellectuals and the Rise of the New Class*, 24.

process of rationalization. It is in the context of an increasingly rationalized modernity that the role of the scientist is and must be restricted to matters of matters of fact engaged before narrow audiences of fellow professionals.

Critical theorists such as Adorno, Horkheimer, and Marcuse picked up and modified Weber's theory of rationalization. Here, as well, questions of values become more remote from the public sphere. While reason played a critical role in the Enlightenment, now reason means the domination of nature and other humans. Marcuse approached this domination both as technological in nature. Not only has technology become a form of domination but modernity has become technological. For Marcuse, we live in "a machine age," a "technological order."[861] The emphasis on efficiency and the decreasing role of substantive rationality that Weber associates with the advance of formal rationality, Marcuse accounts for in terms of the advance of technological rationality. In incorporating technology into corporate efforts to increase competitive advantage we have introduced a logic of efficiency and value neutrality that has become pervasive and serves as the language in which we look not only at technology but also ourselves.

Nonetheless, there are obvious and important differences between these works. Marcuse's view of the technological nature of modern society is decidedly less optimistic than Gouldner's view of the technologically savvy, and technologically motivated, new class. Although the latter are "flawed" insofar as they are generally motivated by the effort to further their positions, these efforts can nonetheless result in large-scale social change vis-a-vis the old class, the bourgeoisie that revolutionized society with the

[861] Marcuse, "Some Implications of Modern Technology," 139. Marcuse, *One-Dimensional Man*, 1.

industrial revolution. By contrast, Marcuse's future, as the future of Weber, seems comparatively closed. And technology has played an important role in the closing off of options.

With Gouldner we encounter a qualified optimism for a world, our world, in which science and technology is at the center of society. With Marcuse, technology is still at the center of modernity, but it is despair, if not Weber's resignation, that we encounter here. Marcuse's hope for a better society hinges on the emergence of critical intellectuals who, in defiantly opposing mainstream society, point the way to a better and more just society. Gouldner's optimism, meanwhile, rests in the structural tension between the bourgeoisie and his new class of technocratic intellectuals as a "flawed" agent of social change. In addition to these kinds of intellectuals--and their contrasting positions on science and technology, there is also the question of how environmentalism as a social movement figures into the relationship between science and modernity.

IV. Environmentalism, Science, and Modernity

Scholars building on and modifying Weber's approach to rationalization highlight the ways that the increasing centrality of science and technology in society went along with the retreat of overarching values and the dominance of what Weber termed formal rationality. Many of the same processes described by the dominance of formal rationality in Weber are described by the legacy of instrumental reason in Adorno and Horkheimer and the dominance of technological rationality in Marcuse. For Weber, the victory of formal rationality represented one of the core features of a modernity defined by the process of rationalization. Although Weber's characterization of modernity was an important influence in the work of critical theorists such as Adorno, Horkheimer, and Marcuse, the differences in these theorists' work is equally instructive. To a significant degree, Adorno, Horkheimer, and Marcuse radicalized Weber's vision of modernity as rationalization came to describe the dual legacy of reason. Where reason had been a critical force in the Enlightenment, it has since devolved into the instrumental or technological rationality that dominates society currently. While Adorno and Horkheimer saw little hope for social change, Marcuse remained hopeful that an oppositional critical theory could point the way towards better ways of organizing society.

While environmentalism as a new social movement posed radical challenges to the effort to position science and technology at the center of postwar society, other strands of environmentalism attempted to leverage the credibility of science to implement a reform-based path to social change. In contrast to the more radical demands of environmentalism as a new social movement, these strands of environmentalism fit more closely the model of social movement organizations described in resource mobilization theory.[862] While new social movements are known for issuing radical critiques that often bring into question the fundamental operations of society, the social movement organizations of resource mobilization theory work pragmatically within the existing framework and seek reform-based solutions based on existing models of political advocacy.[863]

Environmentalism as a new social movement and ecologists as critical intellectuals drew public attention to the experimental character of large scale, contemporary

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862 John D. McCarthy, and Mayer N. Zald, "Resource Mobilization and Social Movements: A Partial Theory," *American Journal of Sociology* 82, no. 6 (May 1, 1977): 1218–23.

863 See Buechler for a critical comparison of resource mobilization theory and new social movement theory. Buechler, *Social Movements in Advanced Capitalism*, 51-7. On contrasting strains of the environmental movement, see Dowie, *Losing Ground: American Environmentalism at the Close of the Twentieth Century*, Preface; Gottlieb, *Forcing the Spring*, chapter 4.

technology-centered projects such as industrial agriculture and nuclear weapons testing. Further, in connecting the practices of "industrial society" with their negative effects, ecology and the environmental movement brought visibility to the hazards that came with approaching the world as a "field of means."[864] As I will discuss below, for many scholars of environmentalism, the movement was important precisely because it called for an engagement with the values driving technology-centered projects.[865] Further, scholars of reflexive modernity have argued that the environmental movement and the science of ecology have played a significant role in the emergence of a political reflexivity associated with the emergence of "risk society."[866] The figuration that brought together the environmental movement and ecology as a science provides a near perfect case for exploring how this theoretical question has played out in practice.

In his work on the emergence of "risk society" Ulrich Beck, has argued that science is necessary in rendering the bads of industrial society visible.[867] Anthony Giddens, Brian Wynne, and Ian Welsh have countered Beck by arguing that social movements such as environmentalism have played the more important role in bringing attention to the bads of industrial society.[868] Giddens has argued that this kind of social movement activity should be considered to be a form of "life politics" and not class-based politics.[869] Elsewhere, Giddens defines life politics as a characteristically late modern

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[864] Horkheimer, *Eclipse of Reason*, 92.

[865] New social movements scholar Alberto Melucci captures this position in *Challenging Codes*. Melucci, *Challenging Codes*, 97 and 163. See also Brulle *Agency, Democracy, and Nature*, 101; Egan, *Barry Commoner and the Science of Surviva*l, 7 and 48; Fischer, *Citizens, Experts, and the Environment*, 110; Giddens, *The Consequences of Modernity*," 158-162 and 170; Habermas, "New Social Movements," 34-5; Jamison, *The Making of Green Knowledge*, 10-16; Shrader-Frechette, *Risk and Rationality*, 3; Tesh *Uncertain Hazards*, 121; Weingart, "Science in a political environment," 204.

[866] Giddens, *The Consequences of Modernity*," 158-162. Welsh, *Mobilising Modernity*, 23-5.

[867] Beck, *Risk Society*, 27; Beck, *Ecological Politics in an Age of Risk*, 115.

[868] Giddens, *The Consequences of Modernity*, 158-62. Welsh, *Mobilising Modernity*, 23-5. Wynne, "May the Sheep Safely Graze," 47-61.

[869] For Giddens, the "the ecology movement" has brought with it "heightened awareness of high-

form of mobilization that centers on a reflexive politicization of the hazards of industrial society.[870] For Giddens, the reflexive engagement of forms of life politics such as environmentalism foregrounds the question of how we should live.[871]

In describing environmentalism as a new, distinctively modern form of political mobilization, Giddens' position is close to that of other theorists such as Alberto Melucci and Jürgen Habermas.[872] More specifically, Giddens' emphasis on life politics as being distinct from class-based politics echoes the much earlier arguments of Melucci and Habermas that new social movements should be distinguished from the class-based movements of the Marxist "old" left.[873] Further, the movements of Habermas, Melucci, and Giddens all resist the encroachment of instrumental rationality into the space of everyday life. Giddens' assertion that life politics are the "politics of lifestyle" echoes Habermas' description of new social movements as centered the question of how to

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consequence risks [of] industrial development." Class based politics, by contrast, are "radical engagements concerned with the liberation from inequality or servitude." Giddens, *The Consequences of Modernity*, 146-7 for more on risk, 161 for the ecology movement, and 156 on class-based movements. See also chapter 1 for more on Giddens' reformulation of new social movement theory as "life politics" and, for an insightful discussion of Giddens' notion of life politics, Charles Thorpe and Brynna Jacobson, "Life Politics, Nature, and the State: Giddens' Sociological Theory and the The Politics of Climate Change" forthcoming, *The British Journal of Sociology*

870 He argues that "While emancipatory politics is a politics of life chances, life politics is a politics of lifestyle. Life politics is the politics of a reflexively mobilised order--the system of late modernity." Anthony Giddens, *Modernity and Self-Identity: Self and Society in the Late Modern Age* (Stanford, CA: Stanford University Press, 1991), 214. Elsewhere he makes the same point: "Life politics is a politics, not of *life chances*, but of *life style*. It concerns disputes and struggles about how (as individuals and collective humanity) we should live in a world where what used to be fixed either by nature or tradition is now subject to human decisions." Anthony Giddens, *Beyond Left and Right: The Future of Radical Politics*, (Stanford, CA: Stanford University Press, 1994), 14-15 emphasis in original. See also Giddens' characterization of late modernity as a period of an unprecedented level of reflexivity. Giddens, *Consequences of Modernity*, 38.

871 Giddens, *Consequences of Modernity*, 161 on the environmental movement. Giddens, *Beyond Left and Right*, 212 on how to live. Thorpe and Jacobson, "Life Politics."

872 To a significant degree then, Giddens' account of "life politics" represents a theorization but also a renaming of "new social movements." After introducing "life politics" in Consequences of Modernity, Giddens goes on to describe the same phenomena using the more common term "new social movements." Giddens, *Consequences of Modernity*, 156.-63.

873 Ibid., 33. See the discussion of Melucci in the above section on social movements and science.

"reinstate" lifestyles endangered by the encroachment of formal rationality.[874] Another prominent theorist of new social movements, Alberto Melucci, expressed this as people's effort "to define themselves and to construct their life spaces" in opposition to efforts to approach life in terms of expediency and efficiency.[875] This was particularly the case, Melucci argues, for the environmental movement:

> The environmental issue, moreover, brings the cultural dimension of human experience to the fore. It demonstrates that lying at the heart of the question of survival is no longer the problem of the expedient system of means (on which both goal-directed rationality and the calculus of political exchange are based), but the problem of ends--that is, of those cultural models which orient behavior and on which daily life, production, exchange, and consumption structure themselves.[876]

These kinds of movements resist the encroachment of instrumental rationality--and the effects of an approach to life based on instrumental rationality--into the space of everyday life.

As an example of this kind of social movement, the environmental movement challenged the dominance of Weberian formal rationality--and Marcuse's technological rationality--and called for an engagement with values and the question of how to live. When Rachel Carson quoted Sears' student in asking “[w]hy should we tolerate a diet of weak poisons” and “[w]ho would want to live in a world which is just not quite fatal?”,

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[874] Habermas, "New Social Movements," 37 and 35. Giddens, *Modernity and Self-Identity*, 214. Using very similar language, Scott Lash has argued that "Reflexive modernization theory, however, holds open another possibility for this turn in modernization in which 'system' advances inexorably to destroy the 'life-world'. It points instead to the possibility of a new positive twist to the Enlightenment's dialectic." Lash, "Reflexivity and its Doubles," 112.

[875] Alberto Melucci, "A Strange Kinds of Newness: What's 'New' in New Social Movements?" In *New Social Movements: From Ideology to Identity* ed. Enrique Larana, et al. (Philadelphia: Temple University Press, 1994), 101. See also Melucci's assertion that new social movements target "cultural models which orient behavior and on which daily life, production, exchange, and consumption structure themselves." Melucci, *Challenging Codes*, 163. ThisJohnston, Larana, and Gusfield also focus on this dimension of new social movements. Johnston, Larana, and Gusfield, "Identities, Grievances, and New Social Movements," 11.

[876] Melucci, *Challenging Codes*, 163.

she was critiquing the intrusion of formal rationality into the life world.[877] The seeming necessity of developing a profitable pesticide for industrial agriculture--or of developing and testing atom and hydrogen bombs that distribute radioactive fallout--should be considered in light of the value of living a life in a world filled with poison. Similarly, when Paul Sears compared humans to factory farmed chickens, he was pointing out the result of the intrusion of the logic of expedient means (the logic of formal rationality) into the life world.[878]

In calling for an engagement with values, environmentalists and critical ecologists played an important role in rendering the hazards of industrial society visible. As I have pointed out in chapter 6, this often took the form of pointing out the experimental character of large scale technology projects. Rachel Carson, for example, approached the application of synthetic pesticides named dieldrin and heptaclor to exterminate fire ants as an experiment. The fire ant campaign, she argued, was

> an outstanding example of an ill-conceived, badly executed, and thoroughly detrimental *experiment* in the mass-control of insects, an *experiment* so expensive in dollars, in destruction of animal life, and in loss of public confidence in the Agriculture Department that it is incomprehensible that any funds should still be devoted to it.[879]

Although the pesticide was intended to kill fire ants, it also killed poultry, livestock, pets, opossums, armadillos, raccoons, and a wide range of birds.[880] In terming insecticides and pesticides as, instead, 'biocides,' Carson is pointing to this lack of specificity and its impacts.[881] The fact that there were so many unintended targets indicated, for Carson, that

[877] Shepard, "The Place of Nature in Man's World," 86, quoted in Carson, *Silent Spring*, 12.
[878] Sears, "The Inexorable Problem of Space," 80,
[879] Carson, *Silent Spring*, 162, emphasis added.
[880] Ibid. 166-9.
[881] Carson was not the first to coin the word 'biocide.' In 1947, E. M. Greenberg wrote the *Saturday Review of Literature* and suggested that, in addition to the newly coined word 'genocide' should be

bodies such as the USDA were often acting based on dangerously partial knowledge. In the case of their campaign against the fire ant, the "chemicals to be used were dieldrin and heptachlor, both relatively new. There was little experience or field use for either and no one knew what their effects would be on wild birds, fishes or mammals when applied on a massive scale."[882] Because the USDA was acting on such incomplete knowledge, their campaign took on the form of an experiment—but one conducted in the world, outside the laboratory.

Carson is here formulating a critique of real-world experiments that anticipates later discussions in science studies. Reacting to the Chernobyl disaster, Wolfgang Krohn and Peter Weingart, for example, comment on the experimental character of nuclear energy. Because of its complexity—and the complexity of safety programs—nuclear energy is tested in an 'implicit' or 'social' experiment. "Society," they argue "has become an experimentation field for complex technologies."[883] A 1980 cover illustration on *Science for the People* perfectly captures the idea of the social experiment.[884] Here we see

added a term to designate "another kind of murder going on all the time all about and within us." E. M. Greenberg, Letter to the Editor, *Saturday Review of Literature*, August, 1947. "Biocide." Oxford English Dictionary, 2nd ed. OED Online. Accessed August 1, 2010, http://dictionary.oed.com/cgi/entry/00337225.

882 Carson, *Silent Spring*, 165.

883 Wolfgang Krohn and Peter Weingart, "Nuclear Power as Social Experiment: European Political 'Fall Out' from the Chernobyl Meltdown," *Science, Technology, and Human Values* 12, 2, Spring (1987): 52. Drawing on the work of Krohn and Weingart, Ulrich Beck has similarly written of the experimental character of society. He argues, for example, that ""Just as sociologists cannot force society into a test-tube, so technologists can only test nuclear reactors if they turn the world into a laboratory." Beck, *Ecological Politics in an Age of Risk*, 122-4, esp. 123. Beck, *World at Risk*, 111. Beck, *Ecological Enlightenment*, 104-6.

884 *Science for the People* was published by the group Science for the People, a radical organization that launched a critique of science--inspired by the New Left and Marxism--that maintained that science was not value-neutral but was instead political to its core. Moore, *Disrupting Science*, chapter 6. This issue of *Science for the People* contained an article by David Kriebel, who was a member of Science for the People and was employed by Commoner's Center for the Biology of Natural Systems at Washington University as well an article by Commoner himself ("The Risk of Cost / Benefit Analysis: Of lollipops and meteorites"). For Commoner's own emphasis on the experimental character of the hazards of industrial society, see Egan, *Science of Survival*, preface, 73, and 192-3; and Commoner, "The Fallout Problem," 1023.

two arms, labeled "big business," injecting pollutants into boxes containing miniature towns. One box reads "asbestos fibers," another "coke plant emissions," and another "rubber ind. emissions."

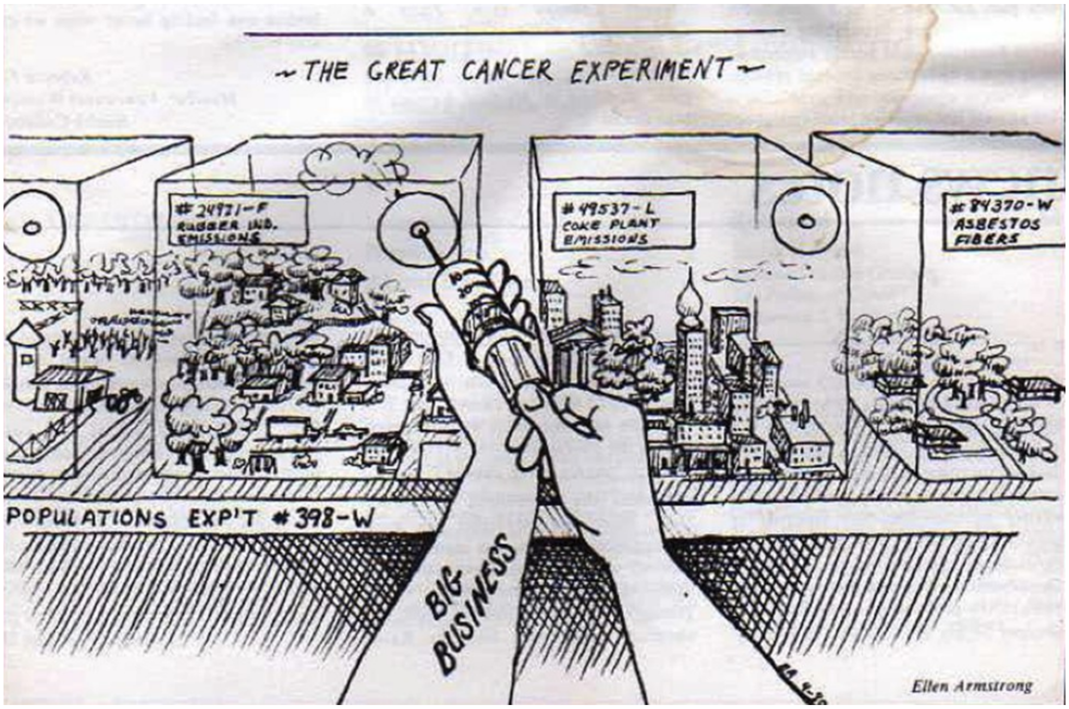

Figure 7.1 - The Great Cancer Experiment. Cover of May / June 1980 issue of *Science for the People*.

By imagining each town in a box, the cartoon captures the experimental logic of controlling potentially confounding variables. At the same time, the fact that this kind of isolation of towns in this way is obviously unrealistic underlines the fact that determining the unknown effects of coke plant or rubber plant emissions on people functions as an experiment, "the great cancer experiment," the cartoon announces.

Both examples--*Silent Spring* and *Science for the People*--highlight the experimental character of the exposure of populations to the hazards of industrial society.

In doing so, they point out the dangers posed by the "colonization" of people's life and health by the logic of profit and emphasis on expedient means--and not the goals to which those means are applied.[885] By highlighting the experimental character of large technology projects, these critiques also call for an engagement with the values driving these real world experiments and so also the question of how we should live.

In drawing attention to the experimental character of technological projects and calling for an engagement with values, environmentalism as a new social movement targeted the question of how to live--the same question that Weber considered science to be incapable of addressing. This was "indisputable."[886] Insofar as scientists addressed the question of how to live, they stepped outside of the role of scientists and into the role of the prophet.[887] It is important to note that Melucci chose to invoke Weberian language in opening *Challenging Codes* by asserting that "Movements in complex societies are disenchanted prophets."[888] Melucci's social movements actively sought to engage the broader public in questions of value, of how to live, in the same way as Weber's prophets in "Science as a Vocation." Significantly, however, Weber considered these prophets to be out of place. They are scientists stepping outside of their proper role and attempting to recapture the meaning and over-arching values of times past.

To the extent that progressive rationalization defined Weber's modernity, it was a

885 Habermas, "New Social Movements," 33, 35, and 37. See also Giddens, *Modernity and Self-Identity*, 214. Further--following Melucci, these efforts point out that "that lying at the heart of the question of survival is no longer the problem of the expedient system of means (on which both goal-directed rationality and the calculus of political exchange are based), but the problem of ends." Melucci, *Challenging Codes*, 163.

886 In "Science as a Vocation," Weber quoted Russian writer Leo Tolstoy as saying "Science is meaningless because it gives no answer to our question, the only question important for us: 'What shall we do and how shall we live?'" Weber continued, "That science does not give an answer to this is indisputable." Weber, "Science," 143.

887 See above discussion on Weber's characterization of the figure of the prophet in the section on scientists as intellectuals.

888 Melucci, *Challenging Codes*, 1.

place closed off from the possibility of meaningful social change. It was defined by formal rationality and the retreat of values and by existing institutions. Although the modernity of "Science as a Vocation" is pessimistic in the extreme, Weber's philosophy of history recognizes the possibility that charismatic social change could counterbalance forces of rationalization. When social critic Lewis Mumford asserted that “[w]e must allow, when we consider the future, for the possibility of miracles," he was similarly describing the possibility of change.[889] In returning to this idea later, Mumford wrote "there are two kinds of future that we don't sufficiently discriminate between. One is the probable future based upon the existing institutions and agencies continuing to act in the same way." He went on to say that the “'probable' future is not necessarily the actual future at all. It is always a summary of the past, and all its predictions are predictions about the past, not the future. The other future is that based on possibility."[890]

Although it was neglected in "Science as a Vocation," the future based on possibility was captured by Weber in the ability of charismatic social relations to upset the trend towards rationalization. In *The Protestant Ethic and the Spirit of Capitalism*, written twelve years before "Science as a Vocation," Weber's modernity was still open to the possibility of change and so veering in as-yet undetermined directions. Although the protestant ethic played an important role in the birth of capitalism, now we are simply pursuing wealth for its own sake.[891] We are living in a cage. However, he proceeds to note that "No one knows who will live in this cage in the future."[892] We also do not know "whether. . .entirely new prophets will arise, or there will be a great rebirth of old ideas

[889] Mumford, "Prospect," 1143.
[890] Mumford, "Closing Statement," 718.
[891] Weber, *The Protestant Ethic*, 181-2.
[892] Ibid., 182.

and ideals or, if neither, mechanized petrification, embellished with a sort of mechanical self-importance."[893] The fate of modernity is open ended here in a way that it is not in “Science as a Vocation.” Further, the prophet is a figure that is capable of bringing world-historic change--not the wishful and out of place figure in "Science as a Vocation." Borrowing Melucci's language, and so also the language of Weber, ecologists as intellectuals and the environmental movement served a prophetic role as a charismatic challenge to ways of living that emerged with industrialism and the promise of limitless economic growth.

In Weber's emphasis on charisma, Melucci's on prophetic social movements, and Mumford's miracles, we are confronted with more than one future. Following the logic of rationalization, and existing institutions, we are confronted with a future in which animals and plants and the earth's atmosphere continue to be treated as means—objects in larger equations designed to calculate profits and power and little else. But as Adorno and Horkheimer--and Sears--warned us, people are not exempt from this logic. With questions of ends “liquidated” people become governed by the same logic, as a field of means for the ends of profit and power. Deploying an image strikingly similar to that of Sears, Mumford points to this outcome in asking, "Are we prepared to breed legless men, satisfied in their urban pens, as we now breed almost wingless fowl?"[894] But like Mumford, Sears, and Odum see another possibility. Whether based in ecology as a form of scientific expertise or in ecology as a subversive, oppositional form of critique, these ecologists imagined a society in which goals such as quality of life guide our policy decisions instead of profit or the determination of the most expedient means.

[893] Ibid.

[894] Mumford, "Prospect," 1142.

As anyone listening to debates about contemporary environmental problems can attest, the question of which of these futures will be ours is still very much open. Similarly, the question of the proper role of science and of scientists in addressing these problems is also up for grabs. The environmental dilemmas we face now are different than those faced by the cold war ecologists whose work I discuss. Now global warming and not radioactive fallout or synthetic pesticides poses the most significant environmental crisis of our time. However, as Michael Shellenberger and Ted Nordhaus have argued in their infamous tract *The Death of Environmentalism*, there has been a disheartening lack of response.[895] And yet, as Naomi Oreskes and Erik Conway have shown, climate scientists have stepped into this gap, often under political fire, to assert the larger relevance of their work on global warming.[896] Here we encounter a new generation of scientists willing to explore the role of the scientist as intellectual in order to address global warming as a problem with a planetary scope. While many existing institutions might continue to push for continued reliance on fossil fuels and narrow technical approaches to the problem of global warming, there is nonetheless reason for hope. As long as scientists and a concerned public push continue to challenge the values underlying our reliance on fossil fuels and remain open to other ways of ordering society, the possibility of a different and more sustainable future exists.

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[895] Michael Shellenberger and Ted Nordhaus, *The Death of Environmentalism: Global Warming Politics in a Post-environmental World,* Breakthrough Institute, 2004. On Shellenberger and Nordhaus, see Ingolfur Blühdorn and Ian Welsh, "Eco-politics Beyond the Paradigm of Sustainability: A Conceptual Framework and Research Agenda," *Environmental Politics* 16, no. 2 (2007): 185–205.

[896] Naomi Oreskes, and Erik Conway, *Merchants of Doubt: How a Handful of Scientists Obscured the Truth on Issues from Tobacco Smoke to Global Warming,* New York: Bloomsbury Press, 2010), 2-5.

Bibliography

Archives

Department of Energy Openness: Human Radiation Experiment Project,
http://www.hss.doe.gov/healthsafety/ohre/roadmap/index.html
Division of Biology and Medicine Oral Histories
Applied Fishery Laboratory Reports, Hanford
Oak Ridge National Laboratory Reports

Department of Energy OpenNet, https://www.osti.gov/opennet.
Applied Fisheries Laboratory, Hanford
Project Gabriel and Project Sunshine

George Washington University National Security Archive,
http://www.gwu.edu/~nsarchiv/radiation/dir/mstreet/commeet/.

National Archives and Records Administration, College Park, MD
Records of the Atomic Energy Commission
Savannah River Operations Office
Records of the Nevada Operations Office
Records of the New York Operations Office
Division of Biology and Medicine Advisory Board
Division of Biology and Medicine, Fallout Studies Branch

National Archives Southeast Division, Atlanta, GA
Atomic Energy Commission, Savannah River Operations Office

Oregon State University, Special Collections and Archive Research Center, Ava Helen and Linus Pauling Papers, Digital Collection,
http://osulibrary.orst.edu/specialcollections/coll/pauling/index.html
Radioactive Fallout Debate of the 1950s

University of Georgia, Hargrett Rare Book and Manuscript Library
Eugene Odum Administrative Papers and Institute of Ecology, 1950-1980,
Eugene Odum Collection Correspondence, 1945-1982,
Eugene Odum Institute of Ecology Papers, 1937-1990,
Eugene Odum and Savannah River Ecological Laboratory, Reprints,
Eugene Odum's Papers as President of the Ecological Society of America,
Eugene Odum Research Files: Eniwetok Atoll, Old Field Plant Specimens, Southern Nuclear Task Force, etc, 1950-1970,
Institute of Ecology,
President Aderhold's Papers,
President Davison's Papers

University of Washington, University Libraries Digital Collections
Applied Fisheries Laboratory, Digital Collection,

http://content.lib.washington.edu/donaldsonweb/history.html
Lauren R. Donaldson Collection
http://content.lib.washington.edu/donaldsonweb/index.html

Books and Articles

"1956 Annual Meeting, Storrs, Connecticut, August 27-29." *Bulletin of the Ecological Society of America* 37, no. 1 (March 1, 1956): 3–5.

Abbott, Andrew. *Chaos of Disciplines*. Chicago: University of Chicago Press, 2001.

---. *The System of Professions: An Essay on the Division of Expert Labor*. Chicago: University of Chicago Press, 1988.

Adam, Barbara, Ulrich Beck, and Joost van Loon. *The Risk Society and Beyond: Critical Issues for Social Theory*. Thousand Oaks, CA: Sage, 2000.

Advisory Committee on Human Radiation Experiments, United States. *Human Radiation Experiments*. New York: Oxford University Press, 1996. Accessed August 1, 2009, http://www.hss.energy.gov/healthsafety/ohre/roadmap/achre/report.html.

Advisory Committee on Mineral Leasing, University System of Georgia. *A Report on Proposed Leasing of State Owned Lands for Phosphate Mining in Chatham County, Georgia*, 1968.

Allen, Barbara L. *Uneasy Alchemy: Citizens and Experts in Louisiana's Chemical Corridor Disputes*. Cambridge, MA: MIT Press, 2003.

Algazi, Gadi. "Scholars in Households: Refiguring the Learned Habitus, 1480–1550." *Science in Context* 16, 1–2 (2003): 9–42.

Altbach, Philip G. "Edward Shils and the American University." In *The Order of Learning: Essays on the Contemporary University*. Edited by Philip G. Altbach, ix-xx. New Brunswick, NJ: Transaction Publishers, 1997.

Anderson, Perry. "The World Made Flesh." *New Left Review* 39 (May - June 2006): 132-9. Accessed February 1, 2012, http://www.newleftreview.org/II/39/perry-anderson-the-world-made-flesh.

Anker, Peder. *From Bauhaus to Eco-House: A History of Ecological Design*. Baton Rouge, LA: Louisiana State University Press, 2010.

---. *Imperial Ecology: Environmental Order in the British Empire, 1895-1945*.

Cambridge, MA: Harvard University Press, 2002.

---. “The Context of Ecosystem Theory.” *Ecosystems* 5, no. 7 (November 1, 2002): 611–613.

---. “The Ecological Colonization of Space.” *Environmental History* 10, 2 (April 1, 2005): 239–268.

Arendt, Hannah. *The Human Condition*. Chicago: University of Chicago Press, 1998.

Argonne National Laboratory. *A Conference on Radioactive Isotopes in Agriculture: Held on January 12, 13 and 14, 1956, at Michigan State University, East Lansing, Michigan*. U. S. Atomic Energy Commission, 1956.

Auerbach, Stanley I. “The Soil Ecosystem and Radioactive Waste Disposal to the Ground.” *Ecology* 39, no. 3 (July 1, 1958): 522–529.

Auerbach, S. I., and J. S. Olson. "Biological and Environmental Behavior of Ruthenium and Rhodium." In *Radioecology; Proceedings of the First National Symposium on Radioecology held at Colorado State University, Fort Collins, Colorado, September 10-15, 1961,* edited by Vincent Schultz and Alfred W. Klement, 509-520. New York, Reinhold Publishing Corporation, 1963.

Auerbach, Stanley I, and David E. Reichle. "U.S. Radioecology Research Programs Initiated in the 1950s: History of the Atomic Projects, The 50s Years: Sociopolitical, Environmental, and Engineering Lessons Learned." Oak Ridge National Laboratory (September 22, 1999), 1-26.

Baer, C. H. “[untitled].” Review of *Fundamentals of Ecology* by Eugene Odum. *Castanea* 19, no. 1 (March 1, 1954): 41.

Balogh, Brian. *Chain Reaction: Expert Debate and Public Participation in American Commercial Nuclear Power 1945-1975*. Cambridge: Cambridge University Press, 1993.

Barnes, Barry S. “Making Out in Industrial Research.” *Science Studies* 1, no. 2 (April 1, 1971): 157–175.

Barrett, Gary W., and Terry Lynn Barrett, eds. *Holistic Science: The Evolution of the Georgia Institute of Ecology (1940-2000)*. New York: Taylor and Francis, 2001.

Barrett, Gary W., George M. van Dyne, and Eugene P. Odum. “Stress Ecology.” *BioScience* 26, no. 3 (March 1, 1976): 192–194.

Barrett, Gary W., and Eugene P. Odum. “Editorial: From the President: Integrative

Science." *BioScience* 48, 12 (December 1, 1998): 980.

Barton, Ruth. "'Men of Science': Language, Identity, and Professionalization in the Mid-Victorian Scientific Community." *History of Science* 41 (2003): 73–119.

Bauman, Zygmunt. *Modernity and the Holocaust*. Ithaca, NY: Cornell University Press, 2001.

Bates, Marston. *Glutton and Libertines Human Problems of Being Natural*. New York: Vintage Books, 1967.

---. *The Forest and the Sea: a Look at the Economy of Nature and the Ecology of Man*. New York: Vintage Books, 1960.

---. "Process." In *Man's Role in Changing the Face of the Earth,* edited by William L. Thomas, Jr., 1136-1140. Chicago: University of Chicago Press, 1956.

Beals, Edward W. "Fundamentals of Ecology Updated." *Ecology* 53, no. 5 (1972): 983–984.

Beck, Ulrich. *World at Risk.* New York: Polity, 2009.

---. "The Terrorist Threat World Risk Society Revisited." *Theory, Culture & Society* 19, no. 4 (August 1, 2002): 39–55.

---. *World Risk Society.* New York: Wiley-Blackwell, 1999.

---. *The Reinvention of Politics: Rethinking Modernity in the Global Social Order.* New York: Wiley-Blackwell, 1997.

---. *Ecological Enlightenment: Essays on the Politics of the Risk Society*. Translated by Mark Ritter. Atlantic Highlands, NJ: Humanities Press, 1995.

---. *Ecological Politics in an Age of Risk*. New York: Wiley-Blackwell, 1995.

---. "The Reinvention of Politics: Towards a Theory of Reflexive Modernization." In *Reflexive Modernization: Politics, Tradition and Aesthetics in the Modern Social Order*. Edited by Ulrich Beck, Anthony Giddens, and Scott Lash, 1-55. Stanford, CA: Stanford University Press, 1994.

---. *Risk Society: Towards a New Modernity*. Thousand Oaks, CA: Sage Publications, 1992.

Beck, Ulrich, Anthony Giddens, and Scott Lash. "Replies and Critiques." In *Reflexive Modernization: Politics, Tradition and Aesthetics in the Modern Social Order*.

Edited by Ulrich Beck, Anthony Giddens, and Scott Lash, 174-215. Stanford, CA: Stanford University Press, 1994.

Beck, Ulrich, and Boris Holzer. "Organizations in a World Risk Society." In *International Handbook of Organizational Crisis Management*, edited by C. M. Pearson, C. Roux-Dufort, and J. A. Clair, 3-24. Thousand Oaks, CA: Sage, 2007.

Becker, Howard S., and James W. Carper. "The Development of Identification with an Occupation." *American Journal of Sociology* 61, no. 4 (January 1, 1956): 289–298.

Becker, Howard S. "Personal Change in Adult Life." *Sociometry* 27, no. 1 (March 1, 1964): 40–53.

---. "Notes on the Concept of Commitment." *American Journal of Sociology* 66, no. 1 (July 1, 1960): 32–40.

Becker, Howard S., and Anselm L. Strauss. "Careers, Personality, and Adult Socialization." *American Journal of Sociology* 62, no. 3 (November 1, 1956): 253–263.

Bell, Daniel. *The Coming of Post-Industrial Society: A Venture in Social Forecasting*. New York: Basic Books, 1976.

Ben-David, Joseph. *Scientist's Role in Society: A Comparative Study*. illustrated ed. Prentice Hall, 1971.

Benford, Robert D. and David A. Snow. "Framing Processes and Social Movements: An Overview and Assessment." *Annual Review of Sociology* 26 (2000):611-639.

Benhabib, Seyla. "Modernity and the Aporias of Critical Theory." *Telos* 49 (1981): 39-59.

Bercovitch, Sacvan. *The American Jeremiad*. Madison: University of Wisconsin Press, 1978.

Biehl, Janet. "Introduction." In *Murray Bookchin Reader*. edited by Janet Biehl, 1-12. Tonawanda, NY: Black Rose Books, 1999.

"biocide." *Oxford English Dictionary,* 2nd edition, 1989. OED Online. Accessed August 1, 2010, http://dictionary.oed.com/cgi/entry/00337225. An entry for his word was first included in *A Supplement to the OED* I, 1972.

Birch, L. C. "[untitled]." Review of *Fundamentals of Ecology* by Eugene Odum. *The Quarterly Review of Biology* 29, no. 2 (June 1, 1954): 151–152.

Bird-David, Nurit. "'Animism' Revisited: Personhood, Environment, and Relational

Epistemology." *Current Anthropology* 40, no. S1 (February 1, 1999): S67–S91.

Blühdorn, Ingolfur, and Ian Welsh. "Eco-politics Beyond the Paradigm of Sustainability: A Conceptual Framework and Research Agenda." *Environmental Politics* 16, no. 2 (2007): 185–205.

Bocking, Stephen. *Ecologists and Environmental Politics: A History of Contemporary Ecology*. Yale University Press, 1997.

---. "Ecosystems, Ecologists, and the Atom: Environmental Research at Oak Ridge National Laboratory." *Journal of the History of Biology* 28, no. 1 (1995): 1–47.

---. *Nature's Experts: Science, Politics, and the Environment*. New Brunswick, NJ: Rutgers University Press, 2004.

Boggs, Carl. *Intellectuals and the Crisis of Modernity*. Albany, NY: State University of New York Press, 1993.

Bookchin, Murray. *Post-Scarcity Anarchism*. AK Press, 2004.

---. *The Ecology of Freedom: The Emergence and Dissolution of Hierarchy*. AK Press, 2005.

---. "What is Social Ecology?" In *Environmental Philosophy: From Animal Rights to Radical Ecology*, edited by M.E. Zimmerman. Englewood Cliffs, NJ: Prentice Hall, 1993. Accessed August 1, 2011, http://dwardmac.pitzer.edu/anarchist_archives/bookchin/socecol.html.

---. "Ecology and Revolutionary Thought." Pp. 19-40 in *Post-Scarcity Anarchism*. Oakland, CA: AK Press, 2004. Originally published in *New Directions in Libertarian Thought*, September 1964.

---. *Our Synthetic Environment*. New York: Knopf, 1975.

Bookchin, Murray, and Dave Foreman. *Defending the Earth: A Dialogue Between Murray Bookchin and Dave Foreman*. Edited by Steve Chase. South End Press, 1999.

Botkin, Daniel B. *Discordant Harmonies: A New Ecology for the Twenty-first Century*. New York: Oxford University Press, 1992.

Boulding, Kenneth Ewart. *Meaning of the Twentieth Century*. First Thus. Allen and Unwin, 1965.

Bowker, Geoffrey C. *Memory Practices in the Sciences*. The MIT Press, 2008.

Bowker, Geoffrey C., and Susan Leigh Star. *Sorting Things Out: Classification and Its Consequences*. The MIT Press, 2000.

Bowler, Peter J. *The Earth Encompassed: A History of the Environmental Sciences*. W. W. Norton and Company, 2000.

Boyer, Paul. *By the Bomb's Early Light: American Thought and Culture at the Dawn of the Atomic Age*. The University of North Carolina Press, 1994.

Breines, Wini. *Community and Organization in the New Left, 1962-1968: The Great Refusal*. Rutgers University Press, 1989.

Browne, Janet. "Charles Darwin as a Celebrity." *Science in Context* 16, 1–2 (2003): 175–194.

Brown, Phil. "Popular Epidemiology and Toxic Waste Contamination: Lay and Professional Ways of Knowing." *Journal of Health and Social Behavior* 33, no. 3 (1992): 267–281.

---. *Toxic Exposures: Contested Illnesses and the Environmental Health Movement*. New York: Columbia University Press, 2007.

Brown, Phil, and Edwin J. Mikkelsen. *No Safe Place: Toxic Waste, Leukemia, and Community Action*. University of California Press, 1997.

Brown, Phil, Steve Kroll-Smith and Valerie J. Gunter. "Knowledge, Citizens, and Organizations: An Overview of Environments, Diseases and Social Conflict." In *Illness and the Environment: A Reader in Contested Medicine*. Edited by Steve Kroll-Smith, Phil Brown, and Valerie J. Gunter, 9-25. New York: New York University Press, 2000.

Brubaker, Rogers. *The Limits of Rationality: An Essay on the Social and Moral Thought of Max Weber*. Boston: Allen & Unwin, 1984.

Brulle, Robert J. *Agency, Democracy, and Nature: The U.S. Environmental Movement from a Critical Theory Perspective*. Cambridge, MA: MIT Press, 2000.

Bruno, Laura A. "The Bequest of the Nuclear Battlefield: Science, Nature, and the Atom During the First Decade of the Cold War." *Historical Studies in the Physical and Biological Sciences* 33, no. 2 (March 1, 2003): 237–260.

Bruun, Hans Henrik. *Science, Values and Politics in Max Weber's Methodology*. Expanded. Ashgate Pub Co, 2007.

---. "Weber on Rickert: From Value Relation to Ideal Type," *Max Weber Studies* 1, 2 (2001): 138-60.

Buechler, Steven M. *Social Movements in Advanced Capitalism: The Political Economy and Cultural Construction of Social Activism*. Oxford University Press, 2000.

---. "New Social Movement Theories." *The Sociological Quarterly* 36, 3 (Summer, 1995): 441-464.

Buell, Lawrence. *The Future of Environmental Criticism: Environmental Crisis and Literary Imagination*. 1st ed. Wiley-Blackwell, 2005.

Buhs, Joshua Blu. *The Fire Ant Wars: Nature, Science, and Public Policy in Twentieth-Century America*. 1st ed. University of Chicago Press, 2004.

Bullard, Robert D. *Dumping in Dixie: Race, Class, and Environmental Quality*. 3rd ed. Boulder, Colo: Westview Press, 2000.

Burgess, Robert L. "The Ecological Society of America: Historical Data and Preliminary Analysis." Oak Ridge, TN: Oak Ridge National Laboratory. Accessed January 15, 2009, www.esa.org/history/docs/BurgessHistory.pdf.

Burke, Peter. “Norbert Elias and the Social History of Knowledge.” *Human Figurations* 1, no. 1 (January 2012). Accessed May 1, 2012, http://hdl.handle.net/2027/spo.11217607.0001.102.

Bush, Vannevar. *Science: The Endless Frontier*. Washington, D. C.: National Science Foundation, 1960.

---. *Modern Arms and Free Men: A Discussion of the Role of Science in Preserving Democracy.* Simon and Schuster, 1949.

---. “A National Science Foundation.” *Science* 105, no. 2725. New Series (March 21, 1947): 302–305.

Bruce, Robert V. *The Launching of Modern American Science 1846-1876*. Ithaca, NY: Cornell University Press, 1987.

Bruford, W. H. *The German Tradition of Self-Cultivation: “Bildung” from Humboldt to Thomas Mann*. First. Cambridge University Press, 1975.

Calvert, Jane. “What’s Special About Basic Research?” *Science, Technology, & Human Values* 31, no. 2 (March 1, 2006): 199–220.

Camic, Charles, Philip S. Gorski, and David M. Trubek. *Max Weber’s Economy And*

Society: A Critical Companion. Stanford University Press, 2005.

Campbell, Nancy D. “Credible Performances: The Performativity of Science Studies.” *Social Studies of Science* 34, no. 3 (June 1, 2004): 433–442.

Cannon, Walter B. *The Wisdom of the Body*. Second ed. New York: W.W. Norton and Company, Inc, 1939.

Cantelon, Philip L., Richard G. Hewlett, and Robert C. Williams, eds. *The American Atom: A Documentary History of Nuclear Policies from the Discovery of Fission to the Present*. Philadelphia: University of Pennsylvania Press, 1992.

Carroll, Patrick. *Science, Culture, and Modern State Formation*. Berkeley: University of California Press, 2006.

Carson, Cathryn. “Objectivity and the Scientist: Heisenberg Rethinks.” *Science in Context* 16, 1–2 (2003): 243–269.

Carson, Rachel. *Lost Woods: The Discovered Writing of Rachel Carson*. Boston: Beacon Press, 1999.

---. *Silent Spring*. Anniversary. New York: Houghton Mifflin Company, 2002.

Casey, Steven. "Selling NSC-68: The Truman Administration and the Politics of Mobilization, 1950-51." *Diplomatic History,* 29, (September, 2005): 655-90.

Caufield, Catherine. *Multiple Exposures: Chronicles of the Radiation Age*. Chicago: University Of Chicago Press, 1990.

Chadarevian, Soraya de. *Designs for Life: Molecular Biology After World War II*. New York: Cambridge University Press, 2011.

Chadarevian, Soraya de, and Harmke Kamminga. *Molecularizing Biology and Medicine: New Practices and Alliances 1910s - 1970s*. Amsterdam: Harwood Academic Publishers, 1998.

Charle, Christophe. "Patterns." In *Universities in the Nineteenth and Early Twentieth Centuries (1800-1945),* edited by Walter Rüegg, 33-80. New York: Cambridge University Press, 2004.

Chernus, Ira. *Eisenhower's Atoms for Peace*. College Station, TX: Texas AandM University Press, 2002.

Cittadino, Eugene. "The Failed Promise of Human Ecology." In *Science and Nature: Essays in the History of the Environmental Sciences* edited by Michael. Shortland, 251-83. Oxford: BSHS Monographs, 1993.

Clark, William. *Academic Charisma and the Origins of the Research University*. Chicago: University Of Chicago Press, 2007.

Clark, William. "On the Professorial Voice." *Science in Context* 16, no. 1–2 (2003): 43–57.

Clarke, Lee, and James F. Short. "Social Organization and Risk: Some Current Controversies." *Annual Review of Sociology* 19 (January 1, 1993): 375–399.

---. "Social Organization and Risk: Some Current Controversies." *Annual Review of Sociology* 19 (January 1, 1993): 375–399.

Clarke, Lee. *Worst Cases: Terror and Catastrophe in the Popular Imagination*. 1st ed. University Of Chicago Press, 2005.

Clements, Frederic Edward, and Victor Ernest Shelford. *Bio-ecology*. New York: J. Wiley & Sons, Incorporated, 1939.

Coile, Zachary. "Gore joins Valley's Kleiner Perkins to push green business". *San Francisco Chronicle* (November 13, 2007). Accessed August 31, 2011, http://www.sfgate.com/bayarea/article/Gore-joins-Valley-s-Kleiner-Perkins-to-push-green-3301231.php.

Collier, Stephen J. "Enacting Catastrophe: Preparedness, Insurance, Budgetary Rationalization." *Economy and Society* 37, no. 2 (2008): 224–250.

---. "Enacting Catastrophe: Preparedness, Insurance, Budgetary Rationalization." *Economy and Society* 37, no. 2 (2008): 224–250.

Collier, Stephen J, and Andrew Lakoff. "Distributed Preparedness: The Spatial Logic of Domestic Security in the United States." *Environment and Planning D: Society and Space* 26, no. 1 (2008): 7 – 28.

---. "On Vital Systems Security." Paper presented at the University of Helsinki Collegium, Helsinki, Finland. June 2008.

---. "The Generic Biothreat, or, How We Became Unprepared." *Cultural Anthropology* 23, 3 (2008): 399-428.

---. "The Vulnerability of Vital Systems: How Critical Infrastructure Became a Security Problem." In *Securing the Homeland: Critical Infrastructure, Risk and (In)Security*. Edited by Myriam A. Dunn and Kristian S. Kristensen, 17-39. New York: Routledge, 2008.

Collier, Stephen J, Andrew Lakoff, and Paul Rabinow. “Biosecurity: Towards an Anthropology of the Contemporary, Biosecurity: Towards an Anthropology of the Contemporary.” *Anthropology Today, Anthropology Today* 20, 5 (October 1, 2004): 3, 3–7, 7.

Collins, Harry M. "Public Experiments and Displays of Virtuosity: The Core-Set Revisited.” *Social Studies of Science* 18 (1988): 725-48.

---. *Changing Order: Replication and Induction in Scientific Practice*. Thousand Oaks, CA: SAGE Publications, 1985.

---. "‘Son of Seven Sexes,’ The Social Destruction of a Physical Phenomenon." *Social Studies of Science* 11(1981): 33–62.

---. “The Seven Sexes: A Study in the Sociology of a Phenomenon, or the Replication of Experiments in Physics.” *Sociology* 9 (1975): 205-224

Collins, Harry M., and Trevor Pinch. *The Golem: What Everyone Should Know About Science*. Cambridge University Press, 1994.

Commoner, Barry. "The Risk of Cost / Benefit Analysis: Of lollipops and meteorites." *Science for the People* 12, 3, (May-June, 1990): 9-10.

---. *The Closing Circle*. New York: Knopf, 1971.

---. *Science and Survival*. New York: Viking Press, 1966.

---. “The Fallout Problem.” *Science* 127, no. 3305. New Series (May 2, 1958): 1023–1026.

Conference on Human Ecology in Space Flight (3rd : 1965 : Princeton, N.J.), Doris Howes Calloway, United States. Office of Naval Research, and United States. National Aeronautics and Space Administration. *Human Ecology in Space Flight III; Proceedings of the Third International Interdisciplinary Conference*. New York: New York Academy of Sciences, Interdisciplinary Communications Program, 1968.

"Conservancy." *Red and Black: the University of Georgia's Student Newspaper*. (January 16, 1968): 8.

Cook, Robert E. "Raymond Lindeman and the Trophic-Dynamic Concept in Ecology". *Science* 198, 4312 (October 7, 1977): 22–26

Couch, Stephen R. and Steve and Kroll-Smith. “Environmental Movements and Expert Knowledge: Evidence for a New Populism." In *Illness and the Environment: A*

Reader in Contested Medicine. Edited by Steve Kroll-Smith, Phil Brown, and Valerie J. Gunter, 384-404. New York: New York University Press, 2000.

Craige, Betty Jean, *Eugene Odum: Ecosystem Ecologist and Environmentalist*. Athens, GA: University of Georgia Press, 2001.

Craige, B. J. *Laying the Ladder Down: the Emergence of Cultural Holism*. Amherst, MA: University of Massachusetts Press, 1992.

Creager, Angela N. H. "Nuclear Energy in the Service of Biomedicine: The U.S. Atomic Energy Commission's Radioisotope Program, 1946-1950." *Journal of the History of Biology* 39, no. 4 (December 1, 2006): 649–684.

Creager, Angela N. H., and María Jesús Santesmases. "Radiobiology in the Atomic Age: Changing Research Practices and Policies in Comparative Perspective." *Journal of the History of Biology* 39, no. 4 (December 1, 2006): 637–647.

Crease, Robert P. "Fallout: Issues in the Study, Treatment, and REparations of Exposed Marshall Islanders." In *Science and Other Cultures: Issues in Philosophies of Science and Technology* edited by Figueroa, Robert, and Sandra Harding, 106-125. New York: Routledge, 2003.

Crick, Francis. *Of Molecules and Men*. Seattle: University of Washington Press, 1966.

---. "The Croonian Lecture, 1966: The Genetic Code." *Proceedings of the Royal Society of London. Series B, Biological Sciences* 167, no. 1009 (April 18, 1967): 331–347.

Crossley, D. A. "Movement and Accumulation of Radiostrontium and Radiocesium in Insects" In *Radioecology; Proceedings of the First National Symposium on Radioecology held at Colorado State University, Fort Collins, Colorado, September 10-15, 1961,* edited by Vincent Schultz and Alfred W. Klement, 103-106. New York, Reinhold Publishing Corporation, 1963.

Cyranoski, David, Natasha Gilbert, Heidi Ledford, Anjali Nayar, and Mohammed Yahia. "Education: The PhD Factory." *Nature* 472, no. 7343 (April 21, 2011): 276–279.

Daniel, Pete. "A Rogue Bureaucracy: The USDA Fire Ant Campaign of the Late 1950s." *Agricultural History* 64, no. 2 (April 1, 1990): 99–114.

Darling, Frank Fraser. "Introduction." In *Future Environments of North America*, edited by F. Fraser Darling and John P. Milton, 1-7. New York: The Natural History Press, 1966.

---. "Conservation and Ecological Theory." *Journal of Animal Ecology* 33 (January 1, 1964): 39–45.

Darling, F. Fraser, and Charles Elton. "Malthus." *Journal of Animal Ecology* 17, no. 2 (November 1, 1948): 262–264.

Daston, Lorraine. *Biographies of Scientific Objects*. University of Chicago Press, 2000.

Daston, Lorraine J., and Peter Galison. *Objectivity*. Zone, 2010.

Daston, Lorraine, and H. Otto Sibum. "Introduction: Scientific Personae and Their Histories." *Science in Context* 16, 1–2 (2003): 1–8.

Davis, J. J., and R. F. Foster. "Bioaccumulation of Radioisotopes Through Aquatic Food Chains." *Ecology* 39, no. 3 (July 1, 1958): 530–535.

Deevey, Edward S., Marsha S. Gross, G. E. Hutchinson, and Henry L. Kraybill. "The Natural C14 Contents of Materials from Hard-Water Lakes." *Proceedings of the National Academy of Sciences of the United States of America* 40, no. 5 (May 15, 1954): 285–288.

Dennis, M.A. "Reconstructing Socio-Technical Order: Vannevar Bush and US Science Policy." In *States of Knowledge: The Co-Production of Science and Social Order*, edited by Sheila Jasanoff, 225-253. New York: Routledge, 2004.

Dennis, Michael Aaron. "'Our First Line of Defense': Two University Laboratories in the Postwar American State." *Isis* 85 3 (1994): 427-455.

---. "Historiography of Science: An American Perspective." In *Science in the Twentieth Century*, edited by John Krige and Dominique Pestre, 1-26. New York: Taylor and Francis, 1997.

Derting, T. L. "Interdisciplinary Nature of Ecology." *BioScience* 48, 10 (1998), 864-865.

Devall, Bill. "The Deep, Long-Range Ecology Movement, 1960-2000--A Review." *Ethics and the Environment* 6, 1 (2001): 18-41.

---. "The Deep Ecology Movement." *Natural Resources Journal* 20 (April 1980): 299-313.

Devall, Bill and George Sessions. *Deep Ecology: Living as if Life Mattered*. Salt Lake City: G.M. Smith, 1985.

Dickson, Paul. *Sputnik: The Shock of the Century*. New York: Walker and Company, 2007.

"discipline." *Oxford English Dictionary,* 2nd edition, 1989; online version June 2012.

Accessed February 2, 2012. An entry for his word was first included in *New English Dictionary*, 1896.

Divine, Robert A. *Blowing on the Wind: The Nuclear Test Ban Debate, 1954-1960*. New York: Oxford University Press, 1978.

Dobson, Andrew, and Paul Lucardie, eds. *The Politics of Nature: Explorations in Green Political Theory*. Reprint. Routledge, 1995.

Dowie, Mark. *Losing Ground: American Environmentalism at the Close of the Twentieth Century*. The MIT Press, 1996.

Drury, William H., and Ian C. T. Nisbet. "Succession." *Journal of the Arnold Arboretum* 54 (1973): 331-368.

Dyne, George M. Van. *The Ecosystem Concept in Natural Resource Management*. Academic Press, 1972.

Eckelman, Walter R., J. Laurence Kulp, and Arthur R. Schulert. "Strontium 90 in Man II." *Science* 127, 3293 (February 2, 1958): 266-274.

Ecological Society of America. "The New York Meeting." *Bulletin of the Ecological Society of America* 1, 1 (January 1917): 1-3.

"Ecology, the New Mass Movement." *Life* (January 30, 1970): 22-30. Accessed June 1, 2009, http://books.google.com/books?id=bFAEAAAAMBAJ&lpg=PA1&pg=PA22#v=onepage&q&f=false.

Edwards, Paul N. *A Vast Machine: Computer Models, Climate Data, and the Politics of Global Warming*. The MIT Press, 2010.

---. *The Closed World: Computers and the Politics of Discourse in Cold War America*. Cambridge, MA: MIT Press, 1997.

Egan, M. *Barry Commoner and the Science of Survival: The Remaking of American Environmentalism*. Cambridge, MA: MIT Press, 2007.

Egerton, Frank N. “The History of Ecology: Achievements and Opportunities, Part One.” *Journal of the History of Biology* 16, no. 2 (July 1, 1983): 259–310.

---. “The History of Ecology: Achievements and Opportunities, Part Two.” *Journal of the History of Biology* 18, no. 1 (April 1, 1985): 103–143.

---. “Changing Concepts of the Balance of Nature.” *The Quarterly Review of Biology* 48, no. 2 (June 1, 1973): 322–350.

---, ed. *History of American Ecology*. New York: Arno Press, 1977.

Eisenbud, Merril. “Deposition of Strontium-90 Through October 1958.” *Science* 130, no. 3367. New Series (July 10, 1959): 76–80.

---. "Oral History of Merril Eisenbud." Interview by Thomas J. Fisher and David S. Harrell, Department of Energy, Advisory Committee on Human Radiation Experiments, Accessed June 15, 2009, http://www.hss.doe.gov/healthsafety/ohre/roadmap/histories/0456/0456toc.html.

---. *Environmental Radioactivity: From Natural, Industrial, and Military Sources*. 3rd ed. Orlando, FL: Academic Press, 1987.

Eisenbud, Merril, and John H. Harley. “Long-Term Fallout.” *Science* 128, no. 3321. New Series (1958): 399–402.

---. “Radioactive Dust from Nuclear Detonations.” *Science* 117, no. 3033. New Series (February 13, 1953): 141–147.

---. “Radioactive Fallout in the United States.” *Science* 121, no. 3150. New Series (May 13, 1955): 677–680.

---. “Radioactive Fallout Through September 1955.” *Science* 124, no. 3215. New Series (1956): 251–255.

Eisenhower, Dwight. "Farewell Address to the Nation." Accessed July 1, 2010, http://mcadams.posc.mu.edu/ike.htm.

Eisner, Thomas, Hans Eisner, Jerrold Meinwald, Carl Sagan, Charles Walcott, Ernst Mayr, Edward O Wilson, et al. “Conservation of Tropical Forests.” *Science* 213, no. 4514 (September 18, 1981): 1314–1314.

Elder, W. H. "Birds of Georgia." Ecology *26,* 4 (1945): 424.

Elias, Norbert. *The Civilizing Process: The History of Manners*. New York: Blackwell Publishers, 1978.

---. *What is Sociology?* New York: Columbia University Press, 1978.

---. "Scientific Establishments." In *Scientific Establishments and Hierarchies*. Edited by N. Elias, H. Martins, and Richard P. Whitley, 3-70. Dordrecht, Holland: D. Reidel, 1982.

Elias, Norbert and John Scotson. *The Established and the Outsiders.* New York:

Humanities Press, 1966.

Ellul, Jacques. *The Technological Society,* translated by John Wilkinson. New York: Random House Books, 1964.

Elton, Charles S. *Animal Ecology*. Chicago: University of Chicago Press, 2001. Originally published by London: Sidgwick and Jackson, 1927.

---. "An Ecological Text Book." *Journal of Animal Ecology 23*, 2 (1954): 382-384.

---. *The Ecology of Invasions by Animals and Plants.* Chapman and Hall, 1958.

---. “The Relation of Man to Animals.” *Journal of Animal Ecology* 8, no. 2 (November 1, 1939): 390–391.

England, J. M. *A Patron for Pure Science*. National Science Foundation, 1982.

Etzioni, A. "Are Public Intellectuals an Endangered Species?" In *Public Intellectuals: An Endangered Species?* edited by A. Etzioni and A. Bowditch, 1-30. New York: Rowman and Littlefield Publishers, 2006.

Eisenbud, Merril. “Deposition of Strontium-90 Through October 1958.” *Science* 130, no. 3367. New Series (July 10, 1959): 76–80.

Eyal, Gil. *The Disenchantment of the Orient: Expertise in Arab Affairs And the Israeli State*. Stanford University Press, 2006.

"Fighting to Save Earth From Man." *Time Magazine* 95, 5 (February 2, 1970): 60-70. Accessed July 28, 2009, http://www.time.com/time/magazine/article/0,9171,878179,00.html.

Foreman, David. "Forward." In *Man in the Landscape: a Historical View of the Aesthetics of Nature* by Paul Shepard, xi-xx. Athens, GA: University of Georgia Press, 2002.

“Foreword.” *Journal of Animal Ecology* 1, no. 1 (May 1, 1932): 1–2.

Foster, John Bellamy. *The Ecological Revolution: Making Peace with the Planet*. New York: Monthly Review Press, 2009.

---. *Ecology Against Capitalism*. New York: Monthly Review Press, 2002.

---. *Marx's Ecology: Materialism and Nature*. New York: Monthly Review Press, 2000.

Foster, John Bellamy, and Brett Clark. "The Sociology of Ecology: Ecological

Organicism Versus Ecosystem Ecology in the Social Construction of Ecological Science, 1926-1935." *Organization Environment* 21 (2008): 311-352.

Foster, John Bellamy, Brett Clark, and Richard York. *The Ecological Rift: Capitalism's War on the Earth*. New York: Monthly Review Press, 2011.

Foster, R. F. and J. J. Davis "The Accumulation of Radioactive Substances in Aquatic Forms." *Proceedings of the International Conference on the Peaceful Uses of Atomic Energy* 13 (1955): 364-367.

Foster, R. F. and R. E. Rostenbach. "Distribution of Radioisotopes in the Columbia River." *Journal of American Water Works Association* 46 (1954): 663-640.

Fromm, Erich. *The Revolution of Hope, Toward a Humanized Technology*. New York: Harper and Row, 1968.

"Front Matter." *Ecological Monographs* 1, no. 1 (January 1, 1931).

Goldsmith, Edward. *The Way*. Boston: Shambhala, 1993.

Greenberg, E. M. "Letter to the Editor." *Saturday Review of Literature*, (August 1947).

Greenberg, D. S. *Science, Money, and Politics: Political Triumph and Ethical Erosion.* Chicago: University Of Chicago Press, 2001.

---. *The Politics of Pure Science*. Chicago: University Of Chicago Press, 1999.

Egler, Frank E. "'Environmental Biology,' or 'Ecosystem Ecology'?" *Ecology* 46, no. 3 (May 1, 1965): 386–388.

Epstein, Samuel S. *The Politics of Cancer*. Garden City, NY: Anchor Books, 1979.

Epstein, Steven, *Inclusion: The Politics of Difference in Medical Research*. University Of Chicago Press, 2009.

---. "Patient Groups and Health Movements." In *The Handbook of Science and Technology Studies*, ed. E. J. Hackett, O. Amsterdamska, M. Lynch and J. Wajcman. Cambridge, MA: MIT Press, 2008.

---. *Impure Science: AIDS, Activism, and the Politics of Knowledge*. Berkeley: University of California Press, 1996.

Feenberg, A. *Heidegger and Marcuse: The Catastrophe and Redemption of History*. New York: Routledge, 2004.

---. *Questioning Technology*. New York: Routledge, 1999.

---. “Marcuse or Habermas: Two Critiques of Technology.” *Inquiry* 39, 1 (1996): 45–70.

---. *Alternative Modernity: The Technical Turn in Philosophy and Social Theory.* Berkeley: University of California Press, 1995)

Ferré, F. *Philosophy of Technology*. Prentice Hall foundations of philosophy series. Englewood Cliffs, N.J: Prentice Hall, 1988.

Ferre, F., and P. Hartel, eds. *Ethics and Environmental Policy: Theory Meets Practice*. Athens, GA: University of Georgia Press, 1994.

Feyerabend, Paul, *The Conquest of Abundance: A Tale of Abstraction vs. the Richness of Being*. Chicago: University of Chicago Press, 2000.

Findlen, Paula. “Becoming a Scientist: Gender and Knowledge in Eighteenth-Century Italy.” *Science in Context* 16, no. 1–2 (2003): 59–87.

Fischer, David. *History of the International Atomic Energy Agency: the First Forty Years*. Vienna: International Atomic Energy Agency Division of Publications, 1997.

Fischer, Frank, *Citizens, Experts, and the Environment*. Durham: Duke University Press, 2000.

---. *Technocracy and the Politics of Expertise*. Thousand Oaks, CA: Sage Publications, Inc, 1989.

Forman, P. "Behind Quantum Electronics: National Security as Basis for Physical Research in the United States, 1940-1960," *Historical Studies in the Physical and Biological Sciences*, 18, 1 (1987), 149-229.

---. "Inventing the Maser in Postwar America." *Osiris*, 2nd Series, 7 (1992): 105-134.

---. "(Re)cognizing Postmodernity: Helps for Historians – of Science Especially," *Berichte zur Wissenschaftsgeschichte*, 33, 2 (2010): 157–175.

---. "On the Historical Forms of Knowledge Production and Curation: Modernity Entails Disciplinarity Postmodernity Entails Antidisciplinarity." *Osiris* 27 (2012): 56-97.

Forman, P., and J. M. Sánchez-Ron. *National Military Establishments and the Advancement of Science and Technology*. Springer, 2001.

Foster, J. B. *The Ecological Revolution: Making Peace with the Planet*. Monthly Review Press, 2009.

Foster, John Bellamy and Brett Clark, "Rachel Carson's Ecological Critique," *Monthly Review*, 59, 9 (2008): 1-17.

Foster, John Bellamy, Brett Clark, and Richard York. *The Ecological Rift: Capitalism's War on the Earth*. Monthly Review Press, 2011.

Foster, Richard F, interview by J. Newell Stannard. June 11, 1979, U. S. Department of Energy OpenNet Project, accessed August 28, 2010, https://www.osti.gov/opennet/advancedsearch.jsp.

Freedman, Lawrence, *The Evolution of Nuclear Strategy*. New York: St. Martin's Press, 1983.

Frickel, S. and K Moore, "Prospects and Challenges for a New Political Sociology of Science" In *The New Political Sociology of Science: Institutions, Networks, and Power*. Madison: University of Wisconsin Press, 2006.

Frickel, S. "Building an Interdiscipline: Collective Action Framing and the Rise of Genetic Toxicology," *Social Problems*, 51, 2 (2004): 269–287.

---. *Chemical Consequences: Environmental Mutagens, Scientist Activism, and the Rise of Genetic Toxicology*. New Brunswick, NJ: Rutgers University Press, 2004.

Frickel, S., and N. Gross. "A General Theory of Scientific/Intellectual Movements," *American Sociological Review*, 70, 2 (2005): 204–232.

Fuchs, S. *The Professional Quest for Truth: A Social Theory of Science and Knowledge*. State University of New York Press, 1992.

---. *Against Essentialism: A Theory of Culture and Society*. Cambridge, MA: Harvard University Press, 2005.

Galison, P. "Ten Problems in History and Philosophy of Science," *Isis* 99, 1 (2008): 111–124.

---. "Removing Knowledge," *Critical Inquiry*, 31, 1 (2004): 229–243.

---. "War against the Center," *Grey Room*, 4 (2001): 7–33.

---. *Image and Logic: A Material Culture of Microphysics.* Chicago: University Of Chicago Press, 1997.

---. "The Many Faces of Science." In *Big Science: The Growth of Large-Scale Research,* edited by P. Galison and B. Hevly, 1-20. Stanford, CA: Stanford University Press, 1994.

---. "The Ontology of the Enemy: Norbert Wiener and the Cybernetic Vision," *Critical Inquiry*, 21*,* 1 (1994), 228–266.

General Advisory Committee to the U. S. Atomic Energy Commission. "Problems Presented by Radioactive Fallout." *Bulletin of the Atomic Scientists* (June 1959): 258-259.

"The George Mercer Award for 1956." *Bulletin of the Ecological Society of America* 38, no. 1 (March 1, 1957): 2–3.

Gerber, Michele, *On the Home Front: The Cold War Legacy of the Hanford Nuclear Site.* Lincoln, NE: University of Nebraska Press, 2002

Gerth, H.H. and C. Wright Mills. *From Max Weber: Essays in Sociology.* New York: Oxford University Press, 1978.

Geiger, R. L. *To Advance Knowledge: the Growth of American Research Universities, 1900-1940*. New York: Oxford University Press, 2004.

---. *Research and Relevant Knowledge: American Research Universities Since World War*. New York: Oxford University Press, 1993.

Ghamari-Tabrizi, Sharon, *The Worlds of Herman Kahn: The Intuitive Science of Thermonuclear War.* Cambridge, MA, Harvard University Press, 2005.

Giddens, Anthony, *The Consequences of Modernity*. Stanford: Stanford University Press, 1990.

---. *Modernity and Self-Identity: Self and Society in the Late Modern Age*. Stanford, CA: Stanford University Press, 1991.

---. *Beyond Left and Right: The Future of Radical Politics*. Stanford, CA: Stanford University Press, 1994.

Gieryn, T. F. *Cultural Boundaries of Science: Credibility on the Line*. Chicago: University of Chicago Press, 1999.

---. "Boundary Work and the Demarcation of Science from Non-science: Strains and Interests in Professional Interests of Science." *American Sociological Review* 48 (1983):781-95.

Gieryn, Thomas F., George M. Bevins, and Stephen C. Zehr, "Professionalization of American Scientists: Public Science in the Creation / Evolution Trials," *American*

Sociological Review 50, 3, Jun. (1985): 392-409

Goffman, Erving. *Interaction Ritual: Essays in Face-to-Face Behavior*. New York: Anchor, 1967.

---. *Asylums: Essays on the Social Situation of Mental Patients and Other Inmates*. New York: Anchor, 1961.

---. *Stigma: Notes on the Management of Spoiled Identity*. New York: Simon and Schuster, 1963.

---. *The Presentation of Self in Everyday Life*. New York: Anchor, 1959.

Godin, B. "The Linear Model of Innovation: The Historical Construction of an Analytical Framework. *Science, Technology, and Human Values*, 31*,* 6 (2006): 639–667.

Goldman, Harvey. *Politics, Death, and the Devil: Self and Power in Max Weber and Thomas Mann*. Berkeley: University of California Press, 1992.

---. "Economy and Society and the Revision of Weber's Ethics." In *Max Weber's Economy And Society: A Critical Companion*, edited by Charles Camic, Philip S. Gorski, and David M. Trubek, 47-69. Stanford, CA: Stanford University Press, 2005.

Golley, F. B. "Establishing the Network." In *Holistic Science: The Evolution of the Georgia Institute of Ecology (1940-2000)* edited by Gary W. Barrett and Terry Lynn Barrett, 38-68. New York: Taylor and Francis, 2001.

---. *A History of the Ecosystem Concept in Ecology: More Than the Sum of the Parts*. New Haven: Yale University Press, 1993.

Goodman, Amy. "Plutonium Files: How the U.S. Secretly Fed Radioactivity to Thousands of Americans." *Democracy Now,* May 5, 2004. Accessed March 1, 2009, http://www.democracynow.org/2004/5/5/plutonium_files_how_the_u_s

Gorz, André, *Ecology as Politics*. Translated by Patsy Vigderman and Jonathon Cloud. Boston: South End Press, 1980.

Gottlieb, Robert, *Forcing the Spring: the Transformation of the American Environmental Movement.* Washington D.C.: Island Press, 2005.

Gould, Kenneth, Allan Schnaiberg, and Adam Weinberg. *Local Environmental Struggles*. New York: Cambridge University Press, 1996.

---. "Legitimating impotence: Pyrrhic victories of the modern environmental movement."

Qualitative Sociology 16, (1993):207-246.

Gould, Kenneth A., David N. Pellow, and Allan Schnaiberg. *The Treadmill of Production: Injustice and Unsustainability in the Global Economy*. Paradigm Publishers, 2008.

Gouldner, Alvin Ward. *The Future of Intellectuals and the Rise of the New Class*. New York: Seabury Press, 1979.

---. “Anti-Minotaur: The Myth of a Value-Free Sociology.” *Social Problems* 9, no. 3 (January 1, 1962): 199–213.

Greenberg, D. S. *Science, Money, and Politics: Political Triumph and Ethical Erosion*. Chicago: University of Chicago Press, 2001.

---. *The Politics of Pure Science*. Chicago: University Of Chicago Press, 1999.

Greeson, Philip, John R. Clark and Judith E. Clark, eds. *Wetland Functions and Values: The State of Our Understanding*. Proceedings of the National Symposium on Wetlands. Minneapolis, MN: American Water Resources Association, 1979.

Greene, Gayle. *The Woman Who Knew Too Much: Alice Stewart and the Secrets of Radiation*. Ann Arbor, MI: University of Michigan Press, 2001.

Gross, Neil. *Richard Rorty: The Making of an American Philosopher*. Chicago: University of Chicago Press, 2008.

Gusfield, Joseph R. “The Reflexivity of Social Movements: Collective Behavior and Mass Society Theory Revisited.” In *New Social Movements: from Ideology to Identity,* edited by Enrique Laraña, Hank Johnston and Joseph R. Gusfield, 58-78. Philadelphia: Temple University Press, 1994.

Gutkind, E. A. "Our World From the Air: Conflict and Adaptation.” In *Man's Role in Changing the Face of the Earth,* edited by William L. Thomas, Jr., 1-44. Chicago: University of Chicago Press, 1956.

Habermas, Jürgen. *The Philosophical Discourse of Modernity: Twelve Lectures*. Translated by Frederick Lawrence. Cambridge, MA: MIT Press, 1996.

---. "The Idea of the University - Learning Processes." *New German Critique* 41, (Spring / Summer, 1987): 3-22.

---. "New Social Movements." *Telos* 49 (1981): 33-7.

---. "Technology and Science as 'Ideology.'" In *Toward a Rational Society: Student*

Protest, Science, and Politics, by Jürgen Habermas, translated by Jeremy J. Shapiro, 81-122. Boston: Beacon Press, 1970.

Hacker, Barton C. *The Dragon's Tail: Radiation Safety in the Manhattan Project*. Berkeley: University of California Press, 1987.

---. *Elements of Controversy: The Atomic Energy Commission and Radiation Safety in Nuclear Weapons Testing, 1947-1974*. Berkeley: University of California Press, 1994.

Hackett, Edward J. "Science as a Vocation in the 1990s." *The Journal of Higher Education* 61, 3 (May-June, 1990): 241-279.

Hacking, I. *The Taming of Chance*. Cambridge: Cambridge University Press, 1990.

Hagen, Joel, *An Entangled Bank: the Origin of Ecosystem Ecology*. New Brunswick, NJ: Rutgers University Press 1992.

---. "Teaching Ecology During the Environmental Age, 1965-1980." *Environmental History* Issue 13 No 4 (October 2008): 704-23.

Hagner, Michael. “Skulls, Brains, and Memorial Culture: On Cerebral Biographies of Scientists in the Nineteenth Century.” *Science in Context* 16, 1–2 (2003): 195–218.

Hannaway, Owen. "The German Model of Chemical Education in America: Ira Remsen at Johns Hopkins (1876-1913)." *Ambix* 23 (November, 1976): 145-64.

Hannon, Bruce M. "The role of input–output analysis of energy and ecologic systems in the early development of ecological economics—a personal perspective." *Annals of the New York Academy of Sciences* 1185 (2010): 30-8

---. “An Energy Standard of Value.” *Annals of the American Academy of Political and Social Science* 410 (November 1, 1973): 139–153.

Hansen, Chuck, *U. S. Nuclear Weapons.* New York: Orion Books, 1988.

Hanson, W. C., and H. A. Kornberg. "Radioactivity in Terrestrial Animals Near an Atomic Energy Site." *Proceedings of the International Conference on the Peaceful Uses of Atomic Energy* 13 (1955): 385-388.

Hardt, M., and A. Negri. *Empire*. Cambridge, MA: Harvard University Press, 2001.

Harkewicz, Laura. “*The Ghost of the Bomb": The Bravo Medical Program, Scientific Uncertainty, and the Legacy of the Cold War, 1954 – 2005* (PhD diss., University of California, San Diego, 2010).

Harrington, A. *Reenchanted Science: Holism in German Culture from Wilhelm II to Hitler*. Princeton, NJ: Princeton University Press, 1999.

Hedgpeth, Joel W. "[untitled]." Review of *Fundamentals of Ecology* by Eugene Odum. *Science* 120, no. 3108. New Series (July 23, 1954): 134.

Heilbron, J. L., and Robert W. Seidel. *Lawrence and His Laboratory: A History of the Lawrence Berkeley Laboratory, Volume I*. Berkeley: University of California Press, 1989.

Heims, Steve J. *The Cybernetics Group*. Cambridge, MA: MIT Press, 1991.

Hermanowicz, J. C. *Lives in Science: How Institutions Affect Academic Careers,* Chicago: University Of Chicago Press, 2009.

---. "What Does It Take to Be Successful?" *Science, Technology and Human Values* 31*,* 2 (2006): 135–152.

Hess, David J. "Health, Environment, and Social Movements." *Science as Culture* 13, 4, Dec. (2004): 421-7.

Hewlett, Richard G. and Jack M. Holl. *Atoms for Peace and War, 1953-1961: Eisenhower and the Atomic Energy Commission.* Berkeley: University of California Press, 1989.

Higham, John. "The Matrix of Specialization." In *The Organization of Knowledge in Modern America, 1860-1920*, edited by Alexandra Oleson and John Voss, 3-18. Baltimore: Johns Hopkins University Press, 1979.

Hilgartner, Stephen. *Science on Stage: Expert Advice As Public Drama*. Stanford, CA: Stanford University Press, 2000.

Hines, Neil O. *Proving Ground: An Account of the Radiobiological Studies in the Pacific, 1946-1961.* Seattle: University of Washington Press, 1963.

Hogan, Michael J. *The Iron Cross: Harry S. Truman and the Origins of the National Security State, 1945 – 1954.* Cambridge: Cambridge University Press, 1998.

Horkheimer, Max and Theodor Adorno. *The Dialectic of Enlightenment*. Edited by G.S. Noerr, translated by Edmund Jephcott. Stanford, CA: Stanford University Press, 2002.

Holifield, Chester E. "Congressional Hearings on Radioactive Fallout." *Bulletin of the Atomic Scientists* (January 1958): 52-4.

Hollinger, D. A. "The Defense of Democracy and Robert K. Merton's Formulation of the Scientific Ethos." In *Science, Jews, and Secular Culture: Studies in Mid-Twentieth-Century American Intellectual History*. Princeton, N.J: Princeton University Press, 1996. Originally published in *Knowledge and Society* 4 (1983): 1-15.

Horkheimer, Max. *Eclipse of Reason*. New York: Oxford University Press, 1947.

Hughes, Thomas P. *American Genesis: A Century of Invention and Technological Enthusiasm, 1870-1970*. Chicago: University of Chicago Press, 2004.

Hutchinson, G. Evelyn "On the Chemical Ecology of Lake Tanganika." *Science* 71, no. 1850. New Series (June 13, 1930): 616.

---. "[untitled]." *Ecology* 21, no. 2 (April 1, 1940): 267–268.

---. "Limnological Studies in Connecticut: IV. The Mechanisms of Intermediary Metabolism in Stratified Lakes." *Ecological Monographs* 11, no. 1 (January 1, 1941): 21–60.

---. "The Biogeochemistry of Aluminum and of Certain Related Elements." *The Quarterly Review of Biology* 18, no. 1 (March 1, 1943): 1–29.

---. "The Biogeochemistry of Aluminum and of Certain Related Elements (Concluded)." *The Quarterly Review of Biology* 18, no. 4 (December 1, 1943): 331–363.

---. "The Biogeochemistry of Aluminum and of Certain Related Elements (Continued)." *The Quarterly Review of Biology* 18, no. 3 (1943): 242–262.

---. "The Biogeochemistry of Aluminum and of Certain Related Elements (Continued)." *The Quarterly Review of Biology* 18, no. 2 (June 1, 1943): 128–153.

---. "Limnological Studies in Connecticut. VII. A Critical Examination of the Supposed Relationship Between Phytoplakton Periodicity and Chemical Changes in Lake Waters." *Ecology* 25, no. 1 (January 1, 1944): 3–26.

---. "Nitrogen in the Biogeochemistry of the Atmosphere." *American Scientist* 32, no. 3 (July 1, 1944): 178–195.

---. "Circular Causal Systems in Ecology," Annals of the New York Academy of Sciences 40, 4 (1948): 221-246.

---. "On Living in the Biosphere." *The Scientific Monthly* 67, no. 6 (December 1, 1948): 393–397.

---. *A Treatise on Limnology, Vol. 1: Geography & Physics of Lakes*. New York: John Wiley and Sons Inc, 1957.

---. “Homage to Santa Rosalia or Why Are There So Many Kinds of Animals?” *The American Naturalist* 93, no. 870 (May 1, 1959): 145–159.

---. *A Treatise On Limnology, Vol. 2 - Introduction To Lake Biology and The Limnoplankton*. New York: John Wiley and Sons, 1967.

---. *A Treatise On Limnology, Vol. 3 - Limnological Botany*. New York: John Wiley and Sons, 1975.

---. *A Treatise on Limnology, Vol. 4: The Zoobenthos*. Edited by Yvette H. Edmondson. Volume 4. New York: John Wiley and Sons, 1993.

Hutchinson, G. Evelyn, and Vaugham T. Bowen. “Limnological Studies in Connecticut. IX. A Quantitative Radiochemical Study of the Phosphorus Cycle in Linsley Pond.” *Ecology* 31, no. 2 (April 1, 1950): 194–203.

---. “A Direct Demonstration of the Phosphorus Cycle in a Small Lake.” *Proceedings of the National Academy of Sciences of the United States of America* 33, no. 5 (May 15, 1947): 148–153.

Irwin, Alan. *Citizen Science: A Study of People, Expertise and Sustainable Development*. New York: Routledge Press, 1995.

Ivie, Rachel. “Playing the Con Game of Academe.” *Nature* 460, no. 7256 (August 5, 2009): 690.

Jackson, Myles. “Harmonious Investigators of Nature: Music and the Persona of the German Naturforscher in the Nineteenth Century.” *Science in Context* 16, 1–2 (2003): 121–145.

Jackson, William. “Survival of Rats at Eniwetok Atoll.” *Pacific Science* 23 (July 1969): 265-275.

Jacob, Margaret C., and Larry Stewart. *Practical Matter: Newton’s Science in the Service of Industry and Empire, 1687-1851*. Harvard University Press, 2006.

Jacoby, R. "Why Intellectuals Are All Bad," *The Chronicle of Higher Education* (February 14, 2010). Accessed August 28, 2011, http://chronicle.com/article/Skewering-Intellectuals/64113/.

---. "Introduction to the 2010 Edition." *The Last Intellectuals: American Culture in the Age of Academe* by Russell Jacoby, xv-xix. New York: Basic Books, 2000.

---. *The End Of Utopia: Politics And Culture In An Age Of Apathy*. New York: Basic Books, 1999.

---. *The Last Intellectuals: American Culture in the Age of Academe*. New York: Basic Books, 1987.

Jamison, Andrew. *The Making of Green Knowledge: Environmental Politics and Cultural Transformation*. Cambridge: Cambridge University Press, 2002.

---. “A Tale of Two Brothers.” *Science* 261, no. 5120 (July 23, 1993): 497–498.

Jamison, Andrew, and Ron Eyerman. *Seeds of the Sixties*. Berkeley: University of California Press, 1995.

Jarausch, Konrad, ed. *The Transformation of Higher Learning, 1860-1930: Expansion, Diversification, Social Opening, and Professionalization in England, Germany, Russia, and the United States*. Chicago: University of Chicago Press, 1983.

---. "Graduation and Careers." In *Universities in the Nineteenth and Early Twentieth Centuries (1800-1945),* edited by Walter Rüegg, 363-392. New York: Cambridge University Press, 2004.

Jasanoff, Sheila. *Reframing Rights: Bioconstitutionalism in the Genetic Age*. Cambridge, MA: MIT Press, 2011.

---. *Designs on Nature: Science and Democracy in Europe and the United States*. Princeton, NJ: Princeton University Press, 2007.

---, ed. *States of Knowledge: The Co-production of Science and the Social Order*. New York: Routledge, 2004.

---. *Science at the Bar: Law, Science, and Technology in America*. Cambridge, MA: Harvard University Press, 1997.

---. *The Fifth Branch: Science Advisers as Policymakers*. Cambridge, MA: Harvard University Press, 1998.

---. *Learning from Disaster: Risk Management After Bhopal*. Philadelphia: University of Pennsylvania Press, 1994.

Johnson, A. Sydney, Hilburn O. Hillestad, Sheryl Fanning Shanholtzer, G. Frederick Shanholtzer. *An Ecological Survey Off the Coastal Region of Georgia*. National Park Service Scientific Monograph Series, 1974. Accessed January 15, 2011, http://www.nps.gov/history/history/online_books/science/3/index.htm.

Johnson, L., and D. Schaffer. *Oak Ridge National Laboratory: the First Fifty Years*. Knoxville, TN: University of Tennessee Press, 1994.

Johnston, Hank, Enrique Larana, and Joseph R. Gusfield, "Identities, Grievances, and New Social Movements." In *New Social Movements: From Ideology to Identity*. Edited by Enrique Larana, Hank Johnston, and Joseph R. Gusfield, 3-35. Philadelphia: Temple University Press, 1994.

Joint Committee on Atomic Energy. *The Nature of Radioactive Fallout and Its Effects on Man. Hearings Before the Special Subcommittee on Radiation of the Joint Committee on Atomic Energy Congress of the United States Eighty-Fifth Congress First Session on the Nature of Radioactive Fallout and Its Effects on Man. May 27, 28, 29, and June 3, 1957.* U.S. Government Printing Office, 1957.

---. *Fallout from Nuclear Weapons Tests: Hearings Before the Special Subcommittee on Radiation of the Joint Committee on Atomic Energy, Congress of the United States May 5, 6, 7, and 8, 1959*. U.S. Government Printing Office, 1959.

“Introductory Statement.” *Human Ecology* 1, no. 1 (March 1, 1972): 1.

Irwin, Alan and Mike Michael. *Science, Social Theory, and Public Knowledge*. Maidenhead, PA: Open University Press, 2003.

Irwin, Alan, Allan, Stuart and Welsh, Ian. "Nuclear Risks: Three Problematics." In *The Risk Society and Beyond: Critical Issues for Social Theory*, edited by Barbara Adam, Ulrich Beck and Joost van Loon, 78—104. London: Sage, 2000.

Jackson, William. "Survival of Rats at Eniwetok Atoll," *Pacific Science,* Vol. XXIII, July (1969), 265-275.

Jarausch, Konrad Hugo, ed. *The Transformation of Higher Learning 1860-1930: Expansion, Diversification, Social Opening, and Professionalization in England, Germany, Russia, and the United States*. Chicago: University of Chicago Press, 1983.

Jolly, J. Christopher. "Linus Pauling and the Scientific Debate Over Fallout Hazards," *Endeavour* 26, 4 (2002): 149-153.

Kahn, Herman. *On Thermonuclear War.* Princeton: Princeton University Press, 1960.

Karabell, Zachary. *Architects of Intervention: The United States, the Third World, and the Cold War, 1946-1962*. Baton Rouge, LA: Louisiana State University Press, 1999.

Kathren, Ronald L. “Pathway to a Paradigm: the Linear Non-Threshold Dose-Response

Model in Historical Context," *Health Physics* 70, May, 5 (1995):621-635.

Kaufman, Burton. *The Korean War*. New York: Knopf, 1986.

Kay, L. E. *The Molecular Vision of Life: Caltech, the Rockefeller Foundation, and the Rise of the New Biology*. New York: Oxford University Press, 1993.

Keller, David R. and Frank Golley, eds. *The Philosophy of Ecology: From Science to Synthesis*. Athens: University of Georgia Press, 2000.

Kevles, D. *The Physicists: The History of a Scientific Community in Modern America, Revised Edition* (2nd ed.). Harvard University Press, 1995.

---. "Foundations, Universities, and Trends in Support for the Physical and Biological Sciences, 1900-1992." *Daedalus* 121, no. 4 (October 1, 1992): 195–235.

---. "Cold War and Hot Physics: Science, Security, and the American State, 1945-56." *Historical Studies in the Physical and Biological Sciences* 20, no. 2 (January 1, 1990): 239–264.

---. "The National Science Foundation and the Debate over Postwar Research Policy, 1942-1945: A Political Interpretation of Science--The Endless Frontier," *Isis*, 68*,* 1 (1977): 5–26.

Killingsworth, M. Jimmie and Jacqueline S. Palmer. *Ecospeak: Rhetoric and Environmental Politics in America*. Carbondale, IL: Southern Illinois Press.

Kinchy, Abby J. "On the Borders of Post-War Ecology: Struggles over the Ecological Society of America's Preservation Committee, 1917-1946," *Science as Culture* 15, 1 (2006): 23-44.

Kinchy, Abby J., and D. L. Kleinman. "Organizing Credibility: Discursive and Organizational Orthodoxy on the Borders of Ecology and Politics," *Social Studies of Science*, 33*,* 6 (2003), 869–896.

Kingsland, Sharon. *The Evolution of American Ecology, 1890-2000*. Baltimore: Johns Hopkins Press, 2005.

---. *Modeling Nature*. 2nd ed. Chicago: University Of Chicago Press, 1995.

---. "The History of Ecology." *Journal of the History of Biology* 27, no. 2 (July 1, 1994): 349–357.

Kippenberg, Hans G. "Religious Communities and the Path to Disenchantment: The Origins, Sources, and Theoretical Core of the Religion Section." In *Max Weber's*

Economy And Society: A Critical Companion, edited by Charles Camic, Philip S. Gorski, and David M. Trubek, 164-184. Stanford, CA: Stanford University Press, 2005.

Kirsch, Scott. "Ecologists and the experimental landscape: the nature of science at the US Department of Energy's Savannah River Site." *Cultural Geographies* 14 (2007): 485-510.

---. *Proving Grounds: Project Plowshare And the Unrealized Dream of Nuclear Earthmoving*. New Brunswick, NJ: Rutgers University Press, 2005.

---. "Harold Knapp and the Geography of Normal Controversy: Radioiodine in the Historical Environment," *Osiris* 19 (2004):167-181.

Kleinman, Daniel Lee. "Science and the World/Science in the World." *Contemporary Sociology* 41, 4 (July 2012): 430-7.

---. *Impure Cultures: University Biology and the World of Commerce.* Madison: University of Wisconsin Press, 2003.

---. Ed. *Science, Technology, and Democracy*. State University of New York Press, 2000.

---. Beyond the Science Wars: Contemplating the Democratization of Science. *Politics and the Life Sciences*, 17*,* 2 (1998): 133–145.

---. "Untangling Context: Understanding a University Laboratory in the Commercial World," *Science, Technology, and Human Values*, *23*, 3 (1998): 285–314.

---. *Politics on the Endless Frontier: Postwar Research Policy in the United States*. Durham, NC: Duke University Press Books, 1995.

---. "Layers of Interests, Layers of Influence: Business and the Genesis of the National Science Foundation," *Science, Technology, and Human Values*, 19, 3 (1994), 259–282.

Kleinman, D. L., and Abby J. Kinchy. "Boundaries in Science Policy Making: Bovine Growth Hormone in the European Union," *The Sociological Quarterly*, *44*, 4 (2003): 577–595.

Kleinman, D. L., S. P. Vallas. Science, Capitalism, and the Rise of the "Knowledge Worker": The Changing Structure of Knowledge Production in the United States. *Theory and Society*, 30*,* 4 (2001): 451–492.

Kline, Ronald. "Construing 'Technology' as 'Applied Science': Public Rhetoric of Scientists and Engineers in the United States, 1880-1945." *Isis* 86, 2 (June 1, 1995):

194–221.

Knight, Thomas J. "[untitled]." Review of *Autonomous Technology: Technics-as-out-of-Control as a Theme in Political Thought*, by Langdon Winner. *Annals of the American Academy of Political and Social Science* 437 (May 1, 1978): 185–186.

Kohler, R. E. "Plants and Pigeonholes: Classification as a Practice in American Ecology," *Historical Studies in the Natural Sciences* 38, 1 (2008): 77–108.

---. *All Creatures: Naturalists, Collectors, and Biodiversity, 1850-1950*. Princeton University Press, 2006.

---. *Landscapes and Labscapes: Exploring the Lab-Field Border in Biology*. Chicago: University of Chicago Press, 2002.

---. *Lords of the Fly: Drosophila Genetics and the Experimental Life*. Chicago: University of Chicago Press, 1994.

---. *Partners in Science: Foundations and Natural Scientists, 1900-1945*. Chicago: University Of Chicago Press, 1991.

---. "The Ph.D. Machine: Building on the Collegiate Base." *Isis* 81, no. 4 (1990): 638–662.

---. "Science, Foundations, and American Universities in the 1920s," *Osiris* 3 (1987): 135–164.

Kopp, Carolyn. "The Origins of the American Scientific Debate over Fallout Hazards." *Social Studies of Science* 9, 4, Nov. (1979): 403-422.

Kramish, A., ed. *Worldwide Effects of Atomic Weapons: Project Sunshine*, R-251-AEC. U. S. Department of Energy OpenNet Project 1953. Retrieved from https://www.osti.gov/opennet/advancedsearch.jsp.

Krause, P. E. A. *Death of the Guilds: Professions, States, and the Advance of Capitalism, 1930 to the Present*. New Haven, CT: Yale University Press, 1999.

Krige, John. "Atoms for Peace, Scientific Internationalism, and Scientific Intelligence." *Osiris* 21, 1 (January 1, 2006): 161–181.

Krohn, Wolfgang and Peter Weingart. "Commentary: Nuclear Power as a Social Experiment-European Political 'Fall Out' from the Chernobyl Meltdown." *Science, Technology, and Human Values* 12, Spring, 2 (1987): 52-58.

Kroll, Gary. "Rachel Carson's Silent Spring: A Brief History of Ecology as a Subversive

Subject." Online Ethics Center for Engineering, National Academy of Engineering, July 6, 2006. Accessed April 1, 2008, http://www.onlineethics.org/cms/9174.aspx.

Kundell, James E. *Management of Georgia's Marshlands Under the Coastal Marshlands Protection Act of 1970*. Governmental Research and Services Division, Carl Vinson Institute of Government, University of Georgia, 1988.

Kurzman, Charles, and Lynn Owens. "The Sociology of Intellectuals." *Annual Review of Sociology* 28, no. 1 (2002): 63–90.

Kuznick, P. J. *Beyond the Laboratory: Scientists as Political Activists in 1930s America*. Chicago: University of Chicago Press, 1987.

Kwa, Chunglin. "Radiation Ecology and Systems Ecology and the Management of the Environment." In *Science and Nature: Essays in the History of the Environmental Sciences,* edited by Michael Shortland, 213-250. Oxford: BSHS Monographs, 1993.

---. "Representations of Nature Mediating Between Ecology and Science Policy: The case of the International Biological Program," *Social Studies of Science* 17 (1987):413-442.

Kulp, J. Laurence, Walter R. Eckelman and Arthur R.Schulert. "Strontium-90 in Man. *Science* 125, 3241, (February 8, 1957): 219-225.

Kulp, J. Laurence, Arthur R. Schulert and Elizabeth J. Hodges. "Strontium 90 in Man III. *Science* 129, 3358 (May 8, 1959): 1249-1255.

---. "Strontium 90 in Man IV. *Science* 132, 3425 (August 19, 1960), 448-454.

Kulp, J. Laurence and Arthur R. Schulert. "Strontium 90 in Man V," *Science* 136, 3516 (May 18, 1962): 619-632.

Lakoff, Andrew. ed. *Disaster and the Politics of Intervention*. New York: Columbia University Press, 2010.

---. "Preparing for the Next Emergency," *Public Culture* 19, 2 (2007): 247-71.

Lakoff, A., S. J. Collier. "Infrastructure and Event: The Political Technology of Preparedness. " In *Political Matter: Technoscience, Democracy, and Public Life*. Edited by Bruce Braun and Sarah J. Whatmore, 243-266. Minneapolis: University of Minnesota Press, 2010.

Lakoff, A., and E. Klinenberg. "Of Risk and Pork: Urban Security and the Politics of Calculation. Theory and Society, 39 (2010): 503-525.

Lampland, M., and S. L. Star. *Standards and Their Stories: How Quantifying, Classifying, and Formalizing Practices Shape Everyday Life*. Ithaca: Cornell University Press, 2009.

Lapp, Ralph E. *The New Force; the Story of Atoms and People*. New York: Harper, 1953.

---. "Strontium Limits in Peace and War." *Bulletin of the Atomic Scientists* (October 1956): 287-9.

---. *The Voyage of the Lucky Dragon*. 1st U.S. ed. New York, NY Harper & Brothers, 1958.

---. "Local Fallout Radioactivity." *Bulletin of the Atomic Scientists* (May 1959): 181-6.

---. "Fallout and Home Defense." *Bulletin of the Atomic Scientists* (May 1959): 187-91.

---. "What is the Price of Nuclear War?" *Bulletin of the Atomic Scientists* (October 1959): 340-3.

---. "A Criticism of the GAC Report. " *Bulletin of the Atomic Scientists* (September 1959): 311-2.

---. *Kill and Overkill: The Strategy of Annihilation.* New York: Basic Books, 1962.

---. *The New Priesthood: The Scientific Elite and the Uses of Power*. New York: Harper and Row, 1965.

---. *The Weapons Culture*. Pelican Books. Baltimore, Md: Penguin Books, 1969.

---. *Arms Beyond Doubt: The Tyranny of Weapons Technology.* New York: Cowles Book Company, 1970.

Larana, Enrique. `Reflexivity, Risk and Collective Action over Waste Management: A Constructive Proposal', *Current Sociology* 49, 1 (2001): 23-48.

Larson, Kermit H. "Continental Close-In Fallout: Its History, Measurement, and Characteristics." In *Radioecology; Proceedings of the First National Symposium on Radioecology held at Colorado State University, Fort Collins, Colorado, September 10-15, 1961,* edited by Vincent Schultz and Alfred W. Klement, 19-26. New York, Reinhold Publishing Corporation, 1963.

Larson, Magali Sarfatti. *The Rise of Professionalism: A Sociological Analysis*. Berkeley: University of California Press, 1977.

Lash, Scott. "Risk Culture." In *Risk Society and Beyond: Critical Issues for Social*

Theory, edited by Barbara Adam, Ulrich Beck and Joost van Loon, 47-62. London: Sage, 2000.

---. "Reflexivity and its Doubles: Structure, Aesthetics, Community." In *Reflexive Modernization: Politics, Tradition and Aesthetics in the Modern Social Order*. Edited by Ulrich Beck, Anthony Giddens, and Scott Lash, 110-173. Stanford, CA: Stanford University Press, 1994.

Lassman, Peter, and Irving Velody. "Introduction." In *Max Weber's "Science As a Vocation* edited by Peter Lassman and Irving Velody, xiii-xvii. Boston: Unwin Hyman, 1989.

Larson, M. S. *The Rise of Professionalism: A Sociological Analysis*. Berkeley: University of California Press, 1977.

Latour, Bruno. ''Where Are the Missing Masses? The Sociology of a Few Mundane Artifacts." In *Shaping Technology/Building Society: Studies in Sociotechnical Change*, edited by Wiebe E. Bijker and John Law, 225–258. Cambridge, MA: MIT Press, 1992.

Laurence, William L. "Vast Power Bared." *New York Times*, April 1, 1954, 1.

Layton, Edwin T. "[untitled]." Review of *Autonomous Technology: Technics-as-out-of-Control as a Theme in Political Thought*, by Langdon Winner. *Isis* 71, no. 1 (March 1, 1980): 169.

Lear, Linda. *Rachel Carson: Witness for Nature.* New York: Mariner Books, 2007.

---. "Bombshell in Beltsville: The USDA and the Challenge of 'Silent Spring'." *Agricultural History* 66, no. 2 (April 1, 1992): 151–170.

Leffler, Melvyn P. "National Security." *The Journal of American History* 77, 1 (June 1990): 143-152

---. "The American Conception of National Security and the Beginnings of the Cold War, 1945-48." *The American Historical Review* 89, 2 (April 1984): 391-400.

Lemaine, Gérard, Roy MacLeod, Michael Mulkay, and Peter Weingart eds. *Perspectives on the Emergence of Scientific Disciplines*. Chicago: Aldine, 1976.

Lemert, Charles C. "The Politics of the Academy and the Limits of the Academy." In *Intellectuals and Politics: Social Theory in a Changing World*, edited by Charles C. Lemert, 177-87. Newbury Park, CA: Sage Publications, 1991.

Lenoir, T. *The Strategy of Life: Teleology and Mechanics in Nineteenth Century German Biology*. Boston: Reidel Publishing, 1982.

Leopold, A., and C. W. Schwartz. *A Sand County Almanac, and Sketches Here and There*. Oxford: Oxford University Press, 1989.

Leslie, S. W. *The Cold War and American Science: The Military-Industrial-Academic Complex at MIT and Stanford*. New York: Columbia University Press, 1994.

"Lewis Strauss's Complete Statement After Bravo and the Japanese Government's Response," in "Race for the Superbomb." Accessed August 28, 2010, http://www.pbs.org/wgbh/amex/bomb/filmmore/reference/primary/straussbravo.html.

Lindee, M. Susan. *Suffering Made Real: American Science and the Survivors at Hiroshima*. Chicago: University of Chicago Press, 1994.

Lindeman, Raymond L. "The Trophic-Dynamic Aspect of Ecology." *Ecology* 23, 4 (1942): 399-417.

Lovelock, J.E. *Gaia: A New Look at Life on Earth*. Oxford: Oxford University Press, 2000.

Lowen, R. S. *Creating the Cold War University: The Transformation of Stanford*. lBerkeley: University of California Press, 1997.

Lotka, Alfred J. *Elements of Mathematical Biology*. New York: Dover Publications, 1956. Originally published as *Elements of Physical Biology*. Williams and Wilkins company, 1925.

Lucier, P. "The Professional and the Scientist in Nineteenth-Century America." *Isis* 100, 4 (2009): 699–732.

Luhmann, N. *Observations on Modernity*. Palo Alto, CA: Stanford University Press, 1998.

Luke, T. W. *Ecocritique: Contesting the Politics of Nature, Economy, and Culture*. Minneapolis: University of Minnesota Press, 1997.

Lutts, Ralph. "Chemical Fallout: Rachel Carson's Silent Spring, Radioactive Fallout and the Environmental Movement." *Environmental Review* 9, 3 (Fall 1985): 210-225.

Lytle, Mark Hamilton. *The Gentle Subversive: Rachel Carson, Silent Spring, and the Rise of the Environmental Movement*. New York: Oxford University Press, 2007.

Maienschein, J. *Transforming Traditions in American Biology, 1880-1915*. Baltimore: Johns Hopkins University Press, 1991.

Maney, David S., Frederick C. Marland, Clifford B. West, eds. *The Future of the Marshlands and Sea Islands of Georgia*. Conference on the Future of the Marshlands and Islands of Georgia at The Cloister on Sea Island, October 1968.

Marcuse, Herbert. "Industrialization and Capitalism in the Work of Max Weber." *Negations: Essays on Critical Theory*. Translated by Jeremy J. Shapiro. London May Fly Books, 2009. Originally published in *Max Weber und die Soziologie heute. Heidelberg, April 28-30, 1964*. Tübingen: J. C. B. Mohr, 1965.

---. "Ecology and Revolution." In *Ecology*, edited by Carolyn Merchant, 51-54. New Jersey: Humanities Press, 1994. Originally published in *Liberation* 16 (September 1972): 10-12.

---. *One-Dimensional Man*. New York: Routledge Press, 2002. Originally published by Beacon Press, 1964.

---. "Some Implications of Modern Technology." In *The Essential Frankfurt School Reader*, edited by Andrew Arato and Eike Gebhardt, 138-162. New York: Continuum International Publishing Group, 1978. Originally published in *Studies in Philosophy and Social Sciences* 9 (1941).

Margulis, L., Ceruti, M., Golubic, S., Guerrero, R., Ikeda, N., Ikezawa, N., Krumbein, W.E., Lapo, A., Lazcano, A., Suzuki, D., Tickell, C., Walter, M., and Westbroek, P. "Forward." In *The Biosphere: Complete Annotated Edition*. Edited by M. A. S. McMenamin, 14-9. Translated by D. B. Langmuir. 1st edition. New York: Springer-Verlag, 1998.

Marx, Karl, and Friedrich Engels. *The German Ideology,*. New York: International Publishers, 1967.

Mazuzan, George T. and J. Samuel Walker. *Controlling the Atom: The Beginnings of Nuclear Regulation 1946-1962*. Berkeley: University of California Press, 1985.

McCarthy, John D., and Mayer N. Zald. "Resource Mobilization and Social Movements: A Partial Theory." *American Journal of Sociology* 82, no. 6 (May 1, 1977): 1212–1241.

McCasland, S. Vernon. "Gabriel's Trumpet. *Journal of Bible and Religion*, 9, 3 (August 1941): 159-161.

McClelland, C. E. *State, Society, and University in Germany, 1700-1914*. New York: Cambridge University Press, 1980.

McIntosh, Robert P. *The Background of Ecology: Concept and Theory*. Cambridge:

Cambridge University Press, 1985.

---. "Ecology Since 1900." In *History of American Ecology*, edited by Frank N. Egerton, 353-372. New York: Arno Press, 1977.

McIntosh, R. P., and E. P. Odum. "Ecological succession." *Science* 166*,* 3903 (1969): 403.

McMullin, Ernan, ed. *The Social Dimensions of Science*. (1992).Studies in science and the humanities from the Reilly Center for Science, Technology, and Values. Notre Dame, IN: University of Notre Dame Press, 1992.

Meadows, Arthur Jack. *The Victorian Scientist: The Growth of a Profession*. London: British Library, 2004.

Medvetz, Thomas. "'Scholar as Sitting Duck': the Cronon Affair and the Buffer Zone in American Public Debate." *Public Culture* 24, 1 (2012): 47-54.

Melucci, Alberto. *Challenging Codes*. Cambridge: Cambridge University Press, 1996.

---. “The Process of Collective Identity.” Pp. 41-63 in *Social Movements and Culture*. Edited by Hank Johnston and Bert Klanderans. Minneapolis: University of Minnesota Press, 1995.

---. "A Strange Kinds of Newness: What's 'New' in New Social Movements?" In *New Social Movements: From Ideology to Identity*. Edited by Enrique Larana, Hank Johnston, and Joseph R. Gusfield, 101-130. Philadelphia: Temple University Press, 1994.

---. “The Symbolic Challenge of Contemporary Movements.” *Social Research* 52, 4 Winter, 1985): 789-816.

---. "The new social movements: A theoretical approach." *Social Science Information* 19 (1980): 199-226.

Merchant, Carolyn. "'The Violence of Impediments': Francis Bacon and the Origins of Experimentation." *Isis* 99 (2008): 731-760.

---, ed. *Ecology*. New Jersey: Humanities Press, 1994.

---. *The Death of Nature: Women, Ecology and the Scientific Revolution*. San Francisco: Harper and Row, 1980.

Merton, Robert K. “The Matthew Effect in Science The Reward and Communication Systems of Science Are Considered.” *Science* 159, no. 3810 (January 5, 1968): 56–

63.

---. "Forward." In *The Technological Society,* by Jacques Ellul. Translated by John Wilkinson. New York: Random House Books, 1964.

---. "The Role-Set: Problems in Sociological Theory." *The British Journal of Sociology* 8, 2 (June, 1957): 106-120.

Meyer, David S. *A Winter of Discontent: The Nuclear Freeze and American Politics*. New York: Praeger, 1990.

Meyer, David S., and Deana A. Rohlinger. “Big Books and Social Movements: A Myth of Ideas and Social Change.” *Social Problems* 59, no. 1 (February 1, 2012): 136–153.

Millar, Susan W. S. and Don Mitchell. “Spectacular Failure, Contested Success: the Project Chariot Bioenvironmental Programme.” *Cultural Geographies* 5, 3 (1998): 287-302

Miller, Richard S. “[untitled].” Review of *Fundamentals of Ecology* by Eugene Odum. *Oikos* 5, no. 1 (January 1, 1954): 134–136.

Miller, Walter. *A Canticle for Lieibowitz*. New York: Bantom Books, 1959.

Mills, C. Wright. *The Causes of World War III*. New York: Simon and Schuster, 1958.

---. *The Sociological Imagination*. New York: Oxford University Press, 2000.

Mishima, Jiro, and Eugene P. Odum. “Excretion Rate of Zn65 by Littorina Irrorata in Relation to Temperature and Body Size.” *Limnology and Oceanography* 8, no. 1 (January 1, 1963): 39–44.

Mitman, Gregg. “Where Ecology, Nature, and Politics Meet: Reclaiming the Death of Nature.” *Isis* 97 (2006): 496-504.

---. *The State of Nature: Ecology, Community, and American Social Thought, 1900-1950*. Chicago: University Of Chicago Press, 1992.

Mitsch, W. J. "Ecology, Ecological Engineering, and the Odum Brothers." *Ecological Engineering* 20 (2003): 331-338.

---. *Wetlands*. New York: Van Nostrand Reinhold Co, 1986.

Mommsen, Wolfgang J. *Max Weber and German Politics, 1890-1920*. Translated by Michael Steinberg. Chicago: University of Chicago Press, 1990.

Moore, Kelly. *Disrupting Science: Social Movements, American Scientists, and the Politics of the Military, 1945-1975*. Princeton: Princeton University Press, 2008.

Moul, Edwin T. "Two Reviews of Odum's Fundamentals of Ecology." *Ecology* 35, no. 2 (April 1, 1954): 297.

Mukerji, Chandra. *A Fragile Power: Science and the State*. Princeton: Princeton University Press, 1990.

---. *Impossible Engineering: Technology and Territoriality on the Canal du Midi*. Princeton, NJ: Princeton University Press, 2009.

Mumford, Lewis. *Interpretations & Forecasts 1922-1972: Studies in Literature, History, Biography, Technics, and Contemporary Society*. New York: Harcourt Brace Jovanovich, 1979.

---. *The Myth Of The Machine: the Pentagon Of Power* New York: Harcourt Brace Jovanovich, 1974.

---. "Prospect." In *Man's Role in Changing the Face of the Earth,* edited by William L. Thomas, Jr., 1141-52. Chicago: University of Chicago Press, 1956.

---. "The Natural History of Urbanization." In *Man's Role in Changing the Face of the Earth,* edited by William L. Thomas, Jr., 382-398. Chicago: University of Chicago Press, 1956.

---. "Closing Statement." In *Future Environments of North America*, edited by F. Fraser Darling and John P. Milton, 718-729. New York: The Natural History Press, 1966.

---. *The City In History*. New York: Harcourt Brace Jovanovich, 1961.

Murphy, Michelle. *Sick Building Syndrome and the Problem of Uncertainty: Environmental Politics, Technoscience, and Women Workers*. Durham, NC: Duke University Press Books, 2006.

---. "Uncertain Exposures and the Privilege of Imperception: Activist Scientists and Race lat the U.S. Environmental Protection Agency." *Osiris* 19(2004): 266-282.

Mythen, G. "Reappraising the Risk Society Thesis Telescopic Sight or Myopic Vision?" *Current Sociology*, 55, 6 (2007): 793–813.

Naess, Arnne. "The Shallow and the Deep, Long-Range Ecology Movement. A Summary." *Inquiry* 16(1973): 95-100.

Nakatani, R. E. and R. F. Foster. "Effect of Chronic Feeding of Sr^{90} - Y^{90} on Rainbow Trout." In *Radioecology; Proceedings of the First National Symposium on Radioecology held at Colorado State University, Fort Collins, Colorado, September 10-15, 1961,* edited by Vincent Schultz and Alfred W. Klement, 358-62. New York, Reinhold Publishing Corporation, 1963.

Nandy, Ashis. *Science, Hegemony and Violence: a Requiem for Modernity*. United Nations University, 1990.

Nathan, Debbie. "Bayou City Body Snatchers: How cold war fears fueled a hot market for Houston's human parts business," *Houston Press* (2001, November 1): 28. Accessed August 28, 2009, http://search.houstonpress.com/2001-11-01/news/bayou-city-body-snatchers/print.

Nathanson, Charles E. "The Social Construction of the 'Soviet Threat': a Study in the Politics of Representation." *Multilingua* 7, 3 (January 1988): 241-83.

National Environmental Policy Act of 1969, 42 U.S.C. §4332 (2000).

Needell, A. A. *Science, Cold War and the American State*. New York: Routledge, 2000.

Neel, J. W., and K. Larson, "Biological Availability of Strontium-90 to Small Native Animals in Fallout Patterns from the Nevada Test Site." In *Radioecology; Proceedings of the First National Symposium on Radioecology held at Colorado State University, Fort Collins, Colorado, September 10-15, 1961,* edited by Vincent Schultz and Alfred W. Klement, 45-50. New York, Reinhold Publishing Corporation, 1963.

Nelkin, D. *Controversy: Politics of technical decisions*. Thousand Oaks, CA: Sage Publications, 1979.

Newcombe, C. L., John F. Reed, Frederick H. Test, R. F. Salmonson, W. D. Billings, Edward S. Deevey Jr., LaMont C. Cole, Henry J. Oosting, E. J. Dyksterhuis, Paul B. Sears, Donald B. Lawrence, Jas. A. Macnab, J. P. Scott, Herbert C. Hanson, J. J. Hickey, J. Speed Rogers, Francis C. Evans, Robert B. Platt, Eugene P. Odum, Willis A. Eggler, Robert A. Darrow, Lee R. Dice, W. A. Dayton, James A. Macnab, Ethan D. Churchill. "Report of the Western Section Meetings at Berkeley, December, 1954." *Bulletin of the Ecological Society of America* 36, 1 (1955): 12-35.

Nicolson, Malcolm. "Humboldtian Plant Geography After Humboldt: The Link to Ecology." *The British Journal for the History of Science* 29, no. 3 (1996): 289–310.

---. "Henry Allan Gleason and the Individualistic Hypothesis: The Structure of a Botanist's Career." *Botanical Review* 56, no. 2 (April 1, 1990): 91–161.

---. “Alexander von Humboldt, Humboldtian Science, and the Origins of the Study of Vegetation.” *History of Science* 25, 2 (June 1987): 167-94.

Nicolson, Malcolm, Robert P. McIntosh, and M. Nicholson. “H. A. Gleason and the Individualistic Hypothesis Revisited.” *Bulletin of the Ecological Society of America* 83, no. 2 (April 1, 2002): 133–142.

Noble, David F. *America by Design: Science, Technology, and the Rise of Corporate Capitalism*. Oxford University Press, 1979.

Norman, D. A. *The Design of Everyday Things*. New York: Basic Books, 2002.

Nowotny, H. "How Many Policy Rooms Are There? Evidence-Based and Other Kinds of Science Policies." *Science, Technology, and Human Values* 32, 4 (2007): 479–490.

Nye, Mary Jo. “Scientific Biography: History of Science by Another Means?” *Isis* 97, 2 (June 1, 2006): 322–329.

Nyhart, L. K. *Biology Takes Form: Animal Morphology and the German Universities, 1800-1900*. Science and its conceptual foundations. Chicago: University of Chicago Press, 1995.

Nyhart, Lynn. “Natural history and the ‘new’ biology.” In *Cultures of Natural History*, edited by Jardine et al, 426-443. Cambridge: Cambridge University Press, 1996.

Palladino, Paolo. “Defining Ecology: Ecological Theories, Mathematical Models, and Applied Biology in the 1960s and 1970s.” *Journal of the History of Biology* 24, no. 2 (July 1, 1991): 223–243.

Ocay, Jeffrey V. "Technology, Technological Domination, and the Great Refusal: Marcuse's Critique of Advanced Industrial Society." *Kritike* 4, 1 (June 2010): 54-78.

Odum, Eugene P. "Variations in the Heart Rate of Birds: A Study in Physiological Ecology." *Ecological Monographs*, 11, 3 (1941): 299-326.

---. "Annual Cycle of the Black-Capped Chickadee." *The Auk* 58, 3 (1941): 314–333.

---. The Vegetation of the Edmund Niles Huyck Preserve, New York. *American Midland Naturalist*, 29, 1 (1943), 72-88.

---. "The concept of the biome as applied to the distribution of North American birds." *The Wilson Bulletin* 57, 3 (1945), 191–201.

---. "The Heart Rate of Small Birds." *Science* 101, 2615 (1945): 153.

---. *Fundamentals of Ecology*. Philadelphia: W.B. Saunders Company, 1953.

---. "Consideration of the Total Environment in Power Reactor Waste Disposal." *Proceedings of the International Conference on the Peaceful Uses of Atomic Energy* 13 (1955): 350-8.

---. "Ecological Aspects of Waste Disposal." In *A Conference on Radioactive Isotopes in Agriculture: Held on January 12, 13 and 14, 1956, at Michigan State University, East Lansing, Michigan*. Argonne National Laboratory, 95-104. U. S. Atomic Energy Commission, 1956.

---. "A.I.B.S. Meetings, Storrs, Connecticut, Pre-Meeting Foray, August 23-26, Annual Meeting, August 27-29, Post-Meeting Foray, August 30-31." *Bulletin of the Ecological Society of America* 37, 2 (1956): 47-48.

---. "The Ecosystem Approach in the Teaching of Ecology Illustrated with Sample Class Data." *Ecology* 38, 3 (1957): 531-535.

---. *Fundamentals of Ecology*. 2nd edition. Philadelphia: WB Saunders Company. 1959.

---. "Organic Production and Turnover in Old Field Succession." *Ecology* 41, (1960): 34-49.

---. "The Role of Tidal Marshes in Estuarine Production." *New York State Conservationist* (June - July 1961): 12-5.

---. "Relationship Between Structure and Function in the Ecosystem." *Japanese Journal of Ecology* 12, 3 (1962): 108-118.

---. "Primary and Secondary Energy Flow in Relation to Ecosystem Structure." (Paper presented at the International Congress of Zoology, Washington D. C., August 20-7, 1963). In *Proceedings of the 16th International Congress of Zoology, 1963.* Vol. 4, Specialized Symposia. Edited by John A. Moore, 336-8. Washington, D. C.: National Academies, 1963.

---. *Ecology*. Modern biology series. New York: Holt, Rinehart and Winston, 1963.

---. "Panel Discussion on Education and Research Training." In *Radioecology; Proceedings of the First National Symposium on Radioecology held at Colorado State University, Fort Collins, Colorado, September 10-15, 1961,* edited by Vincent Schultz and Alfred W. Klement, 643-645. New York, Reinhold Publishing Corporation, 1963.

---. "The New Ecology." *BioScience* 14 (1964): 14-16.

---. "President's Report." *Bulletin of the Ecological Society of America* 47, 1 (March 1966): 8-10.

---. "Alfred C. Redfield, Eminent Ecologist: 1966." *Bulletin of the Ecological Society of America* 47*,* 4 (1966): 166-167.

---. "The Watershed as an Ecological Unit." In *The Cuyahoga River Watershed; Proceedings of a Symposium Held at Kent State University, Kent, Ohio, November 1, 1968*, edited by Dennis G, Cooke. Kent, Ohio: Kent State University Institute of Liminology, 1969.

---. "Energy Flow in Ecosystems: a Historical Review." *American Zoologist 8*, 1 (1968): 11-18.

---. "A Proposal for a Marshbank and the Statewide Zoning of Estuarine, Georgia." In *The Future of the Marshlands and Sea Islands of Georgia,* edited by David Maney et al. (paper presented at the Conference on the Future of the Marshlands and Islands of Georgia at The Cloister on Sea Island, October 1968).

---. "The Strategy of Ecosystem Development." *Science* 164, 3877 (April, 1969): 262-270.

---. "Editorial: The Attitude Lag." *BioScience* 19*,* 5 (1969): 403.

---. *Fundamentals of Ecology*. 3rd edition. Philadelphia: WB Saunders Company, 1971.

---. "The Pricing System." *Georgia Conservancy Magazine* (Fourth quarter 1973): 8-10.

---. "Frank Golley, President, 1976-77." *Bulletin of the Ecological Society of America* 57*,* 3 (1976): 7.

---. "Energy, Ecosystem Development and Environmental Risk." *The Journal of Risk and Insurance*, *43,* 1 (1976): 1-16.

---. "Earth as a Productive System." *Science* 193, 4248 (1976): 138.

---. "The Emergence of Ecology as a New Integrative Discipline." *Science* 195*,* 4284 (1977): 1289-1293.

---. "Diversity and the Emergence of Integrative Disciplines in Universities." Paper presented at the Forty-first Annual Meeting of the Southern University Conference, Birmingham, AL, 1978.

---. "Rebuttal of 'Economic Value of Natural Coastal Wetlands: A Critique." *Coastal Zone*

Management Journal 5 (1979): 231-7.

---. "Preface." In *The Ecology of a Salt Marsh*. edited by L. R. Pomeroy and R. G. Wiegert. New York: Springer-Verlag, 1981.

---. “Wetlands and Their Values.” *Journal of Soil and Water Conservation* 38, no. 5 (September 1, 1983): 380.

---. *Basic Ecology*. Fort Worth, TX: Harcourt Brace College Publishing, 1983.

---. "The Mesocosm." *BioScience* 34*,* 9 (1984): 558-562.

---. "Wetlands as Vital Components of the Nation's Water Resources." In *The Water Resources of Georgia and Adjacent Areas*, edited by Ram Arora and Lee Gorday, 88-92. Georgia Geologic Survey Bulletin 99, Atlanta: Georgia Department of Natural Resources, 1984.

---. "Biotechnology and the Biosphere." *Science* 229*,* 4720 (1985): 1338.

---. "Trends Expected in Stressed Ecosystems." *BioScience* 35*,* 7 (1985): 419-422.

---. "S. Charles Kendeigh, 1904-1986." *Bulletin of the Ecological Society of America*, 68*,* 4 (1987): 508-509.

---. *Ecology and Our Endangered Life Support System*. Sunderland, MA: Sinauer Associates Inc., 1989.

---. "Input Management of Production Systems." *Science* 243*,* 4888 (1989), 177-182.

---. "Great ideas in ecology for the 1990s." *BioScience* 42*,* 7 (1992): 542–545.

---. "Biosphere 2: A New Kind of Science." *Science* 260*,* 5110 (1993): 878.

---. *Ecology and Our Endangered Life-Support Systems*. 2nd ed. Sunderland, MA: Sinauer Associates, 1993.

--- *Ecological Vignettes: Ecological Approaches to Dealing with Human Predicaments*. Amsterdam: Harwood Academic Publishers, 1998.

---. *Ecology: A Bridge Between Science and Society*. 3rd ed. Sunderland, MA: Sinauer Associates, 1997. Originally published as *Ecology and Our Endangered Life Support System*. Sunderland, MA: Sinauer Associates Inc., 1989.

---. “Turning Points in the History of the Institute of Ecology.” In *Holistic Science: The Evolution of the Georgia Institute of Ecology (1940-2000)* edited by Gary W. Barrett and Terry Lynn Barrett, 13-37. New York: Taylor and Francis, 2001.

Odum, Eugene P., Clyde E. Connell, and Leslie B. Davenport. “Population Energy Flow of Three Primary Consumer Components of Old-Field Ecosystems.” *Ecology* 43, no. 1 (January 1, 1962): 88–96.

Odum, Eugene P., and Frank Golley. "Radioactive Tracers as an Aid to the Measurement of Energy Flow at the Population Level in Nature." In *Radioecology; Proceedings of the First National Symposium on Radioecology held at Colorado State University, Fort Collins, Colorado, September 10-15, 1961,* edited by Vincent Schultz and Alfred W. Klement, 403-410. New York, Reinhold Publishing Corporation, 1963.

Odum, Eugene P., and Howard T. Odum. "Natural Areas as Necessary Components of Man's Total Environment." In *Ecological Vignettes: Ecological Approaches to Dealing with Human Predicaments*. 133-43. Amsterdam: Harwood Academic Publishers, 1998. Originally published in Transactions of the 37th North American Wildlife and Natural Resources Conference. March 12-15, 1972. Washington, D. C.: Wildlife Management Institute.

Odum, Howard T. "The Stability of the World Strontium Cycle." *Science* 114 (1951): 407-411.

---. “Trophic Structure and Productivity of Silver Springs, Florida.” *Ecological Monographs* 27, no. 1 (January 1, 1957): 55–112.

Odum, Howard T. and Eugene P. Odum. “Trophic Structure and Productivity of a Windward Coral Reef Community on Eniwetok Atoll.” *Ecological Monographs* 25, 3, (July 1955): 291-320.

Odum, E.P., and A. Pontin. "Population density of the underground ant, Lasius flavus, as determined by tagging with P32." *Ecology* (1961): 186–188.

Odum, E.P., C. E. Connell, and L. B. Davenport. "Population energy flow of three primary consumer components of old-field ecosystems." *Ecology* (1962): 88–96.

Odum, E.P., S. G. Marshall, and T. G. Marples. "The caloric content of migrating birds." *Ecology* (1965): 901–904.

Odum, Eugene P., and A. A. de la Cruz. "Detritus as a Major Component of Ecosystems." *AIBS Bulletin 13,* 3 (1963): 39-40.

Odum, Eugene P., S. I. Auerbach, A. L. Evans, P. Frank, F. Stearns, P. Martin, and A. D. Hasler. [Proceedings]. *Bulletin of the Ecological Society of America*, *47,* 1 (1966): 6-31.

Odum, E. P., and Edward J. Kuenzler. "Experimental Isolation of Food Chains in Old-Field Ecosystem with the use of Phosphorus-32." In *Radioecology; Proceedings of the First National Symposium on Radioecology held at Colorado State University, Fort Collins, Colorado, September 10-15, 1961,* edited by Vincent Schultz and Alfred W. Klement, 113-120. New York, Reinhold Publishing Corporation, 1963.

Odum, H. T., and E. P. Odum. "Trophic structure and productivity of a windward coral reef community on Eniwetok Atoll," *Ecological Monographs* (1955): 291–320.

Odum, Howard T. *Environment, Power, and Society*. New York: Wiley-Interscience, 1970.

Odum, W. E., E. P. Odum, and H. T. Odum. "Nature's Pulsing Paradigm," *Estuaries*, 18*,* 4 (1995): 547-555.

Odum, E. P., P. Williams, D. A. Silvian, S. Culpepper, G. Gilland, M. Smith, and M. L. Barrett. *Eugene Odum [videorecording] : an Ecologist's Life / Writer-producer, Phil Williams ; Producer-director, David Allen Silvian*. Athens, GA : University of Georgia, 1996.

Oleson, Alexandra, and John Voss, eds. *The Organization of Knowledge in Modern America, 1860-1920*. Baltimore: Johns Hopkins University Press, 1979.

Olson, Jerry S. "Analog Computer Models for Movement of Radionuclides through Ecosystems." In *Radioecology; Proceedings of the First National Symposium on Radioecology held at Colorado State University, Fort Collins, Colorado, September 10-15, 1961,* edited by Vincent Schultz and Alfred W. Klement, 121-6. New York, Reinhold Publishing Corporation, 1963.

O'Neill, Dan. *Firecracker Boys*. New York: St. Martin's Press, 1994.

Oreskes, N. "Science, Technology and Free Enterprise." *Centaurus* 52(2010):297-310.

---. "A Context of Motivation: U.S. Navy Oceanographic Research and the Discovery of Sea-Floor Hydrothermal Vents." *Social Studies of Science* 33, 4 (2003), 697-742.

---. "Introduction." In *Nation and Knowledge: Science and Technology in the Global Cold War,* edited by Naomi Oreskes and John Krige. Cambridge, MA: MIT Press, forthcoming.

Oreskes, N., and E. M. M. Conway, *Merchants of Doubt: How a Handful of Scientists Obscured the Truth on Issues from Tobacco Smoke to Global Warming,* New York: Bloomsbury Press, 2010.

---. *Nation and Knowledge: Science and Technology in the Global Cold War*. Forthcoming.

Orians, Gordon H."A Diversity of Textbooks: Ecology Comes of Age." Science 181 (1973): 1238-39.

O'Rourke, Dennis. *Half-Life: A Parable for the Nuclear Age*. Cairns - Queensland, Australia: Camerawork Lrd., 1986. Videocassette (VHS), 86min.

"overkill." *Oxford English Dictionary*, 3rd edition, December 2004. Accessed April 15, 2011, http://www.oed.com/view/Entry/134730. An entry for this word was first included in *A Supplement to the OED* III, 1982.

Owen, David. *Maturity and Modernity: Nietzsche, Weber, Foucault and the Ambivalence of Reason*. New York: Routledge, 1994.

Owen, David S. and Tracy B. Strong. "Max Weber's Calling to Knowledge and Action." In *The Vocation Lectures: Science As a Vocation, Politics As a Vocation*, edited by David S. Owen and Tracy B. Strong, ix-lxii. Indianapolis, IN: Hackett Publishing Company, 2004.

Pauling, Linus. *No More War!* 25th anniversary ed. Dodd, Mead, 1983.

Pauly, P. J. *Biologists and the Promise of American Life: From Meriwether Lewis to Alfred Kinsey*. Princeton, N.J: Princeton University Press, 2000.

Parascandola. Mark, "Uncertain Science and a Failure of Trust: The NIH Radioepidemiologic Tables and Compensation for Radiation-Induced Cancer." *Isis* 93, 4 (2002): 559-584.

Pearson, P. G., L. D. McChesney, J. Major, W. A. Niering, H. J. Oosting, Kirby L. Hays, and A. C. "Proceedings," *Bulletin of the Ecological Society of America*, *45,* 1 (1964): 7-31.

Pearson, P. G., K. Pittsburg, F. A. Pitelka, F. Stearns, A. D. Hasler, J. E. Cantlon, S. Cain. "1965 Annual Meeting, Urbana, Illinois, August 15-20, 1965," *Bulletin of the Ecological Society of America*, 46, 1 (1965): 3-26.

Pichardo, Nelson A. "New Social Movements: a Critical Review." *Annual Review of Sociology* 23 (1997): 411-430.

Pielke, Roger. "In Retrospect: Science - The Endless Frontier." *Nature* 466 (August 19, 2010): 922-3.

Pierpaoli, Paul G. *Truman and Korea: The Political Culture of the Early Cold War.*

Columbia: University of Missouri Press, 1999.

Pinch, T. J. and H. M. Collins, "Private Science and Public Knowledge: The Committee for the Scientific Investigation of the Claims of the Paranormal and its Use of the Literature." *Social Studies of Science* 14 (1984):521-46.

Pomeroy, L. R., and Donald C. Scott. "The University of Georgia Marine Institute: The First Decade." In *Holistic Science: The Evolution of the Georgia Institute of Ecology (1940-2000)* edited by Gary W. Barrett and Terry Lynn Barrett, 128-142. New York: Taylor and Francis, 2001.

Pomeroy, L.R. and R. G. Wiegert, eds. *The Ecology of a Salt Marsh*. New York: Springer-Verlag, 1981.

Porter, Theodore M. "How Science Became Technical." *Isis* 100, no. 2 (June 1, 2009): 292–309.

---. "Is the Life of the Scientist a Scientific Unit?" *Isis* 97, no. 2 (June 1, 2006): 314–321.

---. *Trust in Numbers*. Princeton, NJ: Princeton University Press, 1996.

---. *The Rise of Statistical Thinking, 1820-1900*. Princeton, NJ: Princeton University Press, 1988.

Posner, R. A. *Public Intellectuals: A Study of Decline, With a New Preface and Epilogue*. Cambridge, MA: Harvard University Press, 2003.

"President Eugene Odum." *Bulletin of the Ecological Society of America* 45, 4 (December, 1964): 129-30.

Price, D. D. S. *Little Science, Big Science...and Beyond*. New York: Columbia University Press, 1986.

Proctor, Robert. *Cancer Wars: How Politics Shapes What We Know and Don't Know About Cancer.* New York: Basic Books, 1995.

---. *Value Free Science? Purity and Power in Modern Knowledge*. Cambridge, MA: Harvard University Press, 1991.

Rabinow, P. *Anthropos Today: Reflections on Modern Equipment,* Princeton, NJ: Princeton University Press, 2003.

---. *French DNA: Trouble in Purgatory*. Chicago: University Of Chicago Press, 1999.

Radiobiological Survey of Bikini, Eniwetok, and Likiep Atolls, UWFL-23. United States

Atomic Energy Commission, 1950.

Radiobiological Studies at Eniwetok Atoll Before and Following the Mike Shot of November 1952 testing Program, UWFL-33. United States Atomic Energy Commission, 1953.

Richards, Joan L. "Introduction: Fragmented Lives." *Isis* 97, no. 2 (June 1, 2006): 302–305.

Richards, Robert J. *The Romantic Conception of Life: Science and Philosophy in the Age of Goethe*. Chicago: University of Chicago Press, 2004.

Ringer, Fritz K. "Admissions." In *Universities in the Nineteenth and Early Twentieth Centuries (1800-1945),* edited by Walter Rüegg, 233-267. New York: Cambridge University Press, 2004.

---. "The German Academic Community." In *The Organization of Knowledge in Modern America, 1860-1920*, edited by Alexandra Oleson and John Voss, 409-29. Baltimore: Johns Hopkins University Press, 1979.

Ringer, Fritz K. "[untitled]." *Central European History* 11, no. 1 (March 1, 1978): 107–113.

---. *The Decline of the German Mandarins; the German Academic Community, 1890-1933*. Cambridge, MA: Harvard University Press, 1969.

Risser, P. G. "Systems Failures on Spaceship Earth," *BioScience*, *39,* 11 (1989): 814-815.

Radiobiological Survey of Bikini, Eniwetok, and Likiep Atolls, *UWFL-23*. United States Atomic Energy Commission, 1950.

Radiobiological Studies at Eniwetok Atoll Before and Following the Mike Shot of November 1952 testing Program, UWFL-33. United States Atomic Energy Commission, 1953.

"Random Notes in Washington," *New York Times*, September 2, 1957, 7.

Rhodes, Richard, *Dark Sun: The Making of the Hydrogen Bomb*. New York: Simon and Schuster, 1996.

---. *The Making of the Atomic Bomb*. New York: Simon and Schuster, 1986.

Rosenberg, Charles. "Toward an Ecology of Knowledge: On Discipline, Context and History." In *The Organization of Knowledge in Modern America, 1860-1920*, edited by Alexandra Oleson and John Voss, 440-455. Baltimore: Johns Hopkins University

Press, 1979.

Dorothy Ross. "The Development of the Social Sciences." In *The Organization of Knowledge in Modern America, 1860-1920*, edited by Alexandra Oleson and John Voss, 107-138. Baltimore: Johns Hopkins University Press, 1979.

Ross, Sydney. "Scientist: the Story of a Word." *Annals of Science* 18, 2 (June 1962): 65-85.

Rootes, Christopher. "Environmental Movements." In *The Blackwell Companion to Social Movements,* edited by David A. Snow, Sarah A. Soule and Hanspeter Kriesi, 608-640. New York: Blackwell Publishing, 2007.

---. *Environmental Movements: Local, National, and Global*. New York: Routledge, 1999.

Rudd, Robert L. *Pesticides and the Living Landscape*. Madison: University of Wisconsin Press, 1964.

Rüegg, Walter. "Themes." In *Universities in the Nineteenth and Early Twentieth Centuries (1800-1945),* edited by Walter Rüegg, 3-32. New York: Cambridge University Press, 2004.

Russell, Edmund. *War and Nature: Fighting Humans and Insects with Chemicals from World War I to Silent Spring*. New York: Cambridge University Press, 2001.

Said, E. W. *Representations of the Intellectual: The 1993 Reith Lectures*. Vintage, 1996.

Schmidt, J. *Disciplined Minds: A Critical Look at Salaried Professionals and the Soul-Battering System That Shapes Their Lives*. Lanham, Md: Rowman and Littlefield, 2000.

Schultz, Vincent and Alfred W. Klement eds. *Radioecology; Proceedings of the First National Symposium on Radioecology held at Colorado State University, Fort Collins, Colorado, September 10-15, 1961.* New York, Reinhold Pub. Corp, 1963.

Schumacher, E. F. *Small Is Beautiful; Economics as If People Mattered*. New York: Harper and Row, 1973.

Schwarz, Astrid, and Kurt Jax, eds. *Ecology Revisited: Reflecting on Concepts, Advancing Science*. New York: Springer, 2011.

Schweber, Silvan S. “J. Robert Oppenheimer: Proteus Unbound.” *Science in Context* 16, 1–2 (2003): 219–242.

Sears, Paul. *Deserts on the March.* Washington D. C.: Island Press, 1988. Originally published by University of Oklahoma Press, 1935.

---. "[untitled]." *The Journal of Geology* 58, no. 1 (January 1, 1950): 87.

---. "Biologists and Conservation of Natural Resources." *AIBS Bulletin* (July 19-21, 1953): 19-21.

---. "Human Ecology: A Problem in Synthesis." Paper For Ecological Society of America Sept. 8, 1954 at Gainesville, FL. Reprinted in *Science* 120*,* 3128 (1954): 959-63.

---. "Changing Man's Habitat: Physical and Biological Phenomena. *Yearbook of Anthropology* (1955):31-46.

---. "Some Notes on the Ecology of Ecologists." *The Scientific Monthly* (July 1956): 22-7.

---. "Botanists and the Conservation of Natural Resources," *American Journal of Botany* 43, 9 (1956): 731-735.

---. "The Processes of Environmental Change by Man." in *Man's Role in Changing the Face of the Earth,* edited by William L. Thomas, Jr., 471-484. Chicago: University of Chicago Press, 1956.

---. "Dedication of the New AAAS Headquarters Building," *The Scientific Monthly*, *84,* 1 (1957): 24-25.

---. "Natural and Cultural Aspects of Floods," *Science*, New Series, *125,* 3252 (1957): 806-807.

---. *The Ecology of Man.* Condon Lectures. Eugene, OR: University of Oregon Press, 1957.

---. "The Roles of Science and Ethics." New York University Address August 28, 1958. Reprinted in *The American Journal of Economics and Sociology* 8, 18 (1958):103-104.

---. "The Place of Ecology in Science." *The American Naturalist* 94, 876 (May-June 1960):193-200.

---. *The Biology of the Living Landscape: An Introduction to Ecology*. London: George Allen and Untin Ltd, 1962.

---. "Ecology-A Subversive Subject." *BioScience* 14, 7 (1964): 11-13.

---. "The Inexorable Problem of Space," in *The Subversive Science: Essays Toward an*

Ecology of Man, ed. Paul Shepard and Daniel McKinley. New York: Houghton Mifflin, 1969. Originally published in *Science* 127 (1958): 9-16.

---. "The Steady State," in *The Subversive Science: Essays Toward an Ecology of Man*, ed. Paul Shepard and Daniel McKinley, 395-401. New York: Houghton Mifflin, 1969. Originally published in *The Key Reporter* 24, 2, Jan (1959): 2-3, 8.

---. "Reflections on Science Writing." *The American Biology Teacher* October (1972): 396-399.

Secord, Anne. ": Samuel Smiles, Thomas Edward, and the Making of a Working-Class Scientific Hero." *Science in Context* 16, 1–2 (2003): 147–173.

Seidel, Robert W. "The national laboratories of the Atomic Energy Commission in the early Cold War," *Historical Studies in the Physical and Biological Sciences* 32 (2001): 145-162.

---. "The Origins of the Lawrence Berkeley Laboratory." In *Big Science: The Growth of Large-Scale Research*, edited by P. Galison, 21-45. Stanford, CA: Stanford University Press, 1994.,

Semendeferi, Ioanna, "Legitimating a Nuclear Critic: John Gofman, Radiation Safety, and Cancer Risks," *Historical Studies in the Natural Sciences* 38, 2 (2008): 259–301.

Shabman, Leonard A., and Sandra S. Batie. "Economic Value of Natural Coastal Wetlands: A Critique." *Coastal Zone Management Journal* 4, no. 3 (1978): 231–247.

Shapin, Steven, *The Scientific Life: A Moral History of a Late Modern Vocation*. Chicago: University of Chicago Press, 2008.

---. "Hyperprofessionalism and the Crisis of Readership in the History of Science." *Isis* 96, 2 (2005): 238-243

---. *A Social History of Truth: Civility and Science in Seventeenth-Century England*. Chicago: University of Chicago Press, 1995.

---. "Cordelia's Love: Credibility and the Social Studies of Science," *Perspectives on Science* 3, 3 (1995): 255-75.

---. "Personal Development and Intellectual Biography: the Case of Robert Boyle," *British Journal for the History of Science* 26 (1993): 335-345.

---. "The House of Experiment in Seventeenth-Century England." *Isis* 79, 3 (1988), 373–404.

Shapin, Steven, and Simon Schaffer. *Leviathan and the Air-Pump: Hobbes, Boyle, and the Experimental Life.* Princeton, NJ: Princeton University Press, 1985.

Sharp, Malcolm. "No More War!" *Bulletin of the Atomic Scientists*. 15, 1 (January 1959): 44-46.

Shellenberger, Michael, and Ted Nordhaus. *The Death of Environmentalism: Global Warming Politics in a Post-environmental World*. Breakthrough Institute, 2004.

Shepard, Paul. *Man in the Landscape: a Historical View of the Aesthetics of Nature*. Forward by Dave Foreman. Athens, GA: University of Georgia Press, 2002.

---. "Ecology and Man--a Viewpoint." In *The Subversive Science: Essays Toward an Ecology of Man* edited by Paul Shepard and Daniel McKinley, 1-10. New York: Houghton Mifflin, 1969.

---. “Whatever Happened to Human Ecology?” *BioScience* 17, no. 12 (December 1, 1967): 891–911.

---. “The Place of Nature in Man’s World.” *Atlantic Naturalist* 13 (April - June 1958): 85-89.

Shepard, Paul and Daniel McKinley, eds. *The Subversive Science: Essays Toward an Ecology of Man*. New York: Houghton Mifflin, 1969.

Sherry, Michael S. *In the Shadow of War: The United States Since the 1930s*. New Haven, CN: Yale University Press, 1995.

Shils, Edward. *The Calling of Education: “The Academic Ethic” and Other Essays on Higher Education*. Edited by Steven Grosby. Chicago: University of Chicago Press, 1997.

---. *The Order of Learning: Essays on the Contemporary University*. Edited by Philip G. Altbach. New Brunswick, NJ.: Transaction Publishers, 1997.

---. "The Order of Learning in the United States: The Ascendancy of the University." In *The Organization of Knowledge in Modern America, 1860-1920*, edited by Alexandra Oleson and John Voss, 19-50. Baltimore: Johns Hopkins University Press, 1979.

Shrader-Frechette, K. S. *Burying Uncertainty: Risk and the Case Against Geological Disposal of Nuclear Waste*. Berkeley: University of California Press, 1993.

---. *Risk and Rationality: Philosophical Foundations for Populist Reforms*. Berkeley: University of California Press, 1991.

Shrader-Frechette, K. S., and L. Westra. *Technology and Values*. New York: Rowman and Littlefield, 1997.

Shukaitis, Stevphen, and David Graeber. "Introduction." In *Constituent Imagination: Militant Investigations, Collective Theorization*. Edited by Stevphen Shukaitis and David Graeber, 11-34. Oakland, CA: AK Press, 2007.

Slack, N. G. *G. Evelyn Hutchinson and the Invention of Modern Ecology*. Yale University Press, 2011.

Slayton, Rebecca. "Discursive Choices: Boycotting Star Wars Between Science and Politics." *Social Studies of Science* 37, no. 1 (February 1, 2007): 27–66.

Slobodkin, L. B. *A Citizen's Guide to Ecology*. Oxford ; New York: Oxford University Press, 2003.

Smocovitis, Vassiliki Betty. *Unifying Biology*. Princeton, NJ: Princeton University Press, 1996.

Smuts, J. C. *Holism and Evolution*. New York: The MacMillan Company, 1926.

Soeters, Joseph, and Ad van. Iterson. "Blame and Praise Gossip in Organizations: Established, Outsiders, and the Civilizing Process." In *The Civilized Organization: Norbert Elias and the Future of Organization Studies*. Edited by Ad van. Iterson, Willem Mastenbroek, Tim Newton, and Dennis Smith, 25-40. Philadelphia: John Benjamins Publishing Company, 2002.

Sonnert, G. *Ivory Bridges: Connecting Science and Society*. Cambridge, Mass: MIT Press, 2002.

Spear, Joseph H. *The Sociology of Reductionism: A Case Study of the "Neuroscience Explosion."* (PhD diss, University of Virginia, 2000).

"specialist." *Oxford English Dictionary* 2nd edition, 1989; online version June 2012. Accessed April 15, 2012, http://www.oed.com/view/Entry/18597. An entry for this word was first included in *New English Dictionary*, 1913.

"specialization." *Oxford English Dictionary* 2nd edition, 1989; online version June 2012. <http://www.oed.com/view/Entry/185979>;

accessed 01 August 2012. Earlier version first published in *New English Dictionary*, 1913.

Speth, Gus. "Introduction." In *Deserts on the March,* by Paul Sears, xi-xv. Washington D.C.: Island Press, 1988.

Starr, C. "Social Benefit versus Technological Risk," *Science* 165*,* 3899 (1969):1232–1238.

Starr, C. and C. Whipple. "A Perspective on Health and Safety Risk Analysis. *Management Science*, *30, 4* (1984): 452–463.

Star, Susan Leigh, and James R. Griesemer. “Institutional Ecology, ‘Translations’ and Boundary Objects: Amateurs and Professionals in Berkeley’s Museum of Vertebrate Zoology, 1907-39.” *Social Studies of Science* 19, 3 (1989): 387–420.

Stilgoe, Jack. *Citizen Scientists: Reconnecting Science with Civil Society*. London: Demos, 2009. Accessed August 2011, http://www.demos.co.uk/publications/citizenscientists.

Stoll, Mark. "Rachel Carson's Silent Spring, a Book that Changed the World." Environment and Society Portal. Accessed May 25, 2012, http://www.environmentandsociety.org/exhibitions/silent-spring/overview.

Strack, Barbara Smith, ed. *Savannah River Site at Fifty*. Washington DC: Department of Energy. Stone Mountain, GA: New South Associates, 2002

Sutton, P. W. *Explaining Environmentalism: In Search of a New Social Movement*. Burlington, VT: Ashgate, 2000.

Sylves, Richard T. *Nuclear Oracles: a Political History of the General Advisory Committee of the Atomic Energy Commission, 1947-1977*. Ames, IA: Iowa State University Press, 1987.

Szerszynski, Bronislaw, Scott Lash, and Brian Wynne. "Ecology, Realism, and the Social Sciences. In *Risk, Environment, and Modernity: Towards a New Ecology*. Ed. Scott Lash, Bronislaw Szerszynski, and Brian Wynne, 1-26. Thousand Oaks, CA, Sage Publications, 1996.

Tansley, A. G. “The Aims of the New Journal.” *Journal of Ecology* 1, no. 1 (March 1, 1913): 1–3.

---. "The Use and Abuse of Vegetational Concepts and Terms." *Ecology* 16, No. 3. (July 1935): 284-307

Tarr, Joel, *The Search for the Ultimate Sink: Urban Pollution in Historical Perspective*. Akron, OH: University of Akron Press, 1996.

Taylor, Peter J. "Technocratic Optimism, H.T. Odum and the Partial Transformation of the Ecological Metaphor after World War II," *Journal of the History of Biology* 21 (1988):213-244.

Teal, John M. “Energy Flow in the Salt Marsh Ecosystem of Georgia.” *Ecology* 43, no. 4 (October 1, 1962): 614–624.

Terrall, Mary. “Biography as Cultural History of Science.” *Isis* 97, 2 (June 1, 2006): 306–313.

Tesh, Sylvia Noble, *Uncertain Hazards: Environmental Activists and Scientific Proof*. Ithaca, NY: Cornell University Press, 2000.

Thackray, Arnold, and Robert K. Merton. “On Discipline Building: The Paradoxes of George Sarton.” *Isis* 63, no. 4 (December 1, 1972): 473–495.

“The New York Meeting.” *Bulletin of the Ecological Society of America* 1, no. 1 (January 1, 1917).

"The Threatened Marshes of Glynn." *Time* (November 14, 1969): 88-93.

Thomas, J. "Max Weber’s Estate: Reflections on Wilhelm Hennis’s Max Webers Wissenschaft Vom Menschen." *History of the Human Sciences*, *11,* 2 (1998): 121–128.

Thorpe, Charles, "Review of Storm: Meteorologists and the Culture of Prediction, by Gary Alan Fine." *Contemporary Sociology,* 38*, 2 (2009): 136–137.*

---. “Alienation as Death: Technology, Capital, and the Degradation of Everyday Life in Elmer Rice's The Adding Machine” *Science as Culture* 18, 3 (2009): 261-279.

---. “Community and the Market in Michael Polanyi’s Philosophy of Science,” *Modern Intellectual History* 6 (2009): 59-89.

---. “A Splintered Function: Fate, Faith and the Father of the Atomic Bomb,” *Metascience* 17 (2008): 351-387.

---. “Capitalism, Audit, and the Demise of the Humanistic Academy.” *Workplace: A Journal for Academic Labor* 15, September (2008): 103-125**.** Accessed June 6, 2009, http://ojs.library.ubc.ca/index.php/workplace/article/view/182219/182230.

---. *Oppenheimer: the Tragic Intellect*. Chicago: University of Chicago Press, 2006.

---. “Violence and the Scientific Vocation.” *Theory, Culture and Society* 21, 3, (2004): 59-84.

---. "Disciplining Experts: Scientific Authority and Liberal Democracy in the Oppenheimer Case." *Social Studies of Science*, 32, 4 (2002): 525–562.

---. “Science Against Modernism: The Relevance of the Social Theory of Michael Polanyi.” *The British Journal of Sociology* 52, 1 (March 1, 2001): 19–35.

---. "Atomic Spaces and American Culture," *Social Studies of Science*, 29, 4, (1999): 617–627.

Charles Thorpe and Brynna Jacobson. "Life Politics, Nature, and the State: Giddens' Sociological Theory and the The Politics of Climate Change." *The British Journal of Sociology.* Forthcoming.

Thorpe, Charles, and Steven Shapin, "Who Was J. Robert Oppenheimer? Charisma and Complex Organization," *Social Studies of Science*, 30, 4 (2000), 545–590.

Thorpe, Charles, and Ian Welsh, “Beyond Primitivism: Towards a Twenty-First Century Anarchist Theory and Praxis for Science and Technology,” *Anarchist Studies* 16, 1 (2008): 48-75.

"The Philosophers' Stone," *Time*, August 15, 1955. Monday August 15. Accessed August 28, 2010, http://www.time.com/time/magazine/article/0,9171,807508,00.html.

Thompson, E. P. “Notes on Exterminism, the Last Stage of Civilization,” *New Left Review* 121, May-Jun. (1980): 3-31.

Tobey, Ronald C. *Saving the Prairies: The Life Cycle of the Founding School of American Plant Ecology, 1895-1955*. Berkeley: University of California Press, 1981.

Tocqueville, Alexis de, *Democracy in America*. Edited and translated by Harvey C. Mansfield and Delba Winthrop. Chicago: University of Chicago Press, 2002.

Touraine, Alain. "Neo-Modern Ecology." *marcus* 21, 4 (Fall 2004): 129-133.

---. "On the Frontier of Social Movements." *Current Sociology* 52, 4 (2004): 717-25.

---. *The Post-Industrial Society: Tomorrow’s Social History. Classes, Conflicts and Culture in the Programmed Society*. New York: Random House, 1971.

Traweek, S. *Beamtimes and Lifetimes: The World of High Energy Physicists*. Cambridge, MA: Harvard University Press, 1992.

Trilling, Lionel. "The Leavis-Snow Controversy." In *Beyond Culture*: *Essays on*

Literature and Learning by Lionel Trilling, 126-54. New York: Harcourt Brace Jovanovich, 1978.

Turner, Stephen. "Merton's `Norms' in Political and Intellectual Context." *Journal of Classical Sociology* 7, no. 2 (July 1, 2007): 161–178.

Turner, Stephen P., ed. *The Cambridge Companion to Weber*. Cambridge University Press, 2000.

Turner, R. Steven. "University Reformers and Professorial Scholarship in Germany, 1760-1806." In *The University in Society, Volume II: Europe, Scotland, and the United States from the 16th to the 20th Century*, edited by Lawerence Stone, 495-531. Princeton, NJ: Princeton University Press, 1974.

Turney, Jon, *Lovelock and Gaia: Signs of Life*. New York: Columbia University Press, 2004.

U.S. Fish and Wildlife Service, Council on Environmental Quality (U.S.), Ecological Society of America, and American Institute of Biological Sciences, *Biological Evaluation of Environmental Impacts: Proceedings of a Symposium at the 1976 Meeting of the Ecological Society of America, American Institute of Biological Sciences*. FWS/OBS. Washington, D.C: U.S. Dept. of the Interior, Fish and Wildlife Service, 1980.

Ulanowicz, R. E. *Ecology, the Ascendent Perspective.* Complexity in ecological systems series. New York: Columbia University Press, 1997.

---. *Growth and Development: Ecosystems Phenomenology*. New York: Springer-Verlag, 1986.

Van Sant, Levy. *Representing nature, Reordering Society: Eugene Odum, Ecoystem Ecology, and Environmental Politics*. (MA thesis, University of Georgia, 2009).

Vance, Rupert B. "[untitled]." Review of *Fundamentals of Ecology* by Eugene Odum. *Social Forces* 32, no. 4 (May 1, 1954): 375–376.

Veak, T. J. , ed. *Democratizing Technology: Andrew Feenberg's Critical Theory of Technology*. State University of New York Press, 2006.

Veysey, Laurence R. "The Plural Organized Worlds of the Humanities." In *The Organization of Knowledge in Modern America, 1860-1920*, edited by Alexandra Oleson and John Voss, 51-106. Baltimore: Johns Hopkins University Press, 1979.

---. *The Emergence of the American University*. University of Chicago Press, 1970.

Vernadsky, Vladimir I. *Biosphere*. Edited by M.A.S. McMenamin. New York: Springer, 1998. Originally published in Russian as *Biosfera*, 1926.

Walker, J. Samuel. *Permissible Dose: A History of Radiation Protection in the Twentieth Century*. Berkeley: University of California Press, 2000.

---. "The Atomic Energy Commission and the Politics of Radiation Protection, 1967-1971." *Isis* 85, 1, Mar. (1994): 57-78.

---. "Reactor at the Fault: The Bodega Bay Nuclear Plant Controversy, 1958-1964: A Case Study in the Politics of Technology." *Pacific Historical Review* 59, no. 3 (1990): 323–348.

---. "Nuclear Power and the Environment: The Atomic Energy Commission and Thermal Pollution, 1965-1971." *Technology and Culture* 30, no. 4 (October 1, 1989): 964–992.

Walker, J. S., and U.S. Nuclear Regulatory Commission. *Containing the Atom: Nuclear Regulation in a Changing Environment, 1963-1971*. Berkeley: University of California Press, 1992

Wall, Derek. *Earth First! and the Anti-Roads Movement*. London: Routledge, 1999.

Wall, Derek, Brian Doherty and Alex Plows. "Capacity building in the British direct action environmental movement." Paper for the Workshop on Direct Action at the Local Level, Manchester June 25, 2002.

Walzer, Michael. "The New Masters." *The New York Review of Books*, March 20, 1980. Accessed February 15, 2012, http://www.nybooks.com/articles/archives/1980/mar/20/the-new-masters/.

Wang, Jessica. *American Science in an Age of Anxiety: Scientists, Anticommunism, and the Cold War*. Chapel Hill: University of North Carolina Press, 1999.

Wang, Zuoyue. *In Sputnik's Shadow: The President's Science Advisory Committee and Cold War America*. New Brunswick, NJ: Rutgers University Press, 2008

Waters, Malcolm. *Daniel Bell*. New York: Routledge Press, 1996.

Wacquant, Loïc. "The Self-Inflicted Irrelevance of American Academics," *Academe* 82, no. 4 (1996): 18-23.

Weart, S. R. *Nuclear Fear: A History of Images*. Cambridge, MA: Harvard University Press, 1988

Weber, Max. *The Protestant Ethic and the Spirit of Capitalism*. Translated by Talcott Parsons. New York: Dover, 2003.

---. "Science as a Vocation." In *From Max Weber: Essays in Sociology*, edited by H.H. Gerth and C. Wright Mills, 129-156. New York: Oxford University Press, 1978.

---. "Politics as a Vocation." In *From Max Weber: Essays in Sociology*, edited by H.H. Gerth and C. Wright Mills, 77-128. New York: Oxford University Press, 1978.

---. "Religious Rejections of the World and Their Directions." In *From Max Weber: Essays in Sociology*, edited by H.H. Gerth and C. Wright Mills, 323-359. New York: Oxford University Press, 1978.

Webster, A. "Crossing Boundaries: Social Science in the Policy Room." *Science, Technology, and Human Values*, 32, 4(2007a), 458–478.

---. "Reflections on Reflexive Engagement: Response to Nowotny and Wynne." *Science, Technology, and Human Values*, *32,* 5 (2007b), 608–615.

Weinberg, Alvin. *Reflections on Big Science*. Cambridge, MA: MIT Press, 1967.

Weingart, P. "Science in a political environment." *EMBO reports*, *5*, (2004): S52–S55.

Welsh, I. *Mobilising Modernity: The Nuclear Moment*. London: Routledge, 2000.

Welsome, Eileen *The Plutonium Files: America's Secret Medical Experiments in the Cold War*. New York: Random House, 1999.

Westman, Robert S. "The Astronomer's Role in the Sixteenth Century: A Preliminary Study," *History of Science* 18 (1980): 105-147

Whicker, F. W. *Radioecology: Nuclear Energy and the Environment*. Boca Raton, FL: CRC Press, 1982.

White, Damian. *Bookchin: A Critical Appraisal*. London: Pluto Books, 2008.

Whitley, R. *The Intellectual and Social Organization of the Sciences*. New York: Oxford University Press, 1984.

---. "Changes in the Social and Intellectual Organization of the Sciences: Professionalization and the Arithmetic Ideal." In *The Social Production of Scientific Knowledge*, edited by Everett Mendelsohn and Richard Whitley, 143-170. Boston: D. Reidel Publishing Company, 1977.

Wigner, Eugene P. "Are We Machines?" *Proceedings of the American Philosophical*

Society 113, 2, April, (1969): 95-101.

Wilsdon, James, Brian Wynne, and Jack Stilgoe. *The Public Value of Science*. London: Demos, 2005. Accessed August 2011, http://www.demos.co.uk/publications/publicvalueofscience/.

Wilson, E. O. "Afterward." In *Silent Spring* by Rachel Carson, 357-63. New York: Houghton Mifflin Company, 2002.

Winner, L. *The Whale and the Reactor: A Search for Limits in an Age of High Technology*. Chicago: University of Chicago Press, 1989.

---. *Autonomous Technology: Technics-Out-Of-Control as a Theme in Political Thought*. Cambridge, MA: MIT Press, 1978.

Wolfe, John N. "Impact of Atomic Energy on the Environment and Environmental Science." In *Radioecology; Proceedings of the First National Symposium on Radioecology held at Colorado State University, Fort Collins, Colorado, September 10-15, 1961,* edited by Vincent Schultz and Alfred W. Klement, 1-4. New York, Reinhold Publishing Corporation, 1963.

Wolin, Sheldon S. "Max Weber: Legitimation, Method, and the Politics of Theory." *Political Theory* 9, 3 (Aug., 1981): 401-424.

Wood, L. S. *A More Perfect Union: Holistic Worldviews and the Transformation of American Culture After World War II*. New York: Oxford University Press, 2010

Worster, Donald. *Nature's Economy: A History of Ecological Ideas*. New York: Cambridge University Press, 1994.

---. "The Ecology of Order and Chaos." *Environmental History Review* 14*,* 1/2 (1990), 1–18.

Wright, R. *Three Scientists and Their Gods: Looking for Meaning in an Age of Information.* New York: Times Books, 1988

Wynne, Brian. "Dazzled by the Mirage of Influence? STS-SSK in Multivalent Registers of Relevance," *Science, Technology, and Human Values*, 32, 4(2007), 491–503.

---. "Risk and Environment as Legitimatory Discourses of Technology: Reflexivity Inside Out?" *Current Sociology* 50, 3 (2002): 459-77.

---. "May the Sheep Safely Graze? A Reflexive View of the Expert-Lay Knowledge Divide." In *Risk, Environment, and Modernity: Towards a New Ecology*. Ed. Scott Lash, Bronislaw Szerszynski, and Brian Wynne, 44-83. Thousand Oaks, CA, Sage

Publications, 1996.

---. “Unruly Technology: Practical Rules, Impractical Discourses and Public Understanding.” *Social Studies of Science* 18, 1, Feb. (1988): 147-167.

---. “C.G. Barkla and the J Phenomenon: A Case Study in the Treatment of Deviance in Physics.” *Social Studies of Science* 6, 3/4, Sep. (1976): 307-347.

Yearley, Steven. *Cultures of Environmentalism: Empirical Studies in Environmental Sociology*. New York: Palgrave Macmillan, 2005.

---. *The Green Case: Sociology of Environmental Issues, Arguments and Politics*. New York: Routledge, 1991.

---. “Green Ambivalence About Science: Legal-Rational Authority and the Scientific Legitimation of a Social Movement.” *The British Journal of Sociology* 43, no. 4 (December 1, 1992): 511–532.

York, R. and E. A. Rose. "Key Challenges to Ecological Modernization Theory", *Organization and Environment* 16, 3 (2003): 273-288.

York, Richard, and Philip Mancus. “Critical Human Ecology: Historical Materialism and Natural Laws." *Sociological Theory* 27, no. 2 (May 5, 2009): 122–149.

York, Herbert F. *Race to Oblivion: A Participant's View of the Arms Race*. New York: Simon and Schuster, 1970.

Znaniecki, Florian. *The Social Role of the Man of Knowledge*. Piscataway, NJ: Transaction Publishers, 1968.

Zuckerman, Harriet, and Robert K. Merton. “Patterns of Evaluation in Science: Institutionalisation, Structure and Functions of the Referee System.” *Minerva* 9, no. 1 (1971): 66–100.