The International Library of Environmental, Agricultural and Food Ethics 37

Catherine Kendig
Paul B. Thompson *Editors*

The Social Epistemology of Engineered Agricultural Ecologies

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Volume 37

The ethics of food and agriculture is confronted with enormous challenges. Scientific developments in the food sciences promise to be dramatic; the concept of life sciences, that comprises the integral connection between the biological sciences, the medical sciences and the agricultural sciences, got a broad start with the genetic revolution. In the mean time, society, i.e., consumers, producers, farmers, policymakers, etc, raised lots of intriguing questions about the implications and presuppositions of this revolution, taking into account not only scientific developments, but societal as well. If so many things with respect to food and our food diet will change, will our food still be safe? Will it be produced under animal friendly conditions of husbandry and what will our definition of animal welfare be under these conditions? Will food production be sustainable and environmentally healthy? Will production consider the interest of the worst off and the small farmers? How will globalisation and liberalization of markets influence local and regional food production and consumption patterns? How will all these developments influence the rural areas and what values and policies are ethically sound?

All these questions raise fundamental and broad ethical issues and require enormous ethical theorizing to be approached fruitfully. Ethical reflection on criteria of animal welfare, sustainability, liveability of the rural areas, biotechnology, policies and all the interconnections is inevitable.

The International Library of Environmental, Agricultural and Food Ethics contributes to a sound, pluralistic and argumentative food and agricultural ethics. It brings together the most important and relevant voices in the field; by providing a platform for theoretical and practical contributors with respect to research and education on all levels.

Catherine Kendig • Paul B. Thompson
Editors

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Preface and Acknowledgments

This edited volume and the interdisciplinary research it collects are the result of collaborative discussions that began at a workshop which was held at the W. K. Kellogg Biological Station, Hickory Corners, Michigan and funded as the second conference workshop of "Social Implications of Emerging Technologies in Agriculture," a grant-funded project (award number 2020-67023-31635) from the United States Department of Agriculture's National Institute of Food and Agriculture, Catherine Kendig, Principal Investigator.

One of the aims of the grant was to facilitate interdisciplinary discussion focusing on the social implications of emerging technologies in agriculture and their impact on diverse species and ecologies. The immediate objective of the workshop was to develop a blueprint with which to consider challenges and issues surrounding a research agenda that engages with the scientific, ethical, regulatory, and social consequences of the agricultural use of biological and chemical technologies. Long-term agricultural research provides ample evidence of coevolved species, e.g. microbes and plant roots, wheat and pollinators. But how does the deliberate modification of agricultural products through mechanical, chemical, and genetic engineering change the agroecology, interspecies interactions, and the sorts of agronomy experiments needed to assess these impacts? In our initial invitation to workshop participants, we shared some questions we were keen to discuss:

1. How can we understand the effects gene technologies might have on the microbiome of the target crop?
2. What are the current gene technologies and how should they be evaluated for agriculture to capture their entanglements in the environment—for instance—on pollinators?
3. What impact do/can gene technologies have on the soil microbiome or on plant-related microbes?
4. What values, concepts, and assumptions are framing the evaluation of the conceptual and social impacts of using CRISPR-based gene drives for agriculture? And how could they be expanded?

5. In what ways do crop plants matter and how are they differently conceived by First Peoples, early settlers, as well as current family-owned farms and large farms. In what ways might gene interventions change this?
6. How might technologies be used to maintain or increase ecosystem diversity, e.g., through planting methods such as planting in prairie strips or swales?

In order to forge a strong relationship between social scientists and philosophers of agriculture with agricultural extension researchers to establish an even broader set of potential collaborators, we chose to hold the workshop at the W.K. Kellogg Biological Station (KBS). KBS is Michigan State University's field experimental research station, which focuses on diverse managed and unmanaged ecosystems and long-term ecological research. This was ideal given that the theme of our workshop was "Multispecies ethnographies in engineered agricultural ecologies." With the help of the KBS faculty, staff, and graduate students, we were able to plan lots of engagement and outreach activities. Many thanks go to our hosts at KBS, Fred Janzen, who was the then KBS Director, and all the faculty and graduate students working on the Long-Term Agroecological Research (LTAR) and the Long-Term Ecological Research (LTER) sites. Many thanks also to Brian de Vries who provided much-needed help in office and travel arrangements, and to Wenda Bauchspies, Kurt Richter, Theresa Selfa, and Chris Henke for their valuable insight and support during the beginning stages of the project. Very special thanks go to Tayler Ulbrich, Associate Director of Engagement for LTAR and Brook Wilke, Associate Director for Science and Agronomy for LTAR. Their help in making it possible for us to have our workshop in and among their own field research proved invaluable in shaping much of the content of the chapters in the volume. Field research coordinated by Tayler and Brook on LTAR and by Corinn Rutkoski, Alice Puchalsky, Grant Falvo, Tvisha Martin, and Kevin Kahmark on prairie strips and soil health, nematodes, pollinators, global warming impacts of agricultural lands, soil food webs in agricultural landscapes and precision agriculture as part of LTER and LTAR continue to stimulate our research.

USDA funding for "Social Implications of Emerging Technologies in Agriculture" allowed a bunch of interdisciplinary scholars, many of whom had never met before, to begin thinking together in surprising ways that eventually resulted in this volume. We thank them for joining us in the fields of mid-Michigan. USDA funding for the Open Access of this volume means that you all, as readers, can join us in our interdisciplinary conversations in the fields.

East Lansing, MI, USA

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Chapter 1
Technological Innovations in Agriculture: A Philosophy and Sociology of Science Approach

Catherine Kendig and Paul B. Thompson

Abstract How do human interventions into the environment motivated by different aims transform agriculture in ways that create new causal relationships between organisms above and below ground? We provide a conceptual framework for a philosophical and sociological approach to agricultural biotechnology and its multiple impacts on agricultural systems. We begin with a brief account of the history of the philosophy of the agricultural sciences and the early reluctance of philosophers of science to engage in the philosophy of the applied sciences. Applied sciences in general and the agricultural sciences in particular rely on contingencies in social practice. Here, one would expect diversity among different disciplines and goals. Instead of the basic sciences' aim of discovering a univocal reality, applied sciences were reconciled to the possibility of incompatible prescriptions. Following this, we introduce some concepts and approaches central to discussions of agricultural biotechnologies including social epistemology and social ontology. Our coinage, *engineered agricultural ecologies* is meant to echo debate over novel ecosystems in conservation biology, where attempts to intervene in ecosystems damaged by species loss and climate change are advocated by some, opposed by others. By insisting that farms are *engineered ecologies* we hope to stimulate some crosstalk with environmental philosophers and conservation ecology.

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1.1 Introduction

How does what we know about something affect how we choose to interact with it and how do our interactions with it change it in ways that in turn affect our future knowledge and interactions? The purpose of this volume is to investigate these interactive causes and effects within and between research and development of agricultural technologies and farming practice. Understanding these complex interactions necessitates examining how scientists in agricultural research settings understand their own activity in relation to agricultural practices and farm management decisions. These decisions themselves are, of course, influenced by geological, biological, chemical, climatic, economic, community, and cultural knowledges about the regional ecology of a particular farm.

This volume contains chapters focusing on philosophical and social considerations of the use of biotechnologies for agriculture. As such, it investigates how do human interventions into the environment motivated by different aims transform the landscape in ways that create new causal relationships between organisms above and below ground. The volume is intended to provide readers with conceptual tools through which the use of new agricultural technologies might possibly be better understood and debated. While volumes published in the history of agriculture, sociology of agriculture, and applied ethics are plentiful, those aiming to integrate history, philosophy and sociology of agricultural practices are far less common. The present volume aims to fill this gap.

This introductory chapter provides a conceptual framework for the volume. It begins with a brief account of the history of the philosophy of the agricultural sciences. Following this, we introduce the concepts and approaches referenced in the volume's title; *The Social Epistemology of Engineered Agricultural Ecologies*. We begin with *social epistemology* before explaining what we mean by the phrase "engineered agricultural ecologies" and why these are central to philosophical and sociological discussion of agricultural biotechnologies. It continues with a section clarifying concepts and terms that cut across several of the book's case studies. The book's contributors offer case studies focusing on several different ways agricultural landscapes can be engineered and reengineered, we conclude our introductory remarks with a brief precis of each chapter included within this volume.

1.2 Towards a Philosophy of Agricultural Science

Despite a dramatic uptick in philosophical studies of agriculture and food systems, it is only relatively recently that philosophers with an orientation to the history and philosophy of science have given serious attention to work done in agricultural research institutes. Two interacting and complementary trends account for this. On the one hand, the general orientation in philosophy of science typical of the post-World War II period was simply not conducive to serious work in what was considered to be an applied discipline. On the other hand, the initial impetus for philosophical work on food and agriculture came from ethics and political philosophy, with formative studies suggesting little in the way of an opening to the philosophy of science.

The philosophy of science that emerged during the early decades of the twentieth century was an epistemological attempt to understand how the work of scientists (often cosmologists and physicists) yielded a form of knowledge that was distinct from interpretive disciplines in history, law, religion and, for some, philosophy itself. This early period in the philosophy of science coincides with distinctions made in the sciences themselves as parsing the *pure* or *basic* sciences as distinct from the *applied* sciences. The basic sciences aimed to explain states of affairs, natural processes, cause and effect, and motion or change that were unaccounted for in terms of intentional or willful actions. Basic scientific research was research that was defined as being free and undirected, the pursuit of which was not oriented to any particular goal. The applied sciences would then adapt this research to human activities such as medicine, manufacturing, weapons development and, of course, agriculture. This picture suggested that insofar as applied disciplines were scientific, they adopted the underlying categories of the pure disciplines, though as practical the application of these categories would be steered by human purposes. Vannevar Bush is sometimes credited with institutionalizing the distinction in public policy and in scientific research organization after World War II. Though known for leading the spectacular achievements of applied science during the war, Bush's (1960) report *Science: The Endless Frontier* argued for a robust community of scientists pursuing basic research, unencumbered by applied goals.

These developments suggested that the research in the pure sciences was directed to revealing the basic structure of reality, while the applied or practical disciplines had additional recourse to what was useful for particular aims. Philosophers of science had several reasons for neglecting the agricultural disciplines. First was the view that technology itself is literally an application of theories developed in the basic or pure disciplines. Proponents of this view stressed the detailed theoretical and empirical work of predicting, testing, and explaining that relied upon specifying parameters, instantiating key variables, causes, and laws of nature and they argued that philosophers of science could benefit from closer study of such work. Nevertheless, they offered no epistemological challenge to Bush's basic distinction (Bunge 1966). Second, the very idea of applied sciences implies use for a specific purpose. In application, science would direct and coordinate action toward a given goal, but fixing the goal, not to mention its justification, was often thought to be an extra-scientific matter.

Philosophy of science was, for a long time, a discipline wedged between logical positivist and social constructivist views and one attempting to avoid the taint of ethics, religion, or other messy valuations in scientific research. This "value-free ideal" was seen as a desirable third way to maintain an empirical basis for theories unladen with non-epistemic commitments, sidestepping any influence of ethical, political, or economic interests on empirical results or the justification of research pursuits (Intemann 2001). Although philosophers of science began debating whether science could be "value-free", the applied sciences still did not present an auspicious locus. This was due to their reliance on contingencies in social practice that made them uninteresting for someone focused on the value-free ideal. Here, one would expect diversity among different disciplines and goals. Instead of the basic sciences' aim of discovering a univocal reality, applied sciences were reconciled to the possibility of incompatible prescriptions.

While others, including Marjorie Grene (1966), argued that scientific work was work that was driven by the itch to solve problems and shaped by value judgments, background assumptions, and tacit knowledge. For Grene, scientific disciplines were best understood as conceptually and resource-dependent *social enterprises*. Scientific knowledge is not value-free but ineliminably social and value-laden and as such, all "knowing is a kind of orientation" (Grene 1969: xvi). But, even though she was once a farmer herself, Grene did not pursuit agriculture as a focus of her philosophical work in the sciences (Grene 1995: 35). Finally, even among those scholars who did pursue philosophical work in the applied sciences, the low status of agriculture and farming was disqualifying. Academics and intellectuals alike were long disinclined to take it seriously (Heldke 2006).

There was some early interest in the philosophy of science on the part of specialists in agriculture and food systems. Glenn L. Johnson (1976) argued that the value-free ideal squelched agricultural scientists' willingness to participate in vital discussions about the role and impact of farm technology. However, philosophers' interest in agriculture was focused on different issues. Two influential papers by Peter Singer identified topics that brought philosophers back to food and agriculture after generations of near silence. One was "Famine, affluence and morality," in which Singer used a 1970s food crisis in Bangladesh to motivate a more general ethical argument (Singer 1972). The paper prompted a stream of philosophical work on food security and development assistance that continues to this day. Singer's book *Animal Liberation* had even greater impact, precipitating the growth of animal ethics as a sub-specialization in philosophy, with substantial attention to ethical vegetarianism and the treatment of poultry and livestock in contemporary production systems (Singer 1975). Although philosophers of science might have contributed to either topic, it was ethicists and political theorists who, for the most part, filled the pages of new journals like *Agriculture and Human Values* or *The Journal of Agricultural and Environmental Ethics* after 1980.

1.3 The Agricultural Biotechnology Debate

A more propitious opening to philosophy of science can be found in the academic literature on public reactions to genetically engineered crops and food animals. Within these debates, methods and goals of genetic engineering are often explained in the context of plant and animal breeding. Acknowledging the concerns about the technology can be rationally based, some argue that risks can still be adequately addressed (McHughen 2000). Others are not as optimistic, claiming that environmental and social risks from the new technology are themselves reasons to become engaged in active opposition to its use in agriculture and food systems (Krimsky and Wrubel 1996). But much of the social science literature focused on analyses of the socioeconomic environment that gave impetus to the utilization of gene technology in the agricultural sciences (Busch et al. 1991), or the structure of the social movement that arose in opposition (Schurman and Munro 2013). For their part, philosophers' scholarly contributions during this early period of agricultural biotechnology stressed analysis of underlying assumptions about the criteria for evaluating the technology (see Thompson 1990; Burkhardt 1992).

Given philosophers' emphasis on evaluating agricultural technology and philosophy of science's understanding of technology as applied science, it took some time for researchers specializing in the philosophy of science to notice these debates. Michael Reiss and Roger Straughan's *Improving Nature: The Science and Ethics of Genetic Engineering* (1997) was one of the first studies that reviewed agricultural applications, followed later by Barry Barnes and John Dupré's *Genomes and What to make of Them* (2008) which provided a thorough discussion of interdisciplinary issues associated with the modification of human genomes and the genomic revolution following the Human Genome Project. The rationale for increased interaction between philosophers and social scientists in our project builds on this work in bringing together philosophers of science, scholarly researchers in agricultural biotechnologies, and social scientists working in agriculture and natural resources.

Our contributors' chapters demonstrate that consideration of agricultural biotechnological impacts must include a focus on how these technologies are developed, how they are applied, by whom and for what reasons but also what are the systemic causes and effects on crop plants, cropping systems, micro and macrobial plant and animal communities. A more philosophically nuanced understanding of both old and new technologies (and of all kinds) has the potential to advance public debate and policy review beyond the stalemate that has left many farmers hesitant to make full use of biotechnology's potential whilst maintaining productive and sustainable growing conditions.

1.4 Social Epistemology

Philosophers of the seventeenth and eighteenth centuries developed theories of knowledge as an adjunct to an emerging scientific outlook. The new science demanded a break from wisdom literatures founded on the interpretation of sacred texts or the sayings of ancient sages. René Descartes championed a rationalist approach that emphasized deductive connections among "clear and distinct" basic ideas. John Locke fashioned knowledge as the accumulation of empirical observations, with inductive generalization providing a method for linking sensory experiences. Others sought ways to weave rationalist and empiricist threads into a unified understanding of scientific knowledge. Yet in their founding formulation, both approaches theorized knowledge as the possession or achievement of an individual. Sensations of sight, hearing, taste, smell and touch comprise the basic elements of knowledge for Locke, who imagines the organization of this sensory data as arising within the subjective experience of the knowing subject. Similarly, Descartes imagines the thinking thing testing ideas for logical coherence through an introspective accounting process, isolated from interaction with others.

This highly individualized picture of the knowledge process continues to be influential. Indeed, everyone comes to appreciate the profound sense in which what they know reflects the peculiar outlook and history of an individual human being. Yet it is highly questionable whether this individualized notion of knowledge accurately reflects how we come to know what we know and the social nature of knowledge, including scientific knowledge. Shared knowledge-making and method-generating systems in the natural and social sciences allow researchers to reproduce one another's experimental results through common or shared understandings of what they are observing. These shared understandings increasingly emphasized quantifiably measurable outcomes in the biophysical sciences. Charles Sanders Peirce suggested that scientists obtain knowledge not by introspection, but through carefully specifying measurable outcomes that would obtain under reproducible conditions, and then working collectively to test these hypotheses (Peirce 1986). Scientific knowledge presupposes a community of inquiry.

To a large extent, this social orientation to epistemology is accepted by virtually all contemporary philosophers of science. However, given the innate plausibility of the introspective, individual model, it is often useful to call out the social dimension explicitly. In point of fact, the phrase *social epistemology* has only become commonplace in the last 30 years. The last five decades of work in the philosophy of science (as well as in general epistemology) could be seen as a social turn where greater attention was paid to the actual practices of social interaction. Building on Grene's notion of "scientific enterprises", Helen Longino (1990) argues that rather than being a threat to scientific knowledge, the social character of scientific knowledge is what justifies scientific knowledge as objective through recognized practices of criticism such as peer review and shared standards. Objectivity is possessed by the scientific community—not individual scientists. Answering the hard question which is the title of her paper, "What's social about social epistemology?", Longino argues that it is the participation or interactivity of communities—the "sociality of interaction"—which is central to knowledge production (Longino 2022: 171). This focus on social practices as central to epistemology is a view we share. The interactive practices of specific networks of researchers and the institutionalization of disciplines and research programs have each been theorized as creating and maintaining a community of inquiry. As such, social epistemology is a term of art for scholars whose work on knowledge creation, transmission and reproduction highlights these social practices. It serves as a natural bridge between philosophy and sociology of science. Social interactions that give rise to goals that scientists share with client groups are of particular interest in the case studies that make up this volume. There is thus a sense in which any contemporary epistemology of the agricultural sciences would be social, yet in making special note of social epistemology in our title, we highlight the sense in which active communication and interactivity functions, in linkages between farmers and other human and non-human actors, and how these figure into knowledge-in-the-making.

1.5 Engineered Agricultural Ecologies

Unlike social epistemology, the notion of *engineered agricultural ecologies* is a coinage we developed specifically for this book. It foregrounds the role of human agency in the assembly of organisms and abiotic elements that constitute an agricultural system. The reference to engineering alludes to chemical and biological agricultural technology debates, where advocates and opponents alike referred to techniques for modification of soil systems, as well as plant and animal genomes as "engineering". At the same time, the phrase *engineered ecologies* echoes the debate over novel ecosystems in conservation biology, where attempts to intervene in ecosystems damaged by species loss and climate change are advocated by some, opposed by others (Hobbs et al. 2013). By insisting that farms are "engineered ecologies" we hope to stimulate some crosstalk with environmental philosophers and conservation ecology.

Philosophical, sociological, conservation, environmental, and policy discussions around agricultural engineering require attention to ecologies much more so than to a single crop or type of intervention. Ecologies are composed of interrelationships between multiple above and below ground species of organisms as well as the physical and local climactic features of these local systems. Understanding how multispecies interactions function in different agricultural ecologies relies on research from several disciplines. These include scientific research on interspecies interactions such as the interplay between the environment and epigenomics and proteomics; microbial communities and plant roots; pollinators and flowering plants; the construction of shared niches in various ecologies; and attention to trophic cascades in wildlife management.

In addition, describing a farm or an entire food system as an engineered ecology implies attention to the interaction among the different species populating that system. This would include the companion planting practices of several First Peoples, and in particular the intercropping of corn, beans, and squash, the "Three Sisters" relied upon by the Chokian, Mississippian and Muscogee cultures as well as the Haudenosaunee and Maya (Woods 2004: 256). Many farmers and practicing agricultural scientists will display keen appreciation for multispecies interaction within farming systems which guide the technologies farmers adopt, and shapes experimental methods researchers use. At the same time, the emphasis on commodity crops and animal foods in the agricultural sciences often leads to research streams with an intense focus on the biology of a single species. A philosophical study of plant or animal breeding might follow the actors into an unwarranted emphasis on these species, considered as if their important biological characteristics can be theorized in isolation. One might argue that too much of the philosophical work on agricultural biotechnology has fallen prey to this error.

The error is compounded when one considers how many critiques of contemporary agriculture emphasize monoculture, as if a monoculture really was just a field containing only one species. In fact, even the monocultures of industrial agriculture are approached as multispecies ecologies within the agricultural sciences. A field of plants all ripening and ready for harvest at the same time is well understood to be a banquet invitation for deer, insects and fungi. Overzealous attempts to eradicate one species can turn another relatively benign species into a devastating pest. Populating the farming system with predators of these uninvited guests (e.g. biological control) is a multispecies approach to crop protection. We do not suggest that pointing to the ecological interaction of many species is something new to the agricultural sciences. At the same time, for readers coming to agriculture for the first time (and here we hope to include many philosophers), it is worth stressing the sense in which each of these case studies approaches its subject matter from an ecological understanding of multispecies interaction.

1.6 Agriculture, Agricultural Technology and Philosophy of Agriculture: Some Concepts and Terms

Before proceeding further into to the substantive issues of the book, it may prove helpful to offer some clarification of key terms in agriculture, agricultural technology and philosophy used throughout the volume.

Agriculture includes production of commodity crops such as corn (maize), wheat, soybeans and rice, irrespective of whether they are destined for use as human food or animal feed. It also includes horticulture (e.g. fruit and vegetable production) as well as non-food crops, such as cotton and tobacco. Perhaps less consistent with some forms of common usage, we include livestock production and aquaculture.

Agricultural technology includes the development and use of tools, expertise and equipment which make the causal factors critical to agriculture more manipulable by humans. These tools and expertise are developed to increase crop yield, farm management efficiency, increase farm and land capacity, improved farm production, facilitate farmers' financial well-being, and/or provide more sustainable solutions for agriculturalized ecologies. Agricultural technologies include early innovations such as irrigation such that farmers need not only rely on rain or rivers to provide crops the moisture they require. They also include horse-drawn plows to aid farmers in preparing soil for planting. During the Industrial Revolution, mechanical means of easily extracting sticky seeds from fluffy cotton led to the development of mechanized agricultural solutions like Eli Whitney's cotton gin. Innovations such as the current artificial intelligence equipped cotton stripper harvesters and spindle pickers continue to further minimize the need for a large agricultural workforce while increasing the ease of production from farm to fabric. In addition to mechanical technologies designed to physically manipulate agricultural environments, they also include chemical and biological technologies. Two of the most notable chemical technologies are the widespread use of synthetically produced nitrogen fertilizer developed in 1913 by Fritz Haber and Carl Bosch and the soilless farming techniques developed by Dennis Hoagland and Daniel Arnon (1938). Some of the most notable biological technologies include plant domestication, crop breeding, the development of pesticides, fungicides, and herbicides (like glyphosate) as well as recent genetic engineering techniques.

Genetic engineering is widely understood to mean direct human manipulation of the DNA molecule that structures cellular metabolism in plants and animals. Although traditional breeding alters plant and animal genomes, mutation breeding and recombinant DNA transformation allowed breeders to intervene directly in the sequence of base pairs that compose an organism's genome. Mutation breeding stimulates spontaneous genetic variation by subjecting gametes to chemical or radioactive stress. rDNA transformation exploits the biochemistry of DNA through cutting the molecule and inserting gene constructs that code for desired traits. In early applications, breeders had little control over the insertion point on the genome. In general, we will use the phrase *gene editing* to classify tools for targeting an insertion or deletion of genetic material (e.g. base pairs) at a predetermined locus on the DNA molecule. At present, these tools include TALENs, zinc fingers and CRISPRCas9, though others may emerge. CRISPRCas9 has additional uses. In biomedical settings, CRISPRCas9 can be used to introduce non-heritable changes into the tissues of a living organism. It can also be used in gene drives, that is, in constructs that are intended to move through a population of reproducing organisms. Although there are potential agricultural applications of both uses, we do not believe it is appropriate to include such additional uses under the term *gene editing.* Several chapters discuss the social, ethical and regulatory significance of targeting modification to a specific site on the genome. In focusing attention on this specific approach to genetic engineering, our chapters do not presume to cover the full range of issues in agricultural genetic engineering and synthetic biology.

Philosophy of agriculture focuses on knowledge of agricultural systems (*epistemology*), categorization of the kinds of things, processes, and relationships that exist in agricultural systems (*ontology*), and what are best practices or standards of agricultural activities (*ethics*). We rely on the usual notions of epistemology, ontology, and ethics but our uses of these also reflect the differences in our different subdisciplines in philosophy and the target subdisciplines—from pollinators to pedology. Philosophical discussions frequently focus on identifying what are the causally salient practices and interventions. This is especially true for several chapters in this volume. Our interest in causal efficacy should be unsurprising. The focus of agricultural interventions is often directed to causal factors that are manipulatable by humans and those aspects of agricultural systems whose manipulation makes a salient difference with respect to farmer goals, agricultural production, and ecological impact. Determining what is causally efficacious in a particular agricultural situation also relies on different knowledge assumptions, on one's epistemic commitments, as well as on one's understanding of the sorts of things that exist in the world: one's ontological commitments. What kinds of things exist and how do they relate to each other? For instance, these questions can be asked in terms of what something is or what are the constituent parts of systems—from farming systems to soil systems. We might ask: what sorts of entities or activities are included in a farm that makes it a farm? or What sorts of biological, chemical, and physical components or features make up healthy soil?; What sorts of animals are considered to be livestock? What does pollinator health have to do with crop health and vice versa? How are agricultural standards and policies determined, and who is involved in their determination? or How do interinstitutional relationships affect what is grown, where it is grown, how it is grown, and who grows it? Answers to these questions rely on how they are sorted or classified. How entities, properties, and relationships are sorted into groups rely on formal and informal classification systems used by agronomists, scientists, farmers, and consumers. Much of the philosophical work in this volume investigates how knowledge about agricultural systems is grounded in ontological commitments expressed through farming, agricultural research activities, and the use of agricultural biotechnology tools (Kendig 2024). Put another way, what is known is grounded in ecologically, technologically, and culturally situated activities, and on social epistemologies and social ontologies.

1.7 Chapters Summaries

The volume collects contributions to a project funded by the U.S. Department of Agriculture (USDA) under the aegis of its program on "Social Implications of Food and Agricultural Technologies." The USDA program was initiated in part because of difficulties faced by the first generation of food and agricultural products developed using recombinant DNA. We designed our USDA grant-funded project, "Social Implications of Emerging Technologies in Agriculture" (Principal Investigator: Kendig), to facilitate much-needed discussion of the technological impacts on different scales, across different species, and among individuals, communities, and institutions. In particular, we specifically address two key goals: (1) support greater interaction between social scientists and philosophers studying the debates over agricultural technologies and (2) anticipate the system-wide impacts of recently developed tools for targeting genetic changes at known locations on plant and animal genomes.

The papers in this edited collection focus on different scales of impact within and across engineered agricultural ecologies. These scales of impact include agricultural relationships between micro-, meso-, and macro-organisms, as well as the production, sustainability, and research goals set by farmers and agricultural scientists; the agrotechnological means by which these goals are pursued; and how the conditions of success are adjudicated by farmers, industry leaders, and consumers of agricultural products.

Each chapter considers different scales and impacts of multispecies interactions in engineered agricultural ecologies but does so by intertwined concepts from ecology, biology, engineering, agriculture, and sociology. Contributors' foci target different agricultural systems including soils, pollinators, row crops, livestock, and human interactions that employ historical, ontological, sociological, and governance frameworks. In doing so, the volume as a whole builds on earlier discussions of the discrete social implications of emerging technologies and debates on the use of gene technologies, but does so by taking a systems approach to evaluate not only agroecological technological impacts but their downstream effects.

Catherine Kendig's chapter, "What is Soil, and What is it For? Social Ontologies and Social Epistemologies of Soil Affordances and Soil Experiments" examines different conceptualizations of soil health that have shaped what sort of thing soil is thought to be in the history of soil science and farming practices. She investigates how these conceptualizations have differently shaped knowledge of soil through the choice of different agronomy experiments and the development of different soil amendments. Relying on J.J. Gibson's notion of affordances, Kendig studies the intertwined causes and effects of farm management decisions on crop plants, for microbial communities, mesofauna and other organisms in the soil system in response to different agricultural technologies. In particular, she focuses on the interconnectedness of soil metabolic cycles and the concept of "soil metabolism" coined by J.H. Quastel, the development of the Haber-Bosch process and chemical nitrogen fertilizers produced with the goal of increasing crop yield, and the long-term soil fertility experiments conducted at Tuskegee Agricultural Station under the directorship of George Washington Carver that were performed using the tools and resources that were available to local tenant farmers to ensure research results were replicable in farmers' fields. In doing so, Kendig shows how social ontologies of soil shape social epistemologies of soil by means of feedback loops of managing and valuing.

Wyatt Galusky and Christopher Henke focus their attention on a particularly familiar pollinator, the monarch butterfly, and explore the social basis of their portrayal as a charismatic species and how our portrayal of them as such constitutes an emergent type of agency with us that impacts public understanding of them. In "Dreaming the Butterfly: Engineered Ecologies and Fragile Futures", Galusky and Henke describe as the monarch's "fragile agency", an agency that is determined in light of human goals and activities but one that also depends on relationships and interactions between humans and monarchs in different spaces for butterfly interaction. This sort of agency depends not on one organism or species but on the interactivity between different species—namely humans. For example, in schools, in institutional messaging as mascot, as well as in engineered landscapes. Galusky and Henke explore how the monarch's precarity and charisma are intermixed and reinforce by human interest, and their use in human institutions which rely on their symbolic meaning and wide access to them by students who learn about them in school, citizen scientists who follow their migratory patterns, and their representational use among governmental agencies and conservation groups in the transgenic crop controversies and the ecological threats of climate crises.

Christopher Preston asks us to rethink some basic ontological classifications that have framed discussions of agriculture and gene technology for at least a half century. He reviews how ecologists and environmental philosophers extend notions of agency beyond the human species. Beavers and whales exemplify the shift in Preston's chapter "Agency and Relationships in Engineered Agricultural Ecologies." Both are noncontroversially *active* in ecological processes; their behavior affects water and nutrient cycles, functioning as a component of habitat for other species. However, this behavior includes acts, doings undertaken purposefully, even when impacts on other species are unintended. As such, Preston argues, it does not stretch our concept of agency beyond recognition to see these animals as agents or actants. Pressing a bit further, Preston argues that it then becomes possible to see multispecies groupings as relational wholes, constituted by reciprocal agency. Pushing the concept farther still, he considers how cells and genomes might be thought to constitute those relational wholes we call organisms through a similar notion of reciprocal agency. Preston concludes by noting indigenous and traditional ontologies where humans are situated relationally amongst other species and closes the argument by suggesting that genetic modification disrupts this highly valued relational system.

In "Treading Lightly, Agriculture and Focality," Per Sandin explores sources for the norm of minimizing human impacts on nature, and how it illuminates some prominent criticisms of agricultural biotechnology. For example, Charles III, King of England and philosopher of science, Hugh Lacy each grounded their critiques on a broader view of science and technology as inimical respect for natural limits. Sandin goes to develop this critique in light of Albert Borgman's work on focal practices. Although burdensome, annoying and tiresome, focal practices (such as tending a fireplace) can have the unintended side-effect of creating the conditions for community and meaningfulness in human life. Technological innovations that address the costs also destroy the benefits. Sandin the weakness that arises in trying to apply Borgman's approach in specific cases, such as modifying agricultural plants and animals with recombinant DNA technologies. Most fundamentally, the focal practices approach provides no clear guidance on the contrast case—the alternative that would prevail if a technological innovation is declined. While Sandin concludes that focality has limitations for policy advice, he nonetheless endorses Borgman's approach as helping us understand and articulate moral considerations that have been either vague or overstated in the biotechnology debate, thus far. As such, attention to focal practice in domains such as farming or plant breeding can help reconcile innovation to an ethic of "treading lightly."

Rachel Ankeny's begins her chapter by noting that gene edited crops continue to be received with many of the same reservations that plagued earlier applications of rDNA biotechnology in plant breeding. After noting terminological issues, her analysis of this policy impasse focuses on missed opportunities for gene editing in crop development. Ankeny identifies systems-oriented research programs that would link genetic manipulations more closely to ecological factors in the farm environment, such as soil chemistry, local organismal communities and farming methods that rely on farmer skill. Advocates for gene editing have largely ignored earlier criticisms and continued to develop crop varieties in isolation from such contextual factors. Her chapter, "Reframing Gene Editing in Crops: Unpacking Potential Solutions by Reconsidering the Questions Asked", suggests that defenders of gene editing who stress the precision and speed of the technology would have greater success by realizing that these replies are not answering the questions that scientifically informed critics of GMOs were asking.

Theresa Selfa's contribution notes the frequency with which scholarly reviews of the debate over agricultural biotechnology have called for public engagement. Her chapter confronts three problems that previous attempts at engagement have encountered: creating *authentic* engagement; identifying the framing *value assumptions*; and confronting *conflicting values* and multiple framing assumptions. A narrative approach places participants in a shared activity of vocabulary building and storyline creation, leading to an activity in which they are authentically engaged. Values can be articulated naturally and conflicts will become both evident and negotiable as the narrative develops. "Unpacking Public Engagement in Agricultural Biotechnology: The Role of Narratives and Social Epistemology in a deliberative workshop on gene editing in agriculture and food" provides a detailed discussion of an engagement exercise conducted in 2022 focused on gene editing. Three narratives shaped the engagement process. First was the need for gaining consumer confidence through building trust. Second, the U.S. Government's current practice falls short of an adequate governance practice, and third, although continuing engagement is necessary, gene editing itself does not pose novel problems, topics or opportunities that differentiate it from earlier debates over agricultural biotechnology. Selfa's postmortem analysis of the activity suggests opportunities for improvement on all three elements of engagement.

Paul Thompson's chapter, "A Risk-Based Agricultural Biotechnology Ethics in the Era of Gene Editing: What is New and What Is Not?" provides an overview of ethically contested issues for the first generation of plant and livestock biotechnology—so-called GMOs. He argues that when a risk-based approach is distinguished from the legal constraints of the regulatory process, it is philosophically able to organize and frame ethical disagreements across the range of human health (including food safety), animal welfare, environmental impact and socio-economic issues. In reviewing how gene editing would be evaluated under such a framework, Thompson finds that risks in the environmental and socio-economic categories are virtually unchanged, while the greater precision of gene editing provides some basis for thinking that the new technology could reduce the probability that hazards in human and animal health will materialize. A sufficiently flexible reading of the risk-based approach thus continues to be a useful epistemic framing for evaluating gene-edited crops and livestock, but claims that gene-editing resolves earlier ethical issues are overblown.

1.8 Conclusion

We hope this collection of diverse approaches to the philosophy of agricultural science will stimulate new work by others. At the same time, the individual chapters will certainly be of interest to those who have studied the uncertain career of recombinant gene technologies over the last 25 years. By situating studies of key episodes in that career with pieces that consider questions about the turn to more precise gene editing, we hope to place the science of agricultural biotechnology within a more rounded social context. The book offers case studies that examine alternative philosophical framings of the issues, as well as discussions of topics in the agricultural sciences that do not involve plant and animal genetics. By broadening the scope in this fashion, we suggest how more sustained philosophical attention to the agricultural sciences can facilitate reflection and improved decisions in technological innovations. Finally, we hope to have shown that the agricultural sciences are philosophically interesting in their own right. In this, the book is an invitation for new work in the philosophy of agricultural science.

References

Barnes, B., and J. Dupré. 2008. *Genomes and what to make of them*. Chicago and London: Oxford University Press.

Bunge, M. 1966. Technology as applied science. *Technology and Culture* 7 (3): 329–340.

Burkhardt, J. 1992. On the ethics of technical change: The case of bST. *Technology in Society* 14 (2): 221–243.

Busch, L., W. B. Lacy, J. Burkhardt, and L. R. Lacy. 1991. *Plants, power and profit: Social, economic and ethical consequences of the new biotechnologies*. Oxford: Blackwell.

Bush, V. 1960. *Science, the endless frontier; A report to the President on a Program for Postwar Scientific Research*. Washington, DC: The National Science Foundation.

Grene, M. 1966. *The knower and the known*. London: Faber and Faber.

Grene, M., ed. 1969. *Knowing and being. Essays by Michael Polanyi*. Chicago: University of Chicago Press.

Grene, M. 1995. *A philosophical testament*. Chicago: Open Court.

Heldke, L. 2006. Farming made her stupid. *Hypatia* 21 (3): 151–165.

Hoagland, D., and D. Arnon. 1938. The water culture method for growing plants without soil. *Berkeley: California Agricultural Experiment Station* 347:1–32.

Hobbs, R. J., E. S. Higgs, and C. M. Hall. 2013. Why novel ecosystems? In *Novel ecosystems: Intervening in the new ecological world order*, ed. R. J. Hobbs, E. S. Higgs, and C. M. Hall, 1–8. Hoboken, NJ: Wiley.

Intemann, K. 2001. Science and values: Are value judgments always irrelevant to the justification of scientific claims? *Philosophy of Science* 68:S506–S518.

Johnson, G. L. 1976. Philosophic foundations: Problems, knowledge, solutions. *European Journal of Agricultural Economics* 3 (2–3): 207–234.

Kendig, C. 2024. Human-managed soils and soil-managed humans: An interactive account of perspectival realism for soil management. *Journal of Social Ontology* 10 (2): 80–109. https://doi.org/10.25365/jso-2024-7690.

Krimsky, S., and R. P. Wrubel. 1996. *Agricultural biotechnology and the environment: Science, policy, and social issues*. Vol. 13. University of Illinois Press.

Longino, H. 1990. *Science as social knowledge*. Princeton, NJ: Princeton University Press.

Longino, H. 2022. What's social about social epistemology? *Journal of Philosophy* 119 (4): 169–195.

McHughen, A. 2000. *Pandora's picnic basket: The potential and hazards of genetically modified foods*. New York: Oxford University Press.

Reiss, M. J., and R. Straughan. 1997. *Improving nature?: The science and ethics of genetic engineering*. Cambridge, MA: Cambridge University Press.

Peirce, C.S. 1986. *Writings of Charles S. Peirce a chronological edition*, Volume III 1872–1878. Peirce Edition Project (ed.). Bloomington: Indiana University Press.

Schurman, R., and W. A. Munro. 2013. *Fighting for the future of food: Activists versus agribusiness in the struggle over biotechnology*. Minneapolis: University of Minnesota Press.

Singer, P. 1972. Famine, affluence and morality. *Philosophy and Public Affairs* 1:229–243.

Singer, P. 1975. *Animal Liberation: A New Ethics for Our Treatment of Animals*. New York: New York Review Books/Random House.

Thompson, P. B. 1990. Biotechnology, risk and political values: Philosophical rhetoric and the structure of political debate. In *Biotechnology: Assessing Social Impacts and Policy Implications*, ed. D. J. Webber, 3–16. New York: Greenwood Press.

Woods, W. I. 2004. Population nucleation, intensive agriculture, and environmental degradation: The Cahokia example. *Agriculture and Human Values* 21 (2/3): 255–259.

Chapter 2
What Is Soil, and What Is It For? Social Ontologies and Social Epistemologies of Soil Affordances and Soil Experiments

Catherine Kendig

Abstract Soil has been defined in numerous ways within the scientific study of soil. How soil has been defined and what it is thought to be for have influenced the design of soil experiments and the development of agricultural technologies aimed at its improvement. Normative goals, like improving soil capabilities, increasing crop yield, and sustainably managing soil health for future generations structure the kinds of questions being pursued in soil science research and in turn shape what can be known from agronomy experiments. I analyse how the interplay of epistemological, normative, and ontological conceptualizations of soil have recursively shaped soil knowledge, what we think soil is for, and how soil is categorized. I focus on three case studies to do this: (1) J. H. Quastel's conceptualization of *soil metabolism*, (2) the development of the Haber-Bosch process and widespread use of chemical nitrogen fertilizers; and (3) George Washington Carver's long-term soil improvement experiments. These illustrate both how social epistemologies and ontologies shape development of new agricultural biotechnologies and how adoption of these affords different opportunities and burdens to farmers in virtue of how these technologies affect the chemical, physical, and biological interactions of soil-plant-animal interactions.

Keywords Agricultural biotechnology · Multispecies · Soil health · Long-term experiment · Reproducibility · History and philosophy of agriculture · Ethics · Causal interactions · Soil science

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2.1 What Is Soil?

Soil scientific research is shaped by the concepts being used to understand soil, whether they are used to capture soil's physical characteristics, the interactions with roots and rhizobacteria, or the types of soil a grower has available for planting. In these ways, answers to the question; what is soil?, have been historically intertwined with the practical goals of soil management, the normative concepts used to assess it, and the desired results of successful soil management. At the same time, these practical goals have also in turn conceptualized the relationships between farmer, soil, plant, and crop and structured what was considered to be good soil and what were considered good farming practices. For instance, farmers and gardeners know what good soil is and that having lots of earthworms in your soil is a good thing. Earthworm castings and burrows modify soil in ways that affect ecosystem functioning. Their activities increase soil aeration, the infiltration of water, habitats for microbes, soil carbon storage, and control fungal pathogens (Blouin et al. 2013). Earthworms stimulate plant growth directly by producing signal molecules that stimulate plant defences such as increasing phenolic compounds in tomato plants linked to western flower thrip resistance in soil (Xiao et al. 2017). Plant growth has also been shown to increase as the indirect result of earthworm burrowing and casting activities that alter the soil microbiome (Puga-Freitas and Blouin 2015). The number of earthworms a grower finds in their shovel serves as an indicator of soil goodness in virtue of the causal role earthworms play in the soil conceived of as a dynamic causal system.

Conceiving of soil as a causal system is not new. Several agricultural scientists including Franklin Hiram King and Liberty Hyde Bailey as well as Aldo Leopold treated soil as a system. In the editor's preface to F.H. King's *The Soil, its nature, relations, and fundamental principles of management,* Bailey writes:

> the soil is no longer conceived to be an inert mixture, presenting only chemical and simple physical problems, but it is a scene of life, and its physical attributes are so complex that no amount of mere empirical or objective treatment can ever elucidate them. (Bailey 1895: vi)

Holistic conceptualizations and memorable analogies of the organic and inorganic interactivity of soil as where agriculture takes place capture these systems approaches are included throughout King's work on soil, such as his notion of soil as best conceived of as "the bottom of an aerial ocean";

> we are living at the bottom of an aerial ocean, and this ocean has a depth of 200 or possibly of 500 miles, but, unlike the one of water, it grows so rapidly less and less dense as its upper surface is approached, that in rising upward from the ground through it one would leave behind him in the first 15 miles all but 4.8 per cent of the entire mass. (King 1895: 11)

Systems analogies and concepts are also used by Leopold, including the "fountain of energy flowing through a circuit of soils, plants, and animals… and the living channels which conduct energy upward; death and decay to the soil" and the conception of land health as "the capacity of the land for self-renewal" (Leopold 1949:

216–221). Soil has also been conceived as a multispecies community that includes microbial, macrobial, and megaflora and faunal interactions and importantly its own interconnected metabolic cycles. Building on these systems approaches and others, J. H. Quastel delivers his Leeuwenhoek Lecture entitled "Soil metabolism" to the Royal Society. In it, Quastel (1954) describes his experiments and observations of some of the dynamic processes that contribute to the potential productivity of soil and its continued capacity to sustain life. From these, he concludes that soil systems are not just biological, they are the sorts of processes that metabolize. Outlining several metabolic cycles within soil systems, including the process of nitrification, the manganese cycle and sulphur metabolism among others Quastel, describes their interweaving causal impacts on the soil community. Describing sulphur metabolism, he explains, there are:

> varied species of organisms that arise and are capable of attacking both the initial substrate and the products derived from it. These dependent organisms develop almost simultaneously…forming a cycle where the sulfur acts in a catalytic role because by its varied transformations it secures the growth of the groups of organisms whose energies for development are obtained from oxidations and reductions of specific sulphur-containing substances. (Quastel 1954: 168)

Quastel's soil metabolism provided more evidence against the once widely accepted humus theory of the Phlogistic Period of the late 18th through to the mid nineteenth century (Wild 1988). According to the humus theory, organic matter arising from the living or decaying organisms contributed to the nutritional support needed for plant growth. Plants, due to their vital force, were able to convert the essential elements contained in the humus extracts carbon, hydrogen, oxygen and nitrogen (Wild 1988). On the humus theory, soil was a mineral solution of these elements only. Early evidence against the humus theory and evidence of an interactive relationship between soil fertility and plant nutrition came from Carl Sprengel (1926, 1928) who studied plant rooting systems as well as the ability of plants to gather minerals and other inorganic compounds directly from the soil. Identifying additional essential nutrients for plant growth left out of the humus theory, Sprengel provided evidence for potassium and magnesium as additional essential elements for plant nutrition contradicting the limited humus theory. Building on Sprengel's work on mineral plant nutrition, Justus von Liebig devised an alternative approach that relied on what he called the *law of the minimum*, a law stated in three parts as:

> 1. By the deficiency or absence of one necessary constituent, all others being present, the soil is rendered barren for all those crops to the life of which that one constituent is indispensable. 2. With equal supplies of the atmospheric conditions for the growth of plants, the yields are directly proportional to the mineral nutrients supplied in the manure. 3. In a soil rich in mineral nutrients, the yield of a field cannot be increased by adding more of the same substances. (Liebig 1855: 23–25, Black 1993 translation)

Liebig's *three laws,*[1] as they are often referred to, replaced the previous humus theory of soil and provided the foundation for the development of chemical

[1] Liebig's law of the minimum became the basis for agricultural practice and accepted in Europe, North America, Africa and Asia despite their very different soil profiles. For more on experimental

amendments that could be added to soil to make up the deficiencies in nutrient deficient barren soils so that their fertility could be increased by the addition of what nutrients it lacked.

2.2 Concepts of Soil Fertility and Soil Health

Edaphological soil studies (for agricultural purposes like soil management) shape and are shaped by how soil is understood and what concepts are being used. The management of soil and the multispecies communities within and around soil have an intertwined history in agriculture.[2] Management of soil by growers seeking to improve crop yield share this history and are themselves partial cause and effect of the modified and engineered agricultural ecological systems of which they are a part. Soil improvement practices which might generally be referred to as the tending of soil rely on a variety of different concepts used by growers, landowners, agronomists, soil scientists, agricultural extension agents, and agroindustry business. These concepts shape how soil is understood among diverse agricultural workers as well as how it can be managed and how it can be assessed and improved in response to the development of new technologies.

Underpinning soil management practices are several interrelated normative soil concepts. Several of these have already been mentioned in the work of Sprengel, Liebig, Quastel, and Leopold. Soil fertility or lack of it described as soil barrenness were concepts long used in descriptions of soil and land prior to Sprengel and Liebig's use of these concepts in directing their own research. Leopold's notion of land health as well as later notions of land capability have also played an integral part of assessing the benefits of careful use and detrimental effects of overuse of soil amendments designed to improve soil for agricultural purposes.

The soil concepts of *soil fertility*, *land health*, and *land capability* all refer to different means by which to assess the soil situation in a particular field or region of farmland. While the product of their own histories and contextual differences, each of these assessments aims to indicate not only the current soil situation but also intends to provide an accurate normative evaluation of it. That is: this is "good soil" for a field to have if farming is what you want to do with it.

agriculture in Germany, especially the role played by comparative trials prior to Liebig in the late eighteenth and early nineteenth centuries, see Schickore (2021).

[2] See Kendig (2024) for an examination of how three soil social ontologies of soil management have contributed to different conceptualizations of what are good farming practices in the Ethiopian Highlands and in the American Midwest. The three social ontologies discussed therein include the local and Indigenous classifications farmers and farming communities rely upon to describe their relationships with soil; categorizations of farmers' agricultural goals and priorities; and federal agency classifications that are used by agronomists assessing agricultural capability of different soils.

The concept of soil health has been widely used in agriculture and conservation for the past 25 years (Doran and Zeiss 2000). While the early use of the concept of *soil fertility* was popular up until the 1960s, it was replaced by *soil quality* which became widespread in agricultural studies in the 1970s, and has since been replaced by the concept of *soil health* since around 2000 (Powlson 2020: 2). Reference to soil health is now ubiquitous in academic agricultural literature, extension bulletins, and farming and trade journals, as well as in agroindustry and environmental studies. Definitions of "soil health" often employ related terms like sustainability, continued capacity, soil function, and vitality signalling its importance. For instance, the USDA defines soil health as "the continued capacity of soil to function as a vital living ecosystem that sustains plants, animals and humans.[3] Creating and maintaining a healthy soil is more than just reducing erosion. The benefits of a healthy soil go far beyond crop production" (USDA 2023). The concept of soil health is philosophically interesting because it entails questions of metaphysics: what is soil?, epistemology: what are the measurable indicators of soil health?, and methodological practice: what can be changed to make soil healthy? Soil health describes soil system capacities[4] while also signalling the need for sustainable soil interventions required to achieve and maintain these.

Soil health requires soil management. But what activities should be pursued to make and maintain soil health is not something that can be universally specified. To understand what type of soil management is necessary, the concept of soil health requires operationalization in the form of a tool of normative assessment that is aligned with these soil management goals. Which management practices are required to create and maintain healthy soil necessitate the assessment of current soil status. Soil health tests provide identification of measurable soil characteristics that can be managed or intervened on and associated with soil health. Soil health is at once a normative assessment of soil, a management opportunity, and a concept which can be operationalized in soil health tests designed to furnish information to be used for soil management decisions. Soil health assessments have relied on biological and chemical knowledge, knowledge of plant physiology, and

[3] Soil systems are composed of microbial and macrobial constituents in complex relationships to each other. See Puig de la Bellacasa (2014) for how humans are not just recipients of the benefits of soil but are carers and part co-creators of the soil system.

[4] While I describe agricultural soil ecosystems throughout the chapter in terms of capabilities, one might think that I could have instead discussed them in terms of functions. It should be noted that ecologists and philosophers of ecology have often relied on describing the contributions of forest ecosystems in terms of ecosystem services and functions and analysed in terms of causal role functions (cf. Odenbaugh 2019, Morrow 2023). Because my focus on soil systems is within agriculture, and it is capacities rather than functions which are relied upon more within agriculture, I retain the capacity language. My additional justification mentioned above for capacity language to describe soil systems and their assessments is that capacity language highlights the intentional approach taken in agriculture when describing soil systems locally and as a place where management decisions are made in light of past and current soil capacity assessments and in view of improving future soil capacity. Capacities, in this way, are those things that are indexed to place as well as to what interventions have been directed to soil systems.

anthropological and sociological information gleaned from the activities and motivations of generations of farmers' management decisions each year.

2.3 Soil Health Indicators: Measuring Soil Capabilities and Affordances

Conceptualizing soil health as soil management connects agricultural and soil science to farm management and environmental policy. Soil and its health is a concern for agriculture due to its key role in food production and sustainable food systems, but its health also causally impacts the health of watersheds, oceans, and atmosphere. In their recent review of soil health concepts in *Nature Reviews*, Johannes Lehmann and colleagues describe the concept of soil health as one best understood as a versatile platform concept that serves to represent current and potential properties of soil complexes; "soil health is an overarching principle to which to contribute knowledge, [and] as a property to measure, environmental and societal functions" (Lehmann et al. 2020: 552). While consensus on what the soil health concept means and to what it refers remains a topic of active debate, its assessment by means of soil tests continues in both agricultural research and the day-to-day management of fields. Different soil tests assess the physical, chemical and/or biological indicators of soil health and continue to be the main route by which soil is managed by farmers and understood by researchers. Reviews of the current literature on soil health have identified physical, chemical and biological means by which soil health can be quantified (Bünemann et al. 2018). The categorization of indicators as either physical, chemical or biological does not represent causal categories but categories of soil features that can be easily evaluated. Much of what is of interest to farmers and agronomists alike when considering soil health is availability of nutrients to plants, a process that is as much about chemical composition of soil as it is the biological process of metabolism (Lehmann et al. 2020: 546). Indices are those features of soil considered to be relevant to assessment of soil health, but also those that are fairly easy to measure. Those features which are often used as soil indicators include: nitrogen, sulfur, phosphorus mineralizing enzyme activity; nitrogen mineralization; microbial biomass; microbial activity; earthworms; organic chemical fractions; organic nitrogen; organic carbon; bioavailable nutrients; pH; cation exchange capacity; electrical conductivity; mobile nutrients; heavy metal toxins; aggregation; water storage; penetration resistance; and infiltration (Lehmann et al. 2020: table 1: 548). A *relevant* indicator is defined as one which is informative to researchers and farmers, sensitive to intervention with farm management techniques and amendments, and effective when these interventions are performed.

Indicators are then best understood as functional features of soil systems that can be intervened upon, whose assessment provides information of use in making soil management decisions, and the information provided by the assessment of it is a reliable predictor of soil potential and future capability. Definitions of soil indicators, provide characterizations of the usefulness of soil indicators as well as how they are useful and to whom are they informative. These are salient to their use and, in part, justifies many of the purposes initially conceived of for introducing the concept of soil health in agricultural and environmental policy discussions as well as in agricultural management decisions. For instance, providing a concept legible to policymakers and industry as well as agronomists and farmers; facilitates discussion of the role played by carbon sequestration in soils in matters from climate change mitigation strategies to water safety and sustainable seas.

What is missing from current discussions of the conceptualization of soil health, analyses of its usefulness, and the means by which indicators of it are chosen seems to be a clear account of *what it is* that indicators capture that makes them informative and useful for decision making and justifies their reliability in making predictions of soil system capabilities. Lists of currently used soil indicators, analyses of why these need to be amended, and suggestions for possible additional indicators such as certain pathogens, parasites, or GHG emissions suggests that indicators are not just pragmatically chosen because they are easy to measure or modify but that their measurement actually reports something informative and that to miss what could be a relevant indicator would be undesirable because it means we miss something important about the way soil is and therefore how it could be better.

I contend a clear account of what it is that indicators capture that makes them informative and useful for decision making and justifies their reliability in making predictions of soil system capabilities is that they capture soil *affordances*.[5] What do I mean by *soil affordances*? To explain what I mean by soil affordances, I need to first explain a bit about what affordances are first. In doing so, I will substantially extend and build upon J.J. Gibson's initial notion of affordances as he uses them to describe what some individual entity might offer, provide or furnish to a particularly situated perceiver. An individual entity offers different opportunities to do certain things with them depending on who is interacting with them. Affordances are those things perceived as such within an environment. Affordances are not all good and nor do they always offer good opportunities. Affordances may also be missed or misperceived. For instance, consider an enterprising gardener who comes across a decaying carcass. The carcass offers many affordances. It may afford potential use as fertilizer once properly prepared, but it also affords potential and perhaps unknown contagions. While Gibson often describes affordances in terms of how an animal (including humans) perceives other animals, plants, materials and what they afford in setting up his account of visual perception, the account I propose not only extends the perceiver of affordances to soil microbial communities and plants but also focuses on the companion alliances and co-travellers (whether friendly, adversarial, or neutral) that compose the multispecies consortia of soil systems. In doing so I rely on Gibson's affordances to describe what it is that soil indicators capture in soil health assessments that make them potentially informative.

[5] While "afford" and "affording" are words found in any English language dictionary, "affordance", Gibson points out, is a word he made-up to capture perceived ecological opportunities (Gibson 1979: 127).

2.3.1 Managing Soil by Managing Those Whose Activities Provide Affordances

Talking about soil indicators as affordances of soil systems is meant to shine a light on the intertwined causes and effects of farm management decisions for crop plants, for microbial communities, for mesofauna and for other plants and animals in the soil system. In talking about affordances, we can focus on how the soil amendments used or technologies adopted by the farmer offer affordances to plants, microbial communities, and other soil constituents. Because soil systems contain interconnected relationships between plants, micro-, meso- and macrofloral and faunal communities, talk of affordances means we can also trace what is afforded by, for instance, microbial communities to plants or from plants to mesofaunal communities in the presence of a particular soil amendment such as chemical nitrogen or a particular fertilizer like chicken manure.

Affordances of, for instance, the addition of chemical nitrogen as a soil amendment to a particular field do not afford the same things in all environments to all that perceive them as affordances. But what do I mean here by perceive? Once again, I significantly extend Gibson's original notion of the perceiver from an animal-human notion of perception to a notion of perception that includes the chemical communication of plant roots (rhizomes) by means of the root exudates they secrete[6] as well as the interactivity of soil metabolic cycles.

Determining which affordances a particular soil amendment provides depends on a contingent infrastructure that connects an organism with how it engages with its environment and with other conspecifics and heterospecifics. The organism's engagement in soil and with soil amendments is causally linked to its mode of life, stage, physical and physiological features, as well as how it eats, moves, and communicates through soil environments. In this way, the point of view of the organism and its relationships and communities are what facilitate how something becoming an affordance. The application of a particular soil amendment to a field may be detected as an affordance by means of processes like bacterial quorum sensing.[7] In this way, I would argue, an organism's situated deportment is not just an important part of understanding the concept of affordance, but is actually constitutive of it. The notion of affordances I am quickly sketching here relies on the different ways by which affordances can be detected by differently situated organisms within soil

[6] Root exudates are organic materials that are released through the cells of plant roots made up of soluble organic substances. These are exuded when root cells are harmed either be microbial predation or by physical breaks. Root exudates also aid plants in obtaining needed nutrients and provide chemical communication through mycorrhizal and rhizobia associations with plants and the fungal soil communities and assist with microbial colonization of the plant root surface by providing a food source and chemoattractant for microbes (Danhorn and Fuqua 2007).

[7] Sensing by means of bacterial quorum sensing is admittedly a very long stretch from Gibson's notion of human and animal perception. I am not suggesting that bacterial quorum sensing is perception but instead that sensing affordances is something that can be done by means of different interactions—including animal and human perception but not confined to these capabilities.

systems. Affordances are those soil capabilities which are detected as affordances by means of the different ways organisms or organismal communities encounter them. For example, dolomitic limestone in the soil where a peanut plant (*Arachis hypogaea*) is growing can provide an affordance to the peanut plant as the limestone offers a combination of calcium and magnesium. The nitrogen fixing rhizobium bacteria associated with the peanut plant's root system metabolizes nitrogen in such a way that is beneficial to the peanut plant as well as the root associated microbiome of the rhizosphere. With calcium present in the soil, more plant root nodules are formed (Buchholz 1993). Because the bacteria within the root nodules fix nitrogen, rhizobium-peanut plant symbiotic systems are able to bind nitrogen via the air because of their symbiotic relationship with the rhizobium bacteria in their root nodules (Mohamed and Abdalla 2013). Accessible levels of calcium in the soil are a useful affordance to the rhizobium-peanut symbiotic system as it both regulates plant root rhizobium nodules and in doing so facilitates peanut pod and seed formation and strengthens plant stems (Yang et al. 2020). Affordances may be provided as the result of the activities of other organisms individually or collectively.

Many of these have long been studied. For instance, consider the burrowing activities of generations of earthworms described by centuries of farmers and gardeners as well as Darwin (1904) and others. The porous soil which is produced as a result of earthworm burrowing and castings forms affordances of an aerated soil in which micro- and macrorganisms find habitat, plant roots find easier passage through, and gardeners enjoy better harvests (Kendig 2014: 164). In addition to chemical or biological soil amendments, there are also mechanical and genetic technologies that introduce or reshape affordances. Mechanical technologies introduce affordances when they reshape land. For instance, in levelling fields to solve drainage and irrigation problems, removing rocks so as to encourage efficient harvest, or choosing to plant dwarf stocks of peach and plum trees to provide easier access to farm workers picking fruit without need for ladders (Perry 2011). The reshaping of affordances brought about through genetic technologies can often be traced through the desired agronomic traits which are the aim of these technological interventions. Plants may be bred either through conventional means or through the use of genetic technologies producing plants with higher yields, more nutritious nutrient content, or increased saleable products. Identifying plant traits or soil characteristic that provide these affordances is not a simple classificatory activity.

In the process of decision making around soil management, often what is being considered in implementing a new strategy or maintaining a current strategy in light of information about soil indicators of soil health is that soil management decisions such as which chemical or biological soil amendments to use, which crops to plant in rotation, which irrigation techniques to employ, or whether to till, no-till, or plant cover crops is a choice of what potential affordance we are modifying or introducing into the soil system.

2.4 How Agricultural Practices and Technologies Modify Different Affordances

2.4.1 The Development of the Haber-Bosch Process

Anthropogenic changes to soil systems are the result of research and development of biological, chemical and mechanical technologies by geneticists, soil scientists, agricultural extension specialists, agroindustry, and growers. These technologies have impacted soil relationships and provided new intended affordances as well as unintended ones.[8] Perhaps one of the best examples of a technology developed to provide a valuable affordance but also led to an inextricable mix of helpful and toxic affordances is the result of the Haber-Bosch process, often touted as one of the greatest discoveries and inventions of the world.

Physical chemist Fritz Haber, based in the Department of Chemical and Fuel Technology at the Fridericiana Technische Hochschule in Karlsruhe and Carl Bosch, based at Badische Anilin und Soda Fabrik (BASF) Aktiengesellschaft recognized that the increase in food production yield from agricultural crops was tied to the availability of nitrogen that was required to produce the necessary amino acids that make food life sustaining. Humans need to make proteins to survive, and this requires consuming amino acids from food since, unlike plants, we can't make our own food through photosynthesis (Smil 2004). While nitrogen is plentiful in the air, in the air it is not available to plants. In 1908, Haber discovered that nitrogen gas could be fixed under high pressure to synthesize ammonia and in 1909 Bosch took on the job of developing the means by which the process could be scaled for industry (Kroes 1995). Through their collaboration, a BASF team headed by Bosch opened the first ammonia synthesis plant in 1913 producing a reactive fertilizer nitrogen that was available to nitrifying bacteria in the soil such that they could then convert the ammonium ions into nitrates. These nitrates were then made available as affordances for plants to use in the production of proteins. Food harvested from agriculture crops fed 1.6 billion in 1900 and in part due to the Haber-Bosch process can now feed over 8 billion in 2024 (U.S. Census Bureau 2024). Analyses based on long-term experiments show that around 30–50% of agricultural crop yield is the result of the addition of chemical nitrogen soil amendments made possible by the Haber-Bosch process (Erisman et al. 2008: 637). While the Haber-Bosch process provided significant benefits in providing more food to a growing population, it also

[8] Anthropogenic changes may be beneficial or detrimental and may shift over time from beneficial to detrimental or vice versa. While technological changes may be intended to offer modifications intended or designed with the purpose of improving soil capacity, whether they are beneficial or detrimental is something that the microbial community, plant, or mesofauna will determine to be so by means of their interactions with it as the affordance they detect given their relationships with other constituents in the soil system.

created negative affordances that are now being discussed in efforts to promote more sustainable soil management decisions.[9]

One of the most problematic affordances introduced into the soil system by the use of chemical nitrogen is that around 40% of chemical nitrogen fertilizer is not used by plants but is deposited into soil, air and water (Erisman et al. 2008: 638). This is not just a problem of inefficient use of chemical nitrogen. Over application of chemical nitrogen that is unused by plants becomes an affordance to chemolitho-autotrophic microorganisms that oxidize ammonia via nitrite to nitrate through the process of nitrification (Daims et al. 2015). The nitrification process releases nitrate which is a detrimental affordance, a contaminant that is released into the groundwater and deposited in watersheds. The excess nutrients or eutrophication in estuaries and coastal waters in the form of these nitrates (and also often phosphates) provides extra affordances to water-based plants, in particular algae causing large algal blooms. Too much plant growth and algal blooms restricts oxygen to other organisms creating a hypoxic environment. The decomposition of this plant matter produces high levels of carbon dioxide lowering the pH of coastal waters causing acidified areas unhospitable to many fish and plant species (NOAA 2017).[10] While the use of chemical nitrogen in traditional agriculture is both widespread and required for producing food to maintain a growing population at the same time, its use is exponentially increasing the release of nitrous oxide in the atmosphere and nitrates into the watersheds and oceans. For these reasons, the nitrogen crisis seems to be a wicked problem.[11] The complexity of the problem, the impact on environment and society as a whole, the constraints of a growing population in need of food, and an environment in need to a more sustainable solution mean that while the problem is defined, no definitive formulation of the solution has been identified.

There may be many solutions to the nitrogen crisis, but each seems to rely on how the problem is framed, what systems are discussed, and which affordances are identified as in need of change. In a recent editorial, "How can we possibly resolve the planet's nitrogen dilemma?", published in *Microbial Biotechnology,* a list of multinational and multidisciplinary scholars reviewed some of the possible solutions which have so far been mooted as possible routes by which to solve the nitrogen problem (Matassa et al. 2023). Among the many included along with some of their advocates were: "reduce consumption of meat and dairy products" (Godinot

[9] Of course, there were also infrastructural affordances that made the initial development of the Haber-Bosch process possible. In the U.S., a "swords-to-plowshares project" which was a provision in the 1916 National Defense Act aimed to repurpose the explosives and technologies used to manufacture weapons during wartime technology to reused them in the manufacture of fertilizers during peacetime (Johnson 2016: 209–213). The infrastructural repivoting provided new economic affordances which facilitated considerable expansion of agroindustrial technology research and development by chemical fertilizer manufacturers.

[10] Another product that is the result of excessive nitrogen use is microbially produced nitrous oxide, a greenhouse gas (Krasovich et al. 2022).

[11] Design theorists Horst Rittel and Melvin Webber (1973) conceived of the notion of a wicked problem as those problems with no clear path towards a univocal solution given that how the problem is framed will predetermine the range of possible solutions conceived of as solving it.

et al. 2015); "precision farming" (Klages et al. 2020); "replace mineral nitrogen fertilizer with biological nitrogen (microbially catalysed protein in the form of sugarcane biomass through the use of filamentous fungi or yeast)" (Sakarika et al. 2020, Areniello et al. 2022); "create a circular nitrogen economy" (e.g. reuse nitrogen from food waste or potato or dairy wastewater, strip ammonia from faecal matter for faecal nitrogen like BioFloc technology (Schryver and Verstraete 2009); "Power to Protein" (Gavala et al. 2021) (Matassa et al. 2023: 16–18). While one tempting answer to the "how can we possibly" question posed in the editorial's title might be: try them all! This solution lacks both a stopping rule for determining when it is solved as well as any full throated consideration of how each proposed solution assumes what it sees are prime causes and introduces downstream dilemmas that produce unequal effects on different communities as a result of their chosen solution route, such that:

> [one's] would-be solutions are confounded by a still further set of dilemmas posed by the growing pluralism of the contemporary publics, whose valuations of [the] proposals are judged against an array of different and contradicting scales. (Rittel and Webber 1973: 167)

Rather than evaluating each of these proposed solutions or even analyzing the set of nitrogen problems and solutions introduced by the Haber-Bosch process, looking forward for what could possibly be a solution, I instead look back at how one agronomist designed an experiment to investigate how possibly to improve soil and farmers' crop yield.

2.4.2 George Washington Carver's Long-Term Soil Improvement Experiment

Eleven years before Haber filed his patent for the "Synthesis of ammonia from its elements" based on his research at the Fridericiana Technische Hochschule and 21 years before he was awarded the 1918 Nobel Prize in Chemistry,[12] George Washington Carver was pursuing research on how to investigate soil affordances in the field at the Tuskegee Agricultural Experiment Station. Tuskegee Institute (now Tuskegee University) located in Tuskegee, Alabama, was founded in 1881 and the Tuskegee Institute Agricultural Experiment Station was established in 1890. Tuskegee was one of the first Historically Black Land Grant Universities. Carver was its first director, a position he held from 1896–1942.[13,14] Carver was not alone

[12] While Haber's Nobel Prize was in recognition of his research in ammonia synthesis, Bosch received his Nobel Prize, awarded in 1931, for chemical high-pressure methodologies (Nobel Prize 2024).

[13] Carver was an African American botanist, teacher and former slave. He was the first Black student and the first Black faculty member at Iowa State.

[14] In the U.S., agronomy research and agricultural extension are interconnected historically when agronomy research was made a mission for public universities called Land-grant institutions.

in working on ways to improve depleted soil. Naturally occurring soil amendments like bird and bat guano were widely used and their effects on crop yield were well studied since the mid-eighteenth century. Before the discovery of the Haber-Bosch process, farmers purchased large amounts of guano imported from South American and Pacific islands. The valuable excrement of cormorants, other birds, and bats became a global trade with companies such as the American Guano Company importing the expensive source of nitrogen, marketed as a natural source of nitrogen able to restore soil fertility, without the need to rely on cattle manure (Stoll 2002: 187–189). This further strengthened an agricultural economic system where farmers willingly paid for (and preferred) bagged up soil amendments rather than relying on local animal manures, paving the way for a market for the new chemical fertilizers once the guano deposits were depleted.

Given the emphasis on purchased fertilizer, Carver's research was significant because his soil experiments did not focus on purchased inputs (either guano or chemical fertilizers) or even on special equipment.[15] Instead, the long-term experiments at Tuskegee assessed the ability of locally accessible materials and techniques to improve soil. Before discussing Carver's soil research in more detail, a bit of American history here will help explain why his research and that he was the one conducting it is so significant, for those outside of the United States. Carver is well-known to Americans. They learn about him in grade school as an African American inventor who developed more than 300 products from peanuts, including milk, Worcestershire sauce, cooking oils, paper, antiseptics, and soaps at a time when peanuts were thought of in the United States as a crop suitable only for animal feed. Carver is the inventor who made peanuts the food we know today. Ask most folks in America if they know who Carver is, and they'll likely say: oh, yes, *The Peanut Man*. This is significant given the love of all things peanuty from peanut butter pie and chocolate and peanut butter candy to peanut butter and jelly sandwiches. But despite his fame as an inventor, Carver's most significant contributions to agriculture knowledge and agroecological justice are relatively unknown to many Americans. Carver's long-term agricultural research experiments on soil are those

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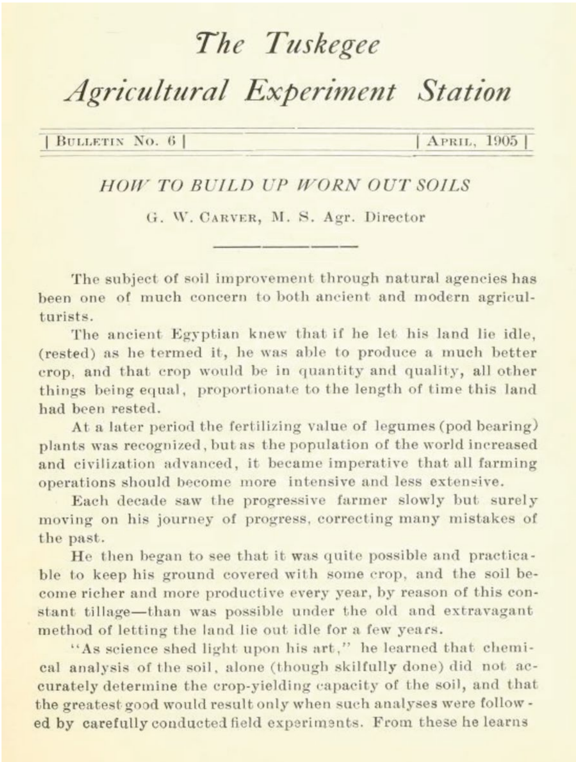
These were established by the Morrill Land Grant Act in 1862 which established schools of agriculture and granting each state 30,000 acres, and a second Morrill Act in 1890 that established Historically Black Land Grant Universities (HBLGUs). It wasn't until 1994 that the Equity in Educational Land-Grant Status Act of 1994 established tribal colleges and universities Land grant universities. For more background on the 1890 Morrill Act, Carver and Tuskegee, see Part III: Departmental File 1897–1915 of the Booker T. Washington Papers contains correspondence and materials between Carver and Washington (Washington 1853–1946, Manuscript Division, Library of Congress, Washington, D.C.).

[15] Several agronomists, such as F. H. King (1911) and Cyril Hopkins (1910) who suggested limiting chemical fertilizer and reliance on animal manures to ensure organic solutions rather than quick fixes in agriculture and Carl Vrooman (1917) who criticized farmers for wasting manure were prominent critical voices in the 1910s. But for farmers growing row crops alone without the finances to afford livestock, the manure missed opportunity was never an opportunity open to them. For a detailed history of soil amendments, see Stoll (2002).

which are particularly pertinent to the present discussion of soil affordances, and how these change when new anthropogenic interventions are made to soil systems.

The results of all agricultural experiments conducted at the Agricultural Experiment Station were written up and shared with local farmers and the local community. These agricultural extension bulletins[16] were designed to provide readers with accessible strategies for increasing their crop yield, decreasing local pests or weeds, and improving soil. In the bulletin, "How to build up worn out soils", Carver describes an eight-year soil improvement experiment beginning in 1897 (Fig. 2.1). Before describing the set-up conditions for the long-term soil improvement study, Carver explains the justification for the experiment as being a study with two intertwined aims: (1) to investigate the effects different soil modifications and management techniques made to the soil and (2) to ensure every operation included in the experiment was possible for local farmers who had minimal access to machinery and similar soils.


The Tuskegee Agricultural Experiment Station

| Bulletin No. 6 | | April, 1905 |

HOW TO BUILD UP WORN OUT SOILS

G. W. Carver, M. S. Agr. Director

The subject of soil improvement through natural agencies has been one of much concern to both ancient and modern agriculturists.

The ancient Egyptian knew that if he let his land lie idle, (rested) as he termed it, he was able to produce a much better crop, and that crop would be in quantity and quality, all other things being equal, proportionate to the length of time this land had been rested.

At a later period the fertilizing value of legumes (pod bearing) plants was recognized, but as the population of the world increased and civilization advanced, it became imperative that all farming operations should become more intensive and less extensive.

Each decade saw the progressive farmer slowly but surely moving on his journey of progress, correcting many mistakes of the past.

He then began to see that it was quite possible and practicable to keep his ground covered with some crop, and the soil become richer and more productive every year, by reason of this constant tillage—than was possible under the old and extravagant method of letting the land lie out idle for a few years.

"As science shed light upon his art," he learned that chemical analysis of the soil, alone (though skilfully done) did not accurately determine the crop-yielding capacity of the soil, and that the greatest good would result only when such analyses were followed by carefully conducted field experiments. From these he learns

Fig. 2.1 How to build up worn out soils. Tuskegee Agricultural Experiment Station (1905) bulletin no. 6. Tuskegee Institute Experiment Station, Tuskegee Normal and Industrial Institute. U.S. Department of Agriculture, National Agricultural Library. OL25940092M

[16] All of Carver's extension bulletins from Tuskegee are now available from the National Archives under "George Washington Carver Papers at Tuskegee Institute, 1864–1943".

Carver chose ten acres of the worst soil he could find, describing just how truly bad the soil was in a way that is immediately recognizable to local farmers, he writes: "the soil was too poor to produce even a small crop of cow-peas" was "variable in character, underlaid with yellow, red and mottled clays, which cropped out here and there" (Carver 1905: 4). Carver's choice of the worst soil he could find on the agricultural experiment station was a necessary material part his long-term soil fertility experiments as the soil was of a common type in Alabama, a very light sandy loam (Fig. 2.2).

This soil had some affordances to the local community, which Carver notes—but what it was known to be good for wasn't farming: "much of the sand for plastering and laying bricks was gotten here…the soil was practically sand and clay" (Carver 1905: 4). Because of the fine grain of the soil, it frequently eroded and was washed away. To make matters worse, in addition to the poor soil, Carver also describes the field and the obstacles to plowing and planting, such as the presence of over a hundred tree stumps that needed to be removed, which was also a common problem in the area. Removing tree stumps was something that could be easily done with a tractor. However, in Tuskegee, local farmers did not own tractors, but instead had access only to one mule and a one-horse plow.[17]

To ensure the results of these experiments were useful to local farmers, Carver's experimental methodologies and protocols were devised to imitate the constraints

Fig. 2.2 George Washington Carver, full-length portrait, standing in field, probably at Tuskegee, Holding Piece of Soil (1906). Johnston, Frances Benjamin, 1864–1952, photographer. Library of Congress, Prints and Photographs Division. LC-USZ62–114302

[17] Carver is making explicit reference to what was known as "the cotton sharecropper's unit" which "was one mule and the land he can cultivate with a one-horse plow" (see Fig. 2.3).

faced by the soil, their access to farming equipment, and availability of natural resources. Carver explicitly stated his intention to connect experimental results of the long-term experiment in response to the difficulties faced by poor soil by Tuskegee farmers in articulating the set-up conditions for the experiment. The plowing of the tree stump strewn field was performed with one-horse equipment so as to "bring it more closely in touch with the one-horse farmer" (Carver 1905: 5) (Fig. 2.3). Making the results of the agricultural station's soil experiments accessible to anyone using the same soil amendments and soil management techniques relied upon in the experiment shaped both its design and implementation. As Carver writes: "the chief aim was to keep every operation within reach of the poorest tenant farmer occupying the poorest possible soil—worthy of consideration from an agricultural point of view" (Carver 1905: 5). This intention shaped what were conceived of as background conditions and what was the experimental target system to be intervened on for all Carver's soil experiments conducted at Tuskegee. Increased soil fertility was altering affordances to soil which relied on what was done with it. Because what could be done with it was constrained by the equipment local farmers had access to, the affordance of improved soil by means of experimental

Fig. 2.3 The cotton sharecropper's unit is one mule and the land he can cultivate with a one-horse plow. 1937. Greene County, Georgia. Public Domain, from The New York Public Library. Creative Commons CC0 1.0 Universal Public Domain Dedication ("CCO 1.0 Dedication")

interventions required protocols reflecting the intersecting ecological, economic, and technological positionality of farmers and their farming activities.

The choice of a long-term experiment was justified in order to investigate the additive effects different soil amendments and management techniques made to the soil, including crop rotation, deep plowing, terracing, and fertilizing in successive growing seasons. The format of the long-term experiment provided the necessary timescale to rigorously test multiple hypotheses about the effects of various causal interventions to the target system understood as a system that included the local farmers, their equipment, and the natural resources available to them.

Carver was rigorously empirical in this and his other long-term soil experiments. This empirical rigor was motivated by Carver's skepticism of the popular unrestricted endorsements of chemical soil analysis as sine qua non to any assessment of soil capacity for all soils everywhere common at that time among chemists and soil scientists. Carver argued that careful experimental design was necessary to make sense of chemical soil analyses. He expressed his suspicions concerning the pervasive uncontested reliance on chemical analyses in lieu of actual in-field crop experiments in his bulletin: "our present methods of chemical analysis do not accurately determine the crop-yielding capacity of a soil, but such analysis should be followed up by carefully conducted crop experiments" (Carver 1905: 5–6). While Carver lists Liebig's laws approvingly,[18] he cautions Alabama farmers that these cannot be relied upon without understanding of plant growth, nutrition, and the availability of soil nutrients and variable needs of different crop plants:

> the four laws of Liebig contain a clear statement of the principles underlying the use of fertilizers: *but* to understand their meaning with satisfactory clearness, we must know something more in detail about such subjects: a) the constituents of plants, b) the materials which furnish plant food, c) the condition these materials must be in before the plant can use them, d) the constituents of soils, e) what forms and quantities of plant food to use on different soils and crops. (Carver 1936: 3)[19]

Following the full description of the long-term experiment designed to intervene on these subjects, Carver reports to farmers which materials furnish plant food, which conditions these materials must be in in order for them to be available as food to plants and how the soil needs to be managed in order for worn out soil to be improved. That is, he explains how can the affordances of plants be understood in relation to the affordances of soils. He writes:

[18] Carver summarizes Liebig's four laws: "1. A soil can be termed fertile only when it contains all the materials requisite or necessary for the nutrition of plants in the required quantity and in the proper form. 2. With every crop a portion of these ingredients are removed. A part of this portion is again added from the inexhaustible store of the atmosphere; another part is lost forever if not restored by man. 3. The fertility of the soil remains unchanged if all the ingredients of a crop are given back to the land. Such a restitution is effected by fertilizers. 4. The fertilizers produced in the course of husbandry are not sufficient to maintain permanently the fertility of a farm; they lack the constituents which are annually exported in the shape of grain, hay, milk, and live stock" (Carver 1936: 3), cf. Liebig (1840).

[19] This was in stark contrast to Liebig's strongly reductive explanations of soil fertility: "the only known ultimate cause of vital force is a chemical process" (Liebig 1848: 99).

> All these experiments seem to show that it pays to make a good seed bed by preparing the soil deep and pulverizing it thoroughly. That swamp muck and leaf mould are valuable as fertilizer and should be used whenever they can be gotten easily… That peanuts should be grown by every farmer. That with proper manipulation our poorest soils may be made to produce an abundance of the staple crops. (Carver 1905: 15)

The aim of the long-term soil experiments at Tuskegee was to improve local growing conditions for farmers. Given this explicit aim, the results of the experimental station experiments must be conducted in such a way as to be reproducible for the tenant farmers relying on the same interventions in their own fields. Reproducibility of the same results of increased soil fertility year to year that the experiment station found as a result of their interventions did not simply rely on Carver's identification of the poorest soil possible on the experiment station or the use of a one-horse plow to conduct all interventions. Carver's 8-year experiment also included swapping cotton and for nitrogen-fixing peanuts in the crop rotation—to garner a free biological soil amendment as an alternative to the expensive chemical nitrogen fertilizers that local farmers could not afford. With one mule, farmers also lacked adequate manure to add to crops. Carver and colleagues at the experiment station found an alternative "green" manure that was locally available—swamp muck and leaf mould.

Carver recognizes that the amount of nitrogen (whether too much or too little) is an indicator of soil degradation or soil fertility. But also, that including peanuts in a farmer's crop rotation meant that the biologically produced nitrogen resulting from the microbial activities of nitrogen fixing bacteria in leguminous crops could provide the much-needed nitrogen to other non-nitrogen fixing plants. In doing so, he effectively reconceptualized many of the standard agricultural kinds thought to be necessary to promote fertile soil, like purchased fertilizers, and the use of high-cost equipment to manage soil and increase crop yield. In mirroring the resources and conditions faced by local farmers, the Carver study succeeded in what it set out to do—increase soil fertility in the worst soil and increase crop yield for farmers with access to one mule and a one-horse plow. Doing so, Carver's approach is intentionally keeping in mind the perspective of the Alabama tenant farmer and the conditions of the soil he was farming. Through the targeted experimental interventions and amendments Carver devised in light of the local farming community, the long-term study provides a particularly vivid example of a perspectivist approach to the management of soil systems and of soil affordances.

2.5 Reshaped Affordances in Engineered Systems

The examples in the foregoing sections illustrate how adoption of biological and chemical amendments and the use of various technological interventions reshape agriculturalized landscapes. These reshaped agriculturalized landscapes furnish different agricultural opportunities and/or burdens to plants, microbial and macrobial communities that compose soil systems as well as humans which are different from those opportunities and burdens afforded to them prior to the technological intervention. How microbial and macrobial communities respond to these new affordances affects the biological and physical makeup of the soil communities within these newly re-engineered agricultural ecologies. A host of inter-species causal interactions are reconceived in light of each new agricultural innovation. As I have shown, soil experiments, the development of technological interventions, soil ontologies and soil epistemologies are conceptually and methodologically intertwined. Agricultural interventions reshape species interactions and in doing so, change the affordances of the constituents of soil systems. The affordances and opportunities that are perceived by microbial and macrobial organisms are influenced by the perceptions of those conceiving of soil health or soil degradation, arable or marginal land.

Perceptions of the affordances of some soil microbes are also shaped by what soil is thought to be for. Soil microbes might be categorized as "beneficial", "neutral", or "pathogenic" depending on whether the role in soil microbiome and whether plant and soil disease are the targets of concern. However, these categorizations on their own disguise the interrelatedness of affordances they provide to other microbes as well as to plants and other macrofloral and fauna. One might interpret pathogenic microbes as a danger to be eliminated. This would be a mistake. Some beneficial microbes eat pathogenic microbes and so these trophic interactions would be disrupted if interventions were taken to remove all pathogenic microbes. The result of which would be decreased soil health rather than increased soil health.

The concepts used to classify soils as capable, healthy, or degraded also influence future research decisions, technological developments, and farm management decisions. Concepts, like those discussed above, of Quastel's *soil metabolism*, Leopold's *land health*, as well as the technological innovations leading to the synthesis of ammonia and the production of nitrogen-containing fertilizers by Haber and Bosch, the reshaping of soil mechanically in Carver's long-term soil improvement experiments, and recent conceptualizations of soil health and the indicators of it by Powlson and Lehmann and colleagues reform what is understood about the causal interactions between the constituents of soil systems.

Conceptualizations of soil, research decisions about soil improvement, and development of better biotechnologies for soil management rely on a value-laden purpose-driven soil epistemology and value-laden soil ontology. How the constituents of soil systems are perceived and valued informs the research questions pursued, the experimentally defined background conditions and the identification of appropriate target systems. The identification and management of different soil constituents as those of particular value—because they are perceived as indicators of soil health, necessary for plant nutrition, or central to soil sustainability—also affects how these constituents are identified and intervened on. Doing so also reconceptualizes what are considered the background conditions and how these elements and relationships of the soil system are controlled for in soil experiments. How these key constituents or relationships are described, used, and investigated determines what is known about them and how they are understood in studies which target these features as those which are worthy of investigation. Understanding soil and soil management in the context of agricultural purposes involves feedback loops of managing and valuing that rely on the social and technological relationships involved in the making and maintaining of agriculturalized ecologies.

References

Areniello, M., S. Matassa, G. Esposito, and P. N. L. Lens. 2022. *Biowaste upcycling into second-generation microbial protein through mixed-culture fermentation*. Trends in Biotechnology.

Bailey, Liberty Hyde. 1895. Preface. In *The soil, its nature, relations and fundamental principles of management*, ed. Franklin Hiram King, v–vi. New York: Macmillan Company.

Black, C. 1993. *Soil fertility evaluation and control*. Boca Raton: Lewis Publishing.

Blouin, M., M. E. Hodson, E. A. Delgado, G. Baker, L. Brussard, K. R. Butt, J. Dai, L. Dendooven, G. Peres, J. E. Tondoh, D. Cluzeau, and J. J. Brun. 2013. A review of earthworm impact on soil function and ecosystem services. *European Journal of Soil Science* 64:161–182.

Buchholz, D. D. 1993. Missouri limestone quality: What is ENM? University of Missouri extension Bulletin. https://extension.missouri.edu/publications/g9107. Accessed 1 Dec 2022.

Bünemann, Else, Giulia Bongiorno, Zhanguo Bai, Rachel Creamer, Gerlinde De Dyn, Ron de Goede, Luuk Fleskens, Violette Geissen, Thom Kuyper, Paul Mäder, Mirjam Pulleman, Wijnand Sukkel, Jan Willem van Groenigen, and Lijbert Brussaard. 2018. Soil quality–A critical review. *Soil Biology and Biochemistry* 120:105–125.

Carver, G. W. 1905. *"How to build up worn out soils" Bulletin no. 6*. Tuskegee: Tuskegee Institute Experiment Station, Tuskegee Normal and Industrial Institute Experiment Station.

Carver, G. W. 1936. *"How to build up and maintain the virgin fertility of our soils". Bulletin no. 42*. Tuskegee: Tuskegee Normal and Industrial Institute. Experiment Station.

Daims, Holger, Elena Lebedeva, Petra Pjevac, Ping Han, Craig Herbold, Mads Albertsen, Nico Jehmlich, Marton Palatinszky, Julia Vierheilig, Alexandr Bulaev, Rasmus Kirkegaard, Martin von Bergen, Thomas Rattei, Bernd Bendinger, P. H. Nielsen, and Michael Wagner. 2015. Complete nitrification by *Nitrospira* bacteria. *Nature* 528:504–509.

Danhorn, T., and C. Fuqua. 2007. Biofilm formation by plant-associated bacteria. *Annual Review of Microbiology* 61:401–422.

Darwin, C. 1904. *The formation of vegetable mould, through the action of worms*. London: John Murray.

Doran, J. W., and M. R. Zeiss. 2000. Soil health and sustainability: Managing the biotic component of soil quality. *Applied Soil Ecology* 15:3–11.

Erisman, Jan, Mark Sutton, James Galloway, Zbigniew Klimont, and Wilfried Winiwarter. 2008. How a century of ammonia synthesis changed the world. *Nature Geoscience* 1:1–4.

Gavala, H. N., A. Grimalt-Alemany, K. Asimakopoulos, and I. V. Skiadas. 2021. Gas biological conversions: The potential of syngas and carbon dioxide as production platforms. *Waste and Biomass Valorization* 12:5303–5328.

Gibson, J. J. 1979. *The ecological approach to visual perception*. Boston: Houghton Mifflin.

Godinot, O., P. Leterme, F. Vertès, P. Faverdin, and M. Carof. 2015. Relative nitrogen efficiency, a new indicator to assess crop livestock farming systems. *Agronomy for Sustainable Development* 35:857–868.

Hopkins, Cyril. 1910. *Soil fertility and permanent agriculture*. New York: Ginn.

Johnson, Timothy. 2016. Nitrogen nation: The legacy of World War I and the politics of chemical agriculture in the United States, 1916–1933. *Agricultural History* 90 (2): 209–229.

Kendig, Catherine. 2014. Hybridity in agriculture. In *Encyclopedia of food and agricultural ethics*, ed. Paul B. Thompson and David M. Kaplan, 1210–1218. Dordrecht: Springer. http://link.springer.com/referenceworkentry/10.1007/978-94-007-0929-4_421.

Kendig, Catherine. 2024. Human-managed soils and soil-managed humans: An interactive account of perspectival realism for soil management. *Journal of Social Ontology* 10 (2): 80–109. https://doi.org/10.25365/jso-2024-7690.

King, Franklin Hiram. 1895. *The soil, its nature, relations and fundamental principles of management*. New York: Macmillan Company.

King, Franklin Hiram. 1911. *Farmers of forty centuries: Organic farming in China, Korea, and Japan*. Madison: Democrat Printing.

Klages, S., C. Heidecke, B. Osterburg, J. Bailey, I. Calciu, C. Casey, et al. 2020. Nitrogen surplus-a unified indicator for water pollution in Europe? *Water* (Switzerland) 12:1197.

Krasovich, Emma, Peiley Lau, Jeanette Tseng, Julia Longmate, Kendon Bell, and Solomon Hsiang. 2022. Harmonized nitrogen and phosphorus concentrations in the Mississippi/Atchafalaya River Basin from 1980 to 2018. *Scientific Data* 9 (1): 524. https://doi.org/10.1038/s41597-022-01650-6. Accessed 21 Jan 2024.

Kroes, P. 1995. Technology and science-based heuristics. In *New directions in the philosophy of technology*, 17–39. Dordrecht: Springer Netherlands.

Lehmann, Johannes, Deborah Bossio, Ingrid Kögel-Knabner, and Matthias Rillig. 2020. The concept and future prospects of soil health. *Nature Reviews* 1:544–553.

Leopold, Aldo 1949. *A sand county almanac, and sketches here and there*. New York: Oxford University Press.

Liebig, Justus. 1840. *Die organische Chemie in ihrer Anwendung auf Agricultur und Physiologie*. Braunschweig: Friedrich Vieweg und Sohn Publishing Company.

Liebig, Justus. 1848. Familiar letters on chemistry and its relation to commerce, physiology, and agriculture.

Liebig, Justus. 1855. *Die Grundsätze der Agricultur-Chemie mit Rücksicht auf die in England angestellten Untersuchungen*. Braunschweig: Friedrich Vieweg und Sohn Publishing Company.

Matassa, Silvio, Pascal Boeckx, Jos Boere, Jan Erisman, Miao Guo, Raffaele Manzo, Francis Meerburg, Stefano Papirio, Ilje Pikaar, Korneel Rabaey, Diederik Rousseau, Jerald Schnoor, Peter Smith, Erik Smolders, Stefan Wuertz, and Willy Verstraete. 2023. How can we possibly resolve the planet's nitrogen dilemma? *Microbial Biotechnology* 16:15–27.

Mohamed, S., and A. Abdalla. 2013. Growth and yield response of groundnut (*Arachis hypogaea L.*) to microbial and phosphorus fertilizers. *Journal of Agri-Food and Applied Sciences* 1:78–85.

Morrow, K. H. 2023. A causal-role account of ecological role functions. *Philosophy of Science* 90 (2): 433–453.

NOAA. 2017. What is eutrophication? National Ocean Service website. https://oceanservice.noaa.gov/facts/eutrophication.html. Accessed 10 May 2017.

Nobel Prize. 2024. The Nobel Prize in chemistry. https://www.nobelprize.org/prizes/chemistry/

Odenbaugh, J. 2019. Functions in ecosystem ecology. *Philosophical Topics* 47 (1): 167–180.

Perry, Ron. 2011. Planting fruit trees. Michigan State University Extension Bulletin. https://www.canr.msu.edu/news/planting_fruit_trees. Accessed 23 May 2019.

Powlson, David. 2020. Soil health—useful terminology for communication or meaningless concept? Or both? *Frontiers in Agricultural Science and Engineering* 7 (3): 246–250.

Puga-Freitas, R., and M. Blouin. 2015. A review of the effects of soil organisms on plant hormone signalling pathways. *Environmental and Experimental Botany* 114:104–116.

Puig de la Bellacasa, María. 2014. Encountering bioinfrastrure: Ecological struggles and the sciences of soil. *Social Epistemology* 28 (1): 26–40.

Quastel, J. H. 1954. Leeuwenhoek lecture: Soil metabolism. Proceedings of the Royal Society of London. Series B, *Biological Sciences* 143 (911):159–178.

Rittel, Horst, and Melvin Webber. 1973. Dilemmas in a general theory of planning. *Policy Sciences* 4 (2): 155–169.

Sakarika, M., J. Spanoghe, Y. Sui, E. Wambacq, O. Grunert, G. Haesaert, et al. 2020. Purple nonsulphur bacteria and plant production: Benefits for fertilization, stress resistance and the environment. *Microbial Biotechnology* 13:1336–1365.

Schickore, Jutta. 2021. The place and significance of comparative trials in German agricultural writings around 1800. *Annals of Science* 78 (4): 484–503.

de Schryver, P., and W. Verstraete. 2009. Nitrogen removal from aquaculture pond water by heterotrophic nitrogen assimilation in lab-scale sequencing batch reactors. *Bioresource Technology* 100:1162–1167.

Smil, V. 2004. *Enriching the earth: Fritz Haber, Carl Bosch, and the transformation of world food production*. MIT Press.

Sprengel, C. 1926. Ueber Pflanzehumus, Humussäure und humussaure Salze. *Archiv für die Gesammte Naturlehre* 8:145–220.

Sprengel, C. 1928. Von den Substanzen der Ackerkrume und des Untergrundes. *Journal für Technische und Ökonomische Chemie* 2:423–474. and 3: 42–99.

Stoll, Steven. 2002. *Larding the lean earth*. New York: Hill and Wang.

The New York Public Library. 1937. "The cotton sharecropper's unit is one mule and the land he can cultivate with a one-horse plow. Greene County, Georgia" The Miriam and Ira D. Wallach Division of Art, Prints and Photographs: Photography Collection, New York Public Library Digital Collections. Creative Commons CC0 1.0 Universal Public Domain Dedication ("CCO 1.0 Dedication").

United States Census Bureau, U.S. and World Population Clock. 2024. https://www.census.gov/popclock/?intcmp=home_pop. Accessed 8 Jan 2024.

United States Department of Agriculture. 2023. Soil health. https://www.fs.usda.gov/nac/topics/soil-health.php#:~:text=Soil%20health%20is%20defined%20as,go%20far%20beyond%20crop%20production. Accessed 20 Apr 2023.

Vrooman, Carl. 1917. Stop tremendous manure waste. *Record of the division of soil fertility investigations*, RG 54 139 (4).

Wild, A., ed. 1988. *Russell's soil conditions and plant growth*. Burnt Mill: Longman and Wiley.

Xiao, Z., X. Wang, J. Koricheva, A. Kergunteuil, R.-C. Le Bayon, M. Liu, F. Hu, S. Rasmann, and A. Biere. 2017. Earthworms affect plant growth and resistance against herbivores: A meta-analysis. *Functional Ecology* 32 (1): 150–160.

Yang, Sha, Jianguo Wang, Zhaohui Tang, Feng Guo, Ye Zhang, Jialei Zhang, Jingjing Meng, Lei Zheng, Wan Shubo, and Xinguo Li. 2020. Transcriptome of peanut kernel and shell reveals the mechanism of calcium on peanut pod development. *Scientific Reports* 10:15723.

Chapter 3
Dreaming the Butterfly: Engineered Ecologies and Fragile Futures

Wyatt Galusky and Christopher R. Henke

Abstract Monarch butterflies are a well-known insect species to many people in North America. Their colorful bodies and migratory behavior, along with their ubiquity in popular culture and advertising, makes them a familiar presence in many communities. Risks to monarch populations, such as habitat loss and potential negative impacts of agricultural practices and technologies, create a sense of threat and potential loss to people who have established a connection with the species. This connection, paradoxically, exists in large part because of co-engineered landscapes and agricultural practices that brought human food systems into proximity and cohabitation with the monarch. In this article, we explore the creation of these co-produced environments that created spatial intersections and affinities between humans and butterflies—especially via the great midwestern U.S. corn belt. We argue that these intermingling environments of humans and nonhumans have created a space for what we term *interspecies agency*, a space that locates and animates contemporary debates about the impact of industrial food systems on species like the monarch, and reveal a contested set of cultural and material discourses that inform larger concerns about human-environmental relationships and visions of our interspecies future.

Keywords Interspecies agency · Biotechnology · Agriculture · Built environment · Charisma · Futures · Monarch butterfly

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3.1 Introduction: Shared Landscapes and Shared Lives

> The monarch butterfly (*Danaus plexippus*) is among the most recognized, studied, and loved of all of North America's insects. Children study monarchs in school. Researchers and citizen scientists track their migration and breeding. Conservationists and government agencies are concerned about threats to breeding, migration, and wintering habitats. (U.S. Forest Service 2023)

Non-human species are embedded in our culture, institutions, and ecosystems, and serve as a way for us to debate the relative merits of different forms of environmental action. When we portray organisms as charismatic or troublesome, endangered or invasive, we give them a role in the social and ecological dramas at the center of our environmental conflicts. At the same time, these non-human entities have their own roles and agency, which help to bring *us* into shared lives with *them*, especially via the extensive built environments that we co-create and cohabitate. In this chapter we use the case of the monarch butterfly to explore the role of organisms in environmental debates and, more broadly, the construction of cultural and material discourses around technology and nature. The monarch is a useful example because, as highlighted in the quotation above from a public-facing page on the U.S. Forest Service website, monarchs bring together a wide range of humans and institutions with interests and concerns about this insect. The monarch has several physical properties, including its relatively large size, its characteristic orange and black coloring, and its migratory behavior that make it among the most familiar insects in North America. In addition, monarchs have important ties to the built environments—especially agricultural landscapes—that humans have constructed over the past two hundred years. This constructed environment and the related physical presence of these butterflies make them a part of people's lived experience and connect them to a sense of place and the rhythms of the natural world. Monarchs are also prominent in important institutions, especially connected to education and marketing, where one can encounter them on an almost daily basis. Finally, monarchs are the subject of scientific research and debates about their behavior and ecology, and citizen science projects that track the insects bring a wide range of participants into dialogues and activism related to their conservation. Each of these key properties of monarchs and their place in our built environments and institutions give them a kind of power based on our shared lives and concerns about shared futures.

Scholarly work on the role of materiality in scientific and environmental controversies has highlighted the importance of "non-human actors," including non-human organisms, for helping to shape what are typically seen as human-centric debates and decisions about worldly phenomena. Though the attribution of agency to non-human entities and objects has been controversial, the larger point that "stuff" has an important influence on the behavior and perceptions of humans is an important corrective to a radically constructivist view of how we determine reality. At the same time, in this paper we illustrate the contingent power that organisms such as butterflies can have on environmental debates. Because our understanding of butterflies like the monarch is so fundamentally embedded in our own institutions and discourses, even the attribution of butterflies' agency is circumscribed by humans' exchange of symbols and meanings. While the monarchs play a significant role in these debates, it is not because they demand to do so, or even ask to do so; rather, humans construct the context in which monarch agency comes to matter in our contestations about the future. Understanding that mix will allow us to better analyze why the monarch shows up so prominently in our discourses.

Overall, the cohabitation of monarch butterflies and humans helps us see how concerns about our multispecies future are envisioned and debated in the context of a specific organism and its place within complex engineered ecosystems. Agricultural transformation helped bring the monarch into public consciousness and made it a familiar visitor to our daily landscapes; new agricultural technologies are perceived to threaten it. While butterflies participate in these debates through their material presence, activities, and vulnerabilities, they do so through a complex and extensive array of human-driven institutions, agendas, and priorities. We term this interface of human and insect actions and agendas as ***interspecies agency***, a space that animates care, concern, and action linking humans and butterflies. By mapping this framework, we can then examine the monarch as a case study for how humans work out their unease and uncertainties about specific ag-biotech innovations and the futures they forecast.

We focus on the case of agricultural biotechnologies because these technologies have been connected to the monarch via a series of studies and reports that raised concerns about the potential impacts they pose for the monarch. Transgenic crops, including especially engineered versions of corn, cotton, and soy, first became commercially available in the U.S. in 1996, and, in the subsequent two decades, have been widely adopted on U.S. farms and, increasingly, on farms throughout the world. Shortly after these technologies were rolled out to the U.S. market, in 1999, a group of agricultural scientists working at Cornell University published a research brief in the journal *Nature*, reporting on laboratory experiments in which monarch butterfly larvae were fed milkweed leaves covered with pollen from transgenic corn (Losey et al. 1999). The Cornell researchers, headed by John Losey, an entomologist, found that nearly half of the monarch larvae died after 4 days of feeding on leaves laced with pollen from transgenic corn, whereas other larvae fed non-transgenic pollen in a control group all survived. The article immediately attracted a great deal of media coverage and generated an intense amount of controversy. Anti-biotechnology activists quickly fixed on the colorful and well-known butterfly as a symbol for the dangers of transgenic crops, arguably bringing the issue of transgenic foods to a much more prominent position in the United States (especially when compared with the level of attention to transgenic foods in Europe and Japan during this time).

At the same time that environmental activists and the popular press were running with the story, portraying the monarch as a "Bambi" of the insect world already threatened by decreased habitat and overuse of agricultural pesticides, a countermovement quickly began to respond to the publicity surrounding the study's results. Following publication of the *Nature* paper, colleagues at Cornell, other research universities, and biotech corporations rushed immediately to caution the public—through statements to reporters and opinion columns published in industry and scientific publications—against overreacting to the Losey group's study. Invariably, critics of the *Nature* article noted the "artificial" context of the research, given that the monarch larvae in the experimental group had no choice as to what to eat or where to eat it—unlike butterflies in a more "natural" setting. These critics questioned the amounts of transgenic corn pollen that the larvae were exposed to and emphasized the need for more research on just how important cornfields are as habitats for monarchs "in the real world" (Monsanto 1999; Shelton and Roush 1999; Shelton and Sears 2001).

While this controversy is the most prominent of those that brought agricultural biotechnologies and concerns about impacts on monarch butterflies and other non-target organisms into the public view, monarch conservation has remained a topic of interest since 1999, with ongoing concerns about habitat loss and the secondary effects of ag-biotech on monarch populations. We trace these debates via multiple methods and data sources, including 27 interviews with scientists, administrators, and policy makers based in U.S. and Canadian universities as well as the U.S. Department of Agriculture (USDA) and Environmental Protection Agency (EPA). These interviews also included discussions with representatives from three agricultural biotechnology corporations that were (and are) key players in the technology of *Bt* corn. This series of interviews was designed to represent the views of the "core set" of players involved in the monarch controversy, or those participants who had the strongest voice in the details of how the controversy developed (Collins 1985, Nelkin 1995).

In addition to the interviews, we rely on an archive of news media content collected from 1999 through 2012, using keyword searches in the Lexis-Nexis database. Terms such as "monarch," "bt corn," and others generated a list of news articles and press releases from international sources. This content was then analyzed using MAXQDA, a qualitative data analysis software package that allows for coding and analysis of textual data. Patterns in the discussion of monarchs in this media content, such as their physical characteristics, migratory behavior, and threats to their habitat, were tracked as discrete codes. These codes, in turn, form a partial basis for the broader discourses described in this chapter.

3.2 Monarch Butterflies: Charisma and Concerns

The term "charismatic megafauna" is often used to describe the role of organisms in human culture, emphasizing the place of particularly well known signature species in shaping broader public awareness and concern. Typically these megafauna include species such as whales, bears, large cats, and elephants—organisms that are the frequent subjects of nature documentaries, children's books, and the symbols of prominent environmental interests (such as the World Wildlife Fund's panda, Greenpeace's whale, etc.; see Fig. 3.1 below for the former logo used by the Union of Concerned Scientists, which featured a monarch alit on planet Earth). Prior

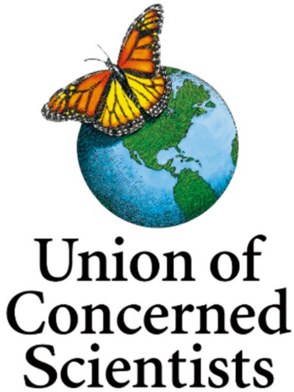

Fig. 3.1 Union of concerned scientists logo, featuring a monarch butterfly

research shows that charismatic megafauna influence not only public perception of which organisms are the most interesting or important (Mitman 2009; Hosey et al. 2020) but also the direction of research in fields such as conservation biology (Ducarme et al. 2013; Shriver-Rice et al. 2022). In this way, our perceptions of the importance of organisms both shapes and is shaped by the production of knowledge.

But what makes some organisms charismatic and others not so charismatic? Clearly a pet can be quite lovable and engaging to its owner but unattractive, annoying, or even repulsive to others with no relationship to the animal (Herzog 2010). Charismatic organisms do not necessarily appeal to everyone, but they have a broad familiarity and attraction to a larger public, and their charisma is not typically invested in a single organism. Instead, the entire species is invested with properties that form the basis for their charisma, and we must question and theorize these properties in order to better understand how a species can draw us to it. The most readily apparent aspects of a species' charisma are its physical properties—characteristics such as size, shape, coloring, behaviors, and other physical markers that we find appealing, perhaps because they remind us of human characteristics and behaviors (Lorimer 2006, 2007). This certainly contributes to the charisma of the monarch butterfly, which are renowned for their relative size, striking orange and black coloring, and migratory behaviors (Fig. 3.2).

But it would be a mistake to stop here or to overemphasize the importance of monarchs' physical characteristics; they are not the only beautiful butterflies that we might encounter on a walk through a field or forest. By reducing the charismatic power of organisms to their material properties, we risk missing how they are embedded in a network of institutions and cultural practices that supports and amplifies their charisma.

The touchstone for understanding the social basis of charisma is Weber's (1978) work on authority, where he discusses charisma as one of three possible sources for the legitimacy of power. In contrast with the two other key forms of authority that he defines — traditional and legal-rational — charismatic authority is based more on the individual characteristics of a leader and the specific aspects of personality, appearance, and manner that project an aura of leadership (Weber 1978: 241).

Fig. 3.2 A monarch butterfly. License: CCO Public Domain, Franziska Pätzold (2023)

Therefore, in Weber's view, charismatic authority is more mercurial and more dependent on the attribution of legitimacy from subjects of this power than other forms of authority, because it has a lesser foundation in social institutions, such as the laws, customs, or practices that may support traditional or legal-rational authority. The "routinization of charisma," however, can preserve and reproduce charismatic authority if the leader and his or her followers put in place an institutionalized form of authority before their lives or their charisma come to an end (246; see also Thorpe and Shapin 2000). Institutionalization is not the death of charisma; in fact, institutions provide the basis for a charismatic afterlife.

This connection between human institutions and the charisma of an organism like the monarch raises questions about the role of agency in their impact on human perceptions: are we more likely to see an organism as charismatic if it also has properties and behaviors that are agentic? This question stems in large part from theories of non-human agency developed in the actor-network theory (ANT) approach, especially in the work of Callon, Latour, and Law. ANT posits a strong view of agency attributable to organisms and things that we would not normally think of as especially active—a speed bump slows us down or a scallop must behave in a certain way to align with the interests of researchers (Latour 1984, 1992, 1993; Callon and Law 1986; de Laet and Mol 2000; Sayes 2014). Thus, non-humans may be enrolled in the network of laboratory practices and emergent facts of scientists and other human actors, but they do not enroll just because humans want them to. If scientific and technical achievements are based in a complex web of intersecting interests, then ANT emphasizes that materiality has a place in this network, too, where non-human agents delimit the ability of humans to make claims about their behavior. As noted by Lorimer (2006: 549), monarch butterflies are particularly well-suited to attract human attention, because of their "detectability"—characteristics that include a complex array of variables, including visibility, but also activity range (spatial and temporal), etc., which coincide with human activities.

While this aspect of ANT has established the agency of non-humans as a key topic of research for scholars working in STS and allied fields, the equivalence of human and non-human agency effectively flattens human social action and, in particular, makes it difficult to develop a cultural theory that could make sense of the charisma of non-human organisms like the monarch butterfly, especially when we are asked to assume that human and non-human agencies are strictly symmetrical. In the context of ANT, charisma is nonsense, because categories of analysis such as culture or charisma are epiphenomenon that are ultimately based in chains of network ties (Latour 1984, 1993). Non-human organisms, however, are not in the same category as humans when it comes to what might be called "cultural agency," which can be defined as the process of assigning and negotiating meaning. It is unclear whether non-human organisms and things can engage in cultural agency at all, but humans are clearly the masters of placing any situation within a frame of reference that depends on a web of meaning.

In this context, monarchs can be said to have agency, but it is a fragile agency, circumscribed by human priorities and action. In addition, the kind of insect agency we are interested in here is almost entirely at the species level; an individual monarch certainly acts according to its own impulses and instincts, but a single butterfly—or even thousands—did not create the web of meanings and resources that humans tap into when thinking about monarchs. Instead, the collective numbers and successive generations of monarchs is the basis for the complex relationship between humans and these butterflies. Perhaps the best way to sum up these relationships and interactions is through the term ***interspecies agency***, to emphasize that monarchs and humans both have agency, have acted in collective and interdependent ways to create complex ecologies, and set a context where humans can worry about, plan for, and act on the place of monarch butterflies in our lives and in our world. Our conception of interspecies agency is allied with the recent work of other scholars writing about the complex ways that humans and nonhuman (or more-than-human) species interact and might even be seen to collaborate and interdepend (Haraway 2013; Vogel 2016; Blattner et al. 2020; Wadham 2021; Galusky 2022; Preston 2023).

Ultimately, the monarch's charisma is built and sustained through the interspecies agency that co-creates spaces where humans and these butterflies interact in schools, media messages, engineered landscapes, and scientific knowledge. It is the basis of an interspecies discourse that includes language and culture, ecologies, organizations, and infrastructures in a web of meaning and materiality, providing a set of resources for us to debate and understand the place of monarchs in our lives. Monarch butterflies enchant us through their appearance, their behaviors, and their presence in our landscapes and culture, creating a system where we can make meaning and assign value to the butterflies and our connections to them. When we learn about and perceive risks to a species like the monarch, their fragility as an insect that seems to flit about aimlessly on the wind and the many hazards that they face due to human manipulation of their environments emphasizes their precarity and our fears about the risks of unchecked environmental change. These concerns have been especially public and controversial in the context of transgenic crops such as engineered corn and soy that have been portrayed as directly threatening to monarchs or more indirectly damaging to their ecologies. We turn to those particular human-shaped landscapes that have contributed to the process of making monarchs matter—as both a material and symbolic presence.

3.3 Monarch Bodies in Engineered Landscapes: The Material Basis of Interspecies Agency

Though we have to this point described the monarch butterfly as a single species, subpopulations of the monarch with distinct behaviors and genetics are now spread through the Americas, Pacific Islands, and Oceania. Recent genetic testing on monarch butterfly populations shows that they developed their migratory behavior around two million years ago, establishing the pattern of annual migration from Mexico to the upper United States and Canada. Subsequently, the monarch spread to other locales, establishing subpopulations that are non-migratory (Zhan et al. 2014; Freedman and Kronforst 2023). Our story in this chapter is focused on the migratory population in North America, not only because its behavior puts it in contact with many human populations across North America, but also because of the geographic overlap between monarchs and the development of industrial agriculture in the nineteenth and especially in the twentieth century. In this section, we demonstrate how both the physical characteristics and migratory behavior of the monarch butterfly make it significant as an icon while also showing how the landscapes of North American agriculture have shaped the interaction of humans and butterflies over the past hundred years and more of industrial agriculture and changing land use patterns.

3.3.1 The Monarch as a Beautiful and Mysterious Migrant

To make an obvious but important point—the monarch butterfly is a large, colorful insect that catches one's eye when floating on the wind through a garden or field. In addition to its striking orange and black coloring as a butterfly, its larval stage includes colorful white, black, and orange alternating stripes (see image in Fig. 3.2 above; Oberhauser and Solensky 2004: vii). These patterns are meant to signal predators that monarch larvae and butterflies are unpalatable and toxic, but they also present to us a very recognizable form that many monarch admirers find beautiful. Indeed, descriptions of monarchs' coloring and perceived beauty are very common in the media depictions of monarchs found in content analysis for this project. Variations on the terms, "beautiful," "colorful," and "majestic" appeared in many of the news stories that featured questions about the impact of transgenic corn on monarchs. In this example, from a story published in London's *Daily Mail* in the summer of 2000, journalist James Chapman wrote about a follow-up study to the Losey group experiment (Jesse and Obrycki 2000), which also presented data showing the possibility of toxic impacts on monarchs from *Bt* corn:

> GENETICALLY modified crops were at the centre of a new safety scare last night after scientists proved they can kill one of the world's most beautiful butterflies.
>
> —"Butterfly Beauty is Poisoned by GM Crop Pollen" (Chapman 2000)

Both the title and the lead for this article emphasize a contrast between the inherent beauty of the monarch and the danger facing it from agricultural biotechnologies. This contrast plays on a tension between human-generated interventions, such as transgenic crops, and the ideal of nature as represented by the monarch. In this way the monarch stands in for nature, serving as a symbolic warning system that is meant to alert humans to the consequences of agricultural biotechnologies. In this interview with an entomologist who was a key player in the monarch controversy, the same themes of recognizability and perceived threat are emphasized:

> You can say to someone, "What's a monarch butterfly?" in North America, and they would say, "Oh, that orange and black one and it migrates … somewhere down south." Everybody understood right away. So it really is a mark of … a healthy environment. It's like talking about a bald eagle for crying out loud you know.
>
> —Author interview with entomologist (2004)

This entomologist ends the quotation with a comparison between the monarch and the bald eagle, the national bird of the U.S. and a key symbol of American power. In the same way that birds were portrayed as an early warning system for nature in peril starting in the 1960s, and especially through their representation in Rachel Carson's *Silent Spring* (1962), here the monarch is depicted through the same frame of prominence and endangerment. In the wake of the monarch controversy triggered by the publication of the Losey group study in 1999, activist groups opposed to the use of transgenic crops quickly adopted the monarch as a direct way to tap into this connection between monarchs, nature, and the threats posed to each by biotechnologies. Protestors dressed in the colors and patterns of monarchs when participating in demonstrations against the technology; for example, a major protest centered around a biotechnology industry summit in Sacramento, in 2003, attracted thousands of activists from a diverse array of NGOs and anti-globalization groups. The monarch provided a way for these protestors to draw on the same theme of nature in peril as depicted in the examples above.

In addition to this focus on the physical characteristics of monarchs and how they visually trigger associations with nature, the unique migratory behavior of the monarch butterfly is also a key feature that makes the monarch compelling to us, but also puts them in the same environs where humans live, allowing us to see and interact with them. The ecology and lifecycle of the monarch includes an annual migration, from mountain forests in Northern Mexico to points as far north as Canada—and back again—that makes them rare in the insect world (see Fig. 3.3 below). This migratory behavior was not fully appreciated until the 1970s, when broader

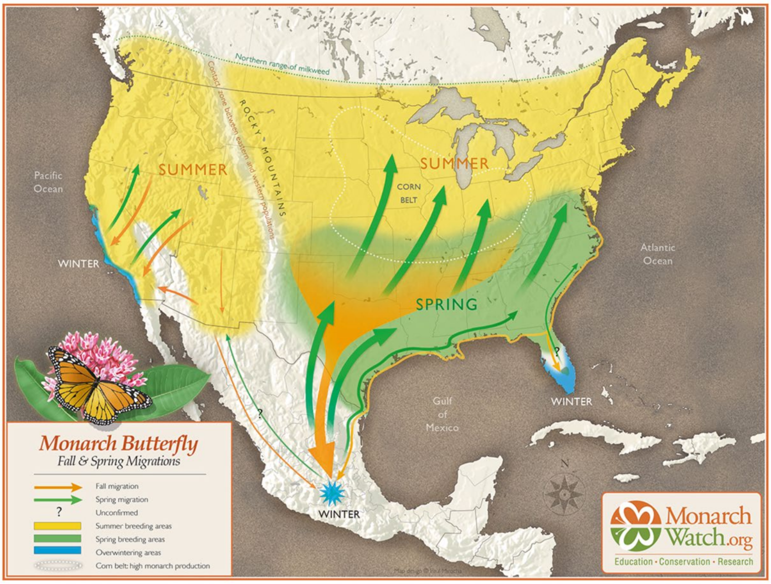

Fig. 3.3 Migration patterns of North American monarch butterfly populations (Monarch Watch 2023)

attention to the phenomenon was generated through the discovery of the monarch overwintering sites in the mountain forests of Michoacán, Mexico, and published in an issue of *National Geographic* with an iconic cover photo (see Maeckle 2012, for the story of this cover, along with other related images of Catalina Trail and Monarch butterfly roosting sites). Since that "discovery" (local groups had obviously known about the monarchs for a long time), concern about deforestation and other threats to the migratory behavior of the monarch has continued to draw attention to dangers facing the species. More recent research showing the loss of habitat in the "corn belt" spanning a large portion of the American Midwest and southern Canada also questions the long-term viability of the migratory path of the monarch (more on this below).

The monarch's annual migration and, especially, the contrast between their long journey and the slight build of the butterfly body provide a fascination for many writers collected in the content analysis portion of this project. At the same time that monarchs are frequently described as "hardy" or "enduring," they are also portrayed as "fragile" and "delicate." In this excerpt, from an editorial by popular Canadian science and nature writer David Suzuki, the monarch migration is, again, made to stand in for the wonders of nature:

> There's also much to celebrate about the monarch butterfly, even though these fragile insects have flown close to the plane of death in recent times. Populations have been reduced by as much as 90 per cent in the past, but there's still hope. That these delicate creatures can make such an arduous journey is in itself a wonderful story of survival and the mysterious workings of nature.
>
> —"Celebrate Life and Butterflies on Day of the Dead" (Suzuki 2010)

Suzuki's reference to the "mysterious" qualities of the monarch is also a frequent theme, where their migratory behavior is described as a beautiful mystery in its own right. Because scientists researching the monarch have only known the location of their overwintering site for a few decades, and there are still many unanswered questions about monarchs' ability to navigate the journey each year, many news items feature quotations that state, "it's a mystery," in response to questions about the migration.

3.3.2 Monarch Butterfly Habitat in the Context of Industrial Agriculture

Overall, the monarch is, as described above, a powerful visual trigger, associated with meanings related to beauty, health, and nature. But other butterflies are pretty, too. Why have those same insects—for example, the lovely yellow swallowtail—not captured our attention in the same way as the monarch? The Eastern swallowtail is more likely to be found in forested areas, where it lays its eggs for larva to feed on the leaves of trees. The monarch, however, has a migratory pathway that puts it in close proximity with patterns of human land use that have made them denizens of cornfields and suburbs.

Figures 3.3 and 3.4 help to demonstrate this overlap; Fig. 3.3 shows the migratory path of North American monarchs, and Fig. 3.4 shows (in shades of green) the United States counties with the highest intensity of corn production.

These maps explain in part how and why monarchs are a compelling symbol for many: humans recognize the monarch as familiar and charismatic because we built ecosystems where we, for a time, coexisted with them. The monarch's migratory behavior coincided with a massive reengineering of the North American landscape during the nineteenth and twentieth centuries. What we know today as the American corn belt was once largely grassland prairie that has since been converted to agricultural production and human development. The human introduction of corn into North American ecosystems has a long history, from the first cultivation of corn's ancestor, teosinte, in Mexico many centuries ago, to Native Americans' dependence on corn as a subsistence crop before European colonization, to the adoption of the crop by those same colonists in the centuries leading up to the industrial era. With the advance of European settlement through the middle-west region of the United States in the nineteenth century, corn began to take over large regions of North America and has only increased its presence through the early twenty-first century. Agricultural technologies, such as mechanized production equipment, synthetic fertilizers and pesticides, and biotechnologies, boosted the productivity of corn farmers and their land throughout the twentieth century, leading "king corn" to its contemporary status as the number one crop commodity produced in the US. In 2023, US farmers planted 94.9 million acres of corn, comprising approximately 4 percent of all US land (USDA ERS; USDA NASS). This represented an increase of

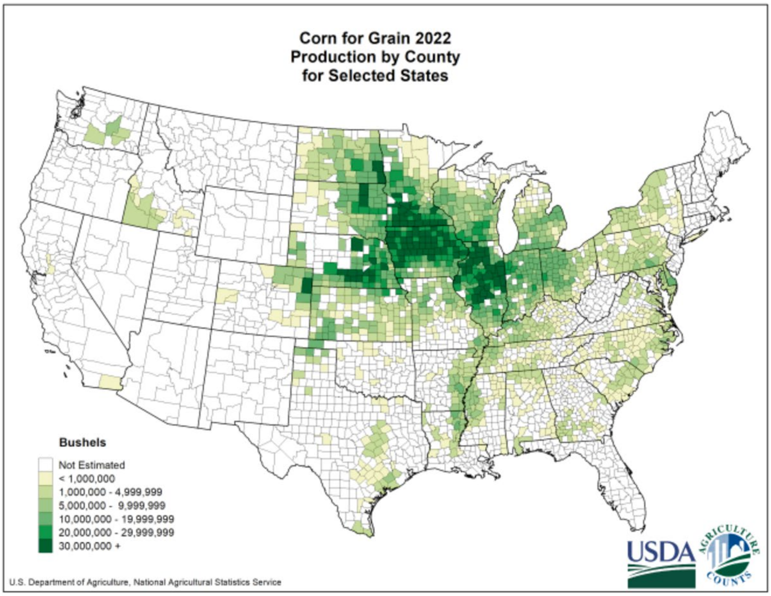

Fig. 3.4 Map depicting U.S. counties where the most corn is grown (USDA 2023)

28 percent since 1990 (when 74.2 million acres of corn were planted), due in large part to the role of corn and corn byproducts in food production as well as US policies supporting the production of biofuels such as corn-based ethanol.

Despite the disruption of native ecosystems through this transformation, where many of the species of prairie grasses were displaced, the corn belt actually provided an important habitat for the monarch and the milkweed on which it depends. Monarch butterflies lay their eggs on milkweed leaves, where their larvae hatch and feed. Toxins present in the flesh of milkweed provide monarch larvae and adults with a kind of built-in resistance from predators that find their taste unpleasant; these same toxins can be harmful to livestock if eaten in large quantities, and so a number of U.S. States and Canadian Provinces at one time designated milkweed as a “noxious weed,” which mandated the control and eradication of the plant. Despite these policies, the corn belt actually created an enormous habitat for milkweed and the monarch, as the plant commonly grew in and around corn fields (Hartzler 2010). This meant that the human transformation of the great American prairie reserved a place for monarchs, and kept them present in the daily lives of many humans throughout the months when monarchs migrate through the U.S. and Canada. In fact, the rise of suburbanization in the U.S. during the late twentieth century meant that many communities were built on land that was formerly agricultural, especially throughout the corn belt (Emili and Greene 2014). In the twenty-first century, the corn belt is also shifting west into land that was previously pasture and prairie, raising concerns about the impact of this land conversion on wildlife populations and wetland ecologies (Wright and Wimberly 2013; Hunt et al. 2020; Lark et al. 2020).

Since the introduction of transgenic corn and soy, however, the corn belt ecosystem has experienced a rapid transformation, shifting the role of milkweed in this ecology. Beginning with the introduction of herbicide-tolerant soy and insect-resistant corn in 1996, more and more growers have adopted these transgenic technologies and used them in tandem with each other. So, for example, a grower who in the past mainly planted corn on their land now more often rotates soy and corn in alternate seasons. Because the soy—and increasingly the corn, too—is designed to be herbicide tolerant, the grower can use more herbicide on their crops, meaning that fewer milkweed plants are proximate to these fields than before the introduction of transgenic varieties. The loss of milkweed means a direct impact to monarch populations, and, in fact, recent research shows that monarch populations are declining, due in part to this loss of habitat through the corn belt (Hartzler 2010; Lark et al. 2020). Many gardeners are now planting their own milkweed to help support the monarch population (see below), though the scale of these plantings are necessarily quite small compared with the sheer size of the ecosystem once provided by corn production.

This shifting dynamic between corn and monarch habitat points to the complex political ecology linking human behavior with that of other organisms, such as the monarch, and how the physical characteristics of a butterfly, as described above, are embedded within a system of biological, political-economic, and cultural forces (Rissing 2021). At the same time, the presence of organisms within a human ecology is not a precondition for us to consider them charismatic; many of the seemingly most charismatic animals are in habitats where humans are not present or are rare, such as whales in the ocean or polar bears in the Arctic. These are examples where those humans who *do* come into contact with the organisms do have a strong interest in the ecological and often economic consequences of this interaction. Whether for hunting, tourism, or impact on another species (such as wolves preying on ranchers' livestock), the connection between human material interests and other organisms' ways of being in the world may, in turn, shape our perception of them, making them seem beautiful, dangerous, or threatened. To more fully understand the charisma of organisms and where it comes from, we need to see how human institutions shape our beliefs and ideologies about them.

3.4 Monarch Bodies in the Classroom and the World: Cultivating Charisma

As we explore above, the charisma of the monarch emerges through the intersection of butterfly characteristics and human practices that become entangled. Trends in agricultural practice, shifts in human settlement patterns, and concerns about technoscientific change map onto the life cycle of an organism that we have come to care about. This intersection appears to be an artifact of co-incidence. The butterflies showed up, their activities coincided with agricultural practices that may have heightened their precarity, and we noticed. But the charisma of the monarch is also the product of more intentional efforts to bring the organism into human awareness, through educational systems and pop-cultural images that cultivate a specific place for the monarch within human institutions. In turning to these institutions, we can see the development of an increasingly entangled sense of interspecies agency, as we learn more about how monarchs develop, how risks shape their continued existence, and how humans adapt their own practices and expectations in light of these relations.

The monarch plays an outsized role in the educational environment in the United States, especially in grade schools. Many of us, in the US educational context, have participated in monarch rearing or releasing activities in grade school. We see that there are efforts across the country to use this insect as a means of conveying lessons about ecosystem functioning, the life cycle, migration, and other key environmental and biological concepts. Teachers create lessons incorporating the monarch into the classroom (the Monarch Teacher Network includes 3.5 k people in their public Facebook group). Every year, thousands of young students learn about the life cycle through the metamorphosis of monarch butterflies, in many cases actually rearing monarchs from eggs to watch first-hand the larval, pupa, and butterfly stages of the organism's transformation. Students then release the butterflies, and can imagine them joining the great migratory flow. They learn that monarchs are special; they can develop a fascination with the butterfly's life cycle based on the experiences they have with them in the classroom. The monarch resonates as a symbol of the non-human world and our concerns for it.

There is a relatively common curriculum that introduces these facets of the monarch to the US student, which illustrates the life cycle (egg, caterpillar, chrysalis, butterfly) and the process of care and emergence. The monarch occupies a place in the educational system that lends itself to being the focus of our concerns. To quote the US Forest Service again, "The **monarch butterfly** (*Danaus plexippus*) is among the most recognized, studied, and loved of all of North America's insects. Children study monarchs in school. Researchers and citizen scientists track their migration and breeding. Conservationists and government agencies are concerned about threats to breeding, migration, and wintering habitats." Here are several key examples of how the monarch gets incorporated into human systems, related to recognition, education, and concern. We learn about the monarch, we adopt practices that keep it visible, and we incorporate this awareness into our legislative bureaucracy.

The use of the monarch for this purpose is no accident, and connects to the exploration of charisma above—there are a variety of factors that help make the monarch more compatible with human experiences, including the relative speed of their development from pupa to butterfly, the low cost of supplying the insect to classrooms, and the migratory spread of the insects. Importantly, people are also often familiar with this butterfly outside of the classroom, and so educators can tap into this presence (how easily they can be spotted, how distinct they are from other species, how geographically dispersed they are, how compatible their active times are to human active times). That charisma is also magnified *because* of these educational settings, where people are trained to look for and cherish these beings. This learning, the incorporation of the monarch into educational and pop cultural systems, can be parceled in the same kind of conceptual categories as we explore above in terms of how this interspecies agency develops: what is at risk (precarity), including those characteristics of the butterfly bring to this relationship, and what role we humans have in promoting the persistence of this species (human responsibility). We take each of those in turn.

The **fragility [precarity]** of the monarch appears to be a part of the general learning experience of the butterfly in the classroom—the paper-thin wings, the squishable caterpillar, the perilous migration for thousands of miles (see, for example, the "Butterfly Threats worksheet", Cooper n.d.). The possibility of disruption has long been a staple of the learning associated with the monarch, and so it's little wonder that issues surrounding transgenic crops intersected with this beloved creature. The precarity has always been a part of the story (Monarch Watch, an organization whose mission involves providing "the public with information about the biology of monarch butterflies, their spectacular migration, and how to use monarchs to further science education in primary and secondary schools," was founded in 1992, and has a major focus on habitat loss). This cultivation of concern, that monarchs are something to be looked at and looked after, forms a key characteristic of the being's charisma. It occupies this place in these institutions (see Fig. 3.1, above).

A child in school learns to treat the caterpillar, and later the butterfly, with care, attending to its needs—even to love these beings. Grade-specific lesson plans vary, but gradually introduce students to natural systems that the monarchs depend upon and on the aspects that threaten them. K-2 lesson plans focus on life cycle elements—learning about the biological components of the monarch's transition from caterpillar to butterfly, and then move out into local habitat and how students can cultivate butterfly gardens. As students get older, more lessons include larger ecological disruptions and other threats to the resilience of the monarch. Students learn to become more broadly aware of global environmental effects and the risks to the butterfly population. The concerns broaden, and students learn about the interconnectivity of habitats and practices for such a migratory species. Monarchs are also used to introduce young students to the interconnectivity of North America, with migratory patterns allowing students to not just trace the flight of the butterfly but also to see that the actions locally impact beings across the continent. Media sources expressing concern about the Monarch around the time of the transgenic crop controversy indicate potential risks from logging in Mexico, as well as transgenic crops (in terms of habitat loss and the spread of herbicides—see Miller 2006; Wikston 2008). More contemporary sources with a greater focus on the climate crisis point to similar human practices, such as logging and agricultural practices (see Vaughn 2021; Schanen 2023; Diaz 2021; Viswanathan 2022; Pellegrino 2021). This learning process contributes to the kind of charisma that the monarch develops, as students learn about the butterfly, but also learn that this entity is delicate and in need of being watched over and cared for.

Importantly, the monarch within educational systems helps to illustrate this interspecies agency that we lay out above. The actions that monarchs play are not simply at the express direction of humans. A meaningful part of the experience with monarchs in the classroom or laboratory helps to illustrate a natural world that is not simply at the direction of humans. There is an entanglement that is established—a sense that the monarch needs a certain set of conditions in which to thrive, but then will do so on its own time and in its own way. The monarch lesson is one of precarity, surely, but also one of a lifeform that, under the right conditions, can be a source of wonder and resilience in the face of obstacles. As MassAudobon phrases it, "[Monarchs] are symbols of both fragility and strength" (Wiseman 2019). The monarch lesson is also one of failure—where students learn that things cannot always go to plan, and that we have to live within that possibility that we will not get the results we hope (or when we hope for them). Monarchs die. Tracking fails (see below). Students confront the problems associated with trying to care for another life. This is a part of the learning that is central to the integration of the monarch experience within the classroom setting.

The engagement with butterflies in the context of education has many of the explicit lessons articulated above, but also involve more ancillary lessons that are critical to establishing the difference of the Monarch. For those encounters that occur in butterfly kits, in the classroom, there is the sense of anticipation that comes from waiting. As one educator put it, "I hope my students and parents always refer back to that September experience with the Monarchs, and remember when that butterfly emerged from its chrysalis—when it was ready. It's a beautiful lesson to learn, and it would be a shame if it disappeared" (Gikas, quoted in Feely 2010). These are the potential outcomes, and the possible recognition that these beings are of themselves and develop on their own time and patterns. We come to love them in the sense articulated by Iris Murdoch: "Love is the extremely difficult realization that something other than oneself is real" (quoted in Jamieson and Nadzam 2015, p. 204). Humans can get in the way, or we can help to create the conditions of possibility (more on this below), but the butterfly plays its part in realizing any potential.

There is an interspecies element even here, however, in the ways that human institutions bracket these experiences and make them possible as such. We are able to see the monarch as an example of independence and interdependence because of the educational structures that make such lessons possible. We come to know the monarch as a being that is a mix of strength and vulnerability—ones that can thrive under the right conditions, but need a little help ensuring that such conditions exist. That help can come from humans or from weather patterns and other conditions related to larger global systems. As Lewis (a professor of entomology at Iowa State University) noted, "Butterflies are not fragile critters, but they do need some gentleness in their environment, which often means absence of spectacular storms, especially at the time when the butterflies are reproducing and the tiny caterpillars are establishing" (quoted in Branom 1999).

Part of the educational incorporation of the monarch involves the roles that students, and humans more generally, can and should play in the flourishing or protection of the butterfly—an articulation of our individual and collective **responsibility**, where our human agency intersects with the butterfly's. This is the means by which interspecies agency can be realized. Our educational systems establish modes of interacting with the monarch and contributing our own actions to their possibility and well-being—as such, the precarity of the butterfly is entangled with our responsibility to its continued existence. We can see this development mimic, to some degree, the life cycle stages of the butterfly itself, as lesson plans geared toward differing levels of students increase in complexity and impact through time. We learn specific ways to condition our own actions, helping to create the context in which a certain type of butterfly existence can be established. There are four interrelated modes that form the structure of our responsibility: emergence, surveillance, cultivation, and protection.

Emergence (guiding the butterfly into existence): most lessons integrating butterflies into the classroom start with a monarch butterfly kit, which allows students to observe and participate with the monarch life cycle. Swallowtail Farms, Inc., sells what they call a “butterfly zoo.” Educational Science has a “butterfly farm.” The human role in curation and cultivation is foregrounded in both references. Generally, kits include monarch caterpillars and some type of viewing apparatus, which allow students to see this process in action, while participating in the care for these creatures. For example, they have to provide for the feeding of the caterpillars, with kits noting that milkweed is either included or required. Monarch Watch sells “rearing kits” that do not include milkweed, but instead have this caveat: “You must have fresh, incontaminated [sic] milkweed for your caterpillars ready when they arrive.” Humans are invited into the lives of the butterflies, to help bring them into the world, which reinforces both the precarity of the being, and our role in bringing it into existence in a manner that is safe and durable.

Surveillance (creating modes of tracking during migration): another component of the monarch integration within these educational and social systems come in the form of tracking the movements of the butterfly on their migration through the monarch watch survey. This process enhances the visibility of the monarch, by extending its presence. We can see the individual butterflies in the classroom or in the garden, but also trace its more species-level travels across the continent. This is an important part of the experience, as part of the allure of the insect is the awe that is generated from learning that such a seemingly fragile creature can travel such long distances. This is part of the monarch story that makes it so compelling—a Methuselah generation that travels thousands of miles in the fall to overwinter in a place that they have never inhabited individually but is a part of their genetic legacy. Students can participate in tracking, by placing tags on their wings prior to migration, and recording/submitting those tag markings for future data collection (in the US, students can place small tags on butterflies that can then be gathered in Mexico after the migration is complete). Students can also explore the success rate of such tagging (for example, according to JourneyNorth.org, the recovery rates for Monarchs tagged in the Eastern US and arriving in central Mexico are 1 in 100), examine the complexities of this practice, and participate in a kind of citizen science.

The citizen science aspect is an important part of this entangled agency we’re exploring here, as these opportunities to participate in the surveillance of monarch migration and behavior (often initiated in formal educational settings) extend beyond the classroom. People are encouraged to stay involved and participate in the monitoring of butterflies, generating data as a means of tracing population numbers and highlighting areas of concern. The term "citizen science" is evoked explicitly as calls to action by government agencies and advocacy groups promoting continuing attention (see, for example, the US Forest Service's Monarch Butterfly Citizen Science project involving tagging, citizenscience.gov's Monarch Larva Monitoring Project, Monarch Joint Venture's Mission Monarch project related to breeding habits, and other "Citizen Science" projects sponsored by JourneyNorth and Monarch Watch). There are apps that people can use, in addition to less connected observation tools. This conception of citizen scientist facilitates the sustained participation of individuals, and the continued incorporation of the monarch within these social and epistemological spheres.

Cultivation (planting and caring for habitat): another stage in the development of human responsibility in the life cycle of the monarch comes in the form of planting and growing milkweed, in backyard gardens or in other areas, often for the purpose of butterflies alone. People are encouraged to think about the needs of monarchs, especially in preparation for and during their migration, and to cultivate habitats that will facilitate success. Milkweed gardens, or milkweed in gardens, are promoted to help create the conditions for successful monarch populations. Planting milkweed for the purposes of aiding monarch populations is advocated in places like *Better Homes and Gardens*, *Savvy Gardening*, *Real Simple*, and *The Victory Garden of Tomorrow* (which offers a sign to plant in your garden announcing "Milkweed for Monarchs"). The practice is not without its critics—for example, Vogt (2022) argues convincingly that people should be sensitive to the entire food needs of the monarch (host plants, like the milkweed, and nectar plants, like goldenrod, coneflower, and sedge), because it's not about a monocropped landscape but a full ecology. Even here the question is not whether humans should get involved, but rather how best to do so. Humans are presented as necessary allies and facilitators to the threatened monarch butterfly population; humans can help create the conditions that may allow the butterfly population to thrive, by intentionally planting milkweed or cultivating a butterfly garden. For example, in a set of lesson plans offered by the National Wildlife Federation for K-2 students, their lesson 4, about cultivating a monarch garden, is subtitled "A friend in need is a friend indeed" ("The Monarch Mission," A4.1). This also has the added benefit of attracting these creatures to one's own landscape. This is the kind of integrated double-benefit expressed in the interspecies agency that we have been exploring—the butterflies benefit from having access to more host plants for their caterpillars, and humans benefit from having more beauty in their gardens and communities.

Protection (engaging in advocacy for larger concerns about habitat destruction—through erasure and through change): a further extension of the development of human responsibility comes in the form of more large-scale political advocacy. These are the kinds of changes that are more abstract, difficult to produce, but relevant to successful outcomes. The calls for protection at this scale can come as an extension of lesson plans, citizen science activity, or general advocacy campaigns connected to established groups like MassAudobon, Monarch Watch, Journey North, and others. Once precarity is identified, either because of farming practices, or logging, or harmful pesticide usage, people are encouraged to promote policy changes and other forms of bureaucratic intervention. This kind of advocacy can also result from concerns related to the limitations inherent in these other forms of human activity, such as those which emphasize cultivated or captive butterflies (see, for example, Preston 2020, 2023): another step in the evolution of the human's entanglement with the butterfly.

These modes of engagement, which are consistent within the monarch's presence in the educational system, heighten the concern that people may be primed to feel with regard to the butterfly. This is integral to the process of cultivating and preserving the charisma of this entity—a process that entangles agencies and manufactures a specific form of "being butterflies."

3.5 Conclusion: More Fragile Futures

Throughout the paper, we have explored how the charisma of the monarch, expressed in the transgenic crop controversy and refracted through human institutions, can be understood as a form of interspecies agency. The butterfly is not simply an expression of human desires and activities; the monarch acts in the world on its own time and for its own ends. The butterfly exhibits that agency, however, within a vast array of human institutions and attitudes that help give it shape *for us*; the monarch is entangled within these systems that modify ecologies, modify institutions, and modify human behaviors that help to condition the possibility of the insect to thrive or be threatened. The monarch's presence in our world as such, a mark of its charisma, shapes and is shaped by these institutions.

Understanding this entanglement, and some of the contours of this interspecies agency, allow us to also understand why our engagement with the monarch can be so durable—why our matters of concern may shift, but our focus on the butterfly can remain consistent. A contemporary example of this can be found with the climate crisis, where we once again see the monarch as a symbol of concern and a motivator for action. There are, clearly, significant differences with the transgenic corn debate. For example, unlike with transgenic crops, there exists a basic scientific consensus around anthropogenic climate change (as both happening and as suboptimal). But from the public's perspective, both realities can be understood as a kind of alien force that one has to operate within (we can choose, for example, to not consume, or plant, or buy, transgenic crops, but we don't get to choose whether these crops exist; we can adapt to the climate crisis, and make certain choices, but largely operate in a world where the climate changes—see Vogel 2016). And we can see that the reasons we should care about monarchs in this context, and what should be done about it, take similar shapes.

3.5.1 Why We Should Care (Value and Risk)

In terms of the climate crisis, we can see the monarch butterfly promoted as a matter of concern—an entity under threat from a changing climate and associated human behaviors, and worth saving because of its place in human culture and in ecological systems (as a pollinator). For the climate crisis, which is a boundary-crossing, global phenomenon, concerns about the persistence of the monarch are linked not just to their beauty and desirable presence for humans to witness (see Pellegrino 2021), but also the central place of the monarch in expressions of cultural heritage and the need for international cooperation. For example, the Nature Conservancy (2021) article, "Monarch Butterflies Bring Together Conservation and Culture Between U.S. and Mexico," highlights the roles that monarchs play in Mexican and Mexican-American cultural celebrations. In particular, due in part to the cyclical rhythms associated with monarch migration, the butterfly is linked with celebrations of *Dias de los Muertos* and associated festivals.

The monarch's precarious circumstance is often linked to anthropogenic climate change. This larger change is presented as a complicating factor to already extant issues related to agricultural practices and habitat loss due to logging, especially in the butterfly's overwintering refuges in Mexico (see, for example, Vaughn 2021; Schanen 2023; Diaz 2021). Habitat change is another major factor, which connects to the monarch's understanding of their environment. A changing climate can make environmental cues that trigger migration or breeding less predictable or reliable. Weather patterns and the intensification of the water cycle can create a less hospitable context for aspects of the butterfly's life cycle. And even milkweed can be disrupted, not just by human agricultural practices, but also in the milkweed's own life cycle and development. For example, unpredictable weather can disrupt the plant's flowering, and warmer weather overall can increase production of milkweed's cardenolide, which can in turn exceed the monarch's tolerance level, turning an important source of food into a toxin (see Viswanathan 2022; Pellegrino 2021).

3.5.2 What Should Be Done

The context of the climate crisis doesn't just highlight the value and precarity of the butterfly in light of human activities, but also calibrates human responsibility to address these issues. As we explored above with regard to transgenic crops, a kind of interspecies agency is coordinated—monarchs are understood as beings with their own resilience and capacities, but still in need of orchestrated human activities in order to facilitate those possibilities. We want monarchs to be a part of a shared world, and must play our roles to help make it possible.

We can credit monarchs for being relatively climate resilient as compared to other species, all things being equal, because of their dispersal ability, short generation time, and high reproductive rate (see Advani 2015). Monarchs have capacities that enable them to possess a good chance of survival even in the context of these disruptions, at least with the right kind of help (for this argument writ large, see Preston 2023). But that's the rub—we need to shift our own behaviors and priorities to enable this possibility. So even in the context of the climate crisis, we can find calls for individual and structural actions in support of butterflies. We are encouraged to create habitats like pollinator gardens and milkweed patches, especially in our backyards and local communities (see, for example, Viswanathan 2022). We are encouraged to take part in citizen science efforts, as advocacy groups like Monarch Watch and Journey North extend their concern to the present day. And we are encouraged to engage in larger advocacy to address the climate crisis, with the monarch as a focus of our concerns—we should seek to develop "climate-informed monarch conservation" ("Monarch Butterflies and Climate Change").

3.5.3 Looking Forward

We have explored in this paper the ways that the monarch can be viewed as a symbol of our concern for the environment—an environment that is both an expression of an otherness, but also a product of human intention and responsibility. One way to understand this interaction is as a kind of interspecies agency, where non-human entities like the monarch express their own behaviors and characteristics, but do so within a set of human institutional frameworks that make those behaviors visible, and even possible, as such. Importantly, there has been a durability to that symbolism, as the monarch's specific kind of charisma has carried through from concerns about transgenic crops to the climate crisis and even immigration (see, for example, Perret 2023). The value of these engagements with butterflies, however, especially ones that entangle awareness of precarity with human action, may be more than simply symbolic. They involve contestations about the future we want to inhabit, and the ways that we might encourage broader participation in the process of configuring those possible futures. For example, de Meyer, et al., argue that we should be moving away from what they call "issue-based narratives" related to the climate crisis, and move more toward "action-based narratives"—ones that model opportunities for meaningful action and target capacities within specific communities of practice (2020). The goal of these action-based narratives, ones that emphasize what people do rather than how they should feel, is not necessarily to undertake profound, global-level changes. Rather, the focus on communities of practice give people the opportunity to do something congruent with their scale and abilities, and thus serve as a means of generating sustained concern and engagement with the larger collective actions that will be necessary. And that people will feel that the future is not something that simply happens to them, but, at least in part, because of them (see also Galusky 2022).

One potential promise of this interspecies agency as we have examined it here can be in generating these engagement opportunities. People are not just made aware of the precarity of monarchs in the face of the climate crisis, but can be centered as actors who have small but meaningful actions to perform. One element of the framework developed by de Meyer, et al., involves ensuring that actions that people take can be experienced as meaningful. And so one of the possibilities contained with this kind of interspecies agency, where human responsibility is entangled with the behaviors and needs of monarch butterflies, is that it may be part of a process of creating to promote action-centered narratives that reorient human-environment relationships in creative and novel ways.

References

Advani, N. K. 2015. *Monarch butterfly*, WWF wildlife and climate change series. Washington, DC: World Wildlife Fund. https://c402277.ssl.cf1.rackcdn.com/publications/845/files/original/Monarch_butterfly_-_WWF_wildlife_and_climate_change_series.pdf.

Blattner, Charlotte E., Sue Donaldson, and Ryan Wilcox. 2020. Animal agency in community: A political multispecies ethnography of VINE sanctuary. *Politics and Animals* 6:1–22.

Branom, Mike. 1999. *Monarch butterfly population on the rise across America*. Associated Press Worldstream.

Callon, Michel. 1986. Some elements of a sociology of translation: Domestication of the scallops and the fishermen of St. Brieuc Bay. In *Power, action, and belief: A new sociology of knowledge?* ed. John Law, 196–233. London: Routledge, Kegan, and Paul.

Carson, Rachel. 1962. *Silent spring*. New York, NY: Houghton Mifflin.

Chapman, James. 2000, August 23. Butterfly beauty is poisoned by GM crop pollen. Daily Mail.

Collins, H. M. 1985. *Changing order: Replication and induction in scientific practice*. Beverly Hills, CA: Sage.

Cooper, Sharon Katz. n.d. Butterfly activity Guide. National Wildlife Federation and American Zoo and Aquarium Association. https://www.fs.usda.gov/wildflowers/pollinators/Monarch_Butterfly/documents/BFCI/BFCI_ActivityGuide.pdf.

de Laet, Marianne, and Annemarie Mol. 2000. The Zimbabwe bush pump mechanics of a fluid technology. *Social Studies of Science* 30 (2): 225–263. https://doi.org/10.1177/030631200030002002.

deMeyer, Kris, Emily Coren De, Mark McCaffrey, and Cheryl Slean. 2020. Transforming the stories we tell about climate change: From `issue' to `action'. *Environmental Research Letters* 16 (1): 015002. https://doi.org/10.1088/1748-9326/abcd5a.

Diaz, Jaclyn. 2021, February 26. What happened to the butterflies? Climate, deforestation threaten monarch migration. NPR, sec. Animals. https://www.npr.org/2021/02/26/971650046/climate-change-deforestation-threaten-monarch-butterfly-migration.

Ducarme, Frédéric, Gloria M. Luque, and Franck Courchamp. 2013. What are 'charismatic species' for conservation biologists? *BioSciences Master Reviews* 1:1–8.

Emili, L. A., and Greene, R. P. 2014. New cropland on former rangeland and lost cropland from urban development: The "replacement land" debate. *Land* 3 (3): 658–674. https://doi.org/10.3390/land3030658.

Feely, Paul. 2010, September 7. Milkweed for the monarchs. New Hampshire Union Leader.

Freedman, Micah G., and Marcus R. Kronforst. 2023. Migration genetics take flight: Genetic and genomic insights into monarch butterfly migration. *Current Opinion in Insect Science* 59:101079. https://doi.org/10.1016/j.cois.2023.101079.

Galusky, Wyatt. 2022. *Protein machines, technology, and the nature of the future*. 1st ed. Palgrave Macmillan.

Haraway, Donna J. 2013. *When species meet*. Minneapolis, MN: University of Minnesota Press.

Hartzler, Robert G. 2010. Reduction in common milkweed (Asclepias Syriaca) occurrence in Iowa cropland from 1999 to 2009. *Crop Protection* 29 (12): 1542–1544. https://doi.org/10.1016/j.cropro.2010.07.018.

Herzog, Hal. 2010. *Some we love, some we hate, some we eat: Why it's so hard to think straight about animals*. New York: Harper.
Hosey, Geoff, Vicky Melfi, and Samantha J. Ward. 2020. Problematic animals in the zoo: The issue of charismatic megafauna. In *Problematic wildlife II: New conservation and management challenges in the human-wildlife interactions*, ed. Francesco Maria Angelici and Lorenzo Rossi, 485–508. Cham: Springer International Publishing. https://doi.org/10.1007/978-3-030-42335-3_15.
Hunt, Eric D., Hannah E. Birge, Christopher Laingen, Mark A. Licht, Justin McMechan, William Baule, and Tom Connor. 2020. A perspective on changes across the U.S. Corn Belt. *Environmental Research Letters* 15 (7): 071001. https://doi.org/10.1088/1748-9326/ab9333.
Jamieson, Dale, and Bonnie Nadzam. 2015. *Love in the Anthropocene*. New York, NY: OR Books. https://www.orbooks.com/catalog/love-in-the-anthropocene-by-jamieson-and-nadzam/.
Jesse, Laura C. H., and John J. Obrycki. 2000. Field deposition of BT transgenic corn pollen: Lethal effects on the monarch butterfly. *Oecologia* 125:241–248.
Lark, Tyler J., Seth A. Spawn, Matthew Bougie, and Holly K. Gibbs. 2020. Cropland expansion in the United States produces marginal yields at high costs to wildlife. *Nature Communications* 11 (1): 4295. https://doi.org/10.1038/s41467-020-18045-z.
Latour, Bruno. 1984. *The pasteurization of France*. Cambridge, MA: Harvard University Press.
Latour, Bruno. 1992. Where are the missing masses? The sociology of a few mundane artifacts. In *Shaping technology/building society*, ed. Wiebe Bijker and John Law, 225–258. Cambridge, MA: MIT Press.
Latour, Bruno. 1993. *We have never been modern*. Cambridge, MA: Harvard University Press.
Lorimer, Jamie. 2006. What about the nematodes? Taxonomic partialities in the scope of UK biodiversity conservation. *Social & Cultural Geography* 7 (4): 539–558. https://doi.org/10.1080/14649360600825687.
Lorimer, Jamie. 2007. Nonhuman charisma. *Environment and Planning D: Society and Space* 25 (5): 911–932. https://doi.org/10.1068/d71j.
Losey, J., Rayor, L., and Carter, M. 1999. Transgenic pollen harms monarch larvae. *Nature* 399: 214. https://doi.org/10.1038/20338.
Maeckle, Monika. 2012, July 10. Founder of the monarch butterfly roosting sites in Mexico lives a quiet life in Austin, Texas. *Texas Butterfly Ranch* (blog). https://texasbutterflyranch.com/2012/07/10/founder-of-the-monarch-butterfly-roosting-sites-in-mexico-lives-a-quiet-life-in-austin-texas/.
Miller, John J. 2006, February 27. Long live the monarchs! – The struggles and triumphs of our Favorite butterflies. National Review.
Mitman, Gregg. 2009. *Reel nature: America's romance with wildlife on film*. University of Washington Press. https://uwapress.uw.edu/book/9780295988863/reel-nature.
Monarch Watch. 2023. Monarch migration. https://monarchwatch.org/migration/. Accessed 30 Sep 2023.
Monsanto. May 20, 1999. *Monsanto statement on BT corn: Environmental safety and a recent report on the Monarch Butterfly*. St. Louis, MO: Monsanto.
Nelkin, Dorothy. 1995. Science controversies: The dynamics of public disputes in the United States. In *Handbook of science and technology studies*, ed. Sheila Jasanoff, Gerald E. Markle, James C. Petersen, and Trevor Pinch, 444–456. Thousand Oaks, CA: Sage Publications.
Oberhauser, Karen S., and Michelle J. Solensky. 2004. *The monarch butterfly: Biology and conservation*. Ithaca, NY: Cornell University Press.
Pätzold, Franziska. 2023. Monarch Butterfly. Public Domain Pictures. https://www.publicdomainpictures.net/en/view-image.php?image=126270&picture=monarch-butterfly. Accessed 3 Oct 2023.
Pellegrino, Mia. 2021. October 18. Monarch butterfly population in decline due to agricultural practices and climate change | the review. https://udreview.com/monarch-butterfly-population-in-decline-due-to-agricultural-practices-and-climate-change/.

Pelton, Emma. 2023, June 15. Keep monarchs wild: Why captive rearing isn't the way to help monarchs. Xerces Society. https://www.xerces.org/blog/keep-monarchs-wild.
Perret, Meg. 2023, March 31. Monarch butterflies become a powerful symbol for justice at the U.S./Mexico border (commentary)." Mongabay Environmental News. https://news.mongabay.com/2023/03/monarch-butterflies-become-a-powerful-symbol-for-justice-at-the-u-s-mexico-border-commentary/.
Preston, Elizabeth. 2020, April 8. What's wrong with butterflies raised in captivity? The New York Times, sec. Science. https://www.nytimes.com/2020/04/08/science/monarch-butterflies-captive.html.
Preston, Christopher J. 2023. *Tenacious beasts: Wildlife recoveries that change how we think about animals*. Cambridge, MA: The MIT Press.
Rissing, Andrea Lukacs. 2021. We feed the world': The political ecology of the Corn Belt's driving narrative. *Journal of Political Ecology* 28 (1): 471–487. https://doi.org/10.2458/jpe.2959.
Sayes, Edwin. 2014. Actor−network theory and methodology: Just what does it mean to say that nonhumans have agency? *Social Studies of Science* 44 (1): 134–149.
Schanen, Naomi. 2023, April 12. Monarch butterflies lose sanctuary in Mexico as climate changes. *Washington Post*. https://www.washingtonpost.com/world/2023/03/26/monarch-butterfly-michoacan-climate-change/.
Shelton, Anthony M., and Richard T. Roush. 1999. Commentary: False reports and the ears of men. *Nature Biotechnology* 17:832.
Shelton, Anthony M., and Mark K. Sears. 2001. The monarch butterfly controversy: Scientific interpretations of a phenomenon. *The Plant Journal* 27:483–488.
Shriver-Rice, Meryl, M. Jesse Schneider, and Christine Pardo. 2022. Charismatic megafauna, regional identity, and invasive species: What role does environmental archaeology play in contemporary conservation efforts? *World Archaeology* 54, no. 3:429–446. https://doi.org/10.1080/00438243.2022.2118161.
Suzuki, David. 2010, November 5. Celebrate life and butterflies on the day of the dead. Victoria News.
The Nature Conservancy. 2021. Monarch butterflies bring together conservation and culture. The Nature Conservancy. https://www.nature.org/en-us/what-we-do/our-priorities/tackle-climate-change/climate-change-stories/monarch-butterflies-us-mexico/. Accessed 31 May 2023.
Thorpe, Charles, and Steven Shapin. 2000. Who was J. Robert Oppenheimer? Charisma and complex organization. *Social Studies of Science* 30 (4): 545–590. https://doi.org/10.1177/030631200030004003.
U.S. Forest Service. 2023. Monarch butterfly in North America. https://www.fs.usda.gov/wildflowers/pollinators/Monarch_Butterfly/index.shtml.
USDA. Monarch Butterfly Citizen Science. https://www.fs.usda.gov/wildflowers/pollinators/Monarch_Butterfly/citizenscience/index.shtml. Accessed 2 Oct 2023.
Vaughn, Adam. 2021, July 19. Climate change to blame for monarch butterfly's recent decline. New Scientist. https://www.newscientist.com/article/2284413-climate-change-to-blame-for-monarch-butterflys-recent-decline/.
Viswanathan, Leela. 2022, June 1. Climate change impacts on monarch butterfly migration and survival. *Indigenous Climate Hub*(blog). https://indigenousclimatehub.ca/2022/06/climate-change-impacts-on-monarch-butterfly-migration-and-survival/.
Vogel, Steven. 2016. *Thinking like a mall: Environmental philosophy after the end of nature. Reprint edition*. The MIT Press.
Vogt, Benjamin. 2022, July 23. No, we don't just need to plant more milkweed. Monarch Gardens. http://www.monarchgard.com/3/post/2022/07/no-we-dont-just-need-to-plant-more-milkweed.html.
Wadham, Helen. 2021. Agency as interspecies, collective and embedded endeavour: Ponies and people in Northern England 1916–1950. *Journal of Historical Sociology* 34 (4): 550–572. https://doi.org/10.1002/johs.12335.
Weber, Max. 1978. In *Economy and society*, ed. Guenther Roth and Claus Wittich, vol. 1. 2 vols. Berkeley, CA: University of California Press.

Wikston, Laura. 2008, June 26. Perfect summer morning is missing something; milkweed in your garden will help. *The Standard*. sec. EDITORIAL/OPINION.

Wiseman, Christina. 2019, March 11. Help protect monarch butterflies. *Political Landscapes Advocacy at Mass Audubon* (blog). https://blogs.massaudubon.org/politicallandscapes/help-protect-monarch-butterflies/.

Wright, Christopher K., and Michael C. Wimberly. 2013. Recent land use change in the Western Corn Belt threatens grasslands and wetlands. *Proceedings of the National Academy of Sciences* 110 (10): 4134–4139. https://doi.org/10.1073/pnas.1215404110.

Zhan, Shuai, Wei Zhang, Kristjan Niitepõld, Jeremy Hsu, Juan Fernández Haeger, Myron P. Zalucki, Sonia Altizer, Jacobus C. de Roode, Steven M. Reppert, and Marcus R. Kronforst. 2014. The genetics of monarch butterfly migration and warning colouration. *Nature* 514 (7522): 317–321. https://doi.org/10.1038/nature13812.

Chapter 4
Agency and Relationships in Engineered Agricultural Ecologies

Christopher Preston

Abstract Naturalness has long been a slippery concept for both agricultural and environmental ethics. The onset of the Anthropocene, where nothing on earth remains free from human influence, complicates things at an environmental level. The advent of gene editing in agriculture is making things worse. Genetic manipulation that does not cross species lines is touted as a creating a 'more natural' GMO. Naturalness is becoming harder and harder to understand. Attention to agency and relationships may provide a helpful alternative for assessing the desirability of engineered agricultural ecologies. Agency is dispersed throughout agriculture from human to microbial communities. The need to maintain diverse and intact relationships between different agents in agricultural ecologies shows promise as a normative guide. The lens of agency and relationships has the potential to find wide support. It invokes parallels with care approaches to ethics and with indigenous relationships to plants and landscapes. It also echoes aspects of multispecies studies, as well as resonating with ideals in permaculture and organic farming.

Keywords Agency · Relationships · Ethics · Naturalness · Care · Multi-species studies · Indigenous thought

There has long been a friendly friction between environmental and agricultural ethics. One source is the former's bias towards leaving things as 'natural' as possible. Non-interference is often environmental ethics' default. Less human manipulation means more naturalness and that has been considered a good thing.

Agriculture, by contrast, always involves interventions into the natural order. Clearing land, ploughing soil, and sowing crops creates a landscape that would not

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have existed without human intervention. Native species are displaced. Ecosystem function is disrupted. Domesticated plants take over, kept alive by intensive management regimes. On the farm, the human hand tightens its grip. At this superficial level, farming engineers an ecology that is far from natural, resulting in tension between ethicists of the two camps.

Attempting to lessen this tension by defining more precisely the meaning of 'natural' sounds helpful but isn't. Helena Siipi identifies no less than eight different ways to understand 'naturalness' and 'unnaturalness' (Siipi 2008). Each of them puts the emphasis somewhere different. Several of the eight come in gradations. As a practical matter, what is natural for one person in one context is unlikely to be natural elsewhere for someone else. Siipi concedes her taxonomy is more a conceptual than a practical tool.[1]

Despite the lack of clarity, naturalness still shows up in agricultural ethics. Practices such as permaculture, organics, and perennial cropping all claim to be 'more natural' than industrial agriculture by offering less disruption to ecological processes.[2] More than a few agricultural ethicists maintain affection for the environmental idea that things are better when they are less manipulated.

In the ethics of agricultural biotechnology, the commitment to naturalness also appears, if by changing where the ethicist hopes to find it. By considering the plant separately from its ecological context, agricultural ethicists have been able to say that, although the ecology created by agriculture may be unnatural, the organism being cultivated might retain it. For decades, the consensus has been that a plant containing genetic material from a different species has lost its naturalness.[3] Soy with an EPSPS gene,[4] maize containing *Bacillus thuringiensis*, and cotton stacked with herbicide and budworm tolerant genes have all, according to this mode of thinking, departed from what's natural. 'Staying within species lines' is okay. But crossing them is the quintessential unnatural activity. Species lines are nature's inbuilt partitions. Traversing them is wrong.[5] Environmental ethicists have tended to agree.

The advent of gene-editing has problematized this relatively settled ground. The possibility of 'cisgenic' gene-edited plants makes 'staying within species lines' a hazy criterion for naturalness. A cisgenic crop has been genetically modified but does not include any transgenes,[6] altering a genome merely by 'knocking out' or 'turning on' existing genes of interest. These changes could have happened without

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[1] Helena Siipi, personal communication.

[2] The Land Institute characterize their vision of widespread perennial crops as 'natural systems agriculture.' See https://landinstitute.org/our-work.

[3] In some assessments, the emphasis is on the product and in others on the process that gets you there. In both cases, transgenic plants usually come out as unnatural.

[4] EPSPS is the enzyme 5-enolpyruvylshikimate-3-phosphate synthase.

[5] Attention to this commitment is not always strict. Commercial strawberries are mixture of two species of the same genus.

[6] A transgene is a gene introduced from another species (https://www.biologyonline.com/dictionary/transgene).

intervention, so the argument goes, through natural evolutionary processes. If crossing species lines is what matters, the plant meets the criterion of naturalness even though it has been subjected to laboratory techniques similar to those that create transgenic plants. With the advent of genetic editing, crossing species lines no longer provides a line in the sand for those uneasy about genetic modification in agriculture (Gheysen and Custers 2017; Friedrichs et al. 2019).

Agricultural and environmental ethicists have found themselves in a confusing conceptual space around naturalness. In agriculture, naturalness related to the ecosystem never worked very well in the first place. Naturalness related to the plant has become more complicated thanks to the novel character of gene-editing. On the environmental side, naturalness has also become slippery. The advent of the Anthropocene means that no landscape on earth remains untouched (Waters et al. 2016). And with the power and reach of technology constantly expanding, the potential for novel types of manipulation of natural systems has exploded. Nanotechnology, biotechnology, and climate engineering open the door to a more synthetic, planetary age (Preston 2018). In both cases, 'the natural' was always a challenging metaphysical category to pin down (Vogel 2015). Perhaps it is time to move on.

My intention in this chapter is to make some initial moves towards an entirely different lens for assessing agricultural practices. In so doing, I hope to uncover a more helpful terrain that might be better shared by agricultural and environmental ethicists. I replace the naturalness lens with a lens based on the idea of 'agency' and the relationships between agents in agricultural systems. Alongside agency and relationship, a whole suite of other ethically important notions will emerge. These include community, integrity, and the value of maintaining diverse connections on the one hand, and concerns about disrupting, simplifying, and thwarting agency and community on the other. My goal is not to specify precisely how an agency and relationship lens would be used in practice. It is to prepare the ground for a fresh approach to the ethics of agriculture in the face technological innovation. We don't just need a lens that skirts the naturalness quagmire. We need a lens sensitive to the range of possibilities in biotechnology, one that also overlaps with important concerns in environmental ethics. I'm using biotechnology, in other words, to seek some sort of rapprochement.

4.1 Organismal Agents and Partners

Let's start by journeying a short distance from the puzzles of agriculture to consider a parallel case of changing attitudes to the living world. Species back from the brink of extinction offer a unique opportunity for innovative thinking. A rare species, especially one whose rarity is caused by humans, often labors under a rigid image created long ago. Think of how easy it was for those who hunted beavers, wolves, and bison to sustain myths about these animals long after the target of their violence was gone (Lopez 1978). The beasts were said to be a certain kind of threat that required a certain kind of treatment. The apocryphal quickly erased the factual as 'firsthand' accounts filtered down through the generations. The animal itself existed only in memory and folklore, with little capacity to contest the account. Caricatures of beavers, wolves, and bison ossified in the cultural imagination of settlers who occupied their former territory.

An animal that returns has the opportunity to create a range of new encounters. As its numbers build, more humans are exposed to its presence, requiring they come to terms with it afresh. They have to reassess the myths and, if the animal has returned as a result of protection, to work out ways to exist alongside it. This provides ample opportunity to consider the animal differently. The rethink is aided by scientists who are now better equipped to provide accurate information about its behaviors. They know more about its ecological relationships than those who wiped it out. The space for a productive rethink is pried opened further by the fact that there are better resources available to adapt to it. Electric fences, tracking devices, and accurate knowledge about the animal's habits make coexistence much easier. The potential for a rethink is boosted by the army of enthusiastic advocates that have coalesced around the animal in its absence. Animal recoveries bring to the public eye species primed for a fresh understanding of who they are (Preston 2023b). This understanding often leads to a new ethic.

Two examples can illustrate the type of conceptual rehabilitation I'm talking about. Beavers in North America have increased more than 150-fold since their low point in the nineteen-tens (Goldfarb and Dan 2019). A more complete understanding of the role beavers play in maintaining healthy ecosystems through their dam building has aided in their rehabilitation. Beavers boost groundwater replenishment, create vegetation supportive of insect diversity and abundance, and help filter excess nutrients out of river systems. Their dams create deep pools that provide shelter for fish in warm weather and soggy patches that provide firebreaks in a drought. Many of the benefits serve human needs. The flood protection and sediment filtering provided by beavers are so beneficial that land managers increasingly build beaver dam analogues (BDAs) to aid in river restoration (Pearce et al. 2021). Beavers and BDAs are proven to reduce the economic costs of extreme weather events.

Although beavers can still be a nuisance in the wrong circumstances, the beaver's image has been transformed. A cadre of 'beaver believers' advocate greater tolerance for the giant rodent's indiscretions and increased admiration for its talents. Humans' ethical relationship to beavers has changed. They are recognized as 'experts' at river restoration and 'allies' in adaptation to climate change. A cottage industry to encourage cohabitation deploys 'beaver deceivers' so the rodents can construct dams without flooding valuable infrastructure. Live-trapping provides a way to halt the most pressing inconveniences. Beavers have gone from 'furry banknotes' to 'teachers' of how to keep river systems in balance. There remains much to learn from them. A popular bumper sticker amongst beaver believers reads 'WWBD?' (What would beavers do?).

As similar transformation has occurred with humpback whales. In the five decades since a moratorium on hunting took effect, humpbacks have recovered dramatically (Bortolotto et al. 2016). Pacific Coast populations have grown from around a thousand to over twenty-two thousand today. In the western South Atlantic, they have climbed from less than five hundred to twenty-five thousand. Worldwide, humpbacks have recovered to ninety-five percent of their pre-exploitation numbers. They are likely to be fully recovered from whaling in a decade.

Seeing a lot more humpbacks has caused a dramatic transformation in their image. Whale tourism has become an economic opportunity in numerous coastal communities, creating widespread goodwill previously hard to find. Studies of whale behavior, including their remarkable feats of communication, has fostered a deep appreciation for the intelligence of whales and the complexity of their societies. Whales are much more likely to be regarded as close peers to humans than as a resource to exploit for oil and baleen.

Recent work on the role of whales in the marine carbon cycle has created an additional layer of regard for the world's mightiest mammals (Pearson et al. 2022; Roman et al. 2014). Not only do whales efficiently store carbon in their tissues, they participate in its sequestration by moving scarce nutrients from high latitude to equatorial regions during migration and from benthic to photic zones when feeding. These nutrients spur phytoplankton growth which ultimately leads to more carbon falling to the depths in the bodies of micro- and macro-organisms. Whales, simply by being alive, turn out to be 'partners' in the climate change struggle. Studies to determine just how much carbon a whale can sequester are underway. Their image has been transformed and they are held in new ethical regard (Giggs 2020; Preston 2023b).

Beavers and whales enjoy a changed moral status thanks to a better understanding of *who they are*. Given what is now understood about river restoration and ocean ecology, and given a growing need to cope with the climate challenge, the role whales and beavers play in shaping their ecosystem is taken much more seriously. Both species are seen as influential agents in their ecology. Their relationships to the system are prized. They are also recognized as intelligent, social beings who live in family groups and treat their kin with civility. Whales and beavers are more likely to be viewed as experts, allies and partners than as exploitable resources. Many of these attitudes towards animals are already embedded within indigenous cultures (Wildcat 2009). Settler cultures have an opportunity to head in this direction as they learn more about the animal's activities and ecological role.[7] Similar examples of ethical rehabilitation are occurring across the animal kingdom as the true character of animal lives becomes known (Preston 2023a, Preston 2023b).

This ethical refresh is instructive for current purposes in how firmly rooted it is in taking the *agency* of other organisms seriously. The refresh is made possible by investigating the habits and personalities of non-human others. We look at how they act and how their actions affect other organisms in the system. We consider their full range of relationships and their dependencies. We become alert to both the sophistication of their behaviors and the breadth of their influence. A refresh that spotlights the agency of non-human others turns out to be instructive when considering

[7] The observation made here is not an attempt to colonize the existing knowledge of indigenous peoples. It is to illustrate how reencountering an animal on the landscape in an informed way can yield attitudes similar those already extant among many indigenous people.

the ethics of agriculture and agricultural biotechnologies. Agricultural biotechnology, it turns out, is primed for an approach that takes non-human agency seriously.

4.2 Innovative Ethics for Emerging Technologies

The ethics of complex emerging technologies has expanded considerably in the last decade and a half. This broadening offers new tools for evaluating the acceptability of developments in agricultural biotechnology. "Responsible, Research, and Innovation" (RRI) emerged in Europe as a way to expand the ethical evaluation of technology beyond simple risk assessment (Owen et al. 2012; Burget et al. 2017). The focus of RRI on "science for society" and "science with society" is a reminder that technological developments like climate engineering, nanotechnology, and biotechnology emerge out of particular social and ecological contexts. These contexts shape the values that drive the technology before the technology shapes the social and ecological context right back. RRI is an effort to remind scientific practitioners that social and ecological networks cannot be ignored when conducting an ethical assessment. A mandate in the Norwegian Gene Technology Act to include three 'non-safety criteria' (ethics, sustainability, and societal impact) in assessment of genetically modified organisms is an example of RRI (Myskja and Myhr 2020). Arguably, the U.S. National Science Foundation's 'broader impacts criterion' is also a step in RRI's direction (Davis and Laas 2014).

Responsible research is particularly urgent with emerging technologies because of the uncertainty they create. Biotechnology operates in the hyper-complex domain of the genome and places its product into equally complex ecological and social environments. It meddles with the metabolism of the living world (Preston 2018). Christopher Groves suggests RRI is compelled to adopt a different frame as a hedge against uncertainty. "If we cannot know all the risks ….," Groves says, "then at least we can perhaps come to an agreement on whether it is worth living with the uncertainties that surround them in the interests of a morally and politically acceptable or even desirable social goal" (Groves 2015, 326–327). The risk, in other words, may not be resolvable. But the values are. We decide collectively "which risks and uncertainties are worth bearing" (ibid. 327).

This observation about the inevitability of risk and uncertainty leads Groves towards a "care-based conception of RRI" (ibid. 332). A care-based approach is an alternative to consequentialist attitudes focused on 'risk-thinking.' Groves suggests care involves practicing virtues like attentiveness in order to appreciate attachments, connectedness, and relationships. These become the filters through which to consider technological innovation. In assessing a new technology, Groves might ask whether a wide range of needs are being met, relationships being maintained, and connections being valued.

Preston and Wickson (2016) share Groves' focus. They advocate for a "care approach" to agricultural biotechnology in the face of the inadequacies of risk-thinking. A care approach insists decisions about the use of genetically modified organisms take into account how a new technology might disrupt relationships, redistribute power, or generate dependencies. Since not all of these future disruptions can be known in advance, the unfolding context must be watched closely. Input from different stakeholders must be continually sought. Preston and Wickson ask that attention be paid to the stories being told on the ground about the arrival of new technologies and to the affective reaction of those who use them (Preston and Wickson 2016, 53–55). None of this is easy. Assessment is not formulaic. Decisions about biotechnological practices, as Groves might put it, emerge from "an open-ended and evolving narrative" (Groves 2015, 328).

The broadening assessment of biotechnology associated with RRI (and especially in versions of it that employ care) focuses primarily on the social context in which biotechnology operates. The care described by Grove, Preston, and Wickson is primarily care for other people and for the social institutions that sustain them. But the anthropocentrism reflects the context in which these theorists were writing. Care does not need to stop with care for humans. Social contexts are shaped by the ecological contexts in which they are embedded. The two form a "coupled system" (Lomba et al. 2020) in which human relationships are shaped by ecological ones and *vice versa*. How much social upheaval a community will be willing to bear for the development of a drought-resistant crop depends on the type of agriculture practiced in that environment and the particular pressures farmers are facing from climate change, topsoil loss, and other challenges specific to the place. Ethical assessments of changing social relationships must take ecological factors into account. And here is the key insight. If the assessment lens in care-based RRI pays attention to attachment, connection, relationships, and dependencies among people, it must do the same for non-humans. It must consider attachments, relationships, and dependencies between human and non-human agents as well as those among non-human agents. Remember, wildlife recoveries have shown there is agency all around. A care approach looking at biotechnology in a coupled system takes very seriously the agency of the non-human world. It considers the relationships and attachments to—and between—wildlife, plants, microbes, and other actors in the socio-ecological amalgam. The tendrils of the community of concern are woven across species lines.[8]

4.3 Biotic Agency, Multispecies Ethnographies, and Indigenous Thought

The suggestion that agency and the relationships between human and non-humans must be taken into account in agriculture is obviously not new. Calls for attention to soil microbes, pollinators, beneficial insects, and intercropping species are

[8] This point had an early Euro-American outing in Aldo Leopold's *A Sand County Almanac and Sketches Here and There* (Leopold 1949).

widespread in non-industrial forms of agriculture. Yields remain high and agriculture becomes sustainable, so the argument goes, when valuable ecological relationships are kept intact. After all, it is the complex interchanges between microbes, nutrients, sunlight, moisture, fungi, and invertebrate life that makes vegetative growth possible in the first place.

Calls to keep non-food organisms alive and their relationships with food crops vibrant are often justified in terms of the 'ecosystem services' provided by the non-food actors in the system. Predatory insects serve to reduce pests. Bees serve to pollinate crops. Earthworms serve to break down plant matter. Agriculture needs to be cognizant of the wider ecological system, according to this argument, because of the *services* it provides. This is an acceptable framing up to a point. But there is a serious shortcoming to the ecosystem services language. In an account based on ecosystem services, the underlying assumption is that meaningful agency exists only in the human actors benefitting from the service. The agency of the non-human actors is either downplayed or completely ignored. These actors are treated as non-agential, incidental, and subservient. Their roles have belatedly been recognized as important, but their services are still regarded as merely 'instrumental' to ecosystem health and agricultural productivity. As such, they have often been thought of as replaceable by chemical or mechanical inputs. The personality of the beetle, the songbird, or the microbe, and their role as fully-fledged agents shaping the system is neglected.[9]

The lessons drawn from the ethical rehabilitation of beavers and whales suggest a richer reconsideration would focus more intently on the agency of the non-human biota that populate the system. The invertebrates that fly above the soil or crawl upon it, the annelids that burrow through it, and the prokaryotes that help maintain its structure and make nutrients available for all life act on their surroundings in ways evolution has fine-tuned them to do. It is an unhelpful distortion to think of their actions as 'services.' Besides, they often act in defiance of human designs on the landscape. Humans shape, but do not determine, their behavior.

Caring about the agency of non-human organisms means maintaining proper relationships to secure their interests and, not coincidentally, our own. We should do what we can to proliferate nitrogen-fixing bacteria, to encourage populations of beneficial insects, and to tolerate the presence of foxes and peregrines so they might reduce crop damage by rodents through their predation. When all the biota of an agricultural system are considered agents or actants, attentiveness to the intricate relationships between them becomes important. Agroecologists have been promoting care for these relationships as the core of sound agricultural practice for three decades (Pimentel et al. 1989). Creating conditions in which the full range of biotic agency can flourish becomes a priority.

Multispecies ethnography supports this approach and offers some helpful tools for understanding what must be done. Ogden et al. define multispecies ethnography

[9] If the 'agent' seems too provocative, 'actant' might be an acceptable alternative label. My own preference is for the term 'agent' because it conveys personality over anonymity.

as "research and writing that is attuned to life's emergence within a shifting assemblage of agentive beings" (Ogden et al. 2013, 6). The multispecies approach starts with the recognition that "all living beings emerge from and make their lives within multispecies communities" (van Dooren et al. 2016, 2). These communities contain "multitudes of lively agents that bring one another into being" (ibid. 3). The ontologies embedded in such approaches are always relational. The world is not comprised of collections of individuals but by many sets of dynamic, overlapping assemblages.

Taking non-human agency seriously means recognizing that humans are not central or fixed powerbrokers in these assemblages. Their identity emerges only through "shifting, often asymmetrical, relationships with other beings" (Ogden et al. 7). Human identity is never entirely secure. If relationships with other beings destabilize, so does the human place in the assemblage. Problems created by agriculture such as erosion, eutrophication, and the belching of nitrous oxide from synthetically-fertilized farmland are already forcing agriculturalists across the world to update their traditions and practices, move to different regions, or spend large amounts of money to harden their defenses against global change. Human agency is compromised when non-human agency is neglected.

It is not hard to find resonance between an emphasis on agency and relationships and indigenous attitudes to one's surroundings. Van Dooren et al. (2016) point out that "In taking up these questions scholars are also engaging with long histories of relational, agentic thinking from indigenous peoples" (p.2). The idea of humans as one among many agents whose livelihoods all need to be secured for any of them to flourish is consistent across indigenous approaches (Kimmerer 2020; Cajete 2005). Such a worldview is often parsed in terms of kinship. "Kinship," says Kyle Whyte, "refers to qualities of the relationships we have with others—whether others are humans, plants, animals, fishes, insects, rocks, waterways or forests" (Whyte 2021, 267). A world in which those relations are broken or strained is morally skewed. Active repair of relationships and ongoing gratitude for their existence is a demand of a morally appropriate life.

Instead of looking at the benefits received from the surrounding world as 'services,' Whyte says that many indigenous people look at them as 'gifts.' "Indigenous people," he says, "feel compelled to honor these gifts and take actions that, in turn, give gifts back to these species in terms of habitat protection" (ibid. 272). Environmental injustice is considered an assault on proper kinship relations, relations that exist at many levels both amongst humans and between humans and the natural world. Looking after these relationships is a necessity in a "kin-centric" worldview (Wildcat 2022).

If the agency of different organisms is prioritized, guiding ethical notions for agricultural practices shift. In biotechnology, debates about 'naturalness' and 'species lines' are nowhere in sight. 'Risk' and 'harm' remain in the mix because prudence is foolish to neglect. But notions like 'community,' 'dependency,' and 'integrity' bubble to the surface and provide the primary layer of analysis. Maintaining the fullest range of relationships between affected agents and recognizing inevitable dependencies becomes paramount. Notions like 'care' and even 'gratitude' become appropriate, applying across the coupled socio-ecological system agriculture creates.

On the social side of the coupled system, a responsible approach to biotechnical innovation will ask how the particular biotechnology impacts relationships between agents on neighboring farms? Is it likely to create power imbalances and dependencies between seed producers and growers? Will it impact the self-determination of farmers? Does it sever valuable partnerships established over decades? On the ecological side, a responsible approach will ask how the gene-edited plant will collide with other actors in the system? What consequences are there for a wide range of insects if the plant is engineered for pesticide resistance? What forms of agency in the soil are compromised to create higher yield? What interactions with other plants, negative or positive, are foreseeable? The ethical focus is not on the risk the biotech product presents to humans or the environment. It is on the impacts to agency and relationships it will cause. The ethicist, in other words, must be alert to an entirely different thing. They must bring a different lens to their analysis.

4.4 Stretching Agency Further

This turn towards agency and relationships has both a familiar and an unfamiliar ring to it. Ecosystems are known to be complicated webs made up of biotic and abiotic elements. Their function is recognized as a product of numerous entangled forces. Paying attention to the fate of the different lifeforms in a system sounds shrewd but not entirely new. It becomes a little more unorthodox, perhaps, when terms like 'agency' are spread as broadly across the non-human world as they are in this account. Outside an indigenous context, the term had previously been reserved for rational human beings (Anscombe 1957). It is particularly unorthodox to think of insects and lifeforms as simple as soil bacteria and earthworms as agents.

But the stretching of ordinary language is not unusual when pushing ethics into new areas. Multispecies scholars willingly go further. Their conception of agency is "increasingly being applied to forms of liveliness that many, but by no means all, of us would consider to be nonliving" (Van Dooren et al. 4). This represents an effort to overcome the 'biotic prejudice' that insists only living beings have the capacity to act on the world in meaningful ways. Van Dooren and his co-authors want to move beyond the biotic prejudice. They suggest that geologic formations, rivers, rocks, chemical species, and glaciers might also be considered agential. Emerging versions of "new materialism" tip our understanding of ontology on its heels and, with it, our obligations in ethics (Bennett 2010).

The account developed here does not promote talk of the agency of rocks or chemical species. But it follows multispecies studies in stretching the notion of agency in an unorthodox direction. Instead of looking for agency outside of the organism, it considers agency *within* organisms. This reason to do this is that these are the kinds of agency that biotechnology impacts the most.

Preston and Antonsen (2021) push the boundaries of ethics in a different direction to ask questions about how biotechnology disrupts agency within individual organisms. This begins in the lab and several layers of agency are in play. These include agency at the whole organism level, agency at the cellular level, and agency at the genome level. Each of these levels are disrupted during the creation of both transgenic and cisgenic crops.

At a minimal level, cells do things. They divide, make proteins, send signals, and absorb nutrients. They also provide structure. Genomes are also actors (or actants). They store and express information, they perform meiosis, and they mutate. It is because genomes do agential things that complex life originated in the first place. Without mutation, the possibility of biological diversity and complexity would not exist. If agency is thought of as the property of acting, then cells and genomes are minimal types of agents (Ginet 1990; Lowe 2009). If this is so, a new ethical terrain opens up. Just as we assessed agricultural practices by asking which agencies and relationships were being recognized or disrupted outside of a plant, so we can inquire about the respecting or disruption of agency within it.

Producing a genetic modification using *Agrobacterium tumefaciens* as a vector compromises the agency and the integrity of both the cell and the genome of the target organism. The cell's agency is disrupted when the bacterium enters through the cell membrane with its plasmid cargo. The genome's agency is compromised when the plasmid inserts its DNA payload into target plant's genome. CRISPR/Cas modifications done with viruses instead of plasmids also create a breach (Liu et al. 2017). When the site-directed nuclease enters the nucleus to create the double- or single-stranded break, the agency of the cell and the genome are interrupted by the agency of the nuclease dispatched by the scientist. The normal operation of both cell and genome are compromised. This disruption is as true for cisgenic crops as transgenic ones.

It is notable that the genome of the target plant does not completely surrender to the agency of the scientist. In some cases, the genome acts unpredictably in the face of the attempted change. 'Off-target effects' are unintended changes that happen elsewhere in the genome in response to CRISPR. Insertions, deletions, translocations, and duplications are all common off-target effects of attempts to create genetic change. These unpredictable occurrences are the bane of genetic editing (Kosicki et al. 2018). Figuring out how to limit off-target effects when using CRISPR-Cas enzymes is a top research priority.

It should also be noted that earlier forms of agricultural biotechnology compromise agency in the plant too. Attempts at mutagenesis using chemical or radiative stress are impositions of agency that seek to disrupt what the plant would otherwise do. Tissue culturing is a widely accepted conventional practice that also disrupts the growth pathway of individual plants. Protoplast fusion is disruptive to cells. The fact these are all widely accepted practices in crop breeding does not mean they automatically have a neutral ethical valence. An assessment lens with agency at its center would not discriminate *a priori* between techniques regarded as 'traditional' and those regarded as 'biotechnical.' Nor would it discriminate *a priori* between techniques that 'cross species lines' and techniques that don't. It would consider the agency and relationships at stake and ask questions about how many of them are being ruptured and for what purpose. The ethical playing field is filled with various actors connected in myriad ways. Interventions have to be judged for what they do to these agencies and their relationships.

4.5 An Ethics of Agency for Agriculture

The framework presented here for assessing biotechnologies is both old and new. It is old because ethics has long been about respecting the integrity of other agents. It is old because ecological approaches already recognize the need take seriously the welter of complex interactions between the living beings needed to sustain ecosystem health. Finally, it is old because respecting the agency of non-human others has always been central to indigenous thought.

The framework is new in that it dispenses with many of the notions common in ethical assessments of biotechnology. 'Naturalness' and 'crossing species' lines are irrelevant. 'Rate,' 'scope,' and the 'precision' of the intended genetic change become tangential. 'Lab' and 'field' are not defining markers of acceptability. In their place, agency and relationships become central.

An ethical evaluation must be alert to the degree of disruption caused by a technological change. Disruption to kinship relations, as Whyte warned in the indigenous context, is the heart of environmental injustice (Whyte 2021, 275). Generally, more disruption suggests more caution about proceeding. When you are concerned about disruption, ideas like community, connectedness, vulnerability, and dependence become relevant. Attentiveness and listening gain importance. Alertness to the operation of different actor-networks is essential. Many of these concerns already appear outside of agriculture in environmental ethics. All of them are facilitated by a deep appreciation of multispecies relationships.

Two observations about this lens may not have escaped notice. The first is that the task of becoming aware of every agential relationship at play in an agricultural context will be endless. Not only are the full range of relationships too complex to know in their entirety. The precise impact of a proposed technology on these relationships cannot be certain. The impacts will appear in both social and ecological domains. They may emerge over many months or years. This is not an approach calling for an accurate prediction of consequences before proceeding. It is more an approach asking for care, attentiveness, and sensitivity to the flood of changes that may cascade from a decision. Then, as Groves suggested, we decide collectively which changes are worth bearing. Given our limited ability to predict all the effects of interventions into complex systems, a healthy dose of humility becomes appropriate.

The second observation is that this lens seeks compromise and not perfection. There is no agriculture that does not break apart existing relationships and disrupt agents. Plow breaks sod. Annuals replace perennials. Forest becomes farmland. Humans consciously change an ecosystem so that it might effectively sustain them.

What some might call the 'unnatural ecology' created by agriculture can be considered a system where some relationships have been destroyed but others have been created. If agriculture—and biotechnology—are done right, these new relationships will be nourishing in every sense. They will sustain people, plants, and wildlife in enduring ways.

The task for those determining the best form of agriculture in a particular place is to ask what is at stake for the community, construed at its broadest. Which relationships will be maintained as a result of this technology? Which agents are set to flourish? And which will be destroyed? This means which people, which pollinators, which beetles, which nematodes, which annelids, which birds, which plants, which bacteria, which cells, which wildlife, and which genomes? A difficult thing to assess, for sure, but one that perhaps gets closer to the heart of what it means to be sustainable.

References

Anscombe, Elizabeth. 1957. *Intention. First*. Oxford: Basil Blackwell.

Bennett, Jane. 2010. *Vibrant matter: A political ecology of things*. Duke University Press.

Bortolotto, Guilherme A., Daniel Danilewicz, Artur Andriolo, Eduardo R. Secchi, and Alexandre N. Zerbini. 2016. Whale, whale, everywhere: Increasing abundance of Western South Atlantic Humpback Whales (Megaptera Novaeangliae) in their wintering grounds. *PLoS One* 11 (10): e0164596. https://doi.org/10.1371/JOURNAL.PONE.0164596.

Burget, Mirjam, Bardone, Emanuele, and Pedaste, Margus. 2017. Definitions and conceptual dimensions of responsible research and innovation: A literature review. *Science and Engineering Ethics* 23: 1–19. https://doi.org/10.1007/s11948-016-9782-1

Cajete, Gregory. 2005. American Indian epistemologies. *New Directions for Student Services* 2005 (109): 69–78.

Davis, Michael, and Kelly Laas. 2014. 'Broader impacts' or 'responsible research and innovation'? A comparison of two criteria for funding research in science and engineering. *Science and Engineering Ethics* 20 (4): 963–983. https://doi.org/10.1007/S11948-013-9480-1/METRICS.

Friedrichs, Steffi, Yoko Takasu, Peter Kearns, Bertrand Dagallier, Ryudai Oshima, Janet Schofield, and Catherine Moreddu. 2019. An overview of regulatory approaches to genome editing in agriculture. *Biotechnology Research and Innovation* 3 (2): 208–220. https://doi.org/10.1016/j.biori.2019.07.001.

Gheysen, Godelieve, and René Custers. 2017. Why organic farming should embrace co-existence with cisgenic late blight-resistant potato. *Sustainability (Switzerland)* 9 (2): 1–11. https://doi.org/10.3390/su9020172.

Giggs, Rebecca. 2020. *Fathoms: The world in the whale*. Melbourne: Scribe.

Ginet, Carl. 1990. *On action*. Cambridge: Cambridge University Press. https://doi.org/10.1017/CBO9781139173780.

Goldfarb, Ben (Environmental journalist), and Dan L. (Dan Louie) Flores. 2019. Eager: The surprising, secret life of beavers and why they matter. White River Junction, Vermont: Chelsea Green. https://www.chelseagreen.com/product/eager-paperback/.

Groves, Christopher. 2015. Logic of choice or logic of care? Uncertainty, technological mediation and responsible innovation. *NanoEthics* 9 (3): 321–333. https://doi.org/10.1007/S11569-015-0238-X/METRICS.

Kimmerer, Robin. 2020. *Braiding sweetgrass: Indigenous wisdom, scientific knowledge and the teachings of plants. Paperback*. New York, NY: Penguin.

Kosicki, Michael, Kärt Tomberg, and Allan Bradley. 2018. Repair of double-strand breaks induced by CRISPR – Cas9 leads to large deletions and complex rearrangements. *Nature Publishing Group Nature Biotechnology 36* (8): 765–771. https://doi.org/10.1038/nbt.4192.

Leopold, A. 1949. Sand County Almanac (1949). In *A Sand County Almanac, 226*. New York: Oxford University Press.

Liu, Chang, Li Zhang, Hao Liu, and Kun Cheng. 2017. Delivery strategies of the CRISPR-Cas9 gene-editing system for therapeutic applications. *Journal of Controlled Release. Elsevier B.V* 266:17–26. https://doi.org/10.1016/j.jconrel.2017.09.012.

Lomba, Angela, Francisco Moreira, Sebastian Klimek, Robert H. G. Jongman, Caroline Sullivan, James Moran, Xavier Poux, et al. 2020. Back to the future: Rethinking socioecological systems underlying high nature value farmlands. *Frontiers in Ecology and the Environment* 18 (1): 36–42. https://doi.org/10.1002/FEE.2116.

Lopez, Barry H. 1978. *Of wolves and men*. New York: Scribner.

Lowe, E. J. 2009. *Personal agency: The metaphysics of mind and action*. Oxford University Press. https://doi.org/10.1093/acprof:oso/9780199217144.001.0001.

Myskja, Bjørn Kåre, and Anne Ingeborg Myhr. 2020. Non-safety assessments of genome-edited organisms: Should they be included in regulation? *Science and Engineering Ethics* 26 (5): 2601. https://doi.org/10.1007/S11948-020-00222-4.

Ogden, Laura A., Billy Hall, and Kimiko Tanita. 2013. Animals, plants, people, and things: A review of multispecies ethnography. *Environment and Society* 4 (1): 5–25. https://doi.org/10.3167/ARES.2013.040102.

Owen, Richard, Macnaghten, Phil, and Stilgoe, Jack. 2012. Responsible research and innovation: From science in society to science for society, with Society. *Science and Public Policy 39* (6): 751–760.

Pearce, Casey, Philippe Vidon, Laura Lautz, Christa Kelleher, and Julianne Davis. 2021. Short-term impact of beaver dam analogues on streambank erosion and deposition in semi-arid landscapes of the western USA. *River Research and Applications* 37 (7): 1032–1037. https://doi.org/10.1002/RRA.3825.

Pearson, Heidi C., Matthew S. Savoca, Daniel P. Costa, Michael W. Lomas, Renato Molina, Andrew J. Pershing, Craig R. Smith, Juan Carlos Villaseñor-Derbez, Stephen R. Wing, and Joe Roman. 2022. Whales in the carbon cycle: Can recovery remove carbon dioxide? *Trends in Ecology & Evolution* 38 (3): 238–249. https://doi.org/10.1016/J.TREE.2022.10.012.

Pimentel, David, Thomas W. Culliney, Imo W. Buttler, Douglas J. Reinemann, and Kenneth B. Beckman. 1989. Low-input sustainable agriculture using ecological management practices. *Agriculture, Ecosystems & Environment* 27 (1–4): 3–24. https://doi.org/10.1016/0167-8809(89)90068-6.

Preston, Christopher J. 2018. *The synthetic age: Outdesigning evolution, resurrecting species, and reengineering our world*. Cambridge, MA: MIT Press.

Preston, Christopher J. 2023a. *Tenacious beasts: Wildlife recoveries that change how we think about animals*. Cambridge, MA: MIT Press. https://mitpress.mit.edu/9780262047562/.

Preston, Christopher J. 2023b. Wolf restoration in Colorado shows how humans are rethinking their relationships with wild animals. The Conversation. https://theconversation.com/wolf-restoration-in-colorado-shows-how-humans-are-rethinking-their-relationships-with-wild-animals-197669.

Preston, Christopher J., and Trine Antonsen. 2021. Integrity and agency: Negotiating new forms of human-nature relations in biotechnology. *Environmental Ethics* 43 (1): 21–41. https://doi.org/10.5840/ENVIROETHICS202143020.

Preston, C. J., and F. Wickson. 2016. Broadening the lens for the governance of emerging technologies: Care ethics and agricultural biotechnology. *Technology in Society* 45:48–57. https://doi.org/10.1016/j.techsoc.2016.03.001.

Roman, Joe, James A. Estes, Lyne Morissette, Craig Smith, Daniel Costa, J. B. James McCarthy, Stephen Nicol Nation, Andrew Pershing, and Victor Smetacek. 2014. Whales as marine ecosystem engineers. *Frontiers in Ecology and the Environment* 12 (7): 377–385. https://doi.org/10.1890/130220.

Siipi, Helena. 2008. Dimensions of naturalness. *Ethics and the Environment* 13 (1): 71–103. Indiana University Press. https://doi.org/10.2307/40339149.

van Dooren, Thom, Eben Kirksey, and Ursula Münster. 2016. Multispecies studies cultivating arts of attentiveness. *Environmental Humanities* 8 (1): 1–23. https://doi.org/10.1215/22011919-3527695.

Vogel, Steven. 2015. *Thinking like a mall: Environmental philosophy after the end of nature*. Cambridge, MA: MIT Press.

Waters, Colin N., Jan Zalasiewicz, Colin Summerhayes, Anthony D. Barnosky, Clément Poirier, Agnieszka Gałuszka, Alejandro Cearreta, et al. 2016. The anthropocene is functionally and stratigraphically distinct from the Holocene. *Science Magazine* 351 (6269): aad2622.

Whyte, Kyle. 2021. Indigenous environmental injustice: anti-colonial action through kinship. In *Environmental justice: Key issues*, ed. Brendan Coolsaet, 266–278. Routledge. https://doi.org/10.3167/10.3167/9781800732452.

Wildcat, Daniel. 2009. *Red alert!: Saving the planet with indigenous knowledge*. Ann Arbor, MI: Fulcrum. https://birchbarkbooks.com/products/red-alert.

Wildcat, Daniel. 2022. Traditional ecological knowledges: An antidote to destruction. In *Re-indigenizing ecological consciousness and the interconnectedness to Indigenous identities*, ed. Michelle Montgomery. Washington, DC: Lexington Books.

Chapter 5
Treading Lightly, Agriculture, and Focality

Per Sandin

Abstract Many thinkers endorse an idea that we humans should leave nature alone or somehow exercise restraint in our relations to nature. Among those thinkers, we find several who take a critical or pessimistic attitude to modernity and modern life in general and to technology, or some specific technologies like genetic engineering in particular. In this chapter, I take a constructive approach starting with an exploration of Albert Borgmann's idea of *focal practices*. I side with Paul B. Thompson in suggesting that agricultural systems offer some potential areas for such focal practices. I argue that even highly engineered environments should contain 'pockets of focality' and that those may provide 'stepping stones' from which a system can be changed. Finally, I argue that there is room for implementing some of these elements within a context of responsible research and innovation, for instance in the form of ethics committees for food and agricultural issues.

Keywords Focal practice · Focality · Nature · Naturalness · Albert Borgmann · Reflective equilibrium

5.1 Introduction: The Otherness of Nature

There is no shortage of authors who endorse some version of the idea that we humans should leave nature alone, not interfere with nature—at least not excessively—or somehow exercise restraint in our relations to nature.

This idea comes in many versions. Some form of it underlies the ideal of nature conservation, pioneered in the U.S. by writers like George Perkins Marsh. In an

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1864 book entitled *Man and Nature*, Marsh wrote about 'the ravages committed by man' and how they 'subvert the relations and destroy the balance which nature had established' (cit. in Purdy 2015, p. 167). A second example is environmental ethicist Paul Taylor, writing some 120 years after Marsh. Taylor promotes 'the attitude of respect for nature'. While admitting that '*some* interfering with or manipulation of the natural world is compatible with respect for nature' (Taylor 2011, p. 94, emphasis added), what Taylor calls 'the exploitative attitude' is not. This attitude 'is taken whenever nature is thought of as nothing more than a vast repository of resources … to be developed used, and consumed by humans for humans ends' (ibid., p. 95). A third illustration comes from biologist Edward O. Wilson in his book *Half-Earth* (2016), where he proposes that 'only by committing half of the planet's surface to nature can we hope to save the immensity of life-forms that compose it' (Wilson 2016, p. 3).

These ideas rely on the premise that humans and nature can be distinguished. There is a vast literature on nature, naturalness and humans relationship to nature (see, e.g. Daston 2019). However, for the purposes of the present paper, we may follow Simon P. James, who recently has articulated this conception of nature in the following way: 'An entity is natural to the extent that its current state has been largely unaffected by human actions (especially ones intended to shape the entity)' (James 2022, p. 110). This understanding of nature can be applied both to 'macro' nature, such as large areas of wilderness, and 'micro' nature, for instance natural processes like fermentation or oxidation of food.

There are many ways of tackling this idea of the 'otherness' of nature. A group of thinkers that might aptly be termed 'nature skeptics' (in James' terminology) dismiss the idea as meaningless (e.g. Vogel 2002). They do have a point in the fact that is increasingly difficult to find something with 'its current state largely unaffected by humans'. Hence the introduction of the term the *Anthropocene* for a geological epoch characterized by human impact on the Earth system as a whole (Hamilton 2017). As Jedediah Purdy puts it:

> The natural and the artificial have merged at every scale. Climate change makes the global atmosphere, its chemistry and weather systems, into Frankenstein's monster—part natural, part made. The same is true of the seas, as carbon absorption turns the oceans acidic and threatens everything that lives in them. […] Even wilderness, that emblem of untouched nature, persists where lawmaking and management create it, artificial testament to the value of natural things. (Purdy 2015, p. 15)

Other authors have attempted to reconceptualise the division between humans and nature in less ontologically demanding ways. A recent example is Anna Deplazes-Zemp, who offers a 'perspectival' account of the concept of nature, according to which it refers to 'what we, humans, encounter as "the given" (i.e., what is not shaped nu activities we *consider* characteristically human, such as purpose-driven design, deliberate choice, and intentional creation) (Deplazes-Zemp 2022, p. 100, emphasis added).

5.2 The Imperative of Treading Lightly

In particular, thinkers like these hold that it is a bad thing when humans attempt to take too much control over nature and natural processes—something that would amount to a totalitarian project of domination. One illustrative example comes from philosopher Eric Katz, who compares (but does not equate) Nazi medical experimentation and ecological restoration. Ecological restoration is the human enterprise of recreating natural ecosystems that have disappeared or been damaged, more often than not as a result of human activity. In Katz' view, ecological restoration and the Nazi experiments 'share one basic, common characteristic: the *domination and control of natural processes*' (Katz 2011, p. 80, emphasis added). 'The history of the Nazi medical experiments there [at Auschwitz] demonstrates the moral evil of the process of domination, whether this domination applies to humans or to natural processes' (Katz 2011, p. 79). The narrative here is the age-old one of *hubris* (Moula 2015): Humanity can go too far in out attempts to control the things around us, and this is an affront to the gods or the natural order. Thus, we should stand back and exercise restraint in our interactions with nature.

Let us call this idea, or family of ideas, the *imperative of treading lightly*.

Does this family of ideas have any bearing on biotechnology and engineered ecologies (or agriculture)? It certainly does. Over the years, there has been a number of criticisms of biotechnology in agriculture, in particular the use of genetically modified organisms (GMOs), that rely on the idea of humans overstepping some limit in attempting to take too much control over nature. In discussing genetic modification and 'concerns with the counter-naturality of the process', Kate Soper asks: 'Are such developments a step too far in the manipulation of nature, a hubristic affront to what one might call our moral sense of what humans might properly do with their powers of invention?' (Soper 1995, p. 3). A representative expression of this attitude was voiced by the Prince of Wales (now King Charles III) in the Reith Lectures on BBC Radio 4 in 2000:

> Above all, we should show greater respect for the genius of nature's designs, rigorously tested and refined over millions of years. This means being careful to use science to understand how nature works, not to change what nature is, as we do *when genetic manipulation seeks to transform a process of biological evolution into something altogether different*. (BBC 2000, emphasis added)

A position echoing that of the Prince of Wales' has been put forward with more scholarly rigor by Hugh Lacey, who is critical of what he calls the 'Commercial-Scientific Ethos', the first tenet of which is as follows:

> The value of gaining *understanding* of phenomena of the world is subordinated to expanding knowledge of what we *can do*, of how we can *expand human powers to exercise control* over natural and technoscientific objects, especially insofar as they potentially contribute to economic growth and other interests of leading commercial bodies. (Lacey 2016, p. 59, emphasis in original)

Against this background, Lacey's critical stance towards agricultural biotechnology, and in particular genetic engineering, might not be surprising. He sees genetic engineering as an expression of a set of values expressing '*specifically modern ways of valuing control of natural objects*' (Lacey 2002, p. 499). As an alternative he offers agroecology, both as a way of farming and as a format for scientific investigation encompassing among oher values that of sustainability 'as subordinating the control of natural objects' (Lacey 2002, p. 507). Thus one of the promises of agroecology is to tread lightly with respect to nature.

Of course, agricultural environments are very much technological, artificial, and engineered ones. There has to be *some* sort of manipulation involved. Pretending otherwise is not helpful. Sometimes such pretending generates ridiculous results, as when some agricultural products are marketed as containing 'all natural ingredients' (Sandin 2017; Siipi 2015) such as the popcorn pack bragging:

> We use only NON-GMO CORN. (Who thought messing with corn genetics was a good idea?) Its 100% NATURAL. (We don't think mankind has improved on what nature produces.)

Obviously, without the 'messing' with the genetics of corn and its ancestors in Central America some 9000 years ago or so, there would not be a plant remotely like corn (maize). The same holds for most other food crops (Doebley et al. 2006).

In many cases, it seems that the main factor that make our steps heavy and prevents us from treading lightly is *technology*. Among environmental thinkers endorsing the idea that we should exercise restraint in our relations to nature or 'leave nature alone', we find several who take a critical or pessimistic attitude to modernity and modern life in general and to technology, or some technologies, in particular. Many examples of what is commonly labelled 'philosophy of technology' share this outlook. Variants of this is the view are endorsed by thinkers like Martin Heidegger, Günther Anders, Jan Patočka, Jacques Ellul (1964), and Albert Borgmann (1984).

In the remainder of this chapter, I will follow Borgmann and explore his idea of a *focal practice*. I will suggest agricultural systems offer some potential areas for such focal practices, and that even highly engineered environments should contain 'pockets of focality', that may provide 'stepping stones' from which a system can be changed. There is room for implementing some of these elements within a context of responsible research and innovation, for instance in the form of ethics committees for food and agricultural issues.

5.3 Focal Practices in Technological Environments

You will not find a stipulative definition of focal practice or a focal thing in terms of necessary and sufficient conditions, on the form 'X is a focal thing if and only if…' or 'a practice is focal *iff*…'. What you will find is *deixis*. Deixis refers to the function of pointing to, or pointing out, something. 'This is a focal practice.' Understanding a deictic expression requires knowledge of the context in which the expression is stated. Without such knowledge, if I refer to 'this presentation' or ask you to 'pass that screwdriver' the reference would be opaque.

Borgmann talks about deictic *explanations* as articulating, ‘to outline and highlight the crucial features of something’ (Borgmann 1984, p. 25). And Einstein’s theories of relativity ‘have deictic power in the sense of delimiting a set of possible worlds and ruling out certain impossible worlds´ (ibid., p. 25f). Deictic *discourse* serves, among other things, to bring forward ultimate concerns, a discourse which embodies an attitude of enthusiasm, sympathy and tolerance (p. 176).

From Heidegger, Borgmann inherits ‘suggestions that focal things seem humble and scattered about but attain splendour in technology if we grasp technology properly, and that focal things require a practice for their welfare’ (Borgmann 1984, p. 200). Borgmann expounds on two examples of focal practices: Running and the Culture of the table. Starting from Borgmann’s ideas, Paul B. Thompson (1999) suggests another focal practice: farming. Let us look to running for a while.

With ‘running’, Borgmann is not referring to someone dashing to catch a bus, a person fleeing from a threat on foot, or an army recruit being commanded by the drill sergeant to make a run for the barracks. It is rather running as recreation or sport, and some rather specific ways of doing that sport. He draws on descriptions of running from George Sheehan’s book *Running and Being*. (I do not know whether Borgmann was a runner himself.) Running is understood as distance running rather than sprinting or middle-distance, and it is assumed to be outdoors, with the runner exposed to the elements and the environment—which might be a city as in the case of the New York Marathon (p. 203).

In order to make his case, Borgmann uses other cases that he contrasts with his preferred activities. Those contrasts are interesting. First, there is driving a car as a contrast to running. Both running and driving is about motion. They are nevertheless different in relevant aspects, Borgmann argues. It is worth quoting him at some length:

> In a car […] we are not moving on our own power and in our own right. We cash in prior labor for present motion […] we release what has been earned and stored and use it for transportation. But when these past efforts are consumed and consummated in my driving, I can at best take credit for what I have done. What I am doing now, driving, requires no effort, and little or no skill or discipline. I am a divided person; my achievement lies in the past, my enjoyment in the present. But in the runner, effort and joy are one; the sprlit between means and ends, labor and leisure is healed. (Borgmann 1984, p. 202)

This comparison is deceptive. Driving a modern car might require little effort, but so might transportation on foot. However, if we compare running a *race* and *driving* in a race (say, a rally competition), the differences are not at all obvious. And while running 5 k at a 5 min pace might be a light warmup for a fit athlete, it might require the utmost of effort for someone else.

A second contrast case refers to an article by Peter Wood on how he (Wood) ran the New York Marathon and then ‘took in the city with body and mind’ (Borgmann 1984, p. 203). Borgmann wants to make the point that there is a difference between ‘good running’, or ‘running in its fullness’, which is contrasted with other activities that also involve physical exercise in the form of moving one’s legs that are not—well, good. The example given in contrast to Wood’s NY Marathon is how 'executives, concerned about their Coronary Risk Factor Profile, run nowhere or ride on stationary bikes' (Borgmann 1984, p. 203).

What happens here is that Borgmann takes something he obviously likes and argues that this something is good, because it has certain characteristics. He identifies those characteristics by contrasting the thing he likes with something he *doesn't* like (driving a modern car, exercising on a stationary device). One senses a certain amount of contempt for the health-conscious executives in the account of their exercise activities. The move might look like rationalization, but that is perhaps not the only problem, let alone the only one.

For one thing, underpinning the condemnation of a thing with a contrast case is tricky. The contrast case being very different, it is difficult to ascertain what are the normatively relevant differences between the cases. Ideally, perhaps, one should go through a process of eidetic variation, comparing the favoured case with a number of similar but slightly different cases. What about, for instance, comparing 'running in its fullness' with running barefoot, running using a GPS device with a heart rate monitor, driving an oxcart, driving a surrey with different types of horse, riding a penny farthing, riding a carbon mountain bike, an electric bike, an old car… and so on. This is in fact a method employed in processes of approaching reflective equilibrium, which is a common method in normative ethics (Rechnitzer 2022).

In fairness, the contrast cases might be more for illustrative than for argumentative purposes (assuming such a distinction can be made), so let us disregard this particular problem. The contrast-case approach still opens for a couple of objections. One is the obvious one: That other reasonable and thoughtful people might have experiences radically different from those of Borgmann or the writers on running or eating that he relies upon. Let me venture the following examples, which incidentally involve stationary bikes:

Consider a group of cyclists. They are master's athletes who know each other well. While not professional or elite athletes, they take their training seriously and do race. They ride on stationary bikes, together, spinning-class style. This activity involves extreme physical exertion. Some of them socialize also outside the training sessions, and some of them have through the cycling activity become very good friends. The training contributes to giving meaning to their lives—more so for some than for others. It would be snobbish to deny that they are not doing something 'in its fullness'.

Or consider the total commitment of the athlete who tries to set a personal record riding all out 1 min on a stationary bike. His effort involves total physical exertion, it is an important part of something that gives meaning to his life, and he pursues the activity in the company of other, like-minded people who support him and matter to him. It is a communal event.

Borgmann does anticipate objections of this kind, by noting that '[s]ince one with *lesser* or different capacities will not experience the same significance, the claim is always possible that what I call significance is … an imposition of mine on a neutral or ambiguous state of affairs' (p. 181, emphasis added). Or, more popularly expressed '"You think it is great, but is it really?"' (ibid.). He dismisses this kind of objection as 'inconsequential', as a 'method of refusing [deictic explanation] which might be mistaken for refutation' (ibid.). The dismissal is quick and mildly condescending, and the whole project has a tinge of intellectual imperialism. However, the dismissal is too quick and it misses the point.

What examples like mine attempt to show is something different. They point to the possibility that someone with similar or greater capacities as Borgmann possesses might well experience something else as significant, and that the greatness of this is *because* of properties that are incompatible with the properties that make the significant thing experienced by Borgmann. Two or more apparently incompatible practices can simultaneously be presented as focal, for good reasons. This is brought forward by focussing on the contrast cases.

The same problem—too quick dismissal of contrast cases—also applies to Paul B. Thompson's discussion of farming as a focal practice in his book *The Agrarian Vision*. The chapter is a revision of a text originally published in 1999 (Thompson 1999). Thompson mentions in passing that farming of course must 'be supplemented by skills and crafts that are not part of farming per se, but building, toolmaking and the martial arts do not center, order, and unify "myself and others" in the way farming does' (Thompson 2010, p. 115). Well, don't they? At least Borgmann seems to think that pre-industrial wheelmaking qualifies, citing George Sturt's memoir *The Wheelwright's Shop*, originally published in 1923 and described by a contemporary reviewer as transporting readers rural England as it was before the hand craftsman had disappeared before the march of machinery' (Anonymous 1923). The martial arts might be an even more poignant case. Consider the complex of virtues associated with warlike endeavour in antiquity, or the intricacies of chivalry among the warrior classes in the Middle Ages.

Another and very much related problem is that the criteria arrived at from the phenomenological exercises might be used in a kind of *reductio* argument. That is, they lend themselves to producing counterexamples. This is in effect what Steven Vogel attempts in *Thinking Like a Mall*. The title of the book is a reference to Aldo Leopold's exhortation that humans learn to think like a mountain. In Vogel's words, 'to see that there is more to the world than we understand, and to recognize the dark complexity and depth of the processes of nature that so exceed out limited ability to grasp and control´ (Vogel 2015, p. 129). In the titular chapter in the book, Vogel recounts the rise, decay and eventual demolition of the City Center Mall in Columbus, Ohio. It opened in 1989 and was demolished 20 years later, to be replaced with a park. Vogel, who admits that he did not particularly like the mall, suggests 'with a certain amounts of seriousness, that malls might possess a similar sort of complexity and teleology as butterflies…' (Vogel 2015, p. 158). In the next step, he goes on to argue that even a machine or other artefact might display similar characteristics, which would potentially make it morally considerable.

The obvious targets of Vogel's argument are positions like the one put forward by environmental ethicist Paul Taylor in the nid-1980s in his book *Respect for Nature* (Taylor 2011). Taylor starts from the idea that living beings have a good of their own, in the sense that they can be benefited or harmed. The main criterion for an entity's having a good of its own is that we can speak of it truly or falsely as things being good for or bad for that entity, without reference to something external, such as an instrumental purpose. My coat might become less useful as an insulating garment if my neighbour soaks it with a garden hose. But it is not the coat that is harmed by the soaking, it is me as coat user. If, on the other hand, my neighbour uses the same garden hose to drown a mole ruining her lawn, it is very much the case that the mole is harmed. The mole, as a living thing, has a good of its own. As does, according to Taylor, all living things, including non-sentient ones like plants and microorganisms. Vogel does not actually endorse moral considerability for artefacts, even though he does argue that humans are responsible for the environment, including artifacts. What he is doing in his essay is showing that criteria for moral considerabilty like the ones Taylor advances would allow for including also entities like malls.

5.4 The Place for Focal Practices and What Makes Them Valuable

Let us, however, stay with Borgmann and admit that a focal practice involves 'the resolute and singular dedication to a focal thing' (Borgmann 1984, p. 219), something that is also exercised in social union (ibid.). Arguably, the debate about biotechnology in agriculture houses several potential focal practices, in addition to Thompson's suggestion of farming.

The first is the involvement in plant breeding itself.

The world's current food supply depends on a (surprisingly small) number of animals and plants, most of which were domesticated from wild predecessors several thousand years ago in different parts of the world: Emmer and Einkorn wheat about 10,000 years ago in the Fertile Crescent of the Middle East, corn somewhat later in Central America, and rice roughly 8000 years ago in present-day China (Doebley et al. 2006). The contents of the plant breeder's toolbox have become increasingly varied and powerful, especially in the last century, with the availability of techniques such as hybridization, backcrossing, mutation breeding, genomic selection, and different types of genetic engineering, to name but a few (Hickey et al. 2019).

In the late nineteenth and early twentieth century, in the US as well as elsewhere, plant breeding became professionalized and institutionalized. The development was strengthened by new scientific discoveries, or as in the case of Mendelian genetics, a scientific re-discovery, and increased public funding (Curry 2014; Wieland 2006). At the same time, non-professional, amateur communities of experimenting plant breeders were very active in experimentation with new plant varieties, then incorporating scientific knowledge. Those communities kept in touch through correspondence with publications like *Garden Magazine* or *American Gardening*, eagerly sharing their results (Curry 2014). Collaborations with professional scientists were occasionally encouraged, as when O.J. Eigsti invited amateur gardeners ('laymen scientists') to plant seeds treated with the mutagen colchicine and report their results

(Curry 2014, p. 555). Today, such initiatives would usually be called ‘citizen science’ (Haklay et al. 2021).

It must be recognized that even with modern tools, enabling more rapid development of plants, the development of a new plant is a *very* long-term undertaking. Let me offer an illustration: Researchers have been entertaining ideas of domesticating wild plants into oilseed crops at least since the 1950s. Wolff and Jones (1958) report on a systematic program for searching for new crops, of which oilseeds make up one category. ‘The need is for plant sources of unusual oils—new and superior types—which can enter industrial markets and serve where presently available oils cannot.’ (Wolff and Jones 1958, p. 6) Replacing petroleum-based products was a major an issue at the time, even if Wolff and Jones mention the possibility of enabling ‘domestic production of many strategic and critical items, now imported’ (ibid., p. 8). The funding came from the US Department of Agriculture. In preceding years, US agricultural research had been focused on finding new uses for existing crops of which there was a mounting surplus. A quarter century later, the situation is in some ways similar: ‘Fats and oils are generally overproduced on a worldwide basis and prices for most are low. Much research and development has been carried out to discover new industrial uses for surplus fats and oils or their fatty acids’ (Princen 1983, p. 478). In 1983, Princen reports that at the time, about 8000 species of plants have been screened for possibly being used as oilseed crops by the Northern Regional Research Center (ibid., p. 479). And obviously, with an oil crisis 10 years in the past, the use of oil crops for energy is also considered in 1983 (ibid., p. 489).

Not only is it a long-term undertaking, but it can also be one requiring commitment and physical effort. An illustration of this is the commitment displayed by Green Revolution ley figure and later Nobel Peace Prize laureate Norman Borlaug and his colleagues in their work (Mann 2019).

The second example is the activity of engaging in activism about biotechnology. Engaging in activism can certainly be focal. But is it a practice? The notion of a practice at work here is arguably the one employed by Alasdair Macintyre in his influential book *After Virtue* (1984). A practice in this sense is.

> ‘any coherent and complex form of socially established human activity through which goods internal to that form of activity are realized in the course of trying to achieve those standards of excellence which are appropriate to, and partially definitive of, that form of activity, with the result that human powers to achieve excellence, and human conceptions of the ends and goods involved, are systematically extended. (Macintyre 1984, p. 187)

Among the examples of practices Macintyre provides we find games like chess or football, the making and sustaining of family life, architecture, and scientific inquiry (systematic plant breeding would fit the bill). He also mentions politics ‘in the Aristotelian sense’. This should not lead us to confuse politics with statemanship. In modern democratic societies, the engagement in deliberation is an essential one and this is what activists may provide.

A biographical example is provided in the form of Mark Lynas, and how he engaged, first, in direct action in the European anti-GMO movement in the 1990s, and later as a pro-biotech advocate (and later than that, advocate for nuclear power).

Another example is Kimberly Nicholas, who in her recent book *Under the Sky We Make: How to Be Human in a Warming World*, offers similar stories, how participating in activism she has been 'inspired to see how just a few people can start something that ripples out to become much bigger' (Nicholas 2021, p 228).

Both Lynas and Nicholas are parts of movements with specific standards of excellence that can be said to be internal to the activist communities. That is, one can be a better or worse activist, not only to the extent that one's campaigns are successful in achieving their goals.

5.5 Limitations on Focal Practices

A perhaps obvious objection to the examples above is the following: If plant breeding can be a focal practice, then why cannot, say, the development of poison gas be one too? And, in the same way if biotechnology activism can be a focal practice, why cannot the activism of a racist group be a focal practice as well? After all, those examples involve people in social union can be singularly and resolutely dedicated to such a thing, in a way that gives meaning their lives.

This problem is not a trivial one and it highlights that focal practices are normative and not merely descriptive categories. But it is not a reason to discard the idea of a focal practice. We see a parallel problem in virtue ethics. Virtues, on a now-prevalent, neo-Aristotelian view, are beneficial character traits. (A bad character trait is a vice.) But they are also to be distinguished from mere skills, in that they have to actively engage the will.[1] A skill is simply an ability to do something. You can be a highly skilled and effective lobbyist for the fossil fuel industry, but that does not make you virtuous. Arguably, utilizing your skill in this way might in fact be as sign of vice.

Similarly, it seems that we must allow some normative constraints that are external to the practice. A minimal requirement is that a practice must not be *inherently evil*. This not a particularly strong requirement. It might even allow practices that are *inherently wrong*. Perhaps one might go further and require in analogy to the doctrine of double effect in catholic bioethics, that the practice itself or its object must be morally good or at least indifferent. Such a constraint can be fleshed out in various ways, which I will not attempt here. In whatever way one does this there are likely to be controversial cases as well as uncertain ones. However, the examples show that there has to be *some* constraint.

Also, a focal practice does not exclude that people act wrongly within it. This is for instance what someone who is a vegan for ethical reasons would claim about some instances of the culture of the table, namely those that involve eating meat or other animal products. Also, it does not exclude that the practice has bad consequences—again, meat eating would be a case in point. Consider Borgmann's hearth

[1] I am building this account on Philippa Foot (1997), cf. Sandin (2007).

or fireplace as a focal thing, in contrast to the central heating system, which is a device providing merely convenient heating. The fireplace used to constitute 'a center of warmth, of light, and of daily practices' (Borgmann 1984, p. 196). Even as technology and architecture developed, the hearth was retained. An example of this is how heating of the great hall in medieval castles evolved. Even with new inventions such as flues, chimneys and recessed fireplaces, the open fire in the hall persisted well beyond the middle ages 'as a matter of convention' (Goodall 2011, p. 35). The smoke was vented through the roof by means of a prominent, often highly decorated louvre—thus, giving the hearth architectural prominence and making it visible from outside the building. Still today a fireplace can function as a symbolical center of the house. But, fires are also lethal. Not just because of the obvious risk of the house burning down, but because of the emissions of soot particles and other hazardous substances resulting from incomplete combustion. A significant number of people die each year from the effects of wood or dung fires.

Also, an observation that has a somewhat phenomenological tinge: Focality often appears to involve the *body*. Borgmann's examples are clear: Running is obviously very much a bodily activity, even to the point of total physical exertion. Though perhaps less physically exerting, the culture of the table is also premised on bodily engagement, including use of the senses—taste, texture and bouquet matter a great deal, as do hunger, thirst, appetite and satiation. Table placement is about bodies and their relation in physical space. Thompson's example of farming, even in the technological age, is illustrative of work that is to a large extent physical and practical. This holds for plant breeding too, and several of the activities of biotechnology activists. Activism often has an element of performance to it. (Again, Lynas' early anti-GMO-activism is a case in point, describing the theatrical actions of SHAG, 'Super Heroes Against Genetix', as 'masked, caped crusaders wearing the trademark superhero garb of underpants over their trousers' (Lynas 2018, p. 15).

5.6 'Pockets of Focality' and Policy Implications

In Thompson's words, focal practices 'are capable of addressing the failure of technology because they unify and harmonize fragmented experiences into a more satisfying hole' (Thompson 2010, p. 111). While Borgmann is concerned with technology, Thompson applies the idea of focal practices to land (ibid.).

The views of both these authors imply that focal practices might occur within a larger system as what I propose we call 'pockets of focality'. This is an important observation and it provides a pragmatic alternative to a wholesale pessimistic view of technological society.

Without going into particular detail, I will take it as granted that our current food system is largely unsustainable due to its for instance, its greenhouse gas emissions, reliance on fossil fuels and non-renewable materials for production of fertilizers and pesticides, and its effects on land use and biodiversity. It is in need of significant reform and change. Those changes will have to involve different levels: global politics and national policy, technological development, and individual behaviour, such as reduced consumption of animal products. Time is also short.

Whether it is change in individual behaviour or policy reform that is most needed, most effective, or should come first, is of course a matter of discussion, but we need not quibble about that. Let us just recognize that given the urgency of the matter, and the short time available, all ways forward are worth pursuing. For instance, in order to reach the goal of stabilizing global temperature increase at 1.5 degrees Celsius, as per the Paris Agreement, we would need to halve the world's carbon pollution by 2030, and that would still mean a world which 'for living creatures … is no picnic´ (Nicholas 2021, p. 28).

The point here is that focal practices provide elements of stability and anchoring, or perhaps, with a plant-related metaphor—rooting.[2] In another metaphor, they may be 'stepping stones' from which a system can be changed.

This might also be relevant from a policy perspective. Focal practices might be identified, supported or actively cultivated. If we take plant breeding as an example, public funds might be used to encourage partnerships between communities of amateurs and professionals (as in some citizen science initiatives).

Over the years, there have been numerous attempts to involve 'the public' in decision-making processes around bioengineering in agriculture, attempts that go beyond and are supposed to supplement the usual mechanisms of policy making In democracies, such as voting for elected representatives. A number of examples exist, for instance the 'consensus conference' model originally developed in Denmark by the Danish Board of Technology in the years before 1990 (Moula and Sandin 2017). A related idea is that of Responsible Innovation, or Responsible Research and Innovation (RRI). According to a common view of responsible innovation, it encompasses four dimensions: *Anticipation*, *Reflexivity*, *Inclusion* and *Responsiveness*. These dimension should not be conceived of as consecutive steps. They mean that in the innovation process, first, social consequences are to be anticipated and fed back into the process. Second, innovators should reflect on the social expectations, values of their innovations and be aware of their own limitations and assumptions, thus, 'at the level of institutional practice […] holding a mirror up to one's own activities, commitments and assumptions, being aware of the limits of knowledge and being mindful that a particular framing of an issue may not be universally held' (Stilgoe et al. 2013, p. 1571). Third, all relevant stakeholders should be included in the innovation process, and fourth, the innovation process should be responsive to societal challenges.

Do focal practices have a role to play in RRI? They may be of importance in all four dimensions.

In their anticipatory activities, innovators should consider potential effects on focal practices. For inclusion, care should be taken to ensure representation of stakeholders involved in focal practices. In the agricultural biotechnology case, it might mean increasingly engaging amateur plant breeders and farmers in the

[2] On a broader but very interesting note, compare Weil (2001).

evaluation processes. Some kind of ethics commission for agriculture and food, as proposed by Kendig et al. (2024) is a potential forum for this. The U.S. lacks such a commission, though there are some examples that focus on gene editing and biotechnology in other countries, such as the Norwegian Biotechnology Advisory Board, an independent body appointed by the Norwegian government with the task to 'valuate the social and ethical consequences of modern biotechnology and to discuss usage which promotes sustainable development' (Bioteknologirådet 2024). The Norwegian Biotechnology Advisory Board has a mandate that is both broader and narrower than what Kendig et al. envisage—the board does not deal with all issues of food and agriculture but only those involving biotechnology, and they are concerned with non-agricultural issues as well, such as medical applications.

Reflexivity requires that cultures of innovation include, as we saw above, awareness that a dominant framing of a problem might not be universally endorsed. An illustration of this from the area of agricultural biotechnology is Hugh Lacey's criticism of transgenic seeds and plants (e.g. Lacey 2016). Lacey claims that transgenics have been developed within 'technoscience', a complex of technology and science without clear distinctions, usually driven by private interests and aiming at intervention: 'expanding human capacities to exercise control over natural objects and furthering the values of technological progress' (Lacey 2016, p. 57). As we saw in the Introduction above, Lacey's concerns are instances of a type of technology criticism endorsed by many philosophers of technology. According to Lacey, technoscience uses 'decontextualized research' strategies—ones that represent the phenomena studied as dissociated from their context. This has led to some risks being overlooked, for instance 'risks to social arrangements that arise from the actual context of the use of transgenics, e.g., undermining alternative forms of farming' (Lacey 2016, p. 58). Note that this is an essentially consequentialist critique of the technoscientific project, with Lacey pointing out undesirable outcomes. It could also be argued that there is something intrinsically wrong with the 'control-and-dominate' attitude it supposedly expresses. I will not investigate this line of argument here.

Innovation processes are dynamic and therefore responsiveness is essential for responsibility. Responsible innovation employs a notion of responsibility that is forward-looking in time (unlike backward-looking responsibility that that concerns ascriptions of blame). Such responsibility presupposes some capacity to affect outcomes (Nihlén-Fahlquist 2019, Ch. 2). To ensure this a number of mechanisms are possible, for instance widening of existing approaches for technology assessment (Stilgoe et al. 2013, p. 1572). Here there might again be a role for ethics food and agricultural ethics commissions (Kendig et al. 2024).

5.7 Conclusion

In this paper, I have made the point that agricultural environments are managed and in part artificial or engineered, often to a very high degree. Despite this, debates about agriculture and biotechnology are often conducted against a background idea of nature and the natural as a guiding principle or ideal. To partly resolve this tension, I think we can bring least something from the idea of nature as guide—what I will call the Imperative of treading lightly. One partial way of making sense of this imperative is to utilize Borgmann's and Thompson's idea of focal practices. The agricultural system offers some potential areas for focal practices, and even highly engineered environments should contain 'pockets of focality', providing 'stepping stones' from which a system can be changed. There is room for implementing some of these elements within a context of responsible research and innovation, for instance in the form of ethics committees for food and agricultural issues.

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References

Anonymous. 1923. Review of the Wheelwright's shop. *Nature* 2816 (112): 586.

BBC. 2000. Reith lectures 2000: Respect for the earth lecture 6: A royal view – The prince of Wales—Highgrove. Transcript. http://downloads.bbc.co.uk/rmhttp/radio4/transcripts/20000517_reith.pdf.

Bioteknologirådet. 2024. The Norwegian Biotechnology Advisory Board. https://www.bioteknologiradet.no/english/. Accessed 21 Mar 2024.

Borgmann, A. 1984. *Technology and the character of contemporary life: A philosophical inquiry*. University of Chicago Press.

Curry, H. A. 2014. From garden biotech to garage biotech: Amateur experimental biology in historical perspective. *British Journal for the History of Science* 47:539–565. https://doi.org/10.1017/S0007087413000411.

Daston, L. 2019. *Against nature*. MIT Press.

Deplazes-Zemp, A. 2022. Are people part of nature? Yes and no A perspectival account of the concept of 'nature'. *Environmental Ethics* 44 (2): 99–119. https://doi.org/10.5840/enviroethics202242736.

Doebley, J. F., B. S. Gaut, and B. D. Smith. 2006. The molecular genetics of crop domestication. *Cell* 127:1309–1321.

Ellul, J. 1964. *The technological society*. New York: Alfred A. Knopf.

Foot, P. 1997. Virtues and vices. In *Virtue ethics*, ed. R. Crisp and M. Slote, 163–177. Oxford: Oxford University Press.

Goodall, J. 2011. *The English castle 1066–1650*. New Haven and London: Yale University Press.

Haklay, M., D. Dörler, F. Heigl, M. Manzoni, S. Hecker, and K. Vohland. 2021. What is citizen science? The challenges of definition. In *The science of citizen science*, ed. K. Vohland, A. Land-Zandstra, L. Ceccaroni, R. Lemmens, J. Perelló, M. Ponti, R. Samson, and K. Wagenknecht, 13–34. Springer. https://doi.org/10.1007/978-3-030-58278-4_2.

Hamilton, C. 2017. *Defiant earth: The fate of humans in the Anthropocene*. Cambridge: Polity Press.

Hickey, L. T., N. A. Hafeez, H. Robinson, S. A. Jackson, S. C. M. Leal-Bertioli, M. Tester, C. Gao, I. D. Godwin, B. J. Hayes, and B. B. H. Wulff. 2019. Breeding crops to feed 10 billion. *Nature Biotechnology* 37:744–754. https://doi.org/10.1038/s41587-019-0152-9.

James, Simon P. 2022. *How nature matters: Culture, identity, and environmental value*. Oxford University Press.

Katz, E. 2011. Preserving the distinction between nature and artefact. In *The ideal of nature : Debates about biotechnology and the environment*, ed. G. E. Kaebnick, 71–83. Baltimore: Johns Hopkins University Press.

Kendig, C., T. Selfa, P. B. Thompson, R. Anthony, W. Bauchspies, G. Blue, A. Das, R. Harrison, C. Henke, S. Jin, J. Kuzma, F. Lipschitz, K. Richter, M. Ruelle, T. Silberg, and B. Takahashi. 2024. The need for more inclusive deliberation on ethics and governance in agricultural and food biotechnology. *Journal of Responsible Innovation* 11:1. https://doi.org/10.1080/23299460.2024.2304383.

Lacey, H. 2002. Assessing the value of transgenic crops. *Science and Engineering Ethics* 8:497–511.

Lacey, H. 2016. Science, respect for nature, and human Well-being: Democratic values and the responsibilities of scientists today. *Foundations of Science* 21:51–67. https://doi.org/10.1007/s10699-014-9376-9.

Lynas, M. 2018. *Seeds of science: Why we got it so wrong on GMOs*. Bloomsbury.

Macintyre, A. 1984. *After virtue: A study in moral theory*. 2nd ed. University of Notre Dame Press.

Mann, C. C. 2019. *The wizard and the prophet: Two remarkable scientists and their dueling visions to shape tomorrow's world*. New York: Vintage Books.

Moula, P. 2015. GM crops, the hubris argument and the nature of agriculture. *Journal of Agricultural and Environmental Ethics* 28:161–177. https://doi.org/10.1007/s10806-014-9526-7.

Moula, P., and P. Sandin. 2017. Ethical tools. In *The ethics of technology*, ed. S. O. Hansson, 115–127. London and New York: Rowman and Littlefield International.

Nicholas, K. 2021. *Under the sky we make: How to be human in a warming world*. New York: G.P. Putnam's Sons.

Nihlén-Fahlquist, J. 2019. *Moral responsibility and risk in society: Examples from emerging technologies, public health and environment*. Routledge.

Princen, L. H. 1983. New oilseed crops on the horizon. *Economic Botany* 37:478–492.

Purdy, J. 2015. *After nature: A politics for the Anthropocene*. Cambridge, MA: Harvard University Press.

Rechnitzer, T. 2022. *Applying reflective equilibrium: Towards the justification of a precautionary principle*. Springer.

Sandin, P. 2007. Collective military virtues. *Journal of Military Ethics* 6 (4): 303–314. https://doi.org/10.1080/15027570701755505.

Sandin, P. 2017. How to label 'natural' foods: A matter of complexity. *Food Ethics* 1 (2): 97–107.

Siipi, H. 2015. Is genetically modified food unnatural? *Journal of Agricultural and Environmental Ethics* 28:807–816.

Soper, K. 1995. *What is nature? Culture, politics and the non-human*. Oxford: Blackwell.

Stilgoe, J., R. Owen, and P. Macnaghten. 2013. Developing a framework for responsible innovation. *Research Policy* 42 (2013): 1568–1580.

Taylor, P. W. 2011. *Respect for nature: A theory of environmental ethics*. Princeton University Press.

Thompson, P. B. 1999. Farming as a focal practice. In *Technology and the good life?* ed. E. Higgs, A. Light, and D. Strong, 166–181. University of Chicago Press.

Thompson, P. B. 2010. *The agrarian vision: Sustainability and environmental ethics*. Lexington, KT: The University Press of Kentucky.

Vogel, S. 2002. Environmental philosophy after the end of nature. *Environmental Ethics* 21 (1): 23–39.

Vogel, S. 2015. *Thinking like a mall*. MIT Press.

Weil, S. 2001. *The need for roots. Prelude to a declaration of duties towards mankind*. Trans. Arthur Wills. London: Routledge.

Wieland, T. 2006. Scientific theory and agricultural practice: Plant breeding in Germany from the late 19th to the early 20th century. *Journal of the History of Biology* 39:309–343.

Wilson, E. O. 2016. *Half-earth: Our planet's fight for life*. New York: Liveright Publications.

Wolff, I. A., and Q. Jones. 1958. Cooperative new crops research: What the program has to involve. *Chemurgic Digest* 17 (9): 4–8.

Chapter 6
Reframing Gene Editing in Crops: Unpacking Potential Solutions by Reconsidering the Questions Asked

Rachel A. Ankeny

Abstract Crop scientists often claim that gene editing will significantly increase food security and other wicked problems. However, various publics are not convinced that the potential risks are offset by the promised benefits. The crux of this disagreement is often unpacked in terms of different values, lack of scientific understanding, or a failure of crop scientists to viewed as trustworthy. This paper revisits the current stalemate between crop scientists and publics, and the resulting conceptual meta-impasse in the scholarly literature on these conflicts. It uses a policy analysis framework to challenge the traditional view that public policies are responses to problems that pre-exist outside of the policy process, waiting to be discovered and solved. Instead, if we view policies as containing implicit representations of the supposed 'problems' that they purport to address, along with unrecognized assumptions and silences, it becomes clear that inadequate attention has been paid to the framing of the claims made by proponents of these technologies. Articulating the underlying problem representations and scrutinizing them can lead to new problem representations and more productive scientific strategies particularly in response to climate change by allowing responsibility to be collectively pursued 'by design.'

Keywords Gene editing · Crop science · Public understanding of science · Framing · Responsibility by design · Responsible research and innovation (RRI)

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6.1 Introduction

> Don't search for the answers, which could not be given to you now, because you would not be able to live them. And the point is to live everything. Live the questions now. Perhaps then, someday far in the future, you will gradually, without even noticing it, live your way into the answer. (Rainer Maria Rilke, *Letters to a Young Poet*)

It is widely claimed in the scientific literature that gene editing of crop plants could result in improvements that will significantly increase food security, particularly in low- and middle-income countries. The types of potential specific benefits attributed to use of gene editing in crops include nutritional enhancement; increased food safety; enhanced resistance to diseases, pests, and weeds; greater affordability of seeds; enhanced climate resilience; and increased biodiversity within cropping systems (see e.g. Eshed and Lippman 2019). Gene-editing technologies permit targeted changes to genomes and are now being widely applied using various constructs including the CRISPR/Cas 9 system (Jinek et al. 2012; Zhang et al. 2019). These new technologies, together with the availability of complete genome sequences and pangenomes associated with many key agricultural crops, allow genome editing to be considerably more accurate, predictable, and precise in its effects than were previous generations of genetic modification (GM) technologies, since gene editing changes the plant's own genes (through making alterations that result in additions or deletions, known as cisgenesis) rather than introducing foreign genes (transgenesis).

However, various publics[1] are still deeply concerned about these sorts of claims coming from scientists and others who advocate for use of gene editing in crops. They are not convinced that the potential risks (or for many, the notion that there are any risks whatsoever, in alignment with a particularly strong version of the precautionary principle) are offset by the promised benefits. The crux of this disagreement is often unpacked in terms of different values and lack of shared understandings of the available scientific information or facts between scientists and those who may use or be affected by gene-edited crops, or a failure of crop scientists to establish conditions under which they can be viewed as trustworthy, particularly given the commercial imperatives viewed by many to be closely associated with the production of GM crops.

This paper seeks to revisit what has become a stalemate between crop scientists who use gene editing and other molecular biological techniques, and publics who may not be actively opposed but are certainly not supportive of this type of research, as well as what arguably has become a conceptual meta-impasse in the scholarly literature on these conflicts. My argument is developed by drawing in part on the feminist political scientist Carol Bacchi's tool, "What is the Problem Represented to

[1] The term 'publics' as utilized here is drawn from the literature in science and technology studies (STS) and indicates a range of diverse groups each of which are unified by interests, responsibilities, roles, or similar, and who tend to share views on particular topics. Individuals typically are members of more than one public as a result of the various roles that they hold and communities in which they participate.

Be" (WPR) (Bacchi 2009; Bletsas and Beasley 2012). This approach to policy analysis challenges the traditional view that public policies are responses or reactions to problems which pre-exist outside of the policy process, waiting to be discovered and solved. Instead, the WPR approach argues that policies contain implicit representations of the supposed 'problems' that they purport to address, which in turn are accompanied by a range of assumptions that generally go unrecognized and unchallenged, as well as a set of silences that are not acknowledged or addressed. These representations put the supposed problem into a certain type of category, and thus restrict and direct the ways in which policies are enacted. The WPR approach forces us to articulate the underlying problem representations and to view them as requiring critical scrutiny, which in turn can lead to both new problem representations as well as novel policy solutions.

This tool can be applied outside of its original domain of policy analysis more generally to allow consideration of a line of research as a response or reaction to problems that exist independently of that line of research. Applying the WPR approach in this context allows us to explore how lines of research may contain within them representations of the problems that they seek to address, as well as a range of assumptions and framings (together with various silences and absences) that largely are overlooked. These problem representations need to be exposed and subjected to critical scrutiny when considering whether a line of research should be supported, and particularly when these lines of research claim to be aimed at creating real-world solutions. As part of this process of scrutiny, we must ask how the problem (and its representations) can be fruitfully disrupted and reframed, so as to allow much more productive research focused on a newly articulated version of the problem to be solved as well as a more widely shared set of representations or conceptualizations of that problem, or even a completely new problem to be addressed.

When we apply the WPR approach to the case of gene editing in crops, it can quickly be seen that inadequate attention has been paid to the framing of the claims made by proponents of these technologies in this context, especially about the advantages and promises of this technology as compared to GM technologies, and that the implicit assumptions that are embedded in these framings are largely overlooked. Most notably, these assumptions promote gene editing as an 'answer' to certain types of problems previously associated with GM. However these problems are not in fact what various public's view as the main problems that GM presents. There is a deep disconnect between how proponents of GM technologies and how publics define the problems that GM seeks to address. In addition, the framing of gene editing typically smuggles in a very particular conceptualization of the systems in which it seeks to intervene, one that relies on holding certain variables or factors largely as constant, as is common in controlled laboratory settings. For example, critical scrutiny reveals that the rapidly increasing impacts of climate change (or, more precisely, our growing recognition of these impacts) have resulted in the need to rethink traditional scientific approaches to crop modification research, which in turn draw this underlying conceptualization into question.

Central to the processes of critical scrutiny that must be used to fruitfully disrupt and reframe the representation of the problem to produce more fruitful lines of research is greater reflection on the values associated with what has come to be known as Responsible Research and Innovation (RRI). I argue that growing recognition of the need to reconceptualize the most productive scientific strategies for producing novel crops in the context of climate change presents an ideal opportunity for integrating RRI principles into the earliest stages of research planning, allowing responsibility to be collectively pursued 'by design.' In addition, these new scientific strategies associated with producing novel crops provide different framings to both the problems to be solved and their potential answers (in the form of lines of research and their associated future outputs). Such framings are likely to be responsive to many publics' concerns that arose in the context of the development and application of GM technologies to crops, or at least have the potential to provide a shared platform for engagement and dialogical processes with diverse publics that could lead to more inclusive and responsible innovation in this space.

6.2 Is Gene Editing 'Better' than Genetic Modification?

> Information can tell us everything. It has all the answers. But they are answers to questions we have not asked, and which doubtless don't even arise. (Jean Baudrillard, *Cool Memories*)

We have considerable empirical evidence about publics' views on GM crops: attitudes differ depending on perceptions about what the frame should be for considering GM (e.g., whether the precautionary principle is invoked), potential benefits in relation to risks, who stands to benefit, and the purposes for which GM is to be used (e.g., Ankeny and Bray 2016). Attitudes toward use of biotechnologies in food production are cautious and tend to be negative (Bray and Ankeny 2017), for instance in comparison to use of biotechnologies in medical applications, in part because many consumers do not see direct or short-term benefits for themselves, their families, or their communities from these types of applications. There is limited empirical information available on publics' views on uses of gene editing as distinct from GM. We know that consumers and community members often have preferences for foods that do not map directly onto the GM versus non-GM distinction. Many prefer food that is 'natural' (sometimes defined as minimally processed: see Lockie et al. 2005), locally produced, healthy and nutritious, and additive-free. One study showed that 45% of Americans viewed GM foods as 'unnatural' and disgusting (Scott et al. 2016).

However, the presence or absence of GM ingredients is not necessarily a main factor in food choice for many. Many publics have concerns about GM and other biotechnological applications that do not relate directly to their use to produce food, including the potential effects on farmers of technologies that prevent seed saving, the association of these technologies with the consolidation of power and intellectual property by multinationals, and feared environmental impacts from increased reliance on agricultural chemicals in farming systems in conjunction with GM (see Deckers 2005; Lusk et al. 2018). Food security is thought to be a significant issue in developed countries, for instance according to one study which found that Americans are supportive of use of GM to increase levels of domestic crop production in order to foster greater food security, but not of GM to produce consumer-related benefits such as improving nutritional content or benefits for farmers (McFadden and Smyth 2019).

The evidence about attitudes to gene editing and other new breeding technologies (NBTs) is extremely limited in comparison to what we know about views on GM. At first glance, it seems to indicate that publics are slightly more positive toward it than to older forms of GM, and slightly more negative about it than they are about food produced using traditional breeding techniques. There appear to be more positive reactions to the 'more targeted' and 'less distant' nature of gene editing as compared with what are viewed as more 'random' and 'distant' GM techniques (e.g., Cormick and Mercer 2017; Gatica-Arias et al. 2019; Kato-Nitta et al. 2019; Batalha et al. 2021; Ferrari et al. 2021; Spök et al. 2022). However, it must be stressed that more evidence is required in this domain: it could be the case that this relative positivity toward gene editing is a result of framing biases in the research to date (for a recent review of the literature on public understandings of NBTs including gene editing, see Grant et al. 2021). In one of the few studies that did not predefine gene editing and other newer technologies as clearly distinct from GM, participants were equally split on whether these techniques were similar or different in important ways (Debucquet et al. 2020).

Despite this lack of empirical evidence about publics' support for gene editing, and preferences for it and other NBTs in comparison to GM, many scientists have claimed that gene editing is likely to be more acceptable to various publics as the science will result in changed consumer perceptions (e.g., Anders et al. 2021). Gene editing methods allow changes in DNA without adding any genetic material from another organism (and thus are cisgenic rather than transgenic), and it is claimed by many scientists that this scientific difference will result in higher levels of public support for gene editing than for GM. They also emphasize the precision of genome editing techniques, such as CRISPR-Cas9, which produce precise cuts at specific DNA loci using site-directed nucleases, and in turn the efficiency and cost effectiveness of these techniques. Additional advantages of the NBTs as compared to earlier forms of GM are the higher speeds at which the changes can be produced and the very precise plant breeding which results, which in turn make it possible to target a predefined region of DNA. Finally, this precision is said to result in less risk of disruption of genes and/or regulatory elements in the recipient genome. All of these more technical advantages are claimed to be likely to generate greater acceptance amongst publics for gene-edited crops than was associated with their GM predecessors.

There are numerous problems with this type of argument. First, amongst many publics in a variety of locales, the term 'GM' (or 'GMO') is still widely used by those opposed to these types of technologies without distinction between the earlier and later forms of technologies including NBTs (Popek and Halagarda 2017). In some locales, for instance the European Union, regulations have treated gene-editing CRISPR-produced crops in the same manner as other forms of GM (an approach which has been criticized by many: see for instance Herman et al. 2019), which makes it difficult to disentangle publics' views on one as distinct from the other. Some attribute this to lack of understanding or knowledge about the newer technologies but given that many of the same concerns that arose with GM (as outlined above) are not significantly different in the case of gene editing and NBTs, it may simply be the case that the precision, speed, and type of modification (i.e., whether transgenic or not) are not the most relevant considerations for these publics, or indeed for regulators.

Indeed, most of these advantages that are generally shared by all forms of gene editing are improvements to laboratory processes, but do not automatically have positive flow-on effects for typical issues of concern to consumers or publics, or to real-life applications of these technologies. For instance, 'risk' in these discussions of advantages is related to the risk of an off-target effect, whereas 'risk' is typically conceptualized by publics as a broader concern related to a range of health, social, environmental, and even economic risks that may be associated with the products and applications that result from such technologies. Similarly, benefits associated with gene editing are often said to include lower costs, but again these are primarily in the context of the laboratory setting and without consideration of whether these technologies will result in more cost efficiencies for the food system for either producers or consumers.

These types of NBTs have also been claimed by some pro-gene-editing groups to be more 'democratic' (Bain et al. 2020; Barrangou 2020) as they will allow more access to novel crops without cost and without the need for as much expertise as was required to produce GM crops. Note again here that the focus of such contentions is on the laboratory end of the process without any evidence about potential democratization for others in the agricultural value chain such as farmers[2] or consumers. Some scientists have argued that gene editing allows for more innovation without being specific about for whom and for what purposes applications of this technology count as something truly novel and positive, or about whether they actually will produce benefits that flow on to consumers and publics. Publics are (rightly) suspicious about the likelihood of such benefits, particularly without any explicit discussion of how likely they are and on what timelines.

Finally, there is fundamental disagreement about what counts as 'gene editing,' as can be seen in the diverse regulatory regimes around the world. Some distinguish all gene editing from GM, while others require closer examination of the processes involved (Lassoued et al. 2018) and only regulate that which can be detected or distinguished from changes that could occur naturally. Interestingly, a survey of scientific experts' views revealed general agreement that those genome-edited crops which are transgenic should be regulated as GM, and those that did not involve transgenic modifications should not be grouped together with GM for regulatory purposes (Lassoued et al. 2019). But what is notable in this way of framing these

[2] It may be the case that some gene-edited crops allow seed saving, unlike most GM crops, and hence do permit more democratization in this sense, but again this feature is not unique to gene-edited crops.

debates is the focus on the scientific features of the technologies and their ontologies to the exclusion of other important considerations, such as perceptions and views particularly of publics: to make claims that GM and gene editing (and other NBTs) are (or are not) fundamentally different from each other and hence warrant particular types of similar (or different) regulation is to overlook the primary purpose of regulation, which is about providing oversight and making policy (i.e., social) decisions.

Thus it can be seen that inadequate attention has been paid to the framing of the claims made by proponents of gene editing and NBTs in the context of crop science and agriculture, especially about the advantages and promises of this technology as compared to GM technologies, and the implicit assumptions embedded in these framings. Notably, these assumptions promote gene editing as an 'answer' to certain types of problems previously associated with GM, when these problems are not those that various publics have viewed as those represented by GM.

6.3 What Is the Question: Or, What Should Crop Gene Editing Be Used For?

> Our minds thus grow in spots; and like grease-spots, the spots spread. But we let them spread as little as possible: **we keep unaltered as much of our old knowledge, as many of our old prejudices and beliefs, as we can.** We patch and tinker more than we renew. The novelty soaks in; it stains the ancient mass; but it is also tinged by what absorbs it. (William James, *Pragmatism: A New Name for Some Old Ways of Thinking*)

In this section, I argue that the framing of gene editing by many scientists typically smuggles in a very particular conceptualization of the systems on which it seeks to intervene, one that relies on holding certain variables or factors largely as constant, as is common in controlled laboratory settings. However, critical scrutiny reveals that the rapidly increasing impacts of climate change (coupled with our growing recognition of these impacts and the need to quickly deliver real products for farmers) have resulted in the need to rethink traditional scientific approaches to crop modification research, which in turn draw this underlying conceptualization into question.[3]

Particularly during periods in which technology development has been the key focus, the emphasis in crop science has been on traits that are valuable due to the understanding that they can provide about fundamental mechanisms in plants, especially in the context of research conducted in university settings. In contrast, research associated with commercial activities has tended to focus on those traits which are easily accessible in technological terms but (unsurprisingly) which also are associated with marketable products. In both cases, research has largely proceeded without adequate attention to the relationship of these sorts of traits to societal

[3] This section draws heavily on the scientific arguments made in Bowerman et al. (2022), on which I am a co-author.

priorities or benefits. This research also has tended to prioritize basic or fundamental research approaches which occur largely in laboratory settings, with limited testing or deployment in the field or exploration of potential real-life applications.

To take just one example, increased yield is often viewed as a main goal in crop biotechnology, and indeed yields are said to have tripled in the past five decades via conventional and GM technologies (Ritchie and Roser 2021). Such an emphasis is often claimed to be aligned with the need to increase global food security. However, many publics are concerned about increased yield because to them it appears to primarily produce benefits for those who grow crops (farmers or corporate entities) and for seed sellers and breeders. However increased yield has the potential to result in use of more resources unless coupled with clear limitations on the amount of land and other inputs, and to have adverse environmental effects in the longer run. More importantly, pursuit of increased yield may be in conflict with other desirable traits, notably resilience, as will be discussed in more detail below.

Many crop breeding programs target genetic vigor (e.g. Richards et al. 2002), with higher yield, quicker maturity, and greater stability being the typical sorts of traits pursued. In order to produce genetic vigor, considerable genetic variation must be created with which to work, along with repeatable target phenotypes and highly accurate selection processes particularly in early segregating generations, all of which can be difficult to obtain in non-laboratory settings. In a sense, the very notion of ‘genetic vigor’ requires a static definition of what counts as ‘vigor’ in any particular crop variety without adequate consideration of changing contexts including different locales and/or variable environmental conditions in the same locale over time.

More generally, much research in molecular crop science proceeds by treating crops in isolation instead of as integrated systems with important connections to the soil, broader environmental conditions, and so on. The limits of such approaches can be seen in the mixed results of various lab-based improvement efforts. Take the example of narrowly defined measures of ‘resistance’ to abiotic stress: attempts to translate laboratory-based efforts to produce greater resistance to abiotic stress have mostly failed due to a narrow focus, for example on a specific stress in a certain tissue, rather than on optimization of resource use efficiency across the growing season (see the review in Passioura 2020). Similarly, identification and growth of cereals with low salt accumulation processes measured over a lifetime in field trials was more successful in terms of yield and other qualities than were efforts to target genes which improved resistance to short, focused episodes of salt stress (Munns et al. 2012).

In addition, crop traits tend to be viewed singularly and in competition with each other. Newer approaches are exploring how greater variability might be created in the ways in which crops respond to different environments by stacking traits additively, rather than antagonistically, and hence creating more options and potentially more resilience. So rather than taking a single target approach, some crop scientists are advocating use of integrative methodologies that allow modelling of a range of reactions based on multiple traits in an integrated system, for instance interactions in response to photosynthesis (see Wu et al. 2019).

These alternative approaches are particularly exciting because of the reality of what many scientists and publics agree is the most important problem currently facing us, and in turn the problem that has considerable potential to be targeted by NBTs and other crop biotechnologies: climate change. The race to use technological interventions to keep pace with the effects of climate change arguably is being lost: for instance, in some geographic localities such as Australia, current genetic gains in yield are not offsetting losses ascribed to climate change (Hochman et al. 2017). Changes in climate also have significantly reduced broadacre farming profitability, evidenced by a 22% decline in Australia since 2000 (Hughes et al. 2019). Future projections are no less troubling: for instance, wheat production is estimated to fall by up to 7% under a scenario of 1.5 °C warming above pre-industrial conditions, and up to 11% under a 2 °C scenario (Liu et al. 2019; Zaveri and Lobell 2019). Future risk for yield losses for maize is estimated to be 6% higher than the historical risk (especially in India), while soybeans (particularly in the USA, Russia, and India) have risks of up to 16% and rice in southeast Asia up to 19.5% (Leng and Hall 2019). Significant impacts on a range of traits, including increased soil salinization and reduced nutrient availability, are predicted due to climate change.

Climate change will not only produce extremes but also surges, for instance in compound drought and heatwave events including those that occur within crops' growing seasons. For example, studies suggest that more than 92% of wheat-producing areas experienced at least one compound drought and heatwave event in each growing season between 1981–2020, with a 28.2% increase in frequency and 33.2% increase in duration as well as rapid spatial expansion of these compound events over the time period studied (He et al. 2022; see also Brás et al. 2021). However such impacts are largely ignored, especially on a global scale, and especially when considering how to structure targets and approaches for molecular crop science research. Variability and uncertainty are likely to be increasingly critical concerns: conventional as well as gene-based breeding methods rely on measurable traits and targets, and struggle to be applied in unpredictable conditions including where variability is highly increased within growing seasons. For instance, between 2010 and 2022, southeastern Australia has experienced every decile of annual rainfall. How can researchers define the 'average environment' for a crop, let alone develop crops that are responsive and resilient against this background of uncertainty and complexity?

Some scientists argue that it is important to re-envisage the aims of crop science research to produce more dynamic and agile farming systems that can better respond to highly variable and more extreme environments, as well as to the increasing frequency of extreme climatic events (Bowerman et al. 2022). However, such a vision requires fundamental shifts in how molecular crop science is performed, away from focus on individual traits in isolation from their various real-world contexts, to use of more complex methodologies including modelling of genotype and environmental interactions and use of multiple field sites which are not highly standardized but instead vary in a real-world manner in terms of climate, soil, and resource availability (as an example, see Crespo-Herrera et al. 2021 on use of Target Population of Environments [TPE] methods in India).

In summary, the reality of climate change is pushing crop science, and particularly GM and gene-editing research, not only in new directions but toward a fundamental shift in the framing and approaches associated with this type of research. Although this point is speculative, it may be that such shifts could provide the basis for increased public engagement with and even support for this type of research, given that publics are not particularly impressed with the benefits to date of single trait-focused GM and NBT research programs, and are evidencing increased concerns about climate change and environmental effects.

6.4 What Does Responsible Research Innovation (RRI) in this Space Require?

It is not the answer that enlightens, but the question. (Eugène Ionesco, *Découvertes*).

As argued in the previous section, there is growing recognition of the need to reconceptualize what are likely to be the most productive scientific strategies for producing novel crops in the context of climate change in terms of multiple traits in the rich contexts (geographic, climatic, and otherwise) in which they occur, rather than focusing on maximizing individual traits in highly idealized and static laboratory conditions. I contend that this transition in methods in the molecular crop sciences presents an ideal opportunity for integrating responsible research innovation (RRI) principles into the earliest stages of research planning and allowing responsibility to be collectively pursued 'by design.'

It is clear that past engagement with publics about GM technologies and products has not been effective if we take a main goal to be fostering reflexive dialogue and debate, including greater debate about identifying problems and possible solutions. This new era of gene-editing technologies provides an opportunity to foster open, transparent, and inclusive societal debate about these technologies in alignment with RRI principles and processes, including whether and how they should be used, particularly to create resilient and sustainable solutions which are responsive to climate and environmental challenges. It is especially important to foster genuine and robust inclusion processes for interested publics. Use of RRI-associated principles could produce longer-term benefits by guiding scientists, publics, policymakers, and others toward "a collective commitment of care for the future through responsive stewardship of science and innovation in the present" (Owen et al. 2013) especially in the wake of climate change.

It is essential to recognize the radical nature of this new starting point. It might initially seem that gene-editing research is part of a continuum with previous GM and conventional breeding before it (and indeed scientists and policymakers often rely on this type of argument). However, when coupled with a fundamental shift in the framing of this type of research to focus on integrated systems contextualized against the background of the novel issues presented by climate change, there is the potential to restart dialogue and discussions about these technologies. I contend that the best way to engage in these processes is to use what has been described as 'responsibility by design' (RbD) approaches (for a review of early related articulations and applications of this concept, see Stahl et al. 2021).

The concept of RbD refers to embedding reflexive engagement with publics in the earliest stages of research by fostering debate about the desirable endpoints of the research that is being proposed, as well as potential concerns, risks, and benefits. In a sense, RbD is a corrective to typical approaches to RRI, where ethical and social considerations are often introduced relatively late, for instance after decisions have been made to pursue a particular line of research or a certain type of project, or after funding or institutional structures have been established that constrain activities and how they are framed. In these types of cases, RRI arguably serves primarily to legitimize these initiatives and perhaps tweak or shape them in more minimal or even trivial ways. In contrast, RbD makes responsibility literally part of the design of the project or line of research by drawing on evidence relating to RRI principles such as anticipation, reflection, and engagement to decide what the problem to be addressed is, whether and what kind of research should be developed, and how.

In addition, RRI often is viewed as an external imposition on researchers, a sort of policing effort that is external to scientific practices, frequently as a result of funding or institutional mandates (think about the proliferation of ELSI and ELSA programs associated with genomic research). RbD instead emphasizes that consideration of various concerns, possible benefits, and potential risks and negative future impacts should be embedded into the very design of applications of any technology particularly because it will occur within broader social contexts, and that such design should occur collaboratively with interested publics. Such collaborations are not only useful as forms of communication or engagement, but also because they create spaces in which alternative solutions might be proposed, especially because publics often ask difficult questions about assumptions or framings that otherwise tend to become invisible or blackboxed within scientific communities.

An additional key value associated with RRI and RbD is described as 'opening up' processes associated with innovation, particularly to foster diversity, inclusivity, and equity. However, opening up typically takes the form of mere inclusion of additional parties to the conversations, often in the form of engaging publics on a limited basis (e.g., through micropublic participatory events or similar). An important component of processes that genuinely seek to open up these dialogues is the incorporation of novel perspectives, which has been argued to require careful consideration of how issues are framed and might be reframed (van Mierlo et al. 2020). Given that the evolving scientific strategies associated with crop science in the light of climate change provide different framings of both the problems to be solved and the potential answers to these problems (in the form of the technologies to be used, and the lines of research to be pursued and their future outputs) associated with such problems, a critical opportunity is presented in this space.

The limited available empirical evidence does suggest that there may be some willingness on the part of some publics be more positively inclined toward novel crops modified to be more resilient particularly in response to climate change if they indeed benefit farmers (especially those seen as family farmers as opposed to multinationals or corporates), or if the crop fulfils other beneficial desiderata such as reduction of agrochemical use or documentable environmental benefits (specific traits or applications are of course likely to be received in different ways by publics depending on their individual characteristics). However, paying much greater attention to processes associated with framing and reframing both of our questions and the potential answers or responses to them may well result in dialogue that is more responsive to many publics' concerns that arose in the context of the development and application of GM technologies to crops. Publics should be involved in identifying the most pressing questions rather than simply being presented with potential preformed solutions that they are asked to adjudicate between. Given broadly shared agreement around the pressing nature of climate change, use of RRI and RbD processes has the potential to provide a shared platform for reflexive crafting of research programs by scientists together with diverse publics that could lead to more inclusive and responsible innovation in the space of crop gene editing.

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References

Anders, S., et al. 2021. Gaining acceptance of novel plant breeding technologies. *Trends in Plant Science* 26:575–578.

Ankeny, R. A., and H. J. Bray. 2016. 'If we're happy to eat it, why wouldn't we be happy to give it to our children?': Articulating the complexities underlying women's ethical views on genetically modified food. *IJFAB: International Journal of Feminist Approaches to Bioethics* 9:166–191.

Bacchi, C. 2009. *Analysing policy: What's the problem represented to be?* Frenchs Forest: Pearson Education.

Bain, C., S. Lindberg, and T. Selfa. 2020. Emerging sociotechnical imaginaries for gene edited crops for foods in the United States: Implications for governance. *Agriculture and Human Values* 37:265–279.

Barrangou, R. 2020. Finding SECURE ground: USDA edits the biotechnology regulatory framework. *CRISPR Journal* 3:136–137.

Batalha, L., F. Foroni, and B. J. Jones. 2021. All plant breeding technologies are equal, but some are more equal than others: The case of GM and mutagenesis. *Frontiers in Plant Science* 12:657133.

Bletsas, A., and C. Beasley, eds. 2012. *Engaging with Carol Bacchi: Strategic interventions and exchanges*. Adelaide: University of Adelaide Press.

Bowerman, A. F., C. S. Byrt, S. M. Whitney, J. C. Mortimer, R. A. Ankeny, et al. 2022. Potential abiotic stress targets for modern genetic manipulation. *The Plant Cell* 35:koac327.

Brás, T. A., J. Seixas, N. Carvalhais, and J. Jägermeyr. 2021. Severity of drought and heatwave crop losses tripled over the last five decades in Europe. *Environmental Research Letters* 16:065012.

Bray, H. J., and R. A. Ankeny. 2017. Not just about 'the science': Science education and attitudes to genetically modified foods among women in Australia. *New Genetics and Society* 36:1–21.

Cormick, C., and R. Mercer. 2017. *Community attitudes to gene technology. Report prepared for the Office of the Gene Technology Regulator*. Instinct and Reason.

Crespo-Herrera, L. A., et al. 2021. Target population of environments for wheat breeding in India: Definition, prediction and genetic gains. *Frontiers in Plant Science* 12:638520.

Debucquet, G., R. Baron, and M. Cardinal. 2020. Lay and scientific categorizations of new breeding techniques: Implications for food policy and genetically modified organism legislation. *Public Understanding of Science* 29:524–543.

Deckers, J. 2005. Are scientists right and non-scientists wrong? Reflections on discussions of GM. *Journal of Agricultural and Environmental Ethics* 18:451–478.

Eshed, Y., and Z. B. Lippman. 2019. Revolutions in agriculture chart a course for targeted breeding of old and new crops. *Science* 366:eaax0025.

Ferrari, L., C. M. Baum, A. Banterle, and H. De Steur. 2021. Attitude and labelling preferences toward gene-edited food: A consumer study amongst millennials and generation Z. *British Food Journal* 123:1268–1286.

Gatica-Arias, A., M. Valdez-Melara, G. Arrieta-Espinoza, F. J. Albertazzi-Castro, and J. Madrigal-Pana. 2019. Consumer attitudes toward food crops developed by CRISPR/Cas9 in Costa Rica. *Plant Cell Tissue and Organ Culture* 139:417–427.

Grant, W. J., Bray, H., Harms, R., Ankeny, R. A., and Leach, J. 2021. Consumer responses to the use of NBTs in the production of food: A systematic literature review. Food Standards Australia New Zealand. https://www.foodstandards.gov.au/code/proposals/Documents/NBTLiteratureReview.pdf.

He, Y., J. Fang, W. Xu, and P. Shi. 2022. Substantial increase of compound droughts and heatwaves in wheat growing seasons worldwide. *International Journal of Climatology* 42:5038–5054.

Herman, R. A., M. Fedorova, and N. P. Storer. 2019. Will following the regulatory script for GMOs promote public acceptance of gene-edited crops? *Trends in Biotechnology* 37:1272–1273.

Hochman, Z., D. L. Gobbett, and H. Horan. 2017. Climate trends account for stalled wheat yields in Australia since 1990. *Global Change Biology* 23:2071–2081.

Hughes, N., D. Galeano, and S. Hattfield-Dodds. 2019. The effects of drought and climate variability on Australian farms. In *ABARES insights*, 11. Canberra, ACT: Australian Bureau of Agricultural and Resource Economics and Sciences.

Jinek, M., K. Chylinski, I. Fonfara, M. Hauer, J. A. Doudna, and E. Charpentier. 2012. A programmable dual-RNA–guided DNA endonuclease in adaptive bacterial immunity. *Science* 337:816–821.

Kato-Nitta, N., T. Maeda, Y. Inagaki, and M. Tachikawa. 2019. Expert and public perceptions of gene-edited crops: Attitude changes in relation to scientific knowledge. *Palgrave Communications* 5:1–14.

Lassoued, R., S. J. Smyth, P. W. B. Phillips, and H. Hesseln. 2018. Regulatory uncertainty around new breeding techniques. *Frontiers in Plant Science* 9:1291.

Lassoued, R., D. M. Macall, H. Hesseln, et al. 2019. Benefits of genome-edited crops: Expert opinion. *Transgenic Research* 28:247–256.

Leng, G. Y., and J. Hall. 2019. Crop yield sensitivity of global major agricultural countries to droughts and the projected changes in the future. *Science of the Total Environment* 654:811–821.

Liu, B., et al. 2019. Global wheat production with 1.5 and 2.0 degrees C above pre-industrial warming. *Global Change Biology* 25:1428–1444.

Lockie, S., G. Lawrence, K. Lyons, and J. Grice. 2005. Factors underlying support or opposition to biotechnology among Australian food consumers and implications for retailer-led food regulation. *Food Policy* 30:399–418.

Lusk, J. L., et al. 2018. Do consumers care how a genetically engineered food was created or who created it? *Food Policy* 78:81–90.

McFadden, B. R., and S. J. Smyth. 2019. Perceptions of genetically engineered technology in developed areas. *Trends in Biotechnology* 37:447–451.

Munns, R., R. A. James, B. Xu, A. Athman, S. J. Conn, C. Jordans, C. S. Byrt, R. A. Hare, S. D. Tyerman, M. Tester, D. Plett, and M. Gilliham. 2012. Wheat grain yield on saline soils is improved by an ancestral Na+ transporter gene. *Nature Biotechnology* 30:360–364.

Owen, R., et al. 2013. A framework for responsible innovation. In *Responsible innovation: Managing the responsible emergence of science and innovation in society*, ed. N. J. Hoboken, 27–50. Wiley.

Passioura, J. B. 2020. Translational research in agriculture: Can we do it better? *Crop Pasture Science* 71:517–528.

Popek, S., and M. Halagarda. 2017. Genetically modified foods: Consumer awareness, opinions and attitudes in selected EU countries. *International Journal of Consumer Studies* 41:325–332.

Richards, R. A., G. J. Rebetzke, A. G. Condon, and A. F. Herwaarden. 2002. Breeding opportunities for increasing the efficiency of water use and crop yield in temperate cereals. *Crop Science* 42:111–121.

Ritchie, H., and M. Roser 2021. Crop yields. In *Our world in data*. https://ourworldindata.org/crop-yields. Accessed 1 Mar 2022.

Scott, S. E., et al. 2016. Evidence for absolute moral opposition to genetically modified food in the United States. *Perspectives in Psychological Sciences* 11:315–324.

Spök, A., et al. 2022. Towards social acceptability of genome-edited plants in industrialised countries? Emerging evidence from Europe, United States, Canada, Australia, New Zealand, and Japan. *Frontiers in Genome Editing* 4:899331.

Stahl, B. C., et al. 2021. From responsible research and innovation to responsibility by design. *Journal of Responsible Innovation* 8:175–198.

van Mierlo, B., P. J. Beers, and A.-C. Hoes. 2020. Inclusion in responsible innovation: Revisiting the desirability of opening up. *Journal of Responsible Innovation* 7:361–383.

Wu, A., G. L. Hammer, A. Doherty, S. Von Caemmerer, and G. D. Farquhar. 2019. Quantifying impacts of enhancing photosynthesis on crop yield. *Nature Plants* 5:380–388.

Zaveri, E., and D. B. Lobell. 2019. The role of irrigation in changing wheat yields and heat sensitivity in India. *Nature Communications* 10:4144.

Zhang, Y. X., A. A. Malzahn, S. Sretenovic, and Y. P. Qi. 2019. The emerging and uncultivated potential of CRISPR technology in plant science. *Nature Plants* 5:778–794.

Chapter 7
Unpacking Public Engagement in Agricultural Biotechnology: The Role of Narratives and Social Epistemology in a Deliberative Workshop on Gene Editing in Agriculture and Food

Theresa Selfa

Abstract Science and Technology Studies scholars have promoted public engagement in science and technology through venues such as deliberative workshops in to order to engage key actors in providing a participatory appraisal of the use of and governance approaches for emerging technologies. This chapter focuses on a case study of a deliberative workshop that was convened to engage publics around use and governance of gene editing in agriculture and food, and explores what values, assumptions and concepts are framing the debate around gene editing. I take a narrative approach to analyze the deliberative workshop text to ask: what are participants' substantive concerns when they are discussing gene editing in food and agriculture; how are these concerns produced in interactive discussion; and what master narratives (or stories) do they draw on in their discussions? Overall, the workshop revealed a narrow framing of the issues by participants, and assumptions of scientific progress and public benefit through neoliberal voluntary governance of agricultural biotechnology were largely shared among participants. This case study reveals challenges with engaging 'publics' in complex and contentious science and technology issues.

Keywords Deliberative workshop · Gene editing in agriculture · Narrative analysis · Public engagement

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7.1 Introduction

Recent STS and critical policy studies scholars have called for more authentic public engagement to inform the use and governance of emerging biotechnologies in agriculture (Jasanoff and Hurlbut 2018; Macnaghten and Habets, 2020; Kuzma 2021). Concerns around the ethical, social and environmental dimensions and implications of emerging genetic technologies in agriculture, such as gene editing, have led to diverse responses from policy makers, industry actors, NGO representatives, government agencies and academics toward engaging with publics to attempt to address these concerns.

STS scholarship has argued that robust and authentic public engagement needs to consider factors beyond strict risks and benefits, and should include concerns such as diverse value systems and epistemologies. Inclusion of broader social and ethical considerations are also thought to contribute to more 'responsible innovation' and governance processes for new and emerging technologies that can be anticipatory of impacts, responsive to societal values and include multiple framings of the issue (Stilgoe et al. 2013; Bellamy et al. 2017; Macnaghten 2016). As such, one proposed outcome of public engagement is to inform *upstream* models of governance, that is anticipating and responding to public concerns related to innovations rather than managing risks, before new technologies become adopted and 'hardwired' and therefore difficult to challenge or reverse (Macnaghen et al. 2005; Macnaghten and Chilvers 2014).

Recent critical policy studies work on governance and regulation of biotechnology in agriculture argues that the intractable nature of many social and ethical issues in agriculture, and little progress in their resolution, suggests that more public engagement will not solve "wicked problems" such as how to regulate gene editing. Wicked problems (Rittel and Webber 1973) lack a shared problem definition, involve conflicting facts and values and are difficult to solve. Simply providing additional opportunities for engagement that reproduce the format and parameters of previous public engagement will not resolve stalemates around issues. Alternatively this work points to the need for more explicit politicization around societal debates and decision-making (Mampuys 2023). Rather than cloaking consensus decision making processes under the veil of scientism or delaying decisions due to continued uncertainty, critical policy scholars advocate for exploring the range of divergent and conflicting values-related concerns that may arise from new technologies (Poort et al. 2022; Mampuys 2023). Moreover, they suggest that more genuine stakeholder participation is only possible if participants and the deliberation design meet particular 'participation ethics' criteria, in which both the participants and the deliberation design are set up to allow and even encourage dissent, as well as include a mutual willingness to consider differing views, and pros and cons (Poort et al. 2022: 1213). These two approaches to navigating social, political and ethical issues in the use and governance of gene editing in agriculture —more authentic public engagement and/or politization around these issues— shape the questions animating the paper. The broad research question (s) that guide the paper include:

- Can we enact more *authentic* public engagement around use and governance of controversial science and technology issues, specifically gene editing in agriculture and food?
- What *values assumptions and concepts* are framing the discussion of the impacts of gene editing for agriculture?
- Are public engagement efforts, such as deliberative workshops, useful for revealing *multiple framings* of issues, and *conflicting values*?

This paper is a first attempt to wrestle with these issues. I come to these questions committed to the practice and promise of public engagement. This paper analyzes the discursive process, and the outcomes of a deliberative workshop organized to engage publics around social and ethical issues related to biotechnology use in agriculture, and aspirationally, as a way to inform more equitable governance of these technologies.

7.2 Designing More Authentic Public Engagement in Gene Editing and Agriculture and Food

STS scholars have promoted public engagement in science and technology through venues such as deliberative workshops in to order to engage key actors in providing an 'upstream' participatory appraisal of the use of and governance approaches for emerging technologies (Pidgeon et al. 2017). Within STS, deliberative workshops have been informed by Responsible Innovation Framework (RIF), which aims to elicit key actor deliberation and input on public knowledge, concerns, and values *before* a new technology is deployed and *before* policies and standards are established (NAS 2017; Partridge et al. 2017; von Schomberg 2019). Recent STS literature has called for the application of RIF to engage with more diverse publics, including those with different epistemologies, as well as differing cultural and livelihood concerns, and to inform globally inclusive governance of emerging technologies, such as gene editing in agriculture (Macnaghten et al. 2015; Jasanoff and Hurlbut 2018; Kofler et al. 2018; Andanda 2019, Macnaghten et al. 2019, Kuzma and Grieger 2020).

STS literature also interrogates the *public* in public engagement, that is: who are publics, how are they constructed, defined, by whom, and for what purpose? Conventional social science research and public participation processes often engage publics as individual citizens, or as stakeholders who represent a group with particular interests, such as NGOs, and consider the public as static and stable participants in engagement processes. This "residual realist" approach sees publics as defined *a priori*, as an aggregation of individuals or as representatives of particular groups, and participatory practices as composed of specific prescribed formats, tools, and techniques that are usually pre-defined (Chilvers and Kearnes 2020). In contrast, STS scholars take a constructivist and relational approach in arguing that 'publics' are constructed or co-created in the process of engagement, rather than being a pre-defined group who has particular 'stake' in an issue. STS scholarship has also highlighted the important role played by *imaginaries,* or assumptions about publics and futures, in constructing public engagement, in shaping and sometimes constraining the way in which opportunities for public engagement are framed.

How can we design more authentic public engagement in controversial science and technology issues, such as gene editing in agriculture and food? While an idealized option for remaking participation might include explicitly creating new experimental forms of participation, a more feasible option proposed is to revise existing participatory formats in order to infuse them with more reflexive intent (Wynne 2016). Chilvers and Kearnes (2020) offer a framework for remaking participatory practices in science and technology. They suggest the need for a commitment to *reflexive participatory practices and experiments*, which attends to the framing effects, as well as openings provided by participatory practices, including who are the objects and subjects of participatory practices, and what models or types of practices are being employed. This "reflexive participatory practice" approach acknowledges how publics and imaginaries are framed and performed in participatory practices, which may range from formal public hearings to public engagement processes such as deliberative workshops (Macnagthen et al. 2019; Chilvers and Kearnes 2020). This approach foregrounds questions such as who is included and excluded in these public engagement venues; how are issues being framed within the engagement practice; what issues are being discussed or avoided; what are the end goals of participation; and how does the structure of the participatory exercise or public engagement processes affect the discussion?

Relational and constructivist approaches to publics and engagement practices clearly pose methodological, empirical and practical challenges, both in terms of the structuring of public engagement, as well as in analyzing the structure and content of the engagement. However, as scholars have noted, situated empirical studies of public engagement practices related to emerging technologies are needed to unpack how publics are constructed and co-produced, how public engagement is framed, and with what impacts (Macnagthen et al. 2019).

Narrative approaches to analyzing texts and democratic engagement practices have been advanced in STS studies (Macnaghten et al. 2019; Middleveld et al. 2023; Macnaghten 2021; Moezzi et al. 2017, Raven 2017). Narrative approaches "explore the interactive qualities of public talk and modes of collective sense making" that can emerge when publics engage around issues such as emerging technologies (Macnaghten et al. 2019: 505). Narratives are described as efforts toward forming a shared vocabulary or story within which to attribute meaning and common understanding to topics that may be scientifically complex, not well understood, and/or contentious. Narratives often underpin both the development of scientific and technological products and the cultural practices that can make them culturally meaningful. Narratives operate as stories with distinct storylines and characters, and can play a performative role in engagement processes.

Analyzing narratives requires attention to the *forms of talk* that are generated in particular discussion formats, and how choices, such as the design of the public engagement process, and the position and role of moderators, facilitate particular kinds of discussion. Narrative analysis of the deliberative workshop not only allows us to focus in on how participants co-construct the meaning and purpose of public engagement around biotechnologies but also contributes to reflexivity about how the structure, format, role of moderators and participants in the workshop all shaped the narrative. Drawing on Macnaghten et al. (2019) in my analysis of the deliberative workshop text below, I broadly ask: what are participants substantively concerned about when they are discussing gene editing in food and agriculture; how are these concerns produced in interactive discussion; and what narratives (or stories) do they draw on in their response to the questions guiding the deliberative workshop?

In the first section, I attend to how the social and physical context shape the discussion at the deliberative workshop, and how the moderators frame and shape the discussion. Then I move on to analyze what is said (content or story) as well as how it is said (talk), including whether and how participants engage in consent/dissent. The verbatim transcripts of the discussion were analyzed to identify the key narratives, discursive frames and recurrent themes, that different actors employ to conceptualize and communicate about the role of publics and public engagement in the development and use of gene editing.

7.3 Case Study: Deliberative Workshop on Public Engagement and Governance of Gene Edited Agriculture and Food

7.3.1 Background and Context

The deliberative workshop took place in person in Washington DC, in February 2022 in the post-COVID context and notably was the first in-person workshop for most of the participants. In terms of who was invited and participated in the workshop, it is relevant to reflect on how we, as researchers, defined 'publics' and how they were recruited. The research team made the decision to recruit representatives of key organizations in the public debate around gene editing in agriculture and food. The representatives of organizations who did participate represented the biotech industry, NGOs (environmental, food and consumer), agriculture/biotech industry organizations, food/retail sectors, and commodity trader/handlers. We attempted to recruit a diverse group of stakeholders, in terms of gender, race, type of organization, and orientation/position toward gene editing in agriculture and food (GEAF). However, we decided not to invite federal agency employees because we assumed they would not likely stray from the official government line to engage in and deliberate broader issues of governance and engagement. In the end, we had nine participants (3 women and 6 men). No representatives from organic and/or sustainable agriculture organizations or representatives from Native organizations opted to come, although several were invited. None of the participants was BIPOC. Because we were required to disclose that the workshop was part of a project funded by USDA, this likely also affected who chose to attend, and influenced some people not to attend. While we did want to include critical voices, we also did not want to create a situation that ended in deadlocked debates, in which people just reiterated their positions and would not engage. However, the representatives of more critical organizations whom we invited were, in fact, not very critical voices.

It became immediately apparent in the beginning of the workshop that many of the participants had prior relationships, and clearly had interacted on these issues before. However, it is also important to remember that these individuals *chose* to attend—to be able to articulate their positions in a public forum, for a project funded by the USDA.

The participants were:

P1. Representative from environmental research organization.
P2. Director at a nonprofit food and nutrition consumer organization.
P3. Head of government regulatory affairs for biotech start-up company.
P4. Director of Food Policy at non-profit organization.
P5. Policy director at non-profit organization focused on food safety.
P6. Executive director of a food industry association.
P7. Senior scientist at an environmental NGO.
P8. Member of regulatory affairs team for a global commodity trader/processor.
P9. Representative from a biotech members organization.

The facilitators at the workshop were academics on the research team from the disciplines of Sociology, Environmental Science, Agronomy, Bioethics, and Science Communication. Many had previous experience facilitating focus groups, workshops, but not in running a deliberative workshop per se.

7.3.2 Workshop

7.3.2.1 First Session: Introduction and Overview to the Workshop

The goal of deliberative workshop was described by a research team member to the participants as:

> One of the big questions that motivated our team is, the question of… will the history of gene edited foods replicate the history of GMOs? Or can it look different? …So our goal for this deliberative workshop was to bring together a key, core set of stakeholders representing divergent perspectives on gene edited foods, where we could present some of our key research findings, and have you engage with those findings, as well as with some key guiding questions that we have. And for you to deliberate these questions.

Upon reflection, the introduction and overview clearly set the stage for asking the participants to think about how public engagement around GEAF could be *less* *contentious* and less intractable than past experiences with GMOs, and by implication, be more "successful" in gaining public acceptance of gene-edited food. Participant roles were identified by the research team as being representatives with divergent viewpoints on this issue, and the participants' task was to engage with our research findings and our questions about public engagement and governance.

In the first session, the Research Team gave an overview presentation about the research findings to date, including results from a public opinion survey on gene editing, and an analysis of media coverage of gene editing in the US and EU. Workshop participants immediately responded, even interrupted, to ask several questions and voice critiques about the survey design and findings, question wording related to gene editing in our survey, and the validity of the mass media content analysis—the intent of their narratives seemed to be to question the validity of what the research team presented. An example quote from a participant illustrates this:

> My question is that if the results [of the survey] would really be materially different if instead of saying gene edited you said mutagenesis. So in other words, are the results really driven by gene editing specifically? Or are they driven by an unfamiliar biological term that may cause some concern? …Well, I think we know that they [the public] don't really understand [the technologies], and that's okay. I'm saying they don't distinguish. I don't think those responses are necessarily, I don't think you establish causation between gene editing and those responses directly.

In this quote, the participant not only highlighted the public's lack of ability to understand scientifically complex technologies like gene editing, but also undermined the research findings and the research team's ability to accurately measure public perceptions of the biotechnology. Many of the participants seemed eager to demonstrate their expertise on the subject and to aggressively assert their dominant knowledge.

7.3.2.2 Second Session: The Deliberation on Public Engagement

We transitioned into the second session focused on "Public Engagement in Gene Editing in Agriculture and Food" which consisted of two breakout groups which then reconvened as a larger group. Moderators asked the participants in both groups to engage in deliberation around three questions. The moderators were fairly hands-off in their facilitation, but would intervene if the discussion strayed too far away from the questions posed. When presenting the questions for discussion, the research team reiterated to participants that "we view you as experts in this arena."

- What role does public engagement play in gene edited food development and oversight?
- What are the most important priorities that *should* be addressed regarding public engagement of gene edited foods?
- What are your recommendations for the USDA regarding the future of public engagement concerning gene edited foods?

7.4 Narrative Findings from the Deliberation on Public Engagement

The narratives that emerged the two each break-out groups were quite distinctive. In broad terms, one group focused on the individual level, on the importance of transparency for consumer choice, trust, and the importance of shared values when discussing the role of public engagement. The other group was more contentious, and disagreed on broader issues related to the role of publics, government and industry in pubic engagement and in governing GEAF. The moderators from the research team were fairly quiet and passive, intervening mostly as time-keepers and to get the group back on to the topic if they had strayed. In the discussion below, I describe the main themes that emerged from each group's dialogue.

Break Out Group 1 This group was very conversational and consensual, and no one really disagreed with what others had said. Their narrative about the role of public engagement tended to be focused on individuals, consumer choice and trust, and personal decision making, rather than organizational or structural level issues. The main themes surfaced by this group were the following: the need for consumers to feel there is transparency, that consumers can trust what is in their food, and that the best way to accomplish these goals is to create "shared values." The importance of having shared values, rather than providing consumers or publics with detailed scientific information, was stressed several times, with references to the mistakes made with the introduction of GMOs. The word transparency was used 21 times in this group. This group also addressed the question of who are 'publics' and articulated that different publics have different needs.

Themes

It's Totally about Transparency: people need to know what they're eating, what they're feeding their children transparency is in the Eye of the Beholder

The importance of transparency for consumers about what is in their food was reiterated multiple times by different participants in this group. In order to gain consumer trust, they suggested that both industry and government need to provide transparency by sharing information about food products, including gene-edited products, and importantly for some, on a product-by-product basis.

There was recognition that federal agencies are not providing appropriate oversight or transparency by informing consumers. The fact that gene-edited foods are in the market, without any labelling or way to identify them, was concerning for members of the group, including both NGO leaders and food industry representatives, and pointed to the lack of transparency

> … the only solution here is serious transparency in the products. You know, and what we don't have right now, … is serious transparency in the product. …And so, but we don't have any sort of, we don't have any way to identify right now, the [gene edited] products on the market. I should say that differently, I should say that [?], a number of products on the market are in no way identified as gene edited behind the current regulations, right, and the SECURE act. I found that remarkable that the industry, the food industry went along with

> that, because it meant that our products are non-transparent for export to countries that won't accept our products and I thought economically that would not fly and the act will go nowhere. But I was wrong, which I often am on politics. And so what I think is, it's fundamental for public engagement, at any level, to have greater transparency.

Providing transparency was important for gaining consumer acceptance and buy-in for gene- edited agriculture and food. In addition, participants suggested that products with 'consumer benefits' such as health or nutritional benefits, need to be developed and released *first* in order to gain consumer demand and acceptance.

> From the retailer's standpoint, we've been trying to encourage, to …make sure that those first few [products] *really resonate with the consumer* as providing them with a health benefit, or sustainability benefit that resonates with them. And you cannot trust that they [consumers] will connect the dots, that if it's for the benefit of the farmer, they don't connect that that's for their economic benefit as well, or for the benefit of the environment. They don't connect that, so it can't be for the benefit of the farmer, it has to be for the benefit of the purchaser.

Participants stressed the need to take a different approach than had been done with GMOs which failed to gain consumer acceptance in part because the benefits were only for farmers, and because anti-GMO activists were successful at galvanizing consumers with the message of consumer's right to know and right to buy. In discussing the failure with transgenics, participants stressed that rather than telling consumers to "trust the science," they [gene editing proponents] need to understand the importance of "shared values". One participant described shared values as: "how [this] fits with other individual values, and perceptions… and the fundamental question then is, who do they trust? Where do they get their information? How do you start to work through those channels in order to help *massage* a decision?"

Another participant stressed again the importance of developing gene-edited foods that connect with consumer values, such as concerns about environmental benefits, and consumers' right to know:

> we've got to understand that from the industry standpoint, that the science may be on our side in spades, but it doesn't matter if we don't say, you know, shared values, if we don't connect with the consumer at a level that they understand and a level that they think and it may be economic and it may be about a value, it may be that this is better for the environment but *we got to find whatever it is that resonates* with them, with each of those groups and put that out there because they have *a right to know* what they're putting in their mouth, and what they're putting in their body.

We Need to Define Public Here

This group also focused in on the question of defining publics (who is the consumer, which consumer), and the need for differentiating publics and their particular interests and values relative to gene-edited foods. How to communicate and provide transparency depends on who is involved. Again, these participants stressed the importance of responding to publics' concerns and values, rather than assuming that science will convince them of the safety and efficacy of gene-edited foods. Participants also highlighted the need to ensure that public engagement included communities who have been historically marginalized.

I always get frustrated when people ask me, 'What does the consumer think about this?' Because I want to say, which consumer are you talking to? And I think we've got to understand that not one size fits all. We've got to understand not only in terms of what are the important priorities, but what's the important priority for each of our groups that we're trying to reach. If we're trying to communicate either transparency or information or whatever values, then we've got to know what are their needs, and try to address that rather than trying to say, but the science says, you know, for some, that doesn't apply.

I totally agree. I also think we need to define public here. Because there are the publics who are most commonly valued, and there are the publics who are disenfranchised, and often not valued. And we need to be able to engage with the entire set of publics, and not just a particular group. And there are some very differently held values and therefore the transparency has to be conveyed differently to some groups.... And then we're very concerned ... we're really trying to make sure that there's environmental justice.

Federal Agencies Should Be Bold and Clear

Participants in this group agreed that consumers, NGOs and other stakeholders want federal agencies to be clear in establishing rules and guidelines for the governance of gene-edited foods. They criticized federal agencies for not being transparent or clear in communicating with the public, and for relying on one-way communication *to* publics via official documents. Participants identified their own challenges in engaging the USDA, which they attributed in part to the agency being beholden to industry.

But I will say that part of it our research has said, how do you want this decision made, and they [consumers] don't want it by ballot initiative. They don't want it by legislation, they want the agency [USDA] to come out, bold and clean and clear about it. And getting the agency to be bold and clear is problematic. Because when USDA thinks that they communicated, they think it's been published in the Federal Register.

You asked, who are the people, who are the entities, the publics that we have tried to engage that haven't been engageable. I would say the agencies, at the moment, are almost the hardest to engage, because they're so concerned about their constituents, and their constituents are fairly powerful in a variety of ways. And of course, there's been a lot else going on in those poor agencies ... But at the moment, you know, it [a company] doesn't have to reveal how they made the product, just reveals that the product exists and is being marketed.

There is an industry component to it as well. I think they've got to go hand in hand [with agencies] ... I don't know if that means mandatory labeling or not. But the registry, at least whatever the consumer can, consumer needs to know that the agencies are keeping their eye on the prize, and that they're keeping them safe on this.

Break Out Group 2 This group discussed the role of public engagement using completely different narratives than the first group, and more disagreements were expressed between participants, especially about the role of publics and government in the regulatory or governance system for gene edited agriculture and food. Participants focused on regulatory and organizational concerns, rather than on consumers or issues such as trust or shared values.

For this group, public engagement meant that the public needs to play an oversight role over the government to ensure that the government is independent and transparent. There was also contention about the public having a role in oversight. Industry was also highlighted as playing an important governance role, and in engaging publics, however a need for more publicity about industry actions was noted. Government agencies were criticized, and public-private partnerships were advanced as important governance tools. Nonetheless, some industry participants admitted that if industry continues to push for *fewer* government regulations, it will lead to industry needing to take a greater role in governance. A dissenting voice stated that the public should play no role in governance. The range of narratives expressed by participants are reflected below.

Public Engagement for Government Oversight, Regulation and Company Input

> I think there's a role for public engagement, a role for the public in oversight, government oversight [or non-government oversight]. … My view would be the government has regulations, [but] there's a role for the public to oversee the government to make sure the government is independent, and things like that. So, there's always a role, no matter what regulatory system the government has, in my mind, there's a role for the public to oversee that regulation… The US public's role is to oversee the government. …I think there's a role for publics and I think there's transparency and the role of the public is to make sure things are transparent.
>
> So I kind of think about it in two ways. So I think about the role that the public plays both in the regulatory system, right, there's a role for the public in the regulatory system through comment and whatnot. And then there's a role for the public in everything that's not the regulatory system, that influence in how companies are able to and how developers are able to get stuff to the marketplace. And that could look like companies having those one-on-one conversations with stakeholders. That could look like people watching public campaigns.
>
> The question is about oversight. … whether the public plays a role in that in your [mind]. It doesn't in mine. I would not call that a priority…

The group made a distinction between the scope and focus of public engagement: the need for public engagement at the product development stages vs. broader industry wide public engagement, with the idea posited by some that more public engagement at the product development stage would lead to a 'win- win' (for industry and consumers). This discussion merged into a broader consideration of whether there is anything unique about public engagement for gene editing in agriculture and food. While the group agreed there is nothing unique about public engagement for gene editing as opposed to other biotechnologies (i.e. transgenics), they stated that engagement needs to be robust so that it "satisfies all curiosities" of publics. A dissenting voice argued that there is no need for public engagement, in relation to gene edited products, transgenics or other biotechnology use in agriculture, and that consumers should simply trust companies and the government.

> I'm generally with you, but you know, in the development process, the more public engagement one can have, the better, we can have better win-win situations for everybody. So the broader that developing, societal development or individual company development, the more that there's more engagement with a broader range of stakeholders, they can find more win-win situations so we can have products that serve multiple needs. And I don't think that's unique to gene editing. And I would say we don't need it [public engagement] much at all. So we're agreeing that they're [gene editing vs. genetic engineering] not different from each other. I'm definitely on a different side than you.

What Is the Appropriate Mix of Roles for Government and Companies in Public Engagement and Governance?
The appropriate role of government in regulating and governing gene editing was also contentious in this group: a few participants thought the USDA should NOT play a regulatory role nor be overseen by publics, and that USDA "engagement" should mainly be educational. However, many criticized what USDA was (not) doing, and that the USDA's idea of engagement is limited to formal public comments, and that they should do more. There was an admission, however, that the more that companies and industry fight for less regulation, it leaves more governance responsibilities for the private sector. One compromise suggestion was for industry and government partnerships in governance efforts. Some pointed to a product registry as a tangible and achievable action to increase consumer knowledge about gene-edited products. Additionally, there was disagreement about what companies are doing to engage the public. Some argued that companies are already actively engaging the public, but it is just not well documented; others who had worked for the biotech industry disagreed and said that companies generally have done a poor job engaging the public. These range of positions are reflected below:

> I don't think USDA would play a [regulatory] role in what you just described. And I'd be a minority dissent on it, as well…I think that if I was going to say my recommendation for USDA, regarding public engagement, it would be fundamentally educational… That's where I would probably start.
>
> If there are transparency principles that need to be executed, outside of the scope of the regulatory system, I'm taking the position that there still can be support, engagement with an agency like USDA. USDA can still do its darndest to defend its regulatory system and why it put things into place. So that in totality, it still is an industry and government partnership that's creating that kind of trust [bubble].
>
> But I also think we have to ask ourselves, as we, as a person who represents companies advocating for fewer things to be regulated, … we have wholeheartedly said, …, the primary focus of the US government agency (defined as whatever) should be to defend the safety of the food system, because they have to. But we also just have to, I think, acknowledge that the more we request or submit comments that fewer things be regulated, that piece of the, that is outside of government kind of grows. So I think that's the only caveat there, is like, it holds true if the regulatory piece of the pie is this big or this big. But the other piece of that equation is going to be a lot more onerous the more we ask for fewer [regulations], more and more things to be kicked out of the regulatory system.

7.5 Discussion

In analyzing the transcripts, the question emerges why are these particular narratives and themes central to the discussion of public engagement around gene editing in agriculture. Why these themes and not others? And, what values, and assumptions and concepts are framing and informing the discussion? One group focused on consumers and the importance of transparency and trust, while the other group was concerned with more structural issues related to relationships between publics, and the appropriate roles of government and industry in regulation, governance and oversight.

However, in broad terms, all of the participants in the deliberative workshop were in favor of using gene editing in agriculture and food, and the framing of the discussion was largely positive. The only concerns raised by a few participants were about possible environmental and human health unknowns, but there certainly were no challenges or questions about whether biotechnology should be used at all, nor discussion of the possibility of alternative agriculture methods, or considerations of values or knowledge systems that would preclude gene editing. Nowhere in the discussion was there any critique or pushback to the use of gene editing in agriculture and food, or serious consideration of alternatives. With the exception of one individual, participants in both breakout groups recognized that USDA is **not** doing enough to provide information about gene-edited food to interested publics, to regulate the technology, or to engage publics around these issues.

I identified three master narratives in these discussions.

1) The need for increasing trust, shared values, transparency, and consumer benefits so that promoters can determine which values resonate with consumers. These suggestions were all aimed toward gaining consumer acceptance of gene editing, and alternatively, at least ensuring that consumers have sufficient information (through product labels or a product registry) to make choices about whether or not to consume gene- edited foods.
2) Government agencies are not appropriately governing gene editing, and they should be clearer and bolder about establishing appropriate regulations, standards, or a product registry. It is difficult for NGOs and publics to engage with government agencies. While private industry is filling a governance gap by providing voluntary information for consumers, a shared responsibility between government and industry is proposed.
3) There is a recognized need and role for public engagement to oversee regulations and regulators, but there is nothing unique about gene editing as a biotechnology tool that requires specific types of, or more, engagement than previous forms of agricultural biotechnology.

One Outlier Narrative:

4) There is no need for government to regulate or to do public engagement, because companies are creating safe products that consumers need and are demanding. However, there is a potential role for government agencies in providing education for consumers.

Overall, in these narratives, publics are seen as having two distinct roles—as consumers of gene-edited foods, or to provide oversight over the government. There is a recognition of the need to be aware of, and responsive to, consumer values and concerns, and to respond to what consumers might consider to be benefits of gene editing. Moreover, even if industry think the science has shown that risk of gene editing is low or non-existent, gene editing promoters realize that they need to listen and respond to consumer concerns and values related to food and agriculture. A common proposal is to create 'shared values,' that is the ability to develop products that consumers want that correspond to their values and needs, and to ensure that consumers have the information they need to be able to make food choices.

In summary, there was a narrow framing of the issues involved, and an assumption among participants that the public *will* benefit from and support gene editing in agriculture and food, although consumer choice is privileged. Returning to the questions and framings at the outset, I offer some reflections here on our deliberative workshop for public engagement around emerging biotechnologies in agriculture. First, there are clear challenges with engaging broader 'publics' in complex scientific and technical issues, like new and emerging biotechnologies, that require significant knowledge to be able to engage in discourse in a workshop. To address this, we opted for participants who represented groups that were important stakeholders in the debate on gene editing in agriculture. However, in fact, participants were 'experts' with well-established positions related to gene editing, and the workshop was an opportunity to articulate these positions, revealing the performative quality of public talk in action, as noted by Macnaghten et al. (2019: 505). Moreover, as experts in this domain, most of the participants knew each other and had interacted with each other in other fora, and perhaps as a result, most of the discussions tended toward consensus instead of contestation or dissent. Although we attempted to recruit more diverse participants with contrasting perspectives and values, they chose not to attend. The one participant who voiced dissenting opinions at the workshop reflected strong pro-biotech and anti-government regulation positions. In the breakoutgroup that expressed differing views, it seemed that a tacit agreement among participants to respectfully disagree emerged, but not much actual contention around broader social issues was expressed in the dialog.

7.6 Conclusion

Reflecting back to the work of critical policy scholars, who suggest that genuine public engagement requires both participants and the deliberation design to meet participation ethics, including a mutual willingness to consider differing views, and pros and cons of the issues under discussion, clearly our deliberative workshop had limitations. These scholars stress the importance of dissent and contention, and the inclusion of social and ethical concerns, when engaging publics in discussion around issues such as biotechnology use in agriculture. In terms of who attended, as well as the design of the workshop, we did not encourage or stimulate participants to express and/or debate opposing positions, or to deeply engage in the ethical or social dimension of the issue.

Together the structure of the workshop and the composition of participants who attended did not afford a more expansive exploration of conflicting values-related concerns, differing epistemologies or perspectives related to gene editing in agriculture and food.

Although the two breakout groups diverged in the thematic emphases of their narratives, an underlying assumption in both groups was that scientific progress and public benefits would be advanced through the use of gene editing in agriculture. One group focused on how to gain consumer trust and stimulate consumer demand in gene-edited foods, and the importance of transparency to facilitate consumer choice. But the assumption was that companies can and will develop products that are more responsive to consumer demand, such as foods with enhanced nutritional benefits and/or environmental benefits. The other group emphasized that the role of consumers is to provide oversight because the regulatory agencies are not providing sufficient oversight, but that a voluntary public-private partnership might be the most effective governance model. This narrative reinforces assumptions about the utility of neoliberal voluntary forms of governance, another strong underpinning supporting the development of biotechnology industry. While the themes and emphases differed between the breakout groups, the underlying assumptions of scientific progress and public benefit through neoliberal voluntary governance of agricultural biotechnology were largely shared. Overall, the case study reveals many thorny issues related to how publics are constructed for and in engagement processes related to emerging technologies, and how to engage publics in these deliberative venues.

References

Andanda, Pamela. 2019. Public engagement as a potential responsible research and innovation tool for ensuring inclusive governance of biotechnology in low- and middle-income countries. In *International handbook on responsible innovation*, ed. R. von Schomberg and J. Hankins, 503–521. Northampton, MA: Edward Elgar Publishing, Inc.

Bellamy, R., J. Lezaun, and J. Palmer. 2017. Public perceptions of geoengineering research governance: An experimental deliberative approach. *Global Environmental Change* 45:194–202.

Chilvers, J., and M. Kearnes. 2020. Remaking participation in science and democracy. *Science, Technology, & Human Values* 45 (3): 347–380.

Jasanoff, S., and J. B. Hurlbut. 2018. A global observatory for gene editing. *Nature* 555 (7697): 435–437.

Kofler, N., J. P. Collins, J. Kuzma, E. Marris, K. Esvelt, M. P. Nelson, A. Newhouse, L. J. Rothschild, V. S. Vigliotti, M. Semenov, and R. Jacobsen. 2018. Editing nature: Local roots of global governance. *Science* 362 (6414): 527–529.

Kuzma, J. 2021. Deficits of public deliberation in US oversight for gene edited organisms. *Hastings Center Report* 51:S25–S33.

Kuzma, J., and K. Grieger. 2020. Community-led governance for gene-edited crops. *Science* 370 (6519): 916–918.

Macnaghten, P. 2016. Responsible innovation and the reshaping of existing technological trajectories: The hard case of genetically modified crops. *Journal of Responsible Innovation* 3 (3): 282–289.

Macnaghten, P. 2021. Towards an anticipatory public engagement methodology: Deliberative experiments in the assembly of possible worlds using focus groups. *Qualitative Research* 21 (1): 3–19.

Macnaghten, P., and J. Chilvers. 2014. The future of science governance: Publics, policies, practices. *Environment and Planning C: Government and Policy* 32 (3): 530–548.

Macnaghten, P., and M. G. Habets. 2020. Breaking the impasse: Towards a forward-looking governance framework for gene editing with plants. *Plants, People, Planet* 2 (4): 353–365.

Macnaghten, P., M. B. Kearnes, and B. Wynne. 2005. Nanotechnology, governance, and public deliberation: What role for the social sciences? *Science Communication* 27 (2): 268–291.

Macnaghten, P., et al. 2015. A responsible innovation governance framework for GM crops: global lessons for agricultural sustainability. In *Governing Agricultural Sustainability*, 225–239. Routledge.

Macnaghten, P., S. R. Davies, and M. Kearnes. 2019. Understanding public responses to emerging technologies: A narrative approach. *Journal of Environmental Policy & Planning* 21 (5): 504–518.

Mampuys, R. 2023. The deadlock in European decision-making on GMOs as a wicked problem by design: A need for repoliticization. *Science, Technology, & Human Values* 48 (6): 1329–1359.

Middelveld, S., P. Macnaghten, and F. Meijboom. 2023. Imagined futures for livestock gene editing: Public engagement in The Netherlands. *Public Understanding of Science* 32 (2): 143–158.

Moezzi, M., K. B. Janda, and S. Rotmann. 2017. Using stories, narratives, and storytelling in energy and climate change research. *Energy Research & Social Science* 31:1–10.

NAS (National Academies of Science, Engineering, and Medicine). 2017. *Human genome editing: Science, ethics, and governance*. Washington, DC: The National Academies Press.

Partridge, T., M. Thomas, B. H. Harthorn, N. Pidgeon, A. Hasell, L. Stevenson, and C. Enders. 2017. Seeing futures now: Emergent US and UK views on shale development, climate change and energy systems. *Global Environmental Change* 42:1–12.

Pidgeon, Nick, Barbara Herr Harthorn, Terre Satterfield, and Christina Demski. 2017. Cross-national comparative communication and deliberation about the risks of nanotechnologies. In *The Oxford handbook of the science of science communication*, ed. K. Hall Jamieson, D. M. Kahan, and D. A. Scheufele, 141–155. Oxford: Oxford University Press.

Poort, L. M., J. A. Swart, R. Mampuys, A. J. Waarlo, P. C. Struik, and L. Hanssen. 2022. Restore politics in societal debates on new genomic techniques. *Agriculture and Human Values* 39 (4): 1207–1216.

Raven, P. G. 2017. Telling tomorrows: Science fiction as an energy futures research tool. *Energy Research & Social Science* 31:164–169.

Rittel, H. W., and M. M. Webber. 1973. Dilemmas in a general theory of planning. *Policy Sciences* 4 (2): 155–169.

Stilgoe, J., M. Watson, and K. Kuo. 2013. Public engagement with biotechnologies offers lessons for the governance of geoengineering research and beyond. *PLoS Biology* 11 (11): e1001707.

Von Schomberg, R. 2019. Why responsible innovation. In *International handbook on responsible innovation: A global resource*, 12–32. Edward Elgar Publishing.

Wynne, B. 2016. Misunderstood misunderstanding: Social identities and public uptake of science. *Public Understanding of Science 1* (3): 281.

Chapter 8
A Risk-Based Agricultural Biotechnology Ethics in the Era of Gene Editing: What Is New and What Is Not?

Paul B. Thompson

Abstract Gene editing enables insertion of DNA sequences (e.g. coding and regulatory genetic constructs) at precise locations in the genome of modified organisms. In the case of livestock species, especially, the additional precision may or may not provide a basis for reevaluating the ethical significance of specific genetic modifications. This paper applies a risk-based ethics to determine when gene editing has ethical significance beyond that of modification using earlier methods utilizing recombinant DNA (e.g. GMOs). Ethical concerns about *any* form of genetic modification, from conventional breeding to gene editing, can be classified into the categories of environmental hazards, socio-economic consequences, food safety and animal welfare. The chapter describes risk-based ethics and discusses the significance of gene editing for each of these categories. Gene editing of agricultural species is ethically significant to the extent that greater precision reduces the probability for realization of specific hazards in one or more of these categories is either increased or lessened. This effect is primarily meaningful in the context of food safety and animal welfare because the potential for unintended and unnoticed disruptions of genetic functionality has bearing on these hazards, and the precision afforded by gene editing is expected to have meaningful impact on the opportunity for such disruption. Gene editing may also have social consequences for the traceability of certain types of genetic modification. In other areas where the ethics of genetically engineered livestock has been debated, gene editing has little material effect when compared to earlier applications of gene technology in agriculture.

Keywords Risk analysis · Agricultural biotechnology · Precision genetic engineering · Animal welfare · Food safety · Environmental impact · Social impact

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8.1 Introduction

This chapter develops an application of risk-based categories to the question, "How do recent methods for gene editing figure in the ethical evaluation of agricultural biotechnology?" As I have argued elsewhere, the risk-based approach is especially well suited to comparing alternative techniques for plant and animal breeding (Thompson 2003). This makes a risk-based approach relevant to a claim at the center of debates over gene editing: that new techniques for controlling the point of insertion or deletion of nucleotide sequences should exempt the next generation of products from some of the regulatory oversight applied to earlier examples of genetically engineered agricultural species. The argument for lowering regulatory burdens presumes that these techniques—collectively referred to as gene editing—pose lower intrinsic risks or uncertainties (Hartung and Schiemann 2014; Van Eenennaam 2018). On the contrary, this paper argues that when it comes to ethics, the difference between gene editing and earlier recombinant techniques for modifying animal genomes is at best a matter of degree, rather than kind. A risk-based ethic clarifies when gene editing of crops and livestock species makes a difference, and when it does not.

Although other approaches to assessment and evaluation of agricultural biotechnology prevail among philosophers and social scientists, the framework of risk assessment has been especially influential in the biophysical branches of agricultural science. The emergence and growing influence of this framework has largely been an implicit process. The risk-based approach was self-consciously developed in toxicology and epidemiology. Actuarial and economic theories for conceptualizing the chance of monetary loss have a longer history, but concepts derived from these methods were only formalized for application to physical and biological hazards in the 1960s and 1970s. Soil scientist Martin Alexander (1930–2017) offered one of the earliest adaptations of this framework to plant biotechnology (Alexander 1985). Robert Wachbroit gave a more general and philosophically reflective discussion of the framework in 1991 (Wachbroit 1991). Later sections of the paper flesh out four categories for conceptualizing the hazards of genetically engineered agricultural species: food safety; environmental impact; animal welfare (broadly construed) and social consequences.

I argue that food safety and animal welfare are the only categories in this set where gene editing makes a material difference to the risk assessment that would have been done for a livestock species modified using recombinant tools available in the 1990s. Although I would not defend risk assessment as an ethically exhaustive approach to the evaluation of any agricultural technology, I do believe many commentators underestimate its potential. For example, Christopher Preston and Trina Antonsen reject the adequacy of a risk-based approach in categorical fashion, stressing the importance of integrity and agency, (Preston and Antonsen 2021). Yet it is not clear why challenges relating to integrity and agency could not be included among environmental and social hazards. If so, the risk-based approach can be adapted to consider the ethical considerations Preston and Antonsen note. As such, it is not clear why they think the ethical considerations they stress cannot be accommodated by a sufficiently nuanced risk-based approach.

As discussed by Kendig and Thompson (this volume), the analysis builds on a distinction between first generation products of agricultural biotechnology (e.g. GMOs) and those that are produced through tools for locating the insertion of a desired genetic construct at a precise location on the target organism's genome. Although many of the points covered could be applied to gene editing in the context of plant breeding, the analysis here centers on genetic alteration of livestock species. This provides a useful simplification because much of what would be said with respect to food safety, environmental and social impacts applies equally to plants and animals, while a discussion of plant biotechnology would omit important considerations of animal welfare. Influential debates over gene flow in plants are given scant attention as a result, though given more space I would argue against the thesis that the contrast between GMOs and gene edited crops makes little ethical difference, even here.

Two scope-limiting disclaimers are prerequisite to the substantive issues of transforming agricultural genomes. First, the chapter does not discuss ethical issues associated with wildlife conservation or animals bred for biomedical research. Second, consistent with a long trend in the ethical debate over genetically engineered animals, the focus is implicitly limited to vertebrate livestock species. This chapter does not attempt to include or summarize issues associated with transgenic insects. Mosquitoes and other insects or arachnids are currently being transformed with recombinant DNA techniques, including gene editing. Some genetic transformations of insect species are made with agriculture in mind (Smanski 2021). Rightly or wrongly, impact on welfare has not been prominent in ethical analyses of genetically modified insects. Categories of ethical significance such as environmental impact could be extended to include non-chordate animals, including agricultural pests such as the spotted wing drosophila. I do not review this category of potential hazards.

8.2 The Risk Based Framework

Risk assessment is a systematic approach to including scientific information in decision-making and planning activities. The schematic diagram in Fig. 8.1 summaries the risk assessment framework. Four domains have distinct cognitive functions. *Hazard identification* is the process of identifying what bad outcomes can occur as a result of adopting one option rather than another. Hazard identification is a largely inductive process of ascertaining the possibility of an adverse outcome based on the current state of the relevant science, and estimating its severity. Simply knowing what *can* go wrong does not provide an estimate of risk, however. *Exposure quantification* utilizes a variety of modeling, statistical and experimental techniques to estimate the probability that a hazard will materialize, given adoption of the technology or course of action under consideration. In the parlance of risk assessment,

Fig. 8.1 Domains of risk assessment

one has not described a risk until some probability of occurrence is associated with the mere possibility of an adverse outcome (e.g. the hazard). Together, hazard identification and exposure quantification make up the scientific elements in risk analysis.

Risk management is the activity of deciding what to do about risk. Options include simply accepting or rejecting the risk, as well as using a risk-benefit tool to decide when expected benefits offset the cost of running a risk. Additionally, one may use insurance or subsidy to compensate losers, or deploy labeling or informed consent mechanisms to distribute the power of decision-making to affected parties. Although some have seen hazard identification and exposure quantification as "purely objective" domains, risk management has always been understood to be a normative domain where values and goals are ineluctably interwoven into the cognitive tasks of decision making. The key point to notice is the distinction between determining what the risk is, and deciding what to do about it.

Risk communication was added to the other three domains as it became clear that public policy decisions require steps such as consulting affected parties, gaining trust, assuring consent, increasing transparency of governance, democratic engagement and seeking information from participants, stakeholders and others having knowledge pertinent to hazard identification and exposure quantification. In response, risk communication was added to the model following an influential U.S. National Research Council study of the 1990s colloquially referred to as "the orange book" (NRC 1996). The schema distorts the function of sharing information on risk in planning, decision-making and communication (Thompson and Dean 1996; Thompson 1999). I have also stressed the role of value judgment *within* the activities of hazard identification and exposure quantification (Thompson 2003). Nevertheless, the framework has advantages neither appreciated nor fully exploited by scholars working in bioethics and environmental philosophy. Disclosing those advantages motivates the treatment given here.

A series of anti-biotechnology critics have attacked the use of risk assessment as if it, rather than biotechnology itself, were the chief culprit, or at least the primary tool of biotechnology advocates (Levidow and Carr 1997; Preston and Wickson 2016; Canfield 2022, pp. 136–147). From the perspective that I will develop in this chapter, these critiques conflate the risk analysis framework with particular configurations of that framework. The specific approaches to hazard identification and exposure quantification deployed in support of certain (primarily U.S.) regulatory decision-making do not exhaust the potential for biotechnology risk assessment *tout court.* In regulatory settings, the basic logical structure of risk assessment is specified in detail. While it may be appropriate to criticize the parameterization used in regulation, in general, regulators have limited authority to modify these parameters. Rather than simply rejecting a risk-based approach entirely, critique of any given regulatory framework is more effective when contrasted with alternative interpretations of hazard identification, exposure quantification or risk management. In venting their ire against risk assessment as an analytic method, critics overlook how other criteria for analyzing risk would lead to a different result.

Governmental regulators operate under authorizing legislation that constrains their authority to consider the full range of hazards that could be covered in risk assessment. United States agencies operate under a suite of laws designed to prevent regulators from managing risks in the socioeconomic sphere. In effect, Congress has reserved authority to decide how socioeconomic risks will be managed to itself, while directing agencies to apply narrowly specified risk management principles to hazards in the domains of environmental impact and human health. This approach can certainly be contested (and I have done so—see Thompson 2020), but these problems have to do with the specific value judgments made in the course of operationalizing a risk assessment framework, rather than conceptual weaknesses in risk assessment as such. Before considering gene editing, it will prove useful to highlight several strengths of the risk framework.

First, the framework is not restricted to utilitarian or consequentialist approaches in ethics. Rights theorists view threats to autonomy, integrity and agency as overriding welfare maximization, but there is no reason why such threats cannot be included among the hazards analyzed. In any case, exposure quantification would assess the conditional probability that the hazard would materialize. The commitment to a consequentialist or deontological decision rule occurs at the stage of risk management. Non-consequentialist risk management criteria might stress coercion (either coercing someone to bear risk, or coercively preventing them from doing so). Similarly, informed consent criteria are often thought to rest primarily on rights-based considerations. The risk-based framework remains open to a wider range of normative interpretation than classic benefit-cost analysis, while sharing its ability to organize deliberative evaluation.

Second, the risk based approach invites collaboration between scientists and ethicists in specifying both the nature of hazards in each category, as well as the likelihood that a given hazard will materialize. In general, regulators have limited authority to modify these parameters. This invitation has ethical implications. The risk-oriented framework anticipates Ben Mepham's ethical matrix, which adapts Beauchamp and Childress's principlist approach to deliberation in medical ethics to situations where environmental and animal interests are at stake (Mepham 2000). In this respect, the risk-based approach articulates a procedural ethic for the development and implementation of gene technologies in the context of food and agriculture. Failure to consider ethical issues any one of these categories constitutes a violation of the procedure. Failing to faithfully execute the procedure is itself ethically wrong. Elsewhere, I argue that biotechnology developers have often (if not always) failed to give adequate attention to animal welfare and to social issues, concluding that this procedural failure is one of the chief moral failings in the development of agricultural and food gene technologies (Thompson 2020).

Next, attention to the ubiquity of two-way arrows in the diagram highlights the interpenetration of otherwise discrete cognitive tasks. In a classic decision theoretic model, hazard identification and exposure quantification precede actual decision making (or risk management). One needs to know what the risks are before one undertakes the ethical task of deciding what to do about them. However, the divisions are never so sharp in practice. In regulatory contexts, authorizing legislation has limited the scope of hazards that can be considered before assessments even begin. In most industrial democracies, regulatory agencies are authorized to restrict use of a product based on risks to human health as well as some defined aspects of animal health and environmental impact. They are precluded from considering politically contentious impacts such as unemployment, bankruptcies or shifts in market power. If you already know that you will not be taking a particular kind of hazard into consideration, there is little reason to include it in your scientific risk assessment. Note, however, that this is the result of prior restriction on an agency's scope of action in risk management, rather than a defect in the risk-based approach. Some critics appear to have presumed that neglect of social consequences is somehow "baked in" to risk assessment, arguing against the use of risk-based thinking (see Devos et al. 2008; Brower 2016). On the contrary, recognizing the four domains in a risk-based approach makes for a more pointed analysis of where the deficiencies in regulatory decision making actually lie.

Finally, the risk-based approach makes ethical critique more legible to scientists and to many policy makers. To the extent that possible outcomes or events can be described as hazards whose likelihood can be assessed, it becomes much easier to demonstrate how regulatory decisions have limited the scope of considerations taken into account in evaluating agricultural technology. Furthermore, it becomes easier to show that even if health and environmental regulatory agencies have been instructed to ignore social consequences, it is not the case that governments do not intervene in the management of socioeconomic risks. In the domain of agriculture, publicly administered policies for crop insurance, loan guarantees and subsidies all function to manage the risks of farm decision making. Food assistance programs raise the food purchasing power of low-income persons. If these social risks are centrally managed, why not others? Thus even if biologically trained scientists who participate in food safety and environmental impact assessments are unaware of governmental intervention in socioeconomic risk management, it is disingenuous to presume that the distribution of these risks is left entirely to market forces. Ethical arguments are as relevant in the socioeconomic domain as in any other.

8.3 Parameters for Evaluating the Risks of Agricultural Biotechnology

As noted already, U.S. regulatory risk assessments for GMOs recognized hazards to health in the form of food safety, as well as environmental hazards in the form of unintended disruption of ecological functions. The agencies assigned to review GMOs under the Coordinated Framework did not consider socio-economic hazards such as impact on farmer's ability to save seeds, practice organic farming methods or prevent their non-GMO harvests from being contaminated by GMOs grown in their neighbors' fields. Nevertheless the U. S. government is deeply implicated in the management of agriculture's socioeconomic risks in the form of subsidy payments, crop insurance and other measures (Peterson 2009). Yet the Coordinated Framework developed in the George H. W. Bush administration did not include agencies charged with managing socio-economic risks to farmers or consumers (OSTP 1986).

The decision to exclude socio-economic impact from the policy evaluation of agricultural gene technology precipitated an extensive critique in the years preceding the first appearance of GMOs in farmers' fields (Hansen et al. 1986; Lacy et al. 1988). In their study of international opposition to GMOs, Rachel Schurman and William Munro identified activists primarily motivated by the exclusion of socio-economic hazards as an important element in a coalition that also included environmentalists, animal advocates and people who feared a slippery slope leading to eugenic modification of human beings (Schurman and Munro 2010). A more detailed discussion of this history is beyond the scope of the chapter. The point is simply that socioeconomic hazards might easily have been incorporated into the risk assessments for agricultural biotechnology. Even if their exclusion might have been rationalized from a policy perspective, a risk-based ethical analysis will be seriously incomplete if an important category of hazards is omitted.

From the standpoint of ethics, the hazard identification for agricultural biotechnology can be organized in terms of values that underlie different types of ethical consideration. Human health and socio-economic outcomes draw upon the entire history of anthropocentric (e.g. human focused) ethics and political thought. Environmental hazards may include more recently articulated concerns about the value of habitat or ecological integrity, while impacts on animals include veterinary health and the sensory experience of sentient beings. Concern that gene technologies limit the autonomy or agency of farmers can be classified as social hazards, while arguments that stress the relational significance of non-human actors can be located in either the environmental or the social category (or both). Indeed, *any* identification of hazards presumes that the outcomes or eventualities to be assessed are in some sense bad, adverse or unwanted. In this respect, hazard identification is so far from a "purely" scientific activity as to require input from ethics to effect this normative element. It is only because hazards in the domain of human health are so non-controversial that risk analysts have been tempted to maintain the fiction of pure scientific objectivity unaffected by values.

The balance of this chapter discusses whether and how gene editing would either introduce new ethical issues or how it provides a basis for moderating the ethical concerns that are associated with GMOs. As already noted, the framework is developed for analysis of gene technologies as applied to livestock species. I do not view the risk-based approach as well suited to every type of moral concern raised against biotechnology. For example, it is arguably less appropriate for addressing the claim that all forms of genetic engineering are morally objectionable (Comstock 2000). However, it is not clear that these so-called "intrinsic" arguments against gene technology introduce something new in the area of gene editing, at least in so far as our subject is confined to the agricultural arena. As discussed briefly below, gene editing *has* revived discussions of human gene therapy, and perhaps here the old "intrinsically wrong" arguments have new salience. As applied to agricultural crops and livestock species, I take it as obvious that if one is persuaded by these arguments, one will not find reasons why a more targeted approach to genetic engineering of animals should be acceptable.

8.4 Environmental Hazards

Environmental risk assessments for GMOs identify two general types of hazard. First, introduction of a genetically modified crop or animal can have unwanted effects on so-called non-target species. The two most common plant GMOs, herbicide resistant crops and Bt crops were both intended to reduce competition for biotic resources from non-agricultural organisms in farmers' fields. Herbicide tolerant crops were intended to allow farmers to expand their use of chemical herbicides to eliminate other plants that could rob the crop of nutrients and water, or that could shade crops, limiting their ability to convert solar energy into growth. As noted already, Bt crops are pesticide delivery systems intended to control larvae that feed on the crop. Thus, weeds and certain specific insects are the target organisms. However, other non-pest organisms can also be affected. This is a major problem for chemical pesticides, which can damage beneficial insects and birds. The possibility that Bt crops could harm monarch butterfly was an early point of dispute over the potential for impact on a non-target species (see Henke this volume).[1]

[1] It is important to note that non-target impacts are not the same thing as off-target effects. The former is a function of the specific form that a genetic modification takes in the phenotype, while the latter indicates random changes in an engineered organism's genome.

The second type of environmental hazard is disruption of ecological function. The most widely discussed hazards of this type involve gene flow and invasiveness. If introduced genes become established in wild relatives, they could affect the species composition of an unmanaged ecosystem by conferring advantages or disadvantages that disrupt existing predator/prey relationships. Similarly, a GMO would become invasive if the genetic modification gave it the ability to become established and thrive in an uncultivated or human-managed ecosystem. Invasiveness was debated primarily with respect to Bt maize, when Bt genes were alleged to have migrated into landraces grown in Mexico (Gewin 2003). The discovery that transgenic Glofish™ are thriving in Brazilian streams has revitalized concerns that they may be invasive (Moutinho 2022). In addition, two Purdue University geneticists developed "the Trojan gene hypothesis": a model that showed how genetic change in animal species could contribute to the extinction of a population under very specific genotype-environment interactions (Muir and Howard 1999). Their model was widely debated in connection with fast-growing Atlantic salmon produced through genetic engineering (Upton and Cowan 2015). Extinction, rather than invasiveness, is the root issue in the case of the Trojan gene hypothesis.

In sum, environmental risks of genetically engineered crops and animals focus on harm to non-target species, and on ecosystem disruption, especially through invasiveness or extinction of organisms. The ethical significance of both hazards could be based on anthropocentric or ecocentric values. A more thorough review or evaluation of the environmental ethics of genetically engineering food animals lies beyond the scope of this chapter (but see Preston, this volume). The point here is to query whether or in what respect the targeted approaches of gene editing introduce new concerns, or significantly modify these concerns. Both risks turn upon phenotypic features of the modified organism. As such, there are no obvious reasons why changes in the method for introducing a genetic change into the organism would have any material impact on the ethics of posing an environmental hazard.

Some precautionary arguments might appear to pose an exception to this judgment. The Precautionary Principle states that full certainty should not be required before actions to mitigate health or environmental risks are taken. (Again, even a summary of the ways that this principle was cited in ethical debates over GMOs exceeds the remit of the current study.) The reason that gene editing might be thought significant to precautionary arguments derives from the greater precision in targeting specific loci on the genome. Considering gene editing for germline modifications of human beings, Julien Koplin, Christopher Gyngell and Julian Savulescu write that the precautionary principle "perfectly describes the controversy surrounding germline gene editing." They go on to discuss philosophically variant versions of the precautionary principle, concluding that their preferred version actually provides moral support for some carefully administered applications of human germline modification. Oddly, their article does not discuss why gene editing, as distinct from other forms of germline genetic engineering, makes a difference to the analysis. Although their application of the precautionary principle stresses gene editing of human beings, Koplin, Gyngell and Savulescu summarize three hazards of germline gene editing (GGE) that would be relevant to environmental risks from agriculture. First are off-target effects (discussed in some detail later in this paper). Second, uncertainties in human genetics mean that it is difficult to anticipate hazards that might occur in a person's later life. Third, benefits of GGE may be offset by an increased risk to other diseases (Koplin et al. 2020).

In a separate article Gyngell and Savulescu (writing with Thomas Douglas) review arguments for and against human germline modification, but their analysis in this 2017 paper begins with the qualification "If proven acceptably safe…" (Gyngell et al. 2017). This qualification begs the main question that critics of the technology have made (see Lanphier et al. 2015; Baltimore et al. 2015). As a general observation, the precautionary approach arose in the context of environmental risks from GMOs as a risk management strategy. It was thought superior to risk/benefit optimization because of uncertainties in the hazard identification and exposure quantification of environmental risks from GMOs. Gene editing arguably introduces greater precision into gene transfer, and Koplin, Gyngell and Savulescu see the reduction of uncertainty about health consequences as a counter to precautionary arguments in the context of human gene therapy. However, defenders of agricultural biotechnology who might trade upon this discussion to suggest that gene editing constitutes a rebuttal to advocates of the precautionary principle would misrepresent the way that the probability for realization of an environmental hazard from GMOs has actually been assessed. It is the phenotype of both the GMO and the gene edited plant or animal that is the source of an environmental hazard. The uncertainty arises from limited understanding of interaction between the modified phenotype and other organisms or abiotic elements in the environment. As such, the utilization of gene editing to introduce the trait responsible for phenotypic effects will not be ethically significant.

8.5 Socio-Economic Benefits and Risks

Gene editing is projected to substantially reduce the cost of developing and commercializing genetically engineered livestock. As such, the primary benefit of the technology sits in this category. In contrast, socio-economic hazards are often the poor relation in ethical evaluations of agricultural technology. Early studies on the ethics of animal biotechnology either gave attenuated attention to the social costs of a technical change in the animal production sector, or ignored these impacts altogether (see NRC 2002; CAST 2010). However, my own work devotes substantial attention to the farm-size distribution risks and to technology as an element of international agricultural development, as well as to problems of public acceptance and social trust (Thompson 2020).

Two socioeconomic problems are associated with technological innovations in agricultural production. The farm-size distribution problem concerns ways in which technological innovations can be disproportionately adopted and mobilized by larger, better capitalized producers. The development problem concerns ways in which an innovation figures in a host of power inequalities that lead to the exploitation of farm producers in less industrialized countries. In both cases, the socioeconomic mechanisms are complex. Some innovations function more effectively when utilized over larger acreages. Some displace forms of employment or deskill aspects of farming or husbandry. Even in the absence of these, innovations that increase the productivity of agriculture induce a "technology treadmill" that fuels a cycle of bankruptcy and absorption of land ownership into larger and larger units. These features can be especially significant in less economically developed areas, where agriculturalists may constitute 40 to 80 per cent of the population, and where impacts on the rural workforce have large impacts on overall social welfare (Thompson 2020).

Some procedural questions can be added. They include philosophical problems in weighing benefits and costs: Can we treat the efficiencies from gene editing on a par with farm bankruptcies or the disproportionality with which the burdens of technical change fall on people who already suffer oppression and systemic victimization? In other words, are all of these impacts measurable in some common ethical coinage, amenable to the summing implied by the utilitarian injunction to seek "the greatest good for the greatest number"? Alternatively, should we think of them simply as reasons that must be included and acknowledged, but not necessarily reconciled, in an act of judgement? It is important that these questions of *how* we should go about conducting an ethical assessment be reflected in the process of evaluating any particular application gene editing for crops or livestock species.

As for environmental impacts, my purpose here is simply to catalog the types of ethical concern that have been associated with animal biotechnology, rather than to weigh in on whether they are, in the final analysis, ethically justified. These are quite general questions that arise in evaluating almost any agricultural technology. They can be and have been raised in connection with mechanization and chemical technology, as well as biotechnology (see Zimdahl 2012; Thompson 2017). In the case of genetic tools and techniques (including classical breeding), the socioeconomic impact will be determined by the way in which the animal phenotype confers social or economic advantages to producers of a given type, or to other actors (such as input firms) in the livestock economy. For example, a new sheep breed made pastoralism economically attractive in the Scottish highlands after 1750. This, in turn, led property owners to enclose the open field agriculture and evict their tenants (Richards 2000). Whether the highland clearances were ethically justifiable or not, genetic changes brought about through gene editing will have comparable effects when changes in the phenotype interact with environmental conditions and the market context. The fact that the change occurs through targeted genetic engineering, rather than breeding, does not make a material difference in the ethical evaluation of the socioeconomic outcome.

8.6 Food Safety and Human Health

Summarizing the argument so far, gene editing of livestock species does not create new types of environmental or socioeconomic risk, and ethical evaluation in these domains depends primarily on the phenotype produced, rather than the process of modification. Although one cannot exclude the potential for other types of human health impact, this section will emphasize food safety. The possibility that genetic engineering of organisms used for food might have health risks has been one of the most contentious areas of debate. Animal food products such as meat, milk and eggs are included. In this category, there is no disagreement about nature of the hazard. Everyone recognizes that food consumption can be a cause of injury, disease and even death, and everyone agrees that these are bad things. However, as universal elements of the human condition, ethics requires some standard of tolerance for these outcomes. In industrialized countries, that standard is *de minimus*: acute risks from food consumption should be as low as is practicably possible. Furthermore, even chronic disease risks (e.g. heart disease; diabetes) should not be elevated by some technological modification of the foodstuff, (see Thompson 2020).

If *de minimus* risk is the ethical norm for food safety, the food safety risks posed by genetic engineering were nonetheless hotly debated when GMOs were introduced in the food chain. Focusing narrowly on the ethical component of the debate, at least two substantive claims were made. Some critics made precautionary arguments about the transfer of genes from one organism to another (Macer 1994). Others saw the uncertainty or ignorance about the possible human health impacts as the most significant factor (Millstone et al. 1999; Hoffmann-Riem and Wynne 2002). The literature is too complex to permit a concise summary. Some arguments against crossing species boundaries advert back to the intrinsic objections. Rather than identifying a specific health hazard, they impute danger as inherent within the very act of genetic modification. It is as if tampering with genes invites cosmic or divine retribution (see Decker 2016). A more specific argument stresses food safety. Here, the nature of the hazard is clearly indicated, but to the extent that stress is laid upon uncertainty, food safety concerns can generate very broad arguments against genetic modification.

A reasonable reconstruction of this argument goes as follows: Since (a) there are alternatives to GMOs, since (b) the food safety risks of GMOs cannot be assessed with reasonable certainty, and since (c) the standard for food safety is *de minimus,* then (d) a precautionary ethic militates against allowing GMOs into the food system (see Sandin 2006). The key philosophical claim is that the food safety risks of GMOs cannot be assessed with reasonable certainty. Evidence for this claim could be derived from the observing the distribution of impacts among individual organisms produced using first generation transformation techniques (VIB 2001, 8–12). Against this claim, GMOs are not, in fact, organisms subject to the almost random distribution of alterations in genome structure occurring immediately after attempts at gene modification. GMOs result from careful selection of promising specimens *among* that population, followed by several generations of backcrossing. Agricultural scientists believe that this provides enough inductive evidence to provide reasonable certainty, (Thompson 2003).

Further clarity on the thrust of these arguments can be obtained from examining the debate over cisgenic modification. As distinct from *trans*genics, which use recombinant tools to move genes from one species to another, *cis*genic or intragenic transformations use the same tools to accomplish genetic modifications within a species. For example, a particular strain or breed of animal (say a Jersey cow) might have a quality such as milkfat content that breeders want to transfer to another breed. If an isolatable genetic construct can be associated with this trait, then recombinant DNA might be used in place of the laborious and time consuming process of animal breeding. This would not be a transgenic modification because genes are simply being transferred within *bos taurus.* The relevant question is: does cisgenic gene transfer reduce the role of uncertainty in exposure quantification for food safety hazards?

In 2006, Bjørn Myskja argued the case for a positive answer to this question, at least as it would be posed with respect to plants. Intragenic modification reduces the uncertainty of genetic modification of food plants. This, in turn, addresses many of the ethical concerns (Myskja 2006). Wendy Russell and Rob Sparrow responded to Myskja's paper with a clarification of the food safety risks from recombinant DNA mediated genetic change, irrespective of the original source of the transferred genetic material. Their analysis is relevant to the discussion of gene editing. Russell and Sparrow argue that the most important source of food safety hazards resides not in the gene transferred through the tools of modern biotechnology, but in the potential for disruption of other genes, including regulatory sequences, that control critical functions in the organism. They point out that intragenic modifications are as likely to do this as transgenic modifications; hence, attending to the *source* of the transgene does not fully mitigate food safety risks (Russell and Sparrow 2008).

Russell and Sparrow's arguments are relevant because the targeting that gene editing tools makes possible *does* substantially reduce the probability that a genetic modification will occur at some locus on the genome critical to organism function. Thus unlike environmental and social hazards reviewed earlier, gene editing does make an ethically significant difference with respect to food safety hazards. However unlikely it might be that a hazardous modification survives the process of breeding and backcrossing that occurs after the initial event of rDNA modification, it is even less likely when scientists are able to control the point on the genome were the genetic modification occurs. It is thus plausible to argue that even if GMOs meet the *de minimus* standard for food safety, gene edited organisms pose even lower food safety risks. A possible counterargument arose with the recognition that although the intended modification takes place at a known locus, there remains the possibility for "off-target effects" or random changes occurring at other points on the genome. However, other non-recombinant tools, such as cell culture, also cause minor, but randomly distributed changes in the genome. This suggests that the work that plant and animal breeders do *after* these techniques are deployed plays an ineliminable role in providing assurance of food safety. Nonetheless, the targeting made possible by gene editing does provide ethically significant grounds for estimating the food safety risks of genetically engineered animals, (Thompson 2020, pp. 346–351).

8.7 Animal Welfare

How does gene editing affect ethical considerations deriving from our responsibilities to animals, themselves? Before addressing this question, it is worth repeating that much of what has been said with respect to environmental, social and food safety hazards applies equally to plant transformation as to genetically engineered livestock. Animal welfare is thus the category that is unique to gene edited livestock. Nevertheless, the preceding discussion sets up a set of considerations that facilitates the answer to this final question. In short, there are aspects of animal welfare that depend entirely on the specific genetic construct being introduced or altered. We would not expect ethical questions about such alterations to be affected by whether the change was accomplished through targeted gene edits or not. In addition, as in the case of food safety, classical techniques for introducing genes lacked any ability to target a specific locus on the animal genome. The potential for damage to animal health and welfare through disrupting gene function is, in fact, one of the primary arguments against germline genetic engineering of human beings. To the extent that gene editing yields greater confidence that gene function is not disrupted by the act of genetic modification, these risks are lower for gene edited livestock than for animals produced using classical forms of recombinant DNA modification. Here, the argument parallels the case of food safety.

Bernard Rollin's *The Frankenstein Syndrome* articulated a basic ethic for evaluating genetically engineered animals. Rollin stipulated his *Principle of Welfare Conservation:* Other things equal, genetic modification should not result in a line, type or breed of animals that have worse welfare or greater pain, disease and suffering, than comparable individuals from the same species. Rollin drew particular attention to pigs that experienced painful deformities after being genetically modified with the addition of a human growth hormone gene, (Rollin 1995). Although he discussed intrinsic or 'playing God' arguments against genetic engineering of animals, Rollin was clear in stating that ethical evaluation must remained focus on an animals' welfare. He understood welfare in each species relative to a *telos,* which he defined as the configuration of genetically based phenotypic traits that create biological drives and physiological needs characteristic of the species. It is, however, important to stress elements of Rollin's approach that have received relatively little comment.

Rollin views all animals, including human beings, as capable of suffering. Some of their specific capabilities are grounded in their genetics, while others may derive from their life experience. An animal may learn to fear certain stimuli as the result of early life exposures, for example. In animal husbandry, ethical responsibility toward an individual animal needs to respect these nurture-based capacities, as well as *telos,* though there may be moments in the process of food production (such as slaughter) when an animal's needs are sacrificed to achieve human ends. In the context of research, responsibilities to individual animals derive from the guidelines imposed by animal ethics committees, or, in the United States, Institutional Animal Care and Use Committees (IACUCs). Here, suffering is limited by minimizing the number of animals used, mitigating their pain, and replacing animal research models entirely, whenever possible. Once these guidelines have been satisfied, the IACUC must make a judgment as to whether animal suffering is offset by the gain in knowledge achieved through conducting an experiment, (Rollin 1995).

In the research context, the difference between the ethics of animal biotechnology and the ethics of human genetic engineering becomes evident in comparing the standards applied by IACUCs and those applied by institutional review boards overseeing the use of human subjects. In the latter case, the key norm is informed consent. Review boards for research on human subjects do not examine protocols based on the trade-off between harm to the research subject and benefits from knowledge leading to improved welfare for others. Instead, the protocol must include procedures for both informing research subjects of risks, and securing their unforced consent to bear those risks. Ironically, one can do some things to humans that one cannot do to non-humans, simply because humans might be willing to give consent as an act of personal sacrifice. Houman subjects research becomes especially problematic when the human beings who bear risk are unable to give consent, such as children. The risks of germline genetic engineering, whether human or not, redound to the individual who will be come into life after the alteration is made. In the case of animals, IACUCs would demand that animals suffering as a result of genetic dysfunction be euthanized—an application of the requirement to mitigate unnecessary suffering. In the case of humans, such a procedure would be ethically unacceptable.

In summary, this distinction allows Rollin to treat the ethics of research animals—even those used in agricultural research—quite differently from the case of an animal intended for use in food production. In the case of research, individual animals are the focus, but the standards deployed by IACUCs both constrain animal suffering while permitting some amount of suffering as the price of scientific advance. In the latter case, it is the resulting breed, characterized by its *telos* that provides the test case for ethical justifiability. It is only when a modification becomes typical for a given subpopulation (e.g. a breed) within the species classification that questions about ethical acceptability arise. Ethical husbandry must accommodate an animal's *telos,* it must not, in short, cause suffering in individuals of the subpopulation by frustrating an instinctual behavior or genetic drive. The idea of *telos* was intended to illustrate how drives might be unique to species or possibly even breeds, entailing specialized husbandry: chickens will be frustrated if they are denied the opportunity to perch, but cows and pigs do not have this genetically based drive. However, Rollin did not have ethically based objections to changing an animals' *telos* through classical breeding or biotechnology (Rollin 1998).

A significant literature arose challenging Rollin's willingness to countenance alterations in *telos* (see, for example, Bovenkirk et al. 2002). This literature emphasized the wrongness of *any* change that alters an animal's "genetic integrity", sparking further philosophical debates over whether the idea of genetic integrity is meaningful (see Thompson 2020, pp. 112–132). Critics of Rollin did not mention the means for genetic transformation, nor did they lay stress on unintended harms caused by disruption of an animal's genome. Rather, the emphasis was on what might be called “animal natures”, or the behavioral traits that are thought to be most typical or essential for animals of a given species. As such, it is difficult to see why the introduction of gene editing has any bearing on this debate. Anyone who offered arguments based on animal integrity (whatever it is) through random gene insertion following microinjection will be opposed to changes in an animal’s integrity brought about by gene editing.

However, the precision of gene editing does provide a reason to think that individuals modified through gene editing will be less likely to experience welfare deficits resulting from unintended changes in their genome. The most immediate implications apply not to animal breeds, but to individual animals used in research—a result that has gone virtually unnoticed in the literature on ethical implications of gene editing. With respect to the genetic constitution or *telos* of a breed or strain of food animal created through gene editing, there is also reason to think that the hazards accruing from vulnerability to disease or cognitive distress are less likely to materialize. However, this would not exempt genetic engineers from the moral obligation to follow Rollin’s *Principle of Welfare Conservation.* They should not be producing animals that are worse off in terms of general health or propensity to fear, pain and other forms of anguish than other individuals of the species, irrespective of whether gene editing is used. Rollin’s approach would require them to relieve the suffering of any individuals produced in the research process, and to insure that genetic constructs associated with such suffering are not incorporated into the *telos* of the new population developed using gene technology. This principle may not have been routinely observed in classical animal breeding, but that only goes to show that classical animal breeding can be unethical, at least as much as animal biotechnology, (see Sandøe et al. 1999).

8.8 Conclusions

What difference does gene editing make to the ethical evaluation of genetically engineered of food animals? The answer is: not much. The hotly debated environmental impacts from genetically engineered animals all derive from the interaction of the phenotype with other organisms in its environment. These interactions, and indeed the very environments in which genetically engineered animals interact, are subject to forces that remain beyond human control. Nevertheless, it is not the *manner* in which a gene construct is introduced, but the way in which that construct affects the organism’s interaction with both biotic and abiotic elements in the environment that matters for environmental hazards. Similarly, the socio-economic implications of an altered food animal hang on its phenotypic characteristics, rather than whether the change was precisely targeted. In both cases, the claim that phenotypes, rather than method of transfer, matter for ethics is consistent with the long-argued claim that the specific product, rather than the process of transformation, is what matters for risk assessment, (Tagliabue 2017). One exception to this generalization applies in the case of ethical evaluation of socioeconomic risks: cost savings from gene editing as compared with earlier methods of genetic engineering might increase benefit and reduce prices for farmers or other end-users of agricultural animals.

Gene editing derives such ethical significance as it does from the way that the ability to target a specific location on the genome reduces the chance that unintended genetic changes will materialize. In the area of food safety, these would include changes that affect an animal's production of toxins within its tissues, either in degree or in the specific tissues affected. One would expect such changes to affect the animal's health and welfare, so the precision achieved by TALENS, zinc fingers and CRISPR/Cas9 also provides the basis for thinking that gene edited livestock have less chance of suffering deficits in animal welfare. In both cases, however, the difference occurs at a fairly early stage in the process of developing a new breed, strain or variety of food animal. Gene editing may help breeders move more quickly to a sub-population exhibiting the genetic stability that is associated with marketable breeds or strains. It has been and will remain observations made in the final stages of developing and certifying genetic stability that the inductive evidence for food safety and acceptable animal welfare becomes available. If a breeder used gene editing to skip these steps, gene editing could even introduce greater risk in the food system, but the institutional structure of animal production militates heavily against the possibility of doing that.

In the case of food safety, the economic interests of biotechnologists coincide significantly with ethical responsibilities because both product safety law and liability law make them vulnerable to negative judgments. There are, of course, critics who question whether technology developers are adequately constrained by these incentives (Meghani 2017), but the contrast to animal welfare is stark, nonetheless. Industrial animal production is rife with situations in which the drive to remain competitive requires producers to select breeds and adopt husbandry practices that are at odds with Rollin's *Principle of Welfare Conservation.* While segments of the animal agriculture industry have taken steps to address some of the most egregious problems, there is nonetheless a very weak alignment between animal welfare and the economic interests of producers or technology developers. As a result, there are persistent calls for tightening regulatory processes to improve animal welfare (Croney and Millman 2007; Bonnet et al. 2020). Much of the debate over gene editing of animals has revolved around the question of whether these standards should be lowered when gene editing, rather than random insertion of transgenes, is the method of transformation, (Van Eenennaam et al. 2019). The question of what burdens of proof regulators should apply in reviewing gene edited animals lies beyond the scope of this paper. From the standpoint of ethics, it is clear that gene editing does not relieve innovators of their responsibility to assure a reasonable standard of animal welfare, altogether.

References

Alexander, M. 1985. Ecological consequences: Reducing the uncertainties. *Issues in Science and Technology* 13:57–68.

Baltimore, D., B. Berg, M. Botchan, D. Carroll, R. A. Charo, G. Church, J. E. Corn, G. Q. Daley, J. A. Doudna, M. Fenner, H. T. Greely, M. Jinek, G. S. Martin, E. Penhoet, J. Puck, S. H. Sternberg, J. S. Weissman, and K. R. Yamamoto. 2015. A prudent path forward for genomic engineering and germline gene modification. *Science* 348:36–38.

Bonnet, C., Z. Bouamra-Mechemache, V. Réquillart, and N. Treich. 2020. Regulating meat consumption to improve health, the environment and animal welfare. *Food Policy* 97:101847.

Bovenkerk, B., F. W. Brom, and B. J. Van Den Bergh. 2002. Brave new birds: the use of 'animal integrity'in animal ethics. *Hastings Center Report* 32 (1):16–22.

Brower, A. 2016. Hawai 'i:"GMO ground zero". *Capitalism Nature Socialism* 27:68–86.

Canfield, M. C. 2022. *Translating food sovereignty: Cultivating justice in an age of transnational governance*. Stanford, CA: Stanford University Press.

CAST (Council on Agricultural Science and Technology). 2010. *Ethical implications of animal biotechnology: Considerations for animal welfare decision making*. Issue Paper No. 46. CAST, Ames, Iowa.

Comstock, G. L. 2000. Against transgenic animals (1992). In *Vexing nature?* Boston, MA: Springer. https://doi.org/10.1007/978-1-4615-1397-1_4.

Croney, C. C., and S. T. Millman. 2007. Board-invited review: The ethical and behavioral bases for farm animal welfare legislation. *Journal of Animal Science* 85:556–565.

Decker, J. E. 2016. Hail Hera, mother of monsters! Monstrosity as emblem of sexual sovereignty. *Women's Studies* 45:743–757.

Devos, Y., P. Maeseele, D. Reheul, L. Van Speybroeck, and D. De Waele. 2008. Ethics in the societal debate on genetically modified organisms: A (re) quest for sense and sensibility. *Journal of Agricultural and Environmental Ethics* 21:29–61.

Gewin, V. 2003. Genetically modified corn—Environmental benefits and risks. *PLoS Biology.* 1 (1): e8. https://doi.org/10.1371/journal.pbio.0000008.

Gyngell, C., T. Douglas, and J. Savulescu. 2017. The ethics of germline gene editing. *Journal of Applied Philosophy* 34:498–513.

Hansen, M., L. Busch, J. Burkhardt, W. B. Lacy, and L. R. Lacy. 1986. Plant breeding and biotechnology. *Bioscience* 36 (1): 29–39.

Hartung, F., and J. Schiemann. 2014. Precise plant breeding using new genome editing techniques: Opportunities, safety and regulation in the EU. *The Plant Journal* 78:742–752.

Hoffmann-Riem, H., and B. Wynne. 2002. In risk assessment, one has to admit ignorance. *Nature* 416:123–123.

Koplin, J., C. Gyngell, and J. Savulescu. 2020. Germline gene editing and the precautionary principle. *Bioethics* 34:49–59.

Lacy, W. B., L. R. Lacy, and L. Busch. 1988. Agricultural biotechnology research: Practices, consequences, and policy recommendations. *Agriculture and Human Values* 5:3–14.

Lanphier, E., F. Urnov, S. E. Haecker, M. Werner, and J. Smolensk. 2015. Don't edit the human germ line. *Nature News* 519:410.

Levidow, L., and S. Carr. 1997. How biotechnology regulation sets a risk/ethics boundary. *Agriculture and Human Values* 14:29–43.

Macer, D. R. J. 1994. *Bioethics for the people by the people*. Christchurch: Eubios Ethics Institute. Online. http://www.biol.tsukuba.ac.jp/~macer/BFP.html.

Meghani, Z. 2017. Genetically engineered animals, drugs, and neoliberalism: The need for a new biotechnology regulatory policy framework. *Journal of Agricultural and Environmental Ethics* 30:715–743.

Mepham, B. 2000. A framework for the ethical analysis of novel foods: The ethical matrix. *Journal of Agricultural and Environmental Ethics* 12 (2):165–176.

Millstone, E., E. Brunner, and S. Mayer. 1999. Beyond 'substantial equivalence'. *Nature* 401:525–526.

Moutinho, S. 2022. Transgenic glowing fish invades Brazilian streams. *Science* 375:704–705.

Muir, W. M., and R. D. Howard. 1999. Possible ecological risks of transgenic organism release when transgenes affect mating success: Sexual selection and the Trojan gene hypothesis. *PNAS* 96:13853–13856.

Myskja, B. 2006. The moral difference between intragenic and transgenic plants. *Journal of Agricultural and Environmental Ethics* 19:225–238.

NRC (National Research Council). 1996. *Understanding risk: Informing decisions in a democratic society*. Washington, DC: National Academy Press.

NRC (National Research Council). 2002. *Animal biotechnology—Science based concerns*. Washington, DC: National Academies Press.

OSTP (U.S. Office of Science and Technology Policy). 1986. Coordinated framework for regulation of biotechnology. *Federal Register* 51 (123): 23302–23350.

Peterson, E. W. F. 2009. *A billion dollars a day: The economics and politics of agricultural subsidies*. Malden, MA: John Wiley & Sons.

Preston, C. J., and T. Antonsen. 2021. Integrity and agency: Negotiating new forms of human-nature relations in biotechnology. *Environmental Ethics.* 43:21–41.

Preston, C. J., and F. Wickson. 2016. Broadening the lens for the governance of emerging technologies: Care ethics and agricultural biotechnology. *Technology in Society* 45:48–57.

Richards, E. 2000. *The Highland clearances: People, landlords and rural turmoil*. Edinburgh: Birlinn Limited.

Rollin, B. E. 1995. *The Frankenstein syndrome: Ethical and social issues in the genetic engineering of animals*. New York: Cambridge University Press.

Rollin, B. E. 1998. On *telos* and genetic engineering. In *Animal biotechnology and ethics*, ed. A. Holland and A. Johnson, 156–187. London: Chapman and Hall.

Russell, A. W., and R. Sparrow. 2008. The case for regulating intragenic GMOs. *Journal of Agricultural and Environmental Ethics* 21:153–181.

Sandin, P. 2006. The precautionary principle and food safety. *Journal für Verbraucherschutz und Lebensmittelsicherheit* 1:2–4.

Sandøe, P., B. Lindstrøm Nielsen, L. G. Christensen, and P. Sørensen. 1999. Staying good while playing God–the ethics of breeding farm animals. *Animal Welfare* 8:313–328.

Schurman, R., and W. A. Munro. 2010. *Fighting for the future of food: Activists versus agribusiness in the struggle over biotechnology*. Minneapolis: University of Minnesota Press.

Smanski, M. 2021. Spotlight on genetic design in a spotted wing crop killer. *The CRISPR Journal* 4:628–630.

Tagliabue, G. 2017. Product, not process! Explaining a basic concept in agricultural biotechnologies and food safety. *Life Sciences, Society and Policy* 13:1–9.

Thompson, P. B. 1999. The ethics of truth-telling and the problem of risk. *Science and Engineering Ethics* 5:489–511.

Thompson, P. B. 2003. Value judgments and risk comparisons: The case of genetically engineered crops. *Plant Pathology* 132:10–16.

Thompson, P. B. 2017. *The Spirit of the soil: Agriculture and environmental ethics*. 2nd ed. New York: Routledge.

Thompson, P. B. 2020. *Food and agricultural biotechnology in ethical perspective*. 3rd ed. New York: Springer.

Thompson, P. B., and W. E. Dean. 1996. Competing conceptions of risk. *Risk: Health, Safety and Environment* 7:361–384.

Upton, H. F., and T Cowan (2015) *Genetically Engineered Salmon.* Washington, DC: Congressional Research Service Report R43518. https://sgp.fas.org/crs/misc/R43518.pdf. Accessed 16 Apr 2022

Van Eenennaam, A. L. 2018. The importance of a novel product risk-based trigger for gene-editing regulation in food animal species. *The CRISPR Journal* 1:101–106.

Van Eenennaam, A. L., K. D. Wells, and J. D. Murray. 2019. Proposed U.S. regulation of gene-edited food animals is not fit for purpose. *npj Science of Food* 3:3. https://doi.org/10.1038/s41538-019-0035-y.

VIB (Flanders Institute for Biotechnology). 2001. *Safety of genetically engineered crops*. Zwinjaarde, BE: VIB.

Wachbroit, R. 1991. Describing risk. In *Risk assessment in genetic engineering*, ed. M. A. Levin and H. S. Strauss, 368–377. New York: McGraw-Hill.

Zimdahl, R. 2012. *Agriculture's ethical horizon*. 2nd ed. Amsterdam: Elsevier.

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