

THE REQUIREMENT OF UNCERTAINTY:  
A MANDATE FOR JUSTIFIED ENVIRONMENTAL HEALTH RESEARCH

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By

Emily Lorraine Evans, M.P.H.

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PREVIEW

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Emily Lorraine Evans, M.P.H.

Thesis Advisor: Tom L. Beauchamp, Ph.D.

ABSTRACT

The central problem animating my dissertation is how to justify environmental health research. The demand for the justification of environmental health research arises from three main conditions: scarce resources, the need to safeguard the integrity of the scientific enterprise, and the imposition of risk [on participants]. To meet this demand, environmental health research must satisfy a set of normative epistemic and ethical requirements. Most efforts to explicate the requirements of justified research have focused on the ethical requirements, resulting in the comparative neglect of the epistemic requirements.

The central objective of my dissertation is the articulation and defense of the epistemic requirement of uncertainty for justified environmental health research. Broadly understood, the requirement of uncertainty holds that, to be justified, research must be designed and conducted to reduce or resolve uncertainty by generating evidence that makes a contribution to the body of scientific knowledge. Research that does not address uncertainty, whether because the uncertainty does not exist or because the study lacks the capacity to generate the evidence needed to reduce or resolve the uncertainty, does not satisfy the requirement and is therefore unjustified.

First, I argue that neither the research ethics nor environmental health risk assessment literature has much to contribute to the development, explication, and operationalization of this

requirement. I then explicate and operationalize the requirement of uncertainty, arguing that environmental health research is justified only if it is designed to reduce or resolve [scientific] uncertainty about pathways and endpoints with respect to an environmental health question of interest. Finally, I use two case studies, one involving research investigating the effectiveness of a biosolids compost amendment in reducing the risks of lead-contaminated soil and the other the question of whether to continue research on the relationship between mobile phones and brain cancer, to demonstrate how my account of the requirement of uncertainty can be used to ensure that environmental health research meets the demand for justification.

PREVIEW

*For Preston – Things be ok.*

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PREVIEW



## Chapter 1: Uncertainty and the Justification of Environmental Health Research

### I. Introduction

Environmental hazards represent a significant threat to the health of populations. The World Health Organization (WHO) estimates that nearly a quarter of the global burden of disease can be attributed to physical, chemical, and biological factors in the natural and built environments (Prüss-Üstün and Corvalán 2006).<sup>1</sup> Many of the risks from environmental hazards are inequitably distributed, with a disproportionate share of the burden borne by children, minorities, and the poor (Shrader-Frechette 2007; WHO 2010). However, insufficient evidence about exposure patterns, toxicological properties, and adverse health effects may limit our ability to effectively address the risks associated with known or suspected environmental hazards.

Environmental health research, which draws on a number of disciplines, including epidemiology, toxicology, biochemistry, physics, and engineering, as well as an array of methods, including computer modeling, laboratory testing, animal studies, and observational or experimental studies involving humans, has the potential to generate evidence needed to reduce environmental risks. The objective of environmental health research is to identify and improve our understanding of the nature and scope of the threats posed by environmental hazards and assist in the development of effective methods for reducing exposures or ameliorating adverse health outcomes.

As critical as environmental health research is to protecting and improving the health of populations, it should not (and cannot) be undertaken in response to every known or suspected

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<sup>1</sup> The WHO definition of environmental health excludes “behaviour not related to the environment, as well as behaviour related to the social and cultural environment, and genetics” (WHO 2012). The built environment refers to developments and infrastructure constructed by humans (e.g., roads) as opposed to naturally occurring features of the environment (e.g., climate).

environmental hazard. Societies face competing priorities for scarce resources, not only in efforts to protect and promote population health, but also to safeguard and advance other interests and goods. The capacity for environmental health research to meet its objectives and generate the evidence needed to reduce environmental risks is also constrained by ethical, methodological, technical, and logistical considerations. Before environmental health research is pursued in response to known or suspected environmental hazards, we need to know whether the research is justified.

The central problem animating my dissertation is how to justify environmental health research. As a resource-intensive enterprise with the potential to significantly impact the health of populations, including the evidence on which policies are based, environmental health research must be justified. The demand for the justification of environmental health research arises from three main conditions: scarce resources, the need to safeguard the integrity of the scientific enterprise, and the imposition of risk [on participants].

To meet the demand for justification, environmental health research must satisfy a set of normative epistemic and ethical requirements. These requirements shape the production of knowledge, prescribing (or prohibiting) the types of research questions, methods, and protocols that should (or should not) be employed. Normative epistemic requirements are those that are fundamental to ensuring that the design and conduct of research is consistent with the principles of scientific reasoning and the objectives of scientific practice. Normative ethical requirements are designed to protect the interests and well-being of human subjects, ensure the humane treatment of animals used in research, and guard against distributive and/or social injustices that may arise from the research enterprise.

The epistemic and ethical requirements of justified research are not strictly distinct; the epistemic requirements have ethical dimensions and vice versa. The evidence generated by research is used to inform policies and decisions that affect the distribution of resources and the interests and well-being of individuals. The process of generating evidence requires social support, including at times, the participation of individuals as [research] subjects. Consequently, epistemic requirements that govern the generation, interpretation, and application of evidence, and endorse particular principles, methods, and ways of reasoning over others, have ethical import (Douglas 2009; Kitcher 2001, 2011; Longino 2008).<sup>2</sup> For example, research that is inappropriately designed or conducted, such that it is likely to generate biased evidence, not only violates basic epistemic requirements (e.g., empirical adequacy [Douglas 2009, Longino 2008]), but is also widely condemned as unethical, particularly if it involves human subjects.

Similarly, the ethical requirements have epistemic dimensions. The development and application of ethical requirements should be informed by the relevant empirical evidence, and determinations as to whether research satisfies them inescapably involves epistemic judgments. For example, determining whether research satisfies the ethical requirement of an acceptable risk-benefit ratio entails assessing the available evidence regarding the nature, magnitude, and likelihood of the harms and benefits. Inadequate epistemic practices, such as relying on an evidence base that is “flawed and inappropriately narrow,” weakens support for claims that research has satisfied this requirement (Kimmelman and London 2011, 1).

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<sup>2</sup> The content of epistemic requirements depends in part on the purposes for which they are employed. For example, they may be understood as representing a minimal set of criteria for acceptable science (Douglas 2009, 94), or they may encompass a richer set of commitments to values or heuristics that guide the selection of research questions, rules of data collection, interpretation of evidence, and evaluation of theories (Longino 2008, 81).

The explication of these epistemic and ethical requirements is needed so that we can determine whether research has satisfied them and met the demand for justification. However, most efforts to articulate and defend the requirements of justified research have focused on the ethical requirements, resulting in the emphasis in modern research ethics on the traditional “participant protection” requirements: informed consent, acceptable risk-benefit ratios, and fair subject selection. Although the emphasis on participant protection requirements stands in contrast to earlier debates over the justification of research,<sup>3</sup> it is not surprising given that canonical codes of research ethics, such as the Nuremberg Code, the Belmont Report, and the Declaration of Helsinki, were developed in response to and designed to prevent research abuses involving failures to demonstrate respect for persons, maximize benefits and minimize harms, and ensure a just distribution of the benefits and burdens of research (Levine 1988).<sup>4</sup>

The normative epistemic requirements of justified research have been comparatively neglected. Only when analyzed *qua* ethical requirements do epistemic requirements receive more than perfunctory treatment, such as with the requirement of equipoise (to be discussed in Chapter 2). Yet the fact that there may be ethical dimensions to these requirements does not “detract from their epistemic character” (Biddle 2007, 30). An adequate understanding of the epistemic requirements of justified research is not a byproduct of explicating the ethical requirements.

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<sup>3</sup> Prior to the 1970s, discussions of medical knowledge and research were “highly ethically charged,” contrary to the claims of historians who cite a “relative absence of ethical discussions...in the first twenty years after World War II” (Marks 1997, 155; Marks 2000). During this period, methodological (epistemic) criteria were often used to demarcate ethical from unethical research (Marks 2000). The centrality of participant protection requirements to contemporary research ethics resulted in part from regulatory developments in the 1960s and the public exposure of a number of egregious research abuses in the 1970s (e.g., the Tuskegee syphilis study).

<sup>4</sup> An accounting of the shift in focus from the epistemic to ethical aspects of justified research is beyond the scope of this dissertation.

What I call the General Epistemic Requirement of Evidence Generation or *GER(EG)* is one such epistemic requirement. *GER(EG)* holds that research must be designed and conducted to generate evidence that contributes to scientific knowledge. Satisfaction of this requirement is critical to ensuring that research meets the demand for justification; the limited resources of a society should not be used to support research that violates *GER(EG)* because it lacks the capacity to improve scientific understanding (and may corrupt the evidence base) and imposes unjustified risks on any participants.

The formulation of *GER(EG)*, while capturing important concerns, provides few specifics regarding its interpretation and application. What counts as a contribution to scientific knowledge? Amid ubiquitous and vague claims that “more research is needed,” does any potential advance, no matter how small, satisfy the requirement? And if the resources of a particular scientific domain are used to support the research, does the expected contribution have to be to that specific body of scientific knowledge? Accordingly, *GER(EG)* stands in need of development and specification.

I argue that we should specify *GER(EG)* in terms of the requirement of uncertainty. Broadly understood, the requirement of uncertainty holds that, to be justified, research must be designed and conducted to reduce or resolve uncertainty by generating evidence that makes a contribution to the body of scientific knowledge. Research that does not address uncertainty, whether because the uncertainty does not exist or because the study lacks the capacity to generate the evidence needed to reduce or resolve the uncertainty, does not satisfy the requirement and is therefore unjustified. Still, if the requirement of uncertainty is to function as a screening test in determining whether environmental health research is justified, further explication and operationalization are needed.

The central objective of my dissertation is the articulation and defense of the epistemic requirement of uncertainty for justified environmental health research. Although environmental health research must satisfy additional normative ethical and epistemic requirements to be justified,<sup>5</sup> my objective is *not* to delineate a set of sufficient requirements. My overall thesis, defended throughout the dissertation, is that justified environmental health research must be designed and conducted to generate the evidence needed to reduce or resolve uncertainty about an environmental health question of interest.

## **II. The Demand for Justification**

The normative epistemic and ethical requirements of justified environmental health research should be formulated to ensure that research satisfying them meets the demand for justification, preventing the waste of limited resources, threats to the integrity of the scientific enterprise, and the unjustified imposition of risk on participants. A more thorough examination of these three conditions is needed to better elucidate the concerns to which the requirement of uncertainty, as a specification of *GER(EG)*, should be responsive.

First, decisions to pursue (or not pursue) research in response to concerns about known or suspected environmental hazards must be justified in part based on whether they represent a responsible allocation of scarce resources. Research is a resource-intensive undertaking, not just from a monetary perspective, but also in terms of the intellectual, social, and institutional investment needed to generate valid and reliable evidence while protecting the interests and well-being of any participants (London, Kimmelman, and Emborg 2010). Other socially valuable

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<sup>5</sup> Consequently, environmental health research that meets the requirement of uncertainty may still be unjustified if it fails to meet other requirements. Throughout the dissertation, when I discuss the justification of research, I am referring to whether research is justified with respect to (i.e., has satisfied) the requirement of uncertainty, unless otherwise specified.

endeavors, such as education, infrastructure development and maintenance, and healthcare and social services, also have legitimate claims to the limited resources of a society.

The claim of environmental health research to a share of these resources is based on the role of this research as part of a social and moral division of labor. The “mission” of environmental health research, both in general and in specific cases, is to generate evidence needed to improve our knowledge of and capacities to address environmental hazards that threaten the basic interests and capabilities of individuals (London 2005; London, Kimmelman, and Emborg 2010).<sup>6</sup> In cases where the basic interests and capabilities of individuals can be more effectively protected and promoted through other means – even in response to environmental hazards – environmental health research may not be justified (London 2005). For example, in the case of efforts to prevent waterborne diseases, the development of infrastructure for the sustainable delivery of potable water, when the knowledge and resources to do so exist, should be preferred to environmental health research. However, if the knowledge and/or resources needed to implement this infrastructure are lacking, environmental health research may be needed to identify new methods for ensuring access to clean water or other methods for reducing the risks of waterborne diseases.

Importantly, privately financed environmental health research does not escape the demand for justification. Privately financed research may be used to attract public funding for an intervention, and public resources may be required to mitigate the adverse consequences of a

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<sup>6</sup> Broadly, basic interests or capabilities are those that are “sufficiently...fundamental to individuals that they are common to each” regardless of differences in individual conceptions of the good (London 2003, 21). My use of these terms does not imply a commitment to a particular account of interests, capabilities, or well-being; the role of environmental health research in the social and moral division of labor is consistent with a variety of theories of social and distributive justice. For specific examples, see Powers and Faden (2006), Rawls (1971), Ruger (2010), and Sen (1992).

policy informed by such research (London, Kimmelman, and Carlisle 2012; Shaw and Elger 2013). The public repercussions of research funded and conducted by private actors also include threats to the integrity of the scientific enterprise (London, Kimmelman, and Carlisle 2012, 545), the second condition giving rise to the demand for the justification of research.

The integrity of the scientific enterprise refers to the ability of science to achieve its objectives, which requires adherence to principles, methods, and procedures designed to formulate testable hypotheses, generate valid and reliable evidence, and support transparent and independent critiques of results, methods, and theories. Insofar as science is a social institution,<sup>7</sup> its integrity is threatened when its ability to fulfill its role in the social and moral division of labor is threatened (London, Kimmelman, and Emborg 2010). Because such threats can arise from both privately and publicly funded research, the normative epistemic and ethical requirements of justified research should be applied to all environmental health research, regardless of funding source, to ensure that the demand for justification is met.

Safeguarding the integrity of environmental health research means protecting its capacity to generate the evidence needed to identify, evaluate, and respond to known or suspected environmental hazards. The responsible allocation of [limited] resources is needed to ensure adequate support for environmental health research. Decisions to pursue environmental health research convey a sense of legitimacy on the questions under investigation and on the scientific acceptability of the methods employed. Devoting financial, intellectual, and social resources to research that is not designed to address a known or reasonably hypothesized environmental risk may skew environmental health priorities. The resulting misallocation of resources compromises

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<sup>7</sup> The claim is not that that science is ineliminably a social institution but that it may operate as such in certain contexts, as in the case of environmental health research.



the ability of environmental health to achieve its objectives (Kimmelman and London 2011; London, Kimmelman, and Emborg 2010).

Practices and institutional arrangements should be structured to facilitate the generation, interpretation, and use of evidence in a manner consistent with the objectives of this research. The integrity of the scientific enterprise is also threatened by the inappropriate legitimization of evidence produced by supporting research that departs from principles of sound science in its design, conduct, and analysis.<sup>8</sup> The consequences of biased, unreliable, or otherwise low-quality evidence entering scientific and public discussions can be severe and long-lasting.<sup>9</sup> Efforts to identify and respond to environmental risks may be hindered, and additional research may be needed to correct the evidence base and ensure that policies and practices adequately protect the health of the population.

Finally, environmental health research must be justified because of the risks it imposes on research participants. Individuals involved in environmental health research may be exposed to hazardous substances, receive interventions that are later determined to be insufficiently protective, or experience the violation of confidentiality regarding sensitive information, among other harms. The imposition of risk always requires justification, and environmental health research that cannot meet this demand is not justified.

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<sup>8</sup> The rare instance in which a study that is not designed, conducted, or analyzed in accordance with sound scientific practices “serendipitously” generates valuable findings does not diminish the importance of safeguarding the integrity of the scientific enterprise via the requirements of justified research (Freedman 1987b, 9). Environmental health research must be assessed prospectively; a study that is not designed to generate valid and reliable evidence cannot be expected to do so and therefore does not satisfy the demand for justification with respect to its effect on the integrity of the scientific enterprise.

<sup>9</sup> A colleague once used a comparison with the drug trade to explain the problem: When a bad batch of heroin enters the drug supply, it is “removed” through use. In contrast, a bad “batch” of evidence often persists in the scientific literature, clinical or public health practice, and public or policy discussions. (See, e.g., Ioannidis, Tarone, and McLaughlin [2011] and Tatsioni, Bonitsis, and Ioannidis [2007] for further discussion and examples of this problem.)

In cases where environmental health research does not involve [human] participants or their data, the demand for justification is not diminished. Research involving animals requires justification and conformity to prevailing rules and regulations to ensure that they are treated in a humane manner. Moreover, the conditions of scarce resources and the need to safeguard the integrity of the scientific enterprise remain in effect, requiring that environmental health research meet the demand for justification.

Both the normative epistemic and normative ethical requirements of justified environmental health research should therefore be designed to ensure that research does not waste limited resources, threaten the integrity of the scientific enterprise, or impose unjustified risks on participants. However, not only have the ethical requirements been the focus of most efforts to ensure that research is justified, they also fail to adequately take into account the importance of safeguarding the integrity of the scientific enterprise. Although this condition is often overlooked with respect to the demand for justification, at least in comparison to the conditions of limited resources and the imposition of risk on participants, it is inescapably connected with both. Research that produces invalid and/or unreliable evidence, which is then used to inform policies that fail to protect the health of the population, results in the misallocation of resources and engenders a loss of individual, social, and institutional support for new research (London, Kimmelman, and Emborg 2010). This in turn makes it more difficult to generate evidence needed to improve the health of the population, threatening the capacity of the scientific enterprise to fulfill its role in the social and moral division of labor.

My articulation and defense of the requirement of uncertainty in Chapter 4 stands as a corrective to the neglect of the epistemic requirements of justified research as well as the importance of ensuring the integrity of the scientific enterprise. In the next section, I begin laying

the foundation for this account, providing an analysis of what “uncertainty” means with respect to this requirement.

### **III. Incomplete Knowledge and Typologies of Uncertainty**

The requirement of uncertainty, like the other epistemic and ethical requirements of justified environmental health research, should reflect the demand for justification<sup>10</sup> and the objectives of environmental health research. To be justified, environmental health research must be designed to reduce or resolve uncertainty about known or suspected environmental hazards; otherwise, it wastes limited resources, generates evidence that may corrupt the evidence base and skew policy, and if participants are involved, imposes risks on them that cannot be justified.<sup>11</sup>

The requirement of uncertainty should function as a screening test for environmental health research, ruling out as unjustified research that fails to satisfy it. Notably, satisfaction of the requirement depends on whether research is designed to reduce or resolve uncertainty, not just whether uncertainty is present. To understand what is entailed by the requirement of uncertainty, two major questions must be addressed: *How should we understand the uncertainty required to justify environmental health research?* and *What does it mean for research to be designed to reduce or resolve it?* An answer to the former is a prerequisite to answering the latter, and in this section and the one that follows, I lay the groundwork for my account of the requirement of uncertainty in Chapter 4 (where both questions are addressed).

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<sup>10</sup> Unless otherwise specified, the demand for justification should be understood as arising from the conditions of limited resources, the need to safeguard the integrity of the scientific enterprise, and the imposition of risks on participants.

<sup>11</sup> Although other requirements are concerned with ensuring that the imposition of risks is justified (e.g., informed consent or acceptable risk-benefit ratios), a failure to satisfy the requirement of uncertainty renders the risks unjustified, as they are imposed for no reason consistent with the objectives of environmental health research.

### *Incomplete Knowledge and the Uncertainty Required to Justify Research*

A long tradition of using the word “uncertainty” to flesh out theories of and claims about knowledge has led to a proliferation of meanings and uses, which, depending on the context and one’s “built-up connotations,” may push in different directions regarding how the term should be understood.<sup>12</sup> For example, uncertainty can refer to a lack of or incomplete knowledge about empirical quantities, the structure of models, methods of producing evidence, or the consequences associated with a policy decision and may arise from missing data, variability, or disagreement (Morgan and Henrion 1990). None of these uses or meanings of uncertainty indicate a justificatory function, however; they do not explicitly identify the uncertainty required to justify research.

Given this conceptually crowded landscape, one might think it reasonable to proceed by trying to produce a uniquely good definition of uncertainty (and that it would be a philosophically interesting task to do so). Yet successfully explicating the requirement of uncertainty for use in determining whether environmental health research is justified does not depend on a particular definition of uncertainty. What is needed instead is an improved understanding of the ways in which our knowledge is “uncertain” and those features or characteristics that are relevant to the justification of research. The virtue of this approach is that it produces an operationalized account of the requirement of uncertainty that is robust across a range of possible definitions.

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<sup>12</sup> I thank James Mattingly and Madison Powers for helpful discussion on this point.

To begin the process of responding to the question of how we should understand the uncertainty required to justify research and provide clarification of key terms, consider the following diagram:

**Figure 1-1. Limitations in Knowledge (Nested Diagram)**

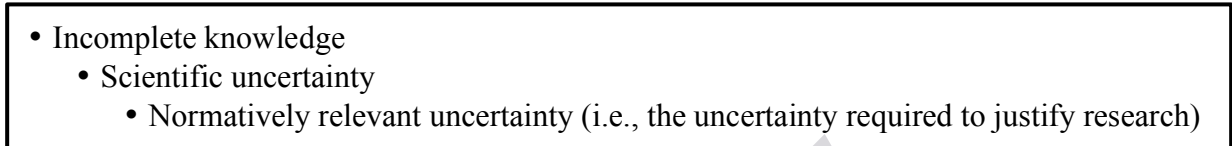


Figure 1-1 depicts a way of organizing and understanding gaps and other limitations in our knowledge. Starting from a basic notion of incomplete knowledge, we can use it to narrow our focus and distinguish the subset that represents the uncertainty required to justify research, or what I refer to as the *normatively relevant uncertainty*.

Figure 1-1 assumes an epistemologically general working definition of knowledge, namely knowledge as justified belief, using an evidential standard of justification.<sup>13</sup> Incomplete knowledge represents a state in which there is inadequate justification for a claim or belief due to insufficient evidential support.<sup>14</sup> The standards by which the evidence is assessed are not invariant, however, and whether claims or beliefs are adequately justified depends in part on the context and the consequences associated with being right or wrong (Kukla 2007, 197).

Because the available evidence will always be insufficient when judged against an absolute standard of proof, there is a sense in which all scientific knowledge is incomplete. As Silbergeld (1991) observes, “scientific knowledge...can never be devoid of uncertainty or the

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<sup>13</sup> For the purposes of this dissertation, I want to avoid Gettier- or Sosa-type problems or other discussions of necessary and sufficient conditions of knowledge.

<sup>14</sup> I thank Tom Beauchamp for this suggestion.

possibility of inaccuracy or incompleteness” (101). Yet the mere fallibility of scientific knowledge does not constitute the uncertainty required to justify research. If it did, the requirement of uncertainty would be too permissive, allowing research that did not meet the demand for justification to proceed.

To distinguish the uncertainty required to justify research from the larger category of incomplete knowledge, we need to determine what sort of “lack” [of knowledge] it represents. When is scientific knowledge uncertain rather than simply incomplete? As I just noted, while we have incomplete knowledge about almost everything, it does not seem that we are uncertain about everything. We make decisions and take action on the basis of knowledge that is incomplete, but our choices and behaviors may change when our knowledge is considered uncertain rather than simply incomplete. Moreover, uncertainty disposes us toward “doing something about it [incomplete knowledge], or thinking that something can be done about it” (Mattingly 2014).

A first step in marking this contrast is to identify the subset of incomplete knowledge that is incomplete in ways about which we can “do something.” Because justified research must be designed to reduce or resolve uncertainty, incomplete knowledge that is not reducible cannot justify research. But when scientific knowledge is incomplete in ways that can be mitigated by conducting further research, there is some matter about which we are appropriately uncertain.<sup>15</sup> I label this category *scientific uncertainty*.

Scientific uncertainty is a subset of incomplete knowledge (see Figure 1-1), reflecting gaps or limits in our knowledge that can *in principle* be reduced through research. In general, scientific uncertainties reflect gaps or limits in our understanding of the causal relationships

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<sup>15</sup> I thank James Mattingly for discussion on this point.

among sets of variables (e.g., biological mechanisms) or in the values of these variables (e.g., exposure levels) that can be mitigated through further research. Even if ethical, methodological, technological, and feasibility considerations limit our ability to reduce or resolve these uncertainties through research, this does not detract from their standing as scientific uncertainties. What matters is whether additional information has the potential to improve our understanding of the phenomena or, as in the case of indeterministic processes, for instance, no additional information is available or can be generated prior to observation of the outcome.<sup>16</sup> Scientific uncertainty is present in the former case, whereas the latter reflects incomplete knowledge of a different sort.

Although scientific uncertainty represents a situation in which there exists an in principle reduction of incomplete knowledge through research, further refinement is needed to identify the uncertainty required to justify environmental health research. That is, the requirement of uncertainty would still be too permissive if, in order to satisfy the requirement, research only needed to be designed to reduce or resolve scientific uncertainty. Definitive answers are elusive in science, and “new knowledge inevitably raises more questions” that are potential targets of future research (Olshan 2008; Savitz 2010, 281). Determining whether research meets the demand for justification and is consistent with the objectives of environmental health research requires a more discriminating account of the uncertainty required to justify research.

Here, we arrive at what I call the *normatively relevant uncertainty* (see Figure 1-1). Normatively relevant uncertainties constitute a subset of scientific uncertainties but are differentiated from the latter based on the presence of a normative rationale to pursue the

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<sup>16</sup> For example, in the case of a fair coin toss, our knowledge of the outcome is limited to a set of probabilities (50:50) and cannot be further improved prior to observing the actual toss.

research needed to reduce the scientific uncertainty. Whether scientific uncertainties are normatively relevant depends on the research context and its governing objectives.

In the context of environmental health research (and for the purposes of this dissertation), normatively relevant uncertainties reflect limits in the available evidence regarding the nature and scope of threats posed by environmental hazards and possible methods for reducing exposures or ameliorating adverse health outcomes. Research designed to generate the evidence needed to address these normatively relevant uncertainties is consistent with the objectives of and has a *prima facie* claim to the resources allocated to environmental health research.<sup>17</sup> This is not to say that research designed to address scientific uncertainties that are not normatively relevant in the context of environmental health research is unjustified *simpliciter*, but that such research is justified only in a context in which the scientific uncertainties are normatively relevant.<sup>18</sup>

The concept of normatively relevant uncertainty provides the needed foundation for the requirement of uncertainty to successfully function as a screening test for environmental health research. To be justified, environmental health research must be designed to generate the evidence needed to effectively respond to known or suspected environmental hazards; it must be designed to reduce or resolve normatively relevant uncertainty. The requirement of uncertainty is

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<sup>17</sup> A *prima facie* claim to resources does not entail that the research be funded; limited resources may force choices among studies that satisfy the normative epistemic and ethical requirements of justified research.

<sup>18</sup> The articulation and defense of the requirement of uncertainty for justified environmental health research assumes that there is a limited set of funds allocated for environmental health research (whether the funding is sufficient or appropriately allocated is another question). Although there is expected to be overlap between frameworks for various categories of scientific inquiry, there will be differences. An important advantage of this approach is that basic science does not have to demonstrate or speculate about its impact on health in order to be justified, which encourages a misunderstanding of the practice of basic science research. A disadvantage is that a funding stream dedicated just to basic science research is often politically vulnerable. (I thank Molly Evans for helpful discussion on this issue.)