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A Framework for Responsible Innovation

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2.1 Introduction

Few would disagree that science and innovation should be undertaken responsibly. "Responsible innovation" intuitively feels right in sentiment, as an ideal or aspiration. It has positive, constructive overtones, where science and innovation are directed at, and undertaken towards, socially desirable and socially acceptable ends, with connotations of trust and integrity. However, in reality, it lacks definition and clarity, both in concept and practice: What might it involve? Who might it involve? When might it be applied? In this chapter we explore these questions, proposing a framework for responsible innovation and highlighting some examples of its translation into practice.

Before doing this we first need to provide some context. Why is there a need for a framework for responsible innovation, and what are the deficits of our current approach to innovation governance? In this chapter we will begin by emphasizing that science and innovation have not only produced understanding, knowledge, and value (economic, social, or otherwise), but also questions, dilemmas, and unintended (and sometimes undesirable) impacts. This is well understood. Some impacts, such as those associated with the financial crisis of 2008, have been both profound and global in nature, see Muniesa and Lenglet, Chapter 10. They have highlighted inefficiencies, and even failures, in the principle of regulation by market choice in liberal economies, which struggles,

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sometimes spectacularly, with "externalities" associated with innovation, see Lee and Petts, Chapter 8. We will describe how, historically, the response to this has been one of governing the products of innovation (we mean products in their widest sense, to include impacts that are co-produced and unintended), usually after these have emerged in society. In this approach, where impacts (e.g., to society, health, or the environment) are found to be undesirable or harmful we may then decide to manage and control these, commonly through regulatory instruments. Such retrospective regulation can also look forward: we may introduce or amend regulation to protect society from such impacts occurring again. Precautionary "data before market" legislation, for example, seeks to ensure that the mistakes of history are not repeated.

But for impacts that are poorly characterized or highly uncertain (including those that emerge as a result of the complex, dynamic, and globalized nature of contemporary innovation and its naturalization process in modern society (see Chapter 1)), this knowledge – and often risk-based – model of regulation fares less well. In these circumstances the current approach consigns scientists, innovators, and users to moral luck (Williams, 1981). By this we mean that in hindsight, and in the fullness of time, the consequences and impacts of innovation may well be judged to be undesirable, even harmful. But, burdened with imperfect foresight, we take a chance, hoping to be excused from moral blame if it can be demonstrated we did not have sufficient knowledge of the future consequences of our actions at the time: that these could not have been "reasonably foreseen" (see Grinbaum and Groves, Chapters 7 and Lee and Petts, Chapter 8). In the absence of certainty, of evidence and understanding, what other option is there? How should we proceed responsibly under such conditions of ignorance and uncertainty (Collingridge, 1980; RCEP, 2008)?

The appropriate (and proportionate) oversight and stewardship of the processes of science and innovation under such conditions then become a central challenge for responsible innovation. Codes of conduct (e.g., European Commission, 2008) and formal processes of ethical review for research and innovation do exist, but only in rather narrow contexts. We will argue the need for a far wider, systemic reconfiguration, and indeed a significant culture change in this regard. Importantly, we will argue that stewardship of science and innovation must not only include broad reflection and deliberation on their products, however uncertain these may be, but also (and critically) the very *purposes* of science or innovation: why do it, what are the intentions and motivations, who might benefit and who might not? What should the targets for innovation be – what Von Schomberg (Chapter 3) describes as the "right impacts" (see also Von Schomberg, 2011a) – and how can these be democratically defined? What values should these based on (see Van den Hoven, Chapter 4)? Despite being important sources of controversy in many areas of science and technology, from genetic modification (GM) to geoengineering, early, ethical reflection and inclusive deliberation on purposes and underlying motivations is currently limited: by the time such deliberation does occur positions may be entrenched and vested interests significant. Here we concern ourselves with the democratic governance of intent (Stilgoe, 2011) and the principle of science *for* society (Owen, Macnaghten, and Stilgoe, (2012)). There is an obvious tension between this and the principle of scientific freedom, one that is far from new (Polanyi, 1962). While this may not be as keenly felt for innovation, for science this is a tension that any formulation of responsible innovation ignores at its peril.

Reflection on purposes implies that any framework for responsible innovation needs to accommodate not only what we do not want science and innovation to do – the

identification, assessment, and where necessary control of their wider impacts and associated risks – but what we *do* want them to do. "What are the risks?" – important question though this is to consider within any framework – is not the departure point for responsible innovation. As we go on to describe, this frames responsible innovation as, at least in the first instance, a discussion concerning what sorts of futures we want science and innovation to bring into the World. This opens up new opportunities for creating value in society through science and technology. But such a conversation requires a new vocabulary. This needs to go beyond narrower preoccupations with, on the one hand, risks and regulation (Owen and Goldberg, 2010) and, on the other, maximizing the economic and social benefits (or "impact") of science and innovation (Kearnes and Weinroth, 2011). It will need to consist of more than a simplistic prescription to, on the one hand "do no harm" and on the other contribute to economic competitiveness and social wellbeing (Guston, 2004, 2007).

Having provided some important context we then develop the framework itself. We first provide a philosophical anchoring for this, looking to those prospective, forward-looking dimensions of responsibility, (notably *care* and *responsiveness*) which allow consideration of purposes and accommodate uncertainty, a defining feature of innovation (Jonas, 1984; Richardson, 1999; Pellizzoni, 2004; Groves, 2006; Adam and Groves, 2011; and Grinbaum and Groves in Chapter 7). We then transcribe this in terms of four dimensions of responsible innovation. These suggest that to innovate responsibly entails a continuous commitment to be *anticipatory, reflective, inclusively deliberative*, and *responsive*. For each there is much we can learn from decades of thought and study in science and technology studies and beyond. These dimensions will require some elaboration in order to impart meaning to them, but they are not in themselves new. Familiar concepts that include technology assessment, "upstream" engagement and anticipatory governance are foundations for responsible innovation that should not be discarded or ignored.

We then consider how such integrated dimensions might be applied in the real world, how they can be translated into practice. We will emphasize that this translation must not be rules-based and that it must be flexible in the face of uncertainty (Richardson, 1999). There are in fact numerous examples, some of which we highlight, where one or more of these dimensions has been applied, to varying degrees. These serve to signpost specific methods and approaches that can allow the dimensions we describe to be translated into practice. We observe that, however, there are currently few, if any, examples of a systematic and institutionally-embedded framework that integrates and iteratively applies all four dimensions together in and around the processes of science and innovation, supporting what Wynne (1993) describes as "institutional reflexivity." Important here is the dimension of responsiveness, that is, the coupling of reflection and deliberation to action that has a material influence on the direction and trajectory of innovation itself. We conclude the chapter with some reflections regarding implementation and how this might be supported, drawn from our own experiences.

In this chapter we will refer to both science and innovation. We will ask how we can embed responsibility within innovation as a complex, multi-actor phenomenon that involves the translation of ideas into some sort of value in the future. But we extend this ambition to the practice of science. Much science is curiosity-driven, producing knowledge and understanding that is not intentionally directed at value creation in a narrower sense. It could be argued that there is less justification for applying such a framework in such circumstances, at least initially. However, we must also remember that many areas of science (e.g., in the fields of quantum mechanics and molecular

biology) have been, and continue to be, an important catalyst for innovation. Recognizing this, the potential (beneficial) impact – economic and social – of even curiosity-driven research is now an increasingly important funding consideration. Such visions of application and impact are important locations for considerations of responsibility (Simakova and Coenen, Chapter 13). Some areas of science are also purposefully funded with the promise of creating economic or social value, for example, to meet societal challenges (Lund Declaration, 2009; Kearnes and Weinroth, 2011). Many areas of science, directed or otherwise, can have unanticipated impacts. As such, we argue the framework we propose should be extended to include both science and innovation, but it is important to note that we make no assumption that it should be applied in every case.

What our following discussion also does not imply is that what has come before has necessarily been "irresponsible innovation" or "irresponsible science." Von Schomberg, in Chapter 3, certainly describes some examples where, in his view, this may have been the case, but these rarely if ever result from the actions of an individual scientist or innovator (Von Schomberg, 2007). Irresponsibility, we (and others) argue, is often the product of a globalized and complex ecosystem of innovation, involving the creation by many (separated across space and time) of what Bessant in Chapter 1 describes as "knowledge spaghetti." It is within such an ecosystem that responsible innovation must be located. The emergent nature of irresponsibility in this context (Beck's "organized irresponsibility" (Beck, 1995)) requires a new way of thinking about responsibility. Responsibility is a social ascription that has changed and evolved over time, in part reflecting the changing nature and norms of society. What we (and others (e.g., Jonas, 1984; Adam and Groves, 2011; and Grinbaum and Groves, Chapter 7) argue is that how we think about responsibility in the context of science and innovation now needs to change again, reflecting the modern context in which innovation occurs. This requires a redrawing of the contours of responsibility, including, but going beyond evidence-based regulation and established codes of responsible conduct in science. This redrawing will need to be done in a way that allows the constructive and democratic stewardship of science and innovation in the face of uncertainty toward futures we agree are both acceptable and desirable: this is *a collective responsibility*. It in turn will require reflection on the societal values in which innovation is anchored (Von Schomberg, 2011a, 2011b; and Von Schomberg in Chapter 3) and the conflicts and dilemmas that inevitably arise when these are considered in combination: for example, the tensions between the goals of innovation for economic growth or environmental sustainability. It will also challenge us to ask how we can and should respond as the future materializes in often complex, unpredictable ways, including ways not initially intended. Some of these challenges we will only be able to touch on here, but they serve to warnus that redrawing the contours of responsibility will be far from easy. Our contribution provides just one input into a broader discussion concerning how this might be achieved.

2.2 Context: the Imperative for Responsible Innovation

2.2.1 Re-evaluating the Social Contract for Science and Innovation

Our capacity, and appetite, for invention and innovation has profoundly shaped human societies and the world we live in since the dawn of civilization. We are an incredibly

inquisitive, imaginative, and innovative species. Science and innovation are an integral part of the structure of nearly all modern societies and their place remains assured. We look to them to meet the myriad societal challenges we currently face – future sources of economic growth, wealth, environmental sustainability, health and the security of food, water, and energy (e.g., BIS, 2011). At least since the Enlightenment in the seventeenth century, and in particular since the middle of the twentieth century, an informal social contract has come to exist between scientists and innovators, and wider society (Guston, 2004; Pielke, 2007). Freedom, social licence, and funding to invent, innovate, and pursue scientific endeavors have been exchanged for the promise, and sometimes expectation, of knowledge, understanding, and value (economic, social, or otherwise). Certain responsibilities are implicit within this contract, including the expectations that existing norms, laws, and standards of conduct are adhered to: there is a long history of responsibility in the context of research integrity in this regard. This includes scientists' responsibilities relating, for example, to fraud, the falsification of data, or plagiarism. Going further, some have argued that within this contract the production of knowledge and its translation into economic and social impact has been (and continues to be) a key responsibility of institutions of science and innovation (see Guston, 2004; and Simakova and Coenen in Chapter 13 for more discussion). Here a desire to demonstrate the public value of science and innovation translates into a responsibility to drive knowledge and technology transfer (Chapter 13).

The last half a century has forced a re-evaluation of this contract. As well as new knowledge and value, science and innovation have time and again been shown to simultaneously co-produce often unintended and unforeseen impacts (Beck, 2000) and to have complex interactions with, and transformative consequences for society. From the environmental effects of chemicals first brought to widespread public attention by Rachel Carson in the 1960s (Carson, 1962), to the profound consequences of complex financial products in the last decade (Mackenzie, 2010; and Muniesa and Lenglet in Chapter 10), we have come to realize that, uncertain though they may be, such impacts *must be expected to occur* (Hoffman-Riem and Wynne, 2002; and Grinbaum and Groves in Chapter 7), sometimes at global and intergenerational scales. This is a symptom of what Hans Jonas described as the "altered nature of human action," mediated through technology and innovation (Jonas, 1984).

2.2.2 The Responsibility Gap

Historically, where free markets have failed to manage so-called externalities of innovation, our response has been one based largely on governance through mechanisms of regulation, that is, legal instruments of authorization and control, which are often underpinned by methods of probabilistic risk assessment and evaluation. Here, the products of innovation may be retrospectively subjected to regulation once they have been developed, marketed, and introduced into society (Lee, 2012; and Lee and Petts in Chapter 8), if and when there is evidence of undesirable or harmful impacts. Governance of this kind can also have a prospective dimension, through a process of adaptive learning. It may be introduced or amended to safeguard society and the environment from known impacts, with the aim of preventing these from occurring again. This has led to stringent regulatory governance in certain areas of innovation, such as medicines, where the harmful consequences of some medicines, such as thalidomide and diethylstilbestrol, (which had intergenerational effects on health) were important catalysts for

regulatory development (EEA, 2001). In addition to general liability regimes (e.g., product liability – see Chapter 8), sector – specific regulation in areas such as pharmaceuticals and novel foods includes precautionary legislation that has evolved over the last half century, and which now requires "data before market" prior to authorization and use, specifically to safeguard health. Safety is considered as important as efficacy in this regard. Prospective legal concepts, such as duty of care in tort law, which are aimed at protecting people and property, have also been developed over the last century.

These forms of legal responsibility have a foundation in knowledge, and specifically, evidence (notably of causality) (Groves, 2006). Knowledge of several kinds is required: first, knowledge of the nature of impacts, knowledge that these are undesirable or harmful, and knowledge of the sorts of behaviors that will have a strong probability of leading to these (what in law can be "reasonably foreseen" given the status of knowledge at the time of acting); secondly, knowledge of the legal, or moral, norms that exist in society and which aim to ensure these impacts and behaviors are avoided or prevented; and thirdly, evidential and causal knowledge that such norms have been transgressed. Transgression of such legal or moral responsibilities may render one accountable (legally in a court of law and/or morally to society), when one is then judged retrospectively in the context of such knowledge, and on the basis of the consequences of one's actions.[1] A pre-requisite for this is that one had the *capacity* to understand these norms at the time and, as autonomous individuals who exert free will, one then transgressed these (intentionally or otherwise i.e., by being reckless or negligent). For this there is a requirement for evidence, often independently verified. One can already envisage the problems this formulation of responsibility poses for science and innovation, with their attendant uncertainties, complexities, and areas of ignorance, and where the limits to knowledge are often great. We will speak more about this presently.

For now we note that responsibility of this kind, manifested, for example, through instruments of regulation, is an important part of responsible innovation, but that it has severe limitations. It is poorly equipped to govern areas of novel science and technology which are highly uncertain in terms of their current and future impacts, or which, by virtue of their novelty, have no historical precedent. Regulation, put simply, struggles with innovations that it has not encountered before, where it has no immune response. And innovation is a process of imagination, invention, and development that *actively seeks* novelty, with the creation of value as its goal. Here, by definition, regulatory forms of governance and control may not exist, or are unclear in terms of their coverage (Lee and Petts, Chapter 8): knowledge of the social norms against which transgression can be judged may also be poorly defined, unclear, or contested. There may in these cases be no requirement for "data before market," because we may not know what data to ask for or we may lack the technical ability to procure it. Such data requirements that do exist may also be limited in context, covering, for example, certain aspects of environment, health, and safety, but not impacts on, or interactions with, society. Areas such as nanotechnology, synthetic biology, geoengineering, and information technologies, which can occur at the interface of disciplines and for which there is often no established regulatory regime, are current examples of these (see Chapters 11–13).

[1] The root of the word responsibility is "respondere," whereby one is held to account and asked to respond in a court of law or some other higher authority (Grinbaum and Groves, Chapter 7).

The requirement for knowledge before regulatory action is, at face value, both rational and logical. It entails the procurement of evidence of impacts, which must be understood with a degree of certainty, which then becomes a key requirement for the establishment or amendment of legal or moral norms, and for the amendment or development of regulation. In many emerging areas of science and technology, programs of research in the fields of safety, environment, and health have often been commissioned that follow in the wake of innovation, and which are directed to support policy and regulatory development, to establish the forms of knowledge we describe above. The limitations of this approach are well known (EEA, 2001; RCEP, 2008; Owen *et al*., 2009a, 2009b). There have been many cases where it did not identify in advance, or in good time, a number of very serious impacts on society, environment, and health (EEA, 2001), serving to remind us of the limits of knowledge, risk assessment, and foresight (Hoffman-Riem and Wynne, 2002), and in turn the limits of evidence-based regulation.

We know from experience that the reach of innovators will always exceed the grasp of regulators, and that it is often many decades before understanding of the wider impacts, implications, and consequences of innovations become clear enough for a case for a regulatory response to be made (EEA, 2001; RCEP, 2008; Pacces, 2010). Long time lags between innovations, understanding of their impacts and the evolution of policies to govern them result (Owen *et al*., 2009a, 2009b). Callon, Lascoumes, and Barthe (2010) use a metaphor of science and technology "overflowing" the boundaries of existing regulatory frameworks. Groves describes this as "a fundamental gap between the technologically-enhanced power of industrialized societies to create futures, and our ability as agents within these societies to take responsibility for the kinds of futures we create" (Groves, 2006). This is compounded by the complex, messy, and often globalized nature of contemporary innovation itself. Innovation is not a simple, linear model with clear lines of sight from invention to impact, and where accountability for such impacts can be traced. It is an undulating path, sometimes with dead ends, involving many, often loosely-connected actors. It is a *complex, collective, and dynamic* phenomenon. We will emphasize later the importance of co-responsibility in this context (Mitcham, 2003; Von Schomberg, 2007). As a consequence, it may not be so much individual scientists or innovators as the *ecosystem of innovation* that supports the emergence of what Beck (1995) called "organized irresponsibility" and which permits an easy discounting of the future. This emergent, ecosystem-level behavior is a product of uncertainty, complexity, and distance, both spatial and temporal. Governing such an ecosystem is, some might argue, an almost impossible challenge.

2.2.3 The Dilemma of Control

The responsibility gap we have described has several important implications. It was David Collingridge who alerted us to the first of these, the risks of technological "lock in" and path dependence (Collingridge, 1980; Arthur, 1989; David, 2001). In essence, by the time we have procured knowledge that leads to a better understanding of the impacts of innovation (notwithstanding the fact that knowledge itself is a source of further uncertainty) the innovation may be so "locked in" to society that we may have little appetite, or power, to do anything about it. The costs (financial or otherwise) of control may be too great, and vested interests may fight this. Lock in and path dependence, sometimes fueled by incentives (as was the case for some notable recent financial innovations),

serve to close down options to modulate, shape, or control innovation (Stirling, 2007, 2008), even in the face of impacts which are profound, but which may be too costly to control (Owen and Jobling, 2012). This is one horn of the "dilemma of control" that Collingridge presents us with when considering how we might govern innovation. The other horn is equally problematic. At the earlier stages of innovation we may have most opportunity to shape and control innovation, with far fewer costs and vested interests; but it is precisely at these early stages that we have little or no evidence to make the case for control. If the dangers of lock in are the price of waiting for the accumulation of knowledge before action, then the risks of missed opportunity are the price of acting too early, of being too precautionary. Given this, promissory statements of benefit can predominate over calls for precaution, which may be seen to slow down, or impede our insatiable appetite for progress.

Under such circumstances we may prefer to take our chances. This subjects scientists, innovators, and users of innovation to "moral luck" (Williams, 1981; and Grinbaum and Groves, Chapter 7). In time such innovations may, with the benefit of hindsight and accumulation of knowledge, be found to have undesirable or harmful impacts. Critically, whether one is held to account for the consequences of one's actions in this context depends, as we have already noted, on what one knew at the time (i.e., the status of the types of knowledge we have described) and what could have been reasonably foreseen. As Grinbaum and Groves argue in Chapter 7, this consequentialist view of responsibility is wholly unsatisfactory in the context of innovation as an uncertain, often knowledge-poor phenomenon. Not only that, but as the results of public dialogues around emerging areas of science and technology (such as synthetic biology[2]) have shown, public desire for scientists (and those that fund them) to actively take more responsibility for the wider implications of their research is strong (TNS-BMRB, 2010; and Sykes and Macnaghten, Chapter 5. Allowing the future to take care of itself in the face of uncertainty is neither a satisfactory, or acceptable approach.

2.2.4 Products and Purposes: the Democratic Governance of Intent

We have so far considered problems associated with the identification and management of impacts under conditions of ignorance and uncertainty: the products of innovation. There is, however, a deeper, but equally important deficit to our current approach to governing science and innovation, one that is also evident from public dialogues concerning new technologies. This is related to products, but is primarily concerned with the *purposes* and *motivations* for the innovation itself. Why do it? Who might benefit and how? Will such benefits be equitable? Will it confer burdens to some or many? In whose interests is it being undertaken and what are the motivations of those involved? Do we (as a society) want it? Our current approach to governing science and innovation rarely, if ever, allows reflection on purposes, underlying intentions and motivations (Stilgoe, 2011).

A framework for responsible innovation must then not just include consideration of products, but also purposes, not just what we do not want science and innovation to do, but what we do want them to do. This is the departure point for responsible innovation. It compels us to reflect on what sort of future(s) we want science and technology to bring into the world, what futures we care about, what challenges we want these to meet,

[2] www.bbsrc.ac.uk/web/FILES/Reviews/synbio_summary-report.pdf.

what values these are anchored in, and whether the negotiations of such technologically-enabled futures are democratic. It asks how the targets for innovation can be identified in an ethical, inclusive, and equitable manner. This takes us beyond the "closing down" framing of conventional ethical review in research, which may be seen as a hurdle for researchers (e.g., where their research involves people, animals, and genetic material). Rather, its primary purpose is to inclusively and democratically define and realize new areas of public value for innovation (Wilsdon, Wynne, and Stilgoe, 2005). Here responsible innovation should be viewed as creating opportunity. Having set the initial direction of travel, responsible innovation then asks how we can change the trajectories of innovation as new information and new perspectives emerge: how we should respond in the face of uncertainty and how innovation might look different in response. It is these dimensions of care and responsiveness that form the philosophical cornerstones of the framework we now describe.

2.3 Locating Responsible Innovation within Prospective Dimensions of Responsibility

How can we address the deficits of our current approach to governing science and innovation in contemporary society? What might a framework for responsible innovation look like, and will it be different to what has come before? To begin we need first to provide a philosophical foundation for the framework, one that locates it within a prospective conceptualization of responsibility that both allows for reflection on purposes, i.e., is ethical and values-based (van den Hoven, Lokhorst, and van de Poel, 2012; and van den Hoven in Chapter 4), and also allows for and accommodates uncertainty, i.e., is responsive to the changing nature of innovation as it makes its uncertain and unpredictable way in the world.

Care and responsiveness are two dimensions of prospective responsibility (Richardson, 1999; Pellizzoni, 2004; Groves, 2006; Adam and Groves, 2011; and Grinbaum and Groves, Chapter 7) that are relevant here. They allow us to reflect on the purposes of science and innovation, to articulate what we want science and innovation to do, and not to do (the dimension of care) and to be responsive to views and knowledge (of many different kinds) both in terms of defining the targets for innovation and how its trajectory then evolves.

Responsiveness is a key dimension that allows options to be kept open (Stirling, 2007, 2008); it is the antidote to lock in and path dependence. It is linked to what Collingridge described as the continuous goal to discover, and act on, those decisions that one has made in error: corrigibility (Collingridge, 1980). Importantly, it not only embeds the concept of responding to a changing information environment, that is, being *adaptive*, but also to responding to the views, perspectives, and framings of others – publics, stakeholders – , that is, being *deliberative*. This introduces the principle of deliberative democracy into the dimension of responsiveness. It is important that such deliberation is widely configured, that it seeks not simply to understand views on the purposes and intended products of science and innovation and their acceptability, but that such engagement pro-actively helps establish and shape new agendas which set the direction of science and innovation themselves. The Altzheimers's Society in the UK, for

example, has a research network of some 200 carers and people with dementia who help set research priorities, prioritize grant applications and sit on grant selection panels[3] (Wilsdon, Wynne, and Stilgoe, 2005).

If care and responsiveness are two dimensions of responsibility that are helpful to underpin a framework for responsible innovation, they are dimensions that will be less familiar in comparison with those of liability, accountability, even blame, which are knowledge based (as we have discussed above), and which are retrospectively applied after the fact. These dimensions of responsibility have a long and rich history. As a social ascription they defined for many generations the contours of acceptable and desirable behavior in societies. Both moral and legal in nature, they have been particularly important since the emergence of liberalism and individualism in the sixteenth century, which is by no coincidence where the modern ascent of science, and the emergence of capitalism from mercantile economies, began in earnest. Although the specifics (e.g., nature of norms and laws) have evolved as our societies have evolved, these dimensions of responsibility have predominated over history, to varying degrees, with ever more sophisticated frameworks that guide, bound, and limit behavior, helping to maintain social order. They are important to maintain the rights of individuals in a "free," democratic society (e.g., in the modern era the right to own property and the right to free speech). Reciprocal forms of responsibility such as these (Groves, 2006), in which we respect each others' rights and are accountable under the law if these are transgressed, can be traced back to classical times (Jonas, 1984) and were, arguably, sufficient for societies where responsibilities were framed predominately in the context of contemporaries who lived close to one another, and whose actions rarely had irreversible effects on the world at large. As a deterrent, responsibility had a future orientation only in as much as one would be judged retrospectively (and evidentially) in the future according to the consequence of one's past actions.

But as we have already noted, and as Jonas so eloquently described, our world is no longer one of close contemporaries. Our actions, mediated through technology, affect others across continents and across generations: from the stratospheric ozone depletion caused by chlorofluorocarbons (CFCs) used in refrigerators and aerosol can propellants, to the collapse of investment banks in the wake of the innovation of collateralized debt obligations based on "toxic," asset-backed securities. While innovation may be a collective, future-oriented activity steeped in uncertainty, what is certain is that it has made our world a far smaller, interdependent, and uncertain place. Jonas and others since (see Chapter 7) argue that, in this context, the predominant reciprocal and consequentialist view of responsibility is inadequate, requiring what Jonas went on to argue should be a new conceptualization, one that goes beyond the "ethics of the neighborhood." When considering matters of science and innovation, this must include dimensions that are non-reciprocal and future-oriented in nature (Adam and Groves, 2011; Groves, 2006). It is within this conceptualization of responsibility that we find dimensions such as care and responsiveness, and which form the cornerstones of a framework for responsible innovation. These allow us to develop an intentionally broad definition for responsible innovation:

> Responsible innovation is a collective commitment of care for the future through responsive stewardship of science and innovation in the present.

[3] http://alzheimers.org.uk/site/scripts/document_pdf.php?documentID=1109.

This definition provides a general framing for responsible innovation, under which we will shortly propose four dimensions, which when integrated together may allow such a commitment of care and stewardship to be enacted.

In fact, we have already implicitly introduced these four dimensions: we have, for example, advocated the need for innovation to be responsive and deliberative. We have also spoken of the need for reflection on the purposes of innovation and the values these are anchored in, and on the need to anticipate the impacts innovation might have. But before explicitly describing these dimensions, we must say one last, important thing about care. We care about what is of constitutive value to us, mediated through our attachments, identities, beliefs, and the various roles we play, and the influences which bear, and which have had bearing upon our lives. The first and foremost task for responsible innovation is then to ask what futures do we collectively want science and innovation to bring about, and on what values are these based? This is reflected in discussions concerning values-sensitive design (see Chapter 4), the need to articulate the "right impacts" of research and innovation (Von Schomberg, 2011a, 2011b) and the focusing of these on societal challenges (e.g., Lund Declaration, 2009), that is, science for society (see Owen, Macnaghten, and Stilgoe, 2012) for a more detailed discussion in a European context). Von Schomberg argues that we cannot aspire to the abstract ideals of the Aristotelian "good life," however contested this may be, and takes a more pragmatic view that, at least in a European context, the "right impacts" are those constitutionally enshrined in the European Treaty, such as a competitive social market economy, sustainable development, and quality of life. Meeting these, he asserts, should be achieved in a way that is ethically acceptable, socially desirable, safe, and sustainable (Chapter 3).

In combination, such targets for innovation of course embed tensions, complex dilemmas, as well as areas of contestation and outright conflict. Two challenges then emerge from this: the first is which if any of these targets should be prioritized as the "right impacts," and whether some of these targets should in fact be excluded? This question had both political and ethical dimensions. The World Wildlife Fund (WWF, 2012), for example, considers the right impacts for innovation as being *dematerialization* (i.e., products, services, or processes that dramatically cut the use of natural resources), *restorative* (i.e., innovations that contribute to net positive environmental impacts and the restoration of biodiversity and the environment), *open loop* (where waste from products is turned back into resource), and *renewable energy and low carbon*. Are these the "right impacts"?

One might extend this to argue that any process of responsible innovation that serves to target innovation at those "right impacts" which support the increasingly unsustainable grand Capitalist project of modernity might, in the longer (or even medium) term, be viewed as an irresponsible innovation in itself. Should responsible innovation as an innovation simply serve to promote the status quo, propagating and expediting the sustainability crisis facing society in the twenty-first century (Thomson, 2011 and references within)? These are inherently political discussions, involving considerations of power, democracy, and equity, and suggest that responsible innovation cannot, and should not, be decoupled from its political and economic context.

The second challenge then is how a framework for responsible innovation can accommodate plurality of political and ethical considerations as these relate to social desirability and acceptability, allowing the inevitable tensions, dilemmas, and conflicts to be identified and navigated, with a view to a democratic, equitable, and legitimate

resolution. These challenges make the case for broad, inclusive deliberation concerning the purposes of, and motivations for, innovation essential.

2.4 Four Dimensions of Responsible Innovation

We suggest that to innovate responsibly entails a collective and continuous commitment to be:

Anticipatory – describing and analyzing those intended and potentially unintended impacts that might arise, be these economic, social, environmental, or otherwise. Supported by methodologies that include those of foresight, technology assessment, and scenario development,[4] these not only serve to articulate promissory narratives of expectation but to explore other pathways to other impacts, to prompt scientists and innovators to ask "what if . . . " and "what else might it do?" questions. Tempered by the need for plausibility, such methods do not aim to predict, but are useful as a space to surface issues and explore possible impacts and implications that may otherwise remain uncovered and little discussed. They serve as a useful entry point for reflection on the purposes, promises, and possible impacts of innovation. Guston in Chapter 6 provides further discussion on this dimension.

Reflective – reflecting on underlying purposes, motivations, and potential impacts, what is known (including those areas of regulation, ethical review, or other forms of governance that may exist – see Chapter 8) and what is not known; associated uncertainties, risks, areas of ignorance, assumptions, questions, and dilemmas.

Deliberative – inclusively *opening up* visions, purposes, questions, and dilemmas to broad, collective deliberation through processes of dialogue, engagement, and debate, inviting and listening to wider perspectives from publics and diverse stakeholders. This allows the introduction of a broad range of perspectives to reframe issues and the identification of areas of potential contestation. Sykes and Macnaghten in Chapter 5 describe a number of specific methods that can be employed, emphasizing the goals of such deliberation should be normative (i.e., that dialogue is the right thing to do for reasons of democracy, equity, and justice) and substantive (i.e., that choices concerning the nature and trajectory of innovation can be co-produced with publics in ways that authentically embody diverse sources of social knowledge, values, and meanings (Stirling, 2005; Stirling, 2008; Marris and Rose, 2010)).

Responsive – using this collective process of reflexivity to both set the direction and influence the subsequent trajectory and pace of innovation, through effective mechanisms of participatory and anticipatory governance.[5] This should be an iterative, inclusive, and open process of adaptive learning, with dynamic capability.

In total we see these combined dimensions as meeting two goals; first, they collectively serve to build what we might rather grandiosely term "reflexive capital" concerning the purposes, processes, and products of science and innovation in an iterative, inclusive, and deliberative way. Secondly, they couple this reflexive capital to decisions about the

[4] See Chapter 9 for more details.

[5] Anticipatory governance is a broad-based capacity extended through society that can act on a variety of inputs to manage emerging knowledge-based technologies while such management is still possible (Chapter 6).

specific goals for innovation, and how the trajectory of innovation can be modulated as it progresses in uncertain and unpredictable ways: that is, how we can collectively respond. Reflection and deliberation are, in themselves, important, but they are of real value and impact if they can inform how innovation should look different in response.

These dimensions align well with a definition of responsible (research and) innovation offered by Von Schomberg (2011a,b), which reflects a vision in which science and society are "mutually responsive to each other with a view to the (ethical) acceptability, sustainability, and societal desirability" of innovation:

> Responsible Research and Innovation is a transparent, interactive process by which societal actors and innovators become mutually responsive to each other with a view on the (ethical) acceptability, sustainability and societal desirability of the innovation process and its marketable products (in order to allow a proper embedding of scientific and technological advances in our society).

To be effective such dimensions must be institutionally embedded in and around science and innovation: they must be far more than principles. This is a significant challenge that may require a reconfiguration of how science and innovation are funded, and undertaken. But this should not be viewed as a restrictive approach that will stifle creativity and curiosity. We make no *a priori* assumptions regarding the nature, trajectory, and pace of any particular area of innovation. Rather, this should necessarily be a product of the reflexive process itself, which may speed innovation up, slow it down, or change its direction accordingly. In this way responsible innovation not only offers space for precaution, but for opportunity.

2.5 Responsible Innovation: from Principles to Practice

Although the term responsible innovation has become increasingly fashionable in recent years (and notably in European policy circles, (Owen, Macnaghten, and Stilgoe, (2012))), as a term it has a history stretching back at least a decade (Hellstrom, 2003; Guston, 2004; Barben *et al*., 2008; Owen *et al*., 2009a; Owen and Goldberg, 2010; Von Schomberg, 2011a,2011b; Lee, 2012; Armstrong *et al*., 2012: see Fisher and Rip, Chapter 9 for a brief discourse analysis). It also has a number of broader synonyms, including "responsible development" (which is, for example, one of four strategic goals of the US National Nanotechnology Initiative (NNI, 2004)). While discussions focused on responsible innovation are relatively recent, they are heirs to earlier ones over the ethical, legal, and social implications of (e.g., genomic) research, human research subjects, technology assessment, socio-technical integration, research integrity, social responsibility and the function of science, intellectual property, and the economic productivity of research (Fisher and Rip review some of these in Chapter 9). Elements of responsible innovation are also visible in science and technology policy discourse, including, for example, calls for collaborations between social scientists, natural scientists, engineers, and publics evident within the EU Framework Programme (in particular since FP5[6]; Rodriguez, Fisher,

[6] For example, "More must be done … to find ways of actively engaging with civil society, stakeholder groups and the public at large in the preparation and execution of research" (Stančič, 2007, p. 1).

and Schuurbiers, 2013), moving toward what Guston describes as "collaborative assurance," which attempts to take the societal and scientific elements of co-production more self-consciously in hand.

Arguably, the language of responsible innovation began to emerge alongside large-scale programs of nanosciences and nanotechnology research, in some jurisdictions (e.g., in the UK) heuristically framed by previous science and technology policy traumas (such as GM) and the desire to ensure that the "mistakes of GM were not repeated again." In the US, the National Nanotechnology Initiative adopted a strategic goal of "responsible development," and in Europe the European Commission developed a Code for Responsible Nanosciences and Nanotechnologies Research (European Commission, 2008). This trend has since accelerated in the emerging fields of synthetic biology and geoengineering.

If the term responsible innovation is an emergent one with a history that can be traced back many decades, then the dimensions of responsible innovation that we have described above have an equally rich history in thought, study, and practice in a number of fields, including science and technology studies, philosophy of science, science policy, and strategic innovation management. In this regard responsible innovation is evolutionary in nature.

The framework we describe brings together a number of established approaches that, in various ways, have contributed significantly to one or more of the dimensions. These recognize the need to stimulate the reflexivity of scientists, broaden the scope of strategic choices, "open up" and embed more reflective capacity into the practice of science (Rip, Misa, and Schot, 1995; Stirling, 2005; 2008; Wilsdon *et al*., 2005). Approaches such as anticipatory governance (Barben *et al*., 2008; Karinen and Guston, 2010), technology assessment in all its various formulations (constructive[7] and real time, for example; Schot and Rip, 1996; Guston and Sarewitz, 2002), upstream engagement (Wilsdon *et al*., 2005), socio-technical integration, and midstream modulation (Fisher *et al*., 2006; Fisher, 2007; Schuurbiers and Fisher, 2009) and values-sensitive design (see van den Hoven, Chapter 4) are all important foundations for, and have significant contributions to make to the concept of responsible innovation. These variously re-affirm the value of concepts of, for example, foresight, engagement, and integration (Barben *et al*., 2008). In some sense responsible innovation blatantly plagiarizes and builds on these foundations, with good justification. More applied approaches from the fields of strategic innovation management (Tidd and Bessant, 2009) and innovation studies (including concepts such as the democratization of innovation (von Hippel, 2005)) and open innovation (Chesborough, 2003) make an equally important contribution, for example, by emphasizing the role of users in innovation and the use of innovation governance mechanisms, such as stage gating, in new product development and beyond.

2.5.1 Some Experiments in Responsible Innovation

Fisher and Rip (Chapter 9) provide several examples of integrated approaches that support the concept of responsible innovation proposed above. We can also highlight one or two specific examples of experiments in responsible innovation that serve as illustrations. Each focuses on one or more responsible innovation dimensions, providing useful insights into how these could be practically taken forward.

[7] Constructive technology assessment aims to broaden technological design, development and embedding in society by including more actors, and to use insights from such actors to modulate technological dynamics (for more details see Chapter 9).

These include one experiment which, through a process of public deliberation, reflected on the purposes of research and used this reflection to frame a research funding call in the area of nanotechnology for medicine and healthcare (Jones, 2008). The public dialogues provided a clear steer about the relative priorities of six potential application areas of nanotechnology for healthcare, informing and shaping the nature of the funding call itself, such that it could respond better to social values (for more detail see Chapter 5). This example illustrates how dimensions of reflection, deliberation, and responsiveness were embedded within the process of science funding.

Another experiment asked applicants responding to a call on nanosciences for carbon capture to reflect on the wider implications of their proposed research and the applications this might lead to (Owen and Goldberg, 2010). In this case scientists were required to submit a risk register identifying the wider risks and levels of uncertainty associated with the project's activities and future impacts (be these social, environmental, health, or otherwise), who would manage these and how. This provided a useful entry point for them to consider some of the wider risks associated with their proposed research. At the same time it clearly showed the limits of an approach based solely on risk assessment, with identified risks being confined largely to health and safety associated with handling and disposal of nanomaterials in the lab, and with little considerations of the wider potential impacts on society or the environment, either for the research itself or what it might lead to. Unlike the first example, in this experiment there was little explicit reflection on the purposes of the research, but some reflection on its wider potential (if only proximal) products. This process exhibited strong, formal mechanisms of responsiveness, notably in that risk registers were evaluated as a secondary criterion by a funding panel which made recommendations as to which projects should be funded. What it also demonstrated was the imaginative capacity of some scientists and researchers to rise to the challenge of responsible innovation. While some were content with the *de minimus* requirement to submit a risk register, others embedded supplementary methods of public engagement, technology assessment, and life cycle analysis that began to explore other dimensions we have proposed.

The Socio-Technical Integration Research (STIR) program is a third example of an experiment in responsible innovation (Fisher *et al*., 2006; Fisher, 2007; Schuurbiers and Fisher, 2009; and Fisher and Rip, Chapter 9). This program has embedded social scientists and humanities scholars into over 25 laboratories on three continents with the aim of testing the viability of "midstream modulation" as an integral part of science and engineering research. Midstream modulation embeds a process which allows for the incremental adjustment of science and innovation to address social norms and values, as science and innovation actually occur. These norms and values Fisher and Rip argue are typically only addressed downstream in the process of innovation (e.g., through regulation as we have discussed), or upstream, during policy and priority setting.

The STIR program uses a protocol that unpacks social and ethical values midstream, that is, as decisions by scientists and innovators are being made, in real-time. The protocol introduces social scientists and humanities scholars into laboratory settings and takes the interdisciplinary collaborators (i.e., natural and physical scientists) through an iterative set of questions designed to probe capacities for responsible innovation (Table 2.1).

As a result of using the protocol on a regular basis during routine laboratory decision-making, STIR laboratory engagements have documented "productive research disruptions" that have led to changes in research direction, experimental design, safety and

Table 2.1 *STIR protocol decision components for "midstream modulation"*

Decision component	Critical question	Capacity built
Opportunity	*What* are you working on?	Reflexive
Considerations	*Why* are you working on it?	Reflexive, deliberative
Alternatives	*How* could you approach it differently?	Responsive
Outcomes	*Who* might be affected in the future?	Anticipatory

environmental practices, and public outreach, that is, the dimension of responsiveness. These changes are voluntary, since the lab researchers choose whether or not to make them, integrative, since they expand the perception of both social values and technical options that are considered, and collaborative.

By way of one final example, Macnaghten and Owen (2011) describe an experiment in the controversial and emerging field of climate engineering research, whereby the dimensions of responsible innovation were embedded within a "stage gating" model of innovation governance, originally drawn from strategic innovation management, but applied in a novel way in this context. Climate engineering embodies a range of potential approaches that are broadly aimed at either carbon dioxide removal from the atmosphere or solar radiation management (SRM) (reflecting incoming solar radiation to reduce air temperature) Royal Society (2009). Research in this area is now being undertaken, and one such project (the SPICE – or Stratospheric Particle Injection for Climate Engineering project) aimed to evaluate candidate particles for SRM, identify feasible ways of delivering particles into the stratosphere, and undertake modeling to understand efficacy and effects, noting that volcanic eruptions of sulfate particles (e.g., Mount Pinatubu in 1991) have been associated with significant, if transitory, decreases in global air temperature.

The project embedded a proposed field trial of a potential particle delivery technology, in which the project team would investigate the dynamics of a 1 km balloon-tethered hose that would spray only water. This would inform the design of a future 20 km high delivery system. The test bed would not undertake any climate engineering itself, but was highly symbolic and attracted significant media interest and a broad range of opinions, including widespread resistance from civil society groups. Before making a decision on whether to allow the field trial to go ahead, the UK Research Councils who funded the project employed a stage gate model of innovation governance, in which we embedded the dimensions of responsible innovation discussed above (Macnaghten and Owen, 2011). Stage gating is a well-established mechanism of innovation management (originally designed for new product development) whereby decision points are periodically introduced into the R&D process, which is thus phased in terms of investment. Traditionally, inputs into each decision gate are technical and market-based considerations of feasibility, market potential, and so on. The stage gate approach was broadened to include the dimensions of responsible innovation described above (Figure 2.1).

The SPICE team were asked to anticipate, reflect, and deliberate (with publics and stakeholders) on the purposes and possible impacts of both the research, and what it could lead to. An independent stage gate panel evaluated their responses and in turn advised the funders on whether, and if so, how to proceed. This evaluation was made in terms of five criteria into which the dimensions of responsible innovation were translated. These were that the test-bed deployment was safe and principal risks had been

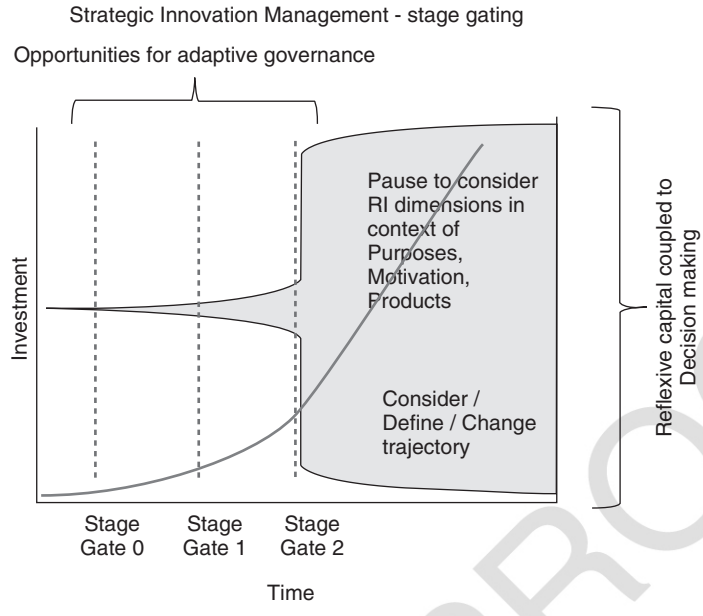

Figure 2.1 *Embedding dimensions of responsible innovation within a stage gating innovation governance model*

identified, managed, and deemed acceptable (Criterion 1); the test-bed deployment was compliant with relevant regulations (Criterion 2); the nature and purpose of SPICE would be clearly communicated to all relevant parties to inform and promote balanced discussion (Criterion 3); future applications and impacts had been described, and mechanisms put in place to review these in the light of new information (Criterion 4); and mechanisms had been identified to understand public and stakeholder views regarding the potential applications and impacts (Criterion 5).

The last three of these criteria were not met fully and the panel advised the Research Councils to delay the test bed to allow these to be addressed, notably to allow a full package of stakeholder engagement to be undertaken and the wider social and ethical issues to be explored. As a result of deeper questioning that followed, and in particular as this related to the purposes and motivations of the research, issues of patenting and commercialization surfaced and the SPICE project team chose to abandon the test bed, concentrating instead on the laboratory and modeling aspects of the research, and (critically) stakeholder engagement.

What these examples demonstrate is that there are in fact numerous ways of implementing the dimensions of responsible innovation, and that as an approach it should not be strongly prescriptive, or rules based in its implementation (Richardson, 1999). Beneath the general framework researchers, innovators, and those who fund them should have flexibility in the details of how its dimensions are taken forward, in creative and imaginative ways that suit its context of application best and that they themselves value.

In summary, responsible innovation coalesces and integrates a number of complementary approaches under a coherent framework. But can it be really any more than a carefully – sewn quilt made up of a patchwork of such previous incarnations?

Owen, Macnaghten, and Stilgoe (2012) distinguish three distinct, emergent features of responsible innovation, the first two of which are strongly evolutionary in nature. The first, as we have discussed, is an emphasis on science and innovation for society – a focus on purposes, where research and innovation are targeted at societal challenges and the "right impacts," underpinned by a deliberative democracy. The second, linked to the first, is an emphasis on science and innovation with society – a focus on the need for research and innovation to be responsive to society in terms of setting its direction, and in modulating its trajectory in the face of the uncertain ways innovation invariably unfolds as part of its naturalization in the world. While many approaches to date have embedded one or more of the dimensions of responsible innovation described above, few have embedded all, institutionally, systematically and iteratively, around the processes of science and innovation in a way that supports reflection on their purposes and products, and enables responsiveness through effective mechanisms of governance. Responsible innovation calls for institutionalized responsiveness, for the coupling of anticipation, reflection, and deliberation to action. Or as Guston and Sarewitz (2002) put it "the key to successfully grappling with unpredictability is to build a decision process that is continuously reflexive, so that the attributes of and relations between co-evolving components of the system become apparent, and informed incremental response is feasible." The strength of a framework for responsible innovation lies in the integration and application of such approaches as an institutionally embedded culture, one in which the total becomes far greater than the sum of its parts.[8]

These two features, as we have already noted, build on trends toward challenge-led research (Lund Declaration, 2009), and socio-technical integration (Fisher *et al*., 2006; Barben *et al*., 2008). The third feature is perhaps more novel, being encapsulated in the explicit linking of research and innovation to responsibility, the "responsible" in responsible innovation (Grinbaum and Groves, Chapter 7). This is currently lacking from both theoretical approaches, and more applied ones such as strategic innovation management (Tidd and Bessant, 2009). It is prompting a re-evaluation of the concept of responsibility as a moral and philosophical social ascription, in the context of innovation as a future-oriented, deeply uncertain, often complex and always collective phenomenon. This in turn is challenging scientists, innovators, business partners, research funders, policy makers and (not least) those who use, benefit from, and are burdened by innovation to reflect on their own roles and responsibilities.

2.6 Toward the Future: Building Capacity for Responsible Innovation

In this chapter we have developed a framework for responsible innovation, based on four dimensions, and grounded in a prospective model of responsibility that emphasizes dimensions of care and responsiveness. We have emphasized that this must be able to reflect on both the products and purposes of science and innovation. We have been reminded of the rich history in a number of fields of study, both theoretical and applied, which make a significant and important contribution both to the framing and definition

[8] The move toward more integrative projects has been catalyzed by some research councils, for example, in Norway (Research Council of Norway) and The Netherlands (Maatschappelijk Verantwoord Innoveren (Responsible Innovation) program: www.nwo.nl/responsible-innovation.

of responsible innovation, and to how this is translated through the dimensions into practice. The chapters that follow in the book provide further perspectives on, and specific details regarding, individual dimensions and attendant methodologies (e.g., Sykes and Macnaghten, Chapter 5).

We now conclude with some closing thoughts on implementation, on how the embedding of responsible innovation as a genuinely transformative and constructive[9] approach can be supported. First of these is the important question concerning which areas and kinds of science and innovation such an approach should be targeted at. We have already alluded to this in the introduction, but it is worth laboring here as it is a question that frequently surfaces. There is clearly a wide spectrum between curiosity–driven science and applied research and development, between Francis Crick and James Watson developing models of DNA at the Cavendish Laboratory in Cambridge in the 1950s, and the development of genetically modified "Round Up–ready" seeds by Monsanto decades later.

Ultimately, the decision of when to employ such a framework will be a judgment call, and it is clear that for some areas of, for example, purely descriptive science there may be little impetus to do so, at least until more specific areas of application become envisioned. But once such visions become plausible (and fundable) our experiences demonstrate the need for such a framework to be considered early on, such that it is embedded from the outset, rather than bolted on, or retro-fitted at a later stage. Von Schomberg (this volume) provides some cautionary examples of technologies that have been pushed in the absence of such an approach and the consequences that have resulted. In the case of the SPICE project described above, for example, this should have been initiated before the launch of the geoengineering funding call, at the time when research funders were considering whether to put resource into this area of science. Efforts to engage publics and stakeholders in areas of controversial and contested science and innovation are likely to be viewed at best as being disingenuous if these are perceived as being simply a way to smooth the pathway of technologies into society in an instrumental way, and they will rightly be suspicious of the motivations. Such deliberation must be extended to decisions as to whether such areas should be commissioned at all.

The expectations of responsible innovation should also be clear to all (Lee and Petts, Chapter 8), and the ability to rise to such expectations supported and resourced accordingly. Our second observation then relates to the concept of capacity. Responsibility is a learned behavior: our children are not born with the capacity to be responsible, or to take responsibility. It is a social ascription that is learned, and we go to some lengths to teach them responsible behavior, to understand the norms and contours of responsibility, before we let them make their independent way in the world. Capacity for responsible innovation must be nurtured, across and within our institutions of science and innovation. Education and training are key to this, supporting the development of the necessary multi- and inter-disciplinary competencies that allow and support the responsible innovation approach we have described (McGregor and Wetmore, 2009). This must be sensitive to cultural differences that exist within and beyond higher education institutions, research institutes, and companies, and that in turn reflect the globalized nature of modern society, and of science and innovation itself (Lee and Petts, Chapter 8).

[9] Note that by the term constructive we do not mean instrumental.

This leads us to our third observation, one which we have already touched on in this chapter. Responsible innovation is ultimately about being responsible, taking responsibility, and innovating responsibly: but this is a collective endeavor. Scientists and innovators play an important role, but responsible innovation must be a holistic approach across the innovation ecosystem, with an important role for universities, institutes, and research funders to play. This stresses the need for co-responsibility (Mitcham, 2003; Von Schomberg, 2007). In this complex landscape where governance is a seemingly insurmountable challenge, those who fund and manage research in our places of learning and in our innovative companies are uniquely placed to help define, and implement, the contours of responsible innovation, to institutionally embed the framework we have proposed.

Fourthly, responsible innovation must be a continuous, iterative process of learning, one that is embedded in and around science and innovation, one which integrates expertise and understanding and invites in perspectives from stakeholders and publics. But as an innovation itself, responsible innovation must abide by its own framework in this regard, and be anticipatory, reflective, deliberative, and responsive in its constitution and implementation. Its own purposes, intentions, and motivations must be clear. We have argued elsewhere that it should be undertaken for substantive and normative, rather than purely instrumental reasons (Owen, Macnaghten, and Stilgoe, 2012). It must also be able to respond to the inevitable resistance such a framework will encounter if it is perceived as posing threats to scientific freedom or national interests – from economic growth to scientific competitiveness. These are not insurmountable challenges. If such challenges can be responded to, and if a framework for responsible innovation can be developed inclusively in a way that supports genuine culture change, perhaps then it might open up new possibilities for science and innovation and support their democratic, and responsible, emergence in society.

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