Sci Eng Ethics
DOI 10.1007/s11948-013-9480-1

ORIGINAL PAPER

"Broader Impacts" or "Responsible Research and Innovation"? A Comparison of Two Criteria for Funding Research in Science and Engineering

Michael Davis · Kelly Laas

Received: 26 June 2013 / Accepted: 8 October 2013

Abstract Our subject is how the experience of Americans with a certain funding criterion, "broader impacts" (and some similar criteria) may help in efforts to turn the European concept of Responsible Research and Innovation (RRI) into a useful guide to funding Europe's scientific and technical research. We believe this comparison may also be as enlightening for Americans concerned with revising research policy. We have organized our report around René Von Schomberg's definition of RRI, since it seems both to cover what the European research group to which we belong is interested in and to be the only widely accepted definition of RRI. According to Von Schomberg, RRI: "… is a transparent, interactive process by which societal actors and innovators become mutually responsive to each other with a view to 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)." While RRI seeks fundamental changes in the way research is conducted, Broader Impacts is more concerned with more peripheral aspects of research: widening participation of disadvantaged groups, recruiting the next generation of scientists, increasing the speed with which results are used, and so on. Nevertheless, an examination of the broadening of funding criteria over the last four decades suggests that National Science Foundation has been moving in the direction of RRI.

M. Davis (✉)
Humanities Department, Center for the Study of Ethics in the Professions, Illinois Institute of Technology, 5300 S. South Shore Drive #57, Chicago, IL 60615, USA
e-mail: davism@iit.edu

K. Laas
Center for the Study of Ethics in the Professions, HUB 204, 3241 S. Federal Street, Chicago, IL 60616, USA
e-mail: laas@iit.edu

Published online: 24 October 2013

Keywords Research policy · RRI · Societally desirable research · Social responsibility · RCR

Our subject is how the experience of the United States (US) with a certain funding criterion, "broader impacts", and some similar criteria, may help in efforts to turn the European concept of Responsible Research and Innovation (RRI) into a useful guide to funding Europe's scientific and technical research. We believe this comparison may also be enlightening for Americans concerned with making research socially more responsible.

We have organized our report around René Von Schomberg's definition, since it seems both to cover the ground that interests the European research group to which we belong and to be the only widely accepted definition of RRI (Owen et al. 2012). According to Von Schomberg (2013), RRI

> … is a transparent, interactive process by which societal actors and innovators become mutually responsive to each other with a view to 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).[1]

We shall soon analyze the broader impacts criterion. But before we can usefully do that, we must provide some background on the federal agency that developed it, the National Science Foundation (NSF), including a brief history of NSF's struggle to get the criterion applied properly. Having done that, we offer a revised version of Von Schomberg's definition. We do that in part to "translate" it into useable American, but in part too to clarify it. We then briefly survey some similar criteria that other US funding agencies, private as well as public, have developed. Our conclusion is that a general criterion with examples (whether of goals or activities) is better than more specific criteria or a single general definition.

Background of Broader Impacts

National Science Foundation is an agency of the US federal government that supports fundamental research and education in all *non-medical* fields of science

[1] The only published alternative to this definition seems to be:

> Responsible Research and Innovation refers to ways of proceeding in Research and Innovation that allow those who initiate and are involved in the processes of research and innovation at an early stage (A) to obtain relevant knowledge on the consequences of the outcomes of their actions and on the range of options open to them and (B) to effectively evaluate both outcomes and options in terms of moral values (including, but not limited to wellbeing, justice, equality, privacy, autonomy, safety, security, sustainability, accountability, democracy and efficiency) and (C) to use these considerations (under A and B) as functional requirements for design and development of new research, products and services. (Directorate-General 2013, 55–56)

We think the Directorate-General definition differs little in substance from Von Schomberg's shorter and simpler version (though it does avoid some of the problems we find in Von Schomberg's).

and engineering.[2] Its medical counterpart is the National Institutes of Health (NIH). With an annual budget of about $7 billion (fiscal year 2012), NSF supports approximately a fifth of all federally supported *basic* research conducted in US institutions of higher learning.[3] In some fields, such as mathematics, computer science, economics, and the social sciences, NSF is the major source of federal funds. Although many other federal research agencies, including NIH, operate their own laboratories, NSF does not. Instead, it fulfills its mission almost entirely by distributing competitive, limited-term grants in response to specific proposals from researchers (NSF 2012).

National Science Foundation received about 50,000 such proposals in 2012, funding about 11,000 of them. Funded proposals are typically those ranked highest by "peer reviewers", though NSF's own program officers make the final selection. The peer reviewers are NSF-recruited independent scientists, engineers, and educators who are experts in the relevant field. Reviewers cannot work at NSF or for an institution that employs those proposing research on which the reviewer must pass. All evaluations of proposals are confidential. While reviewers see the names, institutions, credentials, and budgets of those proposing research, those proposing do not see the names of reviewers (but can see the evaluations). Both peer reviewers and program officers are supposed to base their decisions on NSF's published criteria (NSF 2012).

Between 1981 and 1997, NSF had four funding criteria: *research competence*; *merit of the research*; *utility*; and *effect on infrastructure* (NSF 1995). In 1997, NSF replaced those four criteria with two: *intellectual merit* and *broader impacts.* This change might reasonably be judged to have achieved two purposes. The first was simplification, reducing the first two of the old criteria (competence and merit) to one (intellectual merit) and reducing the second two (utility and effect on infrastructure) to one (broader impacts) (Rothenberg 2010). But the change might also be judged to have broadened the utility-infrastructure criteria considerably (depending on how "utility" and "infrastructure" had been interpreted before).

There was good reason for changing the criteria. Surveys of NSF reviewers conducted in 1991 and of NSF program officers in 1995 showed that most reviewers ignored at least one of the four criteria, with the third and fourth (utility and infrastructure) being the ones most likely to be ignored. The chief reason offered for ignoring those two was that they were not clear. The new term "broader impacts" was to provide the missing clarity (Rothenberg 2010). Starting in 1997, the second criterion was:

What are the broader impacts of the proposed activity?

- How well does the activity advance discovery and understanding while promoting teaching, training, and learning?

[2] Actually, this is not quite right—or is quite right only given a certain understanding of "science". For example, NSF does not typically fund research in criminal justice science, library science (except digital libraries), or animal husbandry, but does fund work in philosophy and history of science.

[3] This amount, though large, is small compared to the overall federal spending on research. NIH alone spends about $30 billion a year on medical research (NIH 2012).

- How well does the proposed activity broaden the participation of underrepresented groups (e.g., gender, ethnicity, disability, geographic, etc.)?
- To what extent will it enhance the infrastructure for research and education, such as facilities, instrumentation, networks and partnerships?
- Will the results be disseminated broadly to enhance scientific and technological understanding?
- What may be the benefits of the proposed activity to society?

If this new criterion achieved more clarity than its predecessors, it certainly did not achieve enough. When NSF reviewed the new criterion after 14 years of experience, it found both reviewers and program officers critical of it.[4] There seemed to be two lines of ideological criticism.

One line, originating within the research community, especially among mathematicians, emphasized the need for science to follow its own internal logic. The broader impact of science is (it was argued) unpredictable in detail but certain in gross. Too close a connection between what politicians want and what gets funded will actually defeat the purpose of funding fundamental research—that purpose being to benefit from the unpredictability of such research. The US might as well close NSF and give its funding to the agencies of applied research as seek to direct NFS's research into economically productive channels. The US has many agencies of applied research—the Environmental Protection Agency (EPA), the National Oceanic and Atmospheric Administration (NOAA), the Office of Nuclear Regulatory Research, the Defense Advanced Research Projects Agency (DARPA), and so on. NSF is supposed to be different from these, to be the only federal agency supporting fundamental (non-medical) scientific and engineering research because that research advances the "frontiers of knowledge" (Holbrook 2012). Indeed, for the first three decades of its existence, NSF did not fund engineering research, deeming it not fundamental enough. This discrimination against engineering research may now surprise even those unaware that the leader in efforts to establish NSF as the agency of "basic research" was Vannevar Bush, an engineer rather than a scientist (Rothenberg 2010).

The other line of ideological criticism, originating in Congress, emphasized the need for fundamental research to repay the public investment. Not only was NSF established in 1950 to "promote the progress of science" but also "to advance the national health, prosperity, and welfare; and to secure the national defense". That remains its official mission (NSF 2012). Thus, NSF's mission has always included certain broader impacts: advancing the national health, prosperity, and welfare; and securing the national defense. The controversy, if there is one, must be over how best to achieve those broader impacts (Hellström and Jacob 2012). Merely letting science follow its own internal logic is a strategy already abandoned by 1981, if not long before, though (it seems) without any evidence that the strategy had failed (Rothenberg 2010).

In addition to these two lines of ideological criticism, there were several more practical criticisms. The most important of these was that both applicants and reviewers tended to interpret the bulleted items under the general question as

[4] The data appear in Appendix C of NSF (2011), a report of over 300 pages (providing many insights into the entire process of re-formulating the broader-impacts criterion).

requirements ("a check list") all of which must be satisfied rather than as five examples of broader impacts. Interpreting the bulleted items as requirements achieved clarity at the expense of research that NSF might want to fund, for example, in mathematics or astrophysics (NSF 2011, 8).

Acknowledging the force of these criticisms, NSF initially proposed the following compromise. The purpose of the criterion of "broader impacts" is to:

Ensure the consideration of how the proposed project advances a national goal(s).[5] Elements to consider in the review are:

1. Which national goal (or goals) is (or are) addressed in this proposal? Has the PI presented a compelling description of how the project or the PI will advance that goal(s)?
2. Is there a well-reasoned plan for the proposed activities, including, if appropriate, department-level or institutional engagement?
3. Is the rationale for choosing the approach well-justified? Have any innovations been incorporated?
4. How well qualified is the individual, team, or institution to carry out the proposed broader impacts activities?
5. Are there adequate resources available to the PI or institution to carry out the proposed activities? (NSF 2011, 264–265)

National Science Foundation hoped this list of questions (combined with its deflationary preamble "elements to consider") would avoid the impression both of requirements and of any supposition that NSF expected reviewers or program officers to predict the broader impacts of fundamental research in detail. The list supposed only that reviewers and program officers could evaluate ("consider") whether a proposal's choice of broader impact was designed to serve a national goal, whether the resources available seemed adequate to carry out the design, how well-justified the design was, and whether the qualifications of those involved were sufficient. Such evaluations required little knowledge beyond what is required for

[5] The first version of the proposed revised merit criterion (NSF 2011, 264) provided the following information about "national goals":

Collectively, NSF projects should help to advance a broad set of important national goals, including:

- Increased economic competitiveness of the United States.
- Development of a globally competitive STEM workforce.
- Increased participation of women, persons with disabilities, and underrepresented minorities in STEM.
- Increased partnerships between academia and industry.
- Improved pre-K–12 STEM education and teacher development.
- Improved undergraduate STEM education.
- Increased public scientific literacy and public engagement with science and technology.
- Increased national security.
- Enhanced infrastructure for research and education, including facilities, instrumentation, networks and partnerships.

Note that even this long list is not exhaustive. The nation's goals simply "include" these. Note too that NSF projects are to advance these goals "collectively". There is no requirement that any particular project advance any of these goals. The list is much the same as the "goals" in the America COMPETES Reauthorization Act of 2010 (H.R. 5116), Sec. 526.

evaluating intellectual merit (which had a list of questions almost identical) (NSF 2011, 13).

This compromise statement received considerable criticism, but mostly of detail, leading to several revisions. Among the revisions was the substitution of the more general "societal goals" for "national goals".[6] The story is well-told in Holbrook (2012). The result of the revisions is the criterion discussed below (formally unchanged but explained somewhat differently).

We must now turn to RRI. How does it resemble the criterion of broader impacts? How does it differ?

Problems with Von Schomberg's Definition

While there is nothing wrong with Von Schomberg's English, there seem to be features of the European context that make it hard for Americans to understand Von Schomberg's definition. The American term "responsible conduct of research" (RCR) is misleadingly similar to RRI in appearance. In fact, RCR is both narrower than RRI and covers somewhat different topics. RCR is not about innovation or marketable products but simply about avoiding certain kinds of misconduct in research (plagiarism, falsification, harm to human subjects, and so on). It is (more or less) the American term for the principles of the "Singapore Statement on Research Integrity" (Singapore 2010).

Even "broader impacts", the American term much closer to RRI in content, has, as we shall see, a quite different emphasis. We will therefore use the rest of this section to bring out our difficulties with Von Schomberg's definition. We believe our difficulties signal assumptions that Europeans may want to reconsider. Von Schomberg's definition may need the refinements we suggest even to be maximally useful in its European context.

We can summarize our difficulties with Von Schomberg's definition as five "problems". The first is the definition's emphasis on "innovation process" and "marketable products". There is no mention of "knowledge". The nearest Von Schomberg comes to talking of "knowledge" is the parenthetical "embedding…*scientific*…*advances* in our society". While "scientific advances" might be knowledge, they might equally well be something else, for example, procedures for extracting DNA from one cell and placing it in another. The reason absence of any mention of "knowledge" is a bar to translating RRI into American is that NSF exists primarily "to advance, if not transform, the frontiers of knowledge" (See, for example, NSF 2011, 1). The definition of "broader impacts" refers back to the knowledge generated by the projects that NSF funds. The broader impacts are

[6] The substitution of "societal" for "national" seems to have been a way to provide more free-play in the choice of impacts to pursue (since there was no Congressional definition of "societal goals" as there was of "national goals"). For those with an ear for language, the question might arise: Why "societal" rather than the shorter and older "social"? There is no official answer. The best guess is that "societal" suggests "society" while "social" also suggests "socialize", "sociable", "socialism", and other ideas slightly less appropriate.

supposed to flow from, or at least complement, the advance of knowledge. So, for example, the latest definition of "broader impacts" reads:

> NSF projects, in the aggregate, should contribute more broadly to achieving societal goals. These "Broader Impacts" may be accomplished through the research itself, through activities that are directly related to specific research projects, or through activities that are supported by, but are complementary to, the project. (NSF 2011, 1)[7]

There is no mention of "innovative processes" or "marketable products" in that definition. Of course, there is a hope, indeed, an expectation, that NSF funding will overall ("in the aggregate") benefit society ("achieve societal goals"), an expectation combined with specific initiatives to help fundamental research do exactly that. For example, NSF has a program of supplementary grants, "I-Corps" ("Innovation Corps"), designed to provide a successful researcher with entrepreneurial training and a mentor to help the researcher investigate any commercial prospects the research might have.[8] But, except for these special programs, whatever societal good is to follow from NSF's ordinary grants is to follow from advancing the "frontiers of knowledge". There is no requirement that the broader impacts of research include an "innovative process" or "marketable product".

Our second problem with Von Schomberg's definition is the phrase "the innovative process and its marketable products". Von Schomberg's explanation of the phrase left us puzzled. On the one hand, he promised to "contrast the process of modern innovations with mere technical inventions" (Von Schomberg 2013). This promise suggests that the innovations in question are not (or, at least, should not be) "mere technical inventions". On the other hand, Von Schomberg asserted that "modern innovations are distributed through market mechanisms whereby property rights allow, in principle, the further improvement of the innovations by other market operators over time" (Von Schomberg 2013). This assertion makes "innovations" sound very much like mere technical inventions (for example, the computer or cell phone). Or, at least, it does if we understand "technical inventions" (as seems reasonable to us) as useful artifacts, processes, or formulae new to the world but designed to help people and things work together better. In the end, as far as we can see, Von Schomberg offers *no* definition of "innovation" (or "invention"). We may then fall back on our common-sense notion of "innovation"—roughly (in the definition's own parenthetical phrasing) "scientific and technological advances" (something much closer to NSF's "knowledge", which includes such innovations as proving the existence of the Higgs boson).

---

7 Almost identical language appears in NSF (2013), Chapter II.C.2.d (the Guide to those proposing research). This is a definition only in the sense that it sets some limits on what counts as broader impact (contribution to societal goals by the research itself or some auxiliary activities).

8 http://www.nsf.gov/news/special_reports/i-corps/program.jsp (accessed May 1, 2013). This is one of many efforts to build on the Bayh–Dole Act of 1980 (a.k.a. Patent and Trademark Law Amendments Act). Codified as 35 U.S.C. § 200–212, and implemented by 37 C.F.R. 401, that legislation permits a university, small business, or non-profit institution to pursue ownership of a federally funded invention (rather than, as had been the practice, letting it fall into the public domain). The idea was that private ownership would speed the movement of scientific advance into practical application. http://en.wikipedia.org/wiki/Bayh%E2%80%93Dole_Act (accessed April 24, 2013).

That brings us to our third problem. We don't understand why the "innovative process" that RRI is to govern must always (or even typically) end in "*marketable* products". After all, at least one of the products Von Schomberg discusses as a failure of RRI, the Dutch electronic patient record system (EPRS), seems *not* to have been a "marketable product" or even, had it been successful, to have been likely to terminate in a "marketable product".[9] While the market is an important means of distributing innovations, it is not the only one. Market failure may require government or private non-profit organizations to undertake distribution instead. There seems to be no reason to define RRI as if the market were the only way to embed scientific or technical advances in society.[10]

Our fourth problem concerns the phrase "(ethical) acceptability, sustainability and societal desirability". Why, we wondered, is the phrase *not* "societal desirability, including sustainability and ethical acceptability"? Both sustainability and ethical acceptability seem to be societally desirable outcomes of the innovation process, making "societal desirability" the general category, not an independent category (as the definition suggests). We would understand the need to treat the three categories as distinct if Von Schomberg had used "societally desir*ed*" instead of "societally desir*able*" (that is, made that criterion equivalent to "achieving societal goals"). Society might in fact not desire sustainability or ethical acceptability, however societally desirable they are. But, having chosen "desirable" over "desired", Von Schomberg has only one reason to mention "sustainability" and "ethical acceptability", that is, because they are outcomes too important to "go without saying" (and, perhaps, nothing else is). But, if they deserve mention for that reason, then the best way to mention them is by stating openly that they are *included*, not by putting them first and second on a list that, terminating with "societal desirability", invites the question, "Why are sustainability and ethical acceptability not societally desirable?"

Our fifth problem with Von Schomberg's definition concerns the final phrase "in *our* society". We are bothered by that "our". Von Schomberg's definition seems to say that RRI need not protect societies other than Europe (the natural referent of "our" in any discussion of criteria for funding European research). But it seems obvious (to us, at least) that neither research nor innovation can be responsible if it does not take into account its desirability for any society in which it will actually be embedded—even if that society is outside Europe. We also gather from what Von Schomberg said that he actually thinks Europeans have a responsibility to fund

9 The point here is not that EPRS could not have been a marketable product in a different environment—as Google Health was supposed to be—but that, even though it was in fact not developed as a marketable product (but as something the public health system would use), it served Von Schomberg well, allowing him to make all the points he wished concerning RRI. It did not have to be a markable produce to elucidate RRI.

10 Interestingly, NSF now uses "products" to include "publications, data sets, software, patents, and copyrights" [NSF 2013, B.2.i(c)]. Since "publications" generally appear in journals or as books that publishers market, even publications would seem to count as "marketable products" (for NSF). So (in the American context at least), not only does "marketable products" leave out products Von Schomberg should include in RRI (those that are useful but not marketable) but also to include some products he may not intend (those marketable products that simply consist in scientific publications). "Product" is another term in need of clarification if it is to be used more narrowly than NSF does.

research that, while not directly benefiting "our society", will help societies outside Europe, for example, by providing vaccines for diseases endemic in Africa but not in Europe. Von Schomberg's definition of RRI thus seems to exclude certain obvious and important groups having a large stake in European research. The definition is ethnocentric in a way Von Schomberg seemed not to have intended.

Revised Definition

For purposes of this article, the best way to resolve these five problems seems to be to revise Von Schomberg's definition in some such way as this:

> *Responsible Research and Innovation* (RRI) is a transparent, interactive process by which researchers, innovators, and other societal actors become mutually responsive to each other with a view to embedding scientific and technological advances in society in societally desirable ways (including, but not limited to, ways that are sustainable and ethically acceptable).

This revision is not only shorter than the original and clearer but, we believe, is also at least as consistent with Von Schomberg's discussion of RRI. If so, then the fundamental elements of RRI are:

1. *Transparent, interactive processes* RRI is not an outcome but a process, one marked by the ease with which outsiders can both understand what is going on in research and innovation ("transparent") and contribute to them ("interactive"). The contribution need not be, and indeed should not be, merely near the end of the process (as in traditional "technology assessment"). All else equal, the earlier outsiders are brought into the process, the better informed they are, and the more continuously involved, the more responsible the research and innovation is. RRI envisions a discussion between researchers, innovators, and other societal actors beginning, perhaps, with the first step in designing fundamental research and ending well after any resulting innovation has been implemented.
2. *Researchers, innovators, and other societal actors* The outsiders with whom researchers and innovators are to work are "*other* societal actors", that is, government, business, end-users, and similar "stakeholders" (and perhaps non-stakeholders such as experts or members of the public who enjoy thinking about scientific and technological advances).[11] RRI is, in part, a process intended to blur the line between researchers, innovators, and all the rest. RRI does not seem to recognize any limits on who may participate in research.
3. *Scientific and technological advances* Both "research" and "innovation" are general terms. There is research in architecture, journalism, law, marketing, religion, and so on. The same is true of "innovation". Such research and innovation are, however, not our concern. The term "RRI" is to be limited to research and innovation that is scientific or technological. These terms

[11] We added "other" to Von Schomberg's "societal actors" because researchers and innovators are, of course, societal actors too. Even "pure science" is a societal activity.

("scientific" and "technological"), though general as well, are somewhat less general than are "research" and "innovation" and, in the context of the funding agencies with which we are concerned, should be specific enough not to give much trouble. In this context, the term "advances" includes inventions and other technical achievements (such as a water treatment plant or system for storing health records) as well as additions to scientific or technical knowledge (whether propositional knowledge, such as knowing that the Higgs boson exists, or know-how, such as knowing how to use the Large Hadron Collider to take photos of a Higgs boson). We assume that medical knowledge is scientific or technical in the European context (though not, according to NSF, in the American).

4. *With a view to embedding the advances in society* RRI does not, *at first glance*, seem to include "pure research"—research that has little or no expectation of ending with practical applications, that is, products embedded in some society or other. RRI is about research and innovation that has the potential to help or harm people.[12] But an important question is left open: "Help or harm people *how*?" For example, is research responsible if it only helps to satisfy public curiosity, say, about the diameter of the visible universe or the logic of impossible worlds? If so, then RRI might include some, perhaps much, pure research (depending on what the public is curious about).
5. *In societally desirable ways* Helping people is, all else equal, societally desirable; harming them is not. So, one objective of RRI is to assure that scientific and technical research and innovation will, all else equal, help people rather than harm them. RRI seeks to direct funding to morally permissible ("ethically acceptable") research and innovation likely to benefit humanity overall. The benefit should be "sustainable", of course—that is, designed to be justly distributed among the present generation while not diminishing the prospects of future generations. Justice too is societally desirable, all else equal; injustice is not. If a society's actual goals may, all else equal, be treated as an approximation of what is societally desirable, we can guess that the desirable goals of European society include (but are not limited to): improved well-being of individuals, improved security, increased economic competitiveness, and enhanced infrastructure for research and education (In fact, Von Schomberg suggested that such goals should derive either from Europe's "grand challenges", for example, climate change, or from its constitutional values, since both derivations have democratic legitimacy).

We must now consider how the NSF's criterion of broader impacts corresponds to RRI so understood.

[12] I am assuming that among the reasons to desire RRI is to avoid the harms scientific and technical advances might impose, such as the loss of privacy or the destruction of the environment. Of course, some research, especially military research, is meant to do harm (to some people). I ignore such research here because it does not seem to be within the bounds of RRI—just a military research is not within NSF's mandate. RRI is, it seems, about certain research compartments, not all. There is a need for the Europeans to be much more explicit about what sorts of research and innovation is outside the bounds of RRI.

Broader Impacts

Effective January 14, 2013, NSF implemented revised merit review guidelines based on a recent National Science Board (NSB) report (NSF 2011).[13] While the merit review criteria remained unchanged from those established in 1997 (intellectual merit and broader impacts), the guidelines sought to clarify and improve the way they function. We may ignore changes concerned with intellectual merit. What is important here are changes in the guidelines for "broader impacts".

After making it clear (as before) that broader impacts may be accomplished through the research itself as well as through auxiliary activities, the instructions add that "NSF values the advancement of scientific knowledge *and* activities that contribute to the achievement of societally relevant outcomes" (NSF 2013, italics ours). Since this sentence appears in the paragraph explaining what is meant by "broader impacts", we must read it as stating two independent propositions: first, that NSF values the advancement of scientific *knowledge* that contributes to the achievement of societally relevant outcomes, one sort of broader impact; and second, that NSF values *activities* that contribute to the achievement of societally relevant outcomes (even if the activities in question do not themselves advance scientific knowledge), another sort of broader impact. This reading is partially confirmed by the list of examples that follow immediately (the successor to "national goals"):

> Such outcomes include, but are not limited to: full participation of women, persons with disabilities, and underrepresented minorities in science, technology, engineering, and mathematics (STEM); improved STEM education and educator development at any level; increased public scientific literacy and public engagement with science and technology; improved well-being of individuals in society; development of a diverse, globally competitive STEM workforce; increased partnerships between academia, industry, and others; improved national security; increased economic competitiveness of the United States; and enhanced infrastructure for research and education. (NSF 2013, 14)

Of the nine examples given, all (or, at least, most) seem independent of any advance in scientific knowledge that a particular project might achieve. Thus, full participation of women, persons with disabilities, and underrepresented minorities might be achieved through a project that only improves scientific literacy or only enhances infrastructure for research or education. It is the first criterion (intellectual

[13] The NSB consists of the NSF director and twenty-four ordinary members appointed by the President of the United States and confirmed by the United States Senate. The NSB meets six times a year to establish NSF's overall policies within the framework of applicable national policies set by the President and Congress. The Board also serves as an independent policy advisory body to the President and Congress on science and engineering research and education and has a statutory obligation to "render to the President and to the Congress reports on specific, individual policy matters related to science and engineering and education in science engineering, as the Board, the President, or the Congress determines the need for such reports," and to "render to the President and the Congress no later than January 15 of each even numbered year, a report on indicators of the state of science and engineering in the United States." [42 U.S.C. Section 1863, Sec.4.(j)(1–2)] The NSF's director is also responsible for administration, planning, budgeting, and day-to-day operations of the foundation.

merit), not the second, that assures that a project is likely to advance scientific or technical knowledge. The problem that the would-be principal investigator faces when drafting a proposal is how to combine an activity having enough intellectual merit with one or more activities or outcomes having enough broader impact. Both criteria must be satisfied but satisfying one a lot may help to win funding for a proposal that does not do such a good job with the other.

So read, we may identify three important similarities between RRI and the criterion of broader impacts:

1. *Societally desirable* NSF apparently has a conception of science, technology, engineering, and mathematics as working to achieve "societally relevant outcomes"—presumably outcomes "relevant" in a positive way, that is, outcomes society should desire (even if it does not). Both RRI and broader impacts seek science and innovation that serve society.
2. *Process* There is in both criteria the idea of a process by which researchers in academia (and other research institutions) might work with industry and others to achieve societally desirable outcomes. Admittedly, the part played by process in the NSF criterion ("partnerships" and "participation") seems far less central than in RRI (more about that below).
3. *Specific goals* The list of societally desirable outcomes that the broader impacts criterion aims at is at least partially the same as that Europe has or might be expected to put together. For example, Europe wants its research and innovation to increase its economic competitiveness just as the US wants its research and innovation to do (See, for example, Directorate-General 2013).

Though these similarities between RRI and broader impacts are significant, the differences between the two criteria seem more significant. There are at least five:

1. *RRI is (primarily) about process; broader impacts is (primarily) about outcomes.* In broader impacts, the only references to process are optional involvement in partnerships with "industry and others" and the greater participation of women, persons with disabilities, and underrepresented minorities. And even these two process outcomes may be achieved without the sort of line-blurring that seems central to RRI (the continual interactivity between researchers and other societal actors). For example, an NSF-style partnership between academia and industry might amount to no more than an agreement to pass on useful discoveries to a particular company well before publication in exchange for the use of some equipment or patents; it need not involve bringing representatives of industry into the planning of research, much less into the research process itself.[14]

   These are, however, not NSF's only process instructions relevant to RRI—and at least one of the others may change somewhat our sense of the relation

[14] Indeed, having had more than three decades of experience with academic-industry partnerships, Americans have become cautious about allowing partnerships to be too close. See, for example, Davis (1991), Krimsky (2004), or Institutes (2009). NSF now requires academic institutions to have conflict of interest policies to keep university-industry relations from becoming too close (NSF 2013, 6–7). RRI seems to risk similar problems.

between NSF's overall funding criteria and RRI. As part of presenting their qualifications, applicants are supposed to describe previous "Synergistic Activities". These are defined as:

> A list of up to five examples that demonstrate the broader impacts of the individual's professional and scholarly activities that focuses on the integration and transfer of knowledge as well as its creation. Examples could include, among others: innovations in teaching and training (e.g., development of curricular materials and pedagogical methods); contributions to the science of learning; development and/or refinement of research tools; computation methodologies, and algorithms for problem-solving; development of databases to support research and education; broadening the participation of groups underrepresented in science, mathematics, engineering and technology; and service to the scientific and engineering community outside of the individual's immediate organization. (NSF 2013, 17)

These "synergistic activities", though adding to the list of broader impacts, mainly fall under the heading of education, outreach, and cross-disciplinary service. Missing from the list is any marketable product or process—or even the partnerships with industry mentioned in the list of possible broader impacts of the proposed project. We don't think this narrow scope for broader impacts is a mere oversight. When one of us (Davis) attended the "Broader Impacts Infrastructure Summit" (University of Missouri at Columbia, April 24–26, 2013), there was a poster session reporting broader-impact activities at a dozen or so universities. The posters were entirely about education and outreach. There was little anywhere in the 3 days about the sort of interactive research Von Schomberg hopes to capture with his definition of RRI.[15]

2. *RRI seeks to make the process of research and innovation transparent.* The closest broader impacts' list of desirable aims comes to transparency is a) improved education in science, technology, engineering, and mathematics and 2) increased public scientific literacy and public engagement with science and technology. There does not seem to be any explicit conception of designing the research (or innovation) so that the public can be involved in research as such. Even "public engagement with science and technology" seems in fact to be largely engagement with science and technology after it has been produced.[16]

[15] There was some sense of that possibility, however. Informal discussions with several of the participants specializing in "outreach" revealed that they often helped to shape the research being proposed as part of helping researchers develop a satisfactory statement of broader impacts. For example, a researcher who (upon the outreach specialist's suggestion) included high school students among those collecting water samples for him could count the students' increased interest in science as a potential broader impact of the proposed research.

[16] One exception to this general separation of research and the public is what has come to be known as "citizen science", that is, projects that recruit members of the public to help gather research data. So, for example, a recent NSF-funded project at Cornell University included volunteers living in areas affected by the Deepwater Horizon oil spill. The volunteers surveyed birds on beaches and in marshes along the Gulf coast. They shared what they learned through a website that automatically built interactive maps showing locations of reported birds in relation to current and forecast oil-slick locations, allowing for quick response when conservation was needed (NSF 2010).

The concluding paragraph in the explanation of broader impacts does, however, include requirements relevant to transparency:

> Plans for data management and sharing of the products of research, including preservation, documentation, and sharing of data, samples, physical collections, curriculum materials and other related research and education products should be described in the Special Information and Supplementary Documentation section of the proposal (see GPG Chapter II.C.2.j for additional instructions for preparation of this section). (NSF 2013, 14)

Two items in the Grant Proposal Guide (GPG) Chapter II.C.2.j seem clearly relevant to RRI. A data management plan "may" include: "policies for access and sharing including provisions for appropriate protection of privacy, confidentiality, security, intellectual property, or other rights or requirements" and "policies and provisions for re-use, re-distribution, and the production of derivatives" (NSF 2013, 29–30). These are, however, options, not requirements. They may also be interpreted as concerned with transparency within the scientific and technological community rather than with public transparency.

3. *Sustainability and ethical acceptability*. Nothing in the broader impacts section, or anywhere else in the instructions to applicants, suggests any interest in sustainability. The instructions do, however, include a section separate from broader impacts concerned with the ethical acceptability of research.

> The AOR [Authorized Organizational Representative] is required to complete a certification that the institution has a plan to provide appropriate training and oversight in the responsible and ethical conduct of research to undergraduates, graduate students, and postdoctoral researchers who will be supported by NSF to conduct research. (NSF 2013, 8)

This is conventional RCR training. A typical curriculum might include: Research Misconduct, Data Management, Conflict of Interest, Collaborative Science, Human Subjects, Lab Animals, Mentoring, Peer Review, Responsible Authorship, and Safety (CITI 2013). There is nothing specific in RCR (as commonly interpreted) about the ethical acceptability of the outcome of the research. Indeed, this requirement of RCR training is limited to undergraduates, graduates, and postdocs. There is nothing about similar training for the chief researchers (the faculty who, leading the research in question, would be in position to make RRI relevant objectives or constraints).

In addition to this RCR training, there is a requirement that any research on human subjects have the approval of the organization's ethical review committee (NSF 2013, 30). Such a committee typically includes at least one member of the public (HHS 2013). A similar committee must pass on research involving animal subjects.

4. *Examples*. While both RRI and broader impacts seem designed to lead to research and innovation benefiting society, most examples of broader impact seem *not* to fit under RRI—either as Von Schomberg originally defined it or as we redefined it. Indeed, RRI seems *not* to be designed to capture such

paradigmatic broader impacts as: full participation of women, persons with disabilities, and underrepresented minorities in science; improved science education and educator development at any level; increased public scientific literacy; development of a diverse, globally competitive scientific workforce; or enhanced infrastructure for research and education. RRI's conception of societally desirable outcomes seems to be primarily about *end*-products of research rather than (as in broader impacts) its *by*-products.

5. *Application of criteria.* NSF is now clear that *not* every fundable proposal must have a broader impact to be funded. Actual broader impact is something to be measured in the aggregate. All any proposal must have is a reasonably good plan for broader impact—and this impact need only be some sort of outreach. RRI, in contrast, even as we have redefined it, seems to require a specific process of research or innovation (transparent, interactive, and so on), one every research project could have. In this respect at least, RRI seems to be broader in application than broader impacts, to reach much deeper into the process of research and innovation, and to demand much more as well. Which raises two fundamental question: First, is RRI to function as one criterion among others (as broader impact does) or as the sole criterion (as some have suggested that intellectual merit should at NSF)? Perhaps RRI should be limited to some research compartments much as NSF's broader impacts criterion is—if only as a result of bureaucratic distribution of functions. Second, how is RRI to protect against too much or the wrong kind of involvement of others in research? Not everyone who wants to be involved in research wants the knowledge. Some simply want a certain outcome; some do not want the research carried out at all (Resnik 2009).

Other Funding Agencies, Private and Public

We will now examine some other US examples of funding criteria similar enough to RRI to help in thinking about how to turn RRI into a useful funding criterion. In doing that, we relied on publically available web sites, as well as the current, rather small, literature discussing the review criteria that these public or private agencies use. Most of the agencies investigated use the criteria of: scientific and technical merit; the feasibility of the project; and the merits and relevancy of the project to the stated goals of the agency (or some subdivision, such as a program). Often, the agency's stated goals explicitly deal with some aspect of societal desirability. While the public agencies generally developed their goals in some such public way as NSF did, the private agencies generally did not. The private agency's governing board or leadership set the goals with little or no public contribution.

Our investigation seems to show that no other US agency has adopted a criterion similar to NSF's broader impacts, though some requests for proposals, subsidiary programs, general standards, or parts of a review process do have similar goals (or, at least, likely effects), for example, a requirement that funded projects include some public outreach. We eventually narrowed our review to two public agencies and one private one. These seem to be a fair sample of how the majority of US funders seek to accomplish something resembling RRI. We offer a critique of each.

National Institutes of Health

The National Institutes of Health is the primary federal agency charged with conducting and supporting medical research in the US. Consisting of 27 "institutes" and "centers", its mission is to "seek fundamental knowledge about the nature and behavior of living systems and the application of that knowledge to enhance health, lengthen life, and reduce the burdens of illness and disability" (NIH 2011). The agency received over $30 billion in funding for fiscal year 2012, 80 % of which was awarded in competitive grants (NIH 2012). NIH funds both basic and applied biomedical research and, like the NSF, has, especially in the last few years, tried to justify its funding of basic research by its possible societal impact.

Like NSF, NIH uses review panels to distribute most of its funds. Unlike NSF, NIH has a two-tier process of review. The first tier employs experts organized into "Scientific Review Groups" to judge the scientific and technical merits of a proposal. These Groups are much like NSF's peer review panels (both in membership and procedure). In reviewing proposals, the NIH uses five criteria: the significance of the proposal to medicine, the experience of the investigators, the innovation of the proposal, the reasonableness of the approach, and the environment in which the research will be conducted. These five criteria may sum to a bit more than NSF's intellectual merit. The significance of the proposal to medicine seems to include potential impact on society as well as on science, since the following questions are suggested as relevant:

> Does the project address an important problem or a critical barrier to progress in the field? If the aims of the project are achieved, how will scientific knowledge, technical capability, and/or clinical practice be improved? How will successful completion of the aims change the concepts, methods, technologies, treatments, services, or preventative interventions that drive this field?

Note, especially, the reference to "clinical practice" and "treatments, services, or preventative interventions".

The National Institutes of Health's "Funding Opportunity Announcements" will sometimes include additional criteria, including criteria concerned with education, recruitment, and retention to enhance diversity (NIH 2013a).

Once NIH's first-tier review is complete, the proposal is handed off to the "advisory council" (or "advisory board") of the appropriate institute or center for a second review. The purpose of this second review is to determine the relevance of the proposed research to that institute or center, including its potential impact on health. Each advisory council is composed of scientific experts and laypersons (in a ratio of two scientists to one layperson) in order to "ensure that the NIH receives advice from a cross-section of the US population in the process of its deliberation and decisions."[17] (Holbrook 2010)

The standards of relevance and impact vary somewhat from one institute or center to another, but one example may serve for all. The advisory council of the National Institute of Mental Health (NIMH) evaluates proposals against two goals: first, will the project "transform the understanding and treatment of mental illnesses through basic and clinical research, paving the way for prevention, recovery and cure"? and, second, is the project proposed likely as well to help "bridge the gap between the development of new, research-tested interventions and their widespread use by people in need"? (NIMH 2008)

Beside these two tiers of "external review", there is an internal review to make sure that proposals meet legal requirements for ethical acceptability for research on humans and animals.[18] Proposers must include a justification for any involvement of human subjects in their proposed project and a plan to protect those subjects from any risk arising from participation in the research.

The National Institutes of Health also requires projects receiving direct funding to make resulting peer-reviewed publications available to the public through NIH's PubMed Central, a publicly available database it maintains (NIH 2013d).

Finally, NIH has two large programs to reduce the time between the discoveries of basic research and their application in ordinary medical practice. One of these, "Clinical and Translational Science Awards", has provided about sixty academic institutions with funding to set up research centers whose goal is to work together to improve the way in which clinical and translational research is conducted across the country (NIH 2012, 2013c).

Translational research is scientific research that helps to turn the innovations of basic research into artifacts, processes, or procedures that enhance human health and well-being. Translational research is a response to the narrow focus of most research (including the specialization of most researchers); translational research is necessarily multidisciplinary, sometimes including psychologists, social scientists, engineers, and even lawyers along with the more usual biomedical scientists and physicians.[19]

Translational research is important in biomedical research, especially as a way to shorten the time between finding a promising drug or therapy and proving its safety and efficacy in humans (Coller 2009). In the past 50 years, there has, it seems, been an increasing disconnect between basic and clinical research, with highly specialized PhDs (and MDs) doing much of the basic research and practicing physicians doing much of the clinical research. Pharmaceutical companies are also

[17] Members of an advisory council are chosen by the respective institute or center and approved by the Department of Health and Human Services. For certain committees, members are appointed by the President of the United States.

[18] For human subjects in research, the relevant laws are 45 CFR Part 46 (HHS) and 45 CFR Part 690 (NSF) Federal Policy for the Protection of Human Subjects; for animals, 7 USC. 2131 et seq., 9 CFR 1.1–4.11.

[19] The terms "translative research" and "translational science" are (more or less) equivalent to "translational research".

spending more money on their own research and so have a diminished interest in pursuing academic discoveries (Butler 2009).

The National Institutes of Health's other translational program, "Bench to Bedside", funds specific research teams seeking to turn basic scientific discoveries into therapeutic interventions (NIH 2013b). Ordinarily, scientists have little incentive to get involved in the complex process needed to move a potentially useful discovery to the bedside. Indeed, given the cost and difficulty of the regulative process, they have considerable incentive not to bother. To overcome that barrier, Bench to Bedside pays basic and clinical researchers to collaborate and provides training, research, and infrastructure to help researchers guide their discoveries or inventions to approval for medical use.

National Aeronautics and Space Agency

NASA is responsible for the US's civilian space program and for aeronautics and aerospace research. In February 2011, NASA published a new mission statement that directs its programs "to reach for new heights and reveal the unknown, so that what we do and learn will benefit all humankind and drive advances in science, technology and exploration to enhance knowledge, education, innovation, economic vitality, and stewardship of Earth" (NASA 2012b). For fiscal year 2012, NASA had a budget of $21.6 billion, of which about $500 million was distributed as research grants (NASA 2012a).

At NASA, all research proposals are reviewed either by a review panel judging a set of similar proposals or by several individual reviewers recruited for expertise in the subject of that particular proposal. The funding criteria vary with the NASA research announcement in question, but are generally: relevance to NASA's mission; the goals of the specific announcement; the scientific and technical merit of the proposal; and the proposal's budget. There is no general criterion that specifies public outreach or educational activities, though the agency does have a program that provides grants for education. NASA's Science Mission Directorate, which conducts scientific exploration, requires that a minimum of one percent of its overall funding go towards education and public outreach (NASA 2012a). The researchers involved in a project need not do outreach. An outside consultant can be hired to do it (Burggren 2009).

The Bill and Melinda Gates Foundation

In 2012, the Gates Foundation gave out about $3.4 billion in domestic and international grants in public health, global development, and improving the US educational system. The Foundation's board (half the members of which are Bill Gates, Melinda Gates, and Bill Gates' father) sets the funding strategy. The Foundation solicits grants both by inviting organizations to submit a letter of inquiry and also by putting out private or public calls for proposals. The Foundation's executives review proposals. Review criteria vary greatly depending on the call but are usually drawn from the strategic goals of the "section" issuing the call. The sectional goals typically include some sort of broader impact. For example, the

Foundation's agricultural development section has the overall goal of reducing "hunger and poverty for millions of farming families in Sub-Saharan Africa and South Asia but increasing agricultural productivity in a sustainable way" (Gates 2013).

The Gates Foundation has been praised by many, especially for supporting research into global health that has had a major impact on government policy (Anderson 2011). *Lancet* (2009) even praised the Foundation for how it had "inaugurated an important new era of scientific commitment to global health predicaments." However, the funding process remains rather opaque; it seems to be managed largely through informal networks rather than through a more transparent review by independent technical experts. There also seems to be evidence that some organizations are favored over others. A study published in *Lancet* in (2009) reported that over 82 % of the Foundation's funding went to US-based recipients from 1998 to 2007. During that same period, 659 grants were awarded to non-governmental or non-profit organizations. Of these, most (560) were organizations in high-income countries. Of the remainder, only 37 went to non-governmental non-profits in middle-income or low-income countries. The article concludes that, "…this raises the question as to whether some organizations might be better characterized as agents of the foundation rather than as independent grantees" (McCoy et al. 2009).

In 2012, a committee established by the Foundation itself reported that investigators who had received funding through the Foundation wanted more transparency in the grant review process (Gates 2012). So, perhaps in a few years, funding procedures at the Gates Foundation will be considerably more transparent.

Conclusions

We may draw two conclusions from the preceding discussion. First, RRI and broader impacts are importantly different criteria. RRI is concerned primarily with achieving societal benefit by bringing other societal actors into the process by which research moves from the mind, to the lab, and ultimately into the wider society. In contrast, the criterion of broader impacts is primarily concerned with benefiting science, technology, engineering, and mathematics. Societal benefit is a toll that fundamental research must pay to keep its funding.

Second, despite these differences between the two criteria, the difficulties encountered in turning them into a guide for funding research are likely to be much the same. There is a need for more specific guidance. But, if guidance is too strict, it is likely to prevent funding much research and innovation that should be funded. It is therefore better to combine a general description of the criterion with enough specific examples to help would-be applicants, reviewers, and others interested in understanding the criterion—*without making the criterion too definite*. The examples may be of appropriate societal goals, specific activities, or both. The explanation of the criterion should make it clear that what the criterion provides is a guideline open to reinterpretation in light of new information or new arguments. The examples should be preceded by some such warning as "including but not limited to". The criterion should allow the funding agency to learn from the proposals made to it.

Acknowledgments This article was written with support from the European Community's Seventh Framework Programme grant number 321400. Thanks to Doris Schroeder and two of this journal's reviewers for helpful comments on earlier drafts.

References

Anderson, I. (2011), "The Bill and Melinda Gates Foundation: Bureaucracy versus business in international development" discussion paper 2, Development Policy Center, Crawford School of Economics and Government, The Australian National University, Canberra.

Bill and Melinda Gates Foundation. (2012) *Improving our work with grantees: A progress report.* (September) http://www.gatesfoundation.org/~/media/GFO/Documents/How%20We%20Work/granteeprogressreport2012.pdf. Accessed May 6, 2013.

Bill and Melinda Gates Foundation. (2013) *What we do: Agricultural development strategy overview.* http://www.gatesfoundation.org/What-We-Do/Global-Development/Agricultural-Development. Accessed May 6, 2013.

Bruggen, W. W. (2009). Implementation of the national science foundation's 'broader impacts': Efficiency considerations and alternative approaches. *Social Epistemology*, *23*(3–4), 234.

Butler, D. (2009). "Crossing the valley of death." *Nature*, *453*, 840–841.

Collaborative Institutional Training Initiative (CITI). https://www.citiprogram.org/rcrpage.asp. April 27, 2013.

Coller, B. S., & Califf, R. M. (2009). "Traversing the valley of death: A guide to assessing prospects for translational success." *Science Transitional Medicine*, *1*(10), 10.

Davis, M. (1991). University research and the wages of commerce. *Journal of College and University Law, 18*(Summer), 29–38.

Directorate-General for Research and Innovation Science in Society. (2013). *Options for strengthening responsible research and innovation: Report of the expert group on the state of art in Europe on responsible research and innovation*. Luxembourg: Publications Office of the European Union. http://ec.europa.eu/research/science-society/document_library/pdf_06/options-for-strengthening_en.pdf. Accessed May 28, 2013.

Editorial. (2009). What has the Gates foundation done for global health? *The Lancet, 373*(9675), 1577.

Hellström, T., & Jacob, M. (2012). Revisiting 'Weinberg's Choice': Classic tensions in the concept of scientific merit. *Minerva, 50*, 381–396.

HHS.gov (2013). *US Department of Health & Human Services. Search human research protections frequent questions*. http://answers.hhs.gov/ohrp/questions/7180.

Holbrook, J. B. (2010). The use of societal impacts considerations in grant proposal peer review: A comparison of five models. *Technology and Innovation, 12*, 220.

Holbrook, J. B. (2012). *Re-assessing the science—society relation: The case of the US National Science Foundation's Broader Impacts merit review criterion (1997–2011)*. http://www.peerev.org/data/7cce53cf90577442771720a370c3c723/PE_doc_28403.pdf. Accessed June 2, 2013.

Institutes of Medicine. (2009). *Conflict of interest in medical research, education, and practice*. Washington, DC: National Academies Press.

Krimsky, S. (2004). *Science in the private interest: Has the lure of profits corrupted biomedical research?*. Lanham, MD: Rowman & Littlefield Publishers.

McCoy, D., Kembhavi, G., Patel, J., & Luintel, A. (2009). The Bill & Melinda Gates Foundation's Grant-Making Program for global health. *Lancet, 373*, 1645–1653.

National Aeronautics and Space Administration. (2012a) *Agency financial report FY2012.* (November 15). http://www.nasa.gov/pdf/707292main_FY12_AFR_121412_FINALv508.pdf. Accessed May 15, 2013.

National Aeronautics and Space Administration. (2012b). *Science mission directorate education and public outreach*. http://smdepo.org/node/544. Accessed May 6, 2013.

National Institute on Mental Health. (2008). *The National Institute of Mental Health Strategic Plan.* http://www.nimh.nih.gov/about/strategic-planning-reports/index.shtml. Accessed April 30, 2013.

National Institutes of Health. (2011). *About NIH*. http://www.nih.gov/about/. Accessed May 12, 2013.

National Institutes of Health. (2012). *Office of budget*. http://www.nih.gov/about/budget.htm. Accessed May 10, 2013.

National Institutes of Health. (2013a). *Peer review process*. http://grants.nih.gov/Grants/peer_review_process.htm#Criteria. Accessed May 10, 2013.

National Institutes of Health. (2013b). *Bench to bedside program*. http://clinicalcenter.nih.gov/ccc/btb/. Accessed May 28, 2013.

National Institutes of Health. (2013c). *Clinical and translational science awards web site*. http://www.ncats.nih.gov/research/cts/ctsa/ctsa.html. Accessed May 29, 2013.

National Institutes of Health. (2013d). *NIH public access policy*. http://publicaccess.nih.gov/. Accessed April 30, 2013.

National Science Foundation. (1995). *Grant proposal guide* (NSF-95-27).

National Science Foundation. (2010). *Award Abstract #1049363. RAPID: Gulf coast sill biodiversity tracker. A volunteer-based observation network to monitor the impact of oil on organisms along the gulf coast*. http://www.nsf.gov/awardsearch/showAward?AWD_ID=1049363&HistoricalAwards=false. Accessed May 23, 2013.

National Science Foundation. (2011). *National Science Foundation's merit review criteria: Review and revisions* (December 14). www.nsf.gov/nsb/publications/2011/meritreviewcriteria.pdf. Accessed April 20, 2013.

National Science Foundation. (2012). *NSF at a glance*. http://www.nsf.gov/about/glance.jsp. Accessed April 27, 2013.

National Science Foundation. (2013). *Chapter II—Proposal preparation instructions*. http://www.nsf.gov/pubs/policydocs/pappguide/nsf13001/gpg_2.jsp#IIC2d. Accessed April 20, 2013.

Owen, R., Macnaghten, P., & Stilgoe, J. (2012). Responsible research and innovation: From science in society to science for society, with society. *Science and Public Policy, 39*, 751–760.

Resnik, D. B. (2009). *Playing politics with science: Balancing scientific independence and government oversight*. New York: Oxford University Press.

Rothenberg, M. (2010). Making judgments about grant proposals: A brief history of the merit review criteria at the national science foundation. *Technology and Innovation, 12*, 189–195.

Singapore Statement on Research Integrity. (September 22, 2010). http://www.singaporestatement.org/. Accessed May 27, 2013.

Von Schomberg, R. (2013). A vision of responsible innovation. In: R. Owen, M. Heintz, & J. Bessant (Eds.), *Responsible innovation*. London: Wiley, forthcoming.