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Policies to increase the social value of science and the scientist satisfaction. An exploratory survey among Harvard bioscientists.

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RESEARCH ARTICLE

Policies to increase the social value of science and the scientist satisfaction. An exploratory survey among Harvard bioscientists. [v1; ref status: indexed, http://f1000r.es/2iq]

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Abstract

Basic research in the biomedical field generates both knowledge that has a value *per se* regardless of its possible practical outcome and that has the potential to produce more practical benefits. Policies can increase the benefit potential to society of basic biomedical research by offering various kinds of incentives to basic researchers. In this paper we argue that soft incentives or "nudges" are particularly promising. However, to be well designed, these incentives must take into account the motivations, goals and views of the basic scientists. In the paper we present the results of an investigation that involved more than 300 scientists at Harvard Medical School and affiliated institutes. The study shows that basic researchers' support for soft incentives is such that the transformative value of fundamental investigations can be increased without affecting the spirit of the basic research and scientists' work satisfaction. After discussing the findings, we suggest a few examples of nudges and discuss one in more detail.

Article Status Summary

Referee Responses

Referees	1	2
v1 published 21 Jan 2014	report	report

1 **Giorgio Scita**, FIRC Institute of Molecular Oncology Foundation at IFOM-IEO Campus Italy

2 **Daniel Strech**, Hannover Medical School Germany

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Introduction

Basic or fundamental research—generally defined as untargeted research seeking to expand knowledge—is a key component of innovation. While it generates knowledge that has a value *per se* regardless of its possible practical outcome, it also delivers knowledge that has the potential to produce more practical benefits[1]. Basic biomedical research in particular is crucial in addressing the challenges we face in our highly interconnected planet in which communicable diseases spread quickly and in which non-communicable diseases cause the premature death of many individuals[2].

Historically, a wide range of basic biomedical research projects have contributed to the advancement of knowledge, from research solely inspired by the researcher's curiosity to projects driven by a vision of how knowledge generated by research could be used as the basis for applied research. All research along this continuum is considered "basic" because it serves as the foundation for further research that may lead to applications. Scientific knowledge is produced by the coming together of all kinds of research streams and ideas. Abraham Flexner captured this aspect of science in the image of the Mississippi river, which "*begins in a tiny rivulet in the distant forest. Gradually other streams swell its volume. And the roaring river that bursts the dikes is formed from countless sources*"[3]. Although it often takes decades to develop, the applied outputs of knowledge advancement (e.g. drugs) have at their roots countless basic investigations.

Given its importance, complexity and breadth, basic research has been primarily funded by public money. This was particularly true in the decades that followed World War II and during which basic research went through a "golden age," being conducted primarily in research universities and paid for with public money[4]. Sadly, public expenditure for research has decreased since then and nowadays fundamental sciences are for the most part underfunded. Basic biomedical research currently receives less support than it received only a few years ago. For instance, in the United States, National Institutes of Health (NIH) funding has been nearly stationary since 2003 in the face of rapid expansion of research activity in existing biomedical fields and the emergence of new ones[1]. One explanation of the low support for fundamental sciences is our cognitive bias in favor of immediate rewards. As our brains are structured in a way that leads us to unduly favor immediate rewards over future benefits[5], we tend to underestimate the importance of human activities and initiatives with benefits that lie in the future[6]. Furthermore, basic researchers are said to owe a moral duty to extract maximum transformative value (the potential to translate into novel and fruitful applied research) whenever their research is publicly funded[7,8]. In an effort to maximize transformative value of research, funding agencies like the NIH already take in some consideration the health benefit potential or (social) "significance" of a research proposal when assigning resources.

Assessing the societal impact of fundamental sciences is however more easily said than done. The topic is debated in the scientific and political communities[9]. Some policies already try to achieve this goal. Those based on strong financial incentives, such as the Bayh-Dole Act in the United States are already being used but they raise concerns as to whether monetary incentives distract basic scientists from focusing on fundamental questions[10,11]. New strategies to successfully maximize the transformative value of basic research without compromising the nature of fundamental inquiries are certainly needed. Softer incentives, which are called by behavioral economists "nudges"[12], seem particularly promising as they have been successfully used in public health but not yet in basic research. If properly designed for basic research, nudges would slightly (and sometimes unperceivably) reorient some scientists in a certain direction without imposing rules or decreasing work satisfaction. However, these "nudges" can be designed well for basic research only if we have a good grasp of what motivates the basic scientists, what their values are and the intellectual frameworks in which they operate so that the proper soft incentives can be tailored around the particular characteristics of basic scientists.

In an effort to improve our understanding of basic scientists' motivations, we designed a study to collect data from basic scientists at Harvard Medical School and affiliated institutions. We designed a survey that was filled out by more than 300 scientists. In the next sections, we present the results of this study and a discussion on how these findings can be used to increase the transformative value of basic biomedical research without decreasing the "basic" nature of these investigations and the motivations and freedom of the scientists. Finally, we suggest a few examples of nudges and discuss one in more detail.

Results

Description of the survey and the sample

The survey was designed as an online questionnaire comprised of 17 questions (Q1–Q17). On average, fewer than 2% of the respondents, with a range from 0% (Q2 and Q3) to 6.3% (Q15) skipped any of the 17 questions. Answers could be provided through multiple choices or, alternatively, textboxes for alphanumerical entries (see Methods section for additional details). 304 scientists took the survey. The first four questions of the questionnaire (Q1–Q4) gathered data on the sample characteristics. The first question (Q1) (all questions hereinafter will be referred to as Q#) aimed at identifying the respondent's academic position: 39.9% declared themselves to be principal investigators, 34.7% to be post-docs, 10.6% to be PhD students and 14.9% to belong to other categories (including "research assistants" and "research technicians") (Figure S1). Q2 focused on gender. The sample's gender distribution turned out to be 42.1% females and 57.9% males (Figure S2). Q3 asked respondents to quantify the amount of their research time allocated to research that they consider to be "basic". On average, respondents reported spending 76.3% of their research time on basic research (Figure S3), with only 3.6% of respondents stating that they were not involved (0%) in basic research. In order to test respondents' commitment to basic research in general, Q4 asked them if they agreed/disagreed with the following statement: "*Despite the current economic situation, public funding for basic biological/biomedical research should be increased*". 92.4% of the respondents agreed with the previous sentence while only 7.6% disagreed (Figure S4). Overall, these results show that our purposive sample was well balanced with regard to academic position and gender and that the surveyed scientists were significantly involved in basic investigations and (for the great majority) supportive of increased public funding for basic biological/biomedical research.

Basic scientists think that considering the practical benefits of their research is compatible with the notion of basic science

The way scientists conceptualize basic research is important not only to define the concept but also to design policies that can effectively promote it. To this purpose, we asked a few questions to define the concept and goals of basic research. Q5 asked respondents to express their level of agreement with the following: "*basic research can be defined as the research that is not intended to yield immediate practical benefits except for advancement of knowledge*". Survey participants had four options to choose: complete agreement, some agreement, some disagreement and complete disagreement. 32.5% of the respondents expressed complete agreement, 43.4% some agreement, 17.5% some disagreement and 6.6% complete disagreement (Figure 1A). To corroborate the responses of Q5, we designed a complementary question (Q6) to determine the level of agreement on the following: "*basic scientists can ponder about the future indirect practical benefits of their research without losing their* "*basic status*"". 71.2% of the respondents expressed complete agreement, 23.2% some agreement, 5.0% some disagreement and 0.7% complete disagreement (Figure 1B). The results of Q6 were therefore in agreement with the results of Q5.

We also designed two questions (Q9 and Q10) to understand what should be the "goals" of biological and biomedical research according to the basic scientists. In particular, Q9 asked respondents to answer the following question: "*What should the most important goal of publicly funded basic BIOLOGICAL (not biomedical) research be?*" Respondents had three options. 71.7% responded "pure advancement of knowledge, regardless of future applicability", 21.9% responded "health benefit to the society (not necessarily in the near future)" and 6.4% responded that the most important goals are "other", such as the "environmental or economical benefit to society" or "sustainability of our species and of the biosphere" (Figure 1C). Similarly, Q10 asked the following question: "*What should the most important goal of publicly funded basic BIOMEDICAL research be?*" Interestingly, we had a very different outcome. Only 8.6% of the respondents answered "pure advancement of knowledge regardless of future applicability", while 85.7% answered "health benefit to society (not necessarily in the near future)" and 5.6% answered that the most important goals are "other" (Figure 1D).

Thus, these results clearly indicate that most scientists think that considering the indirect practical outcome of basic scientific investigations is compatible with the notion of basic research. In other words, basic research should not be conceptualized as being necessarily (or solely) driven by curiosity. Furthermore, these results suggest that scientists perceive the goals of "biological research" and "biomedical research" to be different, with a propensity to include health benefit to society as an important goal of biomedical research only.

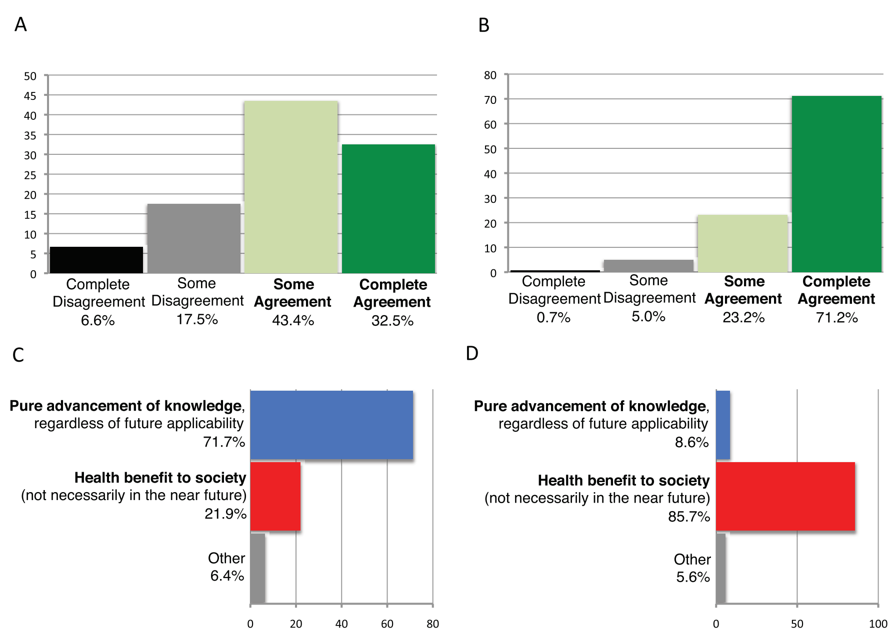
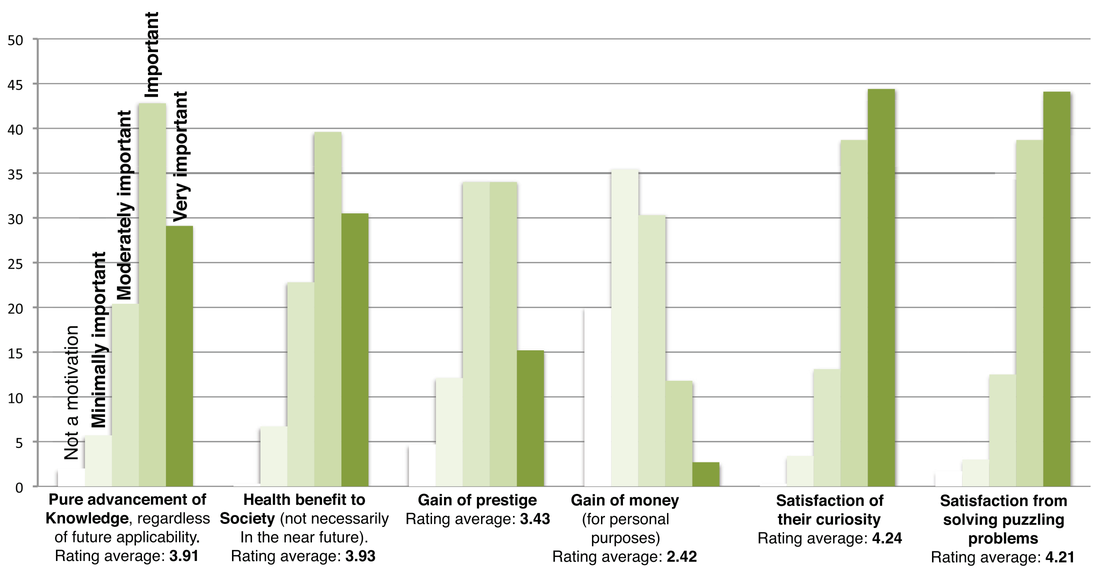


Figure 1. How do scientists conceptualize basic "bio" research? (**A**) Graph shows the levels of agreement to the following statement: "Basic research can be defined as the research that is not intended to yield immediate practical benefits except for advancement of knowledge". 302 scientists answered the question; 2 skipped. (**B**) Graph shows the levels of agreement on the following statement: "Basic scientists can ponder about the future indirect practical benefits of their research without losing their "basic status"". 302 respondents answered the question; 2 skipped. (**C**) Graph shows how scientists answered the following question: "What should the most important goal of publicly funded basic BIOLOGICAL (not biomedical) research be?". Surveyed scientists were given the indicated three choices. 297 answered the question; 7 skipped. (**D**) Graph shows how scientists answered the following question: "What should the most important goal of publicly funded basic BIOMEDICAL research be?" Surveyed scientists were given the indicated three choices. 301 answered question; 3 skipped.

What motivates the basic scientists?

Understanding the motivations of people is important for designing policies that offer incentives to pursue certain goals. We therefore designed two questions to gather information on what motivates-basic scientists. The respondents were asked to select their level of importance ("not a motivation", "minimally important", "moderately important", "important" and "very important") for six motivations. The rating average was then calculated after assigning a score from 1 to 5, to these five options. Scientists were therefore asked to provide feedback on the following (Q7) "*the motivations of most*

A



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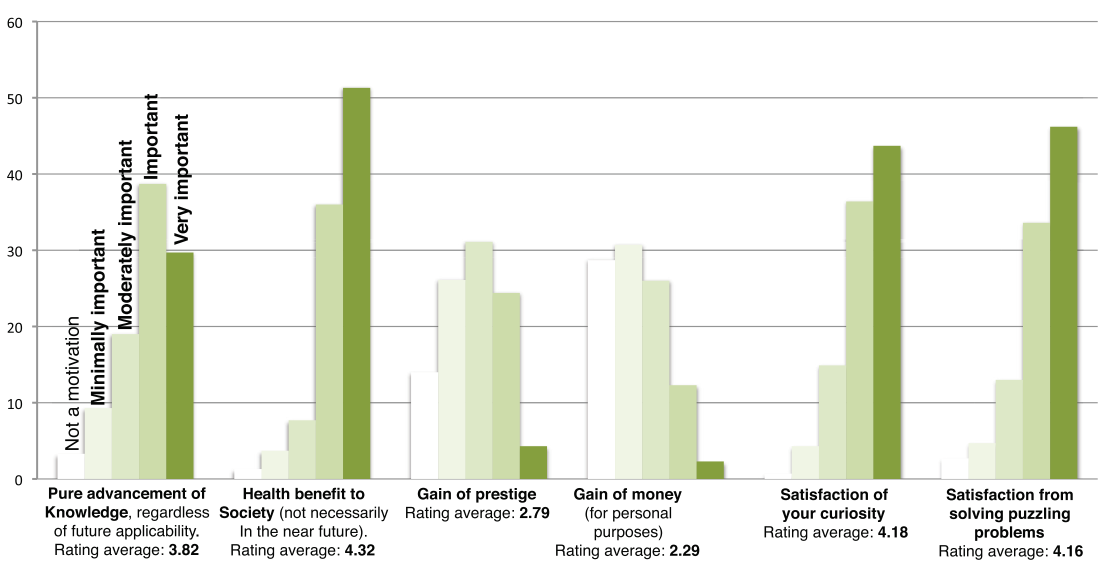

Figure 2. What does motivate the basic scientists? (**A**) Graph shows the responses of the surveyed scientists to the following input: "the motivation of MOST basic biological/biomedical scientists are from:". Six different types of motivations were proposed. Respondents could rate each type of motivation as "not a motivation, "minimally important", "moderately important", "important" or "very important". Rating averages for each type of motivation are also indicated (the scores were 1 to 5, from "not a motivation" to "very important"). 299 respondents answered the question; 5 skipped. (**B**) Graph shows the responses to the following input: "YOUR personal motivations as a scientist are from:". Six different types of motivations were proposed. Respondents could rate each type of motivation as "not a motivation, "minimally important", "moderately important", "important" or "very important". Rating averages for each type of motivation are also indicated (the scores were 1 to 5, from "not a motivation" to "very important"). 302 respondents answered the question; 2 skipped.

basic biological/biomedical scientists are from:". The rating average, for the motivation "pure advancement of knowledge, regardless of future applicability" was 3.91. The rating average for "health benefit to society (not necessarily in the near future)" was 3.93. The rating average for "gain of prestige" was 3.43. The rating average for "gain of money" was 2.42. The rating average for "satisfaction of their curiosity" was 4.24. The rating average for "satisfaction from solving puzzling problems" was 4.21 (Figure 2A).

To see if scientists perceive themselves differently from other scientists, we also asked respondents to provide feedback on the following input (Q8): "*YOUR personal motivations as a scientist are from:*". The rating average for "pure advancement of knowledge, regardless of future applicability" was 3.82. The rating average for "health benefit to society (not necessarily in the near future)" was 4.32. The rating average for "gain of prestige" was 2.79. The rating average for "gain of money" was 2.29. The rating average for "satisfaction of their curiosity" was 4.18. The rating average for "satisfaction from solving puzzling problems" was 4.16 (Figure 2B). Thus, these results show that, with the exception of "gain of money", all other motivations are from "moderately important" to "very important" for more than 50% of the respondents. Moreover, these results show that scientists perceive themselves as more motivated by the pursuit of "health benefit to society (not necessarily in the near future)" and less motivated from the "gain of prestige" and "gain of money" than the average scientist.

Most basic scientists think that estimating the potential future health benefits to society from basic biological/biomedical research is possible

To design policies to increase the practical impact of basic biomedical/biological research, it is first important to understand whether estimating the health benefit potential of basic research is in any way feasible, a topic that has being debated for many years[9]. We gathered feedback on this issue by asking respondents to express their level of agreement on scientists' ability to estimate the potential future health benefits at different stages of the research process. Q11 stated: "*Although it is difficult to assess the potential future health benefits to society from basic biological/biomedical research as described in written PROPOSALS, some degree of estimation is always possible*". 16.7% of the respondents were in complete agreement with this sentence, 57.7% in some agreement, 19.0% in some disagreement and 6.7% in complete disagreement (Figure 3A).

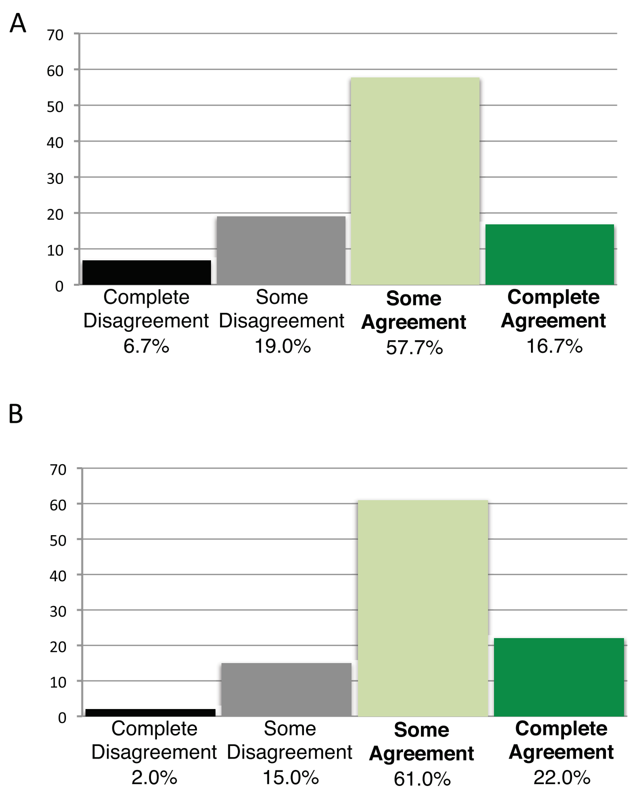

Figure 3. Most scientists think it is possible to estimate future health benefits potential of basic research. (**A**) Graph shows the levels of agreement on the following statement: "Although it is difficult to assess the potential future health benefits to society from basic biological/biomedical research as described in written PROPOSALS, some degree of estimation is always possible". 300 scientists answered the question; 4 skipped. (**B**) Graph shows the levels of agreement on the following statement: "Although it is difficult to assess the potential future health benefits to society from the RESULTS and FINDINGS of basic biological/biomedical research, some degree of estimation is always possible" 300 answered the question; 4 skipped.

Q12 stated: "*Although it is difficult to assess the potential future health benefits to society from the RESULTS and FINDINGS of basic biological/biomedical research, some degree of estimation is always possible*". 22.0% of the respondents were in complete agreement with this sentence, 61.0% in some agreement, 15.0% in some disagreement and 2.0% in complete disagreement (Figure 3B). These results therefore show that the majority (83%) of the surveyed scientists think that estimating the future health benefits to society from the proposals or outcome of basic biological/biomedical projects is realistically feasible.

Most basic scientists think that the discussion of potential medical benefits in basic research proposals is not useful

Funding agencies around the world commonly request that the potential health benefits of basic research projects are discussed in the written proposals. In order to understand what scientists think about this requirement, Q13 asked respondents to express their level of agreement in the following statement: "*Written proposals about basic biological/biomedical research generally contain a section discussing potential future health benefits. These sections increase the likelihood that a project benefits future public health*". 12.3% of the respondents were in complete agreement with this statement, 35.0% were in partial agreement, 35.0% were in partial disagreement and 17.7% were in complete disagreement (Figure 4A).

We also proposed two questions with the purpose to shed light on how scientists would improve current funding criteria. In Q14, we asked to answer the following question: "*What percentage of public funding should be allocated to basic biological/biomedical research proposals in which discussing the potential of future health benefits to society is not required?*" According to the scientists of our sample, 41.6% of public funding, on average, should be allocated to research in which a discussion of the potential health benefits is not required in written proposals (Figure 4B) (standard deviation was 25.72; 3.4% of the respondents to this question declared 0%; 6.6% of the respondents declared 100%).

In Q15 we asked respondents to answer the following question: "*With regard to basic biological/biomedical research proposals in which discussing the potential of future health benefits to society is required, what average weight should be given to this potential in assigning scores for funding decisions?*" The average "weight"

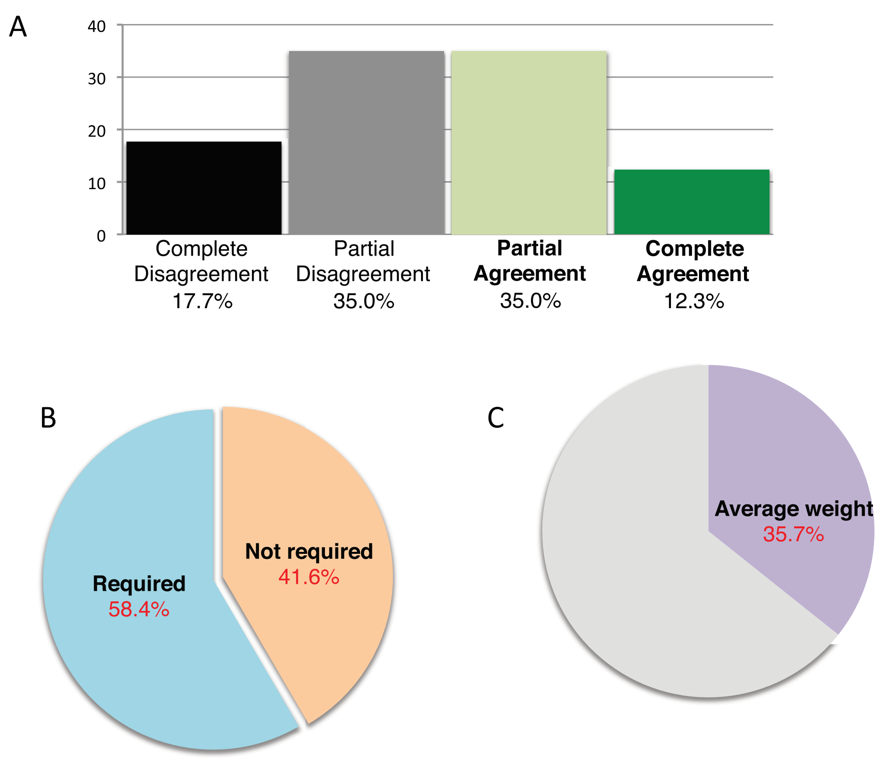

Figure 4. Scientists think more scientific projects should not be asked about their practical outcome potential. (**A**) Graph shows the levels of agreement on the following statement: "Written proposals about basic biological/biomedical research generally contain a section discussing potential future health benefits. These sections increase the likelihood that a project benefits future public health". 300 scientists answered the question; 4 skipped. (**B**) Graph shows how surveyed scientists responded to the following question: "What percentage of public funding should be allocated to basic biological/biomedical research proposals in which discussing the potential of future health benefits to society is not required?". 290 answered the question; 14 skipped. (**C**) Graph shows how surveyed scientists responded to the following question: "With regard to basic biological/biomedical research proposals in which discussing the potential of future health benefits to society is required, what average weight should be given to this potential in assigning scores for funding decisions?" 285 answered the question; 19 skipped.

indicated by the scientists of our sample was 35.7% (Figure 4C) (standard deviation was 25.87; 6.7% of the respondents to this question declared 0%). Thus, this set of results indicates that the majority of scientists think that discussing the potential future health benefits in basic research proposals is not an effective way to increase the likelihood that a project benefits future public health. Interestingly, we noticed that principal investigators were significantly more in disagreement than post-docs (63.4% and 41.2%, respectively) with regard to the effectiveness of this policy in increasing societal benefits (Figure S5). Moreover, scientists believe that a considerable

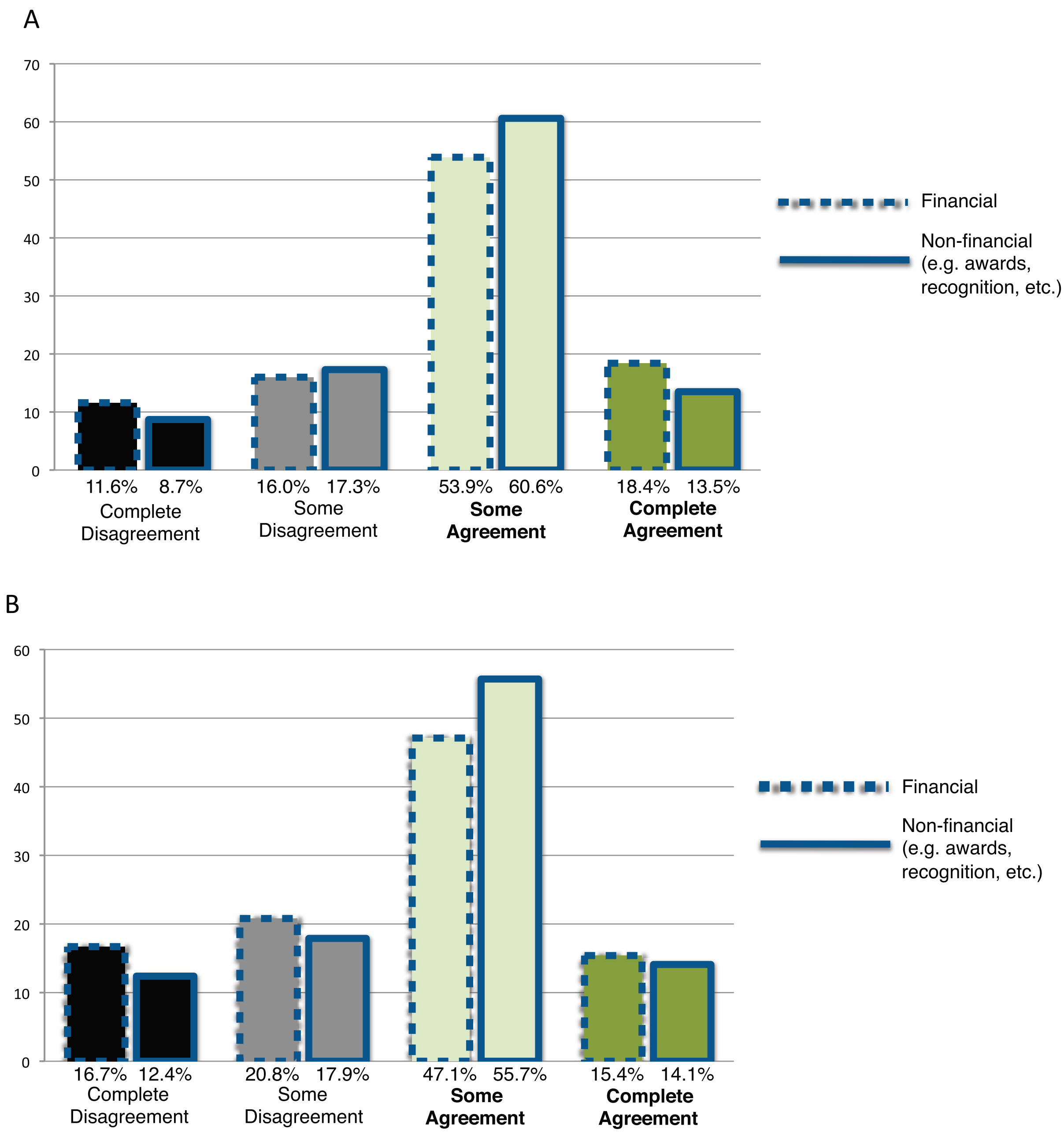

Figure 5. Most scientists are in favor of motivational incentives to increase the health benefit potential of their investigations. (**A**) Graph shows the levels of agreement on the following statement: "Motivational INCENTIVES, which are not based on restrictive policies such as the requirement to discuss the potential of future health benefits, CAN increase the degree to which basic biological/biomedical research is likely to benefit the future health of society". 293 answered the question; 11 skipped. The incentives were proposed either as financial or as non-financial. (**B**) Graph shows the levels of agreement on the following statement: "Motivational INCENTIVES, either "in addition to" or "in substitution of" restrictive policies, SHOULD be used to increase the degree to which basic biological/biomedical research is likely to benefit the future health of society". 294 answered the question; 10 skipped. The incentives were proposed either as financial or as non-financial.

proportion of public funding (41.6%) should be allocated to research proposals in which discussing the future health benefits to society is not required.

Most basic scientists are in favor of motivational incentives to increase the likelihood that a research project benefits future public health

In order to understand if scientists believe that motivational incentives could be more effective than stricter policies (such as the mandatory discussion of the potential medical benefits in research proposals), we asked (Q16) scientists to express the level of agreement on the following statement: "*Motivational INCENTIVES, which are not based on restrictive policies such as the requirement to discuss the potential of future health benefits, CAN increase the degree to which basic biological/biomedical research is likely to benefit the future health of society*". With regard to financial incentives, 18.4% of the respondents were in complete agreement with this statement, 53.9% in some agreement, 16.0% in some disagreement and 11.6% in complete disagreement. With regard to non-financial incentives (e.g. awards, recognition), 13.5% of the respondents were in complete agreement with the statement, 60.6% in some agreement, 17.3% in some disagreement and 8.7% in complete disagreement (Figure 5A).

To understand if motivational incentives should be implemented and used, we also asked respondents (Q17) to express the level of agreement on the following slightly different statement: "*Motivational INCENTIVES, either* "*in addition to*" *or* "*in substitution of*" *restrictive policies, SHOULD be used to increase the degree to which basic biological/biomedical research is likely to benefit the future health of society*". With regard to financial incentives, 15.4% of the respondents were in complete agreement with this statement, 47.1% in some agreement, 20.8% in some disagreement and 16.7% in complete disagreement. With regard to non-financial incentives, 14.1% of the respondents were in complete agreement with the statement, 55.7% in some agreement, 17.9% in some disagreement and 12.4% in complete disagreement (Figure 5B). Thus, these results suggest that the vast majority of basic scientists are in favor of motivational incentives (either financial or non-financial) to be used either "in addition to" or "in substitution of" more restrictive policies to increase the public health potential of basic biological/biomedical research.

Summary of results

The majority of the scientists who participated in the survey indicated that the most important goal of publicly funded basic biomedical research is the production of health benefits to the society (86%) (Figure 1D) and that the desire to effectively benefit society is an important or very important motivation for most of them (87%) (Figure 2B). While the benefits to society may be not realized in the near future, a substantial majority of respondents (74%) (Figure 3A) agreed/partially agreed on the idea that some degree of estimation of the potential contribution to human health is possible for every basic research proposal. Further, they indicated that, ideally, more than half of public funding should be allocated to proposals in which a discussion of the potential future health benefits to society is required. Moreover, with regard to the definition of basic research, nearly all respondents (94%) (Figure 1B) indicated that thinking about the future practical benefits of their research is compatible with the status of "basic" researchers, thus implying that basic research should not be conceptualized as (necessarily or solely) driven by curiosity.

Our data also shed a light on scientists' motivations (besides contributing to health benefit to society). This information is useful to design incentive-based policies. Our survey confirmed that the so-called "puzzle-motivation"—the satisfaction from solving puzzling problems—was an important motivator[13] for almost all basic scientists (among our respondents 93% said that "satisfaction from solving puzzling problems" and 95% that "satisfaction of curiosity" were

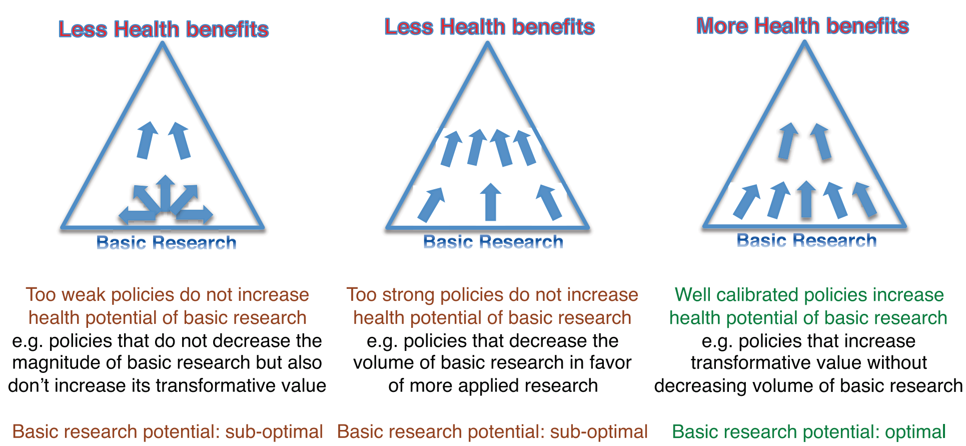

Figure 6. Working model to increase practical benefit to society. In order to increase the health benefits to society from basic "bio" research, policies should produce a good integration between basic and applied investigations and maximize transformative value of basic science. The directions of the arrows are intended only to express the capacity of transformative value of research (arrows pointing towards the top vertex of the triangle have maximum transformative value) and are not intended to reflect neither the quality of research nor the status of "basicness".

from "moderately" to "very important" motivations) (Figure 2B). The so-called "ribbon-motivation"—the gain of prestige and recognition—was significantly more important than the gain of personal money (among our respondents 60% said that the "gain of prestige" was a "moderately" to "very important" motivation for them compared to 41% who said the same for the "gain of money") (Figure 2B). Moreover, the majority of respondents of the survey were in favor of using financial incentives (62%) and non-financial incentives (70%) to increase the degree to which basic biological/biomedical research is likely to benefit the future health of society (Figure 5B).

Responses of Harvard Medical School (and affiliate) scientists to an online survey on basic and biomedical science policy

2 Data Files

http://dx.doi.org/10.6084/m9.figshare.902837

Discussion

The results of this survey provide valuable information to help conceive new effective policies to increase both the health benefit potential of basic biological and biomedical research and the work satisfaction of scientists without altering the nature and volume of scientific investigations (schematized in Figure 6). Building on these results, we conclude that nonfinancial soft incentives (nudges), in particular, are perceived as valuable tools to maximize the transformative value of basic research as they would not entail much work for scientists and can be implemented without significantly increasing public spending and bureaucratic burden. We also believe that soft incentives would be a valuable departure from current policies, which according to the scientists surveyed in our study, are ineffective. Indeed, despite 92% of respondents indicating that they are in favor of an increase in public funding for basic biological/biomedical research (Figure S4), a significant majority of the principal investigators (63%) (Figure S5) declared that the sections in written proposals aimed at discussing the potential future health benefits do not really increase the likelihood that a project will benefit future public health. Scientists also claimed that more public funding (on average the 42% of the total public funding committed to basic biological/biomedical research) should be devoted to basic biological/biomedical research proposals in which discussing the potential of future health benefits is not required (Figure 4B).

Based on these findings, we propose a few examples of policies based on soft (sometimes subconscious) incentives that could gently direct some scientists towards undertaking basic research inquiries with higher transformative value (Box 1). One example would be placing research laboratories in the proximity of hospitals to expose basic scientists to the view of patients and practicing physicians. Another one would be organizing more (non-mandatory) educational meetings in which scientists explain their work to the general public or to associations of patients (giving credit to the participating scientists). A similar proposal would be organizing periodical seminars inside research institutions to discuss the role of scientific research and scientists in society. Indeed we believe that effective policies would be the ones that exploit the scientist's drive to achieve a good reputation and a role in benefiting society.

Box 1. Example of nudges ("soft" motivational incentives) potentially useful to increase the transformative value of basic research without altering its fundamental nature and its volume.

- Locating basic research laboratories in proximity of hospitals
- Organizing educational meetings between scientists and the general public or patients associations. Acknowledging the participating scientists. Considering their participations during grant assignments, promotion, hiring etc.
- Organizing more seminars (in academia and outside) about the role of scientific research and scientists in the society
- Recognizing the work of basic scientists in producing health benefits e.g. Requiring a list of seminal basic research articles for each new drug, medical device or other biological applications (see text for more details)
- Promoting more discussion on the concept and definition of basic research
- Different conceptualization of the notion of basic research (see text for more details)

A model of such an incentive would be to formally recognize the basic scientists when new drugs or medical devices are approved, as we recently proposed[14]. This type of incentive would make use of the "ribbon-motivation" but without undermining the "puzzle-motivation" or research freedom generally[13]. This system could work by implementing a "bibliography of basic papers" for each newly approved drug. To apply this idea, a peer review group would identify the basic papers that have been influential for the development of the drug (or other biological applications) or, alternatively, review a list proposed by the drug owner[14]. A list of fifty to one hundred basic research papers would be selected and appear in the public databases (such as the Orange Book of the FDA) and in the drug package. This system would be a "weak attractor" because it would not distract scientists from basic research but it would represent a small, mostly unconscious, incentive to pursue research lines that can more easily lead to future drugs. Therefore this system would not dramatically affect the whole "ecosystem" of the scientific research that indeed needs to be made of a balanced mix of the different types of research, from the "purely" basic to the "purely" applied (Figure 6). This method would also present the advantage of increasing public awareness of the role of basic science, which we think is often underestimated by lay people as well as politicians.

Moreover, we believe that a different conceptualization of the notion of basic research would help in increasing the transformative values of fundamental investigations. A portion of basic research should (continue to) be devoted to purely curiosity-driven purposes as knowledge *per se* has a value and increases the quality of life of people through fascination and 'soul nourishment'. However, basic research should not be conceptualized as solely driven by curiosity. Indeed, in our survey, nearly all respondents (94%) (Figure 1B) indicated that thinking about the future practical benefits of their research is compatible with the status of "basic" researchers. Therefore, similar to the Organisation for Economic Co-operation and Development (OECD)'s division of the continuum of basic research into pure basic research and oriented basic research (http://stats.oecd.org/glossary/detail.asp?ID=192), we believe basic research can usefully be divided into two broad categories: solely curiosity-driven research and research driven by a vision of how the knowledge generated might be useful for future applications. In this context, the term "blue skies research", sometimes used to define the entire field of basic research[15] might be used for those studies that are solely (or largely) curiosity-driven. Even if curiosity does remain one of the main motivators for conducting and studying science, we believe that basic research should be conceptualized as research that focuses on basic mechanisms of natural phenomena rather than research that is intended to satisfy scientists curiosity (as it is frequently presented in the mass media). Along these lines, we must also revisit the idea that since the future benefits of basic research cannot be accurately predicted, all basic research is equally valuable, i.e. every imaginable basic investigation would have the same exact potential of practical outcome. In fact, the great majority of scientists who took part in our survey pointed out that, despite the fact that it is usually necessary to undertake a very long pathway (the "countless sources" mentioned by Abraham Flexner[3]) before being able to funnel basic knowledge toward more applicative studies, some degree of assessment of the transformative value of basic investigations is always possible. It follows that since the potential benefits for society are roughly predictable, basic research can be evaluated prospectively; this does not lessen the "basic status" of either the research or the scientist. Such a revised mindset could "nudge" more basic scientists (and grant funders) to wonder about the future impact of their investigations.

Basic research advances knowledge that, regardless of its possible practical outcome, has a value *per se*. In addition, basic research has also the potential to produce more practical benefits to humanity, such as the prevention and treatment of diseases. As a society, we have the moral obligation to try to maximize this potential. We believe, and the data presented in the paper support, the idea that soft incentives can be valuable tools for increasing this potential without corrupting the spirit of fundamental investigations, thus further aligning the goals of cell and molecular biologists with those of the broader public health community.

Methods

Ethics statement: On April 2, 2012, the Institutional Review Board (IRB) of Harvard School of Public Health determined that the proposed study meets the criteria for exemption per the regulations found at 45 CFR 46.101(b)[2]. The IRB made the following determinations: Research Information Security Level; the research is classified, using Harvard's Data Security Policy, as Level 1 data. The notification was signed by QA/QI specialist.

The survey was designed as an online questionnaire (powered by SurveyMonkey, www.surveymonkey.com) made of 17 questions (Q1–Q17) plus one additional field for free comments. Answers could be provided through multiple choices or, alternatively, textboxes for alphanumerical entries. Each single question had the option to be skipped. The survey was sent to a sample of scientists involved in basic biological/biomedical studies (for the most part, cell and molecular biology studies). The scientists were also asked to confirm their level of involvement in basic fundamental research (see results section). The responses were collected during 9 consecutive weeks during 2012 (end of April to the end of June). Principal investigator (PI) scientists were contacted by email after consulting the websites of Harvard University and some affiliated institutes (Brigham and Women's Hospital, Beth Israel Deaconess Medical Center, Dana-Farber Cancer Institute, Joslin Diabetes Center and Children's Hospital); the majority of principal investigators were asked to forward the survey to members of their own groups. Post-docs were contacted either by their PIs or by using university-associated mailing lists and networking. Also a few scientists with other types of position (e.g. PhD students, instructors, research assistants) took part in the survey, generally contacted by their PIs. In addition to the specific request to forward the survey to their own groups or to close intra-institutional colleagues, the contacted scientists were specifically asked not to forward the survey to the outside community. The survey was completely voluntary and anonymous.

Data availability

Figshare: Responses of Harvard Medical School (and affiliate) scientists to an online survey on basic and biomedical science policy, http://dx.doi.org/10.6084/m9.figshare.902837[16].

Author contributions

Andrea Ballabeni, Andrea Boggio and David Hemenway designed the study and wrote the manuscript. Andrea Ballabeni collected the data.

Competing interests

No competing interests were disclosed.

Grant information

The author(s) declared that no grants were involved in supporting this work.

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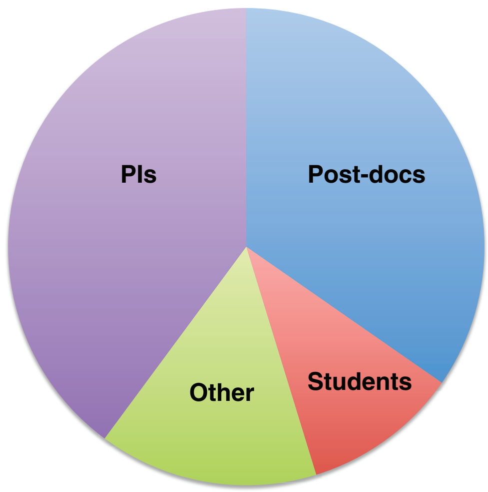
Supplementary materials

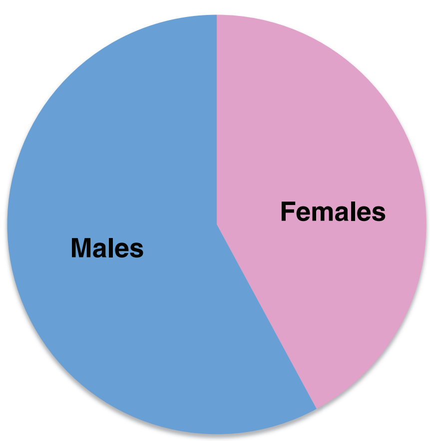
Q1.
Please indicate which of the following best describes you:



Principal investigators	*39.9%*
Post-docs	*34.7%*
PhD students	*10.6%*
Other	*14.9%*
Answered question	*303*
Skipped question	*1*

Figure S1. **Academic positions of the surveyed scientists.**

Q2.
Are you?



Females	*42.1%*
Males	*57.9%*
Answered question	*304*
Skipped question	*0*

Figure S2. **Gender distribution of the surveyed scientists.**

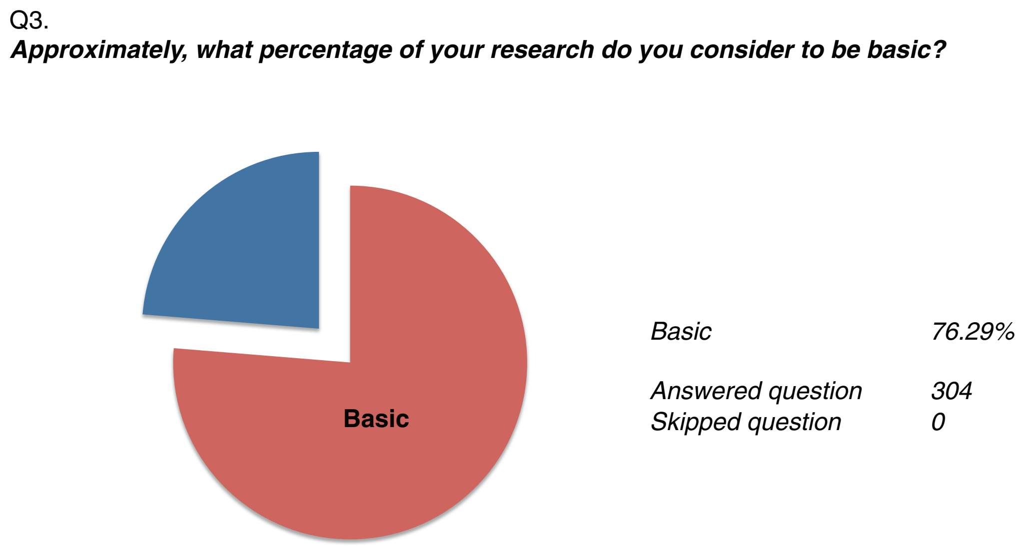


Figure S3. Level of involvement in basic research of the surveyed scientists.

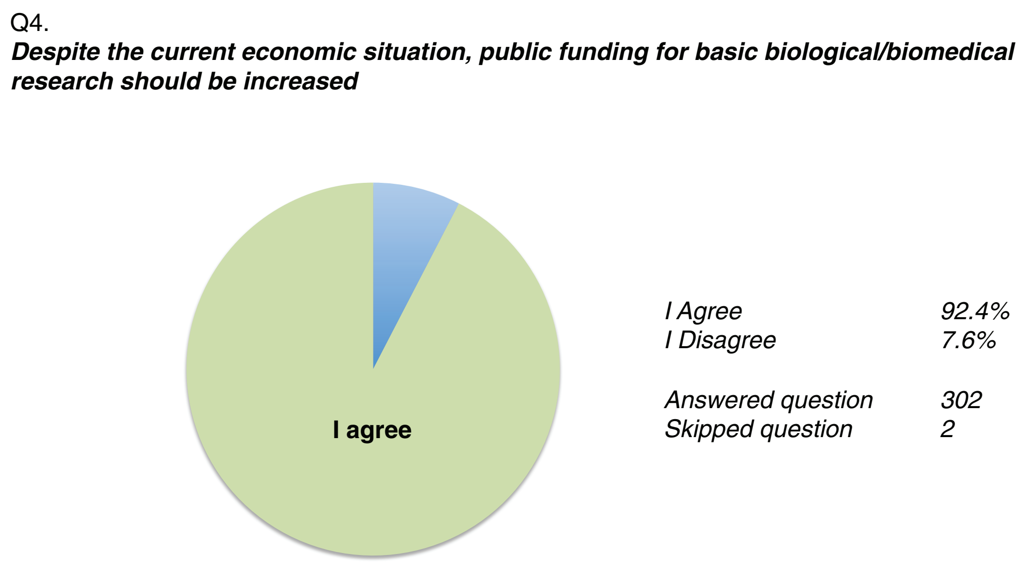


Figure S4. The vast majority of basic scientists think that public funding for basic biological/biomedical research should be increased, despite the current economic situation.

Q13. (Subsets of total sample)

Written proposals about basic biological/biomedical research generally contain a section discussing potential future health benefits. These sections increase the likelihood that a project benefits future public health

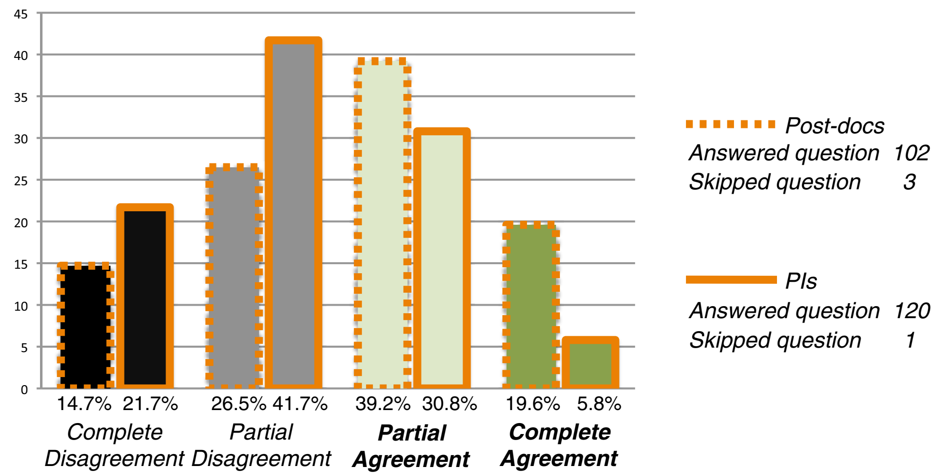


Figure S5. Principal Investigators are sceptical (and more than the post---doctoral researchers) about the effectiveness of discussing potential practical outcome in basic research proposals.

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Data Source

Current Referee Status:

Referee Responses for Version 1

Daniel Strech
CELLS - Centre for Ethics and Law in the Life Science Institute for History, Ethics and Philosophy of Medicine, Hannover Medical School, Hannover, Germany

Approved: 31 March 2014

Referee Report: 31 March 2014
This study addresses an interesting and relevant topic. Box 1 in particular is innovative and makes a good link to the findings.

I have the following comments:

1. More remarks are needed about the relevant body of evidence. Are there other studies that investigated the self-understanding of basic scientists in biomedicine? The Background mentions none and the Discussion only one paper.

2. The main text should make clear that the response rate and reasons for non-response are not known. A brief explanation together with a justification on why this approach was selected should be given.

3. Figure 6 is somewhat simplistic and packed with several unjustified assumptions on what the (true) positive and negative effects of specific pattern of resource allocation to basic or translational research are. This should be deleted. The legend to figure 6 is very general, for example the recommendation saying that one should "*produce a good integration between basic and applied investigations …*".

I have read this submission. I believe that I have an appropriate level of expertise to confirm that it is of an acceptable scientific standard.

Competing Interests: No competing interests were disclosed.

Giorgio Scita
IFOM, FIRC Institute of Molecular Oncology Foundation at IFOM-IEO Campus, Milan, Italy

Approved: 30 January 2014

Referee Report: 30 January 2014
This is an interesting well-conducted study that clarifies the way basic science is perceived by basic scientists.

It would have been interesting to assess whether the career stage of the respondents has any impact on their answers to the survey.

In the discussion a point is raised as to whether there is the need to revisit "*the idea that since the future benefits of basic research cannot be accurately predicted, all basic research is equally valuable*" based on the finding that the majority of scientists believe that "*some degree of assessment of the transformative value of basic investigations is always possible*". However in the absence of a clear definition of what the degree of assessment is, it remains difficult to fully support such a perception. Thus caution should be exerted in drawing a conclusion as to whether this mindset could "nudge" more basic scientists (and grant funders) to wonder about the future impact of their investigations.

The list of soft motivational incentives in BOX1 is thought provoking and stimulating.

I have read this submission. I believe that I have an appropriate level of expertise to confirm that it is of an acceptable scientific standard.

Competing Interests: No competing interests were disclosed.