



OPINION ARTICLE

# Revitalizing biomedical research: recommendations from the Future of Research Chicago Symposium [version 1; referees: 2 approved with reservations]

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**Abstract**

The biomedical research enterprise faces considerable structural challenges after years of stagnant funding coupled with steady growth of the pool of graduate students and postdoctoral scientists. Input from junior scientists into the nature of how these challenges affect both the quality of the enterprise and career outcomes is essential to craft effective reforms that will bring a new era of robustness into biomedical research. In October 2015, junior scientists based in Chicago organized the Future of Research Chicago Symposium. The goals of the meeting were twofold: first, to educate the local community about structural problems in biomedical science; and second, to survey scientists in the Midwest, particularly postdocs, in order to find out their views on these issues and solicit suggestions for improvement. We present the recommendations of Symposium participants as distilled by the organizers. These recommendations reflect junior scientists' desire for diversification of career development opportunities within the framework of doctoral and postdoctoral training and for policies at funding agencies that demonstrate a stronger commitment to supporting trainees and new investigators. We discuss practical steps that can be taken to enable these reforms, highlighting the responsibilities of junior scientists, faculty, funding agencies, and other stakeholders in working toward the goal of a revitalized biomedical research system.

**Open Peer Review**

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- 1 **Christopher L. Pickett**, Rescuing Biomedical Research USA
- 2 **Richard McGee Jr**, Northwestern University USA

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Future of Research

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## Introduction

The biomedical research enterprise in the United States faces significant structural challenges<sup>1</sup>. Since 2000, federal funding for biomedical research and development as a percentage of GDP has declined as Congressional appropriations continually lag behind inflation<sup>2</sup>. Over the past 20 years, the percentage of grant applications funded by the National Institutes of Health (NIH) has fallen by 50%. As funds disappear, biomedical research has become hypercompetitive, with the unfortunate result of fewer biomedical PhDs working in their field of training and increasing percentages leaving research altogether, compared with 25 years ago (Appendix E in 3).

For those early in their scientific careers, including graduate students, postdoctoral researchers (postdocs), and junior faculty, the pressure of structural problems in the biomedical workforce is especially heavy. Postdoctoral training has come under renewed and particularly intense scrutiny in recent years. Postdocs are an important part of biomedical research, providing most of the skilled labor responsible for scientific discovery and innovation<sup>4</sup>. Historically, the postdoc position was designed to be a temporary period of focused training needed for future independent research careers. However, since 1990, the estimated postdoc population has doubled, causing an increase in the average length of postdoc training to 5–6 years and resulting in fewer percentages of postdocs obtaining faculty positions. Many commentators have noted that a postdoc position today serves less as a temporary period of advanced training and more as a source of cheap scientific labor<sup>5–7</sup>, equating to ~\$16/hour with few fringe benefits. In addition, as federal funding for research has shrunk, the average age of NIH investigators and the average age at which an investigator first obtains NIH R01 funding have both steadily increased over the past 25 years<sup>3</sup>. Strikingly, fewer than 3% of NIH funded investigators are now under the age of 36<sup>3</sup>. Together, greater numbers of postdocs without permanent jobs in their academic fields has supported the concept of the ‘postdoc holding tank’.

Beyond economic forces, a lack of preparation or motivation for seeking careers outside academia appears to be contributing to the swelling number of postdocs. The skills acquired during traditional doctoral and postdoctoral training concentrate on preparation for academic careers. However, many career paths for doctorate-level scientists require a broad skill set including competencies in management, business, communications, and leadership that are not a significant focus of the traditional PhD training model<sup>3,8</sup>. Among PhD students, interest in an academic research career declines during graduate training<sup>9,10</sup>. However, junior scientists commonly report that faculty advisors often encourage academic research as the definition of “successful” career paths while explicitly discouraging graduate students and postdocs from pursuing non-academic careers<sup>9,11</sup>.

In response to employment trends among young biomedical doctorates, the NIH recently initiated a program called Broadening Experiences in Scientific Training (BEST)<sup>12</sup> to expand career preparation for biomedical graduate students and postdocs. Between 2013 and 2014, 17 universities across the country received BEST grants, which provide five years of non-renewable funding to develop and test new approaches to career development that would

complement traditional graduate and postdoctoral training. While the BEST program has largely been perceived as a success, it is unclear whether these programs will continue once the funding runs out, or whether the approaches developed within the BEST program can be broadly replicated at non-BEST institutions. Without long-term strategies to address the realities of career trends among PhDs, and absent a major shift in the research funding landscape, the outlook for continuing to attract talented young minds to biomedical research remains dim.

In response to the endemic issues in postdoctoral training, and to the larger problems of the biomedical community as a whole, postdocs and young faculty alike are increasingly engaging in advocacy efforts aimed at changing policies and practices to improve the research environment in the US. A recent notable example is the Future of Research (FoR) Symposium organized by junior scientists in Boston in 2014. A white paper of recommendations produced by FoR<sup>11</sup> was recently included in a survey of panel reports aimed at distilling necessary reforms for biomedical research<sup>13</sup>.

Inspired by the events in Boston and motivated by FoR’s stated desire to see junior scientists advocate for change spread throughout the country<sup>11</sup>, a group of postdocs in Chicago organized their own meeting, the Future of Research Chicago Symposium (FoR Chicago), which took place on October 29, 2015 (for meeting information, see <http://futureofresearch.org/chicago/>). In this report, we, the organizers of FoR Chicago, lay out several major issues for reform identified by our Symposium. We summarize the solutions generated by open discussions among meeting participants and offer specific recommendations for achieving these reforms.

## Part I: Guest speakers at FoR Chicago

The FoR Chicago Symposium opened with keynote lectures designed to introduce policy issues in the biomedical research ecosystem as context for participant-centered discussions later in the day. The speakers were chosen for their expertise in the policy of science, as well as to represent a diverse group of stakeholders. Nancy Schwartz, Dean for Postdoctoral Affairs at the University of Chicago, opened the day with remarks framing the topics of biomedical research sustainability and how to achieve better outcomes for scientists in training. Keith Yamamoto (UCSF), who served on the NIH task force charged with reviewing the biomedical research workforce<sup>3</sup>, delivered the first keynote lecture. According to Dr. Yamamoto, the PhD-to-postdoc transition is currently viewed as a relatively fixed part of scientific training; the postdoctoral period constitutes a “hub” from which trainees may then follow numerous career paths. Dr. Yamamoto proposed that graduate school should be the “hub” from which a newly minted PhD could opt to pursue many career paths. This would be more sensible, said Dr. Yamamoto, because many careers do not require postdoctoral training; furthermore, such a system would help control the growth of the postdoc population. Following Dr. Yamamoto, Greg Petsko (Cornell), who chaired the National Academies’ Committee to Review the State of Postdoctoral Experience in Scientists and Engineers<sup>4</sup>, gave the second keynote talk. Dr. Petsko recounted the study, which led to the National Academies’ 2014 report, “The Postdoctoral Experience Revisited”. After presenting highlights of the report, Dr. Petsko offered some of his ideas about how the postdoc

dilemma fit into larger challenges in the research enterprise related to funding, publishing, and judging high-quality science.

The keynote lectures were followed by a panel discussion exploring the evolution of scientific training. The panelists were Kay Lund (NIH), Gary McDowell (formerly of Tufts University, now with Future of Research), Mary O’Riordan (University of Michigan), and Krisztina Eleki (Chicago Council on Science and Technology), who discussed the mismatch between the aims of traditional scientific training and the contemporary career training needs of graduate students and postdocs, along with ideas for how to align training goals to better meet these needs. In both the lectures and panel discussion, audience members had the opportunity to ask questions of the speakers; there was also time for informal engagement during the morning coffee break and lunch, where the speakers sat among the attendees for extended conversation.

## Part II: Participant-centered discussions

In the afternoon, we invited all the participants of the Symposium—postdocs, students, faculty, staff, and others—to debate key issues and identify potential reforms through a series of moderated workshops. The workshops were organized around the following five topics: Revolutionizing Training, Curricular Reforms/Experiential Learning, Incentivizing Good Science, Funding Mechanisms, and Scientific Workforce Structure. The topics were chosen by the organizers based on key issues identified at the 2014 FoR Boston Symposium as well as similar events taking place in the spring of 2015 at the Universities of Michigan (FOBGAPT; <http://www.rackham.umich.edu/fobgapt>) and Wisconsin-Madison<sup>14</sup>. Participants could attend two workshops of their choosing. During the workshops, problems and solutions were written on sticky notes and grouped into relevant categories. Following the event, we compiled suggestions into briefs from each workshop, and then compared all the briefs to identify major themes. There was a notable degree of overlapping ideas among the different workshops, which underscores the interrelatedness of challenges in biomedical research.

### Theme 1: New training paradigms for biomedical PhDs

In almost every workshop session, participants expressed concern at a lack of education and training for careers paths apart from academic faculty. This shortfall of career preparation for new PhDs is cited by junior and senior scientists alike as one of the major problems facing biomedical research<sup>1,3,10,11,13,15</sup>. Because of the pressing nature of this issue, along with data showing that most biomedical PhDs move into careers outside academia, the NIH recently instituted the BEST program to expand career development resources at a selected group of universities who applied<sup>12</sup>.

Among participants’ suggested solutions to the problem of narrow career training, we identified a set that broadly calls for the establishment of “professional PhD” programs alongside or in place of the traditional PhD education. PhD programs with a stronger professional development component added as curricular or extracurricular activities would provide earlier exposure to non-academic career options, along with enhanced knowledge and skills needed for these careers. Participants put forth a number of implementation methods to create professional PhD programs including: 1) allowing

students to take courses in a professional program of study (e.g. medicine, business, law) as electives, or a part of a “minor concentration” during the PhD; 2) expanding the number of joint degree programs whereby students could simultaneously work toward a PhD and another degree such as an MBA or JD (not counting MD-PhD programs); and 3) adding internship or externship work experience as a regular part of PhD training.

Apart from expanding the range of formal academic approaches to diversifying career preparation, participants also expressed a desire for greater development of “soft” skills that are portable and relevant across many careers. To do this, institutions housing trainees could adopt standards for achieving proficiency in various skill sets and require departments and/or PhD programs to provide training in these areas. One such set of standards that already exists for this very purpose is the National Postdoctoral Association Core Competencies (<http://www.nationalpostdoc.org/?CoreCompetencies>). Furthermore, it was recommended by participants that institutions should solicit input from various career sectors in order to align training goals with the needs of employers.

Participants also said that students and postdocs should take on more responsibility for career planning and work to achieve a higher level of self-confidence in considering future career opportunities. Because many trainees feel pressure to succeed on the project in front of them and to pursue an academic career, they may view time spent on career planning as a waste or an admission of failure. Many participants cited individual development plans (IDPs) as a useful tool for reflecting on one’s career aspirations and for building confidence in those aspirations. Trainees should involve Principal Investigators (PIs) in creating IDPs to establish a clear set of goals as well as a shared sense of responsibility and accomplishment. There were also a number of people who believed that students and postdocs interested in careers outside academia should be empowered to seek out mentors in those areas to provide guidance complementary to that of their PI.

While mentorship was not a specific workshop topic, numerous discussions touched on mentoring as an area in need of significant improvement. Many participants expressed frustration with either a lack of attention or guidance from PIs, or mentoring practices that did not take trainees’ goals into account. Participants felt that improving mentorship would enhance trainee productivity and increase the quality of trainees’ research, as well as promote better development for a range of careers.

Several suggestions were put forth to address this issue. First, the availability of mentor coaching programs to build mentorship skills should be increased. We also think that institutions could provide such training, with guidelines established by funding agencies or scientific societies. An example of such a program is the NIH-funded National Research Mentoring Network (NRMN, <https://nrmnet.net>), which aims to create and disseminate resources for mentoring and professional development that can be used at all stages of a scientist’s career progression. To make PIs more accountable for mentoring, reviews of PI mentoring activities should be included on performance evaluations for both PIs and trainees, and funding agencies should incorporate scoring criteria for mentorship on grants that call for trainee labor.

## Theme 2: Careers for biomedical PhDs

Most participants in FoR Chicago expressed concern over the lack of data pertaining to the career outcomes of biomedical trainees, a problem which has been noted elsewhere<sup>4,11,15-17</sup>. Such career data would give trainees a clearer vision of the diversity of careers available to PhDs and could help guide efforts to design new training models. Most participants agreed that PIs, graduate programs, and/or departments should gather career outcome data on their alumni and make this information publicly available on the Internet.

Collecting employment data will require cooperation between training institutions and the places that hire biomedical PhDs. At the moment, there is little national career data on PhDs; however, participants suggested that such data could be recovered from LinkedIn. A recent report by Silva *et al.*<sup>17</sup> demonstrates the feasibility of this approach for tracking postdocs from a single institution, although it is unclear how this might scale to collect nationwide employment data. Another suggested approach would involve incentivizing companies to track and share PhD hiring trends. Labor data clearinghouses such as Economic Modeling Systems, Inc. (EMSI; [economicmodeling.com](http://economicmodeling.com)) have provided valuable information to scientists and labor economists studying the landscape of post-PhD employment<sup>8</sup>.

The number of postdocs in US biomedical science is unknown; estimates range from almost 40,000 to over 100,000<sup>4,18</sup>. In agreement with other reports<sup>4,8,11</sup>, participants said there are too many postdocs and believed that steps should be taken to reduce their numbers. Many participants agreed that replacing postdocs with permanent, higher-paying staff scientist positions would curtail the growth of the postdoc population while providing a source of skilled scientific labor. This recommendation has been echoed by many commentators<sup>13</sup>. At the same time, participants desired that the purpose and expectations for postdoctoral training be more clearly defined. Doing so would help eliminate the widespread notion that the postdoc is a “default” step in the career progression of PhD scientists<sup>4,19</sup>.

## Theme 3: New approaches to funding

Among our participants, there was a sense that recent declines in funding for science, especially as a part of federal spending, had suppressed the research community’s ability to do important, innovative work. According to participants, scientists should advocate for sustainable federal research budgets. Similar recommendations have been made by many groups<sup>1,11,13</sup>. Additionally, participants favored cost-saving measures that would create greater returns on funding investment. These included directing more funds toward shared equipment or establishing core facilities that could serve multiple laboratories. In order to encourage long-term planning and reduce wasteful spending, participants recommended that the federal government and NIH should lift restrictions on carrying over unused money between funding years. Furthermore, funding agencies should conduct audits of grant spending upon application for renewal.

Many participants felt concerned that the current process of grant review is too political, with established PIs holding a significant advantage over junior scientists to win funding. They also expressed

concerns on grant decisions being biased by scientific pedigree, institutional affiliation, and a heavy reliance on journal metrics as a substitute for quality of ideas. Participants put forward a number of suggestions to improve grant review and help support early-career scientists. The NIH could designate more money for the existing postdoctoral fellowship and career development awards, like the F32 and K award programs. F32 awards support training for individual postdocs with the potential to become independent investigators, while K awards are career development grants for advanced postdocs to move into a PI role, either under the guidance of a mentor (K01) or with more independence (K99). Expanding these mechanisms, particularly the K award program, could provide crucial financial support for new generations of young scientists, and help stabilize the growing average age of NIH funded investigators. However, it was not specified by our participants whether the additional money should support more of these awards or be used to increase their value. Grants originating from early-career scientists should be reviewed separately from mid-career and senior PIs; furthermore, applicant names and institutions should be removed from grant applications to reduce reviewer bias. Creating new block grant mechanisms to fund institutions instead of individual investigators was also put forth as a way to ensure a more equitable funding landscape.

Participants suggested that new PIs should be cultivated for their fresh, innovative ideas. To support this process, study sections should include junior faculty, and funding agencies could expand award programs that support pilot studies or high-risk, high-reward projects that can provide the basis for a prolonged and productive scientific career.

The process of grant writing was viewed widely as cumbersome and burdened by regulations. Participants favored several reforms in this area, including standardizing grant application formats and scoring metrics across federal funding agencies; automating and streamlining the application process; and creating or expanding positions for grant support staff working in research institutions that receive federal support. These changes could relieve some of the time pressure demands on PIs who are writing grants, allowing them to focus more on doing science and mentoring trainees.

## Theme 4: A better culture of research

Our participants, 79% of whom self-identified as trainees, wanted to change the culture of academia to foster robust discovery and innovation and to strengthen the feeling of being part of a scientific community. As a way for scientists to promote innovation (apart from the funding tactics described above), one intriguing suggestion was that major scientific meetings devote a session to highlighting innovative early-career work. Participants called for several actions concerning publishing and data sharing to enable new discoveries and empower the free exchange of ideas among scientists. These included expanding open-access journals, creating open data repositories, and embracing publication of negative results as part of the scientific process.

Finally, participants said that finding joy in one’s work and having self-confidence were critical ingredients for succeeding in science. Unfortunately, they viewed the current culture of science

as depriving too many young people of experiencing powerful positive feelings about their work. As a solution, participants recommended that institutions should dedicate greater resources to promoting social cohesion among young scientists, noting that connection with one's peers can help people remember the joys of science.

## Conclusions

Our vision for the Future of Research Symposium in Chicago was to give a diverse group of scientists, 79% of whom were PhD students and postdocs, a chance to speak out on where reforms are needed in the American biomedical research enterprise and to hear from national leaders. The proposals put forth by the Symposium participants point to several areas requiring critical attention. Scientific training for PhDs and postdocs must be recalibrated to prepare scientists to follow multiple career paths beyond the traditional route in the academy. The postdoctoral training period in particular needs to be revitalized. Young scientists should not have to treat a postdoc position as a default step on their career path, nor should PIs treat it as a source of inexpensive scientific labor. Funding agencies including the NIH and others could take steps to lend greater support to young investigators and encourage bold, innovative research initiatives. And, the scientific community should adopt cultural practices that foster a spirit of openness, collaboration, and community that will help sustain the research enterprise and attract future generations of scientists into its ranks.

Several of the recommendations put forth here echo those made by other commentators. Our proposals add to numerous calls for diversifying career training for students and postdocs, and increasing the number of permanent staff scientists employed in biomedical research laboratories<sup>1,4,11,13–15,20,21</sup>. We also highlight the need for improved mentorship in academia, which reflects a common view among postdocs<sup>11</sup> and other groups studying the contemporary trainee experience in biomedical research<sup>3,4,8,10,17</sup>. We hope that the recommendations provided here will encourage further discussion among scientists and stakeholders from many corners of the biomedical research enterprise and the larger scientific community, thereby adding momentum to the movement for broad reform of the current system.

Translating these ideas into action will require a concerted effort from stakeholders across the research landscape. Recent examples of such teamwork include the ASAPBio meeting ([asapbio.org](http://asapbio.org)) featuring junior and senior scientists, journal editors, and funding agency representatives; the ASBMB Sustainability Summit (<http://policy.asbmb.org/2016/02/01/the-asbmb-sustainability-summit/>), organized by that society's public policy branch; and the work of organizations such as the National Postdoctoral Association (<http://www.nationalpostdoc.org>), Rescuing Biomedical Research (<http://rescuingbiomedicalresearch.org>), and Future of Research (<http://futureofresearch.org>). We hope that these efforts continue to involve people from all levels of science, including junior scientists. In order to achieve reforms, groups such as these must not overlook

the need to win support from rank-and-file faculty across the US. Indeed, we believe that faculty will play a critical role, perhaps the central role, in determining whether the efforts to reform scientific research succeed or fail. In our research system, faculties embody the culture of science; they train young scientists; select which grants to fund; determine which papers should be published, and where; and create institutional policy. Changing the culture of research will require them to buy into the vision of those who would reform it. This is an enormous task, but one that cannot be avoided if we are to create a better future for science and for scientists.

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## Author contributions

K.T.D. drafted the manuscript. All authors were involved in revising the initial draft of the manuscript and have agreed to the final content.

## Competing interests

K.T.D. is a member of the board of directors of Future of Research. The views expressed by the authors do not necessarily reflect those of any institutions or organizations with which they are affiliated.

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# Open Peer Review

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**Richard McGee Jr**

Feinberg School of Medicine, Faculty Affairs, Northwestern University, Chicago, IL, USA

Having reviewed the manuscript prior to reading the comments of the other reviewer, I would concur with most of the points raised so I won't repeat them. In particular, however, the current version makes it difficult for a reader to:

1. Separate new ideas from those in concordance with previous reports, especially those that came out of the Boston meeting of postdocs;
2. Determine which conclusions and recommendations were coming from the meeting participants vs. the authors;
3. Determine which ideas and recommendations had the strongest consensus behind them vs. novel ideas of one or a few individuals

Specific Comments:

Introduction

First paragraph – It is not really true that research funds are 'disappearing'. Stating it this way creates a false sense of rapid decline that is not accurate. The bigger change has been on demand side, not on the supply side, as universities keep applying more pressure to faculty to get grants, decreasing institutional support for faculty salaries, and increasing infrastructure costs. This has led to a big increase in the number of applications for the same research pie.

Second paragraph – As written, this gives the impression that the postdoc is solely a route to academic research career whereas it is also a route to other research careers in industry and government labs, although it is clear there are many postdocs who aspire to but who will never achieve a research-based career in any of these sectors.

Last paragraph – By the end of the introduction, it is still unclear how this event was different than FoR in Boston, whether participants overlapped at all, whether Chicago participants had read the recommendations from Boston, etc.

The meeting – How many individuals attended and about how many participated in each of the breakout groups? As a reader one can't determine if the report represents the collective thoughts of a large or small number of postdocs and others.



Part I – To what degree did these keynotes shape discussion, opinion, and what came out in this report? How were they similar or different from speakers in the Boston event? Essentially, to what degree did the choice and messages lead to or influence the findings and recommendations reported here?

Part II – Who moderated or led the workshops? Were there any guide questions or structure to them, or was it simply as described – providing opportunities for ideas to be ‘voiced’ via sticky notes which were sorted for themes? Do they have any information on the extent of knowledge of prior publications related to the questions being addressed? This is a potentially important issue if a reader is to determine the degree to which what came out of the meeting was spontaneous ideas which can be triangulated with those previously proposed and published, or ‘commentary’ on those.

Theme 1 – new training paradigms – Soft Skills – It is not clear what is meant by these as they can be interpreted in many ways. What are the perceived priorities and how might they be taught? Just giving a link to the Core Competencies is not sufficient to know what the participants raised as important or not.

Improved mentorship is a very vague term and difficult to know what to change. Are there issues that came up other than lack of attention and consideration of trainees’ goals? If so, it would be more valuable to cite them rather than generic better mentorship.

Theme 3 – Several of the recommendations are actually in place and have been for many years, such as carry-forward of unspent funds from one grant year to another. This is standard practice except in unusual circumstances, only requiring clarification if the amount to be carried forward is more than 25%, and even then it is generally approved with reasonable justification. Also, a great deal of funding is going toward shared resources and core facilities, and if more was to go in that direction it would have to come from some other research line.

The recommendation for more F32 and K awards was somewhat hard to grasp given the concerns raised for more emphasis on non-PI careers. Currently, the limiting constraint is the number of tenure-track faculty positions so it is unclear how training more postdocs for these roles will improve the situation. Non-tenure track positions have continued to rise so this is one potential growth area for young scientists, albeit with limited stability.

The suggestion that grants from early career scientists should be reviewed separately was actually implemented several years ago for NIH review panels.

**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, however I have significant reservations, as outlined above.**

**Competing Interests:** No competing interests were disclosed.

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The meeting report “Revitalizing biomedical research: recommendations from the Future of Research Chicago Symposium” from Dolan, *et al.*, describes a meeting in Chicago in 2015 featuring two keynote speakers, a panel session and multiple breakout sessions attended by trainees, staff and faculty. The majority of this report focuses on the recommendations and outcomes of the breakout sessions.

This paper is an important contribution to the growing literature on how postdocs view their place in the biomedical research enterprise. That said, the authors can make several significant improvements to this manuscript to clarify the outcomes of this meeting and what actions should be taken next.

#### Primary recommendations

- The manuscript would benefit from a display item cataloguing the many recommendations made pertaining to each of the themes.
- The authors should state clearly how the outcomes of their meeting relate to (1) McDowell, *et al.*, (2014) and (2) other reports recommending changes to how students and postdocs are trained.
  - Postdocs play a pivotal role in the research enterprise, but this is only the second publication from a postdoc meeting discussing the ailments of the research enterprise. The growth of the postdoc voice in the conversation is an important point that the authors should stress.
  - The authors should clearly state how their outcomes are the same or different from the McDowell paper and what conclusions they draw from these similarities and differences.
  - Many reports have been written discussing trainee issues, and the authors do a nice job referencing much of the literature. The authors should go further to clearly define how their recommendations contribute to the ongoing discussion and highlight areas of agreement or disagreement with these reports.
- It is important for the authors to make very clear for the reader when they are reporting the participants’ recommendations or their own suggestions. In the final paragraph of Theme 1, the authors use “We think...” when discussing recommendations made by participants. This is quite confusing. Other sentences throughout the manuscript should also be clarified to ensure the reader understands who is making the recommendations. It may be useful to move the authors’ suggestions and recommendations to the conclusions and stick to participant recommendations in the themes.
- The authors should take more time in the Conclusions to give direction to the recommendations made at their meeting. Many of the recommendations had been made by others, as the authors indicated, but what does this mean about the progress of change? Which recommendations do the authors think are the most important to focus on? Where, given developments since the end of their meeting, should efforts be focused to make the most change?

#### Secondary recommendations

- The authors list that “postdocs, students, faculty, staff, and others” participated in their event. Rough estimates of the percent attendance by career stage would be important to understand the tenor of the recommendations being made. Furthermore, if the data are available, it is important to communicate if one career group, like postdocs, had more of a say in the recommendations of one theme than other groups.
- It is not clear what the authors are trying to convey with this sentence: “Without long-term strategies to address the realities of career trends among PhDs, and absent a major shift in the

research funding landscape, the outlook for continuing to attract talented young minds to biomedical research remains dim.” What are “long-term strategies to address the realities of career trends” and how do they help recruit young scientists into the enterprise? Would a “major shift in the research funding landscape” do more to retain young scientists in the enterprise or recruit them to it? This sentence should be recast to capture the authors true intentions or deleted altogether.

- The participants in Theme 1 did not offer “implementation methods” as the authors suggest. Implementation requires a plan to make the recommended change a reality, such as who should be tasked with advocating for and making the change and a timeline for the change to take effect. This type of plan is not offered in the manuscript. Rather, the participants make recommendations for alternative models to achieve the objective, and they should be characterized as such.
- In the final paragraph of Theme 1, the authors list, “First, the availability of...” but there is no “Second...”. The sentences should be recast to address this issue.
- In Theme 2, to give an alternative, yet complementary, picture of what the Silva *et al.* group did, the authors should consider referencing The Stanford PhD Alumni Employment Project (<http://web.stanford.edu/dept/pres-provost/irds/PhDAlumniEmployment>). It could also be useful to reference some of the schools that publish career outcomes information such as [UCSF](#), [University of Chicago](#) or [Tufts University](#).
- In Theme 4, the participant’s recommendation suggests a lack of interaction and social cohesion is responsible for people not “experiencing powerful positive feelings about their work.” Is this lack of interaction the root cause of poor morale as identified by the participants? How much of the material in Themes 1-3 play a role in lab morale? The authors should expand and clarify what the participants cited as depressing the lab culture.
- The authors discuss several broad problems facing the research enterprise but sometimes obscure the complexity of the reasons behind them. I recommend recasting these sentences to reflect the complexity of the situation. Specifically:
  - “However, since 1990, the estimated postdoc population has doubled, causing an increase in the average length of postdoc training to 5–6 years and...” Linking population growth directly to the length of postdoc training leaves out many important details. Stagnant research funding, the dwindling number of faculty positions and poor training for jobs outside of academia, in addition to population growth, have affected the length of postdoc periods.
  - “Over the past 20 years, the percentage of grant applications funded by the National Institutes of Health (NIH) has fallen by 50%.” While accurate, it is important to note that, in the context of the rest of the paragraph, this is due to a doubling of grant applications rather than a decline in the raw number of grants funded.
  - As funds disappear, biomedical research has become hypercompetitive...” Stagnant funding is a major contributor to the hypercompetitive environment, but so is the growth in the population applying for grant funding and the increase in applications referenced above.
  - The authors state the BEST program was implemented, “In response to employment trends among young biomedical doctorates...” This is partially true, but again, oversimplified. The BEST program was initiated in response to a recommendation in the NIH Biomedical Workforce Working Group report from 2012, continuous advocacy from parts of the research community, the apparent success of a variety of existing university-specific programs, and yes, an analysis of employment trends.

**References**

1. McDowell GS, Gunsalus KT, MacKellar DC, Mazzilli SA, Pai VP, Goodwin PR, Walsh EM, Robinson-Mosher A, Bowman TA, Kraemer J, Erb ML, Schoenfeld E, Shokri L, Jackson JD, Islam A, Mattozzi MD, Krukenberg KA, Polka JK: Shaping the Future of Research: a perspective from junior scientists. *F1000Res.* 2014; **3**: 291 [PubMed Abstract](#) | [Publisher Full Text](#)
2. Silva EA, Des Jarlais C, Lindstaedt B, Rotman E, Watkins ES: Tracking Career Outcomes for Postdoctoral Scholars: A Call to Action. *PLoS Biol.* 2016; **14** (5): e1002458 [PubMed Abstract](#) | [Publisher Full Text](#)

**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, however I have significant reservations, as outlined above.**

**Competing Interests:** No competing interests were disclosed.

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