Title: Innovative Funding Models for Reintegrating Biology

Authors: Albert Abbott

Summary: Recently a significant number of biological research scientists met in a workshop to explore visions on how to reintegrate biological research through implementation of multidisciplinary teams focused on understanding processes that scale across the time and space of biological organisms. Within the context of this workshop, a number of participants voiced concerns about the emerging trends for funding at NSF and other agencies of which this proposed biology reintegration program was an example. In this short paper, I have tried to capture these concerns with the intent of ensuring that these voices are heard without an over excessive focus on the perceived negatives or positives of such programs but presenting areas where there are opportunities for innovation in funding models.

The vision:
The National Science Foundation has introduced several new funding opportunities which are premised on the idea that over time the study of biology has fragmented into a myriad of sub-disciplines each with focused questions relevant to the subdisciplines but seemingly unconnected to the foundational and emergent principles of biological life. Whether this perception is myth or fact rather depends on the time and scale we view our progress in understanding the fundamental and emergent principles of biology, however, the fact is that NSF has implemented these funding opportunities to address the challenge to reintegrate biology. These programs, such as, the Rules of Life Program and the Biological Institutes Program are directed at cross-disciplinary research with the goal of setting the stage for the next emerging frontiers of biological research and education. (e.g. "National Science Foundation (NSF) unveiled a set of "Big Ideas," 10 bold, long-term research and enabling ideas that identify areas for future investment at the frontiers of science and engineering"). Within the frameworks of these programs are goals such as that of the Biology Institutes Program:

"Integration across biological disciplines is essential if we hope to understand the diverse and ever-increasing data streams of modern biology and tackle emergent questions about living organisms and the environment. Of equal importance is the need for groundbreaking and sustainable training programs that prepare the next generations of scientists to navigate the breadth of biological sciences, training in multiple disciplines without sacrificing depth of learning or innovation. In addition, the biology community must continue to develop practices and adopt strategies that leverage rapid advances in cyberinfrastructure and other technologies to bridge and integrate across subdisciplines and make resources accessible, re-usable, and adaptable for unanticipated purposes".

All these are laudable goals, however, to achieve a measure of success in all these arenas academic institutions and faculty must reinvent themselves in a very short time frame to be competitive. These programs challenge the investigators and their institutions to have strategies or structures in place to compete for such funds. This is likely not the case for many institutions

in the US, therefore, such programs are often perceived by investigators to be elitist by design and not worth the effort to apply. It is easy to state that successful projects will essentially be driven from the bottom up but the mandate to change is being driven by investment in a few top down large scale projects. This contradiction creates a visible anxiety among research scientists with individual research programs that focus, by necessity, on scientific survival in specific subdisciplines. Therefore, it is imperative as we proceed into the "Brave New World" of big concept emergent science and engineering that we understand our scientific history. In this regard, I provide here a brief perspective taken from my own experience and that of my scientific colleagues to describe the very real or perceived challenges of reinventing ourselves for the future.

In order to understand the biological science research trajectory and to alter its path, we need to understand the roles that have been played by the: 1) individual scientists, 2) the individual institutions,3) the funding organizations (federal, state, local, private) and 4) the public. All of these are to some degree complicit and interwoven together in the current fabric of biological investigation and it will take significant investment of time energy and resources from all these players to unravel and reweave this tapestry if indeed this is necessary.

Funding resources and scientific culture.

Realistically and historically biological science research has been focused on specific questions generated by individual investigators and their students/postdocs working in labs focused on utilizing their individual expertise and technologies to address these questions. Under this scenario, the evolution of funding resources was toward funding these individual single laboratory endeavors and consequently, the process of proposal review and funding was organized and directed at evaluating the science at this level and scale. This is the culture of single investigator proposals (my reality when I started) and for the time, space and level of technology led to many great discoveries. In more recent time, several things have significantly changed: big science technology has grown; informatics abilities and technology are expanding; the number of faculty at academic institutions has grown; and biology is no longer a single discipline department but fragmented into multiple subdiscipline departments sometimes in multiple colleges. All of these realities have created significant challenges for funding models to promote integration and large-scale cross-disciplinary biological science. I elaborate on these challenges below.

The Challenges: Funding agencies

1. Large scale across discipline questions have not traditionally been the focus of funding, thus, the infrastructure of the review process needs innovation to meet the challenges posed by these large scale proposals that will be high risk, include facets from multiple disciplines (requiring a review team with cross-discipline expertise) and challenge the reviewers to weight more heavily innovative ideas over preliminary results (high risk, high reward). Traditionally, this is not what reviewers have been asked to do and will require significant efforts on the part of the funding agency to develop innovative ways to evaluate this type of proposal.

2. The reality of academic science is that new or young investigators will not likely have developed the collaborative networks of scientists in their own area of expertise much less in other disciplines. Additionally, there is a funding culture that believes that a starting investigator is not experienced enough to run one of these large-scale proposals as a lead PI. This creates a very big conundrum because young investigators are expected as part of academic institutional culture to develop a program that is "their own" for promotion and tenure. The funding agencies must create and innovative solutions to this problem that foster the ideas and careers of young investigators, while at the same time insuring administration, implementation, and successful completion of the proposal objectives.

3. Since integration of biology will cross disciplinary boundaries then different funding agencies need to innovate on cross cooperation and co-funding strategies. Scientists are being asked to think and innovate across the disciplines and the various agencies have a real opportunity to work together in funding these types of proposals.

4. Biologists in general are educated and trained at the higher degree level in very focused disciplines (ecology, evolutionary biology, biochemistry, genetics etc.) which have specific languages. This is also true for disciplines outside of biology. In order to build cross-disciplinary teams, scientists need to communicate in a common language or at least be able to translate to each other. Funding agencies have an opportunity on innovative strategies to provide venues for allowing opportunities for scientists to cross discipline train. This could be at all levels of academic career development.

5. These large investment multidisciplinary projects will require long term investment as the scale of these projects demands. The funding agencies have a challenge to innovate as to how such long term 5-10+ projects can be funded and sustained once funding is finished. As an example, from my own experience, data repositories need to be maintained over time if they are to serve as substrates for metadata and large-scale scientific inquiry, how will this be achieved?

6. Big science crosses not only disciplinary boundaries but international ones as well. There are significant innovative opportunities for funding agencies to explore cooperative, international funding models and agreements with non-national partners.

The Challenges: Academic/research institutions and young scientists

1. Considering the trends in funding and the trends to big scale science, academic institutions need to innovate on solutions for reshaping the academic infrastructure and culture at all levels. Cross disciplinary science will increasingly require the breakdown of traditional structures for educational programs, potentially leading to innovative educational opportunities for degree programs. Partnerships with funding agencies both public and private can play a significant role in this process.

2. Concomitant with the increased focus on long term, large scale cross-disciplinary projects, the opportunities for young investigators to “get their first grant” have increasingly lengthened in time. This is largely due to: 1) the research resources have not kept up with the increased demand; 2) redirection of internal program funding allocations within the agencies to cover new directions; 3) changes from multiannual submission opportunities to annual submission deadlines for grant panels; and 4) reduction in funding opportunities from state agencies and others. However, the academic cultural norms that demand success within a short 5-7year time frame have not changed. Additionally, at many institutions being part of a large team project does not weigh as much as your own individual project for tenure and promotion considerations. If the funding paradigm and accessibility of single lab grants has changed, then this academic culture must innovate to protect young investigators. In part, this culture is probably responsible for many young people choosing to go into other careers than science or choosing low-risk research questions and collaborations. It would be truly innovative for funding agencies to work with academic institutions to promote a different scientific culture that fosters time and opportunity for young scientists to find their niche and succeed in their career paths. As paths in academic science are diverse and can change in time in space for an individual, funding agencies need to be cognizant of the opportunity to explore innovative funding strategies to encourage the exploration of the needed cultural shifts in academic institutions and their faculties.

3. Academic science career advancement is tied strongly to publication record in particular first name and corresponding author (many cases last name) publications. Participation in large scale multidisciplinary projects by their nature produce publications where most of the participants are not the first or last name on the paper. The contribution of the co-authors is thus difficult to measure by our current cultural scientific norms. Thus, young scientists participating in these types of projects face a time management dilemma: do I invest significant amounts of my time in this large scale project to realize a very limited academic capital; or do I focus on single investigator grants to gain more academic capital but run high risk of submitting proposals over three or more rounds of review with no payoff. As the funding models are complicit in this problem, then realistically there must be innovative strategies to realign academic culture with the goal of developing large scale multidisciplinary science programs such as the Reintegrating Biology Program.

Finally, funding agencies have played a significant role in the fragmentation of biology, but they have the power to be drivers of the innovative and transformational solutions for reintegrating it. However, it is not as simple as saying we have a pot of money available when those competing for such funds must be willing to put their career on the line in an academic system that has no clear metric for measuring success in this endeavor. Perhaps another vision to reinvent biological sciences research for the future would be to underpin the tower of emerging biology by shoring up its foundation with programs that directly facilitate and encourage young investigators and their institutions to build the new emergent cross disciplinary concepts into

their individual research programs. This vision is based on the grassroots philosophy that lasting change can occur from the bottom up through focus and investment of time and resources at the bottom.