Adapt or Perish
Updating the Predoctoral Training Model

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The fate of biomedical research lies in the hands of future generations of scientists. In recent decades, the diversity of scientific career opportunities has exploded multidimensionally. However, the educational system for maintaining a pipeline of talented biomedical trainees remains unidimensional and has become outdated. This Viewpoint identifies inadequacies in training and offers potential solutions and implementation strategies to stimulate interest in science at a younger age and to better align individualized training pathways with career opportunities (precision training). Both interventions support of the ultimate goal of attracting the best possible future leaders in biomedical science.

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> *"But I think it [the Model] is more likely to change when, and because, far-reaching changes in the mental temper of our descendants demand that it should. The new Model will not be set up without evidence, but the evidence will turn up when the need for it becomes sufficiently great."* (222–223)

In his final published work, the eminent scholar C.S. Lewis describes the medieval model that dominated European intellectual life for centuries and explores how and why this model was replaced—because of discovery of dying stars, development of new scientific theories, and more. Aside from being a testament to an exceptional mind, C.S. Lewis' The Discarded Image also contains wisdom directly relevant to the scientific milieu of the 21st century. Over the past 100 years, science and society have experienced unprecedented, dramatic change as a result of globalization, the Internet, advances in scientific capability, and an increasingly diverse and expanding scientific workforce. Such a large shift in the fabric of society has necessitated a corresponding shift in the environment in which we as scientists operate. However, scientific education lingers behind, using principles and processes that have not changed for many decades. The educational system responsible for training a new generation of scientists equipped to successfully navigate this altered environment is not tooled to maintain the pipeline of new talent; overemphasis on the traditional academic training path, outdated and impersonal biomedical training program structures, and the resistance to shifting science outside of cloistered academic centers all stifle initiatives to enact change. The ultimate impact of this inadequate response is a disappointing and evident reality—budding scientists are leaving science or getting stuck in the pipeline at all stages.[1]

Numerous reports have detailed this problem; fewer have proposed solutions.[2,3] Most reports contain generic recommendations like increasing funding or increasing diversity, providing few concrete approaches for achieving those aims. In addition, the proposed solutions largely focus on the postdoctoral through early-investigator phase with less attention paid to the predoctoral training phase. We think that a workable solution will require substantial reform in predoctoral training because this is a critical bottleneck for career decision making. Amazingly, most of the previously organized discussion of this issue lacks input from predoctoral trainees themselves, instead limiting the input to senior scientists far removed from the nuances of graduate school training, both temporally and hierarchically. This article addresses these gaps by including input from 3 trainee authors and offering specific tactics to engage when revising graduate school training.

Why must we reform training at this specific point in the pipeline? To channel C.S. Lewis, the need has become sufficiently great. Millennials, and the younger Generation Z, are not like the budding scientists of yore. There is minimal allure in the pursuit of the traditional—now archaic—aspiration of becoming a tenured professor that characterized the Baby Boomer generation. This change results in part from lack of job security in the traditional academic setting and availability of positions in new sectors. Trainees observe faculty at all levels being forced out of the laboratory because of sustained austere funding. Today's trainee looks beyond this monolithic career path and envisions success with a wider lens, whether in academics, industry, government, or elsewhere. Even those still interested in the traditional academic route think that this path needs to be revamped. For example, one MD/PhD trainee thought, "If [we] are going to [have] to wait until 42 to get an independent R01 (the traditional metric of success, and the current average age at which scientists are achieving it[4]), they need sources of accomplishment in the interim." To appeal to the future generation of scientists, we need to develop a

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precision educational curriculum tailored to their individual career aspirations. In addition, the scientific community and the economy at large require a more diverse workforce. The current training paradigm, which attempts to force a heterogeneous cadre of trainee scientific pegs through the same round hole, risks losing promising talent and does not support the diverse needs of today's trainee.

In the rest of this Viewpoint, we will detail 3 potential solutions to the pipeline issue and strategies to implement these changes, within the framework of predoctoral training.

Create a Buzz Around Science Early in Life

To solve the current scientific trainee crisis, we must maintain recruitment of those who show the most promise but have not yet entered the scientific pipeline. Young students are often unaware or have a poor understanding of the role of the scientist in the 21st century. Efforts must be directed at the earliest stages of intellectual curiosity, where imprinting occurs (K-12 education). The content and delivery vehicle should resonate with their learning style and serve as a catalyst to promote further self-directed learning. This will involve use of platforms with which Generation Z'ers (the iGeneration) regularly interact, like social media, apps, and games. We provide 3 examples of how this might be achieved.

Increase Scientific Appeal

The first tool leverages the widespread influence wielded by the entertainment industry over this predoctoral demographic. With the airing of the popular TV series LA Law in the 1980s, there was an uptick in law school applications (simultaneous with a drop in medical school applications).[5] The power of pop culture, including recruitment of celebrity spokespersons, could be harnessed to provide a generationally targeted, socially and culturally alluring venue for expressing interest in a career in biomedical research, making science sick (the new cool). A second, more personal approach is exemplified by PhUn Week, an outreach program of the American Physiological Society through which physiologists engage local students to explore science in fun and creative ways in the classroom. The National Institutes of Health could urge grant awardees to participate in sessions such as this. Third, we recommend exploiting the attention-grabbing nature of virtual reality or online platforms to engage students with science-related games.

Increase Mentoring and Enhance Selection of Aspiring Trainees

We should support budding scientists via a peer-mentoring program analogous to Collegevine.com that uses undergraduate peer mentors to support high-school students who are applying to colleges. We propose a variation where science-major upperclassmen are recruited to mentor freshman with expressed interest in biological sciences. This should ensure a rich pipeline of enthusiastic successors for today's established investigators. In concert with establishing a mentoring program, it is imperative to ensure that those we mentor and recruit are likely to succeed as they pursue the PhD training path. Newer methods exist for assessment and selection. The traditional trial-and-error method results in high rates of failure. Recent advances in mobile technology and machine learning help identify high potential latent talent with the right set of attributes for academic and professional success. One clever example, Knack (www.Knack.it), is a set of internally validated mobile video games designed to measure an individual's traits including cognitive skills, social and emotional skills, work skills, and other high-impact traits. The instrument was validated using a sample of subjects whose game data were evaluated against standard psychological tests (eg, Big 5 personality, cognitive battery from Educational Testing Service). Results are compared with a reference data set from >24 000 people from >110 countries worldwide. Corporate employers including Fortune 100 companies are using the technology platform to successfully identify high potential candidates best suited for specific employment opportunities; schools and training providers are using the platform to support their learners and students in selecting a course of study and launching their careers. Such tools may have the potential to match a candidate's scientific interest with their science career aptitude.

Create Strategically Focused Personalized Graduate School Training Plans

Once attracted to science, it is imperative to offer multiple training track options to accommodate the more diversified interests of today's aspiring scientists. When asked, predoctoral students describe their experience as lengthy and lacking practical experience in areas other than academia. A National Institutes of Health workforce report from 2012 showed that only 37% of those graduating with a PhD go on to some form of research career (academic, government, or industry).[6] This means that nearly two third of PhD holders end up pursuing a nonacademic career. The one-size-fits-all approach to training R01-funded academic investigators is no longer sufficient. An opportunity is needed to pursue more flexible graduate training programs with transitional glide paths to careers in academics, industry, government, teaching, and technology. This will require reshaping of the PhD-training process.

Foster Early Career Exploration in Graduate School

Current trainees could benefit from a 2-tier curricular update. Tier 1 represents the essential, foundational training that has produced high-quality scientists and must be preserved alongside curricular reform. Tier 1 would mandate the standardization of skills necessary to become an independent researcher, such as interpretation of scientific literature, development of a solid scientific knowledge base, and grant writing. Tier 1 training would also include essential soft competencies such as leadership and managerial skills as recommended by the American Physiological Society, building the foundation required in all science-related career paths.[7] However, programs should not focus on these core areas alone, to avoid projecting an attitude observed by one trainee: The modern researcher cares much less about exploration and discovering new knowledge than about grants and papers in the career sense.

In Tier 2, students would develop an Individual Training Plan based on identified strengths, interests, and aptitudes possibly including an externship at National Institutes of Health, an industry-sponsored onsite internship, or designing and teaching a course at a community college. Doing so will allow trainees to pursue a nontraditional career route that builds on their scientific foundational training while broadening their options for contributing to the national biomedical workforce.

Offer Additional Funding From Alternative Sources

Because no single mentor can provide the comprehensive training and support that is necessary for the trainee to succeed in today's complex job environment, we propose a mentoring team composed of broadly experienced scientists both within and outside of academia, overseen by an institutional career development office. One hurdle associated with such a mentoring scheme is finalizing funding sources for the student. Later stages of training are typically funded from grants of the thesis director or from external predoctoral fellowship grants, all of which steer students down an academic career path. We suggest offering financial support for non–academia-oriented training, from outside sources via apprenticeships and teaching grants. This would harmonize payment sources with the learning experience, incentivize students interested in alternative careers, and provide a steady supply of promising talent for employers in these other sectors. This alternative approach of broadening the training experience and funding sources has the potential to address the predoctoral problem directly, and the postdoctoral problem indirectly, in a more strategic and fiscally sound manner that would improve the caliber of future science employees.

Restructure the Training Environment to Be Accountable and Nimble

The solutions proposed in the previous 2 sections address a snapshot in time: today's trainee dilemma. How do we create an adaptable model equipped to promptly respond to any future deficits in predoctoral training exposed by the shifting forces of science and society? The key is to be nimble and proactive. We have 2 recommendations for developing such a living training program.

Increase Trainee Participation in Decision Making

As mentioned above, members of most task forces, federal oversight boards, and local graduate education curriculum committees are exclusively faculty. Changes in National Institutes of Health predoctoral training program requirements, local graduate curriculum revisions, and modifications in the structure of the individual graduate school recruitment process would all benefit from direct input from trainees. By including graduate students and even undergraduate members on these committees, a needed voice can help optimize decisions and maintain vibrancy and relevance of the educational program at all levels.

Establish a National Biomedical Sciences Graduate Program Accrediting Board

Unlike most other biomedical training programs, there is no national regulatory body that oversees training of biomedical graduate education. This has created a sea of independent programs that can even differ across departments within the same institution. There is no oversight body to establish standards and ensure that recruitment, coursework, mentoring, career planning, and curricular requirements meet those standards. Accrediting bodies typically exist for professional training programs (eg, nursing, pharmacy, medicine), not strictly academic programs. Graduate medical education is evolving to include professional development and would benefit from such oversight. There is an opportunity for implementing a structure that establishes and disseminates best practices, helps to standardize fundamental components of training, ensures accountability, and considers changes needed for more diverse career path curricula for the modern-day graduate student. Such a system would help realize the benefits of a living training program and ensure sufficient flexibility to attract and accommodate a diverse workforce with continuously changing the needs that operate in step with an evolving culture.

Concluding Remarks

Tackling the trainee dilemma is complex, but it is a necessary and pressing task requiring efforts from all those interested in securing the future of biomedical research. We cannot remain complacent in the face of the changing mental temper of the current and future generations. In short, we must update the model including the way we recruit and mentor, the organization of the graduate school curriculum, the availability of professional development opportunities, and the strategies and people we engage to produce such reform. We must also acknowledge that no model is perfect, and we should be prepared to alter the model as needed, heeding Mr Lewis, who suggested that we regard all models in the right way, respecting each and [idolizing] none.

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