2015 Meeting of the National Directors of Graduate Studies in Pharmacology and Physiology

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THE NATIONAL MEETING OF DIRECTORS OF GRADUATE STUDIES (NDOGS) in pharmacology and physiology is a biennial meeting that is a forum for exchanging information among faculty members responsible for training graduate students in the disciplines of pharmacology and physiology. As a collaboration between the American Society for Pharmacology and Experimental Therapeutics, American Physiological Society, and National Institutes of Health (NIH), the meeting has broad participation among colleagues with a common cause and similar challenges.

The integration of our scientific knowledge at the molecular, cellular, and organismal levels is critical to impacting disease in humans. As our insights into molecular and cellular processes has grown, emphasis in many PhD training programs has shifted away from integrated (whole animal or systems) biology, including the biology of humans. The lack of an available scientific workforce with an understanding of integrated or human biology, including drug metabolism and pharmacokinetics, and an appreciation for the unique challenges of converting discoveries into therapies delays the application of discoveries at the molecular and cellular levels to human disease. Scientists trained in the disciplines of pharmacology and physiology form an important part of this necessary workforce. This meeting addresses critical issues related to training pharmacologists, physiologists, and scientists in related biomedical disciplines and was planned in response to a perceived and real decline in training programs in these disciplines. The goals of this meeting are to identify common problems and opportunities that face PhD training programs in pharmacology and physiology and identify best practices for training that will facilitate translational research.

Opening Remarks

The 2015 NDOGS meeting was held on the campus of the University of Cincinnati and was attended by 72 professors, scientists, and professionals from 49 institutions across the country. Opening remarks were delivered by meeting chair and University of Cincinnati Dean of Graduate Education Marshall (Chip) Montrose. Just as conversations among people of different backgrounds and experiences often cultivate creative and novel ways to tackle problems, the NDOGS 2015 meeting was organized such that each day focused specifically on one issue facing graduate education. The focus of Friday’s talks was aimed at “enhancing the professional pipeline”: ways in which maintaining diversity, global health initiatives, and working across disciplines not only helps our students but also strengthens and furthers the goals of our respective fields.

Enhancing the Professional Pipeline

Diversity is essential to the future of science. The first speaker of the day, Dr. David Assai, Senior Director at Howard Hughes Medical Institute, addressed one of the most devastating and greatest challenges to graduate education: a lack of diversity within the scientific community. Dr. Assai stressed that diversity is crucial to the success and future of science. Diversity, he stated, trumps individual ability when 1) the dilemma depends on groups of problem solvers; 2) the problem...
to be solved benefits from the addition of different perspectives, interpretations, and tools; and 3) when the predicament is especially difficult to solve.

The path to science, technology, engineering, and medical (STEM) careers is often described as a pipeline, but it is one that is leaking—badly. While the cohort of students that enter the pipeline are plentiful and reflect the ethnic and sex distribution of the population, diversity is lost along the way. In a 2006 survey, it was found that underrepresented minorities (URMs) (e.g., Hispanics, African-Americans, and Native Americans) comprise \( \sim 29\% \) of the United States workforce; however, URMs make up only \( 9\% \) of the scientific workforce. What is the cause for this discrepancy? It is not due to a lack of interest and/or preparation; URMs are just as likely to enter STEM majors as Whites and Asians and just as likely to obtain a Bachelor’s degree. Yet, before graduation, URMs are twice as likely as Whites and Asians to switch to non-STEM majors (3).

Using the metaphor of a pipette, Dr. Assai challenged us to examine the “inputs” and “outputs” of higher education and identify opportunities to retain diversity. On the input side, transfer students and students that are the first in their family to go to college are an important resource; in fact, \( 49\% \) of STEM baccalaureate graduates earned some of their credits at a community college. However, on the output side, students that begin their postsecondary education at community colleges have a sixfold lower rate of achieving a Bachelor’s degree than those who started out at a 4-yr institution (1). Overall, during undergraduate training, we lose \( 60\% \) of entering STEM students, and \( 80\% \) of these are URMs. For many, the first science course in which a student enrolls is also the last science course that s/he will take. This represents huge opportunities for teachers, scientists, and even politicians to develop initiatives that provide adequate advising/mentoring, offer remedial course work, and afford students with opportunities to engage in early research experiences.

The loss of diversity of the scientific workforce continues at a significant rate throughout graduate education as well. A recent study (2) of the career trajectory of biomedical science PhD students found that URMs and women are significantly more likely to switch to nonresearch careers after graduation compared with Caucasian men. Notably, this trend was highest in female URMs (2). However grim this picture, this problem is not insurmountable; there are things that we can do as educators. Dr. Assai suggested that we begin by examining our own institutions. What percentage of our students are URMs? Are they thriving or just sliding by? He then suggested that we consider and adopt successful models. For example, the Meyerhoff Scholars program at the University of Maryland-Baltimore County has had an impressive impact on increasing the number and successes of URMs in STEM careers. Through regular mentoring, study groups, and an incoming bridge program that provides intensive instruction on study skills, problem solving, and time management in addition to courses in math and science, the Meyerhoff Scholars program equips students with tools that they will need to succeed in both their undergraduate education as well as their future academic or professional pursuits. These elements are being incorporated into programs at Penn State (Millennium Scholars) and University of North Carolina-Chapel Hill (Chancellor’s Scholars) as 5-yr experiments that assess whether the model can be successfully implemented at other universities. Finally, Dr. Assai stated that it is critical for faculty members to have open discussions with students about cultural and sex differences so we can work to overcome challenges and biases that may not be obvious.

**Global health.** In keeping with the theme of diversification of the biomedical workforce, Jason Blackard, Director of the Office of Global Health at the University of Cincinnati, spoke of the value of having a “globalization program” in graduate programs. While still relatively rare in graduate education (only 3 of the colleges within the University of Cincinnati have international/global faculty members), there are many benefits to international educational collaborations. Complimenting Dr. Assai’s talk on diversity, Dr. Blackard stated that global health initiatives are an excellent opportunity to recruit and retain students as well as create lifelong learners. In a survey by the Institute for the International Education of Students (8), nearly \( 90\% \) of students reported that their experiences abroad were invaluable components of their education and continue to play strong roles in shaping their careers.

Global health education also advances insights into health, biology, and disease (Fig. 1). Within the pharmacological and physiological framework, global awareness may lead to new pharmacological targets and awareness of barriers to health. Our current knowledge base illustrates that the study of different cultures, genetic lineages, toxin exposure, and even global latitude provides us with invaluable insights to the basis of disease (5, 6, 12). For example, the role of vitamin D in multiple sclerosis was discovered by evaluating the prevalence of this disease in a north to south orientation across the globe (4). Dr. Blackard used his institution’s program as an example of how international research can be conducted with students. At the University of Cincinnati, students have the opportunity to study malaria, tuberculosis, and human immunodeficiency virus/acquired immune deficiency syndrome in Ghana and South Africa, the epicenters of these diseases. Additionally, in a climate where funding is increasingly hard to obtain, international collaborations also have the added benefit of attracting alternative sources of funding.

Global health education is an investment in the future. One of the principal goals of a global health education is to create well-informed future leaders for the scientific community. Through hands-on training, students become acutely aware of complex ethical dilemmas that face researchers and doctors in areas such as infectious disease control and antibiotic resistance (7). Whether these students stay in research or become

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**Core Tenets of Global Health Programs**

- Create sustainable, country-owned programs
- Strengthen healthcare systems
- Promote partnerships
- Address gender inequalities
- Integrate within and across health sectors
- Improve metrics, monitoring, and evaluation
- Facilitate research and innovation

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**Fig. 1. Core tenets of global health initiatives.**
teachers, mentors, writers, or public policy advocates, the world will benefit from leaders who understand how their scientific discipline impacts global health. Finally, global health initiatives also benefit current researchers and educational leaders. Through partnerships with other countries and institutions, we witness new approaches and successful models that enhance graduate education, strategies we may be able to implement at our own institutions.

Toward the end of his talk, Dr. Blackard handed out a survey to assess the presence and knowledge of global health programs at the represented institutions. Fifty-six percent of attendees were certain that their universities offered global health courses; 28% reported that these courses offered a travel abroad component. However, of those that reported global health initiatives at their institutions, most of these opportunities were geared toward medical students, nursing students, and those in public health science majors as opposed to biomedical graduate students.

**Learning to Communicate Across Disciplines**

**Advanced multidisciplinary training program for systems biology.** The next two presenters discussed the necessity of providing comprehensive multidisciplinary training and the strategies that they have developed to specifically target this need. Yana Zavros, Associate Professor in the Department of Molecular and Cellular Physiology at the University of Cincinnati, is the coleader of an advanced multidisciplinary training program for systems biology graduate trainees. This program, funded by a NIH T32 grant, is aimed at cultivating researchers who will be able to tackle complex mechanisms of human disease through cross-disciplinary approaches by working in teams that can contribute unique perspectives to problem solving.

The cross-disciplinary approach is evident from the complementary expertise of its program codirectors, whose disciplines span developmental biology and mathematics. Furthermore, the program spans 32 faculty members and trainees from 13 degree-granting PhD programs. These mentors identify as being either 1) biological-oriented scientists, 2) theoretical-oriented scientists, or 3) interdisciplinary-oriented scientists. Trainees in this program can expect to receive both didactic and experiential training in interdisciplinary research concepts and approaches. The curriculum is flexible and specific to the needs and goals of each student; that is, students shape their careers by choosing computational and biology elective courses. Moreover, students work on research projects that require interdisciplinary approaches and are mentored by faculty members from different disciplines.

Finally, in a world where large, complex data sets are becoming more plentiful, future scientists must not only think outside their own discipline but be able to work in teams. Therefore, students in this program are continually encouraged to participate in the larger scientific community through seminars, data and journal clubs, and an annual program retreat.

**Postdoctoral research program in clinical pediatric pharmacology.** The next speaker, Alexander Vinks, Professor of Pharmacology and Pediatrics in Clinical Pharmacology at the Cincinnati Children’s Hospital, spoke about a fellowship under his leadership that extends interdisciplinary training into postdoctoral training. Even though children possess unique physiologies (13), there remains a large deficit of resources to properly address this arena of knowledge and practice. For example, pediatric pharmacology is not an officially recognized subspecialty of adult clinical pharmacology. Moreover, pediatric pharmacology is scarcely addressed in adult pharmacology training. The pediatric clinical pharmacology research program helps to bridge the gap and “break down the walls” between pediatric medicine, adult medicine, and adult subspecialties through the use of pharmacokinetics, pharmacodynamics, informatics, metabolomics, modeling, and simulation. With the goal of training translational communication and behavior, this fellowship program trains MD fellows and postdoctoral fellows side by side, allowing them learn with, from, and about each other’s unique and valuable training.

**Tracking Student Progress Before and After Graduation**

The Meeting Chair, Chip Montrose, reentered the stage to open a discussion about how to best prepare students for their chosen careers and to consider whether the tools we use currently correlate with the success of our trainees. He opened by asking about the audience’s use of individual development plans (IDPs) for trainees. About three-quarters of the program directors in attendance indicated that they have integrated IDPs into their programs. IDPs are intended to be used as tools (often in yearly progress reports) to help trainees and mentors discuss and identify individual goals so that the students’ training can be tailored to the desired career.

An IDP tool, called myIDP, available at sciencecareers.org, is often suggested as a way to start IDP conversations since it helps trainees assess their strengths and preferences and compiles a list of careers for which an individual may be best suited. However, there are limitations to the myIDP tool and the overall IDP process, as voiced by attendees of the meeting. First, the myIDP tool is specifically geared toward the basic sciences, so it is not helpful to students in other disciplines, such as the physical sciences. Furthermore, many attendees raised concerns that students are apprehensive about telling their mentor about their true aspirations/desires and may end up not answering the questionnaire honestly. While, theoretically, a mentor’s role is to help equip students with the tools s/he will need to achieve success in the desired career path, it remains a reality that some mentors just want a “clone of themselves.”

Dr. Montrose then went on to say that one of the most telling ways to assess the efficacy of our training programs and mentoring is by keeping in contact with alumni. Are they doing what we trained them for? Could we have prepared them better for the careers they selected? What do we need to change in our curriculum? He then opened the question to those present: how do you keep in touch with your alumni? Are you satisfied? Most answered that social media (Facebook, Twitter, and LinkedIn pages) were most commonly used, although most agreed that international alumni were particularly difficult to track.

**Using Big Data to Understand What Happens in Science**

On Friday night, Bruce Weinberg, an economist at Ohio State University, spoke about “Universities: Measuring the Impacts of Research on Innovation, Competitiveness, and Science” (UMETRICS). UMETRICS is an automated system set
up to examine the impact that investment in research has on the economy. Specifically, UMETRICS is a transaction-based data set that documents how scientific funding supports full-time and part-time salaries, transactions with subcontracts, and vendors of scientific supplies. This large data set also allows researchers to track nuanced information, such as the likelihood of a URM to be a first author, how sex differences affect training environments and career outcomes, and the percentage of women who leave science after their first postdoctoral fellowship. Through UMETRICS, we may be able to make informed decisions about how to better our field for the people in it. Moreover, in a climate where research dollars are always at risk of being cut, UMETRICS allows the scientific community to provide policy makers with data regarding the impact of funding (15).

Fitting Training to Emerging Needs

As new discoveries and technologies are continually shaping the needs of our society, the sustainability of science is contingent on responding to those new demands. Furthermore, as we gain more insights into the brain and how learning works, scientists have a responsibility to modify classrooms in response to this evidence. The discussions on Saturday focused on evidence-based learning and ways to ensure the success of both students and universities.

Broadening Experience in Scientific Training

On Saturday morning, Joey Barnett of Vanderbilt University spoke about NIH-funded Broadening Experience in Scientific Training (BEST) grants. He began by posing the pressing question “Are we training too many biomedical PhDs?” Regardless of the answer any individual might offer, he continued that, we, as educators need to make sure that we are equipping these trainees with the tools that let them use their passion to be of benefit to society. Currently, we train ~6,000 biomedical PhD students every year. While only ~1,000 academic faculty positions are available annually, PhD graduates enjoy low rates of unemployment. These data highlight the opportunities for and impact of graduates in nonacademic careers. In a recent survey of Vanderbilt graduate trainees, approximately half of students entering biomedical PhDs have a goal of becoming academic faculty members. However, interests in careers outside academia emerge as students pursue their PhDs. In fact, by graduation, the survey showed that half of graduates ultimately decide to pursue nonfaculty careers such as science writing and government policy, demonstrating that students have diverse interests, values, and skill sets. Therefore, it is imperative that we make students aware of careers in science beyond academia and prepare them to be successful.

With these concerns regarding graduate and postdoctoral training, an NIH committee/task force recommended the development of NIH BEST programs with the goals of 1) developing sustainable programs to broaden pre- and postdoctoral training, 2) encouraging diverse scientific careers (not just those in academia), 3) providing support for and awareness of diverse science careers through faculty engagement and external partners, and 4) determining best practices to support career development of all trainees. While each institution funded with BEST awards is tasked with the same goals, each is actually a piece of a larger experiment composed of individual institutions using different experimental designs and unique training paradigms. For example, some schools use a small cohort model where BEST resources are targeted to a defined group, whereas others make the BEST resources available to all students. Some programs target graduate education, whereas others medical education, or both. In the end, though, each program aims to provide trainees with career development skills, professional development skills, experiential learning, and mentorship.

Dr. Barnett then went on to describe what this looks like in practice by using his school’s BEST grant as an example. At Vanderbilt University, the BEST grant is realized in a program called “Augmenting Scholar Preparation and Integration with Research-Related Endeavors” (ASPIRE; Fig. 2). Aimed at graduate students, each year of the ASPIRE program offers training activities specific to the needs of a student that year. The first year, called “ASPIRE to plan,” involves a short course on career planning and decision making. Students evaluate their own skills, interests, and values, learn about the diverse career options in science, and learn how to make a plan to realize their career goals. In the second year, a workshop on building professional relationships, “APSIRe to connect,” is offered, where students receive etiquette and advice on meeting new people and establishing meaningful connections. Sessions at this workshop include “Navigating Professional Conferences,” “Leveraging LinkedIn,” “Big Help for Small Talk,” and “Identifying and Exploring Your Network.” Also available to second- and third-year students is an initiative called “Beyond the Lab,” in which students can view video interviews with alumni who have gone into careers outside of academia. This is an especially important component as it gives students an opportunity to hear the stories of former graduates who may have similar interests to their own and have gone on to use their research PhDs in careers outside academia. In the fourth year, Vanderbilt University offers short courses, called “ASPIRE modules,” that provide more indepth training in areas such as business, entrepreneurship, effective communication, clinical research principles, STEM teaching in K–12, commercialization, and communicating with the media. After the first 4 yr of exploration and priming, fifth-year students are given the opportunity to take internships or externships to gain hands-on training and build their professional networks. In this way, students are able to identify their career goals early and

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**ASPIRE program activities**

Fig. 2. The Augmenting Scholar Preparation and Integration with Research-Related Endeavors (ASPIRE) program of Vanderbilt University provides opportunities specific to the emerging needs of graduate students in different stages of PhD training (https://medschool.vanderbilt.edu/aspire/).
cultivate the skills necessary to be successful in their chosen path during their training.

Life Outside Academia: What Training Is Needed for Nonacademic Careers?

The next session was a panel of biomedical PhDs who had or have careers outside academia and, therefore, could speak directly to skills and training required in these kinds of professions. Mary Jeanne Kallman, Director of Nonclinical Global Neuroscience at Covance Laboratories, began the discussion by restating the need to train students for careers outside academia. Not only is there a shortage of faculty positions, but jobs that are available in this sector are often part-time adjunct positions that pay minimum wage (or less) and have no benefits. For example, since 2000, there has been a steady decrease in tenure-track faculty positions and a 300% increase in part-time faculty positions. On the other hand, many opportunities are available in nonacademic jobs (e.g., industry, science writing, and museums), and there are things we can do to help prepare students for these types of jobs. We can hire part-time faculty members who are also employed in the private sector (to provide exposure to jobs outside academia) and encourage students to be mentored by those who reside in nonacademic appointments. Trainees should be encouraged to seek opportunities for interdisciplinary training (e.g., drug development or new laboratory techniques). We can also make certain that curricula include skills such as regulatory processes for new drug registration, translation, and in vivo work. Most importantly, perhaps, we need to make students aware that writing and presenting are the most important skills that will be required, regardless of their career choice, followed closely by mastery of strategic thinking and scientific logic. The graduate school environment is uniquely protective and supportive (in contrast to what will be expected in postgraduation employment); thus, student presentations and journal club participation are ways that trainees can hone these skills.

Dr. Ruth Stevens of Camargo Pharmaceuticals then took the stage and described what her company desires in the PhDs that they hire. Camargo Pharmaceutical Services is an international drug development consulting firm that hires postdoctoral fellows to work in cross-functional, integrated project teams. Dr. Stevens echoed many of Dr. Kallman’s sentiments and indicated that writing skills are important to her company as her employees must be able to gauge the audience and tell their stories in meaningful and comprehensive ways yet be simplistic enough for those with backgrounds outside of science to understand. In fact, before employment, each person under consideration at Camargo Pharmaceuticals is required to take a writing test in which s/he is given a publication, asked to summarize it, and describe how it will impact the drug development program of the sponsor. Camargo Pharmaceutical functions under the awareness that everyone has different areas of expertise and seeks to use individual strengths through teams. Therefore, each potential employee, before hire, is given a questionnaire that assesses mental aptitude and personality scales. While skills in areas of writing and project management are key, it is actually initiative, strategic thinking, and the ability to ask questions that identify top performers and new hires.

The last member of this panel, Dr. Ray Takigiku, President and CEO of Bexion, described how the skills of curiosity, teamwork, and a passion for learning have guided him throughout his career. As the only child of second-generation Japanese-Americans, Dr. Takigiku was strongly encouraged to become a medical doctor. However, as he was pursuing his undergraduate premedicine degree at the University of Colorado, he was influenced by his chemistry professor and went on to earn his PhD in chemistry instead. Dr. Takigiku then took a position at Proctor & Gamble, where he worked on various projects both inside and outside the medical field. It was through this experience that he learned the vital skills of leadership, communication, the ability to work with others, and the power of a team. These skills, along with a penchant to follow his passion and a faith in his ability to learn, empowered Dr. Takigiku to cofound a company that deals with novel cancer therapeutics. “Life is about the pursuit of happiness,” he said. “If people love what they do, they will be good at it.”

The Organization for PhD Education in Biomedicine and Health Sciences in the European System Project: Standards for PhD Training

In recent decades, there has been a drastic increase in output of individuals with biomedical PhD degrees. For example, between 1985 and 2011, there was a doubling of PhD students in the United States alone. However, evidence suggests that there is not room in academia for these recent and future graduates, many promising young scientists are becoming caught into what is referred to as the “postdoc pileup.” According to a report of the Royal Society (14), in 2010, 70% of PhDs left science to find careers outside the discipline.

More than a decade ago, in Croatia, Professor Zdravko Lackovic of the University of Zagreb led a task force to establish an uniform agreement for what constitutes a high-quality biomedical or health PhD program and degree. This task force consisted of representatives from medical schools and/or schools of public health from 33 universities across 21 European countries as well as representatives from four major European organizations: the Association of Medical Schools in Europe, Association of Schools of Public Health of the European Region, European Medical Association, and Association for Medical Education in Europe. Subsequently, in 2005, this collaboration culminated in creation of the Organization for PhD Education in Biomedicine and Health Sciences in the European System (ORPHEUS), an organization committed to safeguarding the reputation of the PhD as a research degree and strengthening career opportunities for PhD graduates. Since then, ORPHEUS, along with the World Federation for Medical Education and Association of Medical Schools in Europe, has produced a document outlining standards for PhD education in biomedicine and health sciences in Europe (10). Its contents include best practices, requirements, and explanations regarding areas relevant to research environments, outcomes, admission policies, PhD training programs, supervision, the PhD thesis, assessment, and structure.

For example, with regard to the research environment, ORPHEUS states that “the success of individual PhD programs must be ensured by having a strong research environment.” If institutions lack facilities or expertise in particular fields, then they “should collaborate with stronger institutions”
to ensure that students have access to environments required of a biomedical/health PhD. The outcome of a PhD program should be that trainees are prepared to be competent scientists able to conduct responsible and independent research. Additionally, the PhD program should include elements that prepare trainees for careers outside of academia or clinical research. In keeping with this, the PhD program itself must include both formal coursework (totaling ~6 mo) that directly applies to the PhD and a substantial amount of coursework that provides training in transferable skills, such as project management, grant writing, teaching, and presentation of research. The standard for a biomedical or health PhD thesis is the culmination of 3–4 yr of research, which is exemplified by the production of at least three papers or manuscripts published in peer-reviewed journals. The assessment committee is perhaps the aspect that differs the most from thesis committees in the United States. In contrast to the United States, where a typical committee is composed of four researchers from the trainee’s department, one outside researcher, and a chair of the committee who is usually the supervisor (mentor in the United States), ORPHEUS maintains that at least two members of the assessment committee must be scientists that are unconnected to the trainee’s institution. Furthermore, the trainee’s supervisor may not be a member of the thesis committee. Thus, while the supervisor has primary responsibility for the project, the evaluations of and recommendations for the project are made by those with no conflicts of interest. The supervisor, as well, is held to ORPHEUS standards. Training in supervision must be available at each institution; likewise, each supervisor must have formal training before mentoring students.

Challenges. ORPHEUS standards for high-quality PhD programs are the result of a consensus among heads of graduate schools across Europe. Nevertheless, ORPHEUS has no real “authority” per se. Countries such as Germany, France, and the United Kingdom already have well-established systems regarding PhD training and are, thus, reluctant to adopt OPHEUS standards. Fortunately, most ORPHEUS standards reflect procedures rather than requirements for resources; thus, even institutions in less well-developed countries or institutions are able to comply.

Vision and Change in Undergraduate Biology Curriculum

Appreciating the scientific process can be even more important than knowing scientific facts. People often encounter claims that something is scientifically known. If they understand how science generates and assesses evidence bearing on these claims, they possess analytical methods and critical thinking skills that are relevant to a wide variety of facts and concepts and can be used in a wide variety of contexts.

National Science Foundation (9)

Thomas A. Pressley, professor of medical education and physiology at Texas Tech University Health Sciences Center, spoke about the Vision and Change initiative. As a self-correcting discipline, science is perpetually under a state of remodeling. An ever-growing body of scientific discoveries and the development of new technology has changed the way we ask questions and made clear the necessity for finding answers by working across disciplines. However, in the 1990s and early 2000s, it became apparent that while the knowledge and practice of science had undergone a major transformation, this advancement had not been reflected in how science was taught in undergraduate biology classrooms. In a world where a growing population presents novel and pressing challenges, it is imperative that biology classrooms present science as an evidence-based, multidisciplinary, relevant tool that can be applied to diverse areas ranging from food science to agriculture to pharmacology (16). Through a series of conversations, workshops, and meetings with researchers, students, teachers, and administrators, the American Association for the Advancement of Science, National Science Foundation, and representatives from Howard Hughes Medical Institute developed a set of core concepts for biological literacy and core competencies for modern biology classrooms, referred to as the Vision and Change report (Fig. 3) (17). Among many recommendations, a set of core competencies and disciplinary practices that constitute scientific literacy were developed.

Furthermore, as research into learning has changed what we understand about ways that students learn best, a key set of action items from these conversations dealt specifically with adopting research-based, effective teaching strategies. For example, student-centered learning, the process by which students actively engage with the subject (thereby internalizing and making connections with what is already known), has far greater efficacy in facilitating knowledge retention and creating lifelong learners than traditional, passive, teacher-delivered lectures (11). The Vision and Change report, therefore, urged teachers to (1) make science courses active and inquiry driven; (2) develop learning objectives that focus on understanding core concepts rather than memorization of (an ever-growing body of) content; (3) relate what is being taught to the world of the learner; (4) provide meaningful and timely feedback; (5) treat the classroom as a science experiment, allowing feedback and outcomes to influence the learning environment; and, finally, (6) be passionate and excited about the subject.

In 2013, as a visiting professor at the United States Air Force Academy, Dr. Pressley was given the unique opportunity to perform a case study applying these concepts in a physiology course for cadets. Since the United States Air Force Academy curriculum has a heavy emphasis on mathematics and engineering, Dr. Pressley used previously acquired knowledge and applied these competencies to biological and chemical principles. For example, to illustrate the permeability of membranes, students were asked to use the Goldman-Hodgkin-Katz equation to determine the concentration of ions after homeostasis. By tapping into knowledge that students already had, Dr. Pressley not only promoted a deeper understanding of course

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**Core Competencies and Disciplinary Practice**

- **Ability to Apply the Process of Science:** Biology is evidence based and grounded in the formal practices of observation, experimentation, and hypothesis testing.
- **Ability to Use Quantitative Reasoning:** Biology relies on applications of quantitative analysis and mathematical reasoning.
- **Ability to Use Modeling and Simulation:** Biology focuses on the study of complex systems.
- **Ability to Tack into the Interdisciplinary Nature of Science:** Biology is an interdisciplinary science.
- **Ability to Communicate and Collaborate with Other Disciplines:** Biology is a collaborative scientific discipline.
- **Ability to Understand the Relationship between Science and Society:** Biology is conducted in a societal context.

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Fig. 3. Core competencies and disciplinary practices as outlined by the Vision and Change report (http://visionandchange.org/).
material but did so in a way that illustrated the interdisciplinary nature of science. At the end of the course, outcomes and feedback suggested that cadets had gained a better understanding of both the interdisciplinary and quantitative nature of biology. Dr. Pressley closed by reminding the audience that “educational reform is an ongoing process. It is always coming, so we must be prepared to use the best and discard the worst.”

**Panel Discussion: National Expansion of Revenue-Driven Degrees; a New Balancing Act**

**MS degree in Pharmacology at the University of Cincinnati.**

The session on Saturday afternoon began with a panel that spoke about revenue-driven degree programs. Dr. M. John E. Maggio of the Department of Pharmacology at the University of Cincinnati spoke about a recently developed Masters in Pharmacology degree program aimed at bringing financial support to the department. Started in 2012, the Masters degree in Pharmacology provides graduates with skills and knowledge of the core principles of pharmacology (dose, pharmacokinetics, drug efficacy, and potency) and clinical drug discovery and development. The program also places special emphasis on safety pharmacology. The Master’s degree is a 1-yr program that requires 30 credit hours fulfilled with required courses (such as Preclinical Drug Toxicology as well as Drug Discovery and Development courses) and elective courses (such as Biochemistry and Cellular Signaling as well as Experimental Design courses). As a new program, it is still being tweaked so that it becomes a financial asset to the department. In the future, online courses and certificate options may be added. However, in the short time this program has been running, it has proven to be a benefit to graduates; with a graduation rate of 100%, 50% of students have continued to pursue a PhD, 40% a MD, and 10% another Master’s degree.

**Online Pharmacology degree programs at Michigan State University.** The next speaker, Bill Jackson of Michigan State University, was hired in 2005 to specifically design and implement programs with the goals of 1) training individuals in integrative pharmacology who already had careers in industry, government, or academia and 2) generating an additional revenue stream for the department of pharmacology while 3) maintaining a research-intensive focus for the department. A decade ago, Michigan State University was interested in taking advantage of the new and growing interest in online degree programs. Administrators told Dr. Jackson that if he was successful, his department would be able to keep 75% of the revenue generated. With $50,000 seed money from the university and funds from a large undergraduate pharmacology course, Dr. Jackson set to work, hiring an education coordinator, an in-house producer, and additional faculty members to design and implement courses (many of whom were former graduate or postdocs). Within the first 3 yr, the university recouped all the money that it had initially invested to get the program running. As with any successful project, there have been modifications all along the way. For example, in the beginning, they had a hands-on laboratory funded by the NIH; yet, this laboratory component proved to be enormously expensive, so they have switched to using online videos from the *Journal of Visualized Experiments*, YouTube, and simulations from other universities. The program has also spurred the development of other degree programs and courses such as a pharmacology and toxicology course that currently has 215 students enrolled, a graduate certificate program in safety pharmacology, and an undergraduate minor in pharmacology.

**Master’s degree in Physiology at the University of Cincinnati.** The last speaker of the revenue-driven degree program panel was Dr. John Lorenz, who runs a Master’s degree program in Physiology at the University of Cincinnati. This program is unique in that it is a credentialing program that gives students who wish to go to medical school a chance to show that they are “med school material.” Indeed, students entering the program usually enter with less than ideal grade point averages and Medical College Admission Test scores. Aimed at preparing students for medical school, the 11-mo curriculum includes immersion in medical school classes with first-year medical school students from the College of Medicine. The program also pairs students with faculty members and peer mentors for additional guidance throughout the year. So far, the program boasts enormous success among its graduates; within 2 yr of graduating, >90% of students have been accepted into medical school.

**Training Grant Workshop**

The final morning of the meeting has historically been reserved for an optional, and well-attended, training grant workshop. Dr. Okita and Dr. Laffan representing, respectively, the program and review functions of the NIH, were in attendance, along with several past and current T32 program directors, former study section members, and other interested parties. Dr. Laffan gave an informal presentation that covered current National Institute of General Medical Science T32 review criteria as well as recent and upcoming changes in program requirements, review, and documentation. The presentation became more of a discussion as Dr. Okita and members of the audience provided questions, clarifications, and shared knowledge and expertise. The session ended after ~3 h of discussion. Many attendees score this portion of the meeting as one of the most valuable.

**Summary**

Some common themes and potential opportunities emerged from the meeting. A prominent theme was the emphasis on developing excellent communication and teamwork skills to be successful in many career environments. This common theme should drive the introduction of additional opportunities for trainees to develop these critical skills, which will serve them well both in and out of academia. Another point of agreement among participants was the recognition of the importance of diversity in the teams that drive discovery. We must continue to better understand the barriers that impair our ability to include and train the very best scientists. Opportunities exist, especially in disciplines such as pharmacology and physiology, to develop teams of clinicians and basic scientists who can train and work together on problems. Two examples of such opportunities were presented: pediatric clinical pharmacology and global health. Innovative ways to develop such opportunities will both attract trainees and drive discovery. A longstanding challenge in graduate education, tracking graduates after they leave a program, continues to be a concern despite being made easier by social media and electronic communication. Finally, help may be on the way for navigating the
complexes associated with providing trainees with exposure to the wide range of opportunities that science offers and giving trainees the tools to be successful in pursuing them. The NIH BEST programs represent an ongoing experiment to define best practices for career guidance and preparation for PhD trainees.

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AUTHOR CONTRIBUTIONS


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