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Special Topic Commentary

An Opportunity for Industry–Academia Partnership: Training the Next Generation of Industrial Researchers in Characterizing Higher Order Protein Structure

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ABSTRACT

Training researchers for positions in the United States biopharmaceutical industry has long been driven by academia. This commentary explores how the changing landscape of academic training will impact the industrial workforce, particularly with regard to the development of protein therapeutics in the area of biophysical and higher order structural characterization. We discuss how to balance future training and employment opportunities, how academic-industrial partnerships can help young scientists acquire the skills needed by their future employer, and how an appropriately trained workforce can facilitate the translation of new technology from academic to industrial laboratories. We also present suggestions to facilitate the coordinated development of industrial-academic educational partnerships to develop new training programs, and the ability of students to locate these programs, through the development of authoritative public resources.

Training researchers for positions in the U.S. biopharmaceutical industry has long been driven by academia. Academic institutions confer the postbaccalaureate degrees (MA, MS, MSc, MPhil, and PhD) held by most industrial scientists. Upon attaining a PhD degree, scientists from fundamental disciplines typically pursue postdoctoral training before seeking permanent employment. Those from more applied science and engineering programs often begin new industrial positions immediately. Thus, both pre- and postdoctoral training is an opportunity for young research scientists and engineers to acquire the skills needed for success in developing, formulating, and characterizing new protein therapeutics. At the same time, young researchers bring expertise from their academic training—particularly in protein biophysical and higher order structural characterization—that holds the promise of advancing promising therapeutics. These skills can be particularly valuable in translating new technologies from academic to industrial laboratories.

These relationships function most productively when training and employment opportunities are balanced, as they have been for many decades. The importance of this relationship is raised in the companion commentary.[1] However, recent years have seen seismic changes in the academic research and training environment. There was a precipitous rise and then a precipitous fall of the Congressional budget allocation for the National Institutes of Health (NIH), and to a lesser extent other federal funding agencies such as the National Science Foundation (NSF). This financial turmoil, combined with a maturing biotechnology industry, has resulted in a divergence between the number of "newly minted" PhDs with training in biophysical sciences and engineering, and their employment opportunities. Moreover, changes in federal funding priorities have led to diminished support for the development of technologies central to characterizing protein therapeutics, especially those in the area of biophysical and higher order structural characterization.

As the number of PhDs trained in these areas will likely decrease going forward, it is essential that their training match the present and future needs of their industry employers. This time of flux is thus both a challenge and an opportunity. Given the time lag between the initiation and completion of PhD training, it is important that both communities be proactive in addressing these questions. In this commentary, we consider how strengthening partnerships between academic and industrial institutions can help

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provide a workforce skilled in the study of protein biophysical properties and higher order structure—tools critical in continuing the prodigious development of biologic therapeutics.

Our discussion is organized around a few key questions. The first asks "How many"? That is, what is the optimum number of industrial scientists that should be trained? Second, how can academic—industrial partnerships help young scientists acquire the skills needed by their future employer, and how can such partnerships help guide the choice of fundamental research topics and focus areas for academic laboratories? Finally, how can an appropriately trained workforce facilitate the translation of new technology from academic to industrial laboratories? This last question has recently taken on increased importance since as put succinctly in the New York Times, "Companies' R&D is moving away from the R toward the D".[2] Finally, we offer some suggestions for coordinating the development of academia—industry partnerships.

Question 1: How Many Industrial Scientists Should be Trained in Biophysical and Structural Characterization?

A vigorous debate ongoing in academic forums is whether our nation is training too many PhD level scientists. For *academic* faculty positions, the answer to this question regarding *the present* is clearly "yes." However, the answer with regard *to 10 years in the future* and for *industrial* research is less clear. This distinction is critically important given the many years of study and apprenticeship required to mint a qualified and capable PhD researcher. The ongoing contraction in both academic and industrial research employment opportunities is being addressed by an ongoing contraction in graduate and postdoctoral training. However, given the lack of synchrony in economic cycles, it is quite possible that an upturn in future employment opportunities will converge with a shortage of appropriately trained scientists. We recommend analyses that consider attrition of skilled workers from the present job candidate pool, along with reasonable predictions of future opportunities, so that qualified candidates will be available to the industry a decade in the future. If timely support from the federal government, which currently supports most of the training of scientists and engineers in these fields through research or training grants, is not forthcoming, it will be important for the biopharmaceutical industry to underwrite graduate training in the study of protein characterization so that a sufficient pool of qualified scientists will be available.

Importantly, industry support in a proactive and collaborative way will offer opportunities to drive fundamental research in areas that are most useful for the broader needs of the biotechnology industry, rather than relying on the hope that federal funding agencies and academic review panels will understand and predict the realities of those needs. For example, a major challenge that directly impacts the analysis of protein higher order structure is the overall decrease in federal research support for technology development, including new technologies and instrumentation to probe and quantify protein biophysical and structural properties, as support for other types of inquiry currently take precedence. In particular, many of the physical considerations essential to the development of protein therapeutics are not considered a high priority for federal support of academic laboratories. These include stability and structure at high concentrations, the impact of therapeutically necessary excipients, and changes in physical properties that control viscosity and aggregation state(s). Thus, it may be essential for industry to more aggressively underwrite the development of the tools and instrumentation it needs for the characterization of higher order structure of protein therapeutics.

Question 2: How Can We Best Train the Future Biopharmaceutical Workforce?

There is an old challenge for the newly minted PhD commencing an industrial research career—independence must be tempered by the ability to work within a team on projects whose creation and termination resides in the hands of individuals higher up the chain of command. Recognition that these skills are essential to PhDs regardless of their career path has resulted in communication, management, and career training becoming available in many graduate programs. Indeed, the NSF, and more recently the NIH, mandate career skills training as a component of their support of graduate research study. Although these general career development programs are clearly an important step, there is more that can be carried out to teach students skills specific to pharmaceutical biotechnology research. We highlight below possible changes from both the academic and industrial sides of the equation regarding how to train the next generation of researchers in understanding, characterizing, and studying higher order protein structure.

1. A tacit belief that lingers in academic graduate training is that a student must work *by himself or herself* if they are to become *independent*. However, in an era when multidisciplinary collaborative studies are the rule rather than exception, we need to replace *solitude* with *team-based work* and explore the guidelines for granting the PhD degree to embrace collaboration in which the student plays a driving or directing role. In addition to defining academic expectations more realistically, this change would shift student training toward the biopharmaceutical work model where projects are typically carried out by teams that hand off a successful project as a potential therapeutic moves along the project pipeline. Thus, redefinition of the PhD degree from "a demonstration of the ability to conduct independent research" to "a demonstration of critical thinking and evaluation, and the ability to direct novel research in a team-based environment" would serve the prevailing models of both academic and industrial research endeavors.

With regard to higher order structural and biophysical analysis specifically, we envision an increased emphasis on fundamental mechanisms and theory, but applied toward industry-relevant issues such as protein aggregation, reversible self-association, folding and stability, and so forth. This approach may be especially desirable if the research project is part of an academic—industry collaborative effort, where a student can benefit from an effective co-advising role for an industrial scientist or mentor, as can the academic mentor.

2. The evaluation of students during their training has historically been conducted using the strictures and language of academia. A good example of this culture is the *Qualifying Examination* typically taken by students at the end of the didactic portion of their graduate training, upon whose passage they begin full time research. "The Qual" typically includes writing and defending an NIH or NSF style research proposal that is crafted around one or several *Specific Aims* or *Objectives*. The blank stare you will receive if you ask most students to describe their project in terms of *Milestones* or *Deliverables* highlights a cultural divide between academia and industry, one that typically falls along the line between basic and applied research. The sooner students appreciate this distinction, the more adept they will become at navigating the industrial research arena. Evaluating students in the language and goals of their future employers will give them a head start developing the skills and mind-sets most beneficial for industrial research. It will also

help educate faculty in this regard, many of whom are traditionally not sensitive to the distinction between applied and basic research agendas.

Toward this end, initial thesis proposal meetings should emphasize the applied nature of a research project (e.g., mitigation of protein aggregation) and stress long-term deliverables (e.g., identification of useful excipients). We note that although this type of research would still address underlying mechanistic questions, it might not start with a mechanistic hypothesis as expected by most academic preceptors. And although this approach may not ultimately result in the “solution” to the “problem,” it stresses the importance of problem resolution and teaches decision-making strategies for best employing effort and resources.

3. As noted previously, most graduate and postgraduate training programs provide some form of professional and career development. Presently, these programs tend to be “add-on” seminars or workshops during the latter years of training, exposing trainees to alternative career options and providing guidance for applying and interviewing for positions. Most existing programs are not embedded into graduate and postgraduate training *at its onset* and, importantly in the present context, do not expose trainees to the industrial research culture that is specific to protein structural characterization. Since the large majority of academic faculty would not be able to effectively teach such a culture due to their lack of exposure, it is essential that industrial biopharmaceutical researchers come to universities and participate in their future colleagues' training. In terms of implementation, basic science graduate programs can learn from applied science and engineering departments that traditionally have had a wider pipeline to the biopharmaceutical industry. This may be in the form of specialized courses in pharmaceutical biotechnology, NIH-funded biotechnology training grants, and multiday research retreats that focus on industry-relevant science.
4. Direct experience is the best teacher. The development of a larger base of industry-funded internships in biophysical and higher order structural characterization will provide students and postdoctoral researchers with the opportunity to experience first hand the biopharmaceutial research environment, learn its nuances, and make an informed decision about whether this is their chosen career path. Existing internships are typically targeted at later stage trainees and are often available only sporadically from year to year. Early stage, regular programs would allow students to integrate industry-appropriate training into their career preparation, as for example outlined in aforementioned points 2 and 3. Other mechanisms include academic—industry collaborations via sponsored research agreements and fee-for-service protein characterization projects.

Question 3: Can Graduate and Postdoctoral Trainees Inoculated by the Biopharmaceutical Research Culture Facilitate Technology and Knowledge Transfer Between Academic and Industrial Laboratories?

Workforce training and technology development and transfer go hand-in-hand. In academic laboratories, graduate and postdoctoral trainees are typically intimately involved in the development of new techniques and specialized technologies. These are the scientists who often bring technology to new venues and also adapt, refine, and enhance it to serve the needed applications. We need to explore how training can be tailored to facilitate this process, noting that this issue is not specific to the techniques used in industry to analyze higher order structure. As noted previously, trainees who are already comfortable with the industrial research culture will be advantaged at integrating new or specialized technology into the industrial research, development, and production pipeline. Correspondingly, trainees familiar with the challenges associated with the development of therapeutics (a perspective perhaps obtained from early-stage internships) could play a role in tailoring new technology for industrial applications and/or identifying unmet needs to drive future academic efforts. This may be particularly true for emerging approaches including theory, computation, and single-molecule analysis that have the potential to revolutionize the study and characterization of higher order structure. In addition, “older” specialized technologies such as analytical ultracentrifugation, scattering techniques (x-rays, neutrons, and lasers), and electron and light microscopy continue to be essential to characterizing new protein therapeutics at all stages of the development pipeline. Young researchers skilled in the application of both novel and older approaches, and interested in their further growth, will be needed to maintain the development of innovator and biosimilar therapeutics.

Suggestions for the Coordinated Development of Industrial—Academic Educational Partnerships

Individual companies, universities, and professional societies have developed and implemented a variety of programs that address the points raised previously. It is not the place here to list or attempt to evaluate these initiatives; every program is crafted to meet a perceived need and is enhanced (or limited) by the inherent biases of its creators. Here, we ask how can students choose among available opportunities, and equally important, how can new initiatives leverage the insight gained from pioneering programs?

A first step for coordinating development of industrial—academic educational partnerships is to simply make a list. To our knowledge, a comprehensive curated list of national and international, industrial educational opportunities is not publicly available. A web site with a searchable database would serve as clearinghouse for program offerings, and a nonprofit organization involved in industry—academia interactions could be a suitable host. The web site could be extended to include reviews, relevant commentaries, and blogs that could evolve into a nexus for the dissemination of information about and development of industry—academia educational partnerships.

A more ambitious goal would be to coordinate the development of guidelines related to needed programmatic areas, program structure and content, and student evaluation. With regard to programmatic areas, a service that consolidated and evaluated employment opportunity predictions would allow more efficient matching of training needs and employability to the benefit of both programs and students. Regarding guidelines for content and evaluation, an electronic forum that allowed new programs to learn about what works and what does not should speed the development of educational programs without compromising their individuality.

The most ambitious goal would be to develop and implement program certifications or accreditations. Although not new concepts, these have not been widely applied to the training of industrial researchers. Accreditation encompasses both content and structure and has the potential to set a high bar for educational standards. Certifications also provide employers with metrics for the skill sets of their prospective employees. An example of an accreditation program is that conducted by the American Society for Biochemistry and Molecular Biology for undergraduate biochemistry training programs (http://www.asbmb.org/accreditation/) or that conducted by the Accreditation Board for Engineering and Technology (http://www.abet.org/). While there are clear challenges to getting independent programs to cooperate in training the next generation of industrial researchers, the benefit of such cooperation to the industry is an ample workforce skilled in the study of higher order structure.

In summary, new models and approaches will be necessary to train the next generation of industrial scientists in biophysical and structural characterization. In addition to the suggestions presented previously, a number of small-scale initiatives have already found success at the authors' institutions. These include inviting senior scientists from industry to serve on academic thesis committees, hosting of industry scientists for “minisabbaticals” in academic laboratories, guest lectures and seminars from industry leaders, beta testing of cutting edge instrumentation supplied by corporate manufacturers, pre- and postdoctoral funding from industry-aligned foundations such as PhARMA (Pharmaceutical Research and Manufacturers of America), and adjunct faculty or “professor of practice” positions for full-time teaching at the undergraduate and graduate levels. Both small- and large-scale innovations leveraging partnerships between industrial and academic scientists will undoubtedly improve the training of the next generation of industrial researchers, so that they may surpass their teachers even further.

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