The Toxicology Education Summit: Building the Future of Toxicology Through Education

Aaron Barchowsky,*† Lorrene A. Buckley,‡ Gary P. Carlson,§ Vanessa A. Fitsanakis,‖ Sue M. Ford,¶ Mary Beth Genter,|| Dori R. Germolec,||| Teresa L. Leavens,|||| Lois D. Lehman-McKeeman,*** Stephen H. Safe,**** Courtney E. W. Sulentic,†† and Betty J. Eidemiller‡‡

*University of Pittsburgh, Pittsburgh, Pennsylvania 15219; †Eli Lilly & Company, Indianapolis, Indiana 46240; ‡Purdue University, West Lafayette, Indiana 47906; §St John's University, Jamaica, New York 11439; ||University of Cincinnati, Cincinnati, Ohio 45267; |||National Institutes of Environmental Health Sciences, Research Triangle Park, North Carolina 27709; ||||North Carolina State University, Raleigh, North Carolina 27607; ‡Bristol-Myers Squibb Company, Princeton, New Jersey 08543; **Texas A&M University, College Station, Texas 77845; ††Wright State University, Dayton, Ohio 45435; and ‡‡Society of Toxicology, Reston, Virginia 20190

To whom correspondence should be addressed at Department of Environmental and Occupational Health, University of Pittsburgh Graduate School of Public Health, Suite 332, Bridgeside Point, 100 Technology Dr, Pittsburgh, PA 15219. Fax: (412) 624-9361. E-mail: aab20@pitt.edu.

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Toxicology and careers in toxicology, as well as many other scientific disciplines, are undergoing rapid and dramatic changes as new discoveries, technologies, and hazards advance at a blinding rate. There are new and ever increasing demands on toxicologists to keep pace with expanding global economies, highly fluid policy debates, and increasingly complex global threats to public health. These demands must be met with new paradigms for multidisciplinary, technologically complex, and collaborative approaches that require advanced and continuing education in toxicology and associated disciplines. This requires paradigm shifts in educational programs that support recruitment, development, and training of the modern toxicologist, as well as continued education and retraining of the midcareer professional to keep pace and sustain careers in industry, government, and academia. The Society of Toxicology convened the Toxicology Educational Summit to discuss the state of toxicology education and to strategically address educational needs and the sustained advancement of toxicology as a profession. The Summit focused on core issues of: building for the future of toxicology through educational programs; defining education and training needs; developing the “Total Toxicologist”; continued training and retraining toxicologists to sustain their careers; and, finally, supporting toxicology education and professional development. This report summarizes the outcomes of the Summit, presents examples of successful programs that advance toxicology education, and concludes with strategies that will insure the future of toxicology through advanced educational initiatives.

Key Words: toxicology; education.

BUILDING FOR THE FUTURE OF TOXICOLOGY

Building for the future of toxicology as a profession begins with increasing the perception of toxicology as an important integrative and viable field of endeavor. This effort includes fostering the recognition by other disciplines of the importance and need for toxicology and recruiting and retaining diverse undergraduate, graduate, and postdoctoral trainees from a variety of disciplines into toxicology. Central to discussing these themes is what professional societies like Society of Toxicology (SOT) can do to advance and sustain the profile and vitality of toxicology as a profession.

All too often, toxicology is perceived as a necessary, but nebulous, academic pursuit; a service; or a regulatory profession. There is great need to change these perceptions and demonstrate that toxicology plays an important role in the life sciences and health professions and that toxicologists have leading roles as “guardians” of both environmental and human health. In leveraging the risk assessment expertise of toxicologists, the profession should play a more prominent role in disease prevention and health policy development by providing critical qualitative and quantitative insights on identification and management of true health risks. The toxicologist should be seen as an essential source for informing policy and regulatory decisions that advance commercial enterprise while creating a safer and healthier world.

In recent years, SOT has greatly increased strategic development and utilization of state-of-the-art media and communication tools as well as increased liaison and communications with industries and government to enhance the perception of toxicology. Other closely related societies, such as the American Chemical Society, have also advanced the significance of toxicology as a vital part of “green” chemistry initiatives and are creating educational programming to incorporate toxicological principles into the critical thinking of chemists. More needs to be done to keep the profile of toxicology in clear focus at all levels of safety and health.
decisions and health policy debates. Continued action by SOT (both National and Regional Chapters), various government-supported Environmental Health Sciences and Superfund Basic Research Centers, and individual university toxicology/environmental health programs should play essential roles in advancing the profile of toxicology. SOT needs to serve in a leadership role in assessing ongoing activities by filling in the gaps and addressing unmet needs for improving the perception of toxicology. This should be a continuing effort that includes facilitating informed discussions and mediating interactions between many often opposing interests, such as industry, regulatory agencies, and advocacy groups with the ultimate goal of resolving important issues that impact environmental and human health.

The future of toxicology will only be as strong and vital as the students and new professionals recruited into the profession. It is essential not only to recruit the best and brightest undergraduate, graduate, and postdoctoral trainees into toxicology as a profession but to also broaden the discipline to include scientists in fields with different skill sets, such as chemistry, medicine, public health, engineering, physics, biostatistics, and others. Another critical goal should be to recruit and retain a diverse population of new toxicologists domestically and from around the globe with attention to providing opportunities for many underserved populations. This will enhance recognition of toxicology in other fields and raise the perception of toxicology as a viable and productive career option as well as respond to global trends and economic drivers. Recruitment to toxicology should be part of the broader recruitment of students into advanced careers in science, technology, engineering, and mathematics (STEM) that has been identified as a national priority for maintaining the global role of the United States in science and technology. There are major initiatives led by the National Science Foundation (NSF) to advance general STEM education from K-12 programs through the undergraduate levels. In addition, the National Institutes of Health (NIH) and specifically the National Institute of Environmental Health Sciences (NIEHS) have led efforts to raise interest and participation in health sciences including toxicology through their funded centers, training grants, and K-12 education programs. The Environmental Protection Agency, Departments of Energy and Defense, the Food and Drug Administration (FDA), the Howard Hughes Medical Research Foundation, and other industrial and private foundations play important roles in education programs that include various toxicology-related components. Strengthening linkages between SOT and NIEHS, other federal and international regulatory agencies, industry, and nongovernment organizations and foundations will be important for maintaining the future success of the recruitment process as well as retention of the next generation of toxicology professionals. Beyond sparking the interest of students at the K-12 levels, the vast undergraduate and community college systems should be recognized as important venues for increased recruitment and curricular development. The community college systems should be recognized as a new and important source for recruitment, because their trainees are often directly employed in toxicology and environmental health professions, and many community college graduates go on to complete advanced undergraduate and graduate training.

A presentation by Dr Sally Rockey, NIH Deputy Director for Extramural Research, revealed the disappointing statistics showing that the diversity of professionals in government-supported health research in general and in toxicology is low despite many past efforts to recruit minorities and underserved populations into the sciences. The NIH, NSF, and other entities strive to correct this disparity, and a number of initiatives were discussed, including promoting inclusive educational paradigms that retain bright students in the sciences instead of paradigms designed to weed students out and drive them to nonscience professions. Government and private sector programs are in place to support inclusion of underrepresented students in research opportunities that would otherwise be unavailable and that foster excitement for careers in the sciences. However, their support should be sustained and expanded. More than two decades ago, the SOT Committee for Diversity Initiatives created the Minority Undergraduate Program, which is recognized as a very positive strategic program making great strides in bringing both minorities and underserved populations into toxicology training programs and retaining them in toxicology careers. Every year, the program brings a large number of undergraduate students to the national SOT meeting where they are given the opportunity to discover the breadth of opportunities in toxicology, allow them to meet with leaders in the field, connect them with toxicology training programs that could advance their careers, and expose them to a broad array of science in the field. The success of the program is evident from the many distinguished toxicologists whose interest in the field was sparked by the undergraduate program and their experiences at SOT meetings. They have built productive careers and are now leaders themselves in helping SOT to promote the minority and undergraduate programs. Moreover, many of the attendees who were connected to undergraduate toxicological research through the program have carried the toxicological perspectives gained into diverse careers in medicine, industry, academia, and government. Similarly, the competitive Pfizer Undergraduate Travel Award provides support for top students in research who have also advanced in toxicology or related careers. Programs like these should be expanded to enhance the awareness of toxicology as a viable and valuable profession, to retain promising students in the field, and to improve the perception of toxicology.

Mentorship is a vital and essential pillar in building for the future and sustaining toxicology. Mentoring is critical at all levels of development, from the science teacher who sparks the winning school science project through the senior toxicologist advising early and midcareer professionals. Mentorship in
undergraduate education is essential for recruiting bright scientists into the field and directing them toward viable career and advanced educational options. Development of students by mentors at the graduate and postgraduate levels increases productivity and opens opportunities for these students in successful careers as independent academic researchers and leaders in industry and government. Mentoring is valuable throughout career development, and mentoring programs should be expanded to assist those in midcareer or redirecting careers. Career changes often involve the difficult transition from bench science to management or regulatory science and can benefit from the guidance of a mentor. Mentorship and creating opportunities for mentoring relationships are important focal points for SOT in building the future of toxicology and sustaining the pipeline of new generations of successful toxicologists.

Although SOT and its educational programs already address many of the needs of this profession, it can do more by enhancing support to: integrate toxicology curricula at every level in academia (including medical and related health programs), raise awareness of the value of toxicology, provide additional resources for recruitment through its Regional Chapters and Specialty Sections, facilitate development of new outreach tools, work with other environmental and health-related professional societies to promote the stature of toxicology, and increase support for mentoring programs including funding for mentors to bring their students into the profession. These approaches coupled with ongoing SOT activities will help to successfully build for the future of toxicology.

IDENTIFYING EDUCATIONAL TRAINING NEEDS

A strategically important starting point for improving toxicology through education is identifying educational training needs. Four major issues discussed in this area included: definition of the fundamental educational needs in undergraduate and graduate toxicology curricula; advancement of curricular content to adapt to the changing demands of academic, regulatory, and industrial toxicology; identification of new technologies and teaching paradigms to advance toxicology training; and development of the postgraduate and midcareer training to strengthen and broaden career opportunities. Critical needs that were highlighted focused on mentorship throughout the training period and beyond, as well as the need for an interdisciplinary, integrated training approach that does not compromise learning basic principles of toxicology. Indeed, Dr Carol Shreffler, Program Director for training and career development at NIEHS, indicated in her presentation on the current state of NIEHS training programs that there is a directive to emphasize multidisciplinary and interdisciplinary approaches in training. In addition to an interdisciplinary training approach, it was strongly recommended that increased emphasis should be placed on practical applications of toxicology principles (i.e., incorporation of applied exercises, using case studies, and developing industry partnerships) as well as training that emphasizes regulatory toxicology. Because there are often fewer academic positions than graduates, most M.S. and Ph.D. graduates (not just toxicology graduates) choose nonacademic careers where practical application of toxicology principles is essential. For these graduates, practical applications and critical real world problem solving are areas of weakness that must be improved.

In a plenary talk, Dr William Slikker, Director of the FDA National Center for Toxicological Research, noted that emphasis on training in systems biology and whole animal research, an area important to regulatory toxicology, has decreased and has often been eclipsed by molecular biology. He also emphasized the need for increased awareness of global toxicological issues in regulatory toxicology and health policy. Unfortunately, a major barrier to developing or maintaining toxicology training programs comes from university administrators who may not perceive the value of toxicology research and training or of employing faculty trained in toxicology. These training deficiencies can be remedied by facilitating collaborations between industry, government, and academia to provide students with appropriate training opportunities. There are many examples of toxicology training programs that have fostered industry partnerships in training relationships (e.g., University of Connecticut, Rutgers, Texas A&M University, Kansas University Medical Center, and others) that have been successful in recruiting students to programs with an applied focus and in advancing graduates into successful careers within and outside of academia. There are also many examples of graduates from these programs who return to teach in adjunct faculty positions. These types of successful educational collaborations may also increase the perceived value of toxicology among administrators who make decisions for programmatic and curricular support. A similar model is needed in medical training where there is a general lack of toxicology in medical and nursing school curricula even though practicing health care providers will likely be relied on to answer toxicologically relevant questions from their patients.

Organizations like SOT can play a major role in strengthening the quality and training of both those entering the profession and those needing continuing education to keep pace with an ever advancing profession. Increasing communication and fostering mentoring are two major contributions that can be made by professional societies. The value of mentoring was discussed above and was a recurring theme during the summit. Communication efforts focused on increasing awareness of resource availability, opportunities, educational needs, and successful models for effective education are an essential part of mentoring and societal sustainability. Unfortunately, all too often resources are made available but are underutilized because of poor communication. A good example of helpful communication can be found in the wealth of resources available through SOT for advancing education and mentoring.
as well as providing connections to funding and support programs. Strategically, SOT is moving forward with programs at the National and Regional Chapter levels to improve communication and promote educational programs. Programs such as MentorMatch, ToxScholar, Global ToxScholar, and Global Senior Scholar Exchange are effective means of outreach that both enhance the profile of toxicology and facilitate recruitment and retention in the profession.

Effective communication using the new age of social media has been promoted through ToXchange to improve networking of educators and enhance mentoring. The development of the network of undergraduate faculty and educators was presented as an example of how SOT facilitates communication and resource development. The ToXchange undergraduate faculty network creates a framework where undergraduate faculty at diverse educational institutions cooperatively share and develop curricular materials, mentor new faculty in curricular development, and cooperate to find support for undergraduate toxicology programs and research. The network helps fill the identified need for increased training of undergraduate and graduate faculty in new paradigms for teaching the basic principles of toxicology and its application to human and environmental health. Undergraduate faculty who have contributed to and benefited from this networking resource emphasize that it has provided resources and insight for bringing toxicology into traditionally nontoxicology courses (e.g., biology and chemistry) and provides a means for educating students and the community on the importance of toxicology as a discipline.

SOT has long been interested in providing resources for toxicology education in K-12 to graduate programs and beyond. The Regional Chapters have been an essential part of communicating toxicology and implementing educational programs at the local level. For example, the Northern California Regional SOT chapter in collaboration with the UC Berkeley Toxicology Student Association (ToxSA) provides financial and lecture support for an undergraduate toxicology course. This program has support from the national SOT in the form of ToxScholar awards that facilitate visits to academic, industrial, and government toxicologists who provide examples of applications in the field and successful careers that can be fostered. Several other chapters have very active K-12 programs (e.g., Mid-Atlantic’s Inspector Tox and Ohio Valley’s Totally Toxic). To capitalize on existing efforts within SOT and Regional Chapters, SOT’s Education and Communication Committees are working with the Regional Chapter Collaboration Committee to facilitate increased communication and collaboration between all SOT component groups to promote these outreach efforts.

There are many educational and training opportunities available at all levels of career development, however, many are missed due to lack of awareness that opportunities exist or how such opportunities can be successful. SOT and other professional societies should continue improving communications and networking to insure that members are aware of resources that already exist to meet identified needs. Enhanced communications within the society can enhance awareness of training and internships opportunities for undergraduate and graduate student training or midcareer sabbaticals in government regulatory toxicology, industrial practice, and global experience. SOT should increase partnering with other societies, government agencies, and the private sector to enhance educational communication, opportunities, and curricular materials. Although SOT should not endorse and recommend a specific toxicology curriculum, it can make curricular resources available. Partnering with others will facilitate the generation of a repository of curricular material, real world case studies, and practical cutting edge laboratory exercises that support education from early to late career development.

**TRAINING THE TOTAL TOXICOLOGIST**

Defining the ideally trained individual who can meet the needs of the advancing field of toxicology is a primary consideration in identifying educational and training needs. There is significant concern that a serious “mismatch” exists between the academic training that students receive in toxicology curricula and the needs of employers. This emphasizes the need for effective communication between academia and employers (even if the employer is academia) to ensure that graduates receive a contemporary, relevant, and applicable education. To begin addressing this concern, the SOT Professional Needs Assessment Task Force (PNATF) conducted a professional needs assessment to define the skills and credentials the Total Toxicologist should have and identify methods for SOT and various partners to work together in training toxicologists for successful careers without the need for extensive on-the-job training. These needs include the education of recent graduates and continuing education for the professional who must keep pace with the field and perhaps make career changes. Toxicology is a highly integrative discipline, and Table 1 lists a number of desirable areas of expertise in which the Total Toxicologist should have significant competence.

Although many of the core competencies are traditional and rooted in the science of the discipline, two skills that were uniformly identified by participants in the SOT Education Summit as deficient in new graduates and postdoctoral trainees are communication (both oral and written) and critical thinking skills. To prepare for future needs, curricula must adopt mechanisms for developing 21st century thinking and problem solving. Problems with communication skills include both clear scientific writing as well as written and oral communication for interactions with elected officials, administrators, the media, and the public. Trainees are often so focused on the minutia of basic concepts and their own research that they fail to effectively communicate the “big picture,” i.e., namely, the implications and importance of the overall question being

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**Table 1: Desirable Areas of Expertise**

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<th>Area of Expertise</th>
<th>Description</th>
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<tr>
<td>Chemistry</td>
<td>Rooted in the science of the discipline.</td>
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<tr>
<td>Biology</td>
<td>Relevant and applicable education.</td>
</tr>
<tr>
<td>Environmental Health</td>
<td>Contemporary, relevant, and applicable education.</td>
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TABLE 1
Core Competencies for the “Total Toxicologist”

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<tr>
<th>Competency</th>
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<tr>
<td>Fundamentals of toxicology</td>
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<td>Advanced principles of toxicology</td>
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<tr>
<td>Pathophysiology</td>
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<tr>
<td>Anatomy and physiology</td>
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<tr>
<td>Applied systems biology</td>
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<td>Biochemistry</td>
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<tr>
<td>Molecular genetics</td>
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<td>Regulatory frameworks</td>
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<tr>
<td>Experimental design</td>
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<tr>
<td>Communication skills</td>
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<tr>
<td>Critical thinking skills</td>
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<td>Data and statistical analysis</td>
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Deficits in critical thinking skills result from how students are taught in the classroom and how they are tested. In her talk on student demographics, especially minority students, and their retention in science majors and biomedical research, Dr Rockey indicated that many of the best and brightest are lost to traditional didactic exercises and are tested on facts that do not require development of critical thinking. Although learning key concepts from textbooks is an essential part of any toxicologist’s training, experience-based learning, whether through group interaction or using case study examples, aids in the development of problem solving and critical thinking skills. The importance of a broad qualifying examination was also emphasized. Ideally, this should include both oral and written evaluation of the student’s grasp of important general toxicology concepts, other core competencies, and topics related to the student’s research. In addition, practical applications through research in academic or industrial laboratories are essential for providing real world development of competencies beyond the textbook.

In addition to being an integrated discipline, toxicology is an applied science, and there are many means for SOT and its partners to increase the numbers and strengthen the quality and training of new Total Toxicologists. First, additional needs assessment is required to more formally collect data on what employers are looking for in newly trained toxicologists, thereby assisting educators in modifying their curricula accordingly. Communication skills could be improved by mentored workshops or summits for students and professionals focused on communication training and practice with scientific and nonscientific audiences. Industrial partners and mentors in regulatory toxicology would greatly enhance this experience, and in return, benefit from the experience gained by the trainees. There should also be incentives or templates for incorporating communication of toxicology or related issues into university English departments and journalism programs to improve written and oral scientific communication and communications with the public. Problem-based learning is an effective means of teaching real world applications that can be facilitated by industry and government partners providing case studies. A database of these case studies would be a valuable resource for both providing learning opportunities and promoting critical thinking skills.

The value of developing effective educational and training opportunities through facilitating partnerships between educators, the private sector, and government cannot be over emphasized. There were several examples of industry and government professionals who go to universities to teach as adjunct faculty and thereby bring diverse perspectives and practical application to the curriculum. There were also examples of universities partnering with industry to bring students into real world applications and practical education opportunities. Many programs at the community college level are most successful in training or retraining students if they are associated with practical work settings and internships. Events, such as bringing both educators and trainees to laboratories and industrial settings, provide benefit from learning what constitutes a “day in the life” of a toxicologist and what skills are desirable in performing their jobs. Communication of success stories in training the Total Toxicologist would greatly foster development of these essential partnerships, especially when informing administrators of the immense return they would gain from investment in these types of programs.

In conclusion, a critical step in refining the training of Total Toxicologists who are competent in the skills sought by employers will require facilitating stronger partnerships between educators and employers. Although a needs assessment sponsored by SOT might be an effective initial effort, awareness of educational and training needs is most effectively achieved by partnering and communication between academic, government, and private sector professionals. In addition to focusing on educating students, faculty could be educated through enhanced academic interactions with government or the private sector (collaborative research, mentor-mentee, etc.). In this way, the practical insights gained by a single faculty member can be used to educate many. In addition, partnerships in educating the Total Toxicologist should not stop with academic education because there are great needs for continuing education to keep the practicing professional abreast with the constantly advancing field.

CONTINUING EDUCATION

Continuing education plays an essential role in sustaining or redirecting a career in the face of rapid and dramatic changes in
new technologies, societal needs, global economics, and public health. Many of the goals for enhancing continuing education are shared with developing the academic experience and include: identifying the educational needs of the midcareer professional; identifying mechanisms for effective training and retraining; evaluating the need for core competencies; and providing for those in other disciplines to acquire toxicology expertise. Discussion of developing continuing education and educational opportunities for the midcareer professional is facilitated by outcomes from the recently completed PNATF needs assessment survey.

Continuing education courses and workshops at the annual SOT meeting have been well subscribed and successful in providing knowledge and training in cutting edge technical advances and contemporary toxicological issues. Many of these courses are available in an online repository that is available to SOT members nationally and internationally. These peer-reviewed courses are created and given by SOT members and meet educational needs and expectations of the participants for basic to advanced, cutting edge knowledge. Improvements to the continuing education program have been suggested and include a need for lengthened sessions that cover more material and/or more depth than what can be accomplished in a single afternoon course. These sessions could be available to more participants if they are incorporated into more than one day at the Annual Meeting or offered at other times during the year. Inclusion of other venues such as universities or industries located near the annual meeting sites might also provide excellent opportunities for conducting hands-on technique-oriented sessions that can update trainee skills. Regional Chapters provide exceptional continuing education programs that have a more limited immediate audience. However, with the advent of effective electronic communications, these programs can either be archived or streamed in real time to share with wider audiences. The ability of Regional Chapters to coordinate with local academic, industry, or government groups can bring depth in topical content to these regional continuing programs.

The greatest challenge for creating effective continuing education is to provide relevant cutting edge content. Creation of competitive sessions by the SOT Specialty Sections and Special Interest Groups greatly helps to produce diverse and relevant courses. Nonetheless, additional courses are needed in nonscientific but highly useful professional skills that increase the value of the trainee and keep them abreast of new developments. Possible topics in this category include courses on new management techniques, professional ethics, current regulatory practices, product development, consulting, globalization, and novel educational tools. Sessions on the translation of basic research results to clinical research and clinical trials would be extremely beneficial and complement what was gained from the trainee’s academic education. Courses focused on educational paradigms and technologies would benefit those who are transitioning into academic faculty positions as well as educators who wish to update their approaches to teaching. All levels of professionals can use continuing education to develop communication skills, especially in promoting the value of toxicology to the nontoxicologist and the public.

The form of continuing education itself must modernize. New programs, such as Current Concepts in Toxicology (CCT) developed by SOT have been well received and could be expanded to provide exceptional opportunities for continuing education. These are highly focused topical meetings that last more than a day and provide the opportunity for expanded workshops and hands-on breakout sessions. Partnering with universities or industry in CCT-like meetings could facilitate training and teaching those who come from basic or molecular backgrounds in the conduct of whole animal research, regulatory toxicology, and systems approaches in toxicology.

Newly developed electronic media can greatly enhance the creation of continuing education programs for broad audiences. Requests for webinar-based training and educational programming were made by a majority of respondents at all career levels in the PNATF survey. This form of continuing education course can support a range of topics from basic principles of toxicology to highly focused technical topics. The webinars can be stand-alone sessions or part of an educational series linked by a common theme. Several other professional societies, such as the Society for Environmental Toxicology and Chemistry, the American Chemical Society, the American Society for Pharmacology and Experimental Therapeutics, Society of Toxicologic Pathology, Environmental Mutagen Society, Teratology Society, and the American College of Toxicology have educational programs with a toxicology focus. Partnering with these societies to develop new continuing education programs will increase capacity to develop courses with broad interests and serve the dual role of educating scientists in other disciplines about toxicology. In addition, communication will enhance awareness of society members to the valuable educational resources and opportunities that exist and that will be offered. Finally, mentoring is also an essential form of continuing education and facilitating connection to mentors and providing resources that enhance mentor/mentee interactions should be a goal for sustaining the vitality of the professional society.

EDUCATION AND TRAINING SUPPORT

Who will and should provide support for toxicology education and training are critical questions with multifaceted and uncertain answers. First, it must be acknowledged that support comes in many forms, including those with minimal monetary cost. Clearly, financial investments from academic institutions, industry, private foundations, and government are essential to sustain high levels of education and applied training for early career development. Worker training and retraining in midcareer requires private sector and government
Advocating for the value of toxicology in sustaining a safe and healthy world will greatly increase support for toxicology education and training. Reports from Drs Rockey and Shreffler presented realistic views of the shrinking pool of government funds that support research and training programs. However, they also presented new approaches by the NIH to form partnerships with other government agencies and the private sector to stretch the funding and more efficiently target funds to translational and disease-oriented research. The NIH spent 2.6% of the FY2010 extramural budget on training and overhead for training programs, along with 52% spent on basic research. The numbers of applications for NIH-supported education and research are increasing, but flat or declining funding resulted in fewer awards. Loss of extramural research dollars has reduced research training opportunities for many graduate students and postdoctoral fellows as their mentors have reduced capacity to support them. In addition, transition of fellows to independence or advancement in academia is hampered by intense competition for support in a system that is perceived to be skewed toward more experienced investigators. Government needs to make science and research funding priority to increase competitiveness in the global economy rather than use funding as a target for budget reductions. Public perception of toxicology as a service rather than a discipline that leads in improving health and commercial development in many economic sectors does not help in directing support to toxicology education. However, there are positive signs that advocating the value of toxicology can increase prioritization for support. Dr Rockey provided an excellent example where toxicology support is recognized as essential for a newly funded National Center for Advancing Translational Science, a partnership supported by the NIH, Defense Advanced Research Projects Agency, and FDA. Toxicology and safety pharmacology are critical components of this Center’s workflow and funding priorities. As such, it provides excellent opportunities for training in translational science. In addition, FDA recognizes a great need for individuals trained in regulatory toxicology and practice and as a result supports training programs to help meet this need. The NSF/FDA Scholar-in-Residency program at the FDA is an example of government-supported programs to train academic students, fellows, and faculty in regulatory safety assessment and developing novel tools for safety assessment of medical devices, especially ones that are made with materials that are difficult to assess with standard procedures. This is an excellent example of toxicology training being provided to those from other disciplines, in this case bioengineers, and as a consequence raising awareness of toxicology in their practice.

There are many examples of successful industry/academic partnerships that have brought support to academic training programs and increased the quality of applied education and training. Trade organizations, such as the Pharmaceutical Research and Manufacturers of America (PhRMA), have long been a source of support for student, fellow, and faculty awards that target both pharmacological and toxicological research and training. The majority of support follows the traditional paradigm of supporting Ph.D. students, fellows, and faculty. However, Dr Rockey indicated that industry is also looking for M.S. graduates, and NIH is questioning whether to financially support M.S. candidates to help fill this need. Clearly, identifying, supporting, and implementing new approaches in training will require joint efforts between academia, government, and industry. SOT could play major roles in initiating and mediating these efforts.

Despite clear examples of government and private sector support for toxicology education and training, there are also examples of where increasing the profile and improving the perception of toxicology as a discipline would aid in increasing support from the private sector. Dr Victoria McGovern of the Burroughs Wellcome Fund presented a chronology of lost educational funding opportunities, when in 2001, the Fund decided that pharmacology and toxicology were derivative sciences or service oriented and not critical to their educational mission. It was surprising that toxicological research was not perceived as essential to leading programs translating bench research to population scale health research when desired focuses were to be in areas such as gene/environment interactions; effects of environmental exposure to toxins, allergens, and immunogens; and biomarker identification, validation, and use in population research. A stated goal of the grants supported by this fund is to educate the student or trainee in developing “bilingual” communication skills so that they can communicate their science to peers as well as policy makers and stakeholders. Their education should have depth in science and also have cross-disciplinary dimensions to produce professionals with broad skills to solve the health challenges of the future. Dr McGovern emphasized that such opportunities for support of toxicology training can be gained by improving recognition of toxicology as an essential science and a priority for financial support.

The NIEHS has provided invaluable funding to university-based toxicology training programs as well as intramural and extramural support for individual toxicology training fellowships and transition-to-independence awards. Innumerable toxicologists started or developed their careers with this educational support, and the NIEHS has maintained the training programs as a priority. This is not to say that it is not challenging to sustain training as a priority, and Dr Shreffler was clear in presenting current and future difficulties in obtaining support. However, she indicated that many of the funding programs available are not fully subscribed due to lack of awareness of their existence. This was especially evident in the lack of awareness of administrative supplements targeted to increase support for retention and training of minorities in biomedical research. It was surprising to hear that there have
been very few applicants in recent years for the F33 sabbatical support awards that provide funds for midcareer training or redirection of research. Many do not know of the recent mentored transition-to-independence awards that have been a great aid in supporting the difficult transition from postgraduate training to new faculty or research positions. Increased communication of the availability of funding and support mechanisms as well as improved mentoring to direct trainees and new professionals to these educational opportunities are straightforward means of sustaining toxicology education.

CONCLUSIONS

The overall outcome of the Toxicology Educational Summit was consensus that the discipline of toxicology is strong and essential to public health and the global economy. Nonetheless, much more can be done to modernize educational paradigms and increase support for educational programs to build and sustain the discipline and profession. It is evident that great effort should be made to elevate the image of toxicology and keep the value of toxicology and careers in toxicology as high priorities for funding and support. Partnerships between all sectors of the profession from academia to industry and government need to be fostered to improve educational curricula and programming to sustain excitement, relevance, and value in learning. Needs assessments have to be coordinated and communicated between these partners to insure development of programs that produce the Total Toxicologist who can meet the challenges of the 21st century and beyond. Educational paradigm shifts and revitalizing curricula must be made from K-12 programming through graduate and postgraduate education. These efforts should be made with partners in government, professional societies, and private sector foundations to accomplish recruitment and retention of students in STEM disciplines and to instill awareness of toxicological principles in a broad range of disciplines. Education cannot stop with attainment of an advanced degree and must continue throughout a career so that the toxicology professional can keep pace with ever developing challenges, technological advances, and global change. Mentoring is an essential part of recruitment, education, retention, and advancement and should be fostered by the Society. Mentoring and improving communication of needs, opportunities, and awareness of resources are vital in building for the future through education. Every member of SOT can be an educator, can communicate the value of toxicology, and should advocate for toxicology as a high profile profession that leads in creating a safe and healthy world.

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