GSBS List of Professional Skills/Competencies for Biomedical Sciences Trainees

The Dean of the Graduate School appointed and charged a faculty committee to identify competencies/skills that biomedical science trainees should have by the time they graduate. It was recognized that there are multiple career paths for our graduates and that there are skills and competencies that will be needed for success of our students in their chosen careers. We were to develop a list with the wide variety of career areas that trained biomedical scientists enter in mind. These include positions in academia, government, industry, not-for -profit organizations, and private consulting. Depending on the specific career goal, trainees may need to further develop their skills in research, teaching, administration and management, communications, business, law, information technology, or other areas. Trainees should consider what their personal career goals are and ask mentors who work in those areas about the types of skills that are particularly important to develop. However, it should be noted that, for most professional positions, some proficiency in all of these areas would be of value.

It was also recognized students need to be trained as lifelong learners. Scientific theories, knowledge, and research and teaching methodologies are constantly changing, reflecting the very nature of the scientific endeavor. Scientists must be open to and actively seek new knowledge in addition to new and better methods for acquiring that knowledge and for sharing it with the wider community. Therefore, scientists-in-training must not only seek to develop a high degree of skill in the current knowledge and methodology of their specific field, but they must also develop the motivation and skills to constantly update both. Ultimately, to be a scientist is to be a lifelong learner.

It is important to also recognize that many of the trainee's learning experiences do not occur within the context of formal coursework or training programs. Mentors and role models also are critical in guiding students and helping the student to obtain the knowledge, skills and competencies to be successful. Thus, it was recognized that training must be coordinated effort between program coursework and mentors, advisory committees, staff and other students. Furthermore, successful students should also be encouraged to seek opportunities to achieve professional development goals that they have set for themselves, including additional training in those skills required to be successful in their career path. Thus, the goal was to provide a list of skills and competencies that will provide a foundation for future success of our students, which can be used to help guide restructuring of our current graduate school curriculum and training opportunities.

To develop this list, the committee utilized a list developed by the American Physiology Society. In 2002, The American Physiological Society and the Association of Chairs of Departments of Physiology began compiling a list of important professional development skills for physiology trainees (http://www.the-aps.org/education/skills.htm). Although this list was developed for the benefit of training of physiologist, the list was comprised of skills and competencies that apply to every trainee in biomedical sciences. Thus the committee utilized this list as a starting point for discussion.

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Document Organization

The list of professional skills/competencies is divided into major categories. At the beginning of each category is a description of the overall category along with suggestions of career fields where these skills are especially important. The nine major categories are:

1. *Core Biomedical Science Knowledge*
2. *Professional Ethics*
3. *Laboratory-Related Skills*
4. *Research/Analytical Skills*
5. *Communication Skills*
6. *Teaching and Mentoring Skills*
7. *Personnel and Management Skills*
8. *Lifelong Learning Skills*
9. *Career Development Skills*

The categories are not listed in order of importance.

Across categories, there are redundancies in the specific skills listed. For example, knowing how to organize ideas in a useful manner is cited as an important skill in both “Technical Writing” and “Presentations” in the *Communications Skills* category. Similarly, skill in conceptualizing specific problems is listed under both “Problem-Solving/Reasoning” and “Experimental Design” in the *Research/Analytic Skills* category. This type of redundancy is intentional and in recoginition that some skills are important to more than one area of professional activity.

Lists Of Professional Skills/Competencies

1. *Core Biomedical Science Knowledge*

Graduate students in biomedical sciences face the task of becoming both experts and generalists in their field. They must become experts within there field of study, with detailed knowledge of the historical and current research, theories, and methodologies. However, they also must have a broad working knowledge of biomedical, from the molecular to the systems levels in order to understand their specific field in the overall context of living systems and to facilitate interdisciplinary collaborations.

Major Skills	A Trainee will understand the importance of and work to develop
A. Core biomedical science knowledge	a. Biochemistry • Have a basic understanding of the structural features of components of a cell (proteins, lipids, carbohydrates and nucleic acids) and how they influence their function. • Knowledge of how enzymes work. • Knowledge of how and from where energy is generated in a cell. • Knowledge of how and which cellular components are made, stored, recycled or degraded. b. Molecular Biology • Knowledge of how DNA replication, mutagenesis and repair occurs • Understanding of how transcription occurs and how it is regulated • Knowledge of the process of translation and synthesis of proteins c. Genetics • Understand the basic structure and function of Genes, Genomes and Chromosomes • Knowledge of mendelian Inheritance • Knowledge of multigene Inheritance (Linkage and complex inheritance) d. Cell Biology • Knowledge of the organization of cells and tissues • Knowledge of how cells multiply or die • Understand how cells communicate with each other • Understand the key concepts in cell signaling e. Immunology • Understand what types of host responses are generated against different classes of microbes • Knowledge of the differences between innate and adaptive immunity • Understand the process of inflammation and how this can contributes to resolution or pathology of disease. • Knowledge of antibody structure and function f. Physiology • Understand the concept of homeostasis and how feedback loops contribute to this process. • Have a broad understanding of how different physiological systems work in concert to maintain homeostasis and how it's failure leads to pathophysiology. g. Pharmacology • Have a basic understanding of pharmacokinetics and pharmacodynamics (PK/PD) h. A working knowledge of contemporary techniques and technologies used in biomedical sciences

B. Discipline specific knowledge	a. Foundation knowledge of scientific discipline required for qualifying exam. (Defined by each program/discipline) b. Foundation knowledge after qualifying exam (Defined by each program/discipline) c. Detailed knowledge of specific area of research (Defined by mentor and advisory committee and student)

2. *Professional Ethics*

Professional ethics is integrated into all areas of training, but often it is not taught explicitly as a separate topic. However, the importance of developing professional ethics in any career cannot be overemphasized. The scientist who does not develop the professional attitudes and behaviors recognized as the norms for his/her profession and who does not adhere to the mandated protocols for use of living organisms and handling of data and information will find it difficult to be successful in the long term. *Development of and adherence to professional ethics is vital to professionals in all fields.*

Major Skills	**A Trainee will understand the importance of and work to develop**
A. Professional attitudes	a. Awareness of responsibility as a scientist b. Awareness of the ethical implications of one's area of research c. Understanding of public affairs and how it relates to research
B. Professional behavior	a. Knowledge of and adherence to professional societies' codes of ethics b. Recognition and acknowledgment of potential conflicts of interest c. Understanding of appropriate steps or procedures for dealing with conflicts of interest d. Understanding of and respect for intellectual property rights e. Understanding the need to ensure integrity of own publications and communications f. Knowledge of what constitutes fair use of copyrighted material
C. Use of human/animal subjects	a. Knowledge of appropriate use of human/animal subjects b. Knowledge of proper treatment of human/animal subjects c. Introduction on how human use and animal care committees work d. d. Knowledge of proper protocols
D. Confidentiality	a. Knowledge of role of confidentiality in human research and research contracts b. Understanding of role of confidentiality in dealing with individuals

3. *Laboratory-Related Skills*

The laboratory materials, equipment, and protocols used by scientists change regularly as new methods are developed and new safety and procedural regulations are mandated. Furthermore, scientists often cannot predict where a particular research question will lead them. A molecular question may well lead to whole organ experiments and vice versa. Thus, it is important for students to take every opportunity to learn diverse methods, as well as developing expertise in the primary methods used in one's own field. This includes understanding what is involved in using animals or humans in research, as well as the safe handling of radioactive and other hazardous materials.

Finally, it is critical to learn early in one's training how to maintain accurate records, logs, and protocols. *While laboratory skills are obviously important for researchers, they are also critical to those engaged in teaching courses that include a laboratory component.*

Major Skills	**A Trainee will understand the importance of and work to develop**
A. Laboratory-related skills	a. Knowledge of guidelines and institutional certification in human experimentation, animal experimentation, and laboratory safety, including use and disposal of radioactive and hazardous materials b. Knowledge of operation and maintenance of basic lab instrumentation, including reliability and limitations c. Knowledge of sound laboratory practice and ability to maintain records, logs, and protocols, including organization and reporting in lab notebook d. Skill in making quantitative measurements from biological systems e. Basic laboratory skills, including calculations

4. *Research/Analytical Skills*

This is another area that is vital to any career and, in truth, to daily life. Problem solving and planning skills, as well as literature skills, can be utilized regardless of the type of work in which the scientist is engaged. Time and resource management are crucial to life at work and home. Skills in experimental design, while of most necessity to the scientific researcher, also can be useful in other careers, and information technology skills must be constantly upgraded in all professional fields. Many of the skills in this section are often categorized as critical thinking skills, underscoring their generality and applicability to many fields of endeavor. *Research and analytical skills are important for biomedical scientists working in all career areas.*

Major Skills	**A Trainee will understand the importance of and work to develop**
A. Problem solving/reasoning	a. Ability to conceptualize problems b. Ability to brainstorm (and question) ideas in a group c. Ability to combine and integrate information from disparate sources d. Ability to break down and understand complex content e. Ability to solve problems by staying current and up-to-date in new technologies f. Ability to use troubleshooting skills g. Ability to identify irregular results h. Ability to evaluate hypotheses and data critically i. Ability to reach and defend independent conclusions j. Knowledge of appropriate qualitative approaches to research problems k. Ability to express a problem or solution using quantitative approaches l. Ability to generate multiple solutions m. Ability to develop creative solutions (divergent thinking) n. Ability to support a position or viewpoint with argumentation and logic o. Ability to interpret data validly
B. Planning	a. Ability to prioritize tasks and multi-task b. Ability to identify needed resources c. Knowledge of how to develop a budget
C. Experimental design	a. Knowledge of the scientific method to organize and test ideas and hypotheses b. Ability to recognize meaningful problems and questions for research c. Ability to define the problem precisely d. Knowledge of different research methodologies e. Ability to select appropriate instruments to acquire data f. Skill in designing experimental protocols, including appropriate use and number of experimental subjects g. Understanding of the principles and procedures for institutional approval for use of animal/human subjects h. Skill in evaluating experimental evidence i. Ability to draw conclusions from data (data analysis)

D. Informational technology	a. Skill with computers, both software (word processing, reference manager software, spreadsheets, databases, Internet, email) and basic equipment setup b. Ability to select appropriate graphical methods and appropriate use of graphical representations c. Proficiency in information storage and retrieval d. Knowledge of and ability to use large information databases, including ability to search databases effectively
E. Data analysis	a. Knowledge of and ability to select appropriate statistical approaches b. Ability to determine accuracy of computed results
F. Time management	a. Organizational skills b. Ability to prioritize tasks and troubleshoot c. Ability to plan a project timeline
G. Resource management, including lab management	a. Ability to organize resources for projects b. Knowledge of how to maintain equipment/work area c. Knowledge of inventory and supply maintenance
H. Scientific literature	a. Familiarity with the research literature within the student's discipline, including familiarity with major historical developments b. Ability to understand and assess of scientific literature i. Understanding methods ii. Ability to understand and interpret data iii. Ability to correlate data presentation with author conclusions iv. Critical assessment of scientific literature c. Ability to keep abreast of major research developments both within a particular research area and in the general area of the student's discipline d. Ability to locate and assimilate new information rapidly

5. *Communication Skills*

Communication skills are the hallmark of professionals in all fields of biomedical sciences. They are required regardless of what career path is chosen, scientific or not. Every person needs to know how to express him/herself in speaking and writing. Whether presenting a symposium, coaching an employee, being interviewed for a job, or simply talking with a neighbor or colleague, being able to communicate clearly is critical. Being able to express ideas clearly and succinctly in writing also is essential whether it is in a manuscript, grant proposal, job application cover letter, or letter to the editor.

Major Skills	**A Trainee will understand the importance of and work to develop**
A. Interviewing (Interviewee)	a. Skill in preparing for diverse types of interviews b. Knowledge of how to conduct oneself at interviews c. Knowledge of appropriate post-interview actions
B. Presentations	a. Ability to speak clearly in English b. Ability to organize ideas in a useful fashion c. Ability to use graphics effectively to communicate ideas d. Knowledge of how to develop poster presentations e. Knowledge of how to develop various types of oral presentations f. Ability to convey complex information in appropriate fashion to audiences with different levels of scientific knowledge g. Ability to speak before large and small groups h. Ability to assess audience response to determine how well ideas are being conveyed i. Ability to make persuasive arguments in oral presentations j. Ability to handle audience questions
C. Technical writing	a. Ability to write at all levels in clear English: brief abstracts to book-length manuscripts b. Ability to organize ideas in a useful fashion c. Ability to write logical instructions, e.g. protocols, SOP's, etc. d. Ability to use graphics and tables to effectively to communicate ideas e. Ability to revise one's own work to make a document or presentation clearer or more persuasive f. Ability to edit and proofread g. Knowledge of publication process for scientific journals and other publications h. Ability to cite and critically analyze the scientific literature in written work, including writing bibliographies and utilizing reference manager software. i. Ability to convey complex information in appropriate fashion to audiences with different levels of scientific knowledge

D. Grant/proposal writing	a. Ability to develop clear and testable hypothesis, objectives, and research plan b. Knowledge of how to identify various funding sources c. Knowledge of types of grants and different approaches to writing them d. Knowledge in developing grant budgets e. Knowledge of submission, evaluation and grant review processes f. Ability to use scientific literature effectively in writing grant proposals
E. Peer Review	a. Ability to give and receive appropriate constructive criticism in writing and evaluating manuscripts and other types of writings b. Ability to give and receive appropriate constructive criticism in giving and evaluating oral and poster presentations c. Ability to give and receive appropriate constructive criticism in writing and evaluating grant applications/research proposal

6. *Teaching and Mentoring Skills*

Teaching skills are another example of skills that everyone, regardless of career choice, can use. Even those that do not teach formal courses will use teaching skills in seminars, coaching employees, and developing audio-visual materials for presentations and publications. While those trainees planning on a teaching career should hone their teaching skills to the highest level, most professionals have need of teaching skills, either in the workplace or at home.

Mentoring is a skill that graduate students begin practicing almost immediately, both seeking advice from those ahead and giving advice to those following behind. Knowing how to be a good mentee and mentor is invaluable at all stages of a career. *Teaching and mentoring are both important for biomedical scientists working in all career areas.*

Major Skills	**A Trainee will understand the importance of and work to develop**
A. Teaching	a. Ability to convey the competence in subject matter and confidence in one's ability to teach b. Effective use of common instructional aids, including audiovisual techniques c. Ability to help students understand the general principles and concepts underlying a particular topic d. Ability to explain both basic and difficult concepts clearly e. Ability to put a specific topic into larger context (clinical relevance, prior material) f. Ability to ask good questions g. Ability to provide feedback to students h. Ability to foster an effective learning environment including showing respect for the student, encouraging their intellectual growth and providing a role model for scholarship and intellectual vigor

B. Mentoring	<u>Skills for being a mentor:</u> a. Ability to evaluate someone's strengths and weaknesses, and help guide them to build on strengths, improve on weaknesses b. Knowledge of how to provide feedback, constructive criticism, and advice c. Knowledge of how to listen to someone to understand their perspective on their own situation d. Knowledge of the rules and procedures related to mentee's situation – e.g., as a student, postdoctoral fellow, or junior colleague
	<u>Skills for utilizing a mentor:</u> a. Knowledge of the role(s) mentors can play at all career stages b. Knowledge of how to select a good mentor c. Knowledge of when to approach mentor for advice, guidance, or advocacy d. Knowledge of how to develop a good relationship with a mentor e. Ability to articulate one's individual needs, desires, concerns, and limitations with regard to one's own career development f. Knowledge of what to do when one disagrees with a mentor g. Knowledge of how to listen to someone to understand their perspective on their own situation

7. *Personnel and Management Skills*

While personnel and management skills may not be an area of primary importance to graduate students (although some may be given partial supervision of undergraduates or technicians), it becomes increasingly important as one's career progresses. Regardless of the type of career chosen, personnel and management skills are essential, requiring understanding of both supervisory strategies and personnel procedures. The importance of networking for staying current in one's field and for future development and of teamwork cannot be overstated. *Personnel, management, and teamwork skills are important to professionals in all fields.*

Major Skills	**A Trainee will understand the importance of and work to develop**
A. Supervising staff and other employees	a. Listening skills b. Ability to explain goals, objectives, guidelines c. Sensitivity to different perspectives and cultures
B. Management of projects/grants	a. Knowledge of and compliance with institutional and other relevant regulations and ethics b. Understanding of importance of ensuring integrity of own publications and communications c. Knowledge of how to create a cooperative work environment

C. Networking	a. Knowledge of how to develop a base for possible collaborations b. Knowledge of how to professionally contact other researchers at meetings c. Knowledge of how to professionally contact with other researchers via email
D. Working in teams	a. Ability to work well with many different people/cultures b. Respect for and placing value on different perspectives c. Ability to provide and respond to constructive criticism d. Ability to work well under pressure and willingness to work hard e. Ability to apply oneself to a variety of tasks simultaneously f. Knowledge of how to work within a team

8. *Lifelong Learning Skills*

As noted earlier, to be a scientist is to be a lifelong learner. Regardless of position or status, learning must continue in all areas included in this document to ensure continued competency. *Lifelong learning skills are valuable for physiologists working in all areas.*

Major Skills	**A Trainee will understand the importance of and work to develop**
A. Lifelong learning	a. Awareness of various career opportunities available b. Awareness of contemporary issues in biomedical sciences c. Willingness to examine, adapt, and adopt practices, methods, and ideas from perspectives very different from your own d. Commitment to continuously upgrade one's education e. Skills associated with independent learning f. Self-skills (self-motivation, self-confidence)

9. *Career Development Skills*

On first glance, career planning may be perceived as a skill solely for graduate students. However, scientists at all levels must engage in career planning. Opportunities can arise very unexpectedly and the successful physiologist is prepared to take advantage of them. A current example is entrepreneurial skills. Whereas once they were not viewed as important, for many of today's physiologists they are fundamental, critical to the success of their overall research or development program. Professional societies offer scientists an important venue for developing and honing many professional skills and for exploring possible avenues for career development. *Professionals in all fields must afford time to career planning.*

Major Skills	**A Trainee will understand the importance of and work to develop**
A. Career planning	a. Periodic self-assessment of one's skills and interest b. Knowledge of diverse career options and current/future job markets c. Ability to investigate necessary skills/knowledge for particular careers d. Ability to adapt to a changing environment e. Willingness to examine, adapt, and adopt practices, methods, and ideas from perspectives very different from one's own f. Ability to identify and seek advice from a mentor(s) g. Understanding of expectations for current position and/or for job advancement h. Prepare a C.V., resume and biosketch i. Skills in negotiating for first job
B. Interacting with professional societies	a. Understand the benefits of belonging to and participating in a professional society b. Knowledge of appropriate societies to select for membership c. Understanding how to get the most benefit from attending scientific meetings d. Skill in presenting one's research e. Exposure or knowledge of editorial work (Reviewing manuscripts)
C. Entrepreneurial skills	a. Knowledge of intellectual property rights and patents process b. Recognition and acknowledgment of potential conflicts of interest c. Understanding of appropriate steps/procedures for dealing with conflicts of interest