ASSESSING BIOENGINEERING AND BIOINFORMATICS RESEARCH TRAINING, EDUCATION AND CAREER DEVELOPMENT: OPPORTUNITIES FOR NIH AND NSF COLLABORATION

Richard E. Swaja (NIH), Sohi Rastegar (NSF), Linda G. Griffith(MIT), Murray B. Sachs (JHU), and Shankar Subramaniam (UCSD)

August 24, 2001

EXECUTIVE SUMMARY

The National Institutes of Health (NIH) and the National Science Foundation (NSF) make significant investments in research training, education, and career development in the multi-disciplinary fields of bioengineering and bioinformatics. During interagency discussions between NIH and NSF regarding their roles in these fields, questions have been raised concerning (l) how well current NIH and NSF programs are meeting the needs of these rapidly growing disciplines and (2) whether the agencies should consider collaborative efforts to address training and education gaps. To obtain community input on these issues, a workshop was held on June 13-14, 2001, at NSF Headquarters in Arlington, Virginia. The objectives of this workshop were to (l) assess needs in bioengineering and bioinformatics research training, education, and career development at all levels and (2) develop a list of recommendations for NIH and NSF collaborative actions to address identified gaps and support the needs with the objective of assuring the availability of future generations of highly-trained professionals in these fields. Twenty-seven participants from academia, industry, laboratories, and foundations with strong interests in bioengineering and bioinformatics participated and provided their perspectives related to the objectives of the workshop. In addition, six senior NIH and NSF staff also participated as information resources during the discussions.

The workshop provided a detailed assessment of the gaps in research training, education, and career development at all career levels; the main obstacles or barriers to having the gaps addressed; actions that can be taken to make careers in these scientific fields more attractive to all social groups; and collaborative actions for the NIH and NSF to enhance training and education opportunities for the bioengineering and bioinformatics communities.
Specific priority recommendations based on plenary discussions for NIH and NSF consideration included:

1. Provide a clear and continuous path of education and career development opportunities from the undergraduate through senior career levels (e.g., to address gaps in mechanisms of support for cross-disciplinary training at the junior faculty or mid-career levels);

2. Develop additional opportunities for cross-disciplinary training beyond those offered through institutional training grants (e.g., NSF training supplements to NIH research grants, and NIH support of IGERT-type research and training opportunities);
3. Increase the number of individual fellowships and institutional training grants at all career levels that include quantitative biology, computational biology, and integrative systems modeling; are cross-disciplinary (e.g., basic life scientists and engineers or computer scientists); include funds to support faculty with complementary expertise (e.g., computer scientists to teach biologists or basic biologists to teach engineers and physical scientists); and support the development and testing of curricula;
4. Develop programs that include interactions with industry (e.g., career counseling and potential sources for a research experience, using industry scientists to teach courses, supporting industry internships, including the participation of scientists from industry in the review process, expanding training plans of post-doctoral staff and fellows involved in research to include teaching and experience in industry, and conducting reviews of NIH and NSF training activities by industry panels);
5. Provide opportunities or infrastructure support for training (e.g., databases, hardware, software, and personnel for bioinformatics and state-of-the-art teaching laboratory equipment for bioengineering); and
6. Strengthen the review process for multi-disciplinary research and training grant applications to ensure that the importance of cross-disciplinary, non-hypothesis-driven research is appreciated and considered and that the reviewers' qualifications are appropriate for the proposed projects.

These recommendations and other results of the workshop will be evaluated by a Joint NIH/NSF Bioengineering and Bioinformatics Training Committee which will determine a course of action regarding collaborative efforts. These results will also be made available to individual NIH research institutes and NSF engineering and science programs as information that may be useful in the development of agency education and training initiatives.

WORKSHOP SUMMARY AND RECOMMENDATIONS

BACKGROUND

The National Institutes of Health (NIH) and the National Science Foundation (NSF) make significant investments in research, research training, education, and career development in the multi-disciplinary fields of bioengineering and bioinformatics. The development of trained professionals in these areas requires opportunities and support all along the career continuum including the undergraduate, pre-doctoral, post-doctoral, junior career, and senior career levels. Considering the nature of these fields, training and education programs require trans- or cross-disciplinary interaction between the engineering, physical, and computational sciences and the biological and medical sciences.

During interagency discussions, questions were posed concerning (1) how well current research training, education, and career development programs of NIH and NSF are meeting the needs of these rapidly growing fields and (2) whether the agencies should consider collaborative efforts to address training gaps. A committee of NIH and NSF representatives (Joint NIH/NSF Bioengineering and Bioinformatics Training Committee) was formed under the auspices of the Bioengineering Consortium (BECON) to address these questions and to coordinate subsequent interagency efforts.

A workshop to obtain community input on these issues was held on June 13-14, 2001, at NSF Headquarters in Arlington, Virginia. The objectives of the one-and-one-half days workshop were to (1) assess needs in bioengineering and bioinformatics research training, education, and career development at all levels and (2) develop a list of recommendations for NIH and NSF collaborative actions to address identified gaps and support these needs with the objective of assuring the availability of future generations of highly-trained professionals in these fields. Twenty-seven extramural participants from academia, industry, laboratories, and foundations with strong interests in bioengineering and bioinformatics research training and education were invited to participate and provide their perspectives on the objectives of the workshop. In addition, a total of six NIH and NSF staff also participated as information resources during the discussions. The agenda and the list of attendees (invited participants, NIH resources, and NSF resources) are attached as Appendices A and B, respectively.

WORKSHOP FORMAT

For the purpose of this workshop, three technical areas – bioengineering, medical engineering, and bioinformatics - were defined based on curricular differences required to support research training in each area and differences in ultimate career paths. *Bioengineering* was considered to be an emerging basic engineering discipline with cellular and molecular biology as the underlying core science (just as the science of chemistry underlies chemical engineering). Bioengineering includes the development of molecular-to-systems analytical models that predict system behavior based on fundamental physiochemical and kinetic phenomena as well as the synthesis of new products such as engineered molecules and tissues. While some applications of bioengineering can involve clinical medicine, other applications can also involve the agricultural, pharmaceutical, and biotechnology industries. *Medical engineering* represents the application of all engineering and/or physical science fields to clinical medicine. It includes the rapidly growing application of bioengineering and physics to clinical medicine and also encompasses a wide range of endeavors such as instrumentation and imaging that require in-depth training in the physical sciences, electrical engineering, mechanical engineering, etc., as well as some training in physiology and clinical medicine. Medical engineering does not generally require comprehensive training in biology especially at the cellular or molecular levels. *Bioinformatics* refers to the application of computational or mathematical techniques to address a variety of biological or medical problems. This field emphasizes the ability to discern predictive patterns and correlations from large data sets, to make predictions from those patterns, and to manage the data effectively. The range of data considered in the discussions was from genomic sequence through structure and function to pathways and tissues reaching to predictive outcomes from therapies.

To ensure active interaction, opportunities for participation, and adequate consideration of the unique needs of each technical area, the participants were divided into three groups of nine members each according to their areas of specialty – bioengineering, medical engineering, and bioinformatics. The overlap in expertise among all groups and the fact that the groups were not mutually exclusive were recognized and discussed by the participants and were not believed to be obstacles in addressing the objectives of the workshop.

The NIH and NSF offer a number of opportunities aimed at supporting the education and research training of students, faculty, and career scientists. To provide background information on these opportunities, participants were provided with information about the relevant NIH and NSF programs in the areas of bioinformatics, medical engineering, and bioengineering prior to the workshop. Additional orientation was provided during the first session of the workshop, which included oral presentations by senior NSF and NIH staff on the research training, education, and career development programs of the respective agencies.

To keep the discussion focused on the objectives of the workshop, the groups were asked to address the following five questions with regard to their specialty areas:

(1) What are the priorities or opportunities which are currently being addressed at all career levels?

(2) What are the gaps in research training, education, and career development at all career levels?

(3) What are the main obstacles or barriers to having these gaps addressed?

(4) What actions can be taken to make careers in these scientific disciplines more attractive to all groups?

(5) What can NIH and NSF do collaboratively to enhance the training, education, and career development opportunities for the bioengineering, bioinformatics, and medical engineering communities?

Following group discussions of these questions, participants presented their recommendations in a plenary session. As a final exercise during a plenary session, the invitees were asked which recommendations they considered to be the highest priorities for research training, education, and career development.

SUMMARY OF DISCUSSIONS

During the afternoon plenary session on June 14, results of the morning group discussions were presented and summarized. A summary of the plenary discussions and group recommendations is given in the following text. Many of the results were similar for the three working groups, and some of the following items are combinations of similar recommendations.

1. What Are The Gaps in Research Training, Education, and Career Development at All Career Levels?

Career Level: K-12. Students have little or no exposure to these three fields in their science curricula or through other formal or informal educational activities.

General: There is generally no support for administration of inter-disciplinary programs (i.e., funding for teaching release, etc.) in addition to research and teaching responsibilities at universities. Most universities provide no support for faculty who invest a lot of time establishing inter-disciplinary programs primarily because these types of rewards are handled by individual departments.

Career Level: Undergraduate

- Advanced biology courses are often not available to engineering students due to limited enrollment. Basic and advanced computer science and engineering courses are often not accessible to science students due to limited enrollments and the large number of prerequisites in math and engineering analysis.

- Courses in bioengineering and bioinformatics, like other engineering courses, are not usually provided in the early stages of undergraduate education.

- Undergraduate interdisciplinary research experiences that are integrated into the education curriculum are minimal.

- More exposure to industry perspectives (e.g., the need for integration from molecular/organism to product level) through formal courses, internships, and interaction with professional societies is needed. Review of NIH and NSF training activities by industry panels would provide an industrial viewpoint to the broad perspective which is essential for the national scientific enterprise to fully thrive and produce benefits to society. Since industry stands to gain much from these efforts, joint funding (Federal and industrial sources) may be appropriate.

- Opportunities to understand the role of engineering in clinical medicine should be made available. Undergraduates need to develop an appreciation for the impact that engineers can have in medicine without going to medical school. Although campus biomedical engineering societies or premed societies may partly fill this need, formal exposure to clinical needs and opportunities may be more effective.

Career Level: Graduate

- Support for the first two years of graduate school is not widely available resulting in students having limited choices from which to select research projects/experiences.

- There is insufficient academic training for interdisciplinary work in areas such as integrative systems modeling which are of interest to industry.

- Overall, the numbers of bioengineering and bioinformatics students are insufficient to keep up with the demand.
- Students find it difficult to bridge the gap between bioengineering/bioinformatics curricula and research experiences in the clinical setting.
- Training programs generally lack plans that incorporate alternatives to an academic career (e.g., experiences in technology development that encompass the continuum from prototype development to application).
- Resources to support new ways of learning and sharing information (e.g., on-line curricula, databases, and informatics tools, etc.) are lacking.
- Opportunities for experiences in industry are limited.

Career Level: Post Graduate

- Courses that enhance the ability to do multi-disciplinary research are not available.
- Professional development opportunities in areas other than research (e.g., teaching and project management) are minimal.

Career Level: Mid-Career

- There is an absence of resources and limited or no available time for professional development for junior- and mid-level faculty or mid-career industrial scientists who wish to take courses or have a research experience in another technical discipline.

2. What Are the Main Obstacles or Barriers to Having These Gaps Addressed?

Career Level: Undergraduate

- Several obstacles were identified that relate to how well undergraduate students are prepared academically for interdisciplinary experiences including:

  - The revolutions in cell biology, genomics, and proteomics that have occurred in the past decade provide an important new scientific foundation for engineering applications in the future and should be an integral part of undergraduate engineering education through both basic science courses and as components in core subjects. Many faculty in traditional engineering disciplines who teach core engineering subjects have not had the opportunity to be educated in modern biology, and thus cannot integrate material from biology adequately into core undergraduate engineering curricula. Support for release time should be made available for faculty to take intensive subjects in molecular cell biology, proteomics, and genomics. At the same time, as biology becomes more quantitative and mechanistic in the post-genomic world, funds should be made available to support release time and training of biology faculty who are preparing for the era of large-scale systems biology and informatics.

- Core curricula for some science and engineering disciplines have not been updated to take advantage of multi-disciplinary approaches to problem-solving. While engineering courses must be updated to include the role of biology, biology courses must also consider the role of engineering.

- Bioengineering and bioinformatics students interested in medical engineering as defined in this Workshop do not have adequate exposure to clinical environments.

- Support for research experiences in industry (e.g., internships, fellowships, and summer/semester programs) is insufficient or not available.

Career Level: Graduate

- Restricted class sizes in the basic sciences and computer sciences limit educational opportunities for students in multi-disciplinary fields.

- There are few individual fellowships or institutional training grants in bioengineering and bioinformatics. This is compounded by the fact that most training grants seem to be concentrated at a few universities.

Career Level: Post Graduate

- The research environment in industry involves a team approach. Students who are not trained in integrated, multi-disciplinary research are at a disadvantage.

Career Level: Mid-Career

- Traditional engineering and basic science departments generally do not reward (i.e., promotions, access to departmental funds, and access to graduate students) faculty for participation in multi-disciplinary and inter-departmental training and research. This serves as a disincentive for junior or mid-career faculty.

- Federal agencies do not provide sufficient research support for integrative science and engineering projects which also fund graduate student research projects.

3. What actions can be taken to make careers in these scientific disciplines more attractive to all groups?

Opportunities for all members of the population to participate in research training, education, and career development programs are necessary to ensure that the best scientific talent can be identified and developed to meet the education and research agendas of the 21st century. Workshop participants were asked to identify ways to attract all groups to science and engineering. The groups were unanimous in recommending that mechanisms be developed to specifically target the recruitment of under-represented populations into bioengineering and bioinformatics at all career levels. Specific suggestions included:

Career Level: K-12:

- Develop middle and high school programs that expand students' perspectives so that they might consider careers in bioengineering and bioinformatics. Involve teachers in research laboratories to expand their knowledge of science and engineering.

Career Level: Undergraduate

- Promote good societal role models for bioengineers
- Change the perspectives of students about bioengineering and bioinformatics through better career counseling and exposure to industrial practice.
- Promote summer programs at universities to introduce (1) high school students to bioengineering and bioinformatics as well as campus life and (2) undergraduate engineering or science students to biomedical research.
    - Foster interdisciplinary “teams” of students at the undergraduate level, such as the University of Maryland's Gemstone Program (http://www.gemstone.umd.edu/).

Career Level: Graduate

- Increase the participation of under-represented minority groups on training grants and individual fellowships.
- Provide research experiences by working with multi-disciplinary teams of researchers.
- Promote short-term intensive training programs such as those at Cold Spring Harbor Laboratory and Woods Hole.
- Develop special grant supplements for students who are co-mentored by a biologist and an engineer.

Career Level: Mid-Career

- Provide career development awards to junior and mid-career faculty interested in interdisciplinary research.

4. What can NIH and NSF do collaboratively to enhance the training, education, and career development opportunities for the bioengineering and bioinformatics communities?

The consensus of the participants was that the very existence of the Workshop reflected the importance of the fields of bioengineering and bioinformatics for the NIH and NSF with regard to the missions of the agencies, and discussions during the Workshop reinforced the key role of training to support these missions. Although there are differences between the views and scopes of bioengineering and bioinformatics that are fostered by the NIH and NSF, and differences between the cultures and constituencies of the agencies, these multi-disciplinary and evolving fields represent an interdependence of resources and objectives that is the result of the revolution in biology and medicine (biomedicine) and is important to both agencies if they are to succeed in their missions. Not only do the agencies have to be cognizant of this interdependence, but they also have to be aware of their constituents (scientists and educators) as well. The NIH and NSF must take positive and pro-active steps to establish communication and collaboration among their various organizational components and to establish appreciation and cooperation with the cross-constituencies. Reliable and articulate spokespersons within the agencies and constituencies will be necessary to support and establish structured programs resulting from the Workshop. An Advisory Committee would provide a continuous body that would help maintain the focus, both internally and externally, towards the constituencies.

Although research is currently and appropriately the central issue at both agencies, the "pipeline" for investigators is often neglected. These evolving disciplines are revolutionizing biology and medicine (academic and industrial). Education of the workforce defines the fields and is vital to progress and the economy. Producing "clones" of existing researchers will not fill the research training and education needs required for multi-disciplinary, integrative research. Collaborative efforts by the NIH and NSF can address gaps in the career continuum and support the types of programs required to provide future generations of high-quality bioengineers and bioinformaticians.

General:

- NIH and NSF should share information about each other's programs with investigators and students in bioengineering and bioinformatics. Possible modes of implementation for this communication include joint workshops/symposia, demonstration projects, and periodic reviews by non-Federal committees.
- The agencies should collaborate with regard to advertising education and training opportunities to ensure that appropriate members of the community are informed.
- Consideration should be given to increasing the duration of institutional training grants from the current 3-5 year awards to ten years with 2-year non-competitive renewals.
- An extramural advisory committee to periodically assess NIH and NSF bioengineering and bioinformatics education and training opportunities and programs and to recommend changes to address gaps and deficiencies should be considered.

Career Level: Undergraduate

- NIH should consider supporting undergraduate training programs. Joint BS-MS programs could provide a partial solution to the problem of limited undergraduate training opportunities.

- NSF and NIH should jointly fund the development of interdisciplinary, problem-based modules for implementation as part of the undergraduate curriculum starting at the freshman level.

Career Level: Graduate

- NIH and NSF should jointly sponsor individual graduate and postdoctoral fellowships in bioengineering and bioinformatics.

- NSF and NIH should jointly support and help establish guidelines for industrial internship programs that include bioengineering and bioinformatics. The agencies should help establish guidelines for issues such as intern salaries, intellectual property, and conflict of interest issues for these internships. Joint Federal and industrial funding for these opportunities should be considered.

Policy Considerations:

- Develop consistent approaches to bioengineering and bioinformatics training and education by:

  - Developing standard definitions of “training” and “education”;
  - Accepting bioengineering and bioinformatics education and training as areas of joint interest; and
  - Communicating their shared interests in bioengineering and bioinformatics training to the communities possibly by a position paper in a widely read scientific journal (e.g., *Science*).

- Expedite the funding of short-term and long-term programs in multi-disciplinary research training, education, and career development by:

  - Supplementing grants to support students and faculty development to promote integrative research;
  - Increasing the number of training grants targeted to bioengineering and bioinformatics;
  - Providing support for administration of inter-disciplinary training and research programs; and
  - Supporting combined BS-MS degree programs to partly alleviate limited undergraduate training opportunities.

- Facilitate cross-disciplinary training by having bioinformaticians or bioengineers and basic scientists as co-training directors on training grants and as co-mentors on individual fellowships.

- Strengthen interdisciplinary training by supporting:

  - The development of curricula as part of training grants at all career levels;
  - The development of faculty in the areas of bioengineering and bioinformatics at all career levels; and
  - Some level of clinical training for students in a bioengineering curriculum.

- Evaluate the way fellowship and training grant applications are reviewed to ensure that the reviewers appreciate the importance of multi-disciplinary research which might not be hypothesis-driven (i.e., needs- or technology-driven projects) and that the reviewers' qualifications are appropriate for the proposed projects.

PRIORITY RECOMMENDATIONS FOR NIH AND NSF CONSIDERATION

The following items were identified as priority recommendations for NIH and NSF consideration during the closing plenary session on the afternoon of June 14. Although some can be handled by the individual agencies, several may be more effectively addressed by collaborative opportunities.

- Provide a clear and continuous path of education and career development opportunities from the undergraduate through senior career levels. Develop specific mechanisms to support cross-disciplinary training for junior and mid-career faculty and administration of inter-disciplinary research and training programs.

- Support additional opportunities for cross-disciplinary training beyond that offered through institutional training grants (e.g., NSF training supplements to NIH research grants, NIH support of NSF IGERT-type programs, and NIH opportunities for NSF Engineering Research Centers that are focused on bioengineering and bioinformatics research and education).

- Increase the number of individual fellowships and institutional training grants at all career levels in bioengineering and bioinformatics that:
  - Include quantitative biology, computational biology, and integrative systems modeling;
  - Are cross-disciplinary (e.g., basic life sciences and engineering or computer science);
  - Include funds to support faculty with complementary expertise (e.g., computer scientists to teach biologists or basic biologists to teach engineers); and
  - Support the development and testing of curricula and new training approaches.

- Support training programs that increase interactions with industry. Examples include but are not limited to (1) career counseling that includes information about industry as a potential source for a research experience; (2) involving industry scientists in teaching courses; (3) increasing the number of industry internships; and (4) increasing the participation of scientists from industry in the grant review process. Another option is to expand the training plans of postdoctoral staff and fellow involved in research to include teaching and experience in industry. Industrial input to NIH and NSF training activities could also provide a commercial perspective which is essential for national scientific enterprise to fully thrive and produce benefits to society. Industrial contributions to funding these positions should be considered to supplement Federal support and reflect the commercial sector commitment.

- Increase opportunities for infrastructure support such as databases, hardware, software, systems, and personnel (e.g., systems support staff, maintenance personnel, operations instructors) for bioinformatics and state-of-the-art teaching laboratory equipment for bioengineering.

- Strengthen the review process for multi-disciplinary research and training grant applications to ensure that the importance of cross-disciplinary, non-hypothesis-driven (needs-driven) research is appreciated and considered and that the reviewers' qualifications are appropriate for the proposed projects.

FUTURE ACTION

The challenge following this workshop is to convert the findings and recommendations into viable and effective programs at the NIH and NSF. To ensure that all results have been adequately addressed and considered, all workshop participants will have an opportunity to review and comment on this report. Based on these comments, a revised report will be prepared and circulated to members of the BECON and NIH/NSF Bioengineering and Bioinformatics Training Committee for information. A meeting of the NIH/NSF Joint Training Committee will then be held to discuss and evaluate the workshop results and recommendations and to determine a course of action. The version of the report used for NIH/NSF Joint Training Committee and BECON discussions will be placed on the NIH Bioengineering Web site.

ACKNOWLEDGEMENTS

The authors gratefully acknowledge the valuable contributions of the NIH/NSF Workshop Committee in supporting all aspects of this effort including program planning, meeting logistics, and information management. Committee members included Dr. Bettie Graham (NIH), Dr. Wyn Jennings (NSF), and Ms. Mariaileen Sourwine (NIH). The contributions of NIH and NSF senior staff who provided important contributions as technical and information resources during the workshop are also gratefully acknowledged. These resource staff members included Dr's. James Cassatt, Warren Jones, and Daniel Sullivan of the NIH and Dr's. Denise Caldwell, Mita Desai, and Lynn Preston of the NSF. Financial support for this Workshop was provided by the NIH's National Institute of Biomedical Imaging and Bioengineering and the National Science Foundation.

APPENDIX A: AGENDA FOR NIH/NSF WORKSHOP

June 13 – Arlington Hilton and Towers

7:00 PM **Welcome Dinner**

8:00 **Orientation and Charge to the Committee**
Dick Swaja, NIH and Sohi Rastegar, NSF
Overview of NSF and NIH Training and Career Development Programs
Walter Schaffer, NIH and Wyn Jennings, NSF

9:00 **Adjourn**

June 14 – NSF Headquarters, 4201 Wilson Boulevard, Arlington, VA

8:00 AM **Continental Breakfast** (Stafford Building, Room 375)

8:30 **Welcome by NSF and NIH Representatives** (Stafford Building, Room 375)
Joe Bordogna, NSF and Donna Dean, NIH
Meeting Logistics and Agenda
Sohi Rastegar, NSF and Dick Swaja, NIH

9:00 **Concurrent Sessions: Training, Education and Career Development Needs** (Stafford Building)

Group1: Bioengineering, *Linda Griffith, Chair* (Room 365)

Group2: Bioinformatics, *Shankar Subramaniam, Chair* (Room 380)

Group 3: Medical Engineering, *Murray Sachs, Chair* (Room 390)

10:00 **Coffee Break**

10:15 **Return to Concurrent Sessions**

11:30 **Working Lunch** (Stafford Building, Room 375)
Each group to prepare a summary of its discussions for presentation during afternoon sessions.

1:00 PM **Summary of Training/Career Development Needs - Results of Morning Discussion** (Stafford Building, Room 375)
Presentations by Group Chairs and Discussion by Participants
Sohi Rastegar, Moderator

2:30 **Coffee Break**

2:45 **Recommendations for NIH and NSF Collaborations**
Discussion with Participants and NIH/NSF Staff
Dick Swaja, Moderator

3:45 **Course of Action and Summary,** *Sohi Rastegar and Dick Swaja*

4:00 **Adjourn**

APPENDIX B: PARTICIPANTS AT NIH/NSF WORKSHOP

Gilda Barabino, PhD
Vice Provost for Undergraduate Education & Associate Professor of Chemical Engineering
112 Hayden Hall
Northeastern University
Boston, MA 02115
TEL: 617-373-2842
FAX: 617-373-8589
E-MAIL: g.barabino@neu.edu

Kenneth R. Diller, ScD
Biomedical Engineering, ENS 612
University of Texas, Austin
Austin, TX 78712-1084
TEL: 512-471-7167
FAX: 512-471-0616
E-MAIL: kdiller@mail.utexas.edu

Drena L. Dobbs, PhD
Bioinformatics and Computational Biology Graduate Program
Iowa State University
2014 Molecular Biology Building
Ames, IA 50011
TEL: 515-294-1112
FAX: 515-294-6790
E-MAIL: ddobbs@iastate.edu
http://www.bcb.iastate.edu

Lynda B.M. Ellis, PhD
Department of Laboratory Medicine and Pathology
University of Minnesota
420 SE Delaware Street
Mayo Mail Code 609
Minneapolis, MN 55455
TEL: 612- 625-9122
FAX: 612- 625-1121
E-MAIL: lynda@tc.umn.edu

Janie Fouke, PhD
College of Engineering
3410 Engineering Building
Michigan State University
East Lansing, MI 48824-1226
TEL: 517-355-5113
FAX: 517-355-2288
E-MAIL: fouke@egr.msu.edu

Linda G. Griffith[1], PhD
Department of Chemical Engineering
Massachusetts Institute of Technology
77 Massachusetts Avenue
Building 66-466
Cambridge, MA 02139
TEL: 617-253-0013
FAX: 617-258-5042
E-MAIL: GRIFF@mit.edu

Isaac Kohane, PhD
Harvard-MIT Division of Health Science and Technology
Massachusetts Institute of Technology
77 Massachusetts Avenue /E25-510
Cambridge, MA 02139
TEL: 617-355-7821
FAX: 617-734-6371
E-MAIL: isaac_kohane@harvard.edu

Michelle C. LaPlaca, PhD
Coulter Department of Biomedical Engineering
Georgia Institute of Technology
315 Ferst Drive
Atlanta, GA 30332-0535
TEL: 404-385-0629
FAX: 404-894-2295
E-MAIL: michelle.laplaca@bme.gatech.edu

Cato T. Laurencin, MD, PhD
Department of Orthopaedic Surgery
School of Medicine
Department of Chemical Engineering
Drexel University
3141 Chestnut Street, Room CAT383
Philadelphia, PA 19104
TEL: 215-895 6210
FAX: 215 895 6219
E-MAIL: Laurencin@drexel.edu

[1] Bolded names represent members of the external advisory committee and group moderators for this workshop.

Carol L. Lucas, PhD
CB# 7575, 152 MacNider Hall
Department of Biomedical Engineering
School of Medicine
University of North Carolina at Chapel Hill
Chapel Hill, NC 27599-7575
TEL: 919-966-1175
FAX: 919-966-2963
E-MAIL: clucas@bme.unc.edu

Linda Lucas, PhD
100 Hoehn Engineering Building
Department of Biomedical Engineering
University of Alabama - Birmingham
1075 - 13th Street South
Birmingham, AL 35294-4440
TEL: 205-975-5890
FAX: 205-975-4919
E-MAIL: llucas@eng.uab.edu

Daniel R. Marshak, PhD
Cambrex Corp. 8830
Biggs Ford Road
Walkersville, MD 21793-0127
TEL: 301-898-7025
(direct ext 2455; asst. ext 2451)
FAX: 301-845-6099
E-MAIL: dan.marshak@biowhittaker.com

Lee G. Pedersen, PhD
Department of Chemistry
UNC-CH CB#3290
Chapel Hill NC 27599
TEL: 919-962-1578
FAX: 919-962-2388
E-MAIL: pedersen@shabam.niehs.nih.gov
or lee_pedersen@unc.edu

Brenda Russell, PhD
Department of Physiology and Biophysics
University of Illinois, Chicago
835 Wolcott Avenue
Room E201 MSB, MC 901
Chicago, IL 60612 -7342
TEL: 312-413-0407
FAX: 312-996-6312
E-MAIL: russell@uic.edu

Murray B. Sachs, PhD
Whitaker Biomedical Engineering Institute
Johns Hopkins University
Ross Building, Suite 720
720 Rutland Avenue
Baltimore, MD 21205
TEL: 410-955-0716
FAX: 410-502-9814
E-MAIL: msachs@bme.jhu.edu

John C. Salerno, PhD
Biology Department
Rensselaer Polytechnic Institute
110 8th Street
Troy, NY 12180
TEL: 518-276-6392
FAX: 518-276-2344
E-MAIL: salerj@rpi.edu

Pat Stayton, PhD
Department of Bioengineering
University of Washington
Box 352125
Seattle, WA 98195
TEL: 206-685-8148
FAX: 206-685-8256
E-MAIL: stayton@u.washington.edu

Shankar Subramaniam, PhD
Department of Bioengineering
University of California, San Diego
9500 Gilman Drive, Room 4109
La Jolla, CA 92093-0412
TEL: 858-822-3228
FAX: 858-534-5722
E-MAIL: SHANKAR@bioeng.ucsd.edu

Thomas C. Skalak, PhD
Department of Biomedical Engineering
University of Virginia
Box 800759
Charlottesville, VA 22908
TEL: 804-924-0270
FAX: 804-982-3870
E-MAIL: tskalak@virginia.edu

Bruce Tidor, PhD
Department of Chemistry
Massachusetts Institute of Technology
77 Massachusetts Avenue, Room 6-135
Cambridge, MA 02139-4309
TEL: 617-253-7258
FAX: 617-252-1816
E-MAIL: tidor@mit.edu

Peter J. Tonellato, PhD
Bioinformatics Research Center
Medical College of Wisconsin
8701 W. Watertown Plank Rd.
Milwaukee, WI 53226
TEL: 414-456-8871
FAX: 414-456-6595
E-MAIL: tone@mcw.edu

Michael W. Vannier, MD
Department of Radiology
University of Iowa College of Medicine
200 Hawkins Drive - 3966 JPP
Iowa City, Iowa 52242
TEL: 319-356-3371
FAX: 319- 356-2220
E-MAIL: michael-vannier@uiowa.edu

Harel Weinstein, DSc
Department of Physiology and Biophysics
Mount Sinai School of Medicine
One Gustave Levy Place
Box 1218
New York, NY 10029-6574
TEL: 212- 241-7018
FAX: 212- 860 3369
E-MAIL: hweinstein@inka.mssm.edu

H. Steven Wiley, PhD
Fundamental Science Division
Pacific Northwest National Laboratory
MSIN: P7-56
P.O. Box 999
Richland, WA 99352
TEL: 509-373-6218
FAX: 509-376-6767
E-MAIL: steven.wiley@pnl.gov

Jack Winters, PhD
Department of Biomedical Engineering
Marquette University
P.O. Box 1881
Milwaukee, WI 53201
TEL: 414-288-3375
FAX: 414-288-7938
E-MAIL: jack.winters@marquette.edu

John Yin, PhD
Associate Professor and Cargill Faculty Fellow
Department of Chemical Engineering
University of Wisconsin-Madison
1415 Engineering Drive
Madison, WI 53706-1691
TEL: (608) 265-3779
FAX: (608) 262-5434 (shared)
E-MAIL: yin@engr.wisc.edu

FOUNDATIONS

John H. Linehan, PhD
Vice President
The Whitaker Foundation
1700 North Moore Street, Suite 2200
Rosslyn, VA 22209
TEL: 703-528-2430
FAX:703-528-2431
E-MAIL: linehan@whitaker.org
http://www.whitaker.org

NSF Staff

Sohi Rastegar, PhD, PE
Bioengineering and Environmental Systems Division
National Science Foundation
4201 Wilson Boulevard
Arlington, VA 22230
TEL: 703-292-7946
FAX: 703-292-9098
E-MAIL: srastega@nsf.gov

C. Denise Caldwell, PhD
Physics Division
National Science Foundation
4201 Wilson Boulevard, Room 1015
Arlington, VA 22230
TEL: 703-292-7371
FAX: 703-292-9078
E-MAIL: dcaldwel@nsf.gov

Mita Desai, PhD
Division of Experimental and Integrative Activities
National Science Foundation
4201 Wilson Boulevard
Arlington, VA 22230
TEL: 703-292-5346
FAX: 703-292-9030
E-MAIL: mdesai@nsf.gov

Wyn Jennings, PhD
Division of Graduate Education
National Science Foundation
4201 Wilson Boulevard
Arlington, VA 22230
TEL: 703-292-5307
FAX: 703-292-9048
E-MAIL: email: pjenning@nsf.gov

Lynn Preston, MA
Engineering Education and Centers Division
National Science Foundation
4201 Wilson Boulevard, Suite 585
Arlington, VA 22230
TEL: 703-292-8381
FAX: 703-292-9051
E-MAIL: lpreston@nsf.gov
http://www.eng.nsf.gov/eec/erc.htm

Sylvia Spengler, PhD
Division of Biological Infrastructure
National Science Foundation
4201 Wilson Boulevard
Arlington, VA 22230
TEL: 703-292-8470
E-MAIL: sspengle@nsf.gov

Gerald Selzer, PhD
Division of Biological Inftrastructure
National Science Foundation
4201 Wilson Boulevard
Arlington, VA 22230
TEL: 703-292-8470
E-MAIL: gselzer@nsf.gov

NIH Staff

Richard Swaja, PhD
Senior Advisor for Bioengineering
Office of Extramural Research
National Institutes of Health
1 Center Drive, Room 152
Bethesda, MD 20892
TEL: 301-402-2725
FAX: 301-496-0232
E-MAIL: swajad@od.nih.gov

Bettie J. Graham, PhD
National Human Genome Research Institute
National Institutes of Health
31 Center Drive, Room B2-B07
National Institutes of Health
Bethesda, MD 20892-2033
TEL: 301-496-7531
FAX: 301-480-2770
E-MAIL: bettie_graham@nih.gov

James C. Cassatt, PhD
National Institute of General Medical Sciences
National Institutes of Health
45 Center Drive, Room 2AS.19C
Bethesda, MD 20892-6200
TEL: 301-594-0828
FAX: 301-480-2004
E-MAIL: cassattj@nigms.nih.gov

Warren Jones, PhD
National Institute of General Medical Sciences
Natcher Building, Room 2AS.43E
National Institutes of Health
Bethesda, MD 20892
TEL: 301-594-5938
FAX: 301-480-2802
E-MAIL: jonesw@nigms.nih.gov

Daniel C. Sullivan, MD
National Cancer Institute
National Institutes of Health
6130 Executive Blvd., Room 6070
Rockville, MD 20892
TEL: 301 496-9531
FAX: 301 480-3507
E-MAIL: sullivda@mail.nih.gov

Mariaileen Sourwine, MS
Office of Extramural Research
National Institutes of Health
Building 1, Room 152
Bethesda, MD 20892
TEL: 301-402-5664
FAX: 301-496-0232
E-MAIL: SourwinM@od.nih.gov