

NHGRI Research Training and Career Development Workshop 10-11 April 2013

TABLE OF CONTENTS

| | | |
|-------------|--|---------|
| I. | BACKGROUND RELEVANT TO THE RECOMMENDATIONS | |
| A. | Historical Perspective | Page 2 |
| B. | Challenges and Expected Outcomes | Page 3 |
| C. | NIH Training and Educational Initiatives and Programs | Page 4 |
| | 1. NIH Director's Initiatives Biomedical Workforce Working Group Report Working Group on Diversity in the Biomedical Research Workforce Working Group on Data and Bioinformatics (Training) | |
| | 2. NIH Institutes and NLM Training and Career Development Initiatives | |
| D. | NHGRI ELSI Training and Career Development Initiatives | Page 7 |
| E. | Examples of Genomic and Genomic Medicine Training Programs | Page 7 |
| II. | RECOMMENDATIONS | |
| A. | Career Development (K) Programs | Page 8 |
| B. | Training | Page 9 |
| C. | Short Courses | Page 11 |
| D. | Overarching Principles for Training and Career Development Initiatives | Page 11 |
| E. | Recurring Themes Applicable to Training and Career Development Programs | Page 11 |
| III. | APPENDICES | |
| A. | Agenda | Page 13 |
| B. | Roster | Page 16 |

REPORT of NHGRI Research Training and Career Development Workshop 10-11 April 2013

1. BACKGROUND RELEVANT TO THE RECOMMENDATIONS

A. Historical Perspective for the Workshop

NHGRI's training and career development programs started in 1990 with the beginning of the Human Genome Project. At that time, our focus was on preparing the next generation of scientists to develop the tools, technologies and methods of analyses to facilitate the mapping and sequencing of the genomes of model organisms and of humans, a measurable product. As such, our focus was on recruiting individuals in the fields of bioinformatics, mathematics, physics, chemistry, computer, quantitative and engineering sciences (i.e. Foundational sciences) to become genome scientists and on providing geneticists and molecular biologists with knowledge and skills to use these data. At that time, training initiatives in the Ethical, Legal and Social Implications (ELSI) of genomic and genetics research were in an early stage of development. In 2005, NHGRI expanded its research programs to include research at the interface of genomics and medicine, thereby defining a new discipline-- genomic medicine¹. Currently there are no training or career development funding opportunity announcements in genomic medicine.

In February 2011, NHGRI published its new strategic plan: Charting a course for genomic medicine from base pairs to bedside (<http://www.genome.gov/Pages/About/Planning/2011NHGRIStrategicPlan.pdf>). The plan was an all-encompassing document for the field of genomics. NHGRI is currently in the process of defining the specific goals for its research and training and career development programs.

Toward that end, NHGRI convened a small working group of Council members in March 2012 to discuss NHGRI's long-range plans for training and career development. Very briefly, the group: (1) identified the types of expertise that are needed in order to take advantage of the very large data sets being generated in genomic science and genomic medicine; (2) discussed the challenges of how to train scientists in genomic medicine; (3) confirmed that there is still a need to train individuals in disciplines foundational to genomics, such as, bioinformatics and statistics; and (4) acknowledged that bioinformatics and biostatistics are high demand areas representing a challenge that is NIH-wide and is not specific to NHGRI. The working group requested additional information about NHGRI's training programs, especially their training goals and how they are aligned or plan to align with the strategic plan. At the May 2012 National Advisory Council for Human Genome Research, staff presented an analysis of NHGRI's institutional training grant program and reported that all were conducting training in areas of need identified by the working group and many were planning to expand their genomics training into clinical areas. The next step in the process was to convene a larger group of experts to review NHGRI's training and career development programs and to provide advice about current aims and on how to expand into clinical areas to encompass genomic medicine. This workshop was held 10-11 April 2013. The agenda (Appendix I) and roster (Appendix II) are attached.

¹ NHGRI's current working definition of genomic medicine is: *An emerging medical discipline that involves using genomic information about an individual as part of their clinical care (e.g., for diagnostic or therapeutic decision-making) and the other implications of that clinical use.*

B. Challenges and Expected Outcomes

Challenges and Expected Outcomes

Eric D. Green, the Director, NHGRI, opened the meeting by stating four challenges for the group based on the state of genomics and the budget. Very briefly, they are:

- The pace of genomic advances. It is not possible to predict how fast research will expand from understanding the structure of genomes to improving the effectiveness of health care. The pace could be slow (“casual walk”), medium (“speed walking”), or fast (“sprint”). The factors that determine the pace are multiple.
- The need to target multiple audiences. The individuals that need training and education include many groups—high school, undergraduate and graduate students, postdoctoral fellows, and new, mid-level and experienced investigators. Needs include training in the genomic foundational sciences as well as the clinical sciences.
- The reduction in appropriated dollars. Until recently, NHGRI has received annual budget increases. For the first time, we have recently experienced a situation in which the budget did not keep up with inflation. Moreover the likelihood of any increases in the near-term are low. Compounding the issue are trans-NIH initiatives from the Office of the Director, NIH (e.g. Big Data to Knowledge (BD2K) Initiative) which requires funding from all institutes and centers. These trans-NIH initiatives compete for funding with initiatives generated by the individual NIH institutes and centers.
- The challenge of identifying NHGRI's niche within the strategic plan. The strategic plan is a comprehensive blueprint for all of genomics and genomic medicine. NHGRI has to identify what in the plan is unique to its mission, both in terms of research and training and career development.

It is anticipated that the recommendations from the workshop will be implemented over several years and it will be important for the workshop participants to suggest priorities and recommend areas where we can partner with the other institutes and centers.

Bettie J. Graham, Director, Division of Extramural Operations, described the expected outcome of this workshop--the publication of funding opportunity announcements that will convey to the community the types of long- and short-term training and career development initiatives that address the needs in the strategic plan and that are unique to NHGRI. These initiatives will provide a path forward in training the next generation of scientists and clinicians at least for the next decade. Prior to publishing any funding opportunity announcements, NHGRI staff will seek advice and approval from NHGRI's National Advisory Council for Human Genome Research. NHGRI will also appoint a Council subcommittee on training and career development which will include Council members and scientists from the outside community to advise the NHGRI in these areas.

To develop these funding opportunities, NHGRI sought specific information from the workshop participants:

- What knowledge and skills will the next generation of basic and clinical scientists need to generate and manipulate increasingly large and complex data sets of many types?
- What are the most effective ways and environments to cross-train scientists?
- What are the most effective ways to enhance training in the quantitative, computational biology and bioinformatics sciences for undergraduate and graduate students, and new and experienced basic and clinical researchers?
- What are the most effective environments for training students and new and experienced researchers interested in integrating genome science with genomic medicine?
- What is the best way to leverage training in the clinical areas, which is the domain of the categorical institutes?

- How can we use the latest information technology and social media to effectively train a larger or more geographical dispersed number of individuals?
- What percentage of NHGRI's extramural budget should be devoted to training and career development initiatives.

This was a short list of the kinds of information for which NHGRI was seeking guidance. These examples were not meant to confine the discussion, but rather to stimulate the discussion.

C. NIH Training and Education Initiatives and Programs

To provide the workshop participants information about the types of education and training activities that are supported by NIH institutes and that may be of interest to NHGRI, staff from the NIH Director's Office, several institutes, and the National Library of Medicine were invited to talk about their training initiatives.

1. NIH Director's Initiatives

- Initiatives from the NIH Director's Office. Sally Rockey, NIH Deputy Director for Extramural Research Director, Office of Extramural Research, NIH, discussed the proposed implementation plan for the Biomedical Research Workforce Working Group (http://acd.od.nih.gov/Biomedical_research_wgreport.pdf). The charge was to: (1) develop a model for a sustainable and diverse U.S. biomedical research workforce that can inform decisions about training of the optimal number of people for the appropriate types of positions that will advance science and promote health and (2) make recommendations for actions that NIH should take to support a future sustainable biomedical infrastructure.

From the data gathered, the working group concluded that: (1) It is becoming increasingly difficult for US-trained PhDs to launch a traditional, independent, academic research career. (2) The long training time and relatively low early-career salaries, when compared to other scientific disciplines and professional careers, may make the biomedical research career less attractive to the best and brightest of our young people. (3) The current training programs do little to prepare people for anything besides an academic research career, despite clear evidence that a declining percentage of graduates are finding such positions.

The working group recommended that: (1) the career paths in biomedical research be modified by diversifying and shortening the time to Ph.D; (2) the career path to an independent career for postdocs be shortened; (3) pay and benefits be increased; and (4) a better career tracking system be developed in order to capture the progress of trainees and understand where individuals start their careers.

- Big Data to Knowledge Training (BD2K) Initiative. Michelle Dunn, a NCI Program Director, and the co-chair of the trans-NIH BD2K training subcommittee, provided an overview of the Advisory Committee to the NIH Director's ACD Working Group on Data and Informatics. This initiative focuses on five areas: (1) promote data sharing through central and federated catalogues; (2) support the development, implementation, evaluation, maintenance, and dissemination of informatics methods and applications; (3) build capacity by training the workforce in the relevant quantitative sciences such as bioinformatics, biomathematics, biostatistics, and clinical informatics; (4) develop an NIH-Wide "On-Campus" IT Strategic Plan; and (5) provide a serious, substantial, and sustained funding commitment to enable recommendations 1-4. The implementation plan calls for: (1) an Associate Director for Data Science (Eric Green is the current acting Associate Director); (2) Scientific Data Council composed of high level NIH leaders, such as institute directors; and (3) BD2K initiative that

will enable the biomedical research community to gain full value of the Big Data generated in biomedical research. The BD2K initiative has four implementation areas: (1) facilitating broad use of biomedical big data; (2) developing and disseminating analysis methods and software for biomedical big data; (3) enhancing training for biomedical big data; and (4) establishing Centers of Excellence for Biomedical Big Data. The BD2K training goals are to increase the number of computationally skilled biomedical trainees; strengthen the quantitative skills of all biomedical researchers' and enhance NIH review and program oversight.

The BD2K training subcommittee published a Request for Information about what programs and curricula are needed for cross training, what knowledge and skills are needed to analyze big data, and how to ensure a diverse workforce. NIH received over 100 responses that fell into several categories: features of training programs; novel and experimental learning systems; and types of curricula and infrastructure. A workshop will be held in late July. Isaac Kohane (Harvard Medical School) and Karen Bandeen-Roche (Johns Hopkins University) will co-chair the workshop. Approximately 60 participants have been identified to participate. The expectation is that the workshop will provide input into shaping the BD2K training agenda. NIH staff will use these inputs to develop RFAs in specific areas. NIH has allotted approximately \$10 million to the training initiative.

2. NIH Institutes and NLM Training and Career Development Initiatives

- National Institute of General Medical Sciences. Program Officers, Scott Somers and Susan R. Haynes described NIGMS' research and training efforts. NIGMS is the major supporter of research training at NIH. It was recently reorganized to consolidate all training in the Division of Training, Workforce Development and Diversity. Their 2011 strategic plan: *Investing in the Future: National Institute of General Medical Sciences Strategic Plan for Biomedical and Behavioral Research Training 2011* (http://publications.nigms.nih.gov/trainingstrategicplan/Strategic_Training_Plan.pdf) will help ensure that the institute's training activities contribute most effectively to building the scientific workforce the nation needs for improving health and global competitiveness. The presentation focused on two training areas: (1) Pre-doctoral training in bioinformatics and computational biology which has the goal of training pre-doctoral students in the theory and biological application of information sciences, and use in the study of relevant biological problems. In FY12, there were 11 predoctoral T32 programs and a total of 55 trainees. There is an equal mix of programs emphasizing bioinformatics and computational biology or combination of both. (2) Their post-doctoral training programs target physician scientists, rather than Ph.Ds. who spend two years conducting research. The areas of emphasis are: anesthesiology; clinical pharmacology; medical genetics; and trauma, burn, and peri-operative injury. During the traineeship, fellows receive rigorous training in basic or applied research, with an emphasis on the chosen clinical area. In FY 2012, there were nine postdoctoral medical genetics T32 programs with a total of 41 trainees. NIGMS' commitment to training and career development in FY2012 was: fellowship-\$19M, 415 trainees, 0.9% of GM budget; institutional training grants-\$172.3M, 3,905 trainees, 7.6% of GM budget; career development awards- \$22.4M, 92 awards, 1% of GM budget ; and research training and education-\$72M, 3.2% of GM budget. Totaling all F, T and K awards, NIGMS spends 12.7% of its extramural dollars on training and career development activities.
- NHLBI-Summer Institute for Biostatistics Program (SIBS). Song Yang, from NHLBI's Office of Biostatistics Research described a summer program to increase interest in biostatistics among advanced undergraduate, recent graduates and beginning graduate students. The program started in 2004. During the first 6 years, the SIBS program had more than 400 students. Among the participants who were followed up, more than 60 percent went to graduate schools in biostatistics-related programs. Some of the program features that make the program a success are face-to-face meetings at NHLBI, regular teleconferences between NHLBI staff and the grantees, regular communication with participants between peers and between participants and

the program directors. Under the latest Request for Applications (<http://grants.nih.gov/grants/guide/rfa-files/RFA-HL-13-015.html>) co-sponsored by NCATS, eight programs are funded and will run from 2013 to 2015.

- National Cancer Institute. Susan Lim, Program Director, Center for Cancer Training, described NCI's training efforts. NCI uses all the trans NIH F, K and T awards, but it also has NCI-specific K awards for career development: (1) K05 or established investigator award; (2) (K07 or cancer prevention, control, behavioral, and population sciences career development award; (3) K22 or NCI transition career development award to promote diversity; (4) institutional training grant, (5) K12 or the Paul Calabresi Award for Clinical Oncology and (6) R25 for short term training and curriculum development. NCI has 18 training programs in medical genomics, bioinformatics and statistics funded by a combination of T32, R25 and K12 grants. NCI funds 213 individual fellowships (\$9M), 331 career development awards (\$48.6M) and 259 K, R25, and T awards (\$96M). NCI's total training and career development budget of \$153M represents 3 percent of NCI's total extramural budget.
- National Library of Medicine. Valerie Florance, Associate Director for Extramural Programs, presented NLM's training and career transition programs. The goal of its programs is to enable graduates to conduct original basic or applied research at the intersection of computer and information sciences with one or more biomedical application domains such as health care, public health, basic biomedical research, or clinical translational research. Informatics is concerned with the optimal organization, management, dissemination and use of information. Graduates conduct research in academic institutions, not-for-profit research institutes, governmental, public health agencies, pharmaceutical and software companies, and health care organizations.

Training. NLM's training authority comes from the Medical Library Assistance Act, not the National Research Service Award (NRSA), but the financial support tracks with the NRSA financial support. Their university-based training grants provide five years of support. Pre-doctoral trainees can be supported for up to five years, through completion of their Ph.D and postdoctoral trainees can be supported up to three years and most obtain an MS degree in another relevant discipline during this time. NLM supports 14 university-based programs in the areas health care informatics, translational bioinformatics, clinical research informatics, public health informatics. The National Institute of Dental and Craniofacial Research supports dental informatics at three of the institutions. A total of 178 trainees are supported: 109 predoctoral and 79 postdoctoral. Candidates for the program must have computer science and quantitative skills to be considered. The curriculum includes core courses in database design and management, knowledge representation, information retrieval, modeling and algorithms, probability and uncertainty and policy and ethics. Trainees in the program have dual mentors and the program focuses on having trainees be "bilingual". All trainees participate in an annual conference that is rotated among the supported universities. The focus of the meeting is on research presentations, poster sessions and networking. The top seven journals for trainee publications are JAMIA, PNAS, Bioinformatics, Journal of Biomedical Informatics, BMC Bioinformatics, International Journal of Biomedical Information and Journal of Molecular Biology. The places of employment of NLM trainees are: 59% in academia; 22% in industry; 14% pursuing additional training; and 5% percent in government or not-for-profits.

Career Development. NLM supports two career transition awards, the K22 and the K99. NLM had its own K22 award. Twenty-one individuals have been supported between 2004 and 2013; ten have NIH or Agency for Healthcare Research and Quality grants. Of the 20 K99 awardees, 12 have successfully transitioned to academia. Career awards are 6% of NLM's extramural budget.

NLM's budget for training and career development represents 26% of their extramural budget. This is the highest percentage allotted for training and career development by any other NIH institutes and centers.

D. NHGRI ELSI Training and Career Development Initiatives

The Ethical, Legal and Social Implications or ELSI program is an integral part of NHGRI's research mission. It has provided training through a variety of mechanisms, most recently through its Centers of Excellence in ELSI Research (CEER) Program. Joy Boyer, a Program Director in the ELSI Program described the current efforts and future plans. The ELSI program was created in 1990 and Congress established a set aside for the ELSI program. The current ELSI extramural annual budget is \$18M. Some of the disciplines relevant to the ELSI program include anthropology, clinical genetics, epidemiology, ethics, genetics, genomics, history, health economics, law, philosophy, psychology, and sociology. Some of the challenges of developing a training program include: (1) the diversity of trainee backgrounds; (2) lack of a traditional academic home for multi-disciplinary trained scholars; and (3) need for trainees to include practical skills, such as ethics consultations, policy development, and teaching, in addition to research. In the area of training, the ELSI Program uses most of the trans-NIH training activities (F31, F32 and F33), but not the institutional training grant (T32) activity. The program also provides support for diversity and re-entry into research. In the area of career development, the ELSI program has supported scholars under the mentored K01 program and the pathway to independence program (K99/R00). The CEER program was created in 2004 and has been a very important venue to train ELSI scholars. To date it has trained 150 individuals (25% undergraduate students, 40% graduate students, 30% postdoctoral fellows, and 5% faculty). One-third to one-fourth of trainees are of racial or ethnic minority backgrounds underrepresented in research. Of the approximately 31 postdoctoral fellow alumni, twenty-two have received academic appointments and twelve are currently funded by NHGRI. The CEER program provided funding for mentors/training faculty and has created a sense of community with annual meetings. The ELSI program in collaboration with its community is currently devising a plan for future training initiatives. The plans include exploring the use of institutional training grant to support ELSI training and to develop more robust approaches to long-term tracking of ELSI trainees.

E. Examples of Genomic and Genomic Medicine Training Programs

To set the stage for the discussion on training, Mike Boehnke, program director of the University of Michigan's NHGRI-supported training grant, and Jeffery Vance, a faculty member at the University of Miami Medical School, who recently instituted a Master's degree in genomic medicine that runs concurrently with medical school training, presented information about their programs.

- University of Michigan Genome Science Training Program. Mike Boehnke described their program which has been active for 18 years. This program trains pre-and post-doctoral students at the interface of mathematics (primarily statistics) and human genomics/genetics. The training faculty is from multiple departments, specifically human genetics, biostatistics, epidemiology, ecology and evolutionary biology, bioinformatics, statistics, environmental health sciences, mathematics and molecular, cellular, and developmental biology. Most trainees come to the program with a major in one discipline with sufficient coursework in a discipline complementary and relevant to genomics. Prior to admitting a student, the faculty will discuss any potential deficits relevant to success in the program. If the student is motivated, s/he will prepare for admission by engaging in directed reading, pursuing remedial coursework, taking advantage of tutoring sessions, or participating in a boot camp. Some essential components of the training program include inviting first year trainees to matriculate the summer prior to the start of the academic year, tutoring for trainees, team mentoring, traveling to scientific meetings, and participating in periodic focus groups for feedback on how to improve the program. The program director has an open door policy to listen to all concerns. Since the students come from many departments, there are many activities to achieve cohesiveness. These include such activities as: orientation for new students; spring retreat that includes career enhancing activities such as grant review; effective oral presentation; scientific writing; journal clubs; seminar series in which students host the speaker for the day; and frequent social gatherings. One measure of success of

the program is where former students end up post-graduation or completion of their postdoctoral training. Of the 46 who have completed their postdoctoral training, 42 or approximately 90% are in research. With access to extra funds for recruiting URM, there has been a stronger emphasis and more success with URM recruitment and retention. Regarding advice of what else should be considered in looking at the future of training support, some suggestions or observations were: support masters level training in high need areas like statistical genetics and bioinformatics; support outstanding foreign students; encourage love of math and science in grades 4-12 (Some participants thought this should be K-12.); continue to focus on strong interdisciplinary training; and measure success by time from receiving the bachelor's degree to being employed in a tenured position, rather than time of degree from bachelors to Ph.D.

- University of Miami Master's Program in Genomic Medicine (<http://medgen.med.miami.edu/education/msgm>). Jeffery M. Vance described a new program that incorporates a MS degree in genomic medicine into the medical school curriculum with the goal of creating physicians knowledgeable about how to incorporate genomics into the clinic. The training includes 30 credit hours which run concurrent with the regular four year medical school curriculum. New didactic course work is given weekly with online modules. This is supplemented with weekly small group discussions with the course professor. The curriculum includes: (1) first year (second semester)—fundamentals of genomic medicine; clinical applications of genomic medicine; genome ethics; and public policy and genomic medicine laboratory. (2) second year—computational methods for genomic medicine; clinical applications of genomic medicine; research ethics; and pharmacogenetics; (3) years three and four—genomic medicine clerkship and genomic medicine practicum. Some of the challenges to implementing this program are: the added cost of obtaining a second degree to the student/parents; not all students can handle both programs; students have to devote more time in order to keep up with the program. Benefits seen by current students are: being pioneers in genomic medicine, adding value to residencies; and realizing that genomic medicine is in all aspects of medicine. Initial students are interested in ophthalmology, neurosurgery, oncology, internal medicine and pediatrics.

II.RECOMMENDATIONS

A. Career Development (K) Programs

Portfolio Analysis of K Awards

Tina Gatlin, Training Program Director, described the history of the NHGRI career development awards. Briefly: From 1990 to 1994, NHGRI made six Research Career Awards for newly independent scientists (K04): and eight mentored research scientist development awards (K01). The K01 awards are used to recruit non-biologists (mathematicians, physicists, chemists, and computer and engineering scientists) into genomics. Between 1995 and 1999, only five K01 awards were made. Between 2000 and 2004, a total of 18 (K01/K25) awards were made; the K25 is very similar in purpose to the K01 award. During that period, NHGRI supported 17 two-phased K22 awards which provided up to two years of postdoctoral support and up to three years of faculty-transition support. From 2005 to 2012, the majority of K awards made were K99 which are similar to the K22 awards. Of the 89 K awards (also equal to the number of K awardees) made from 1990-2012, 43 of the 89 K awardees went on to successfully obtain NIH research grants (R awards). Of the 76 R awards, 20 were supported by NHGRI. Compared to NIH, NHGRI spends about ~0.1 % of its extramural funds on K01/K25 career development awards compared to ~0.5% for NIH. Compared to NIH, NHGRI spends ~0.1% of its extramural funds on K22/K99 career transition awards compared to ~0.2 percent for NIH.

Recommendations

- Continue to support and better publicize K01, K25 and K99 career awards.

- Expand the Mentored Research Scientist Development Award (K01) to include awards in genomic medicine with the focus being to cross-train genomicists and clinicians in genomic medicine.
- Give priority to supporting individual K awards, over institutional K awards, at least in the near term. Institutional Ks are a large investment; individual Ks offer flexibility and will help define whether larger programs are needed, and if so, how to best structure them.
- Direct NHGRI K awards toward solving general problems in genomic medicine, rather than the application of existing solutions to a particular disease.
- The key elements of the career award development program should address include:
 - a statement addressing the general approach the applicant is trying to develop or the general problem to be solved, and how that could be applicable across diseases;
 - dual mentoring;
 - an environment rich in genomic research, the generation of large datasets and the clinical interpretation of these data;
 - access to raw data;
 - access to critical resources, such as health information datasets, clinical datasets, patients, etc.;
 - a defined curriculum and a plan to take the appropriate courses and laboratory rotations, or to undertake the clinical experiences needed to complement their existing expertise;
 - an outreach plan to URM communities and practicing physicians.
- Establish an annual meeting for K awardees to discuss progress, share experiences and network. If possible include K awardees from other ICs doing genomic medicine.
- Continue to support non-biologists in genomics should they apply, but do not aggressively recruit them as in previous years.
- Support individuals interested in technology development because this type of knowledge and skill set will continue to be critical in genomics and genomic medicine.

B. Training

Portfolio analysis of T32 Programs

Heather Junkins and Bettie J. Graham presented information about NHGRI's institutional training grants and individual fellowships.

Institutional Training Grants (T32): NHGRI currently supports 161 trainees (129 pre-doctoral and 32 postdoctoral) on eleven institutional training grants. Seven of the training grants support a mix of pre- and post-doctoral trainees. No medical students are supported on any of NHGRI's training grants. The number of positions per grant ranges from four to 30. Most of the trainees are already working in areas identified in the strategic plan and many are planning or are already involved with faculty in clinical departments. Trainees who have completed the program identified the following as strengths: multi-disciplinary nature of the program and the opportunity to cross train in another discipline; financial support; opportunity to present research findings which sharpens trainees' written, verbal, organizational and analytical skills; curriculum, quality of the faculty; learning how to communicate across the computational/biology divide; and learned how to manage large data sets. Past trainees provided some suggestions for improving the program: increase opportunities for students to interact more with peers and faculty within and external to their department and institution; add ELSI topics that encompass genomic medicine; more feedback from faculty on research progress; instructions on how to manage and leverage big data sets; require all students to take a bioinformatics/biostatistics course; provide opportunities to interact with industry; provide opportunities to write grant applications; and align program course requirements with department course requirements so that students do not take essentially duplicate course.

A portfolio analysis of the institutional training grants from 2008-2012 showed the following: The number of training grants funded has remained constant. For a short period, NHGRI supported three T90/R90 awards in collaboration with NHLBI on hemoglobinopathies. The purpose was to apply genomics to

research in hemoglobinopathies. This five-year program was discontinued in 2010. During the period of support, 2.7% of NHGRI institutional training grants were in T90 support as compared to 0.7% for NIH's total funds allotted to institutional training grants.

Individual Fellowships: During 2008-2012, NHGRI supported diversity fellowships (F31), postdoctoral fellowships (F32) and senior fellowships (F33). A comparison of funding based on dollars awarded between NHGRI and NIH revealed: F31: NHGRI spends 30.4% versus 37.3% for NIH; F32: NHGRI spends 68.7% versus 62.5% for NIH; F33: NHGRI spends 1.0% versus 0.3% for NIH.

NHGRI's investment in institutional training grants and individual fellowships represents 1.7% of its extramural budget versus 2.9% for overall NIH.

Recommendations

- There is a clear need for expansion of training to encompass genomic medicine. The field of genomic medicine is in its infancy, and existing knowledge is insufficient to provide a solid foundation for the field. Consequently training programs should teach trainees the current state of science while providing them with the technical foundation to extend it to enable the full promise of genomic medicine.
- There is clear need for continued and expanded support in foundational sciences, such as bioinformatics, biostatistics, computational biology, technology development, etc.
- Continue to support individual fellowships (Fs) and institutional training programs (T32s);
- Publicize the individual fellowship program to faculty.
- Course requirements for institutional training grants should be flexible, given that many students entering graduate school now, as opposed to five years ago, have sufficient backgrounds in biology and the quantitative, bioinformatics and computational sciences.
- Training in the data sciences, including quantitative approaches such as machine learning, is essential to strengthen the foundation of genomic medicine trainees.
- Increase investments in the foundational sciences that are critical to genomics and genomic medicine research because there are new needs that were not evident five years ago and continuing advancement is essential;
- Genomic medicine is not yet sufficiently established to provide a rigorous graduate training program. Therefore, training in genomic medicine should be limited to postdoctoral training, where individuals with a strong background in genomics or in clinical medicine can cross-train to become experts in genomic medicine.
- Graduate programs should continue to provide rigorous training in genomics, allowing options for clinical exposure. They will be a major source of trainees in genomic medicine at the post-doctoral and faculty levels.
- As with K awardees, an annual meeting of trainees to discuss progress, share experiences and network would be beneficial. This might overlap with ELSI annual meetings.
- Institutional (post-doctoral) training grants in genomic medicine should:
 - Include those with Ph.Ds. and MDs.
 - Offer two to three years of training, depending on prior training.
 - Have a critical mass of a minimum of four trainees for a viable training program.
 - Provide didactic training as an essential component of the training.
 - Allow entry in the program by clinicians during their fellowship.
 - Make training in the ethical, legal and social implications of genomic research an integral part of the required courses.
 - Provide two paths for clinicians gaining genomic medicine skills: (1) becoming a master clinical genomicist or (2) becoming a genomic medicine researcher. An application may include one or both paths. For each path, applicants must clearly describe the goals of the program and a training plan that is consistent with the goals.
 - Allow clinicians to maintain their skills, by permitting up to 25% effort for clinical experiences, keeping 75% effort or more for research. The 25% clinical time should

ideally be used, in part, to apply genomics in the clinic, while allowing a mixture of responsibilities that allow maintenance of clinical credentials.

- An example of a current institutional postdoctoral training opportunity in the clinical sciences is: NICHD' Postdoctoral Research Training in Pediatric Clinical and Developmental Pharmacology (T32) <http://grants.nih.gov/grants/guide/rfa-files/RFA-HD-10-005.html>.
- Partnering with existing MD-focused NIGMS T32 training programs to add PhD slots may be an efficient way to invest in genomic medicine.

C. Short Courses

- Continue to support short courses to disseminate new genomic tools, methods of analyses, technologies, etc. that are relevant to genomics and genomic medicine to the larger scientific community.
- Pursue new methods of disseminating information to encompass massive open on-line courses. The effectiveness of these new methods should be rigorously evaluated.
- Couple courses in genomic medicine with continuing medical education courses or annual meetings that are conducted in collaboration with professional societies.

D. Overarching Principles That Apply to All NHGRI Supported Training and Career Development Programs

- The main goals of NHGRI-supported training and career development programs should be to: (1) expand the base of knowledge in genomic medicine; (2) continue to support the foundational sciences, with emphasis on acquiring strong quantitative skills; and (3) develop the leaders in genomic medicine and genome sciences.
- NHGRI needs to ensure sufficient investment, relative to its extramural budget, to train future leaders in the foundational sciences and genomic medicine. Its training role is more akin to NIGMS than the disease-specific institutes.
- The training of population scientists, such as, behavioral scientists, health services researchers, epidemiologists, etc. in genomics and genomic medicine is important because these scientists play an important role in developing strategies for translating genomic information into clinical care and public health practice.
- For graduates of career development and training programs to be effective and creative, they must be trained "broad and deep" in the complementary and relevant scientific disciplines.
- Many institutions have the research, clinical and training infrastructure to host training and career development programs in genomic medicine.
- There is still a great need to continue and increase support for the foundational sciences that are critical to genomics and genomic medicine
- A professional network should be developed for trainee and career development awardees by supporting annual meeting that rotate among funded institutions.
- The Diversity Action Plan provides training and research with enhancements that benefit URMs as well as other program participants and should continue to be supported.

E. Recurring Themes that Apply to All NHGRI Supported Training and Career Development Awards

- Increase Diversity
 - Find creative ways to increase the pipeline.
 - Recruit URM physicians into research programs. The number of URM MDs is greater than the number of Ph.Ds. This is an opportunity to develop a genomic medicine training program for URMs.

- Find creative ways of identifying a diverse pool of candidates for training and career development, providing mentoring and professional opportunities to facilitate their success, and retaining them in the pool of funded investigators.
- Work with other agencies, such as the Indian Health Services, to recruit candidates for training and career development programs.
- Publicize the loan repayment program more aggressively to the URM community.
- Consider developing programs that pair HBCUs with research intensive institutions; NCI has several career award programs targeted to URM and liaisons with Historically Black Colleges and Universities. (<http://grants.nih.gov/grants/guide/pa-files/PAR-09-201.html#SectionIV3A>; (<http://grants.nih.gov/grants/guide/rfa-files/RFA-CA-10-503.html>)).
- Use a Variety of Metrics to Measure Success

In addition to the traditional measures of success, such as being a principal investigator on a peer-reviewed grant, publishing in peer-reviewed journals, obtaining a tenure-track position, other measures of success should be considered, such as:

 - Impact factor of publications.
 - PI on a sub-contract or sub-project.
 - Recognition of patents and development of software.
 - Research productivity as measured by peer-reviewed papers.
 - Whether the research influenced the practice of medicine.
 - Whether the individual is conducting research at the interface of genomics and genomic medicine.
 - Number of years from the bachelor's degree to an independent research position.
 - Ability to generate additional funding.
 - Ability to monitor the careers of trainees, mechanisms for long-term follow-up (e.g. brief annual surveys).
 - Be flexible in measuring program success to include individuals who work in for –profit organizations, working in teaching intensive institutions, and the government.
 - The definition of academic success should be expanded from the narrow definition of an independent principal investigator to also include those who roles are fundamentally collaborative and integral to the success of the research program, such as ELSI, bioinformatics, biostatistics, etc. Given the importance of these disciplines to genomics/genomic medicine, those trained in these disciplines should have career pathways and metrics for advancement.
- Educate Practicing Physicians
 - Engage and participate with professional societies in developing competencies for literacy in genomic medicine.
 - Work with professional societies to disseminate information about how to implement genomic medicine in the clinic. These professional societies would include both organizations focused on genetics and genomics such as the National Coalition for Health Professional Education in Genetics, National Society of Genetic Counselors and American College of Medical Genetics and others with successful models for embedding genetics and genomics such as the American Society of Clinical Oncology
- Collaborate with other NIH Institutes and Centers to Leverage NHGRI Support

Revised 3 June 2013.

III. APPENDIX A

AGENDA

NHGRI's 2013 WORKSHOP ON RESEARCH TRAINING AND CAREER DEVELOPMENT

10-11 April 2013

5625 Fishers Lane (5th Floor)

Rockville, MD

Workshop Co-Chairs: Gail Jarvik and Robert Waterston

Purpose: To discuss how NHGRI's training and career development programs should be aligned to meet the goals of the strategic plan and to ensure that these programs provide the future biomedical research workforce with the unique skills and expertise needed to pursue basic and clinical genomic research.

Grand Challenges: (1) to design the critical elements of training and career development programs that align with the strategic plan and are unique to NHGRI; (2) to determine the optimum number and kinds of K and T awards; and (3) to determine the percentage of NHGRI's extramural budget or number of awards that NHGRI should support.

WEDNESDAY, 10 April

| | | |
|--------|---|---|
| 10:00 | Welcome, Introductions , and Setting the Stage | Eric Green |
| 10:30: | Purpose of Workshop and Expected Outcomes | Bettie Graham |
| 11:00 | NIH Initiatives Related To Training | |
| | Working Group on Data and Informatics (Training) | Michelle Dunn |
| | Biomedical Workforce Working Group Report | Sally Rockey |
| | Working Group on Diversity in the Biomedical Research Workforce | Sally Rockey |
| 12:00 | Lunch | |
| 1:00 | Panel Discussion: Training and Career Development Programs in Other IC Components | |
| | NIGMS | Scott Somers and Susan R. Haynes |
| | NHLBI | Song Yang |
| | NCI | Susan Lim and Michelle Dunn |
| | NLM | Valerie Florance |
| 2:00 | Review of NHGRI's Career Graham | Tina Gatlin, Heather Junkins and Bettie |

Development Programs

3:00 Break

3:30 Discussion of the Characteristics of NHGRI's Future Career Development Programs

(Questions to seed the discussion)

- Should NHGRI continue to recruit scientists with backgrounds in informatics, mathematics, physics, chemistry, and computer and engineering sciences into genomics?
- Should NHGRI initiate career awards in other areas and if so, which?
- Should NHGRI support clinical career awards, if so, what should be the elements of the didactic part of the training?
- How should a clinical K program be designed so that it is unique to NHGRI?
- Should individual as well as institutional K awards be supported; if institutional, what should be the maximum number of appointees per award?
- What is the appropriate environment for career development training?

6:00 Adjourn until Thursday, 11 April, 8:30 am

THURSDAY, 11 April

8:30 ELSI Research Training

Joy Boyer

9:00 Examples of Training Programs in Biostatistics and Genomic Medicine

Mike Boehnke and Jeffery Vance

10:00 Break

10:30 Review of NHGRI's Training Programs (Tina Gatlin, Heather Junkins and Bettie Graham)

11:30 Discussion of Characteristics of NHGRI's Future T32 Training Programs

Participants

(Questions to seed the discussion)

- Are current institutional training programs aligned with the new strategic plan?
- Are there new areas where new or additional training is needed?
- If new training areas are identified, describe the training goals, determine the critical elements of such a training program, identify the target group(s), and determine the career level?
- Are there foundational sciences, such as bioinformatics and the quantitative sciences, etc., in which additional training should be supported?
- How should training programs be designed so that they are not one-dimensional, but broad?
- What is the appropriate environment for institutional training grants?

12: 30 Lunch

1: Discussion of Characteristics of NHGRI's Future T32 Training Programs continued

3:00 Recommendations for the Path Forward

3:30 Discussion

4:00 Adjourn

III.B

ROSTER

**NHGRI Research Training and Career Development Workshop
Fifth Floor Conference Room
5625 Fishers Lane
Rockville, MD
April 10-11, 2013**

Bruce Birren
Broad Institute
7 Cambridge Center
Cambridge, MA 02142
(617)258-0913
bwb@broad.mit.edu

Joann Bodurtha
Johns Hopkins School of Medicine
600 N. Wolfe Street
Baltimore, MD 21287
(410)955-1699
jbodurt1@jhmi.edu

Mike Boehnke
University of Michigan School of Public Health
1415 Washington Heights
(734)936-1001
Ann Arbor, Michigan 48109
boehnke@umich.edu

Joy Boyer
National Human Genome Research Institute
National Institutes of Health
5635 Fishers Lane
Bethesda, MD 20892
(301)435-5698
Joy_boyer@nih.gov

C. Titus Brown
Michigan State University
428 Shaw Lane
East Lansing, MI 48824
(517)355-1646
ctb@msu.edu

Brian Burke
Technical Assistant
National Human Genome Research Institute
National Institutes of Health
5635 Fishers Lane
Bethesda, MD 20892
(301)435-5698
brian.burke@nih.gov

Michelle Dunn
National Cancer Institute
National Institutes of Health
6116 Executive Blvd
Bethesda, MD 20892
(301)594-6557
Dunnm3@mail.nih.gov

Valerie Florance
National Library of Medicine
National Institutes of Health,
6705 Rockledge Drive
Bethesda, MD 20892
(301)496-4621
valerie.florance@nih.gov

Jose' Florez
Broad Institute
185 Cambridge Street
Boston, MA 02114
(617)643-8630
jcflorez@partners.org

Tina Gatlin
National Human Genome Research Institute
National Institutes of Health
5635 Fishers Lane
Rockville, MD 20892
(301)496-7531

christine.gatlin@nih.gov

David Gifford

Massachusetts Institute of Technology
32 Vassar Street
Cambridge, MA 02139
(617)253-6039
Gifford@mit.edu

Eric D. Green

National Human Genome Research Institute
National Institutes of Health
31 Center Drive
Bethesda, MD 20892
(301)496-0844
egreen@nhgri.nih.gov

Susan Haynes

National Institute of General Medical Sciences
National Institutes of Health
45 Center Drive
Bethesda, MD 20892
(301)594-0943
Susan.haynes@nih.gov

Gail Jarvik

University of Washington Medical Center
Box 357720
Seattle, WA 98195
(206)221-3974
gjarvik@medicine.washington.edu

Destiny Lancaster

Technical Assistant
National Human Genome Research Institute
National Institutes of Health
5635 Fishers Lane
Bethesda, MD 20892
(301)496-7531
destiny.lancaster@nih.gov

Teri Manolio

National Human Genome Research Institute
National Institutes of Health
5635 Fishers Lane
Bethesda, MD 20892
(301)402-2915

Bettie J. Graham

National Human Genome Research Institute
National Institutes of Health
5635 Fishers Lane
Bethesda, MD 20892
(301)496-7531
Bettie_graham@nih.gov

Mark Guyer

National Human Genome Research Institute
National Institutes of Health
5635 Fishers Lane
Bethesda, MD 20892
(301)496-7531
Mark_guyer@nih.gov

Chanita Hughes-Halbert

Medical University of South Carolina
68 President Street
Charleston, SC 29425
(843)876-2421
hughesha@musc.edu

Heather Junkins

National Human Genome Research Institute
National Institutes of Health
5635 Fishers Lane
Bethesda, MD 20892
(301)496-7531
heather.junkins@nih.gov

Susan Lim

National Cancer Institute
National Institutes of Health
9609 Medical Center Drive
Rockville, MD 20892
(240)276-5630
lims@mail.nih.gov

Gabor Marth

Boston College
140 Commonwealth Avenue
Chestnut Hill, MA 02467
(617)552-3571
Marth@bc.edu

manolio@nih.gov

Lisa Parker

University of Pittsburgh
3708 Fifth Avenue
Pittsburgh, PA 15213
(412)647-5780
lisap@pitt.edu

Jane L. Peterson

National Human Genome Research Institute
National Institutes of Health
5635 Fishers Lane
Bethesda, Maryland 20892
(301)496-7531
Jane_Peterson@nih.gov

Toni Pollin

University of Maryland School of Medicine
660 West Redwood Street
Baltimore, MD 21201
(410)706-1630
tpollin@medicine.umaryland.edu

Karen Rothenberg

National Human Genome Research Institute
National Institutes of Health
31 Center Drive
Bethesda, MD 20892
(301)318-2674
karenrh@mail.nih.gov

Sarah Soden

The Children's Mercy Hospitals and Clinics
2401 Gillham Rd
Kansas City, MO 64108
(816)234-3552
ssoden@cmh.edu

Scott Somers

National Institute of General Medical Sciences
National Institutes of Health
45 Center Drive
Bethesda, MD 20892
(301)594-3827
Scott.somers@nih.gov

William Pavan

National Human Genome Research Institute
National Institutes of Health
49 Convent Drive
Bethesda, MD 20892
(301)496-7584
bpavan@mail.nih.gov

Sharon Plon

Baylor College of Medicine
1102 Bates Street
Houston, TX 77030
(832)824-4251
splon@bcm.edu

Sally Rockey

National Institutes of Health
1 Center Drive
Bethesda, MD 20892
(301)496-1096
Sally.rockey@nih.gov

Jeff Schloss

National Human Genome Research Institute
National Institutes of Health
5635 Fishers Lane
Bethesda, MD 20892
(301)496-7531
Jeff_schloss@nih.gov

Heidi Sofia

National Human Genome Research Institute
National Institutes of Health
5635 Fishers Lane
Bethesda, MD 20892
(301)496-7531
Heidi.sofia@nih.gov

Carolyn Taylor

Technical Assistant
National Human Genome Research Institute
National Institutes of Health
5635 Fishers Lane
Rockville, MD 20892
(301)594-6406
taylorca@mail.nih.gov

Jeffrey M. Vance

John P. Hussman Institute for Human Genomics
1501 NW 10 Avenue
Miami, FL 33136
(305)243-2283
jvance@med.miami.edu

Robert Waterston

University of Washington School of Medicine
1705 NE Pacific Street
Seattle, WA 98195
(206)685-7347
watersto@u.washington.edu

Christina L. Wassel

University of Pittsburgh Graduate School of Public
Health
130 DeSoto Street
Pittsburgh, PA 15261
(412)624-1122
cwassel@pitt.edu

Song Yang

National Heart, Lung and Blood Institute
National Institutes of Health
6701 Rockledge Drive
Bethesda, MD 20892
(301)435-0434
Song.Yang@nih.gov