NCI/NIBIB Workshop
for New Investigators
in Medical Physics and Biomedical Engineering

Report and Recommendations

1. Introduction

The National Cancer Institute (NCI) (Radiation Research Program) and National Institute for Biomedical Imaging and Bioengineering (NIBIB) of the National Institutes of Health (NIH) co-sponsored a workshop in Bethesda, Maryland on September 16-17, 2004. The workshop agenda was focused specifically on the next generation of investigators, and was framed within the context of future implementation of the NIH Roadmap [http://nihroadmap.nih.gov/] Several questions served as points of departure for discussion: What are today's scientific opportunities and challenges in medical physics and bioengineering? What are the roadblocks to research progress for new investigators? What is needed to overcome these roadblocks? The workshop program was organized around presentations on research, education and training, and "grantsmanship". A detailed schedule is given in Appendix I and individual presentations can be found at http://www3.cancer.gov/rrp/newinvestigators.html. The formal program included first-day sessions devoted to exploring current and emerging areas of research with focused examples from radiation oncology, diagnostic imaging and bioinformatics along with examples of current undergraduate, graduate and post-doctoral education and training programs. The second day of the workshop included a panel composed of program representatives from NCI, NIBIB, DOE, NIST and NSF presenting summaries of grant mechanisms and sources of research funding. A final presentation was given on the mechanics of grant writing, communication with the granting agencies and interfacing with the grant review process. This report summaries the workshop presentations and breakout discussions, and serves as a means to disseminate recommendations to the medical physics and bioengineering communities and interested organizations.

1.1 Workshop Goals

The goals of the workshop were to: 1) acquaint new investigators in medical physics and bioengineering with state-of-the-art research in cancer diagnosis and therapy, 2) identify emerging areas of research opportunities, 3) identify current sources of research funding, 4) review grant-writing skills and the NIH grant review process, and 5) produce a summary document that would identify current obstacles to new investigators and to make recommendations for overcoming these obstacles and challenges.

1.2 Necessity for New Investigators in Medical Physics and Bioengineering

In keeping with the NIH mission of creating new knowledge in the prevention, detection, diagnosis, and treatment of disease and disability, the goal of the NIH Roadmap is to accelerate both the pace of discovery in these key areas and the translation of therapies from bench to bedside. The NIH Roadmap identifies the most compelling opportunities in three main areas: new pathways to discovery, research teams of the future, and re-engineering the clinical research enterprise. In the course of developing the NIH Roadmap, it became clear that increasingly, scientific advances are being made at the interfaces of traditional disciplines, and that approaches to science are becoming more integrative. Medical Physicists and Biomedical Engineers work at the interface between basic physical and biological science; instrumentation development and clinical diagnosis and therapy. Thus they are uniquely positioned to meet the challenges of the Roadmap. Yet their numbers are compromised by a lack of knowledge about the opportunities, by high clinical workloads and by uneven implementation of interdisciplinary training.

2. Workshop Overview

2.1 Research Opportunities

A unifying theme of the workshop was the multidisciplinary approach to medical physics and bioengineering research and the closer integration of technologies as exemplified by: 3D imaging for radiation oncology treatment planning; molecular diagnostic imaging and numerous bioinformatics applications.

2.1.1 Radiation Oncology Physics

Image guidance for precise conformal radiotherapy is currently one of the most active areas of research in radiation oncology physics today. While the delivery of radiation has traditionally been guided by the use of imaging, greater precision in the extent and localization of disease is needed, due mainly to increased desire to dose escalate and/or spare healthy normal tissues.

However each of these goals is constrained by geometric uncertainties in the process of radiation planning and delivery. A novel imaging system has been developed to generate high-resolution, soft-tissue images of the patient at the time of treatment for the purpose of guiding

therapy and reducing such uncertainties. Called "cone beam CT" [Jaffray (3)*], the system is based on a large-area, flat-panel detector and has been successfully adapted to a medical linear accelerator. This system now provides an image guided RT platform to explore high precision RT. Daily online corrections are required to assure coverage of target volumes and compensating for residual dose errors and changes in patient geometry over the course of therapy can reduce conventional planning target volume (PTV) margins in addition to the dose given to adjacent critical structures. This 'adaptive' planning and delivery framework is a valuable tool for evaluating online and offline strategies.

Dr. Keall (1) presented the rationale for "4D radiotherapy" and stated that this is an over-arching term, that is used to define the "explicit inclusion of temporal changes in anatomy during the imaging, planning and delivery of radiotherapy". He also gave advice on getting research under way by means of outlining his own path to funding.

A more specific approach to 4D radiotherapy is the helical tomotherapy process, which includes in one system, megavoltage CT acquisition, automated segmentation of CT images, dose reconstruction using the CT image set, deformable registration of CT images, and reoptimization. As described by its founder, Dr. Mackie (2), helical tomotherapy was designed from first principles as an integrated image-guided intensity-modulated radiotherapy system and allows new verification processes based on megavoltage CT images to be implemented. Thus it has involved physicists, engineers, programmers and clinicians since the inception of its design and throughout its implementation .

2.1.2 Diagnostic Imaging

Diagnostic imaging research embraces both anatomical and "functional" or "molecular" imaging and spans the spectrum of modalities to include, conventional x-ray, computed tomography (CT), magnetic resonance imaging (MRI), ultrasound (US), nuclear medicine (NM) and positron emission tomography (PET). Molecular imaging is now generating much enthusiasm for its potential to help better understand the cellular basis of cancer and to lead to cancer specific imaging. Molecular imaging may be defined as the "visualization of cellular processes in space and time at a molecular or genetic level of function" (4) [Blasberg]. Molecular and cell-based imaging has the

* The number within the () is the numerical order of the presentation on the workshop agenda.

potential to significantly impact both cancer treatment and diagnosis and medical physicists, along with biomedical engineers, have a great opportunity to contribute to the development of new biological reagents and probes, as well as to the development of new imaging technologies.

Research in diagnostic imaging has traditionally relied upon the identification of morphologic and physiologic changes to characterize the natural evolution of a disease process, e.g. tumor volume or changes in blood flow. Even though medical physics and bioengineering researchers have made numerous contributions to clinical imaging, it still largely remains a descriptive discipline. The opportunity for medical physics and bioengineering research is to now add quantitative understanding of clinical observations. In addition to tumor-specific MR agents, the introduction of MR functional imaging (fMRI) is now revolutionizing neuro-physiology and image-guided therapies of the brain. Numerous opportunities exist for the mathematical description of tissue signals and their interrelationship with other imaging modalities. In order to arrive at the goal of truly quantitative imaging, significant support of preclinical research involving both the use of physical models and laboratory animals is needed.

Diagnostic imaging research, once directed to higher resolution anatomical imaging is now being driven to develop quantitative molecular and functional methods, tissue specific probes and multimodality correlations. The purpose being to reveal the underlying biological processes of cancer non-invasively and in 3D. The use of imaging is becoming increasingly important to provide quantitative assessments of tumor response in cancer therapy clinical trials.

A major focus of cancer research using CT is for image guided diagnosis and therapy. In the evolution of CT for this purpose, significant effort is now being devoted to the development of CT as a true 3D volumetric imaging modality. Hardware developments include increasingly rapid (sub-second) gantry rotation speeds and large field-of-view, high-resolution, multi-row array or flat-panel detectors. In parallel with the CT hardware development, there are increasing research opportunities in image-processing software development of virtual endoscopy 3D displays, and software systems for radiation therapy treatment planning based on volumetric CT images [Townsend (6)].

Cancer research using MRI and Magnetic Resonance Spectroscopic Imaging (MRSI) is directed toward both enhancing hardware performance as well as quantitative tissue characterization. Hardware developments include high-speed imaging through the use of multiple (8, 16, 32, 64, 128, ...) simultaneous transmit/receive RF channels and the investigation of ultra-high field-strength systems (3-8 tesla). Improved tissue (tumor) characterization is being investigated

using mathematical model-based analysis of dynamic contrast enhanced (DCE) images and through the development of tissue specific contrast agents. Other inherent MR contrast mechanisms such as sodium imaging, phosphorus chemical shift imaging and BOLD (Blood Oxygen Level Dependent) offer new ways of characterizing cancer stage and response to therapy[Gore (5)].

Radionuclide imaging with both SPECT and PET are considered the reference molecular imaging modalities for human research. Research areas include improved image reconstruction algorithms, quantitative mathematical modeling of tumor kinetics for diagnosis and staging and the development of cancer specific radiolabeled compounds [Blasberg (4)]. Another active research area is functional (PET) co-registered with CT for image guidance for radiation therapy treatment planning as an alternative to using anatomical image guidance with CT alone [Townsend (6)].

As with other imaging modalities, ultrasound embraces both new hardware developments and investigations into new contrast agents. Significant research is now being directed to the development of micro-bubble based contrast agents used for both tumor perfusion assessment and for tissue specific imaging. Hardware developments include quantitative power Doppler, harmonic imaging and ultra-high frequency imaging.

In summary, even though significant progress has already been made, the quantitative validation of imaging methods for characterizing cancer and for therapy guidance has yet to be fully accomplished. The status and description of active areas of research can be found in the final report of the NIBIB Image-guided Interventions Workshop held May 13-14, 2004 in Bethesda, Maryland (http://www.nibib1.nih.gov).

2.1.3 Biomedical Engineering [*]

Biomedical engineering research encompasses all aspects therapeutic and diagnostic modalities and includes hardware development as well as software development for both image formation and feature extraction. Important biomedical engineering contributions and developments are now being made in the general area of optical imaging (10) [Sevick-Muraca]. Optical imaging includes both bioluminescence and fluorescence and spans a wide range of frequencies. New so-

[*] The NIH working definition is: "Bioengineering integrates physical, chemical, or mathematical sciences and engineering principles for the study of biology, medicine, behavior, or health. It advances fundamental concepts, creates knowledge for the molecular to the organ systems levels, and develops innovative biologics, materials, processes, implants, devices, and informatics approaches for the prevention, diagnosis, and treatment of disease, for patient rehabilitation, and for improving health."

called “smart” near-infrared-fluoresence (NIRF) molecular imaging probes have been designed that are sensitive to different enzyme targets such as those overexpressed by certain tumors.

Numerous challenges remain in optical imaging technology. These include further development of tomographic systems and the extension of these methods to clinically relevant problems. Even though biomedical engineering research is commonly associated with device development, important areas of research are now evolving in image perception(11)[Myers]. The goal of this research is to develop methodologies that allow quantitative assessments and comparisons of different imaging “systems” rather than treating each component separately. These receiver-operating-characteristic (ROC)-like methods allow the evaluation of new hardware technologies, as well as a quantitative assessment of computer-aided- diagnosis (CAD) systems. Another area of evolving research is the use of EPR/ESR to image tissue oxygen content [Pelizzari (12)]. By coupling oxygen imaging to Intensity Modulated Radiation Therapy (IMRT), areas of hypoxic cells can be given an extra dose relative to normal cells. EPR has the potential of producing quantitative maps of oxygen, temperature, viscosity and pH but is still in its infancy.

The broad new discipline of bioinformatics will be an integral part of advances in imaging and translational research [Vannier (13)]. The conclusions of a symposium conducted for the first time by the trans-NIH's Bioengineering Consortium (BECON) and the Biomedical Information Science and Technology Consortium (BISTIC) (http://www.becon.nih.gov/symposium2004.htm),stated that there is a great need for research and development in support of the development of methods to harmonize clinical data collection across multiple biosensor platforms, such as gene expression, proteomics, and imaging. The goal is to reduce the uncertainty in heterogeneous data collection due to variations in platform and clinical protocol. There are many opportunities for development and optimization of software tools needed to accommodate the changing scale of the spatial and temporal resolution of the data collections, their high dimensionality, and the unprecedented data complexity such as that anticipated to realize the ultimate goal of personalized medicine. Access to the database resources is critically required so different communities may engage in this research area without the need to be concerned about the methods for data collection--a well recognized barrier.

2.2 Training in Medical Physics/Bioengineering

2.2.1 Current Status of Training Programs

Traditionally, the field of medical physics pertains to the diagnostic, and or therapeutic, application of x rays, radioactive sources, particle beams, ultrasonic radiation, radio-frequency radiation and magnetic fields. Medical physicists are concerned with the quality of the images produced, the amount and distribution of dose delivered, and the required hardware and software resources. These areas can have significant overlap with health physics and biomedical engineering. Due to the traditional structure of medical practice, the medical physicist and biomedical engineer typically function as a member of either the diagnostic imaging or radiation therapy clinical services. This can be both a blessing and a curse, since it allows them the opportunity to translate physical research to the clinic yet it can constrain their time for non-clinical work as well as the scope of their scientific vision.

When one considers the fact that medical physicists and biomedical engineers are required to have a basic understanding of human anatomy and physiology, in addition to an in-depth understanding of a broad spectrum of different clinical modalities, it is easy to see how training in medical physics and biomedical engineering presents many challenges. While courses must include basic training in mathematics and physics, there is also a need for hands-on training in the emerging areas of imaging and therapy, as well as in related courses such as in anatomy, cancer biology, radiation biology, physiology, electronics, etc. Also, elective courses in the student's selected research area need to be encouraged. It is expected that students demonstrate competence via a comprehensive examination and obtain sufficient exposure to research topics in order to be matched with a scientific advisor for their dissertation research. It should be noted that the broad aim of such graduate training is two fold: (1) to have the student acquire a high-level of technical knowledge and (2) to learn how to be an independent investigator in terms of adding new knowledge to the field and effectively communicating these findings. Such training goes beyond didactic and practicum rotations, and requires mentoring by a dedicated faculty member and interaction with a broad array of scientists, engineers and clinicians both locally and at national meetings (as a participant and as a presenter of scientific work).

Strong pre-doctoral graduate medical physics training programs include two or more years of coursework often arranged in 14-16 different topical courses [Deluca (9) and Giger (8)]. Training should include all the technical elements as well as training in ethics, human use, animal use, and

protection of patient information. Fundamentally important is to maintain the interdisciplinary nature of the training. Especially important is to provide training at an introductory level in proteomics/genomics, biostatistics, basic cell biology, and human disease states

Nationally, the Commission on Accreditation of Medical Physics Education Programs, CAMPEP, promulgates recommended graduate training curricula and provides a highly recognized accreditation mechanism (http://www.campep.org/). In the US, there are currently twelve CAMPEP accredited programs. These Ph.D. graduates are a major element in the research and technology base for Medical Physics. There is reasonable uniformity in these programs, however rapid advances in translational research have created the need for more training. These programs are currently only able to train about 30-50% of the scientists entering these areas of research [Deluca (9)].

Post-doctoral programs in cancer research further strengthen the fundamentals of multidisciplinary training initiated in pre-doctoral training by often requiring multiple mentors with additional formal coursework in cancer biology and proteomics/genomics all in addition to any training that might be required to accomplish a project in a highly specialized scientific area [Price (7)].

Biomedical Engineering (BME) is a rapidly emerging discipline. The Accreditation Board of Engineering and Technology (ABET) currently lists thirty-three accredited BME programs (www.ABET.org). The Biomedical Engineering Society (BMES) is the primary academic and professional BME society and offers the ***Annual Review of Biomedical Engineering*** which covers the significant developments in the broad field of Biomedical Engineering, including bioelectrical engineering, biomechanical engineering, biochemical engineering, and biomedical imaging.

Important efforts directed toward improved BME educational opportunities are underway. In October 1999, the National Science Foundation funded the Vanderbilt-Northwestern-Texas-Harvard/MIT Engineering (VaNTH) Research Center (www.VaNTH.org). The VaNTH vision is to transform bioengineering education to produce adaptive experts by developing, implementing and assessing educational processes, materials and technologies that are readily accessible and widely disseminated. VaNTH proposes to be a working model for how multidisciplinary, multi-institutional groups can define an approach to developing & testing curricula for rapidly evolving knowledge bases. Over the past decade The Whitaker Foundation (www.Whitaker.org) has take a lead role in the development of BME research and training. Even though the Whitaker Foundation

is scheduled to cease functioning in 2005, the website contains many useful databases of current degree granting academic programs and grant opportunities.

2.2.2 Barriers and Challenges

While high-quality medical physics and bioengineering training programs exist, challenges remain for all such programs. For example, under curriculum development, new courses are required due to the escalating rise in new imaging and therapy techniques. In addition, current courses are expected to benefit from periodic updates both in terms of material content and presentation (such as, in converting lectures from paper to electronic presentations). However, current training grants do not allow for faculty salary support even though graduate teaching is also not compensated at many institutions. In addition, many programs include foreign students whose research may ultimately contribute to the well being of the National research agenda, though these students may not be eligible for grant supported funding.

Another challenge to medical physics training programs, as well as the field of medical physics in general, is the accurate and timely communication of such training, (especially to those in traditional physics programs). Typical college physics majors are not aware of the field of medical physics due to its interdisciplinary nature and lack of inclusion in college physics curricula. These issues are present in all of biomedical research, but there are additional problems which are specifically encountered in medical physics and biomedical engineering. For example, new investigators in these disciplines are less likely to have access to mentors who have been successful in obtaining major NIH support, since there are fewer engineers and medical physicists among NIH investigators, when compared to basic biomedical scientists. Medical physicists and biomedical engineers must be especially vigilant during their training to gain the skills and experience needed to succeed in NIH- sponsored research. In particular, grantmanship is essential, but instruction and information are not easily found by inexperienced aspirants who need it most.

Historically, federally funded research in the medical physics community has been low compared to many other disciplines. An American Association of Physicists in Medicine (AAPM) survey was conducted in 2004 under the direction of Brett Poffenbarger and Paul Keall (http://www.aapm.org/pubs/protected_files/AAPM-Research04.pdf). The survey was designed to measure the extent to which AAPM members are actively involved in research. The survey found

that approximately 12% of AAPM members had been a Principal Investigator on a grant within the past three years and approximately one-third of AAPM members authored an article within the past three years. Medical Physics has a unique and yet unfulfilled opportunity to bridge the gap between bench and bedside in a crucial area of medical research.

2.3 Funding Mechanisms

2.3.1 The NIH Granting Process

Grantsmanship, the "art of obtaining grants", was discussed at the workshop as a skill to be acquired by new research investigators. Obtaining peer-reviewed funding, especially at the national level, can be daunting. The National Institutes of Health receive ~80 thousand grant applications per year, for example, with the top 15-20 percentile earning support. It is likely that the quality of the science of the applications a few percentile below the funding cutoff score is not much different from that in the few percentile above; "grantsmanship" may make a difference. There are a number of websites, courses and workshops that educate new investigators on how to effectively write a grant proposal. The NIH website, http://www.niaid.nih.gov/ncn/grants/default.htm, includes "All About Grants" tutorials. The tutorials contain information about the logistics of filing applications, but also advice on how to develop a strategy for planning an NIH grant, how to choose an application topic, developing a solid hypothesis, and practical tips on how to write a strong application. The NIH website includes specific advice for new investigators, also the Center for Scientific Review has produced a video of a mock study section meeting (http://www.csr.nih.gov/Video/Video.asp) to provide an inside look at how NIH grant applications are reviewed for scientific and technical merit. The video shows how outside experts assess applications and how review meetings are conducted to ensure fairness. The video also includes information on what applicants can do to improve the chances their applications will receive a positive review. A few other useful websites include:
http://www.research.umich.edu/proposals/PWG/pwgcontents.html [Don Thackrey];
http://www.whitaker.org/sanders.html [Wendy Sanders];
http://www.survival.pitt.edu/library/documents/grantspersonshipmanual.pdf [Beth A. Fischer, Michael J. Zigmond];

http://grants.library.wisc.edu/organizations/proposalwebsites.html [a compilation of useful websites by the University of Wisconsin].

These websites provide information from the viewpoint of successful grant writers and reviewers. Workshops with mock review sessions are given periodically in conjunction with societal annual meetings and give insight into the review process for a new investigator [Smaglik P. "The secrets of success", Nature 2004 Nov 11;432 (7014):253].

When submitting an NIH grant, it is worthwhile to know something about those individuals who will be reviewing grants. Information regarding review committee membership is available at http://www.csr.nih.gov/Committees/rosterindex.asp.

2.3.2 NIH Training Support

The NIH offers numerous grant mechanisms to support pre and postdoctoral research training as well as a variety of different career level investigator awards through the National Research Service Award (NRSA) program (15)[Khachaturian]. These mechanisms are summarized in Table 1). Similar programs are also available from the NSF and NIST. Additional training information can be found at the NIBIB website: http://www.nibib1.nih.gov/training/training.html.

Another NIH website [http://grants1.nih.gov/training/kwizard/index.htm], which is called the 'Career Award Wizard' is designed to help identify an Individual NIH Career Award appropriate to the specific background and objectives of the applicant. However, as with all web queries, one is forewarned to contact the most likely funding Institute or Center and confirm the search results before acting upon them.

For new investigators, there are a number of grant mechanisms to get one started before applying for national-level funding. Such grants can provide needed equipment and/or stipends for graduate students and postdoctoral trainees for 1-2 years. These include: NIH sponsored Cancer Center seed grants or new investigator grants (R03 mechanism), state grants, industry sponsored grants and grants from professional societies. In addition, each federal agency that sponsors research, also must set aside a certain fraction of its budget for small business research grants (SBIR and STTR mechanisms) and these can often be used to support early stage research for new investigators especially those involved in the physics and engineering related areas.

TABLE 1) List of NIH Training Award Mechanisms	
Predoctoral:	
•Ruth L. Kirschstein National Research Service Awards - Institutional Training Grants	T32
•Ruth L. Kirschstein National Research Service Awards for Individual Predoctoral Fellows	F31
•NIH Predoctoral Fellowship Awards for Minorities and Students with Disabilities	F31
Postdoctoral:	
•Ruth L. Kirschstein National Research Service Awards - Institutional Training Grants (T32)	T32
•Ruth L. Kirschstein National Research Service Awards for Individual Postdoctoral Fellows (F32)	F32
Career Level:	
•Mentored Research Scientist Development Award (K01)	K01
•Independent Scientist Award (K02)	K02
•Mentored Clinical Scientist Development Award (K08)	K08
•Mentored Patient-Oriented Research Career Development Award (K23)	K32
•Midcareer Investigator Award in Patient-oriented Research (K24)	K24
•Mentored Quantitative Research Career Development Award (K25)	K25

3. Summary and Recommendations

There is a critical and immediate need to engage new investigators in medical physics and biomedical engineering in original research that advances biomedical science and ultimately brings the results of fundamental work into clinical practice. A major obstacle to this success is the

transition from a graduate or post- graduate trainee status to an independent investigator. Biomedical science is a highly competitive field, and new investigators must compete (with a modest adjustment for their "junior" status) for the same funds that experienced established investigators must seek.

To facilitate the transition from unfunded aspiring investigator to an NIH- sponsored researcher and principal investigator of a peer-reviewed research project, NCI and NIBIB have established many mechanisms for sponsorship. The mechanisms available for graduate and post-graduate education, career transition, retraining in a new discipline, and new investigators are highly specific with strictly applied criteria. Given such a multitude of programs and mechanisms, an inexperienced aspirant will find it very difficult to select the most appropriate mechanism and apply successfully. So, a major impediment for new investigators is the complexity of the application process and need to select the most appropriate mechanism to match the circumstances and needs of a particular individual. There are variations in the amount and term of support, pool of competing applications, available resources, and time needed to apply and ultimately receive support. A new investigator is strongly encouraged to seek the advice of NIH program staff who have expertise in the process and mechanisms. Grantsmanship favors individuals who are in institutions where there are many established experts who are willing to offer their advice and mentorship. The programs offered for education, training and new investigators by NCI and NIBIB have gaps that leave some vulnerable new investigators or trainees in circumstances where they may be ineligible, at least temporarily, or support may be delayed so their career development is impacted negatively despite the merit of their work and the future potential they represent. A common concern of many new investigators is the general lack of availability of career mentoring or a structured career development course in their training program.

On the other hand, most mentors feel that more support for education and training program development is essential and that creative and highly innovative training in multidisciplinary areas will require support from outside the academic institution. Educational institutions are not agile in this process largely due to entrenchment of existing programs and the challenges of funding the up-front costs of program development. Lack of such funding is a barrier to improved and increased training.

Mentors also feel that there should be a consolidation of multiple support mechanisms (T, F and K awards, in NIH terminolgy) into fewer categories with broader discretion at the review and program levels to match the "best" trainees and new or aspiring investigators with more flexible

sources of support. The process of matching individuals to means of support should not be left at the applicant's level, where they may not be sufficiently knowledgeable or experienced to determine the optimal means of seeking support.

Workshop participants felt that the common good is best served by a concerted effort to identify the most promising and productive young investigators and removing impediments to their ultimate success. The application mechanisms and process are incidental to this goal, so broad recognition at review and program levels of new investigators who have especially strong potential should be emphasized.

Using analysis augmented by surveys of successful and unsuccessful applicants, a study should be done to identify potential gaps in support so they can be identified and bridged in the future.

A continuing issue in translational science is the need to accept, encourage, and develop funded programs that are not mechanistic and hypothesis driven, since it can be argued that rapid advances in biomedical science are built upon the enormous advances founded in technology and process.

These issues and concerns resulted in the following recommendations:

Non-Federal Program Recommendations

- Within existing and new training programs, there is a need to create structured modules for mentoring in career development.
- Journal review articles, which help post-doctoral fellows to both identify potential areas of research as well as to help keep current in their area of research, are to be strongly encouraged.
- Specific programs should be created for teaching fundamentals of biology to physical scientists (eg. encourage professional Societies such as AAPM, SPIE and ISMRM to provide continuing education programs to teach relevant biology to physical scientists). And these programs need to be taken to the venues where they can be most available to the physical scientists.

Federal Program Recommendations

- Create more K-like awards for basic science trainees (vs. clinical science) should be created.
- Expand mechanisms for academic/industrial partnership initiatives in research (eg. a competitive K25 type fellowship award for industry experience as one example)

- Create funding mechanism(s) for summer undergraduate research training and mentoring.
- Increase funding for foreign trainees: e.g., T90-type programs
- Create new funding mechanisms for underrepresented minority institutions which:
  a) allow a consortium of small minority institutions to apply for and establish T32-type training programs;
  b) centralize NIH activities on minority issues;
  c) allow pre-approved slots for minority candidates within existing T32 programs.
- Expand funding for interdisciplinary training linking physical sciences with life sciences.
- Create an NIH website to allow pre and postdoctoral trainees to query funded research laboratories and training programs

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4. Appendix

Current BECON Bioengineering Training Opportunities:

- Mentored Quantitative Research Career Development Award - PA-02-127 - Released July 10, 2002
  *** The K-25 Program Announcement has been extended until a new solicitation is released. Please see notice NOT-OD-05-047 in the "NIH Guide" (released May 3, 2005) for details. ***
- NSF/NIH Scholar-in-Residence Program (NSF 98-48)
- Biomedical Engineering Summer Internship Program

Current NIH Bioengineering Training Opportunities:

- Training Opportunities in Bioengineering and Bioinformatics at the National Institutes of Health (NIH) & the National Science Foundation (NSF) - by Career Level
- NIH Research Training Opportunities

Appendix I

Workshop for New Investigators in Medical Physics

Co-sponsored by the National Cancer Institute (NCI) (Radiation Research Program) and The National Institute for Biomedical Imaging and Bioengineering (NIBIB)

September 16th and 17th, 2004

Doubletree Hotel, Rockville, MD

Co-chairs: Mary K. Martel, Ph.D., Ron Price, Ph.D.

NCI: James Deye, Ph.D.

NIBIB: Elijah Weisberg, MSE, Henry Khachaturian, Ph.D.

Thursday, September 16th, 2004

7 AM	Continental Breakfast
7:45 AM	Introduction: James Deye, Ph.D.

Radiation Oncology Scientific Session

Introductions: Mary K. Martel, Ph.D.

8:00 AM	(1) Paul Keall, Ph.D.
	"*4D Radiotherapy"*
8:30 AM	(2) T. Rock Mackie, Ph.D.
	"Tomotherapy"
9:00 AM	(3) David Jaffray, Ph.D.
	"*Image-guided therapy"*
9:30 AM	Break

Diagnostic Imaging Scientific Session

Introductions: Ron Price, Ph.D.

10:00 AM	(4) Ronald Blasberg, M.D.
	"Molecular Imaging"
10:30 AM	(5) MRI: John Gore, Ph.D.
11:00 AM	(6) PET/CT: David Townsend, Ph.D.
	"Developing PET/CT: from concept to practice"
11:30 AM	Discussion
Noon	Lunch

Mentoring/Training Session

Introductions: Ron Price, Ph.D.

1:00 PM	(7) Ron Price, Ph.D.
	"*Post-Doctoral Training in Cancer Imaging Research: Opportunities and Challenges"*
1:30 PM	(8) Maryellen Giger, Ph.D.

"Pre- & Post- Training in Medical Physics at the University of Chicago: Opportunities and Challenges"

2:00 PM (9) Paul DeLuca, Ph.D.

"Education and Training for Medical Physics –An Emergent Career Opportunity?"

2:30 PM Break

Bioengineering Scientific Session

Introductions: Mary K. Martel, Ph.D.

3:00 PM (10) Eva Sevick-Muraca

"In Vivo Molecular Imaging with fluorescent agents"

3:30 PM (11) Kyle Myers

""Image Perception and its Impact on Image Quality"

4:00 PM (12) EPR/ESR Imaging: Chad Haney, Ph.D. and Charles Pelizzari, PhD

4:30 PM (13) Bioinformatics: Michael Vannier, MD

5:00 PM Discussion

Friday, September 17th, 2004

8:00 AM (14) Panel: Sources of Funding

a) NIBIB, b) NCI, c) NASA, d) NIST, e) NSF

9:00 AM Discussion

9:30 AM Break

10:00 AM (16) Mary K. Martel, Ph.D.

"Interfacing with grant reviewers: lessons in grantsmanship"

11:00 AM (15) Career awards: Henry Khachaturian, Ph.D.

11:30 AM Lunch

1:00 PM Report writing

4:00 PM ADJOURN