PLANNING FOR THE FUTURE WORKFORCE IN HEMATOLOGY* RESEARCH

Short title: THE FUTURE WORKFORCE IN HEMATOLOGY RESEARCH

W. Keith Hoots1, Janis L. Abkowitz2, Barry S. Coller3, Donna M. DiMichele1

1 Division of Blood Diseases and Resources, National Heart Lung and Blood Institute, National Institutes of Health; 2 Division of Hematology, University of Washington; 3 Allen and Francis Adler Laboratory of Blood and Vascular Biology, Rockefeller University Hospital

Corresponding Author: W. Keith Hoots, M.D., Director, Division of Blood Diseases and Resources, National Heart, Lung, and Blood Institute, National Institutes of Health, 6701 Rockledge Drive, Room.9136, Bethesda, MD 20892-7950, Office (301) 435-0080, Fax 301-480-3820, hootswk@nhlbi.nih.gov
ABSTRACT

The medical research and training enterprise in the United States is complex in both its scope and implementation. Accordingly, adaptations to the associated workforce needs present particular challenges. This is particularly true for maintaining or expanding national needs for physician scientists where training resource requirements and competitive transitional milestones are substantial. For the individual, these phenomena can produce financial burden, prolong the career trajectory and significantly influence career pathways. Hence, when national data suggest that future medical research needs in a scientific area may be met in less than optimal manner, strategies to expand research and training capacity must follow. This paper defines such an exigency for research and training in non-neoplastic hematology and presents potential strategies for addressing these critical workforce needs. The considerations presented herein reflect a summary of the discussions presented at two workshops co-sponsored by NHLBI and the American Society of Hematology.
INTRODUCTION

The research conducted by investigators in the field of non-malignant hematology has been very impactful for more than three decades and continues to be ever more impactful. Despite this, the number of investigators submitting and being awarded NIH grants has declined dramatically over the past decade. To address this paradoxical situation, the Division of Blood Diseases and Resources (DBDR) of the National Heart, Lung and Blood Institute (NHLBI) in collaboration with the American Society of Hematology (ASH) convened a series of two overlapping working groups (June 8th, 2012 at the NIH Neuroscience Building in Rockville, Maryland1 and June 18th, 2013 at the Lister Hill Auditorium, NIH) to discuss the exigency of a perceived declining physician clinical and research workforce in hematology*. A group of invited guests, including academic representatives from the hematology and pediatric hematology/oncology community, joined hematologists and other scientists from: 1) government, representing NIH (extramural and intramural programs in NHLBI and NIDDK), National Science Foundation, Health Services Resources Administration, Centers for Disease Control and Prevention and U.S. Department of Defense; and 2) ASH to constitute the panels for these two one-day meetings. This Forum focuses on the research and training aspects of these discussions, with a special focus on how to support the research activities of physician scientists and their optimal training. Companion documents will address the clinical non-neoplastic hematologic workforce. Table 1 enumerates strategies that could enhance both clinical care and research in hematology.

Delineating the Challenges

Several challenges to the United States biomedical enterprise were identified: 1) The declining NIH budget and the corresponding reduction in application success rates for R01 and other investigator-initiated research grants; 2) The declining level of government-funded research and development as a proportion of gross domestic product at a time when other countries are expanding their investments; and 3) The declining share of biopharmaceutical patents granted to inventors, mirrored by a growing share of such patents granted in other countries. MD scientists face additional obstacles as the physician-discoverer model that served specialties like hematology so well in the last century has become harder to sustain. Potential causes for this include the prolonged gestation periods for clinical medicine and basic investigation, changes in requirements for specialty training and board certification, the outsourcing of research to PhD scientists, and a medical school curriculum that creates an intellectual conservatism and risk aversion that does not encourage discovery.

Concerns regarding the adequacy of the workforce in hematology are in part congruent with concerns reported more broadly across medical research2 3. Recently, the Director of the NIH, Francis Collins, established a Workforce Working Group on the Physician Scientist Workforce (PSW)4. This group was charged to develop approaches that can inform decisions about U.S. PSW Workforce, to analyze the size of the PSW, to assess the needs and career opportunities for physician scientist trainees and to identify incentives and barriers to entering the PSW. All of these charges overlap with the aims for research and training for the hematologic workforce discussed herein. Similarly, the NIH group and the group represented in these two workshops are utilizing evolving workforce data to define national needs and
to strategize about how to meet these needs. An added concern for the hematology workforce is that hematology focuses on a multitude of relatively rare diseases and overlaps with many other scientific disciplines. Hence, the future of hematology research must embrace team and integrated science models. Similarly, hematologists must be trained in these overlapping areas.

As an example, the explication of the biologic interface between blood, vasculature and other human organ systems has begun to transform medical practice in areas such as traumatic injury and sepsis. As these medical advancements require a fundamental understanding of blood science, bending the attrition curve of the hematology workforce is essential the advancement of health, both in traditional and nontraditional areas.

What is the evidence of such attrition in research hematology and what is unique about it among other research medical subspecialties? The number of funded grants in each of the Divisions of the National Heart, Lung and Blood Institute has mirrored this downward trend in overall NIH funding. Accordingly, the total number of investigator-initiated (RO1) grants that the NHLBI Division of Blood Disease Resources (DBDR) funds (almost all of which have non-malignant hematologic science as their emphasis) has declined over the past decade, as have the number of unique RO1 investigators. (Figure 1) Total spending has declined less dramatically because of initiative funding. Moreover, in certain sub-specialty areas, such as erythrocyte or leukocyte biology, the number of RO1 principal investigators who are funded by DBDR has declined even more dramatically. Other NIH Institutes (e.g. NIDDK) also fund in these areas which has helped to reduce the impact on these focused scientific areas. Although decreases in funding are similar across the NIH and NHLBI, the fact that DBDR is the smallest of the NHLBI Program Divisions accentuates the impact on the hematologic scientific capacity.

Despite the decline in unique DBDR RO1 investigators for most of the last decade, their mean age has remained constant, at least through 2008. (Figure 2) This suggests that young hematology investigators continue to compete successfully for RO1 grants potentially aided by special consideration under Early Stage Investigator funding. The quality of hematology research has been very high for many decades and shows evidence of becoming even higher as judged by the overrepresentation of papers from hematology grantees that are highly cited. Thus, approximately 25% from this group from 1980-2009 have consistently been in the top 10% of cited papers in years 1980-2009 (Figure 3a). During the same time period, the percentage in the top 1% of highly cited papers has increased from ~5 to 14% (Figure 3b). These data support the contention that augmenting the PSW in hematology is likely to yield high quality and impactful scientific discoveries.

**Exploring ways to Bend the Attrition Curve of Hematology Researchers**

There was a consensus that the role of physician scientist is critical to the long-term societal success of hematology research since the bench to bedside to bench intellectual engine needs such individuals for ignition. Further, the link between clinical and basic science has always represented one of hematology's strongest assets. Since defining health needs is a crucial part of translational research, it is important that physician scientists continue to participate in the clinical care of patients. Moreover, the
movement to develop “learning healthcare systems” requires rigorous scientific assessment of all phases of healthcare delivery. Stated more succinctly, the central goal of medical education should be to develop compassionate physician discoverers and to inculcate the principle that physicians have a responsibility to make discoveries about patients and to share these discoveries with the rest of the world. With this in mind, the stages from research career training to academic advancement were discussed.

1. Recruiting the next generation of hematology physician scientists

Introducing more opportunities for discovery into medical school training should not only result in higher likelihood of producing physician scientists, but also should enhance the attractiveness of medical specialties such as hematology, which permit rapid and clinical and tissue correlation (since blood and marrow represent human tissues that can be collected relatively non-invasively). Such opportunities help to emphasize the essential role that scientific inquiry plays in optimal medical practice. Achieving this aim nationally will likely require partnering with entities in the public and private sectors. For example, the NSF takes a comprehensive approach to investing in the development of future scientists and engineers that includes aligning funding with goals, leveraging investments that support both training and research, and developing partnerships. The following paragraphs contain ideas that were presented for training scientists and engineers in general and how they may be adapted to attract individuals, including PhD, MD PhD and MD scientists to careers in hematology. Although the discussions focused on the United States’ scientific and training programs, similar principles will likely apply to Canada, Europe and elsewhere, given the global nature of hematology research and the many collaborations among investigators internationally.

1.a. Specialty-specific strategies to enhance the early hematologist pipeline. Possible strategies that have been or are being pursued include the following: identifying promising young people early in their career for summer internships; offering travel awards to hematology meetings (a strategy that ASH has pioneered for hematology undergraduates, residents, and fellows); targeting educational opportunities for students from diverse backgrounds who have demonstrated an interest and aptitude for science or medicine (another ASH initiative), and upgrading the medical school Introduction to Hematology course at medical schools around the country. Traditionally, U.S. medical schools offer formal courses in hematology during the second year of instruction. More recently, however, a number have now chosen to teach blood-related science earlier in the curriculum and often in association with other disciplines to allow quicker entry by students into clinical rotations. This may have the undesirable effect of diluting the student experience in hematology which may secondarily reduce the likelihood of their choosing the discipline for enhanced training during elective rotations, or conversely if integrated with the concepts of discovery and emphasizing the excitement and importance of research, could enhance the likelihood of the recruitment of physician-scientists. In this regard, it is important that hematology researchers remain active participants in curriculum decision-making and in teaching at their institutions.

Partnering with the pharmaceutical industry and its collective drug development effort offers another possible opportunity. Industry and academia not only share the requisite knowledge pipeline for
workforce; in addition, in many instances, translational and clinical trials initiating within the pharmaceutical industry provide learning and teaching opportunities for trainees in the academic setting.

An additional avenue is to introduce pre-doctoral students to both the field of hematology and to hematologic physician scientists is through mentored laboratory experiences. NHLBI and NIDDK are planning a pilot R25 short-term grant program utilizing funded hematologic core laboratory programs for up to six months of mentored laboratory experiences in scientific centers of excellence for predoctoral, as well as postdoctoral, trainees. These grants will fund travel and support interim living expenses for these students who will be able to acquire additional skills at convenient times during their training.

1.b. Strategies to expose physician trainees to hematology research during residency and fellowship:

Clinical residencies in the U.S. are required for medical licensure almost universally. The ever expanding knowledge required to practice a medical specialty demands a more than full-time commitment to learning from clinical practice situations. This makes incorporation of research opportunities or experiences into the training curriculum challenging at best. For individuals who have elected subspecialty training beyond clinical residency, research is in most cases required. At, a minimum, it is encouraged. However, for residency trainees with little or no prior research exposure, inspiring a passion for a future career that is research focused is less likely. Mentorship by committed clinician scientists during residency may overcome this research naïveté. Yet, a more proactive approach is to formally incorporate a research perspective into residency training.

Also, in the United States the certification process for physicians, overseen by the Accreditation Council for Graduate Medical Education (ACGME), has a major impact on trainees’ choice of medical specialty. In the broader arena of medical workforce enhancement, Drs. David Goodman and Russell G. Roberson have proposed broad educational reform of Graduate Medical Education in their recent paper, Accelerating Physician Workforce Transformation Through Competitive Graduate Medical Education Funding⁶. It is their hypothesis that were medical teaching/training programs forced to compete in a peer-reviewed process for funding based on data-documented innovation, the quality of training would improve. Such an approach could be complementary to many of the strategies proposed herein.

With regards to the importance of hematologic certification to the viability of clinical care, training and research in the discipline, it is helpful to differentiate adult and pediatric certifications. The American Board of Internal Medicine (ABIM) through its Hematology Sub-Board certifies adult hematologists. Similarly, The American Board of Pediatrics (ABP) through its Sub-Board in Pediatric Hematology-Oncology certifies pediatric hematologists. Among Pediatric Hematologists/Oncologists who recently took the Sub-Board re-certification exam, only 3.7% self-identified as research scientists, and only 9% characterized their practice as primarily pediatric hematology, academic or otherwise. Despite the small number of individuals identifying themselves as being engaged in hematologic care, in 2014 the ABP plans to offer three hematology/oncology options for maintenance of certification: hematology/oncology, hematology only, and oncology only.
ABIM has a standing option that accredited training programs that would like to offer innovative training options may submit pilot project applications. In addition, ABIM allows exceptions to its certification requirements to programs that submit petitions on behalf of trainees who can complete training in less than the required minimum time. This flexibility offers opportunities for creative programs of training, including new pilot pathways that join clinical and research training requirements without prolongation of training time. Such alternative pathways would, of necessity, have built into them frequent “exit ramps” that would mitigate the time penalties for individuals who undertake a combined clinical and research trajectory, but who subsequently choose to forego the research path for a career in clinical hematology. It was emphasized that such creative pilot career paths would not only need to protect trainees who undertake them, but also require data collection on all participants’ career outcomes to ascertain the success or failure of the pilot.

Training curriculum expansion for preparing fellows for a greater breadth of both practice and research competencies was discussed in the context of whether such alterations would fit within the potential ABIM and ABP flexibilities cited above. One example is to collaborate with other specialty fields such as surgery, anesthesiology, and obstetrics and gynecology to design training curricula in hematology with more elements devoted to critical care (e.g., vascular injury, acute hemostatic management, etc.). There are examples from other countries that could serve as a template for such innovation. Another opportunity may lie in the creation of a specialized training path for lifelong hematologic chronic diseases. Since there are combined residency programs in Medicine and Pediatrics, there may be an opportunity to focus and compress in time a fellowship path that includes clinical research across the age spectrum for individuals wishing a career in chronic hematologic disease management. If successful, such pilots could serve as a rationale for codifying such training within certification guidelines of both ABIM and ABP.

It was noted that for innovative training pilots to transition to viable expanded hematologic career options, there must be a parallel effort to employ data to justify reimbursement of these capabilities by the healthcare system. Otherwise, no one will seek this expanded training.

There was agreement among participants that greater fiscal support for scientific mentoring by established investigative clinician scientists is another approach to enhance training. National or institutional or foundation funding for supporting a substantial commitment to mentoring may prove attractive to potential trainees as well as create an institutional resource for recruitment of the best and brightest to programs undertaking such an effort. Such an approach would, of course, also apply more broadly to the mentoring of physician scientists in multiple disciplines.

An over-arching theme of the training discussion was the inextricable link between clinical and basic science that is critical to maintain across medical specialties in order for the United States to remain competitive internationally. Hematology, because of many of the factors discussed in these workshops, is particularly vulnerable to a decline because this clinical-basic link is jeopardized by multiple challenges.
Consistent with this recognition, it behooves hematology to take advantage of new opportunities in computational biology. For research training, vast amounts of scientific data are accessible for query and analysis. These data from NIH and other sources are available to hematologists (those in training and to established investigators throughout their academic career). Other medical research specialties have exploited these opportunities more consistently. It may be worthwhile for NIH and ASH to systematically inform hematology programs training directors about the data and biologic specimens that are available for generating and testing thoughtful research hypotheses. These may furnish the basis for joint ASH-NIH educational initiatives to introduce computational skills into hematology training programs and for more intense short course experiences for those wanting a deeper understanding of the methodology. The NHLBI-funded Biologic Specimen and Data Repository Information Coordinating Center (BIOLINCC) are but one example of these available resources. Further, these computational tools can also be exploited to enhance the research capabilities of epidemiology and clinical studies.

1.c. Improving the academic advancement of hematology physician scientists and their transition to independence

A novel strategy to enhance the later research physician-scientist pipeline is to support K12 or K23 clinical research training grants that emphasize specialized training in clinical trial design, comparative effectiveness/cost effectiveness study methodology, epidemiology, and implementation research for young physician scientist trainees interested in clinical, but not lab-based basic or translational, research. ASH, through its Clinical Research Training Institute (CRTI) program for senior fellows and beginning assistant professors, is an important partner. The impact of such specialized training on health outcomes in aggregate could be assessed by how effective their research is in impacting such clinical parameters as use of blood products and anticoagulants or ICU length of stay. ASH and the European Hematology Association (EHA) cosponsor a similar training program to mentor early translational researchers (Translational Research Training in Hematology, TRTH). An alternative strategy could include funding of K12 grants to supplement Clinical and Translational Science Award Programs (CTSAs), with requisite mentoring by senior hematologists with R01 support until and even after the junior investigator successfully receives R01 funding. Achieving this end for hematologists without PhD training will likely require eight years of mentored research support to prepare them to compete with PhD and MD/PhD candidates with 8-10 years of mentored graduate and postdoctoral research experience. One potential avenue forward would be for NIH to create an 8 year mentored program for “late bloomers” (i.e. MDs without PhDs) that would be the equivalent of a K12 (DL2) +K08or K23. As part of the curriculum, specific training in bioinformatics, phenotyping, and other research tools for advanced clinical research capability could be incorporated into the curriculum.

This same multi-Institute sponsored program is also intended to support intense and focused training for post-doctoral fellows with MD or MD-PhD degrees who are earlier in their research career development and who wish to augment specialized laboratory skill sets that may not be available in their local academic environment. Upon traveling to one of the designated specialized laboratories, these individuals will be mentored by a senior scientist with the requisite laboratory and educational expertise. It is hoped that such experiences will create new avenues for hematologic research.
collaboration for these individuals and also facilitate their abilities to apply for and acquire sustainable research funding during this critical early career stage.

1.d. Modeling Workforce and Research Funding  Drs. Richard Larson and Navid Ghaffarzadegan of the Engineering Systems Division, Massachusetts Institute of Technology have performed pioneering work in modeling the PhD. biomedical workforce in the United States⁸ ⁹. During the second workshop Dr. Ghaffarzadegan presented data on how these models may help predict workforce needs for the U.S. in hematology. He pointed out that the reproductive nature of the scientific workforce and how a high-quality science workforce engenders (i.e., educates and mentors) the next generation science workforce.

This phenomenon can be modeled using a demographically-derived \( R_0 = 1 \) replacement function whereby, in a steady state, each mentor enables his own scientific successor. When \( R_0 > 1 \), the scientific workforce grows exponentially. When complexities confound the simple replacement of generational workforces, these can be mathematically attributed within the model accordingly to create the best fit within the model.

A number of questions arose as to how such a model might be best utilized to predict future societal needs for hematologists. Dr. Ghaffarzadegan pointed out that the purpose of the model is to provide policy insights rather than implement a means to stabilize a workforce. An example of why this may be salient for hematology is that downstream workforce needs may be complicated by the need for mentoring in new scientific expertise outside the traditional training purview of the hematologist. To include these disciplines in such a model requires collaboration between individuals with expertise in mathematical modeling and the hematology mentoring community. Included in such collaborations would be consideration of influencing economic forces within the medical system in general and hematology specifically.

Well-designed data collection and tracking are essential for workforce assessment and planning. Hence, a session in the second workshop was dedicated to a discussion of what types of data might be critical to collect and analyze retrospectively and prospectively to define more precisely the status of the workforce in non-malignant hematology. Relevant questions that cannot be adequately answered without cross-sectional or longitudinal data collection are listed in Table 2. The data must be built on a cross-sectional understanding of the size and distribution of the hematologic workforce presently, the assessed capacity of the specialty to adapt to current and future healthcare system needs and the integrated role that hematologic researchers need to play in future team science direction and implementation and in training future physician scientists in hematology. For these reasons, we cannot estimate with acceptable confidence intervals how many hematologists will be needed in the U.S. in 5, 10 or 20 years. However, by implementing strategies for data collection, advancing the next generation mathematical models, and assessing the overlap of research needs with other complementary medical sub-specialties and their research workforce requirements, national needs might be better estimated in the future and thus allow optimal resource allocations and better resource planning.
2. Protecting and enhancing current and future hematology workforce

A particular concern expressed by participants in these Workshops was that, given the difficulty experienced by mentors in securing and maintaining research funding support (NIH and otherwise), mentees will wonder about their own potential for a long and successful career in research. Besides some of the strategies for improving funding for Early Stage Investigators (discussed above), others being explored within NIH and more broadly include funding investigators rather than research projects. This would potentially provide funding security for longer periods, reducing the daunting reapplication focus that exacerbates these career concerns. Other ideas that were brought forward include government-private sector partnerships with the pharmaceutical industry since U.S.-centric companies need a secure academic workforce because they are dependent on the same developmental pipeline for research hematologists as are government and academia.

The need to develop exit pathways for trainees was mentioned earlier. A commitment to fundamental medical research requires passion and commitment by the trainee over many years, oftentimes with associated financial sacrifice. If along the way, he or she loses this requisite passion for a research career for any reason, prior integration of clinical and research training would alleviate some of the time penalty for abandoning the research path. Creating such paths will require broad cooperation among responsible stakeholders.

Some novel programs have recently been created to begin to address some of these challenges. ASH has recently established a “Bridging” Grant program to provide interim research funding for investigators who wrote meritorious grants for funding from NIH. This allows them to keep key staff engaged while they reapply for longer term funding. ASH’s criteria for awarding bridge monies include the importance of the individual to his or her local academic hematology community as well as the excellence of the science. In addition, NHLBI and NIDDK have prioritized their R56 Bridge funding mechanism which is similar to the creative one established by ASH and targets grants that fell just short of the funding cutoff.

It is apparent that no single strategy will enhance the hematologic research workforce. However, by undertaking some of the strategies described herein and connecting them to other, yet to be proposed creative recruitment and retention strategies, there is foundation for creating an integrated and collaborative pathway to enhancing the nonmalignant hematologic research workforce in the U.S. In Table 3, several possible work groups to address these strategic goals are proposed.

Conclusion

Research by investigators in hematology has been highly impactful for at least the last 35 years and shows evidence of being ever more impactful at the highest level over this same period. Despite this extraordinary record of sustained productivity, the number of NIH applications and awards in this
discipline has declined by ~ 70% over the last 13 years. To optimize U.S. hematologic research and training capabilities, the specialty needs to: broaden training capacities to incorporate new scientific expertise at the molecular, cellular, and computational level; expand partnerships among government, academia, regulatory organizations, and professional organizations, most notably ASH, to create new flexibilities for certification that do not increase the length of training; build the discipline’s strength in comparative effectiveness assessments; and broaden its scope to include not only the traditional capabilities such coagulation, diagnostics, and transfusion therapies, but also new ones at the interface with other medical disciplines, such as critical care medicine, geriatrics and obstetrics. This needs to be coupled with secure methods to support and retain productive hematology researchers in academic medical schools and at other research sites.

*Note: The opinions expressed in this manuscript are those of the authors and workshops participants. They should not be interpreted to represent the position of the NIH, HHS, the Federal Government, or the American Society of Hematology.*
TABLE 1: SUGGESTED STRATEGIES FOR FUTURE ENHANCEMENT OF HEMATOLOGY IN THE UNITED STATES

1. The Hematologist of the Future

The hematologist of the future would be:

- Expert in:
  - Malignant and non-malignant disorders of the hematopoietic, hemostatic, and lymphatic systems, and disorders of the interaction between blood and blood vessel wall.
  - Hematopoietic stem cell transplantation, stem cell biology and cellular therapies; genetics, genomics and gene therapy; transfusion and laboratory medicine; coagulation and vascular biology
  - The statistical and computational methods of epidemiology, quality assessment, and comparative effectiveness research applied to hematology
- Facilitated by:
  - A multi-disciplinary strategy for the scientific and clinical integration of hematology with other medical and surgical fields
  - Innovative and flexible training programs
  - Board certification and recertification policies that encourage research careers
- Supported by:
  - Expanded and innovative roles in the hospital health system, and laboratory
  - Funding opportunities from governmental and non-governmental sources for:
    - Institutional and individual training of junior physicians
    - Training of physician scientists
    - Mentoring
    - Retraining
    - Generation and analysis of data to support this mission

2. Recruiting Physicians into Hematology

The recruitment of more physicians into the field of hematology requires:

- Introducing the excitement of hematologic practice and discovery to high school students through ‘NOVA’ type programming
- Broadly demonstrating to medical students, in the classroom as well as in hospital/clinic settings, the wide range of hematologic practice and the high impact of hematologic discoveries
- Developing mechanisms to provide early experience in hematology research to medical students
- Providing incentives through secure mentored research training programs that are sufficiently long to increase the likelihood of successful research funding in hematologic research
- Providing a diverse choice of career options for residents and fellows who are considering careers in the field, including:
  - Teaching the field
3. **The Elements of Hematology Centers of Excellence in Research and Training**

The primary elements of the Hematology Center of Research and Training Excellence would include the following:

- Hematology Research and Training partnerships that provide outstanding:
  - Multidisciplinary, mentored research opportunities
  - Mechanisms to allow trainees to acquire a broad range of expertise through training opportunities at several institutional partners
  - Balanced training in malignant and non-malignant hematology disorders
  - Opportunities for cross-training in medical and pediatric hematology for lifecycle care
  - Training in hematologic disease related to global health
  - Physical proximity between clinical and research training venues allowing the trainee to move easily between clinic and laboratory
  - Maximized integration of hematology with other medical, surgical and basic research disciplines to allow for
    - Generalized practice opportunities for those desiring a clinical career pathway
    - Consultative specialization
    - Clinical laboratory medicine and blood banking expertise
    - Cross-disciplinary research opportunities with opportunities to collaborate with PhD scientists
  - Sustained and integrated NIH support for the training pathway

4. **Potential Partners in Ensuring the Future Hematology Workforce**

Potential partners as identified by the group included:

- ASH and allied professional societies
- Integrated support from all federal agencies including HRSA, FDA, CDC, CMS, AHRQ
- Patient interest organizations
  - Harnessing the collective advocacy power of patients with rare diseases
  - Partnership with genetics colleagues
- Mobilization within the profession
  - To advocate on behalf of itself with the support of multidisciplinary colleagues
    - Capitalize on advocacy training through ASH
    - Increase national awareness through initiative focused on national standards of hematologic health
    - Creation of a congressional caucus on hematology
    - Engage state governments and public health agencies
  - To lead the way in developing fields such as regenerative and personalized medicine
TABLE 2 CRITICAL QUESTIONS ABOUT THE HEMATOLOGY WORKFORCE AND HEMATOLOGY RESEARCH THAT REQUIRE MORE DATA

- What influences trainees to pursue careers in hematology?
- How many hematologists will be needed in the U.S. in 5, 10, and 20 years? How many are entering and leaving the field (the RO)?
- What are the research needs of the U.S. in this field in subsequent decades and what human resources will be required to insure the ongoing scientific innovation that will lead to advances in the field?
TABLE 3: POSSIBLE WORK GROUPS TO ADDRESS STRATEGIC GOALS FOR ENHANCING THE SPECIALTY OF HEMATOLOGY IN THE USA

Clinical
- Hospitalist and other career enhancement opportunities through engagement of hospitals
- Engagement with and assessing the impact of regulatory entities such as ABIM, ABP, ABLM, AGCME, JCAHO, and others
- Impact of the Affordable Care Act (ACA) and the Patient Centered Outcomes Research Institute (PCORI)
- Enhancing mentorship of the clinical hematologist

Training
- Research training—opportunities for redesigning the pathway to research independence
- Enhancing flexibility in training along clinical/translational/basic pathways with requisite “entry” and “exit” ramps to protect the trainee against time penalties
- Exploring opportunities for special trainee pathways (e.g., Medicine/Pediatrics; Critical Care across the age spectrum; Chronic disease management across the age spectrum)
- Fostering/expanding/supporting mentorship for research and career development

Research
- Enhancing basic and clinical research mentorship
- Centers of Excellence creation/expansion for specialized training and broadened mentorship
- Establishment of an integrated longitudinal pathway for researcher development
- Exploration of public-private partnership opportunities for research support
- Creating funding mechanisms that encourage established scientists to take risks and that support innovation
- Developing funding mechanisms to bridge established investigators when needed to maintain a science workforce.
- Consider other ways to make the pursuit of translational or basic research a secure career option

Data Collection and Analyses
- Database creation and tracking of trainees in hematology
- Modeling of societal needs and trends
- Assessment of who should be partnering with whom and what data is critical
- Education of the public about how hematology care and research impact their health and well-being
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ACKNOWLEDGMENTS

The authors thank Michael S. Lauer, Division Director, National Institutes of Health, for his portfolio analysis, and Terrie Squadere, National Institutes of Health who provided assistance with the manuscript preparation. Dr. Janis Abkowitz, as ASH President, helped lead one of the workshops, co-wrote the manuscript and provided on-going editing.

AUTHORSHIP AND CONFLICT OF INTEREST STATEMENTS

Dr. Keith Hoots and Dr. Donna DiMichele organized and co-chaired the workshops, analyzed the portfolio data, and wrote the manuscript. Dr. Barry Coller was one of the co-chairs for two of the workshops. He provided input into the manuscript development, including writing and editing. Dr. Janis Abkowitz co-wrote the manuscript and provided on-going editing.

The authors have no conflicts of interest to disclose.

*In this paper we will define the term (H)ematology as specific for Non-malignant or Non-neoplastic Hematology for both pediatric and adult sub-specialties.

WORKSHOP PARTICIPANTS

Charles S. Abrams, M.D.
Hussein Ahmad
Gowthami Arepally, M.D.
Janis L Abkowitz M.D.
Thomas Abshire, M.D.
James P. AuBuchon, M.D., FCAP
Mila N. Becker, Esq.
Edward J. Benz., MD
Nancy Berliner, M.D.
R. Lorraine Brown, RN, BS, CPHP
Michael P. Busch, M.D., Ph.D.
Ronald Warren, Ph.D.
Ellen Werner, Ph.D.
Gilbert C. White, II, M.D.
David A. Williams, M.D.
Ted Wun, M.D., FACP, FRCPA
Daniel G. Wright, M.D.
Neal S. Young, M.D., MACP
Shimian Zou, Ph.D.
Figure Legends

Legend Figure 1: New Investigator-initiated R01 principal investigators (PIs) applying to (red line) and funded by (blue line) the National Heart Lung and Blood Institute (NHLBI)/Division of Blood Diseases and Resources (DBDR) beginning in fiscal year 2000 and ending September 30, 2013 (FY 2013). Each funded PI is included only in the first year during which he or she applied or was funded. This includes new and established PIs who were funded prior to FY 2000. The graph may be said to represent the “steady-state” of new or re-entering hematologic PIs funded by NHLBI/DBDR over the represented time period.

Legend Figure 2: This graph plots the average age of principal investigators funded by The Division of Blood Diseases and Resources, National Heart, Lung and Blood Institute between the years 2000 and 2008.

Legend Figure 3a: This graph shows the percentage of published papers authored by investigators funded by the Division of Blood Diseases and Resources, NHLBI in the years 2000-2010. For ranking purposes, all articles cited in Web of Science are evaluated by a proprietary algorithm developed by Thompson-Reuters. The denominator is the total of top 10% papers published by any investigator funded by NHLBI in that year.

Legend for Figure 3b: (Note: Designation as a top 1% paper is made utilizing the same Thompson-Reuters algorithm cited in Figure 3a) Shown is the percentage of articles published by DBDR-funded investigators from 1980-2000 that are ranked top 1% papers in Web of Science. The denominator is the total number of top 1% papers published by any investigator funded by NHLBI in that year.
Figure 1
Planning for the future workforce in hematology research

W. Keith Hoots, Janis L. Abkowitz, Barry S. Coller and Donna M. DiMichele