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How will we recruit, train, and retain physicians and scientists to conduct translational cancer research?

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Abstract

Advancements in clinical medicine require effective translational research. Ideally, this research will be performed by multidisciplinary teams that include both physicians and basic scientists. However, the current system does not appropriately train either physicians or basic scientist for these careers. Additionally, translational researchers are often not properly rewarded, creating a disincentive to pursuing this kind of research. The roles and challenges for physicians and basic researchers in the field of translational research will be discussed, along with proposed solutions to improve their recruitment, training and retention.

Introduction

In a book entitled *The Vanishing Physician-Scientist?*, Timothy Ley documents that over the last 30 years the number of M.D.'s in the United States has more than doubled to 900,000, but the number of physician-scientists has stayed static at approximately 15,000.[i] Less than 2% of U.S. physicians are now engaged, full time, in laboratory and clinical research and the number of physician-scientists has changed little over three decades. To maintain current numbers of academic physicians, 500-1,000 new physician-scientists must be trained each year to offset retirement or attrition with an aging workforce. Between 2002 and 2011, the number of physicians in research declined 9% from 14,526 to 13,557 .[ii] Given the current uncertainty regarding research funding, many have questioned whether we can maintain the current number of physician-scientists.

The limited number of physician-scientists is a particular challenge for translational research. Physician-scientists have led in the conception and performance of translational research. If their number is not likely to increase, it is imperative that we develop other strategies to train a new generation of investigators who are well versed in the art of translational research.

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What is translational research?

Investigation of human disease spans a complete spectrum of research, ranging from studies of genetic abnormalities, alterations in protein structure-function, aberrations in cellular signaling and pre-clinical models to human clinical trials. This full range of research is required to improve human health as promptly as possible, given the many gaps in our understanding of normal and diseased cells, a paucity of predictive pre-clinical models and the difficulty in predicting where to find the key bits of new knowledge that will impact patient care. Too often, the spectrum of biomedical research is simply divided into the two large categories of basic science and clinical research. This division seems natural as basic science is usually performed by Ph.D.-trained scientists and clinical research is generally conducted by M.D.-trained physicians. Basic science focuses on the fundamental processes and mechanisms at work in biology through hypothesis-driven experiments. Often, these fundamental studies will not utilize human material or relate directly to unmet needs in patient care, but can lay the foundation for subsequent advances in the clinic that can occur over decades. Conversely, clinical research is performed directly on humans with the aim of making an immediate improvement in patient outcomes. Clinical trials often test novel interventions against the current standard of care without actually testing hypotheses. Clinical investigators often care more about *if* something works than *why* it works.

Simply dichotomizing research ignores the importance of a third type of scientific endeavor, translational research that bridges the gap between the basic and clinical sciences and includes aspects of each. Translational research can be difficult to define, but for the purpose of this commentary we suggest that translational research aims to improve patient care by using the laboratory to understand the biology of human disease and to develop new strategies, agents and methods, not only for treatment, but also for prevention and detection that can be tested in the clinic or community. During translation, clinical observations, images and specimens are returned to the laboratory for analysis to refine new strategies and to develop more effective agents and methods. Thus traffic on the translational bridge must be in both directions.[iii]

Translational research is not new. Physicians and scientists have worked at the interface between the laboratory and clinic for more than a century and a half.[iv] In the 19th Century, German (Johannes Peter Muller, Rudolf Virchow, Robert Koch, Paul Ehrlich) and French investigators (Claude Bernard, Louis Pasteur) brought the insights of anatomy, pathology, physiology, bacteriology and immunology to bear on human disease. In the first half of the 20th Century, physician-scientists such as Alexander Fleming, Howard Florey and Selman Waksman pioneered in the development of antibiotics, transforming the management of infectious diseases. Banting had co-discovered insulin. Since World War II, the role of Ph.D.-scientists has become increasingly important in basic research, exemplified by the discovery of the Double Helix by Watson, Crick, Wilkins and Franklin. Since Nobel Prizes were first awarded in Medicine and Physiology in 1901, 107 of 201 laureates (53%) have been physicians.[v] While 80% of Nobel Awardees in the first 4 decades of the 20th Century were physicians, from 2001 to 2013, 24 of 32 (75%) were Ph.D.'s.[iv]

In contrast to basic science, much translational research is still performed by physicians whose medical training and experience have given them insight into unmet clinical needs and immediate access to test new strategies and to obtain clinical material. A major concern explored in this article is the decreasing number of physician-scientists in the face of increasing opportunities and needs for leadership in translational research. There is clearly an opportunity to train and to include additional Ph.D.'s in bridging the laboratory and clinic. Education and career challenges will be discussed, as well as possible solutions to filling an international need for translational investigators.

Educational challenges in translational research

Physicians

Three of the most important challenges for physicians who want to perform translational research are dedicated time, institutional commitment and resources, and relevant expertise. Physicians must spend time in research outside of clinical practice. Since time spent in research does not generate clinical revenue and physicians are a major source of revenue for health care institutions, dedicated time for research is usually granted sparingly, if at all, by universities and cancer centers that are increasingly stressed with narrowing reimbursement for clinical care. Many universities and research institutes do not have a physician- or clinical-scientist faculty track that could provide them with the resources and dedicated time needed to perform translational research. Additionally, a successful research program can take many years to develop and dedicated research time must be sustained over an extended period. This makes support of physician-scientists and clinician-investigators a significant financial commitment for an institution. Even with appropriate dedicated time, translational research is not easy to perform, requiring specialized biological, technical, and procedural skills both in the laboratory and in the clinic. Medical school curricula train physicians to care for patients, but do not fully prepare them to perform laboratory-based translational research or to plan and execute clinical trials. Competent patient care may or may not require understanding the basic mechanisms of disease. With an ever-increasing volume of patient-care information, there is a temptation to truncate basic science in the medical curriculum. Understanding the molecular, cellular and clinical pathophysiology of illness is, however, essential to conducting successful translational research. Physician-scientists must acquire in depth knowledge of at least their subspecialty to establish and conduct an optimal translational research program. Additionally, medical school courses do not explore the latest experimental methods and technologies in depth and generally do not provide detailed instruction in developing and conducting clinical trials. Translational research must utilize the most appropriate methods to answer a question and then often identify a complimentary or confirmatory method to convince skeptics of a novel finding or, perhaps more important, to be sure that a discovery is worthy of translation. Laboratory methods change constantly as technology advances. Physicians who complete only a medical curriculum and clinical residency are unlikely to be prepared for the technical complexities of laboratory-based translational research or for executing hypothesis-driven clinical trials.

Basic scientists, on the other hand, are trained, in depth, in the principles and details of biology and in the methods of laboratory-based biomedical research. They are taught to think critically, to challenge convention and to test hypotheses through a Ph.D. training program. Ideally, an optimally-trained translational investigator would earn both M.D. and Ph.D. degrees. For this purpose, physician-scientist (M.D./Ph.D) training programs have been developed to train physicians to perform clinically relevant biological and translational research. With subspecialty training and postdoctoral fellowship, however, this course career track may require some 15 years of postgraduate training and has its own challenges (see below).

Scientists

While scientists have been trained in the methods and intricacies of laboratory-based research, they often lack knowledge of clinical disease, making it difficult to identify unmet clinical needs or to find the most clinically-relevant scientific questions to examine. With a lack of clinical knowledge, especially for changing treatment paradigms, it is easy to study something that is not a clinical problem. For example, the resistance mechanism of colon tumor cells to a drug is only useful if that drug is being used to treat colon cancer. Further, the practical concerns that limit translation are often not known to scientists. It may not be appreciated how difficult, or unethical, it is to change standard first line treatments, even if the laboratory data on a new drug look amazing. Additionally, scientists are trained to focus on one specific problem and understand all aspects of that problem, but translational research often requires a perspective for the larger picture of a problem and a willingness to solve it even with an incomplete understanding for the problem or the solution.

Educational solutions

Clearly, the field of translational research has a major personnel problem. No one is perfectly trained or available to perform all of the essential research. One solution to this problem is to build new training programs specifically for translational research. Fortunately, these programs are being developed and they are targeted toward M.D., M.D./Ph.D. and Ph.D.-educated researchers. A second strategy is to accelerate the development of Team Science.

Physicians

Obviously, physician-scientist training programs are an important part of the physician education process, but they are only one part of the necessary training infrastructure. Many physicians do not want to earn a Ph.D. or decide later in their education/career that they want to pursue research. There must be education programs for non-Ph.D. physicians who want to participate in research or lead their own research. There are many well established residency and fellowship programs that provide a year or more of protected time for research. These are beneficial as a stepping stone to additional research experiences, or as a window into the research process. It would be beneficial to further expand these research programs to include medical students and any physician who is interested in the research process, even if they do not want to pursue a research career.. Changes in modern medicine are driven by laboratory-based research findings and it would be worthwhile for nearly all physicians to have some exposure to the research process during their training. These programs are useful, but are not a substitute for more extensive research training for physicians who want to lead a research laboratory.

For physicians who want to lead a translational research laboratory there are masters-level and fellowship training programs that provide more than just time in a lab. These programs can include coursework and mentoring that facilitate more effective research and provide a foundation of knowledge not provided during medical training. In oncology, this can take the form of didactic courses in tumor biology, cell signaling and new technologies, as well as the development of novel clinical trial design and development of correlative science. A track should also exist for the occasional clinically trained physician who is highly motivated to earn a Ph.D. Another opportunity exists for international medical graduates who have already earned a medical degree and can enroll in graduate Ph.D. programs.[vi]

Scientists

Over the last four decades, Ph.D. curricula in medical schools have evolved to meet the exponential expansion in knowledge of molecular and cellular biology. In the past, Ph.D. candidates at some medical schools completed the first two years of the medical curriculum including anatomy, histopathology, pathophysiology, microbiology and pharmacology. In recent years, most Ph.D. curricula are focused on genetics, molecular and cellular biology, biochemistry and the quantitative sciences, with very little whole animal biology or medical science.

For scientists there are now, however, clinical and translational sciences training programs at the graduate and postdoctoral levels. These programs provide courses on medically-related topics including histopathology and pathobiology of disease in multiple organ systems. Without requiring the extensive work of medical school such courses can provide background in medical science that is not traditionally covered in graduate school. Some programs even include observation time in medical clinics. The Translational Research In Multi-Disciplinary (TRIUMPH) program at the M.D. Anderson Cancer Center was one of the first programs of this type for postdoctoral fellows. This program includes 5 courses on clinical and translational research and 5 rotations through different clinical departments; including surgical oncology, medical oncology and radiation oncology. These concepts have also been applied to graduate training program, Clinical and Translational Sciences, at the University of Texas Graduate School of Biological Sciences (GSBS) in Houston.

Clinical exposure should be an important part of translational research training for scientists. This experience provides much more insight than can be taught in a classroom. The realities of clinical medicine can be eye-opening to a scientist who is accustomed to carefully controlled experiments to test general principles. In the clinic each patient is unique, and there are many factors beyond the biology of the tumor that can influence patient outcomes. Among the most evident variables are comorbidities, such as diabetes, that can predispose to neurological toxicity; heart or lung disease that can increase the risk of surgery; and liver or kidney disease that can affect pharmacokinetics, altering the doses of drugs that can be given safely to a patient. Graduate students and postdoctoral fellows can witness at first hand communication among physicians and between physicians and patients. Many are impressed by the evident needs of cancer patients and the urgency of making progress as promptly as possible.

Scientists also need to learn that clinical medicine contains many logistical barriers that may prevent the ideal experiment from being feasible or practical. For example, in some tumor types systemic chemotherapy is given after the tumor is completely removed from the patient. This makes it nearly impossible to analyze the response of the tumor cells to the treatment. Multiple biopsies to measure a biomarker for response in the tumor cells before, during and after treatment may not be feasible or tolerable. Only by understanding the clinical disease and the standard treatment paradigms can a scientist identify unmet clinical needs and design clinically relevant translational experiments. This understanding can be gained by spending time with physicians both in and out of the clinic. Similarly, there are many different clinical subtypes of disease that may have different treatment paradigms for biological, anatomical or practical reasons. Scientists must gain an appreciation for the clinical subtypes of disease either through coursework, clinical observation or discussion with physicians. Graduate students and postdoctoral fellows can also judge whether they would enjoy leading or contributing to a team that includes both physicians and scientists.

Clinical observation will also expose a scientist to the language of physicians. Scientists and physicians speak different languages, which can make communication and collaboration challenging. Translational research requires a team of researchers with different training and expertise, and since teamwork requires effective communication it is important that scientists learn to communicate with physicians and vice versa. A useful way to improve one’s understanding of a new language is to have frequent exposure to that language and interactions with fluent speakers. This is one reason that scientists should spend time in the clinic. They will learn the language of physicians. Additionally, if scientists spend time in the clinic they will gain an appreciation for the unique perspective that physicians have on the progression and treatment of disease. It is also important for scientists to learn that physicians have a different objective. To a physician the most important issue is how to treat the patient in front of them. Studying the disease is a secondary endpoint, and only important because it may improve the treatment for future patients. This is generally reversed for scientists. Lastly, clinical exposure will teach the scientists about the pressures and time constraints of clinical medicine.

In addition to clinical observation, translational research education for scientists ought to include didactic coursework. A major focus of this should be on methods and ethics of human subject research. Traditional scientist education does not include the details of writing protocols for permission to work with humans or their tissue, and it rarely covers the logistics of running a clinical trial. All of this information is important for a full understanding of translational research. In oncology, understanding tumor biology, the path to developing conventional and targeted therapy, the discovery and application of biomarkers for personalized therapy, and the development of predictive pre-clinical models are all relevant topics that lend themselves to didactic courses. Familiarity with the role of Academe, Pharma, NCI, FDA and community oncologists should all be considered. A goal should be to think translationally about each new laboratory discovery, considering the path required for application to better patient care. Conversely, translational scientists should be able to connect unmet clinical needs with new agents and technologies, understanding the path to discovering new targets, drugs and devices.

Career challenges in translational research

Physicians

Since translational research does not fit into the traditional basic science or clinical research paradigms researchers who choose this area are likely to face challenges in career advancement. For physicians, running a laboratory is a risky endeavor since it requires independent research funding. A physician-scientist, like any scientist, must write and secure grant funding to maintain a research program. This can be especially difficult for physician-scientists since they may only be in the laboratory part-time but compete with full-time scientists for funding. While there are many grants specifically for physician-scientists the ultimate goal is still to secure R01-funding. For physician scientists, this is at approximately age 44-45, at least two years later than Ph.D.s. Data suggest that physician-scientists applicants for R01s have the same rate of success as Ph.D.s for initial awards, but there are three time more Ph.D.s.[i] Still, less than 50% of physician-scientists who earn a career-development award go on to secure R01 funding within 10 years[vii], so many take other career paths, including community practice. Sustaining a career as a physician-scientist has been a particular challenge for women who wish to establish their families while maintaining a clinical practice and obtaining grant funding for their laboratories.

Becoming a physician-scientist can also have a financial cost. Although a federal loan repayment program can reduce or eliminate medical school debt, further training with post-doctoral research only postpones the attainment of a physician-level salary. Additionally, physician-scientist salaries at an academic medical center are often lower by a factor of two or more compared to private practice. Finally, because physicians usually generate more clinical revenue than research revenue for an institution, there is a constant pressure to increase clinical time/revenue.

Scientists

For scientists the decision to pursue translational research can involve substantial risk. Jobs, promotion and tenure are traditionally judged on the individual accomplishments of the investigator. The primary measures of accomplishment are almost exclusively first or last author publications and grants as principle investigator (PI). Many of these challenges are also relevant to physician-scientists. Because translational research usually requires a team of researchers it may be difficult for a Ph.D. scientist to be first or senior author or as PI on a team science grant. This problem is amplified for trainees and young investigators with less seniority. Large team science translational research projects are most likely to secure funding if they include a well-known experienced investigator as the PI, even if the PI only contributes a small effort to the project. For this reason a young investigator will rarely be chosen as PI, even if they contribute a large fraction of effort. Additionally, if a translational research grant application includes a clinical trial as one part of the project it may be necessary to include a physician as PI on the application. Similar scenarios can occur when it comes time to publish the findings of the project. While it is possible and common to designate co-first and co-last authors on a publication of a translational research project, that designation is still not universally accepted by peers.

For a young investigator, a career in translational research may not be compatible with promotion criteria at many institutions. Unless Team Science is rewarded, participating in potentially transformative translational research projects such as large clinical trials, P01s, SPOREs, or the TCGA may not yield large numbers of publications and first or last authorships. This can discourage young investigators from participating in these important projects. Young faculty members are often encouraged to develop a more “independent” project of their own. The situation is even more problematic for postdoctoral trainees, who have yet to secure a tenure-track position. There are often dozens of applicants for every open position at major institutions. Candidates are easily filtered based on high impact publications and individual investigator grants. While most departments want to hire someone who will collaborate, they are often hesitant to hire a translational researcher who needs to collaborate. For strong candidates, in choosing a new institution as an assistant professor, it would be important to identify successful translational scientists as mentors and as evidence that the institution supports translational research. Training in clinical and translational research should also prepare Ph.D. investigators for a career at NCI, the FDA, Pharma or Biotech and opportunities in government or the private sector should also be explored.

Challenges Shared by both physicians and scientists

There are also shared challenges for PhDs and MDs trying to start a research program. One major challenge is lack of institutional support for junior faculty MD’s. and PhDs. While there are numerous K awards from NIH and seed grants from other granting agencies (see Table 1), these awards require substantial institutional financial support for junior faculty MD’s, as the stipends are not adequate, particularly for the non-medical specialties. Thus these K awards are often used as a way to identify individuals worthy of institutional support and dedicated time. While this is one useful function, it depends critically on availability of institutional funds, which varies from place to place and time to time. Such funding dilemma is more pronounced for PhD trained scientists, since even if they receive the desired K award or the subsequent R01, they are required to provide between 40-100% of their salary on grants (depending on their institutions). Such salary-on-grants principle depletes the hard earned grant dollars quickly and drastically, preventing the hiring of the lab personnel needed to perform the proposed aims of the grant by the junior faculty.

Other shared challenges involve time spent on teaching activities and service to the institution. In University settings, junior faculty (both MD and PhD trained scientists) are often asked to direct courses or give lectures to both graduate and medical students. These activities, while very needed for an educational entity, is also time away from the lab or the clinic. The junior faculty is often pressured to take over these responsibilities from more senior faculty and in doing so can curtail their own career path in the field of translational research. Institutional service is also quite daunting for junior faculty, whether it is to serve on IRB or IACUC committees or admissions committee for the graduate/medical school, a lot of time and energy will be spent on these activities making it very difficult to progress in their research endeavors.

Solutions

For physicians, it is important that departments make a commitment to provide dedicated research time, particularly until peer-reviewed funding is attained. Administrative resources can greatly assist the grant writing process, while clinical and translational science training opportunities can help fill any educational needs. Finally, mentoring by both junior and senior physician-scientists can greatly benefit early career physician-scientists by providing institutional connections, feedback on grants and papers, and guidance on research directions. All of these will help increase the odds of success for young physician-scientists.

For scientists, the promotion and tenure system must be modernized to recognize contributions to Team Science. R01-equivalent effort and funding as part of a large project should be considered as valuable as an individual R01. Similarly, while first and last author status on a publication implies a certain amount of contribution to that project, other contributions may also be significant, vital to the project, and worthy of notice. Evaluating translational research may require discussion with collaborators about the true effort and contribution of an investigator. Individual contributions to a large translational research project must be recognized and rewarded during the tenure and promotion process. If institutions want to be leaders in translational research it is important for them to update the reward structure to include team science, and identify a clear path to tenure for translational researchers. These policies can then be used as a recruiting tool and a way to promote collaborative science on an institutional level.

For both physicians and scientists, their departments and institutions should not pressure them into any classroom teaching or fellowship training activities. Additionally, serving on institutional committees should be reserved for those faculty (either PhD or MD) who have secured tenure.

There are also numerous career development award opportunities from different granting agencies available to both MD and PhD trained scientists. A comprehensive list of these award mechanisms are listed in Table 1 providing requirements (MD or PhD), duration of support, description of the funding and applicable web sites. It is important to note that while K awards are the major source of funds for junior faculty, there are many other granting agencies and foundations which provide funding for specific diseases that could provide the much needed funding to initiate, or continue, a translational research project.

Finally, pairing translational physicians and scientists together may be another option to help both succeed. In this scenario a physician and a scientist would share laboratory space, lab meetings and some personnel. The physician would provide the clinical expertise and be the connection to the clinic, while the scientist would provide the laboratory expertise and be the connection to biological mechanism and experimental rigor. Each researcher could initiate their own projects but also have joint collaborative projects. In a modernized promotion and tenure system each investigator would be evaluated on their contribution, not on their authorship position, but in the current system it would be possible for the investigators to share authorship or alternate authorship from paper to paper. Ideally both investigators would contribute equally to the research, but unequal partnerships could still be mutually beneficial. For example, physicians who want to be involved in research but do not want to perform research could still help a scientist with translational research. In this scenario the physician might attend laboratory meetings and advise on projects and grants but would not need to commit as much time to the research. The scientist would benefit from frequent physician input and clinical expertise, while the physician would get to contribute to research without the risk and challenge of running a laboratory.

Conclusion

Despite the career challenges faced by physicians and by Ph.D. scientists, the opportunities for clinical and translational science to impact patient care and to understand human disease are greater than ever. Moving forward, we must identify, train and retain physician scientists with sustained dedicated time and mentorship. To reverse the growing deficit in leaders for translational research, we must identify, train and retain Ph.D. scientists with a curriculum in clinical and translational science, experiences in the clinic, interaction with M.D.s, effective mentorship and realignment of promotion and tenure policies to support Team Science.

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Table 1

Federal and Non-Federal Sources of Career Development Awards

AWARD	DEGREE	DESCRIPTION
National Institutes of Health		
K01 **Mentored Research Scientist Development Award (Parent K01)**	M.D. Ph.D. or equivalent	Provides salary and research support for a sustained period of "protected time" (3-5 years) for intensive research **career development** under the guidance of an **experienced mentor** in the **biomedical, behavioral or clinical sciences** leading to research independence. Provides salary + fringe and other program-related expenses such as 1) tuition and fees; 2) supplies, equipment and technical personnel; 3) travel to research meetings; and 4) statistical services. Although all participating NIH Institutes and Centers (ICs) use this mechanism, others utilize it for individuals who propose to train in a new field or for individuals who have had a hiatus in the research career. **NCI** uses this mechanism to increase research workforce diversity. http://grants.nih.gov/grants/guide/pa-files/PAR-12-050.html http://grants1.nih.gov/grants/guide/pa-files/PA-14-044.html
K02 **Independent Scientist Award (Parent K02)**	M.D. Ph.D. or equivalent	This award is intended for **newly-independent scientists** who can demonstrate a need for a period of intensive research focus in order to enhance their research careers. **Limited NIH Institute and Center participation - NCI is not a participant**. This award provides 3-5 years of salary support and protected time; assumes other research support exists. Size and duration of award varies. http://grants1.nih.gov/grants/guide/pa-files/PA-14-045.html
K07 **Cancer Prevention, Control, Behavioral Sciences, and Population Sciences Career Development Award (NCI)**	M.D. Ph.D. or equivalent	Provides salary and research support for a sustained period of "protected time" (3-5 years) to **junior investigators** who are interested in developing academic and research expertise in **cancer prevention, cancer control, or the behavioral or population sciences**. NCI will contribute 9-12 person months (75%-100% of full-time professional effort), up to the allowable salary cap, per year toward the salary of the career award recipient. NCI will contribute $30,000 per year toward research development costs. Award is not renewable. Candidates must identify a **mentor** who will supervise the proposed career development and research experience. For the purpose of this funding opportunity, a junior investigator is defined as a senior postdoctoral fellow, research fellow, clinical fellow, or similar title; a non-tenure-track faculty appointment equivalent to the level of assistant professor or below; or an assistant professor within the first two years of a tenure-track appointment. http://grants1.nih.gov/grants/guide/pa-files/PA-12.067.html
K08 **Mentored Clinical Scientist Research Career Development Award** **(Parent K08)**	M.D. Ph.D. or equivalent	Provides salary and research support for a sustained period of "protected time" (3-5 years) to support **didactic study** and/or **mentored research** for individuals with clinical doctoral degrees. Provides support for an intensive, **mentored research career development** experience in biomedical or behavioral research, including translational research leading to research independence. Award may be used by candidates with different levels of prior research training and at different stages in their career development. Provides salary + fringe and other program-related expenses. **NCI** uses this mechanism to increase research workforce diversity: http://arants.nih.aov/arants/auide/pa-files/PAR-12-051.html http://arants1.nih.aov/arants/auide/pa-files/PA-14.046.html
K22 **The NCI Transition Career Development Award**	M.D. Ph.D. or equivalent	Provides **up to 3 years of support** for the most promisina and exceptionally talented **mentored, non-independent investigators** who 1) have earned a terminal clinical or research doctorate; 2) have at least 2 years of postdoctoral trainina in cancer research at the time of submission of the initial application; 3) have no more than a total of 8 years of mentored, non-independent research trainina experience after the terminal clinical or

AWARD	DEGREE	DESCRIPTION
National Institutes of Health		
		research doctorate at the time of initial application or subsequent resubmission; 4) have not already obtained an individual career development award from the Federal Government; and 5) do not already have a full-time tenure-track assistant professor faculty position. This period of support is to allow the investiaator to work towards establishina his/her own independent research proaram and to prepare an application for research arant support (R01 or equivalent). Award budaets are composed of salary and other proaram-related expenses. NIH will contribute $100,000 per year toward the salary of the career award recipient and $50,000 per year toward research costs. **NCI** also uses this mechanism to increase research workforce diversity: http://arants.nih.aov/arants/auide/pa-files/PAR-12-062.html http://arants.nih.aov/arants/auide/pa-files/PAR-12-121.html
K23 **Mentored Patient-Oriented Research Career Development Award** **(Parent K23)**	M.D. D.O. D.D.S. Pharm.D or equivalent	Provides salary and research support for a sustained period of "protected time" (3-5 years) to ensure a future cadre of well-trained scientists conductina NIH-supported **Patient-Oriented Research (POR)** who will become competitive for NIH research project (R01) arant support. Candidates must have a **clinical degree** (Candidates with **Ph.D.** dearees are eliaible for this award if the dearee is in a clinical field and they usually perform clinical duties). For the purposes of this award, Patient-Oriented Research is defined as research conducted with human subjects or on material of human oriain such as tissues, specimens and coanitive phenomena for which an investiaator interacts directly with human subjects. This area of research includes: 1) mechanisms of human disease; 2) therapeutic interventions; 3) clinical trials; and 4) the development of new technoloaies. Award budaets are composed of salary and other proaram-related expenses. **NCI** also uses this mechanism to increase research workforce diversity: http://arants.nih.aov/arants/auide/pa-files/PAR-12-052.html http://arants1.nih.aov/arants/auide/pa-files/PA-14.049.html
K25 **Mentored Quantitative Research Development Award (Parent K25)**	M.D. Ph.D. or equivalent	The award is intended for research-oriented investiaators at any level of experience, from the **postdoctoral level to senior faculty level**, who have shown clear evidence of productivity and research excellence in the field of their trainina, and who would like to expand their research capability with the aoal of makina sianificant contributions to behavioral, biomedical (basic or clinical), bioimaaina or bioenaineerina research that is relevant to the NIH mission. This award is for scientists from **quantitative scientific and technical backgrounds** such as mathematics, statistics, economics, computer science, imaaina science, informatics, physics, chemistry, and enaineerina, who are interested in pursuina basic or clinical biomedicine, bioenaineerina, bioimaaina, or behavioral research. Candidate must identify a **mentor** who will supervise the proposed career development and research experience Award budgets are composed of salary and other program-related expenses. Candidates may request 3-5 years of support. http://grants1.nih.gov/grants/guide/pa-files/PA-14-048.html
K99 / R00 **NIH Pathway to Independence Award** **(Parent K99/R00)**	M.D. Ph.D. or equivalent	Provides **up to 5 years of support in two phases**. The **initial mentored phase** provides **support for up to 2 years** for new investigators who have ≤ 5 years of postdoctoral research training experience at time of initial application and do not have a full-time tenure-track assistant professor position. The candidate must propose a research project that will be pursued during the K99 phase and transition into an independent project during the R00 phase. Following the mentored phase, the individual may request **up to 3 years** of support to conduct research as an **independent scientist** at an extramural sponsoring institution/organization to which the individual has been recruited, been offered and has accepted a **tenure-track full-time assistant professor** position. This support will allow the individual to establish his/her independent research program and prepare an application for regular research grant support (R01).

AWARD	DEGREE	DESCRIPTION
National Institutes of Health		
		Award budgets are composed of salary and other program-related expenses. **K99**: salary support up to $100,000 + fringe benefits per year research support up to $30,000 per year **ROO**: total cost may not exceed $249,000 per year http://grants1.nih.gov/grants/guide/pa-files/PA-14-042.html
Congressionally-Directed Medical Research Programs		
Bone Marrow Failure	M.D. Ph.D. or equivalent	http://cdmrp.army.mil/bmfrp/default.shtml
Breast Cancer		http://cdmrp.army.mil/bcrp/default.shtml
Lung Cancer		http://cdmrp.army.mil/lcrp/default.shtml
Neurofibromatosis		http://cdmrp.army.mil/nfrp/default.shtml
Ovarian Cancer		http://cdmrp.army.mil/ocrp/default.shtml
Peer-Reviewed Cancer		http://cdmrp.army.mil/prcrp/default.shtml
Peer-Reviewed Medical		http://cdmrp.army.mil/prmrp/default.shtml
Prostate Cancer		http://cdmrp.army.mil/pcrp/default.shtml
Tuberous Sclerosis Complex		http://cdmrp.army.mil/tscrp/default.shtml
Foundations/Professional Associations That Support Translational Research		
Alliance for Cancer Gene Therapy		http://www.acgtfoundation.org/
American Association for Cancer Research (AACR)		http://www.aacr.org
American Cancer Society		http://www.cancer.org/
American Institute for Cancer Research (AICR)		http://www.aicr.org/
American Society for Therapeutic Radiation and Oncology (ASTRO)		https://www.astro.org/
American Society of Clinical Oncology (ASCO)		http://www.asco.org/
American Society of Hematology (ASH)		http://www.hematology.org/
Association for International Cancer Research (AICR)		http://www.aicr.org.uk/
Cancer Research Institute (CRI)		http://www.cancerresearch.org/
Concern Foundation		https://www.concernfoundation.org
Conquer Cancer Foundation		http://www.conquercancerfoundation.org/

AWARD	DEGREE	DESCRIPTION
National Institutes of Health		
Damon Runyon Cancer Research Foundation		http://www.damonrunyon.org/
Elsa U. Pardee Foundation		http://www.pardeefoundation.org/
Hope Funds for Cancer Research		http://www.hope-funds.org/
James S. McDonnell Foundation		https://www.jsmf.org/
Sidney Kimmel Foundation		http://www.kimmel.org/
The SASS Foundation for Medical Research, Inc.		http://sassfoundation.org/
The V Foundation for Cancer Research		http://www.jimmyv.org/
Cancer-Specific Foundations/Professional Associations That Support Translational Research		
Brain Cancer		
American Brain Tumor Association		http://www.abta.org/
John McNicholas Pediatric Brain Tumor Foundation		http://www.livelikejohn.org/
Matthew Larson Pediatric Brain Tumor Foundation		http://www.ironmatt.org/
Breast Cancer		
Mary Kay Ash Charitable Foundation		Not open to MD Anderson
Susan B. Komen for the Cure		http://ww5.komen.org
Gastrointestinal Cancer		
Foundation for Digestive Health and Nutrition		http://www.gastro.org/aga-foundation/grants
Genitourinary Cancer		
Bladder Cancer Advocacy Network		http://www.bcan.org/
Urology Care Foundation		http://www.urologyhealth.org/
Kidney Cancer Association		http://www.kidneycancer.org/
Gynecologic Cancer		
Foundation for Women's Cancer		http://www.foundationforwomenscancer.org/
Marsha Rivkin Center for Ovarian		http://www.marsharivkin.org/

AWARD	DEGREE	DESCRIPTION
National Institutes of Health		
Cancer Research		
Ovarian Cancer Research Fund		http://www.ocrf.org/
HERA Women's Cancer Foundation		http://www.herafoundation.org/
Head and Neck Cancer		
American Head & Neck Society		http://www.ahns.info/
Leukemia/Lymphoma/Myeloma		
Cutaneous Lymphoma Foundation		http://www.clfoundation.org/
Gabrielle's Angel Foundation for Cancer Research		http://www.gabriellesangels.org/
Leukemia & Lymphoma Society of America		http://www.lls.org/
Lymphoma Research Foundation		http://www.lymphoma.org/
Multiple Myeloma Research Foundation		http://www.themmrf.org/
When Everyone Survives Foundation		http://www.wheneveryonesurvives.org/
Lung Cancer		
A Breath of Hope Lung Foundation		http://abreathofhope.org/
American Lung Association		http://www.lung.org/
Lung Cancer Research Foundation		http://www.lungcancerresearchfoundation.org/
Mesothelioma Applied Research Foundation		http://www.curemeso.org/
National Lung Cancer Partnership		http://www.freetobreathe.org/
Uniting Against Lung Cancer		http://www.unitingagainstlungcancer.org/
Neuroendocrine Tumors		
Caring for Carcinoid Foundation		http://www.caringforcarcinoid.org/
North American Neuroendocrine Tumor Society		http://www.nanets.net/
Prostate Cancer		

AWARD	DEGREE	DESCRIPTION
National Institutes of Health		
Prostate Cancer Foundation		http://www.pcf.org/
Sarcoma		
Desmoid Tumor Research Foundation		http://www.dtrf.org/
Sarcoma Foundation of America		http://www.curesarcoma.org/
Skin Cancer / Melanoma		
American Skin Association		http://www.americanskin.org/
Harry J. Lloyd Charitable Trust		http://www.hjltrust.com/
Melanoma Research Alliance		http://www.curemelanoma.ora/
Melanoma Research Foundation		http://www.melanoma.ora/
The Skin Cancer Foundation		http://www.skincancer.ora/
Pediatric Cancers		
Alex's Lemonade Stand		http://www.alexslemonade.ora/
Children's Neuroblastoma Cancer Foundation		http://www.cncfhope.ora/
Children's Tumor Foundation		http://www.ctf.ora/
Curesearch for Children's Cancer		http://www.curesearch.ora/
Thrasher Research Fund		https://www.thrasherresearch.ora/
Cancer Prevention		
Prevent Cancer Foundation		http://preventcancer.ora/