Expanding the Pipeline for Pediatric Physician-Scientists

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Academic departments of pediatrics strive to improve care for children and recognize that sustained progress requires creating new knowledge about childhood diseases and translating this knowledge into new care paradigms. Pediatric physician-scientists are central to this process, reflecting that they are uniquely equipped to pose clinically relevant questions that link biomedical research to clinical care for children.

The percentage of physicians devoting a significant portion of their professional time to research has decreased from 5% in 1980 to 1.5% in 2007[1] (and is likely lower now), and the absolute number of physician-scientists has been steadily declining.[2] Moreover, current physician-scientists are aging, as highlighted by the fact that the percentage of National Institutes of Health (NIH) R01 grants awarded to MD investigators over 50 years old increased from 25% in 1980 to over 50% in 2007.[1] Among the R01 equivalents awarded by the NIH to MD or MD/PhD pediatric investigators during the period between 2012 and 2017, approximately 60% were awarded to individuals at the rank of professor.[3]

With these demographic shifts in mind, it is imperative that we strengthen the pipeline for pediatric physician-scientists.

Recruiting Research-Oriented Medical Students into Pediatric Careers

Recruitment of research-oriented medical students into pediatric residencies is a key priority for increasing the pediatric physician-scientist workforce. Many medical schools incorporate significant research experiences into undergraduate medical curricula, including year-long programs such as those at Duke University and Vanderbilt University. Other medical schools offer an opportunity for an additional 1 or 2 years of scientific training, sometimes concluding with a Master's degree. Combined MD/PhD training programs account for a substantial segment of research-oriented medical trainees and now enroll roughly 5400 trainees in at least 90 programs nationally, including 45 programs that receive support from the National Institute of General Medical Sciences in the form of a Medical Scientist Training Program grant.[4] MD/PhD programs graduate approximately 600 students each year[5] (of approximately 20 000 annual MD graduates[6]). According to the Association of American Medical Colleges MD/PhD Program Outcomes Study, 12.6% of MD/PhD program graduates choose residency training in pediatrics.[7] How can we increase this percentage, and how can we recruit more research-oriented medical students into pediatric residencies?

There are 3 important strategies to enhance recruitment of medical students interested in discovery-based careers into pediatrics. The first comes through seeking opportunities to serve as research mentors for these students. Faculty should participate in research training programs appropriate to their field of research and should keep research websites current and populated with images that highlight exciting science. Participation in recruiting functions (presentations and poster sessions) provides a chance for mentors to meet students interested in research training. Engagement in the admissions process for MD/PhD candidates often influences future decisions by students about laboratory rotations, the first step in selection of a thesis laboratory. The key goal of these efforts is to attract research-oriented students for research training, including MD/PhD students, MD students who are pursuing a Master's degree, and MD students who are not pursuing an additional degree but are interested in a significant research experience. Because students are often the most effective recruiters of students, a research team that includes students is likely to continue to attract students.

A second strategy to enhance recruitment of research-oriented students into pediatrics is for pediatric faculty to teach in the preclinical medical curriculum and the graduate curriculum. These efforts will be directed at junior students before professional identity has been formed. The most

ABP	American Board of Pediatrics
ARP	Accelerated research pathway
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NIH	National Institutes of Health
PGY	Post-graduate year
PI	Principal investigator
PSDP	Pediatric Scientist Development Program

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influential forms of teaching involve continuity with learners, either in the form of delivering a series of large-format lectures or workshops, or leading a small-group discussion section as part of a larger course. These experiences offer opportunities for pediatric faculty to become knowledgeable about the professional interests of individual students and to communicate enthusiasm for research in general and for pediatric research in particular. The familiarity with students afforded by such interactions provides additional opportunities for faculty to engage with students in research or other professional activities. An equally important recruiting opportunity comes from teaching during inpatient or outpatient clinical service. Providing clinical instruction at the bedside or in the clinic, illustrating important gaps in knowledge about pathophysiology, diagnosis, treatment, and prevention, serves to highlight the many important questions in human health that could be answered by pursuing a career in Pediatrics. Furthermore, having a scientist devote time and bring passion to clinical pediatrics provides learners with a powerful example of what is possible in the career of a pediatric physician-scientist.

A third strategy to increase the number of research-oriented students who pursue careers in pediatrics is to lead by example. Academic pediatricians at all faculty ranks should find time to serve as academic advisors for medical students, especially those interested in discovery-based careers. Leading a medical student advisory college (now common at many medical schools) provides the chance to plan and implement a variety of career development activities, including sessions focused on careers in research. Faculty giving talks about their own research or career progression at research seminars or retreats attended by students offers an additional opportunity to lead. Department chairs and division directors have a special obligation to lead, by serving as role-model academic pediatricians and encouraging (and creating time for) departmental faculty to do the same. Institutional leaders should ensure that junior faculty members are included as mentors in rosters of available research training programs and that senior faculty members are nominated for research training program leadership roles.

All 3 of these strategies serve to increase the visibility of academic pediatricians for research-inclined students and to emphasize the numerous opportunities for discovery-based careers in pediatrics. Faculty should take advantage of these opportunities to project optimism in academic pediatrics and to express enthusiasm for the chance to contribute to child health through research. Indeed, there are few fields more ideally suited than pediatrics to make contributions at the interface of genetics and the environment that will literally shape our future: an exciting prospect.

Opportunities for Pediatrician-Scientist Development during Residency

Although there were times when residency was simultaneously training a clinician and an investigator, nowadays it is much more difficult for residents to combine clinical training with a substantive research experience. Are there strategies to facilitate investigative experiences for research-oriented residents during their journey to learn clinical pediatrics? This challenge falls on departments of pediatrics and pediatric residency programs.[8] Some may be able to support developing multiple research-oriented residents in a single residency class, whereas others may be able to support only 1 per year, or 1 every few years, or only through collaboration with a partner institution. Regardless, there are major advantages to supporting research experiences for research-oriented residents, not only to advance the careers of pediatric physician-scientists who may have profound impact on child health through their work, but also to expose a local environment and peers to a research mindset.

Options for Developing Pediatrician-Scientists in Residency

There are at least 3 well-defined pathways that can be used to train future pediatric physician-scientists during their residency. The easiest involves creation of an individualized curriculum that provides 6 four-week blocks for research engagement over the course of a 3-year pediatric residency, satisfying the program requirement of the Accreditation Council for Graduate Medical Education for an individualized curriculum. This approach can provide time to advance research goals and promote an ongoing process of investigation, creating career momentum. Here, research planning typically begins late in post-graduate year (PGY) 1, and the actual research takes place during the PGY2 and PGY3 years. The 2 more formal research pathways offered by the American Board of Pediatrics (ABP) are the integrated research pathway (IRP) and the accelerated research pathway (ARP). Both are considered "nonstandard pathways" and have specific and detailed requirements (https://www.abp.org/content/non-standard-pathways) designed for "committed" pediatrician scientists. A commitment to the IRP or ARP must be made within the first 9 months of PGY1, requiring approval by the ABP for the IRP and notification of the ABP for the ARP. The IRP provides an opportunity for 11 months of research during residency training, facilitating research momentum at the start of fellowship at the same or a different institution and ideally involving initiation of a project that continues through fellowship. In contrast, the ARP is a 2-year accelerated pediatric residency experience linked to a 4-year instead of a 3-year fellowship experience, resulting in an additional year of research during fellowship and often preparing the fellow for earlier transition to research independence. All 3 of these pathways require advanced planning and flexibility by a residency program and department.

Helpful Accommodations and Structures

Although the ABP has specific requirements for resident and fellow physician-scientist pathways, departments can make important contributions to ensure the success of trainees growing as investigators. A focus on "active seeking" as

opposed to "simply supporting" can create a positive culture for the recruitment of scientists through placing priority on scientific promise in resident selection. Given the usual objective metrics that define medical student success (eg, grades, standardized examinations, Alpha Omega Alpha, Gold Humanism Honor Society), how can research potential be recognized and prioritized in the process of resident selection? One strategy is to create a separate pediatrician-scientist residency track, with the program at Texas Children's Hospital representing 1 example.[9,10]

There are additional accommodations worth considering. First, given the need to engage the resident in relevant research development, the challenges presented by work duty hours should be considered proactively. As research-oriented residents can be driven by opportunity in science, it will be useful to consider service and coverage obligations during times that these residents are scheduled for research. Gone are the days when research during residency training was feasible after clinical work was done, and programs should recognize the need for dedicated research time.

Second, it is important to tailor the schedule for research-oriented residents. For example, if a resident is a budding neuroscientist and the institutional neuroscience lecture conflicts with a scheduled residency activity, an accommodation and remediation plan should be considered to foster the training and scientific advancement of this resident. In other words, when it comes to creating opportunity for research-oriented residents, flexibility is critical.

Finally, it is essential to promote structures for effective mentoring. A unifying characteristic of successful physician-scientists is the role of an array of mentors.[11] Departments can be proactive in connecting research-oriented residents with potential mentors crossing a spectrum of mentoring needs. Examples outside of a conventional primary research mentor include a clinical mentor, a career mentor, and a peer mentor. It is important that some mentors not be involved in direct, hands-on research with the resident to provide distinct perspectives of research directions and prospects for career advancement. An ideal mentoring structure will allow for transparent dialogue around the best interests of the resident with a vision toward academic differentiation and proactive fellowship transition with maintenance of research cadence.[10]

Objectives and Outcomes

Iterative objectives to enable growth and success as an investigator during pediatric residency can help prevent losing sight of research in the midst of clinical immersion. A series of goals such as incremental publications defining an area of specialization and internal grant applications to refine ideas can help maintain research momentum.[12] Ideally a research-oriented resident will be able to begin a fellowship with a "running start," prepared to take early advantage of the NIH career development award programs. This preparation may help stem the tide of longer lead times before first independent investigator awards. Furthermore, investing in research-oriented residents can offset the greater downstream costs required to support junior faculty who are just beginning to seek career development awards.

As an overarching objective, the advancement of physician-scientists should encompass a culture of research. As noted by Sir William Osler, investigating the human condition is part of being a clinical observer. Fostering the curiosity and presence of research-oriented residents within a pediatric residency can help advance a culture of investigation that can benefit all.

Nurturing Fellows as Physician-Scientists

From the standpoint of subspecialty training, fellows are the "great connectors," highly valued for linking faculty and the next generation of potential fellows (residents and students). However, their very close association with a subspecialty may hamper their understanding of the institution, their exposure to possible mentors, and their ability to form research collaborations beyond the walls of the subspecialty. Thus, grooming fellows for careers as physician-scientists must incorporate strategies to elevate them beyond divisional boundaries.

In honing many of these strategies over the past 32 years, the Pediatric Scientist Development Program (PSDP), a National Institute of Child Health and Human Development-funded career development program for US and Canadian pediatric fellows (75% MDs, 25% MD/PhDs), provides some approaches that can be adapted to institutional fellowship programs to overcome both the shortage of fellows seeking research careers and the vagaries of extramural funding. Based on ABP work force data, of 3040 PGY3s, 38% (1170) will enter a fellowship, but only 250 will have a stated interest in a research career.[13] After funding by an NIH T32 grant, only 7% of MD fellows and 19% of PhD fellows serve as principal investigator (PI) of a research project grant (RPG; R01, R03, R15, R21, R34).[14] In contrast, 49.4% of 192 PSDP graduates are PIs of an RPG (331 NIH grants, including 73 K awards and 89 R01s). A return-on-investment analysis shows that the $60 million invested by the National Institute of Child Health and Human Development since 1990 has yielded more than $533 million in NIH grant awards to PSDP graduates serving as PIs, but it is important to understand that these returns required a "germination period" of approximately 10 years before grant awards to PSDP graduates as PIs surpassed annual NIH investment.

Four specialized approaches to expand the cadre of physician-scientists among fellows and to maximize return-on-investment have proven highly advantageous.

Mentoring

Although a scholarly oversight committee largely confined to division faculty may provide good guidance to those fellows seeking a clinical career in the subspecialty, physician-scientists will benefit from a multidisciplinary approach. Well-funded mentors outside the division and even outside the walls of a department of pediatrics provide great value

in their expertise and offer the fellow a far broader career network than could be obtained within the confines of the division.

A peer mentor (or "life" mentor) is also useful for physician-scientists in fellowship, because trainees may be reluctant to discuss issues such as work/life balance or childbearing with senior faculty.

Explicit Expectations: The 2-Way Street

Subspecialty training has been well served by the requirement of an approved scholarly work product before board eligibility is approved. In addition, physician-scientists in fellowship must receive explicit guidance about balancing clinical and research responsibilities. Although the PSDP expects that no clinical responsibilities will be assigned to fellows in their first 2 years of the program, this expectation may not be feasible in all subspecialty divisions. Instead, front-loading clinical responsibilities into the first 14-18 months of a 3-year fellowship can provide the research-intensive time required for development of physician-scientists.

Fellows must also understand that there is a timetable for repaying the privilege of protected time: an abstract after ~18 months of research, a first-authored paper within 24 months of research, and a K application within the first 2 years of a faculty appointment. These goals must be reiterated and supported by the scholarly oversight committee.

Scientific Network

When the potential physician-scientist works with a well-funded faculty member in the subspecialty division, efforts to broaden the scientific network must be a priority. Approximately 70% of PSDP fellows receive research training outside their respective departments of pediatrics. Encouraging the potential physician-scientist to find the best mentor at the institution for his or her topic, rather than the best one in the division, is key. The goal should be to transcend lab boundaries or divisional walls to enable the fellow to build a scientific network that may extend beyond the subspecialty division.

A proven model is the assembly of PSDP fellows at the annual meeting of the Association of Medical School Pediatric Department Chairs, with poster and platform presentations for second- and third-year PSDP Scholars. In modifying this approach for small and large departments of pediatrics, a "Fellows' Crosstalk" has been a game-changer. As practiced at Yale (~40 fellows) and at Cincinnati (~200 fellows), Fellows' Crosstalk is a twice-monthly gathering at which 2 fellows from different divisions give 15-minute platform presentations of their research from a common template. With faculty facilitators, fellows in the audience are divided into 3 groups to comment on (1) strengths of the presentation; (2) areas needing improvement; and (3) opportunities for collaboration. Having fellows provide feedback in a group format absolves any single commentator from the burden of negative feedback, and the suggestions for collaboration almost always lead to exciting new avenues of research. Early in the academic year (July-October), presentations come from fellows who are just beginning their research studies. This approach facilitates modifications of the research program before it is irretrievably underway. Fellows' Crosstalk has yielded outstanding results, summarized in the Table and publication.[15]

Table. Goals and results of Fellows' Crosstalk[15]

Anticipated goals	Actual results
Interactive forum for feedback	82% participation from ACGME-accredited programs
Development of effective presentation skills	67% reported new knowledge of essential presentation skills
Transdisciplinary interactions	90% reported new knowledge 78% introduced to new collaborators
Guidance on developing grant proposals	33% increase in publications, 8% increase in extramural funded grants

ACGME, Accreditation Council for Graduate Medical Education.

Multidisciplinary mentoring, explicit expectations, opportunities to expand the scientific network, and a forum for shared communication of research contribute positively to the development of pediatric physician-scientists during fellowship.

Positioning Junior Faculty for Success as Investigators

Institutional financial pressures have narrowed the interval available to young faculty to achieve success in the physician-scientist career pathway, generally defined as obtaining independent funding, such as an NIH R01 award or equivalent. Academic institutions and their leaders can play important roles in maximizing the likelihood of success by providing purposeful and thoughtful institutional support.

How to Decide to Whom to Offer a Research Track Appointment

It typically takes at least 5 years of research experience to make a successful transition from mentee to independent investigator. Most graduating pediatric fellows will have 2 years of research at most as part of their fellowship training and will need a few more years of mentored research training. It is ideal for this training to be continuous, aiming to maximize productivity during this critical stage of career development. This training experience includes developing a track record of publications and the preliminary data required to compete for external funding. With this information in mind, there are distinct advantages for a graduating fellow to remain at his or her current institution with his or her current research mentor, continuing the project that was initiated during fellowship until obtaining a K award. Leaving the institution earlier runs a substantial risk of disrupting the momentum that the trainee has hopefully developed. Exceptions might be an individual with a PhD or other substantial prior research experience. In addition, personal circumstances may necessitate an earlier move.

When considering appointing a graduating fellow to a faculty position, helpful criteria include demonstrated passion

for a research career, a track record of productivity, favorable input from the fellow's research mentor, and evidence of aptitude for research. One way to assess aptitude is to have the candidate give a "chalk talk" attended by senior faculty who can evaluate the candidate's thought process and mastery of his or her area of research. The same approach is applicable when considering a candidate who is already a junior faculty member at another institution.

Expectations and Milestones for Junior Faculty

It is helpful to provide junior faculty with defined milestones and to request that they submit an annual progress report demonstrating progress toward achieving those milestones. Appropriate milestones will generally include 2-3 peer-reviewed publications annually, successful application for a K award or equivalent within 2-3 years of completing fellowship, and an independent award, such as an R01 or equivalent, prior to expiration of the K award. Assignment of a minimum of 40% effort on the first R01 submission is reasonable. It is important to be flexible with these milestones if the candidate is making good progress.

How to Develop an Appropriate Startup Package

Mentorship is the most critical resource that the department can provide. Outstanding scientific mentorship is so critical that if an appropriate senior scientific mentor with expertise in the candidate's research and a commitment to be available to the candidate is not available, offering a faculty appointment may be unwise. A number of departments of pediatrics have created a mentor-mentee contract that spells out the expectations of both the mentor and the mentee. This contract includes a commitment to meet at least weekly to discuss the mentee's research and the establishment of a mentoring committee that should meet at least once every 6 months. The mentoring committee assists the junior faculty member in developing a 3-year career development plan, which is submitted to departmental leadership and updated after each committee meeting. The University of Iowa has also established a peer mentoring forum called K Club, where young faculty present their research and their grant proposals to both peers and senior faculty for feedback and discussion.

In addition to a senior research mentor, a typical support package includes a commitment of funding, tailored to the individual needs of the candidate and covering the cost of a technician or research assistant, supplies or other consumables, and animals (if appropriate) for an initial period of 3 years, along with 70%-80% protected time. Further support is forthcoming upon achieving funding milestones. Obtaining a K award results in additional funding and continued protected time. Obtaining an R award results in independent laboratory space, including equipment for that space.

Resources to support a startup research package can come from a variety of sources, including department funds, school of medicine funds, philanthropic funds, intramural grants, institutional training grants, and foundation career development awards, with variability from one institution to another.

Maximizing the likelihood of success requires careful assessment and selection of candidates, outstanding mentorship, protected time, and sufficient financial support to allow faculty to generate the preliminary data needed to successfully compete for external funding and graduate to independent investigator status.

As we strive to improve child health, it is essential that we strengthen the pipeline of pediatric physician-scientists, addressing contributors at all levels, including medical students, residents, fellows, and faculty. Our departments of pediatrics are filled with talented people who have the potential for success as physician scientists, in particular with a supportive environment, appropriate resources, and thoughtful guidance. ■

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