

The Highly Structured Physician Scientist Training Program (PSTP) for Medical Students at the University of Pittsburgh

Richard A. Steinman, MD, PhD, Chelsea N. Proulx, MPH, and Arthur S. Levine, MD

Abstract

The University of Pittsburgh School of Medicine Physician Scientist Training Program (PSTP) is a 5-year medical student training program designed to prepare the next generation of MD-only physician-scientists engaging in preclinical research. This article provides an overview of the program, including the novel longitudinal structure and competency goals, which facilitate success and persistence in a laboratory-based physician-scientist career. The authors present data on 81 medical students accepted to the program from academic year 2007–2008 through 2018–2019. Extrinsic outcomes, such as publications, grant funding, and

residency matching, indicate that PSTP trainees have actively generated research deliverables. A majority of eligible PSTP trainees have earned Howard Hughes Medical Institute Medical Research Fellow funding. PSTP students have produced a mean of 1.6 first-authored publications (median, 1.0) and a mean of 5.1 total publications (median, 4.0) while in medical school and have authored 0.9 publications per year as residents/fellows, excluding internship. Nearly 60% of PSTP students (26/46) have matched to top-10 National Institutes of Health-funded residency programs in their specialty (based on Blue Ridge Institute rankings).

PSTP alumni are twice as likely as their classmates to match into research-heavy departments and to publish first-authored papers. Results of a 2018 program evaluation survey indicate that intrinsic outcomes, such as confidence in research skills, significantly correlate with extrinsic outcomes. The program continues to evolve to maximize both scientific agency and career navigation skills in participants. This medical student PSTP model has potential to expand the pool of physician-scientist researchers in preclinical research beyond the capacity of dedicated MD-PhD and postgraduate training programs.

A revolution is now at hand: Medicine is improving the human condition through innovations like whole genome sequencing, functional magnetic resonance imaging and tomographic cryo-electron microscopy, immune manipulation, genome editing, artificial intelligence, and machine learning. PhD-trained scientists have contributed to these revolutionary advances in medicine, but they cannot draw from clinical observation to optimize the application or to inform the development of these

advances. Historically, MD investigators have thrived at the upper echelons of research, receiving 41% of basic research Lasker Awards (1984–2014) and 37% of Nobel Prizes in Physiology or Medicine (1989–2014).¹ Between the wars in Korea and Vietnam, the United States had a physician's draft, and one way for men to meet their military obligation was to undertake research training and experience at the National Institutes of Health (NIH), Centers for Disease Control and Prevention, and/or other federal entities. This resulted in a cadre of exceptional young physician-scientists, many of whom now work at a senior level in institutions nationally.^{2,3}

The pipeline has changed, and the current generation of physician-scientists is inadequate to fill future needs.^{1,4,5} MD-only (versus MD-PhD) trainees may represent an underdeveloped pool of potential physician-scientists to continue to advance the biomedical enterprise. In 2012, only 0.9% of physicians had NIH research grants, and half of these were MD-PhDs—despite the 33-fold excess of MD-only graduates compared with MD-PhD graduates.^{6,7} This percentage represents a decrease over a decade (from 77% in 2000 to 55% in 2010) in the proportion of physician-scientist

R01-equivalent grants (i.e., health-related research and development grants) awarded to MD-only applicants.^{6,7} Similarly, the percentage of MD-only scientists applying for and receiving awards from foundations has fallen.⁸

Compared with MD-PhDs, MD-only trainees generally lack the intensive exposure to role models, debt minimization, supportive infrastructure, and esprit de corps through which Medical Scientist Training Programs (MSTPs) promote identity formation and expertise in the MD-PhD students training for careers as physician-scientists.^{9,10} Barriers to recruitment into physician-scientist paths include inadequate exposure to successful role models, immersion in a culture supportive of a primary identity as clinicians, and limited access to structured training programs.^{11–13}

Preprofessional research-intensive options involving MD-only (i.e., non-MD-PhD) students have included single-year-out research programs (e.g., the program described by Laskowitz and colleagues¹⁴), the 2-year-out NIH Clinical Research Training Program (in effect from 1997 through 2002),¹⁵ the NIH Medical Research Scholars Program, and foundation-sponsored year-out

Please see the end of this article for information about the authors.

Correspondence should be addressed to Richard A. Steinman, 2.26f Hillman Cancer Center, 5117 Centre Ave., Pittsburgh, PA 15213; telephone: (412) 623-3237; email: Steinman@pitt.edu.

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programs, including the Howard Hughes Medical Institute (HHMI) Medical Fellows program (which ended in 2018).¹⁶ These programs have generally begun after the second-year of medical school and lack a research curriculum integrated with medical school curricula.

The University of Pittsburgh School of Medicine (Pitt SOM) instituted a medical student Physician Scientist Training Program (PSTP¹⁷) distinct from its MD–PhD program in 2007 to support the most competitive medical students who are committed to laboratory-based careers as physician–scientists. Unlike traditional year-out medical student laboratory research options, the PSTP offers a longitudinal research enrichment curriculum. We describe the structure, curriculum (including the competency goals), and outcomes of the program, as well as feedback from program graduates. We conclude with a discussion of the results of our evaluation in the context of existing programs and future directions.

Program Overview

PSTP structure, costs, and administration

The PSTP is structured as a 5-year program to support the development of medical students who plan careers that integrate basic/translational research and clinical medicine. Those interested in clinical research are not candidates for this program. PSTP students complete the standard Pitt SOM curriculum (though one Pitt SOM research-preparatory course is waived), and they take 6 additional PSTP-designed courses, as well as 2 summer laboratory rotations. All PSTP students complete a year of research between their second and third years of medical school, after they take the United States Medical Licensing Exam Step 1. A subset (5 of 81 or 6%) of PSTP students have chosen to continue full-time research for a second year. For those individuals completing 2 years of dedicated research, a customized 2-week, nongraded, noncredited inpatient rotation is available to facilitate their reentry into medical school.

PSTP students receive a stipend (\$3,500) during their 2 summer laboratory rotations. During their research year, they receive another stipend (\$30,250, split with the mentor) and health insurance. Individuals electing to undertake a

second research year have been supported through non-PSTP funds (second-year HHMI support, NIH R01 supplements, or other grants). PSTP students also receive a \$10,000 tuition credit for each year they remain in the program, as well as up to \$3,000 for approved scientific meetings. Pitt SOM supports operational costs, PSTP stipends, tuition costs, and a 0.5 full-time exempt program manager. The overall costs average \$578,000 per year (\$112,000 in administrative costs, \$222,000 in stipends and travel, \$4,000 for executive coaching [see below], and \$240,000 for tuition credits).

Leadership consists of the PSTP director (R.A.S.) along with 3 physician–scientists who constitute the PSTP Promotions/Steering Committee. Additional faculty serve as instructors, career advisors, and/or members of the PSTP Admissions Committee.

Admission into the program

All applicants who are invited for Pitt SOM interviews receive invitations to submit a supplemental application to the PSTP, and about a quarter of those interviewing participate in an optional PSTP informational session (i.e., 1,123 of 4,728 [24%] in academic year 2018–2019). The PSTP Admissions Committee considers individuals who have been accepted or wait-listed by Pitt SOM and invites select PSTP applicants for interviews in January prior to their matriculation into medical school. Over the past 4 academic years (2015–2016 through 2018–2019), the number of PSTP applications has averaged 145 per year. The pool of individuals initiating PSTP applications over that period has been 54% (313) male and 46% (267) female, 12% (70) underrepresented minorities (URM), and 4% (23) international students.

The PSTP accepted 81 medical students, including 39 women (48%), 3 students from URM backgrounds (4%), and 2 international students (3%), between 2007–2008 and 2018–2019. Of these 81, 45 (56%) completed and graduated from the program, 30 (37%) were still enrolled at the time of this analysis, 1 (1%) left the program, and 5 (6%) applied to and were accepted internally into the Pitt SOM/Carnegie Mellon University MSTP during their PSTP research year. The mean grade point average (GPA) of the 2014–2015 through 2018–2019 matriculants ($n = 35$) is 3.78 (range, 3.12–4.00; median,

3.85), and their mean Medical College Admission Test (MCAT) score (including only scores on the 2015 or later versions) is 516.4 (range, 507–524; median, 516). These metrics are comparable to the most recent (2018–2019) Pitt SOM applicant pool (GPA, 3.74 [range, 2.6–4.0; median, 3.81]; MCAT score, 516.4 [range, 499–527; median, 518]). The PSTP focuses on MD-only trainees, but on rare occasions (5 enrollees since the 2007–2008 academic year) it admits incoming medical students with PhDs in basic research who justified the added value of further research training with a translational focus to complement their existing skill set. None of the PSTP students applied to the MSTP, and the programs appear to draw from distinct cohorts—only 4 (12%) of current (including incoming in fall 2019) PSTP students had applied to any MSTP, and of these, half chose the PSTP over the MSTP (though they were accepted into both programs). Informal feedback indicates that applicants have not applied to traditional MD–PhD programs for the following reasons:

- They desire a more compressed training time-course;
- They desire a faster transition to the clinical years;
- They have international status (which limits their MSTP options); and/or
- They already have a PhD.

We matriculate up to 8 students per year. Limited spots are available for internal applicants to the program (who may apply during their second year of medical school).

Oversight

At the start of medical school, each PSTP student is assigned a physician–scientist (or rarely a PhD-only) career advisor in their general area of scientific and/or clinical interest who is distinct from the research mentor. The PSTP career advisors, chosen based on an established record of both mentoring and academic experience, meet with the student at least twice yearly throughout the student's tenure at Pitt SOM to offer feedback and guide reflection. The career advisor reviews and discusses the trainee's progress, plans, biosketch (which students should continually update), and reflective self-assessment. The PSTP Steering/

Promotions Committee annually reviews nonconfidential career advisor input and the trainee's status relative to the program's good standing criteria.

Curriculum and competencies

Courses in the PSTP curriculum focus on professional development skills, biostatistics, grant proposal and abstract/paper writing, experimental design, and critical analysis of the literature. The goals, objectives, and activities of each course are summarized in Supplemental Digital Appendix 1 at <http://links.lww.com/ACADMED/A802>. The courses introduce or reinforce competencies as summarized in Table 1. Students' achievement of competencies is assessed through instructor and peer assessment, self-reflective writing exercises, written homework, presentations, and programmatic review of milestones (e.g., career development plan goals) and deliverables (e.g., biosketches, grant proposal drafts). All PSTP students take a 3-semester weekly journal club/seminar course with their MSTP classmates to bolster the intellectual and social interaction between these 2 groups. The PSTP students attend a distinct (PSTP students only) mandatory, one-day annual scientific retreat.

In addition to mastering scientific and medical material, the PSTP provides an important opportunity for students to develop agency in balancing competing research, clinical, and nonacademic demands and to frame plans for meeting personal and professional goals through skillful time management. PSTP trainees are exposed to these topics in workshops, during meetings with role models in professional development courses, and, in later iterations, through individual sessions with professional coaches.

Data Collection and Analysis

This program evaluation focuses on the 12 PSTP cohorts enrolling from June 2007 through June 2018. We have limited our analysis to those who were admitted into and completed (or are on track to complete) the PSTP; therefore, we have excluded the 5 individuals who transferred from the PSTP to the MSTP partway through their medical school training and the single student who left the program. We have applied no other exclusion criteria (e.g., research duration, degrees prior to PSTP enrollment).

Through tracking, surveying, and reviewing the curriculum vitae (CVs) of PSTP participants, we collected data related to both extrinsic factors (e.g., publications, grants, other deliverables) and intrinsic factors (e.g., confidence in research skills, facilitators/barriers for a physician–scientist career) that contribute to persistence and success in academia.¹⁸ To collect intrinsic measures, we developed and distributed an online Qualtrics survey (Qualtrics, version 12/2018, Provo, Utah) via an anonymous link to 75 current and past PSTP trainees in the winter of 2018. The University of Pittsburgh Institutional Review Board approved the protocol to survey and collect CVs from this population.

Publications and grants

We collected metrics of scholarly output, including the number of all first-authored and coauthored publications, the number of national/regional presentations, and the number of grant applications submitted and funded. Through reviewing CVs, we collected information about the types of grant applications submitted and the types awarded. Additionally, we collected from PubMed all publications attributable to PSTP graduates' time as medical students (i.e., articles based on work in medical school). Accounting for any last name changes, we tabulated these publications for all alumni up to those graduating in 2018. We checked ambiguous listings against the student's CV when available and against the final research report (i.e., the scholarly research project) submitted by the student to the PSTP just before graduation. We collected publications attributable to the postgraduate (either residency/fellowship or early career) period from PubMed, CVs, and LinkedIn profiles. We attributed these publications to the postgraduate period if the affiliation the authors listed as their postgraduate institution(s) matched existing Pitt SOM records and/or if the publication focused on a specific postgraduate research/academic topic known to be a focus of the graduate. We excluded then-current interns (academic year 2018–2019) from analyses of postgraduate publications.

Matching to research-focused departments for residency by PSTP trainees versus other students

We analyzed whether the PSTP trainees chose and matched to clinical

departments with robust NIH support as an indicator of potential post–medical school exposure to career models and instructive projects. For this analysis, we extended the span of trainees to include those matching in spring 2019 for whom match results were newly available. We examined residency match rankings for all 1,434 Pitt SOM graduates since 2010. We used the Blue Ridge Institute's rank listing of department NIH funding for each specific graduation year,¹⁹ to determine the NIH funding of each graduate's departmental match. For 2019 matches, ranks were not yet available, so we used the 2018 listings instead. For those in plastic surgery (for which Blue Ridge does not provide a ranking), we used the rankings listed in Silvestre and colleagues' report.²⁰ We ascribed combined training programs to just one departmental ranking (e.g., we gave those in a medicine–pediatrics program the associated internal medicine ranking). Departments or hospital matches excluded from Blue Ridge¹⁹ and Silvestre et al²⁰ (e.g., radiation oncology, maxillofacial surgery) accounted for 131 (9%) of residency matches during the 10-year period.

Measurement of facilitators and barriers to careers as physician–scientists

The survey tool we developed for current and past MSTP students included questions addressing the barriers and facilitators respondents envisioned encountering as they pursued physician–scientist careers. We adapted some questions from published studies on challenges facing academic surgeons and medical subspecialists,^{12,13,21–24} and we adopted other questions from consultations with established physician–scientists at the University of Pittsburgh. The final tool listed 12 potential facilitators and 15 potential barriers that respondents rated on a 5-point Likert-type scale from “not at all influential” to “extremely influential.”

Data analysis

We compared the number of publications and research residency ranking between HHMI and non-HHMI recipients by 2-tailed *P* values using Mann–Whitney tests. *P* values correlating survey responses used simple linear regression. Correlations used nonparametric methods and are reported using Spearman's *r* due to the right-skewed distribution of many of our

Table 1

Competency Goals as Met by Components of the University of Pittsburgh School of Medicine Physician Scientist Training Program^a

Competencies	Rotations	PD1	PD2	RBMK	Research year	Workshops	Reentry	Committee	CA
Cognitive									
Recognize innovative and significant science		✓	✓	✓					
Articulate strong and weak components of research plans/papers			✓	✓					
Develop compelling and well-supported hypotheses and research strategies	✓		✓		✓				
Identify whether given experiment/plan is Type A, B, or C ^b		✓	✓		✓				
Propose experiments grounded in state-of-the-art literature and techniques	✓				✓				
Develop a coherent approach to working through ethical/integrity challenges						✓			
Articulate factors influencing experimental reproducibility		✓			✓				
Choose and use statistics and graphical design properly		✓	✓	✓	✓				
Professional development									
Enhance work quality by accepting/responding to criticism			✓	✓					
Identifying strengths/weaknesses of mentor/mentee match and strategies to optimize interactions and outcomes		✓			✓				✓
Frame and adapt a detailed career development plan with milestones and evaluation criteria			✓						✓
Develop and execute a networking strategy			✓			✓			✓
Devise a strategy to fill gaps in scientific knowledge	✓	✓			✓				
Devise a strategy to fill gaps in professional skills					✓	✓			
Develop collaborative and communication skills (peer and others)		✓			✓	✓			
Productivity oriented									
Integrate clinical and research roles		✓					✓		
Write clear, coherent abstracts and papers	✓				✓				
Write clear, thoughtful, and compelling grant proposals			✓						
Present own research eloquently (both formally and informally)	✓	✓	✓		✓				
Collaborate to answer scientific/ethical questions						✓		✓	
Collaborate in support of social learning and curriculum						✓		✓	
Apply literature analysis to technical and intellectual labwork and build troubleshooting skills	✓		✓		✓				
Strategically identify rotation laboratories		✓							✓
Achieve deliverables including publications, grants, national presentations	✓				✓				

Abbreviations: PD, Professional Development; RBMK, Research Basis of Medical Knowledge course; CA, career advisor.

^aElements of the physician–scientist training program include two 10-week summer research rotations, 2 summer-long professional development courses (PD1, PD2), a 3-semester course called Research Basis of Medical Knowledge that meets weekly, a dedicated research year, monthly work-in-progress talks, and topical workshops (including on ethics), a postresearch year transition with surrogate patients (reentry), committee work, and twice-yearly meetings with an individual program-specific career advisor. Details of the courses are available in Supplemental Digital Appendix 1 at <http://links.lww.com/ACADMED/A802>.

^bType A: any result is informative; Type B: a certain result is informative but if the alternative occurs it is uninformative; Type C: Results are uninformative or do not move beyond description.

outcome measures (publications, rate of publications, research residency percentile rank). We conducted comparisons of NIH funding between residencies matched by PSTP, MSTP, and other Pitt SOM medical students through 1-way analysis of variance with Tukey correction for multiple comparisons, assuming a percentile rank of 100 for any matches to residency departments not listed on the Blue Ridge Institute NIH ranking list.¹⁹ We considered differences significant at the $P < .05$ level. Open-ended comments on the survey (focused on additional facilitators and barriers) were coded and subjected to a thematic analysis.

Research Outcomes of PSTP Trainees During Medical School and After Graduation

Publications and grants during the PSTP

Of 45 PSTP graduates, 41 (91%) have authored at least one publication and 30 (67%) have served as first author on at least one publication based on their medical school work. These percentages compare favorably to the proportions of non-MSTP/non-PSTP Pitt SOM students who have authored articles—of whom 55% have authored articles and 30% have served as first author at least once (see Conroy et al²⁵ and the Pitt SOM 2018 Scholars Report, unpublished). Since the program's inception, PSTP graduates have authored a mean of 5.1 publications (median 4.0) and served as first author on 1.6 articles (median 1.0) that are attributable to work while in medical school. Not surprisingly, total

number and number of first-author publications per student are correlated ($r = 0.751$, $P < .0001$). Supplemental Digital Appendix 2 (at <http://links.lww.com/ACADMED/A802>) shows the mean number of publications per student grouped by year of graduation.

Of 47 eligible PSTP students who applied for HHMI Medical Scholar grants during their PSTP training, 25 (53%) received awards (of whom 3 subsequently applied for and received a second-year award). This rate exceeds the national award rate of 36% as published in 2010 by HHMI.²⁶ Other grants that PSTP students have obtained during their PSTP training included NIH R01 research grant supplements; an intramural NIH TL1 training grant; as well as other foundation, specialty society, and institutional grants—totaling 15 awards.

Residency training at academic institutions

At the time of this analysis, 45 PSTP trainees had graduated from medical school between academic years 2009–2010 and 2018–2019 and an additional 6 fourth-year PSTP students had participated in the Match. All of these 51 PSTP trainees matched to academic programs. Forty-three matches (84%) were to clinical departments that were ranked by NIH funding by the Blue Ridge Institute,¹⁹ and 3 matches (6%) were to plastic surgery for which we used the rankings as listed by Silvestre and colleagues.²⁰ The remaining 5 (10%) matches were to programs unavailable for analysis.

Of the 46 PSTP graduates whose matched departments had available NIH funding rankings, 26 (57%) matched to top-10 residency programs in their specialty and 33 (72%) matched to the top quartile of programs on the Blue Ridge Institute ranked lists.¹⁹ As shown in Table 2, the PSTP students matched into leading research-focused residency departments at a rate comparable to students earning MD–PhDs in our MSTP program and at a significantly greater rate than other Pitt SOM students. The mean NIH rank of programs matched by PSTP and MSTP students was not significantly different; however, the mean NIH rank of programs matched by other Pitt SOM students was significantly lower than either PSTP or MSTP graduates ($P < .001$). Notably, we did not include matches to Harvard hospitals in the above determinations because their associated departmental NIH funding is excluded from Blue Ridge statistics.¹⁹ As shown in Supplemental Digital Appendix 3 at <http://links.lww.com/ACADMED/A802>, exploratory inclusion of these matches, presuming Harvard hospitals are in the NIH's top 10 by funding, had no effect on the main conclusions.

Publications following graduation from the PSTP

At the time of this analysis, 24% (11/45) of PSTP graduates had finished all postgraduate training, 56% (25/45) were in residency, and 20% (9/45) in fellowship. Figure 1A (total publications) and Figure 1B (rate of publications) show that students continued to publish articles following graduation from the

Table 2

Matching of PSTP, MSTP, and Other University of Pittsburgh School of Medicine Students Into Research Residencies in Departments Ranked for NIH Funding by the Blue Ridge Medical Research Institute^a

Program	Graduate year	Number of graduates	Matched to top-10 NIH-funded residency in specialty, No. (%)	Matched into residencies ranked by NIH funding, No. (%)		
				Top 25% of NIH-funded residency programs	Residency programs ranked at the 26th to 50th percentile	Residency programs ranked below the 50th percentile
PSTP	2010–2019	46	26 (57)	33 (72)	7 (15)	6 (13)
MSTP	2010–2019	76	40 (53)	53 (74)	8 (11)	15 (20)
Non-MSTP, non-PSTP	2010–2019	1,181	350 (30)	516 (43)	209 (18)	456 (39)

Abbreviations: PSTP, Physician Scientist Training Program; MSTP, Medical Scientist Training Program; NIH, National Institutes of Health.

^aThese numbers include only residency programs ranked by the Blue Ridge Institute¹⁹ or plastic surgery programs as listed by Silvestre and colleagues.²⁰

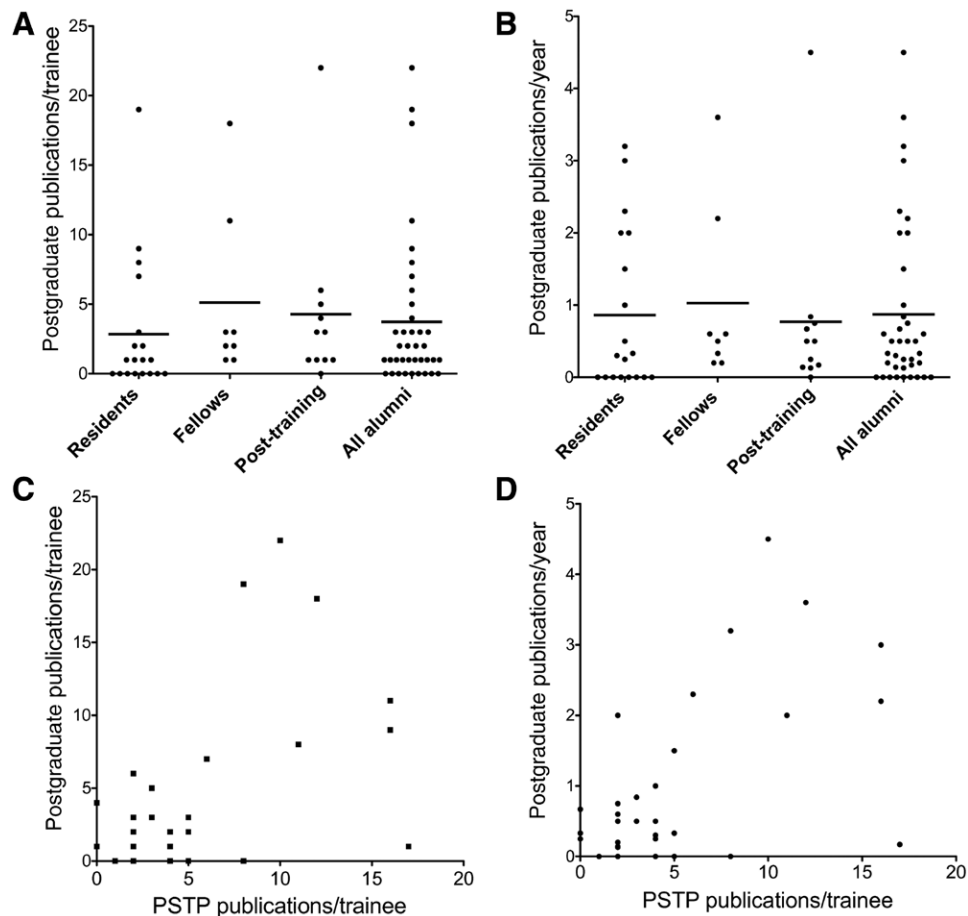


Figure 1 Publications following graduation from the University of Pittsburgh Physician Scientist Training Program (PSTP). Each graduate is represented by a dot. The top 2 figures show publications grouped by the current stage of the PSTP graduate, specifically (A) the total number of publications and (B) publication rate per year for each graduate. The heavy horizontal bar indicates the mean for that training stage. The bottom 2 figures show the publications per trainee attributable to their time as medical students in the PSTP graphed against (C) their total number of postgraduate publications and (D) their yearly rate of publications following graduation.

PSTP. Seventy-four percent of graduates (28/38 postinternship) published during their training or early career, and 53% (20/38) had published at least one first-authored paper unrelated to their work during medical school.

The mean number of postgraduate papers (including coauthorships) for PSTP graduates who were post internship was 3.7 per trainee at a pace of 0.87 papers per year. The rate was 0.86 papers per resident per year and 1.03 papers per fellow per year. Figure 1C highlights the relationship between each individual PSTP graduate's number of postgraduate publications and their PSTP publications based on their work during medical school. These measures of productivity correlate with a Spearman $r = 0.42$ ($P = .009$). The number of publications as a PSTP medical student also correlates with postgraduate publications per year (Figure 1D; $r = 0.42$, $P = .008$).

PSTP graduates continue to author articles in the basic sciences, which, collectively, represent 36% of all PSTP graduates' postgraduate publications following residency. Half of the graduates at this stage published in basic science. As many PSTP graduates published first-authored basic research articles as published first-authored clinical articles. These efforts resulted in more clinical research than basic research papers, however (Table 3).

PSTP graduates' grant support and academic appointments

During residency/fellowship training, 12 graduates (27% out of 45) received a total of 14 foundation or institutional grants.

Of 11 PSTP alumni who finished training (i.e., completed their residency/fellowship programs) by 2018, 7 (64%) began academic positions (i.e., as either instructors or assistant professors)

and 5 (45%) are conducting research. This rate surpasses the 16%–20% rate of academic employment reported at similar time to follow-up for the NIH Cloister and Medical Research Fellows Program^{16,27} and parallels a 65% academic appointment rate reported for MSTP graduates.²⁸

PSTP trainee perceptions of physician–scientist training

We surveyed current and past PSTP students to understand, at a deeper level, the program elements that they viewed as most or least valuable and what they perceived to be facilitators and barriers for progression and persistence as a physician–scientist. Of the 75 PSTP students and graduates to whom we sent the email survey, 69 (92%) initiated a response. Due to incomplete data, we included the responses of 51 PSTP participants (68%; 25 medical students, 19 resident/fellows, 7 physicians post-

Table 3

Characteristics of Publications by University of Pittsburgh School of Medicine Physician Scientist Training Program Graduates^a

Metrics	Basic research, No. (%)	Clinical research, No. (%)	Review articles or case reports, No. (%)
All publications (n = 87)	31 (36)	35 (40)	21 (24)
First-authored publications (n = 28)	12 (26)	24 (51)	11 (23)
PSTP graduates (in fellowship training or beyond; n = 19) with a post-MD publication	10 (53)	9 (47)	13 (68)
PSTP graduates (in fellowship training or beyond; n = 19) with a post-MD <i>first-authored</i> publication	6 (32)	6 (32)	9 (47)

^aThe data include program participants who graduated in 2010–2015 who were in fellowship training or beyond. Basic indicates basic/translational work that was laboratory based or involved algorithm development and image analysis; clinical research involved analysis of patient or population databases; and review articles and case reports were explicit as such. Authors reviewed titles, abstracts, or, as needed, the full article to determine category.

training) in the final sample. Of these, only 2 (4%) reported low interest in continuing to do research in the future. On average, respondents spent 23% of their effort conducting research, 3% teaching, 58% providing clinical service, and 1% working in administration. Of the 26 respondents at the residency/fellowship or early-career stages, 80% reported some research with an average effort of 36% (range, 0%–90%). Clinical service encompassed 54% of effort (range, 15%–99%). Half of the postgraduate respondents planned to continue basic research; half, translational; and none, clinical research. In addition to scaled survey responses, we examined free-form comments, grouping them for thematic analysis (comments summary, Supplemental Digital Appendix 4 at <http://links.lww.com/ACADMED/A802>). Of the 45 who submitted comments, 44 (98%) identified at least one aspect of the PSTP as useful in their careers.

Confidence in research skills

To assess PSTP students' and graduates' confidence in research skills, we used a modified version of the 12-item Clinical Research Appraisal Inventory (CRAI).²⁹ We modified the CRAI after consulting with practicing physician–scientists to reflect confidence in skills relevant to researchers both in and outside of clinical research, including basic science researchers. Our modification resulted in an 8-item instrument. Respondents could rate their confidence on each item, using an 11-point scale, with 10 indicating highest confidence and 0 indicating no

confidence (see Supplemental Digital Appendix 5 at <http://links.lww.com/ACADMED/A802>).

Current PSTP students reported less confidence in research skills than those who had completed their postgraduate training. We noted several correlations between different research skills:

- confidence in writing a results section strongly and positively correlated with confidence in writing a discussion section ($r = 0.78$) and
- confidence in drafting a competitive specific aims page highly and positively correlated with arranging for constructive feedback on a grant application ($r = 0.80$).

Furthermore, confidence in the ability to write a results section ($P = .003$), in the ability to write a discussion section ($P = .001$), and in the ability to identify faculty collaborators ($P = .027$) all significantly predicted total publications; those reporting higher confidence authored more publications.

Survey comments were consistent with planned PSTP-focused competencies. To illustrate, most respondents identified the opportunities to generate scholarly output and to develop and improve research skills as highly useful features of the PSTP program.

Perceived facilitators and barriers to persisting as physician–scientists

PSTP students and graduates rated factors that could facilitate training as

a physician–scientist (Supplemental Digital Appendix 6 at <http://links.lww.com/ACADMED/A802>). Overall, they indicated that the 2 factors of greatest importance were (1) having access to a role model who is a physician–scientist and (2) identifying a research question and project that aligns with one's passion. According to the free-form comments of 42 respondents, other perceived facilitators to persisting in a career as a physician–scientist included the following: funding opportunities, mentoring, protected research time, the availability of dedicated postgraduate research tracks, and exposure to a broad range of physician–scientist role models.

According to their survey responses, and consistent with prior reports,^{13,30} PSTP students and graduates viewed inadequate funding as a major barrier in pursuing a successful physician–scientist career (see Supplemental Digital Appendix 4 at <http://links.lww.com/ACADMED/A802>). Notably, PSTP respondents considered time management an equally important barrier, particularly managing clinical and research responsibilities, followed by managing personal and professional responsibilities. These concerns regarding time management have, in part, prompted us to begin providing executive coaching to each of our graduating PSTP seniors, with a focus on adaptability, alignment of institutional and personal priorities, and strategic time-management planning.

Discussion

The Pitt SOM PSTP engages medical students in preclinical research for at least 16 months in the context of a 5-year longitudinal curriculum aimed at building professional and research competencies, and it provides them with extensive exposure to MD-only physician–scientists. Our analysis at the 11-year mark indicates that this PSTP model, like MD–PhD/MSTP training programs, is a promising source of physician–scientists committed to laboratory investigation.

The most proximal comparator for added value from the PSTP program is the non-MSTP cohort at Pitt SOM. All students at Pitt SOM who are not in the MSTP complete a required 4-year longitudinal research project (LRP, formerly scholarly

project), which builds analytical thinking skills, provides research mentorship, and strengthens training in the scientific method—and 90% participate in summer research.^{31,32} While the LRP has doubled medical students' research productivity since its initiation,²⁵ the students in our PSTP are twice as likely to attend residencies in the highest NIH-supported departments and twice as likely to publish first-authored papers during medical school.

From a long-term perspective, we cannot yet measure how PSTP training correlates with academic success; however, early outcomes at the resident, fellow, and new faculty level indicate that PSTP graduates retain their interest in research and engage with productive investigators both during their graduate training and at the beginning of their careers. They have continued to publish first- or coauthored articles during residency and fellowship at a high rate. Moreover, thus far, half of the PSTP graduates who have completed their residency training have published papers with a bench or basic science component indicating a persistent interest in laboratory investigation, despite the predominance of clinical research opportunities during residency and fellowship.

Published analyses of the outcomes of MSTP programs focus on long-term outcomes including the academic or research-focused appointments of trainees, persistence in research, and the prevalence of and success rates in acquiring research funding and publishing.^{28,33–35} Such data are not yet available for our PSTP cohort; however, available performance metrics indicate that those who have chosen the shorter PSTP path develop competencies that are similar to or overlap with those of MSTP students. While rates of serving as first authors by graduating MSTPs exceed those of PSTP students (4.2 versus 2.0 per student in the 2018 cohort), 67% of the PSTP group (versus 100% of MSTPs) experience writing and publishing a first-authored paper during medical school despite their significantly shorter time conducting research (compared with MSTPs) during undergraduate medical training. Graduates of both PSTPs and MSTPs (at nearly twice the rate of other students) have chosen residency matches that were deeply resourced to support research. This match rate for

PSTP graduates is consistent with the ongoing commitment of surveyed PSTPs to remain in the physician–scientist track. We plan to determine how the publishing and other examined parameters correlate with long-term career outcomes for graduates of both the MSTP and PSTP.

Early training for physician–scientists must not only develop trainees' foundational knowledge, investigative skills, and the ability to publish and write grants but must also give them intra- and interpersonal skills to persist in a challenging though rewarding career.³⁶ There is a risk of attrition at each level of professional transition. The PSTP curriculum, which includes mentoring and training in writing, critical review of the literature, and statistical analysis, is designed to build persistence; however, early phases of our curriculum did not explicitly address skills in time management or in dealing with the unpredictability of funding, 2 of the challenges that PSTP students and graduates identified as barriers to persisting in a physician–scientist career. To build these skills in trainees and to help them optimally negotiate career transitions, we have instituted individual executive coaching sessions,^{37,38} which focus on adaptability and skills related to resiliency (e.g., reframing obstacles), for PSTP senior students before their transition to residency. A future study will analyze the effects of this intervention.

More research is needed to assess how research training initiated during medical school compares with similar training initiated at the residency/fellowship or the early-career stages to foster success in launching or maintaining a career as a physician–scientist. An ideal program would informally—or perhaps, formally—carry forward mentorship and individual skills-based development from the pre-MD through postgraduate period. We have begun to enroll a subset of PSTP graduates who remain at our institution for postgraduate training into a new resident/fellow “Physician Scientist Incubator Program”³⁹ to facilitate and study this longer span of coherent training.

Our 5-year medical student PSTP may represent a generalizable model that captures talented trainees who seek a shorter training course than combined degree programs and who, without

this option, might otherwise be lost to biomedical research. The need for a shorter pathway to research is particularly acute for URM applicants^{9,40} and women applicants.^{9,41} We are currently instituting programmatic and process initiatives to increase our recruitment of URM applicants. The PSTP has reached gender parity with its 2019–2020 class.

The early outcomes of the Pitt SOM PSTP are encouraging enough to warrant longer-term assessment of program alumni, specifically their initiative in continuing to access post–medical school opportunities for further research training, and their agency, satisfaction, and productivity as academic physician–scientists. In conjunction with emerging efforts to support the success of “late bloomers” committing to investigative careers as residents and fellows,⁴² a robust flow of medical students trained in preclinical research will put needed wind into the turbine of discovery.

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R.A. Steinman is associate professor of medicine, director, Medical Scientist Training Program and Physician Scientist Training Program, and associate dean, University of Pittsburgh School of Medicine, Pittsburgh, Pennsylvania; ORCID: <https://orcid.org/0000-0002-8354-418X>.

C.N. Proulx is evaluation coordinator, Clinical and Translational Science Institute and Department of General Internal Medicine, University of Pittsburgh School of Medicine, Pittsburgh, Pennsylvania; ORCID: <https://orcid.org/0000-0001-9269-2355>.

A.S. Levine is senior vice chancellor, Health Sciences, and Petersen Dean, University of Pittsburgh School of Medicine, Pittsburgh, Pennsylvania; ORCID: <https://orcid.org/0000-0002-1847-3055>.

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