

AUTHOR QUERIES

AUTHOR PLEASE ANSWER ALL QUERIES

AQ1 = For indexing purposes, please confirm that author names have been correctly identified as given names (red) and surnames (blue). Color in the byline will not appear on the final published version.

AQ2 = Please review the abstract closely to make sure that its content/data match those of the main text. Also check that the word count does not exceed the limit of 300 words. If you need to make changes, look for opportunities to remove nonessential words (e. g., “that”) or to make other minor edits. Do not remove essential content, such as the study period, raw numbers, or other data.

END OF AUTHOR QUERIES

A Multi-Institutional Description of Processes and Outcomes of Postbaccalaureate Research Education Programs in the Mid-Atlantic Region

AQ1 Cynthia F. Wright, PhD, Laura M. Kasman, PhD, Donita L. Robinson, PhD, Gregory B. Carey, PhD, Joshua D. Hall, PhD, Joyce A. Lloyd, PhD, Rita Shiang, PhD, Edward J. Smith, PhD, and Katherine L. Wilson, PhD

AQ2 Abstract

Outcome data from 6 National Institutes of Health–funded Postbaccalaureate Research Education Programs (PREPs) in the Mid-Atlantic region were combined to give a multi-institutional perspective on their scholars' characteristics and progress through biomedical research training. The institutions hosting these programs were Johns Hopkins University School of Medicine, the Medical University of South Carolina, the University of Maryland

School of Medicine, the University of North Carolina at Chapel Hill, Virginia Commonwealth University, and Virginia Polytechnic Institute and State University. The authors summarize the institutional pathways, demographics, undergraduate institutions, and graduate institutions for a total of 384 PREP scholars who completed the programs by June 2021. A total of 228 (59.3%) of these PREP scholars identified as Black or

African American, 116 (30.2%) as Hispanic or Latinx, and 269 (70.0%) as female. The authors found that 376 of 384 scholars (97.9%) who started PREP finished their program, 319 of 376 (84.8%) who finished PREP matriculated into PhD or MD/PhD programs, and 284 of 319 (89.0%) who matriculated have obtained their PhD or are successfully making progress toward their PhD.

In 2000, the National Institute of General Medical Sciences at the National Institutes of Health (NIH) launched the Postbaccalaureate Research Education Program (PREP).¹ The goal of PREP is to develop a strong pool of well-trained, diverse postbaccalaureate scholars who will succeed in biomedical PhD or MD/PhD programs with the ultimate outcome of diversifying the biomedical workforce. PREP research training grants are currently hosted by 46 research-intensive universities across the United States.²

PREPs are independently designed by each institution, with all trainees engaging in both mentored research experiences (approximately 75% of their time) and professional development (approximately 25% of their time; e.g., courses, scientific skills, and

presentations). These programs address many elements suggested by Estrada et al³ to improve the persistence of students from groups historically underrepresented in science, technology, engineering, and mathematics to complete their degrees. These components include reducing institutional barriers, providing resources, and connecting scholars to meaningful experiences. PREP scholars receive a salary and fringe benefits to support them during their time in the program; participants are typically supported for 1 year but occasionally up to 2 years, depending on assessed needs. The NIH's current expectations for institutional outcomes are that more than 75% of PREP scholars matriculate to a PhD or MD/PhD program within 2 years of completing PREP and complete graduate training and obtain degrees at rates comparable to, or greater than, their institutional peers.⁴ PREPs recruit and support PREP scholars in cohorts, and most institutions have funding for 5 to 10 positions per year. Grant periods are typically for 5 years.

Four individual PREP institutions previously reported their program outcomes,^{5–8} and in 2015, the NIH published PREP scholar outcomes from programs funded between 2001 and 2014.⁹ Their analysis of the cohort of scholars from institutions who

participated in early PREP funding cycles, and thus had time to finish PhD programs, found a PREP attrition rate of 6%, a PhD matriculation rate of approximately 65%, and, of those who matriculated, a PhD completion rate of approximately 63%. The report speculated that the outcomes of PREP scholars appointed after 2007 may be improved because of modifications made in the 2007 funding announcement, which included setting institutional targets for PhD matriculation rates and funding PREPs only at research-intensive institutions. Indeed, the outcomes reported more recently by PREP institutions show higher matriculation rates to PhD programs, ranging from 73% to 95%.^{5,7,8}

We present the structure and outcomes of 6 PREPs in the Mid-Atlantic/Southeast region of the United States: Johns Hopkins University School of Medicine (JHU SOM), the Medical University of South Carolina (MUSC), the University of Maryland School of Medicine (UM SOM), the University of North Carolina at Chapel Hill (UNC), Virginia Commonwealth University (VCU), and Virginia Polytechnic Institute and State University (VT). These programs were chosen by virtue of their institution's participation in a regional partnership called the Mid-Atlantic PREP and *Initiative for Maximizing Student*

Why is this text in italics?

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

Correspondence should be addressed to Cynthia F. Wright, Department of Microbiology and Immunology, Medical University of South Carolina, 173 Ashley Ave., Ste. 203, MSC 504, Charleston, SC 29425; telephone: (843) 792-5381; email: wrightcf@musc.edu.

Acad Med. 2023;XXX:XXXX–XXXX.

First published online

doi: 10.1097/ACM.0000000000005622

Copyright © 2023 the Association of American Medical Colleges.

Supplemental digital content for this article is available at <http://links.lww.com/ACADMED/B512>.

Development (IMSD) Research Symposium (MAPRS) and are all in at least their second NIH-funding cycle. By reporting the combined metrics from 6 institutions with PREP funding histories ranging from 6 to 19 years, with full access to training milestones and outcomes for scholars in each program, we gained valuable insight into the demographics of PREP scholars, their institutional pathways, and their progression in graduate programs. To our knowledge, this is the largest combined analysis of PREP program outcomes since the 2015 NIH report.⁹

Scholar Selection

All programs use holistic practices when choosing scholars to participate in their programs. Consensus attributes we look for are the need for a significant research experience to build confidence and demonstrate competence, commitment to the PhD training pathway, and evidence of having taken foundational science courses in science and math. In general, programs seek students who have undergraduate grade point averages (GPAs) of 3.0 or above but also consider life circumstances that might lead to a lower GPA, research experience, recommendations, and personal statements. Program directors also reach out to applicants to their PhD programs who were not successful in applying the first time as excellent sources of students committed to PhD training who need additional coursework or research to be successful applicants. According to the program directors, acceptance rates for applicants to the PREPs range greatly across the institutions from approximately 7% to 33%.

Training Program Activities

T1 Table 1 summarizes the various activities of the 6 programs. As detailed in the article by Remich et al,¹⁰ 3 areas of growth are important to include in postbaccalaureate programs: research skills, academics, and science identity (including presenting oneself). All PREPs have elements to help students grow in each domain, and although independently conceived, there is a great deal of commonality in the activities conducted by the institutions.

All programs begin with an onboarding process to orient scholars to campus and

provide them with essential training before they enter labs, such as training in laboratory safety, responsible conduct of research, and/or rigor and reproducibility. Scholars are also oriented to the expectations of graduate-level work and craft individualized development plans to map their activities for the year. Some programs developed structured summer bootcamps to build skills in lab math, analyze scientific articles, engage in experimental design, and practice scientific writing before the scholars begin lab research. At MUSC and UNC, directors originally designed wet bench lab experiences, lasting several weeks, to provide hands-on experience with molecular biology, data analysis, and data presentation. However, because most scholars enter PREP with some laboratory research experience and have diverse research interests, after consideration and in response to scholar feedback, both programs dropped these activities so scholars could enter their research laboratories sooner. In addition, multiple programs (JHU SOM, UM SOM, UNC, and VT) have an initial focus on social events designed to facilitate a sense of community and belonging among the scholars and their cohort, program staff, and institution.

Research skills are fostered through a variety of activities. Because the PREP experience centers on a yearlong immersion in laboratory research, PREP scholars need to match to a home laboratory and faculty research mentor. Program directors use a variety of different strategies to assign scholars to labs. These strategies range from assigning laboratories on entering the program to doing short, in-laboratory rotations. At JHU SOM, students interview with prospective mentors before they arrive on campus, and the program director uses detailed feedback from everyone (scholars and potential mentors) to match students to laboratories. At UM SOM, researchers seeking to mentor PREP scholars give short talks during the first 2 weeks to introduce themselves and their projects, and scholars perform several brief (approximately 1-week) rotations before finalizing their lab and mentor selections. At MUSC and VCU, scholars are interviewed by the program directors and then guided to faculty who share their research interests, with scholars responsible for setting up interviews.

Most faculty allow scholars to briefly shadow in their labs and/or attend lab meetings; after meeting with 3 to 4 mentors, scholars select the lab they would like to join. At UNC, applicants are brought to campus for in-person interviews (like a PhD interview weekend). They often meet researchers at this event with whom they end up working. If not, they interview faculty after they arrive to find a lab. At VT, scholars can come to campus before PREP starts to interview mentors and complete 3 rotations (4 weeks each) before selecting their mentor. Given the short timeframe of PREP (typically 1 year), all programs prioritize matching scholars with a lab within 4 weeks of joining the program.

Most programs expect PREP scholars to write a research proposal early in their project. These proposals range from a 1-page abstract (MUSC and VT) to 2- to 6-page proposals (VCU, UM SOM, and JHU SOM). Instead of a written proposal, UNC scholars write an abstract summary of their project and initial data to submit to a fall conference, providing written clarity for projects. UNC also has scholars write a short paper on their research findings toward the end of their PREP experience. In many programs, longer proposals are created gradually over several months as a collaboration among the program directors, scholars, and their lab. Writing proposals has the advantage of helping scholars to practice scientific writing and allows program directors to ensure the scope of research is appropriate for a yearlong project that fosters independence.

Increasing scholars' academic portfolios is also an important part of the PREP experience. Most programs require scholars to participate in graduate-level coursework during their PREP year, especially scholars who might need to remediate a poor undergraduate grade(s). In several programs, there is flexibility in choosing courses, depending on the scholars' interests and needs, and in most programs the courses are for credit and transcripts are issued. Many of the programs additionally incorporate a journal club-style course into the PREP year to help scholars learn how to read and critically evaluate the current literature. Participating in graduate-level coursework has at least 3 advantages. First, students learn the expectations and

Table 1

Postbaccalaureate Research Education Program (PREP) Scholar Training Program Activities at the Mid-Atlantic PREP and Initiative for Maximizing Student Development Research Symposium (MAPRS) Institutions

word program used twice?

Activity	Institution					
	VT	UNC	VCU	JHU SOM	MUSC	UM SOM
Initial onboarding						
Summer boot camp (professional development, critical thinking, orientation)	X	X	X		X	
Mini lab rotations (mentor selection)	X					X
Interviews to choose potential mentors		X	X	X	X	X
Major program activities						
Research skills						
<i>Research proposal</i>			X	X	X	X
<i>Independent research project</i>	X	X	X	X	X	X
<i>Training in safety and rigor and reproducibility and responsible conduct of research</i>	X	X	X	X	X	X
<i>ABRCMS and/or SACNAS presentations</i>	X	X	X		X	X
<i>Presentation at regional or national research conference (including MAPRS)</i>	X	X	X	X	X	X
<i>Final research paper</i>			X	X		X
<i>Cohort oral research symposium (finale)</i>	X	X	X	X	X	
Academics						
<i>Required graduate foundation course</i>	X				X	X
<i>Journal club or critical thinking course</i>		X	X		X	X
<i>Discipline-specific graduate course(s)</i>	X	X	X	O	O	X
Fostering science identity						
<i>Individual development plan</i>	X	X	X	X	X	X
<i>Writing workshops</i>	X	X		X		
<i>Near peer mentoring by graduate students, postdocs, and alumni</i>	X	X	X	X	X	X
<i>Regular cohort advisory meetings with program faculty</i>	X	X	X	X	X	X
<i>Individual advisory meetings with program faculty</i>	X	X	X	X	X	X
<i>ABRCMS and/or SACNAS networking</i>	X	X	X		X	X
<i>Program advice on graduate school applications</i>	X	X	X	X	X	X
<i>Mock graduate school interviews</i>	X	X	X	X	X	X

Abbreviations: ABRCMS, Annual Biomedical Research Conference for Minoritized Scientists; JHU SOM, Johns Hopkins University School of Medicine; MUSC, Medical University of South Carolina; O, optional; SACNAS, Society for the Advancement of Native Americans and Chicanos in Science; UM SOM, University of Maryland School of Medicine; UNC, University of North Carolina at Chapel Hill; VCU, Virginia Commonwealth University; VT, Virginia Polytechnic Institute and State University.

pace of graduate-level coursework side by side with current PhD students. This approach helps PREP scholars transition to a graduate-level mindset and prepares them for future graduate coursework. Second, scholars learn how to manage their time so they can simultaneously progress in their research and do well in their coursework. Third, although the number of credits is not sufficient to amend a low GPA, performing well in graduate courses boosts their confidence and demonstrates to prospective graduate programs that they can perform well in a graduate curriculum. Many research-interested scholars who may have struggled in memorization-based,

undergraduate lecture courses find that they perform much better in discussion-based, problem-solving graduate coursework. Although research shows that undergraduate GPA is not a good indicator of success in graduate school for biomedical sciences,¹¹ some graduate admissions committees rely on this metric as an admissions criterion. Thus, PREPs have an important role in providing opportunities for scholars to mitigate potential GPA-based barriers to graduate school.

A key element of PREP is the individual counseling, coaching, and advising scholars receive to help them gain

confidence and foster their science identity. Many PREP scholars come from backgrounds where they are the first in their family to achieve an undergraduate degree, much less pursue a graduate degree. Because many PREP scholars express feeling lost or overwhelmed by the complexity and nuances of the graduate school application process, program directors have key roles in demystifying this process. For example, they show scholars how to strategically select programs of interest, provide feedback and mentoring toward writing effective and targeted personal and research statements, and help scholars prepare for interviews. The cohort model

for PREP is also useful because scholars are all applying to graduate schools at the same time, which increases accountability in adhering to timelines. Scholars also help answer each other's questions and exchange information about the graduate programs for which they apply and interview. In addition, all 6 programs connect current PREP scholars with PREP alumni and/or current graduate students to allow for near-peer mentoring, including with PREP alumni at institutions where current scholars are interviewing. Finally, science identity is further fostered by having scholars attend national science conferences, such as the Annual Biomedical Research Conference for Minoritized Scientists or the annual conference hosted by the Society for the Advancement of Chicanos/Hispanics and Native Americans in Science. Venues such as these allow scholars to practice science presentations in a setting that is encouraging and at which they can network with other students and recruiters from graduate programs and see presentations by notable scientists.

Participant Outcomes

Table 2 summarizes outcomes as of June 2022 for all participants who finished the 6 PREPs by June 2022. These programs have supported 84 unique participants from 2003 to 2021. Most scholars were funded by their respective NIH PREP grant; however, most institutions have funded additional scholars through institutional funding, research grants, or other sources. In 2007, the NIH funding opportunity announcements changed the length of expected funding for each student on the grant from 2 years to 1 year. We report the outcomes for scholars who participated in all aspects of PREP at their respective institutions for the full duration of the program, no matter their source of funding. All scholars had identical access to all programming regardless of funding source.

Geographic pathways into and out of PREP

Supplemental Digital Appendixes 1 and 2 (at <http://links.lww.com/ACADMED/B512>) display maps that show the undergraduate schools that scholars came from to join these 6 PREPs and their graduate institutions after PREP completion (these data may be explored in an interactive fashion in the

Supplemental Digital Appendixes at <http://links.lww.com/ACADMED/B512>). All scholars are represented on the incoming (undergraduate institution) map, but only those who entered PhD or MD/PhD programs are represented on the destination (graduate institution) map. Interestingly, certain PREPs have developed networks with particular regions (e.g., UNC has strong recruitment from Puerto Rican institutions). We also observed that increasing our programmatic partnerships through the MAPRS led to more frequent scholar cross-pollination at the graduate level among our institutions. This observation suggests that scholar familiarity with partner institutions, and vice versa, improved recruitment to PhD programs at MAPRS institutions. Moreover, many programs encourage scholars to consider MAPRS consortium and PREP/IMSD-hosting institutions for their PhD training because those institutions already have familiarity with diversity, equity, inclusion, and accessibility training and mentoring. This finding highlights an additional benefit when programs create regional partnerships and interact with each other.

Demographic characteristics of PREP scholars

Collectively, 187 PREP scholars (48.7%) across the 6 programs earned their undergraduate degrees at institutions classified as Carnegie group R1 or R2¹² (doctoral universities with very high or high research activity). This number is consistent with a recent report that found that the largest overall number of individuals in the United States earning research doctorates performed their baccalaureate studies at R1 institutions.¹³ A total of 51 (13.3%) of our scholars attended historically Black colleges or universities or historically tribal colleges, and an additional 36 (9.4%) attended schools in Puerto Rico, which are largely considered Hispanic-serving institutions.¹⁴ Therefore, 87 (22.6%) of our scholars in total came from minority-serving institutions.

The characteristics of all scholars in our programs were as follows: 2 (0.5%) American Indian, 12 (3.2%) Asian, 228 (59.4%) Black or African American, 116 (30.2%) Hispanic or Latinx, 18 (4.7%) multiracial, and 2 (0.5%) Pacific Islander. Two-thirds of the Hispanic scholars

graduated from undergraduate colleges on the U.S. mainland and one-third from Puerto Rico. Schools with undergraduate programs often recruited from their own institutions: VCU acquired 15 (23.8%) and VT acquired 20 (15.9%) of their scholars from their undergraduate populations. We also note that 269 (70.0%) of the scholars in our programs were female, which was remarkably consistent across programs. The high representation of female scholars in the PREPs was largely a reflection of the male-female ratio of applicants to the programs.

inappropriate line break

PREP scholars are successful in matriculation to and retention in PhD programs

Retention rates in our PREPs were exceedingly high (Table 2). Only 8 of the 384 participants did not finish PREP, giving the combined programs a 97.9% program completion rate. Programs were also highly successful in their primary goal to prepare scholars for successful entry and graduation from PhD programs. A total of 305 of 376 scholars (81.1%) who completed PREP transitioned directly to PhD or MD/PhD programs, with 297 of 305 (97.4%) entering PhD programs. If we include scholars who took a few additional years before matriculating into PhD programs, then 319 of 376 (84.8%) of our scholars joined PhD or MD/PhD programs. An additional 22 students (5.9%) matriculated into MS programs. Some of our member institutions also have data on scholars who applied to PhD programs (typically unsuccessfully) before entering their PREP; this number ranged from 34.0% to 46.0% of their scholars. Given that the eventual matriculation rate for all scholars was 84.8%, we conclude that PREP participation was extremely successful in helping students boost their competitiveness the second time. This finding is especially noteworthy because students initially denied entry into PhD programs may choose a different career path. By providing the additional experience and support needed to matriculate into PhD programs, these promising individuals are not lost from scientific research and leadership pathways. Among the PREP scholars who entered PhD or MD/PhD programs, 95 (29.8%) matriculated into graduate programs at their PREP institution and 224 (70.2%) matriculated into other institutions. In most programs, PREP

Table 2

Postbaccalaureate Research Education Program (PREP) Scholar Outcomes as of June 1, 2022 Close bracket missing under UM SOM

Outcome	No. by institution (year PREP started)						All institutions, total no. (%)
	VT (2003)	UNC (2010)	VCU (2010)	JHU SOM (2015)	MUSC (2015)	UM SOM (2016)	
Scholars funded by NIH R25 PREP grants	125	87	61	28	27	24	352/384 (91.6)
Scholars funded by other mechanisms on entry to PREP	2	16	3	5	4	2	32/384 (8.3)
Total PREP scholars	127	103	64	33	31	26	384/384 (100)
Scholars completed PREP program	123	102	61	33	31	26	376/384 (97.9)
PhD admission rate							
Primary outcome: transitioned directly to PhD or MD/PhD program by June 1, 2022	93	94	45	30	24	19	305/376 (81.1)
Transitioned directly to PhD program	93	94	45	26	23	16	297/305 (97.4)
Transitioned directly to MD/PhD program	0	0	0	4	1	3	8/305 (2.6)
Later transitioned to PhD	6	1	3	2	1	1	14/376 (3.7)
Total admitted to PhD or MD/PhD programs by June 1, 2022	99	95	48	32	25	20	319/376 (84.8)
Attending PREP institution for PhD or MD/PhD	24	43	15	9	3	1	95/319 (29.8)
PhD retention rate							
PhD earned by June 1, 2022	47	32	12	1	1	0	93/319 (29.2)
In PhD training as of June 1, 2022	34	53	33	24	22	17	183/319 (57.4)
In MD/PhD program as of June 1, 2022	0	0	0	4	1	3	8/319 (2.5)
Left PhD program with MS	18	3	0	2	1	0	24/319 (7.5)
Left PhD program without degree	0	7	3	1	0	0	11/319 (3.4)
Retention of matriculated PhD and MD/PhD in their programs	81	85	45	29	24	20	284/319 (89.0)
Secondary outcome: PhD or MD/PhD earned or in progress on June 1, 2022	81	85	45	29	24	20	284/376 (75.5)
Other outcomes							
Admitted to an MS program	7	4	10	0	1	0	22/376 (5.9)
MS degree earned or in progress through MS program by June 1, 2022	7	3	10	0	1	1	21/22 (95.5)
Left MS program without degree	0	1	0	0	0	0	1/22 (4.5)
Transitioned to MD or other professional degree program	8	1	2	0	1	3	15/376 (4.0)
MD or other professional degree earned or in progress on June 1, 2022	8	1	2	0	1	3	15/15 (100)
Transitioned directly to industry, biotechnology, or other science career	4	1	0	0	3	2	10/376 (2.7)
Transitioned to nonscience career	1	1	0	1	1	0	4/376 (1.1)
Outcome unknown	4	0	1	0	0	0	5/376 (1.3)

Abbreviations: ABRCMS, Annual Biomedical Research Conference for Minoritized Scientists; JHU SOM, Johns Hopkins University School of Medicine; MUSC, Medical University of South Carolina; NIH, National Institutes of Health; SACNAS, Society for the Advancement of Native Americans and Chicanos in Science; UM SOM, University of Maryland School of Medicine; UNC, University of North Carolina at Chapel Hill; VCU, Virginia Commonwealth University; VT, Virginia Polytechnic Institute and State University.

scholar applications to their respective graduate programs are encouraged and welcomed but not required. PREP scholars are usually not automatically given interviews but compete with the national pool of applicants and are often successfully recruited, given their intense

research training and success in PREP. Our scholars have developed a strong reputation as being well-prepared, focused, and promising researchers on entry to graduate school, a viewpoint fueled by their success as graduate students.

The retention rate for PREP alumni in PhD or MD/PhD programs is high. As of June 1, 2022, only 24 students (7.5%) left their PhD programs with an MS degree, and 11 (3.4%) left without a degree, giving the combined programs an 89.0% success rate for progression toward and

graduation with a PhD. These matriculation and current retention rates put our programs on track for an overall 75.5% PhD attainment rate of scholars who complete PREP. None of our alumni have left MD/PhD programs.

In terms of national impact, the 6 PREPs reported here together have successfully launched 93 U.S. citizens and permanent residents from historically underrepresented backgrounds with PhDs into the biomedical sciences workforce as of June 1, 2022. Of note, some of our institutions have relatively new PREPs that have not been in existence long enough to have alumni that have earned the PhD. However, based on our 75.5% PhD attainment rate, we anticipate that our 6 programs will be yielding at least 30 PhD graduates from underrepresented groups annually. According to the National Center for Science and Engineering Statistics, in 2020 the number of U.S. citizens or permanent residents from underrepresented groups who earned a PhD in biology or biomedical sciences was 1,032 (17.2% of 6,008 total).¹⁵ Hence, our 6 programs alone could contribute almost 3% of all underrepresented PhD graduates in these disciplines, and the 46 PREPs nationwide could contribute 22%.

Finally, among our 19 PREP alumni who did not join graduate or professional degree programs, 10 (52.6%) transitioned into careers in biotechnology and related industries and, therefore, persisted in the scientific workforce. Our program directors view this outcome as a different, and yet still positive, aspect of PREP. Some students realize PhD programs are not for them and still find fulfillment in related scientific careers. Although program directors strive to screen for applicants who truly want a graduate research career, some students decide to pursue the professional school track: 15 (4.0%) of our scholars immediately or later entered professional school programs (mainly medical school).

Career outcomes

For programs that have been in existence for the longest amount of time (e.g., VT and UNC), many alumni have completed their PhD programs and transitioned to postdegree positions. Nearly all such alumni are in scientific careers, fulfilling

the overarching goal of the National Institute of General Medical Sciences PREP funding initiative. Gratifyingly, many alumni are currently in academic postdoctoral positions or are in tenure track academic faculty positions as of June 2022. Of note, 1 PREP alumnus was recruited to a tenure track faculty position at the institution where they were a PREP scholar. Other alumni have taken research positions in industry or medical centers. Several alumni who are currently postdocs have plans to pursue academic faculty positions during the next few years. Given the length of time generally required to achieve academic faculty positions, we anticipate that an increasing number of PREP alumni will join the research professoriate and related careers and will thereby inspire future generations.

Comparison of outcomes with the NIH study

The multi-institutional nature of this report has allowed us to follow the pathway and outcomes of the largest cohort of PREP scholars tracked since the NIH published their study in 2015.⁹ The NIH report analyzed participants from 2001 to 2014 and broke their analysis into pre-2007 and post-2007 cohorts. They focused on an outcomes analysis of 25 programs nationwide for which they had renewal applications. Our report is essentially a post-2007 analysis because only 1 of our programs had continuous funding before that. The previous analysis relied on NIH databases for identifying and tracking scholars, which are necessarily more indirect sources than we had as program directors. We also included non-NIH-funded scholars in our analysis (8.3% of scholars). The PREP completion rate is similar between the 2 studies: the NIH report found that 94% of scholars completed PREP, and our outcomes were slightly higher at 97.9%. However, the PhD matriculation rate from our cohorts was 84.8%, whereas the NIH outcomes were 64%. As mentioned above, changes in the funding announcement made in 2007 to limit PREPs to research-intensive institutions may have improved PREP scholars' guidance and readiness. We report a PhD retention rate of 89.0% of matriculants: in the NIH study, there was a 63% PhD completion rate of those who matriculated into PhD programs in the pre-2007 cohort.

Conclusions

The combined data from this study suggest that PREPs are successful in the overall attainment of underrepresented students to achieve a PhD in biomedical science. Despite the fact that the programs are conceived individually, many of the strategies for scholar success are common across the institutions and include intensive research exposure with a defined project, graduate coursework, a cohort structure, professional development, and intensive coaching by program directors. Although our study was limited because many of our matriculants are still in their programs, leaving us unable to provide PhD completion rates for most of our cohort, our institutions cover only a particular U.S. region, and data were from a smaller number of PREP institutions, the outcomes suggest that this cohort strategy, which includes intensive mentoring, is effective in preparing students for success in biomedical science PhD programs and future careers.

Acknowledgments: The authors wish to thank Kristina Nance (JHU SOM), Suzanne Hennigan, PhD (MUSC), and Zhihong Yan (VT) for their help in data collection and management of the programs.

Funding/Support: This study was funded by grants R25 GM066534 (E.S.), R25 GM089560 (D. L.R.), R25 GM089614 (R.S. and J.A.L.), R25 GM109441 (K.L.W.), R25 GM113262 (G.C.), and R25 GM113278 (C.F.W. and L.M.K.) from the National Institute of General Medical Sciences.

Other disclosures: None reported.

Ethical approval: Reported as not applicable.

Data sharing: Additional data containing interactive Supplemental Digital Appendixes 1 and 2 can be accessed at <https://tinyurl.com/4nscjkur>.

C.F. Wright is professor, Department of Microbiology and Immunology, and **associate dean for admissions and career development**, Medical University of South Carolina, Charleston, South Carolina.

L.M. Kasman is associate professor, Department of Microbiology and Immunology, and assistant dean for postdoctoral affairs, Medical University of South Carolina, Charleston, South Carolina.

D.L. Robinson is professor, Bowles Center for Alcohol Studies, and associate dean for graduate education, University of North Carolina at Chapel Hill, Chapel Hill, North Carolina.

G.B. Carey is associate professor, Department of Microbiology and Immunology, and director of student summer research and community, University of Maryland School of Medicine, Baltimore, Maryland.

J.D. Hall is senior program officer, Center for the Advancement of Science Leadership and Culture, Howard Hughes Medical Institute, Chevy Chase, Maryland.

J.A. Lloyd is professor, Department of Human and Molecular Genetics, and associate dean of the graduate school, Virginia Commonwealth University, Richmond, Virginia.

R. Shiang is associate professor, Department of Human and Molecular Genetics, and ~~graduate program director~~, Virginia Commonwealth University, Richmond, Virginia.

E.J. Smith is professor, Department of Animal and Poultry Sciences, Virginia Polytechnic Institute and State University, Blacksburg, Virginia.

K.L. Wilson is professor, Department of Cell Biology, Johns Hopkins University School of Medicine, Baltimore, Maryland.

References

- 1 National Institute of General Medical Sciences Postbaccalaureate Research Education Program (PREP). Accessed August 19, 2022. <https://nigms.nih.gov/training/PREP>.
- 2 National Institute of General Medical Sciences Post-Baccalaureate Research Education Program Institutions. Accessed August 19, 2022. <https://nigms.nih.gov/maps/Pages/Post-Baccalaureate-Research-Education-Program-Institutions.aspx>.
- 3 Estrada M, Burnett M, Campbell AG, et al. Improving underrepresented minority student persistence in STEM. *CBE Life Sci Educ*. 2016;15(3):1–10.
- 4 National Institutes of Health Postbaccalaureate Research Education Program (PREP)(R25-Independent Clinical Trial Not Allowed). Accessed August 19, 2022. <https://grants.nih.gov/grants/guide/pa-files/PAR-22-220.html>.
- 5 Hall JD, Harrell JR, Cohen KW, Miller VL, Phelps PV, Cook JG. Preparing postbaccalaureates for entry and success in biomedical PhD programs. *CBE Life Sci Educ*. 2016;15(3):ar27.
- 6 Krulwich TA. A major role for social work input during development of an innovative post-baccalaureate research education program in a medical center environment. *Soc Work Health Care*. 2009;48(7):653–664.
- 7 Schwartz NB, Risner LE, Domowicz M, Freedman VH. Comparisons and approaches of PREP programs at different stages of maturity: challenges, best practices and benefits. *Ethn Dis*. 2020;30(1):55–64.
- 8 Smolock E, Robert J. Broadening and strengthening underrepresented group inclusion in immunological research. *Front Immunol*. 2020;11:465.
- 9 Hall AM, Mann J, Bender M. Analysis of scholar outcomes for the NIGMS postbaccalaureate research education program. August 28, 2015. Accessed June 23, 2022. www.nigms.nih.gov/news/reports/documents/prep-outcomes-report.pdf.
- 10 Remich R, Naffziger-Hirsch ME, Gazley JL, McGee R. Scientific growth and identity development during a postbaccalaureate program: results from a multisite qualitative study. *CBE Life Sci Educ*. 2016;15(3):1–12.
- 11 Hall JD, O'Connell AB, Cook JG. Predictors of student productivity in biomedical graduate school applications. *PLoS One*. 2017;12(1):e0169121.
- 12 The Carnegie Classification of Institutions of Higher Education. Updated September 9, 2022. Accessed November 2022. <https://carnegieclassifications.acenet.edu>.
- 13 Gordon J, Einaudi P, Kang K. Baccalaureate Origins of U.S. Research Doctorate Recipients. National Center for Science and Engineering Statistics InfoBrief. National Science Foundation; 2022. Accessed December 28, 2022. <https://nces.nsf.gov/pubs/nsf22321>.
- 14 U.S. Department of Education. Lists of Postsecondary Institutions Enrolling Populations With Significant Percentages of Undergraduate Minority Students.. Accessed January 20, 2023. <https://www2.ed.gov/about/offices/list/ocr/edlite-minorityinst-list.html>
- 15 National Center for Science and Engineering Statistics. Doctorate Recipients from U.S. Universities: NSF 22-300. Published 2020. Accessed September 15, 2022. <https://nces.nsf.gov/pubs/nsf22300>.