Journal of Medical Education and Practice

Vol. 2, No. 1, 2025
ISSN: 3009-6421 (print)
DOI: 10.21608/JMEP.2025.359435.1008

COMMENTARY ARTICLE

The introduction of Combined Clinical Medicine and Scientific Research Degrees in the Postgraduate Medical Education. A perspective

Hassan Mohammed Elnady
Department of Neurology and Psychological Medicine, Sohag University, Sohag, Egypt.

Correspondence to *Hassan Mohammed Elnady, MD, Department of Neurology and Psychological Medicine, Sohag University, Sohag, Egypt.*
Mobile no.: +201005369758
E-mail: elnadyhassan1974@hotmail.com, hass_elnady@yahoo.com.

Abstract

Since the dawn of the twenty-first century, a more idealistic paradigm for medical school missions has emerged, wherein research assumes a pivotal role in safeguarding and supporting all other objectives. Many medical schools worldwide (especially in North America) have implemented undergraduate or postgraduate programs integrating clinical medicine and scientific research to recruit appropriately prepared personnel (i.e., Physician-scientists). While some studies indicate limitations in undergraduate combined training programs for physician-scientist development, other studies suggest that postgraduate dual training models may offer more effective outcomes. The author of this article outlines a proposal for dual degrees as national programs for developing physician-scientists. The proposed programs are dual clinical and scientific master's degrees. Egyptian medical school graduates can apply for any of these proposed programs after completing their bachelor's degree (MBBch). The programs aim to gradually develop the physician-scientist workforce based on the available infrastructure (whether clinical or laboratory) and, therefore, will be available to a limited number of medical school graduates.

Keywords Dual degree, Postgraduate, MD/PhD, Research training, Physician-scientist.

Journal of Medical Education and Practice.
Vol.2, No.1

INTRODUCTION

Although there is evidence that medicine was practiced in Egypt as early as 2,500 B.C., medical education was only included in the university system in 1919[1]. Given the many emerging models worldwide, ongoing advancements are imperative to ensure Egypt's emergence as a foremost global medical center. Egyptian medical colleges must take the initiative.

Humanity's most significant accomplishment has been using the scientific method to enhance health and lessen suffering from disease. The relationship between science and medicine is taken for granted[2]. In the twentieth century, the common understanding of medical schools' missions was that they were triplets, including education, patient care, and research. This perception was deemed gravely faulty by the start of the third millennium, and it negatively affected the organization and function of medical schools by suggesting that research was an independent activity distinct from patient care and education. Therefore, an ideal mission concept was adopted for medical schools, where research serves as the cornerstone and protector of all other goals. The prevailing idea is: "Research is not one of the missions of the medical schools -it is the mission"[2].

Physician-scientists have been instrumental in rapidly translating fundamental scientific discoveries into clinical applications[3]. Many medical schools worldwide (especially in North America) have implemented undergraduate or postgraduate programs that integrate clinical medicine and scientific research to better recruit appropriately prepared personnel[3 - 5].

This article highlights the importance of dual degrees in medical education and argues that postgraduate programs have many positive aspects. Moreover, the article advocates for combined degree programs to foster a new generation of physician-scientists who can revolutionize healthcare through innovative research.

Basic scientists' dilemma:

Basic scientists working in the medical field (frequently termed non physician-scientists) have made groundbreaking contributions to medicine. However, their research often lacks the clinical insights to refine its practical implementation and future innovation[6]. The core questions explored by basic scientists might not always translate directly into new therapies or clinical improvements. Although their research provides promising new medical insights, they do not seek to develop and implement further studies to translate their fundamental scientific discoveries into innovative medical technologies, diagnostic tools, or clinical treatments. Physicians and basic scientists often fail to engage in effective communication. This disconnect leads to barriers that enhance the cultural divide separating the two fields (i.e., clinical medicine and science)[7].

Distinguished cadres are needed:

Medical research increasingly demands scientists who can bridge the gap between scientific discovery and patient care, requiring a nuanced understanding of human disease and patient needs[8]. Physician-scientists are physicians who prioritize research over clinical practice. They dedicate themselves to discovering insights and developing novel strategies to improve disease diagnosis, treatment, and prevention[9]. The involvement of physicians in translational research is indispensable for developing novel technologies and therapies. To facilitate the advancement of translational research, it is imperative to train physician-scientists capable of bridging the chasm between basic scientists and physicians[10].

According to a 2012 publication, physicians engaged in scientific research have been awarded more than half of the Nobel Prizes in Physiology or Medicine[11].

Several previous articles have detailed the contributions and responsibilities of physician-scientists in advancing translational medicine[2 - 4, 10 - 12].

Targeting levels of training:

Physician-scientist training in the United States (and other countries) is offered at multiple stages of medical education and in various configurations. The program is known as the Physician-Scientist Training Program (PSTP) when it targets postgraduate students during residency, fellowship, or even higher level. However, it is known as the Medical-Scientist Training Program (MSTP) when it targets undergraduate students[4, 5]. (See Figure 1).

Figure 1A demonstrates the traditional track, usually called Doctor of Medicine (MD) only. It is a professional track. The MD degree is awarded after four years of undergraduate medical education. The MD denotes a professional degree in the USA and other countries[13]. Figure 1B demonstrates a research track available for students motivated for research. In this track, a Doctor of Philosophy (PhD) degree is intercalated during the undergraduate medical education (MD-PhD), usually termed MSTP. The PhD is the most common degree at the highest academic level, awarded following a course of study and research[5]. Figure 1c: The PhD degree is intercalated during residency or fellowship in this track. It is usually termed PSTP[14].

It is important to note that medical schools exhibit diverse missions, with some prioritizing research (research-intensive medical schools), others primary care (Primary care medical schools), and many a balanced approach. These differing emphases influence curricular design and research expectations. As a result, research-intensive medical schools are where most physician-scientist development occurs[15].

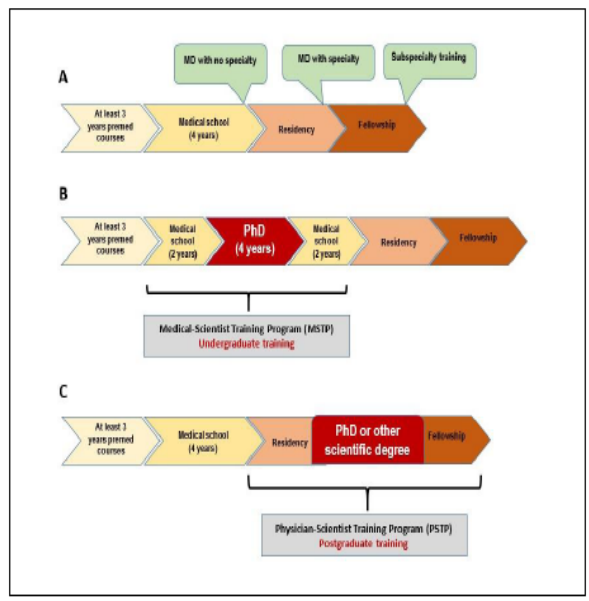

Figure 1: Demonstrates different medical school professional and research tracks (for more details, see text).

The first steps toward the modern physician-scientist: Mainly a postgraduate approach:

The manner of Physician-Scientist involvement in the research enterprise has evolved over time. However,

Germany began the process of producing modern Physician-scientists in the mid-19th century. The laboratory, not the hospital, became the hub of research in the German medical school, and the microscope—rather than the stethoscope—became the primary teaching tool. By the end of the nineteenth century, the leading European medical schools were starting to drastically alter their teaching methods due to the massive increase in scientific research in medicine. At that time (the end of the nineteenth century), several prestigious American medical schools that had faculty with European training followed suit, such as Harvard, Johns Hopkins, and the University of Pennsylvania. The early 1900s marked a turning point, as the US outpaced Germany to become the world's leading force in medical discovery. American medical schools also increasingly empowered graduates to pursue research careers through postgraduate training opportunities[16]. The prevalent pattern in the USA throughout the first half of the 20th century was for physician-scientists to have their primary scientific training during residency or fellowship research periods subsequent to their medical school graduation[17].

Transition to the undergraduate level:

The start of combined degrees crystallization:

The United States National Institute of Health (NIH) was given authority over research and research training by the Public Health Service Act of 1944. The increasing complexity and specialization of medicine and science in the latter half of the 20th century posed significant challenges for training physician-scientists. The extended duration of training made it difficult to balance multiple areas of expertise[17]. These circumstances have given rise to a movement that involves undergraduate students in the training process. In 1956, Case Western Reserve University pioneered what was the first –in the USA- combined Doctor of Medicine/Doctor of Philosophy (MD-PhD)program[17].

In 1964, the United States NIH, led by Dr James Augustine Shannon, developed what is called the Medical-Scientist Training Programme (MSTP) to fund undergraduate medical students interested in the combined degrees[5]. Although initially limited to a few universities, MD-PhD programs expanded significantly by 2016, with 120 US medical schools offering such programs. The NIH provided funding for 45 of these programs, while the other 75 were independently operated. The program spans eight years. Students begin with two years of medical school, followed by a dedicated four-year research period. They then return to complete the final two years of their medical degree (i.e., 2 + 4 + 2)[5]. From the outset, it was anticipated that the majority of MD-PhD program graduates would pursue careers in academic settings, including medical centers, universities and research institutes like the NIH. It was also anticipated that program graduates would establish connections between their medical training, clinical practice, and research pursuits, enabling a synergistic approach that would be unattainable for scientists without a medical background[9].

Undergraduate combined degrees outside the USA:

To improve recruitment of suitably trained personnel, many other countries of the world (table 1) have introduced combined medical (MBBS, MBChB, or MD) and research (PhD) degrees similar to that found in the USA[5].

Canada:

Canadian MD/PhD programs are structurally comparable to their US counterparts. The Canadian Institutes of Health Research (CIHR) has overseen the Medical Scientist Training Program (MSTP) since the 1980s, cultivating a cadre of Canadian clinician-scientists[18]. Due to financial constraints and other factors, CIHR discontinued its MD/PhD program in 2016[19]. Notwithstanding the absence of CIHR financial support, certain Canadian universities will persist in offering the combined degree program[5].

UK:

Combined Bachelor of Medicine/Doctor of Philosophy (MB/PhD) programs are uncommon in Europe, with the University of Cambridge introducing the first such program in 1989[8]. Undergraduate students in this intercalated program can earn two degrees in nine years. The program is structured with four years of core clinical training, a three-year research period, and a final two years of specialized clinical practice[5].

Other UK universities soon followed suit, with University College London (UCL) launching its MB/PhD program in 1994[20]. The program follows a 4+3+2 structure, similar to Cambridge[5].

A number of British universities currently offer combined medical and research degrees, including Imperial College London, the University of Manchester, Newcastle University, and the University of Leicester[5].

Singapore:

In 2000, the MBBS/PhD program at the National University of Singapore (NUS) was launched. Eight years make up the combined degree (3 + 3 + 2)[21]. Admission to the NUS MBBS/PhD program is highly competitive, with typically only three to four students selected each year[21]. Successful candidates in this program receive exceptional support, including full tuition, stipends, global research experiences, and early insights into diverse career paths in clinical practice, basic research and industry[5].

South Africa:

The University of Cape Town in South Africa was the first African university to introduce optional research training into its undergraduate medical curriculum through the establishment of a Clinician-Scientist Training Programme in 2011[22]. Medical students seeking a PhD must undergo a stepwise academic progression, beginning with a BSc (Med), followed by an MSc (Med) and concluding with a PhD[22]. This South African program is potentially a valuable catalyst for others in Africa[5].

Other countries:

Undergraduate students in other countries, including Switzerland, Japan, and Australia, can pursue dual degree programs[5] (see Table 1).

Undergraduate versus postgraduate training:

Unfavorable opinions about undergraduate MD-PhD:

While the American model began incorporating physician-scientist training at the undergraduate level in the mid-1950s, the outcomes fell short of expectations. In a 1979 analysis of NIH funding trends for postdoctoral research fellows, research-career-development awardees, and research-project-grant principal investigators, Wyngaarden concluded that physician-scientists were endangered species [23]. Brass and colleagues reported that the number of applicants to undergraduate MD-PhD programs annually constitutes a mere fraction of those applying to medical school, and the number of MD-PhD graduates remains a small subset of the total medical school graduates[9]. The percentage of United States Physician-Scientists (physicians engaged in research as their major professional activity) decreased from 4.6 percent in 1985 to 1.8 percent in 2003. At the same time, the absolute number of physician-scientists dropped from a peak of about 23,000 in 1985 to 14,000 in 1995. Moreover, almost half of the MD-PhD students indicated they did not wish to become physician-scientists as currently defined[24]. One explanation for why the MD-PhD students do not want to work as physician-scientists is that after graduation, they will face 7 to 8 years of clinical training before applying for grants as faculty, at which point their PhD experience may be outdated. Even for those who want to be physician-scientists, the length of clinical training will cause them to change their career goals[25].

According to Andrew I. Schafer, the undergraduate MD-PhD programs may not be as effective at producing physician-scientists as is generally believed[24].

The data presented here suggest that the undergraduate training model is not the most effective way to cultivate physician-scientists. On the other hand, Kosik and colleagues reported that investing resources and efforts in postgraduate training may yield superior outcomes. The authors also emphasized the potential of doctoral programs to generate many physician-scientists within a relatively brief timeframe. Additionally, most postgraduate students possess research experience and exhibit greater maturity in their career aspirations. This often translates to higher success rates in securing tenure positions and lower dropout rates[4].

Table 1: Combines clinical medicine and scientific research degrees available for medical students in different countries:

Country	Year of first introduction	Name of the program	Description	The university provides the program	Reference
USA	1956	MD/ PhD (The NIH-funded programs are also termed MSTPs)	2 years of medical school + 4 years of full-time research + return to complete the remaining 2 years of their medical degree (i.e., 2 + 4 + 2)	About 120 medical schools, including but not limited to Case Western Reserve University, 1956; Albert Einstein College Of Medicine, 1964; New York University, 1964; Northwestern University At Chicago, 1964; Duke University, 1966; Stanford University, 1968; University Of Chicago, 1968; University Of Wisconsin-Madison, 1968; Columbia University, 1969; University Of Pennsylvania 1969; Washington University, 1969; Yale University, 1969; University Of Washington, 1970; University Of Rochester, 1973; Cornell University Medical Center, 1974; Harvard University Medical School, 1974; Johns Hopkins University, 1975 and others.	Alamri[5] Harding *et al.*,[17]
Canada	the mid-1980s	MD/ PhD	The same as the USA	University of Toronto. 6 Some Canadian universities, However, continued to offer the combined degree even without financial support from the CIHR.	Alamri[5] Lewinson *et al.*, [18]
United Kingdom	1989	MB/PhD	4 years of core clinical practice, 3 years of full-time research, and 2 years of specialist clinical practice.	University of Cambridge, 1989; University College London, 1994; Imperial College London, University of Manchester, Newcastle University, and University of Leicester	Cox, Wakeford[8] Stewart[20] Alamri[5]
Switzerland	1992	MD/PhD	The same as the USA	Switzerland's MD/PhD program is centrally overseen by two organizational bodies: the Swiss National Science Foundation and the Swiss Academy of Medical Sciences. All Swiss universities with medical faculties participate in the MD/PhD program.	Alamri[5]
Japan	2008	MSTP	- The program is modeled after American MSTPs at the University of Tokyo. - Runs over two phases at Fukushima Medical University.	The University of Tokyo, 2008; Fukushima Medical University, 2011.	Alamri[5]
Singapore	2000	MBBS/PhD programme	The combined degree spans 8 years (3 + 3 + 2)	The National University of Singapore, 2000.	Hooi *et al.*, [21] Alamri[5]
Australia	1998	The combined MBBS/PhD program	Students took 2 or 3 years to undertake full-time research in the middle of their 4-year MBBS program (2 medical + 2/3 research + 2 medical)	The University of Sydney, 1998.	Alamri[5]
South Africa	2011	# BSc (Med) Hons/MB ChB track # MB ChB/ PhD track	See text.	The University of Cape Town, 2011.	Katz *et al.*, [22]

A Canadian study found that physicians who earned their PhD after completing their MD degree were more likely to pursue research-focused careers than those who obtained both degrees concurrently[12]. According to the authors of a survey conducted among 138 Johns Hopkins School of Medicine residents, residency is the best period to cultivate a physician-scientist[26].

Back to Postgraduate Training:

While postgraduate training for physician-scientists, starting in the US in 1910, was ongoing, it did not follow the structured curriculum already established for undergraduate MD-PhD. Those physician-scientists who were trained at the postgraduate level were referred to as "late bloomers." It is important to note that they made up the bulk of the physician-scientist workforce[12].

Dual degrees at the postgraduate level began to appear in the United States in the latter two decades of the 20th century. The following paragraphs will highlight examples of these.

Specialty Training and Advanced Research (STAR) Program:

In 1993, the University of California, Los Angeles (UCLA) Department of Medicine established the Specialty Training and Advanced Research (STAR) Program. This program provides funding and protected time for medical trainees to pursue a PhD in basic science near the completion of their specialty or subspecialty clinical training[27].

Trainees applied to the STAR program simultaneously with their traditional clinical residency or fellowship applications. The program consists of 4 tracks. Regarding the Physician-Scientist track, most awardees finished at least a year of core clinical specialty training (e.g., Neurology, Ophthalmology, Pediatrics, Medicine, etc.). Trainees from Caltech or UCLA basic science departments earned PhDs in basic science (e.g., biological chemistry, biomedical engineering, human genetics, microbiology, immunology, etc.). The results of the UCLA STAR program over the previous 20 years indicate that it is possible and beneficial to integrate graduate-level research at the specialty or subspecialty clinical training level in order to prepare trainees for long-term careers as physician-scientists[25].

Advanced Residency Training at Stanford (ARTS)[28]:

A program for advanced residents or clinical fellows interested in becoming physician-scientists was introduced at Stanford Medical School in 2007. Under the Advanced Residency Training at Stanford (ARTS) program, a limited group of fellows and residents can work toward a PhD while finishing their clinical training. Surgical trainees, as well as more conventional medical trainees, have previously benefited from this approach. One or more years of postgraduate clinical training precede a research study in a graduate degree at the Schools of Medicine, Engineering, or Humanities and Sciences at Stanford University[28].

Stimulating Access to Research in Residency (StARR)[29]:

The NIH launched the Stimulating Access to Research in Residency (StARR) R38 program in 2018 to provide residents with mentored research opportunities. According to preliminary results, the program may greatly encourage clinical trainees from a variety of specialties to pursue careers in research[29].

The situation in the Middle East:

The Middle East lacks MD-PhD programs for aspiring physician-scientists, as reported by the authors in a previous study[30]. Middle Eastern medical graduates have yet to be allowed to enroll in formal dual clinical and research programs. Consequently, those inclined toward research must pursue standalone scientific degrees (Master's and PhD) after their undergraduate medical education. This approach could be suitable for graduates whose primary objective is a research position. Still, it is far less ideal for those who want to practice medicine and research (aspiring to become physician-scientists)[31]. To the author's knowledge, the situation in Egypt is part of the broader situation in the Middle East.

The author's perspective:

The author of this article outlines a proposal for dual degrees as national programs for developing physician-scientists. Based on its own and the parent university's capacities, the author suggests that each medical school decide how many dual degrees are offered annually. A hypothetical timeline is provided in Supplementary File 1.

As evidenced by the preceding information, the author's perspective advocates for including dual degrees within postgraduate medical education. Also, it is worth noting that Egyptian medical students differ from their American counterparts (Those who enjoy the best combined undergraduate degrees in the world) in that they come directly from high school and have not received three years of pre-medical education. This will make integrating them into a research program one that may not achieve the relative success that the program has achieved in the United States. We also need to examine the prior unfavorable perceptions of undergraduate dual degrees, particularly the Canadian experience (see above), which ended sponsorship for the program after around 30 years.

The proposed programs (The Physician-Scientist Training Programs):

The proposed programs are dual clinical and scientific master's degrees. Egyptian medical school graduates have the option to apply for any of these proposed programs after completing their bachelor's degree (MBBch degree). These programs aim to gradually develop the workforce of physician-scientists based on the available infrastructure (whether clinical or laboratory) and, therefore, will be available to a limited number of medical school graduates.

The clinical departments will be divided into three groups (see supplementary file 1). It will be mandatory for one group's departments to accept applications for one combined degree each year. This means that each clinical department will offer the opportunity to apply to this program to one graduate every three years. The candidate will complete an accelerated residency program featuring early tenure and a research exemption while adhering to standard resident protocols. Early tenure (at the start of residency) is key to incentivizing high-achieving students to pursue this dual track. From the outset, the clinical department should determine its objective for the dual degree and strive to ensure that the scientific

degree is consistent with the candidate's expected clinical subspecialty. For example, the scientific domain of the combined degree will be immunology if the neurology department wishes to train a physician-scientist with a subspecialty in demyelinating disorders.

The duration of this program is five years (Figure 2). The resident physician will spend the first two and a half years in one of the clinical departments, during which he will pass two exams (first and second parts) but will not be conducting research. Then, he moves to one of the scientific departments (Table 2) to spend another two and a half years obtaining a master's degree in a scientific domain. Once more, he will follow the same guidelines as other (scientific) candidates while pursuing a master's degree from the scientific department. This includes taking the same classes, using the same assessment techniques, and conducting experimental laboratory research (a thesis).

During the clinical training period, the candidate will be committed to spending one day per week in the scientific department during the clinical training period to ensure scientific acclimatization (the small column of Figure 2). He/She will also spend one day a week in the clinical department during the scientific training period to maintain clinical experience (the small column of Figure 2).

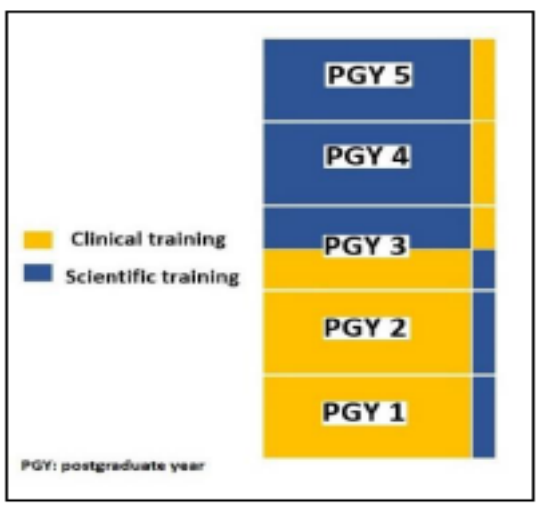

Figure 2: An illustration showing the proposed distribution of clinical and scientific training of the proposed combined degree program.

Upon successful completion of this program, the graduate receives a combined degree (for example, a combined master's degree in neurology and immunology). After that, he was appointed an assistant lecturer in the clinical department.

This program will guarantee that clinical practice and laboratory research are conducted in unison. It is a suitable first step toward a future as a laboratory-based physician-scientist. Given the existing structure of Egyptian university education, where master's degrees follow bachelor's degrees, the author proposes this model as both fitting and sensible for the Egyptian context. Furthermore, it allows for future expansion, facilitating the pursuit of doctoral studies in scientific research alongside clinical specialization (i.e., by obtaining this dual degree, clinical faculty members passionate about research can get a PhD in their scientific specialty, enhancing their research capabilities).

While this article presents a personal overview of dual degree inclusion, the relevant clinical/scientific departments will ultimately decide on the specific implementation details.

The most crucial steps are those aimed at preserving Cader's position as a physician-scientist for the future. Supplementary file 2 provides some recommendations to ensure this.

Table 2: Scientific master's degrees' domains:

Domain	The department providing the degree
Biochemistry	Biochemistry, Faculty of Medicine
Immunology	Microbiology and Immunology, Faculty of Medicine
Microbiology	Microbiology and Immunology, Faculty of Medicine
Molecular biology	Molecular biology, Faculty of Science
Physiology	Physiology, Faculty of Medicine
Physics	Physics, Faculty of Science
Biomedical Engineering	Biomedical Engineering, Faculty of Engineering
Others, based on the contribution to medical innovation	Related departments in the Faculties of Engineering, Pharmacy, Science, or others.

CONCLUSION

While establishing primary care medical schools is a common practice worldwide, transforming them into research-intensive medical schools is a complex and long-term endeavor that requires a dedicated team of research-minded individuals. Global models demonstrate that incorporating physician-scientist development programs into medical education is a national requirement. As evidenced by the preceding information, the author's perspective advocates for including dual degrees within postgraduate medical education. This approach may produce a perfect generation of physician-scientists who

work in laboratories and can help any primary care medical school in Egypt become a research-intensive institution. It can also significantly boost medical schools already on track.

LIST OF ABBREVIATIONS:

ARTS	Advanced Residency Training at Stanford
CIHR	Canadian Institutes of Health Research
MBBS, MBChB	Bachelor of Medicine, Bachelor of Surgery
MD	Doctor of Medicine
MSTP	Medical-Scientist Training Program
NIH	National Institute of Health
NEWS	National University of Singapore
PhD	Doctor of Philosophy
PSTP	Physician-Scientist Training Program
STAR	Specialty Training and Advanced Research
StARR)	Stimulating Access to Research in Residency
UCL	University College London
UCLA	University of California, Los Angeles

DECLARATIONS:

ACKNOWLEDGMENTS:

Not applicable.

ETHICS APPROVAL AND CONSENT TO PARTICIPATE:

Not applicable.

CONFLICTS OF INTEREST

There are no conflicts of interest.

FUNDING

No funding was received for conducting or publishing this work.

REFERENCE

1. Badrawi N, Hosny S, Ragab L, Ghaly M, Eldeek B, Tawdi AF, et al. Radical reform of the undergraduate medical education program in a developing country: the Egyptian experience. BMC Medical Education. 2023;23(1):143.
2. Coller BS. 4. Translational Research and the Physician-Scientist. In: Andrew IS, editor. The Vanishing Physician-Scientist? Ithaca, NY: Cornell University Press; 2011. p. 67-83.
3. Williams CS, Rathmell WK, Carethers JM, Harper DM, Lo YMD, Ratcliffe PJ, et al. A global view of the aspiring physician-scientist. eLife. 2022;11.
4. Kosik RO, Tran DT, Fan AP, Mandell GA, Tarng DC, Hsu HS, et al. Physician Scientist Training in the United States: A Survey of the Current Literature. Eval Health Prof. 2016;39(1):3-20.
5. Alamri Y. The combined medical/PhD degree: a global survey of physician-scientist training programs. Clinical medicine (London, England). 2016;16(3):215-8.
6. Steinman RA, Proulx CN, Levine AS. The Highly Structured Physician Scientist Training Program (PSTP) for Medical Students at the University of Pittsburgh. Academic medicine: Journal of the Association of American Medical Colleges. 2020;95(9):1373-81.
7. Lindahl S, Marincola F. Translational medicine. Encyclopedia Britannica2023.
8. Cox TM, Wakeford R. The MB PhD programme. Training to be a clinician-scientist in the UK. Journal of the Royal College of Physicians of London. 1993;27(2):147-50.
9. Brass LF, Akabas MH, Burnley LD, Engman DM, Wiley CA, Andersen OS. Are MD-PhD programs meeting their goals? An analysis of career choices made by graduates of 24 MD-PhD programs. Academic medicine: Journal of the Association of American Medical Colleges. 2010;85(4):692-701.
10. Salto-Tellez M, Oh VM, Lee EH. How do we encourage clinician-scientists in Singapore? Ann Acad Med Singap. 2007;36(11):879-80.
11. Schwartz DA. Physician-Scientists: The Bridge between Medicine and Science. American Journal of Respiratory and Critical Care Medicine. 2012;185(6):595-6.
12. Elnady HM. The Central Role of the Physician-Scientist in Translational Medicine. An Overview. Sohag Medical Journal. 2024;28(1):41-9.
13. Decherney, Sophia. "Doctor of Medicine". Encyclopedia Britannica, 4 Feb. 2025, https://www.britannica.com/science/Doctor-of-Medicine. Accessed 20 March 2025.
14. Williams CS, Gallagher EJ, Rockey DC, Ajijola OA, Hu PJ, Kazmierczak BI, et al. Structural insights into the career path between pre- and postgraduate physician-scientist training programs. eLife. 2023;12.
15. Lewkonia RM. The missions of medical schools: the pursuit of health in the service of society. BMC medical education. 2001;1:4.
16. Schafer AI. 1. History of the Physician as Scientist. In: Andrew IS, editor. The Vanishing Physician-Scientist? Ithaca, NY: Cornell University Press; 2011. p. 17-38.
17. Harding CV, Akabas MH, Andersen OS. History and Outcomes of 50 Years of Physician-Scientist Training in Medical Scientist Training Programs. Academic medicine: Journal of the Association of American Medical Colleges. 2017;92(10):1390-8.
18. Lewinson RT, Beers CA, Capozzi LC, Iablokov V, Keough MB, Peplowski MA. The Canadian MD/PhD training program needs reinstated support. Nature medicine. 2015;21(10):1111.
19. Webster PC. CIHR cutting MD/PhD training program. CMAJ. 2015;187(12):E381-2.
20. Stewart GW. An MBPhD programme in the UK: the UCL experience. Clinical medicine (London, England). 2012;12(6):526-9.
21. Hooi SC, Koh DR, Chow VT. The NUS MBBS-PhD program: nurturing clinician-scientists for tomorrow. Ann Acad Med Singap. 2005;34(6):163c-5c.

22. Katz AA, Futter M, Mayosi BM. The intercalated BSc (Med) Honours/MB ChB and integrated MB ChB/PhD tracks at the University of Cape Town: models for a national medical student research training program. South African medical journal = Suid-Afrikaanse tydskrif vir geneeskunde. 2014;104(2):111-3.
23. Wyngaarden JB. The Clinical Investigator as an Endangered Species. New England Journal of Medicine. 1979;301(23):1254-9.
24. Schafer AI. 14. Revitalizing the Nation's Physician-Scientist Workforce: The Association of Professors of Medicine Initiative. In: Andrew IS, editor. The Vanishing Physician-Scientist? Ithaca, NY: Cornell University Press; 2011. p. 227-44.
25. Wong MD, Guerrero L, Sallam T, Frank JS, Fogelman AM, Demer LL. Outcomes of a Novel Training Program for Physician-Scientists: Integrating Graduate Degree Training With Specialty Fellowship. Journal of graduate medical education. 2016;8(1):85-90.
26. Rivera JA, Levine RB, Wright SM. Completing a scholarly project during residency training. Perspectives of successful residents. Journal of General Internal Medicine. 2005;20(4):366-9.
27. Fogelman AM. Strategies for training generalists and subspecialists. Ann Intern Med. 1994;120(7):579-83.
28. Pizzo PA. 8. The Role of Academic Medical Centers and Medical Schools in the Training and Support of Physician-Scientists. In: Andrew IS, editor. The Vanishing Physician-Scientist? Ithaca, NY: Cornell University Press; 2011. p. 120-37.
29. Price Rapoza M, McElvaine A, Conroy MB, Okuyemi K, Rouphael N, Teach SJ, et al. Early Outcomes of a New NIH Program to Support Research in Residency. Academic medicine: Journal of the Association of American Medical Colleges. 2022;97(9):1305-10.
30. Alamodi AA, Abu-Zaid A, Anwer LA, Khan TA, Shareef MA, Shamia AA, et al. Undergraduate research: an innovative student-centered committee from the Kingdom of Saudi Arabia. Medical teacher. 2014;36 Suppl 1:S36-42.
31. Anwer LA, Anwer AN, Mahmood M, Abu-Zaid A, Shareef MA. Meeting the global need for physician-scientists: a Middle Eastern imperative. Medical education online. 2014;19:26138.