ORIGINAL RESEARCH

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Performance report for a 10-year-old MD/PhD Program: A survey of trainees at the University of Ottawa

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Abstract

Purpose: Integrated MD/PhD programs are relatively new in Canada and represent a platform to train the next generation of clinician-scientists. However, MD/PhD programs vary substantially by structure, funding and mentorship opportunities, and there exists a paucity of data on the overall students' successes and challenges. The purpose of this study is to assess objective and subjective metrics of the MD/PhD Program at the University of Ottawa.

Methods: Students in all years of the program were invited to complete a 58-question survey, and the resulting data were analyzed by descriptive statistics.

Results: Our survey had an 88.5% (23/26) participation rate. The program has been gaining interest and the number of applications increased by 178% between 2013 and 2018. Tuition support was considered an essential element in accepting the admission offer, as 47.8% of students would have declined admission without full tuition coverage. The MD/PhD students were heavily engaged in scholarly activities, with an average of 8.3 presentations/publications per respondent. Respondents indicated low satisfaction with formal career planning advice (28.6% satisfied/very satisfied) and program transition guidance (22.2%). When delivered informally by peers, both career planning advice and program transition guidance were experienced as more satisfying (65.2% and 63.6%, respectively). Only 34.8% of survey respondents identified as female, highlighting the challenge of achieving diversity in clinician-scientist training programs.

Conclusion: Our report contributes to the body of knowledge on concrete obstacles experienced by students within MD/PhD programs and key areas that can be improved upon—locally, provincially and nationally—to further advance student success.

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Introduction

Physician-scientists play an integral role within our health research environment, engaging in the full spectrum of scientific exploration from novel discovery to clinical translation. These individuals possess fluency in the languages of both scientific discovery and medicine, employing their bilingualism to facilitate essential crosstalk between individual domains. Despite the repeatedly acknowledged value of physician-scientists, their vulnerability to attrition has been underscored for decades [1–4]. Most recently, a report by The National Institutes of Health Physician-Scientist Workforce Advisory Group demonstrated that the physician-scientist demographic is increasingly composed of older investigators, forecasting a decline in the number of physician-scientists [5]. Recommendation number one from the Advisory Group was for the The National Institutes of Health to “sustain strong support for the dual training of MD/PhDs”.

The MD/PhD programs—in which students pursue parallel training towards both an MD and PhD degree—offer a critical pathway in the education of the next generation of physician-scientists. Although these programs are not immune to criticism and their efficacy has been questioned [6,7], MD/PhD programs have generally met their training objectives and broader educational goals within academia. In the United States, where dual MD/PhD programs are more abundant, efficacy of these programs has been evidenced by multiple single institution [8–11] and nation-wide studies [12–14]. In the most comprehensive study on MD/PhD programs to date, by the American Association of Medical Colleges in April 2018, up to 80% of MD/PhD program alumni surveyed indicated involvement in research; consistent with the initial objective of their MD/PhD training [14]. While there exists a paucity of outcome data on Canadian MD/PhD programs—due in large part to their relative novelty—similar trends to our American counterparts have been identified [15–17]. In a 2017 nationwide outcome study of MD/PhD program graduates, 83% of respondents were appointed as faculty at academic institutions and 53% had been principal investigators on at least one recent funded project [16]. Of the respondents appointed at academic institutions, 77% dedicated at least 20% of their time to research and 44% dedicated at least 50% to research. Similar trends have been identified at the institutional level: at the University of Calgary, 40.6% of MD/PhD trainees five years or more beyond graduation were classified as physician-scientists [17]; at McGill University, 60% of MD/PhD graduates who completed training became physician-scientists, the majority of which remained in Canada [15].

Despite the success of Canadian MD/PhD programs, there is a lack of 1) programmatic evaluation identifying common challenges and 2) sharing of best practices. A recent pan-Canadian survey highlights that MD/PhD programs vary widely by structure, funding, tuition and mentorship opportunities [18]. Due to significant inter-program variation, further efforts are required to disseminate innovative changes to individual curricula after identifying old and new challenges. However, to the best of our knowledge, there exists only one detailed examination of an MD/PhD program’s performance and areas for improvement based on student perspective [19].

The University of Ottawa MD/PhD program follows a common three-block structure, where students complete pre-clerkship (two years), then PhD studies (two to four, but usually three years), followed by clerkship (two years) for a total program duration of seven (range six to eight) years. Considering that the compressed timeframe of a mean of three years for PhD completion may pose a challenge to achieving a productive research experience, flexibility for bolstering research time exists, including 1) completion of manuscript publishing and thesis defence during clerkship, 2) commencing part-time PhD studies during pre-clerkship and 3) under extenuating circumstances, extension of full-time PhD studies. We first reported on the MD/PhD program at the University of Ottawa in 2012; three years after its establishment [20]. With the graduation of the first cohort in 2017, it was time to examine the successes and challenges of the program to date. The goal of our present study is to assess the objective and subjective metrics of the MD/PhD program at the University of Ottawa, with a particular emphasis on the trainee perspective. Our report contributes to the growing body of knowledge surrounding the many concrete obstacles experienced by students within MD/PhD programs and the key areas that can be improved upon locally, provincially and nationally to further facilitate success.

Methods

Survey design

We designed a 58-question survey (available upon request from author) containing a mixture of Likert scale, restricted and unrestricted multiple-choice questions and open-field text questions (AP, MS). Survey design was based on author feedback. While there is no standard in the field for evaluating MD/PhD program efficacy and student experience, we used previously published survey designs as a guide [16,19]. Our survey consisted of three parts: part one included program demographics, accomplishments and productivity; part two included student experience in the

program, covering administrative support, financial support, career planning advice, program transition guidance and formal mentorship; part three included global narration of program strengths and weaknesses. All questions in the survey were optional.

Survey distribution

The survey was coded into an internet-based survey platform and distributed by e-mail by the program administrator (who was not involved in preparation of this article) to all current students and alumni, totaling 26 students. The survey was distributed on January 4th, 2018 with a completion deadline of February 18th, 2018; two reminder emails were sent in the interim. Participants were informed of the length and purpose of the study and had the option to change their answers at any point. No personal information was collected. Survey participation was voluntary and no incentives were provided. All initiated surveys were completed.

Data analysis and interpretation

Survey participation was open, but all responses were validated to be from independent respondents and subsequently anonymized (by an individual not involved in manuscript preparation). Data were analyzed by blinded authors who did not participate in the codification and anonymization process (AP, LC, ABR). All analyses were limited to descriptive statistics. Given the small cohort size, we did not perform any subgroup assessments to preserve participant anonymity. When analyzing and graphically representing Likert scale satisfaction data, we grouped positive and negative responses together (i.e., satisfied with very satisfied and dissatisfied with very dissatisfied). When a question did not apply to a student based on the stage of their training, we excluded their response from the analysis (e.g., pre-clerkship students were not considered in PhD award success). Data interpretation was initially performed by AP, with subsequent feedback from all authors.

Results

Survey respondent demographics

Our survey received a high (23/26, 88.5%) participation rate. To examine diversity in the program, survey respondents were asked to self-report various identity metrics (Table 1). The majority of respondents (65.2%) were male and 39.1% of respondents identified as members of a visible minority. One respondent identified as Indigenous and one respondent identified as a person with a disability.

Interestingly, 56.5% of the respondents held a Master's degree prior to entering the program, which is higher than the national average of 23.5% in comparable programs [16].

TABLE 1. Demographic information of survey participants

Demographic information		Number	Percentage (%)
Sex	Male	15	65.2
	Female	8	34.8
Age at admission	19-22	8	34.8
	23-26	11	47.8
	27-30	4	17.4
	31-35	0	0
	>35	0	0
Language of study	French	9	39.1
	English	14	60.9
Visibly minority	Yes	9	39.1
	No	14	60.9
Indigenous	Yes	1	4.3
	No	22	95.7
Person with a disability	Yes	1	4.3
	No	22	95.7
Previous education	Honours Bachelor's degree	10	43.5
	Master's degree	13	56.5
Graduate program	Cellular and Molecular Medicine	11	47.8
	Microbiology and Immunology	5	21.7
	Biochemistry	3	13.0
	Neuroscience	1	4.3
	Biology	1	4.3
	Undecided	2	8.7

TABLE 2. Admission statistics 2013–2018

Admission parameters	2013	2014	2015	2016	2017	2018
Number applied	92	125	182	157	247	256
Number interviewed	8	9	16	7	8	8
Number admitted	2	4	4	4	4	2
Percentage of applicants admitted (%)	2.17	3.20	2.20	2.55	1.62	0.78
Percentage of students in MD entering class (%)	1.22	2.44	2.44	2.44	2.44	1.22
Number enrolled (total)	11	15	19	23	27	29

Admission statistics

In addition to survey data, we examined admission statistics from 2013–2018 (Table 2). The number of applicants has steadily increased from 2013–2018, with a 178% increase in number of applicants between 2013 and 2018. During the same period, the number of admitted students remained relatively constant, with either two or four students admitted each year. Consequently, the percentage of applicants admitted into the program has steadily decreased, with the highest percentage of 3.20% admitted in 2014 and the lowest rate of 0.78% in 2018.

Awards and productivity

Tracking student accomplishments during trainee years is one metric for elucidating student success. As these data are primarily restricted to the research accomplishments, we only queried respondents who had started or completed their graduate studies. Across the 16 survey respondents who had started or completed their graduate studies, a total of 45 national and/or provincial scholarships were awarded (Figure 1A). Of note, none of these awards could be held concurrently, so by necessity many of these awards were declined. Regarding program research output as one measure of productivity, students were heavily engaged in academic activities including conference participation, poster presentations, and manuscript publications (Figure 1B). Across the 16 survey respondents who had started or completed their graduate studies, a mean of 6.4 conferences and/or workshops were attended and 8.3 poster and/or oral presentations delivered. Mean number of manuscripts published by students (not stratified field of publication) was

3.5. Manuscripts were published predominately in the field of basic science and discovery (70.3%).

Tuition support

We next sought to investigate the role of tuition support in attracting candidates to the MD/PhD program. Of note, all survey participants were, and for those still in the program, are, recipients of full tuition coverage for the duration of the program. When asked directly whether tuition coverage influenced the respondents' decision to accept program admission, the majority (19/23, 82.6%) of respondents answered affirmatively (Figure 2A). Almost half (11/23, 47.8%) of respondents indicated they would have declined their offer of admission into the MD/PhD program had full tuition support not been provided (Figure 2B).

Mentorship and program meetings

Overall satisfaction with mentorship was mixed, with 40.9% of respondents indicating satisfied or very satisfied and 22.7% of respondents reporting dissatisfied or very dissatisfied (Figure 3A). At the time of this survey, the MD/PhD program provided a formal peer mentorship program, whereby incoming first-year students were paired with third-year students. Notably, satisfaction was widespread for informal peer mentorship (81.0%) in contrast to the formal peer mentorship program (22.2%). Respondents' satisfaction with program-wide meetings was largely neutral; with 69.6% of respondents indicating neither satisfied nor dissatisfied (Figure 3A). The majority of respondents (65.2%) indicated a preference for semesterly program-wide meetings (Figure 3B). When aggregating respondents' top three preferred topics to be discussed at program meetings, priorities were

FIGURE 1. Scholarship success and student productivity.

A) Success of the survey respondents on five key publicly funded awards. Participants were surveyed on which awards they had been offered, not which awards they held. Eligible students were defined as those who had completed pre-clerkship and thus passed at least one cycle of graduate funding applications.

*Students who enter the program directly from an undergraduate degree are eligible to apply for the Canada Graduate Scholarship-Master's Award.

B) Scholarly activity of students, including attendance at conferences and workshops, posters and presentations and publications in three main overarching domains. Mean and standard deviation indicated.

wide-ranging and included planning for transition points within the program (17/22, 77.3%), program administration (15/22, 68.2%) and career planning (15/22, 68.2%) (Figure 3C).

Career planning advice on becoming a clinician-scientist

Overall, satisfaction with career planning advice pertaining to becoming a clinician-scientist was low, with 42.9% of respondents reporting dissatisfied or very dissatisfied (Figure 4A). Satisfaction remained highest when advice was received from peers and senior trainees in the program (65.2%) and

FIGURE 2. Influence of tuition support on acceptance of admission offer. All survey participants are recipients of full tuition coverage for the duration of the program.

A Did your offer of full tuition coverage influence your decision to accept admission to the University of Ottawa MD/PhD program?

B Would you have declined your offer of admission to the University of Ottawa MD/PhD program if you did not receive full tuition coverage?

by the participants' direct research supervisors (55.0%). In contrast, satisfaction was markedly low for career planning advice when received by faculty-administered workshops (20.0%) or individual career counselling (18.8%). Respondents' top priorities of sources of career planning advice to improve remained varied (Figure 4B). The highest proportion of respondents indicated Faculty-administered planning workshops and the MD/PhD Program Director as the top priority (6/23, 26.1%). However, when aggregating the respondents' top three priorities for improvement, career planning advice provided by the faculty members was ranked highest by respondents (14/23, 60.9%).

Program transition guidance

Overall satisfaction with program transition guidance was low, with 55.6% of respondents indicating dissatisfied or very dissatisfied (Figure 5A). Interestingly, the degree of satisfaction was highest during early program transitions of the curriculum (e.g., program entry (78.8%) and transferring to summer research (47.6%)) and substantially decreased for transitions later in the program (e.g., transfer to clerkship (12.5%)). Respondents were most satisfied with guidance provided by peers and senior trainees (63.6%) and least satisfied with guidance from the administrative support (18.2%). Respondents' top priority to improve pertaining to transition guidance included administrative support (10/23, 43.5%) (Figure 5B).

Formal clinician-scientist training

The majority of respondents (78.3%) indicated interest in taking a course designed specifically for clinician-scientist trainees (Figure 6A). In addition, many respondents (82.6%) expressed interest in an MD/PhD program-specific workshop that covers topics such as career planning, program transitions and scholarship applications (Figure 6B).

Discussion

The MD/PhD program is becoming more competitive

With a 178% increase in the number of applicants between 2013 and 2018 it is clear that the number of students interested in the program is growing. Comparatively, the University of British Columbia witnessed a 250% increase in MD/PhD applicants between 2010 and 2015 [21]. Despite the increase in number of applicants, the number of seats available has remained unchanged at our institution. Since the inception of the program, a maximum of four students have been admitted per year; paired with rising student interest, the admission to the program has become increasingly competitive, as measured by the declining ratio of admission to applicant numbers.

Achieving mission-appropriate diversity remains a challenge

In our previous report on the MD/PhD program at the University of Ottawa in 2012, the low number of women in the program, at the time 20%, was identified as an issue to

FIGURE 3. Mentorship and program-wide meetings. A) Respondents' satisfaction with various components of mentorship and program-wide meetings. Numerical values in bar segments indicate percentage of respondents who selected the indicated option. B) Respondents' preferred frequency of program-wide meetings. C) Respondents' priority ranking when asked what content should be included at program-wide meetings, from highest (1) to lowest (7) priority.

address [20]. While indeed we have seen marked improvement as 34.8% of survey respondents identified as female, there is still room for improvement. In 2011, only 40.3% of trainees enrolled in MD/PhD programs nationally were women, while 58% of medical trainees were women [22]. More recently, 58.2% of the 2,951 first-year students who enrolled in Canadian faculties of medicine in 2016/2017 were women [23]. Despite the more balanced gender distribution in MD streams, MD/PhD programs continue to see underrepresentation of women. Further work must be done to identify and, if present, mitigate

barriers contributing to why fewer women are enrolled in clinician-scientist training programs.

MD/PhD students are scholarly and productive

Survey respondents reported widespread success with a variety of national and provincial scholarships (Figure 1A). For example, in the past five years, 71.4% (10/14) of the Canadian Institutes of Health Research Vanier Canada Graduate Scholarships awarded to University of Ottawa were to students enrolled in the MD/PhD program. Of

FIGURE 4. Satisfaction with career planning advice. A) Respondents' satisfaction with various sources of career planning advice. Numerical values in bar segments indicate percentage of respondents who selected the indicated option. B) Respondents' priority ranking when asked which sources of career planning advice should be improved, from highest (1) to lowest (8) priority.

note, students may have also received additional private scholarships (e.g., those granted through non-for-profit organizations) that were not captured in this survey. Students were, on average, considered productive, with the average publication rate of 3.5 manuscripts per student during the monitored time frame (Figure 1B). Again, these values may

underrepresent total productivity during the program, as we polled students at all stages in the program, not just program alumni. Commonly, students continue to publish papers related to their PhD topic for several years following successful completion of the program.

FIGURE 5. Satisfaction with program transition guidance (i.e., advice, instruction and/or support). A) Respondents' satisfaction with guidance received at various program transitions and satisfaction with the various sources of program transition guidance. Numerical values in bar segments indicate percentage of respondents who selected the indicated option. Number of respondents are indicated, as we included only responses from students who had received advice for that stage of training. B) Respondents' priority ranking when asked which sources of program transition guidance should be improved, from highest (1) to lowest priority (6).

FIGURE 6. Formal clinician-scientist training. A) Respondents' interest in taking a course designed specifically for clinician-scientist trainees. B) Respondents' interest in, and preferred frequency of, an MD/PhD program-specific workshop that covers topics such as career planning, program transitions and scholarship applications.

An interesting question is whether the current graduate studies timeline of the MD/PhD program limits research success. To compare MD/PhD students to PhD peers, we acquired internal scholarship and publication data from two University of Ottawa graduate studies departments (both of which have MD/PhD students enrolled). In one department, 59% of PhD graduates published a first authored paper, while in comparison, 100% of MD/PhD students have published a first author paper by the time of formal PhD completion. In another department, 41% of graduate students received external funding, while 100% of MD/PhD students received external scholarships. Furthermore, of the prestigious Vanier Scholarships awarded to the Faculty of Medicine from 2013–2019, 63.2% of the awardees were MD/PhD students, despite only constituting approximately 4% of the total graduate student body. While these data are limited, they suggest that the restricted timeline of the MD/PhD program by itself does not limit research productivity by MD/PhD students in comparison with that of their PhD peers. Future studies will seek to directly compare MD/PhD and PhD students to further explore this question.

Tuition support may play a role in attracting candidates

It is well known that tuition support plays an integral role in a variety of outcome metrics for MD/PhD programs. For example, a higher education debt burden is associated with a lower chance of program completion, a reduced likelihood of pursuing faculty appointments and decreasing program satisfaction [24–28]. While the explanations for these trends are largely qualitative, they are intuitive: MD/PhD programs necessitate lengthier training, which can lead to higher debt loads and a significant earnings deferral, and there remains a perception that clinician-scientists experience reduced remuneration compared to their clinical colleagues without responsibilities to conduct research [29,30]. Thus, it is striking, but perhaps not surprising, that 47.8% of survey respondents would have declined their offer of admission into the MD/PhD program in the absence of full tuition support (Figure 2B). We may speculate as to the reasoning behind survey respondents' choice, such as competing MD/PhD program offers or a balancing of tuition support against the financial disincentive of pursuing MD/PhD training. Regardless, on an individual institution basis,

financial support remains a key component of attracting candidates.

Mentorship remains a challenge, although peer mentorship shines

Canadian MD/PhD students have identified mentorship as important to their success, yet the majority of students express some level of dissatisfaction with the mentorship received [28]. In our survey, overall satisfaction with mentorship was mixed, with 40.9% of respondents indicating satisfied or very satisfied and 22.7% of respondents reporting dissatisfied or very dissatisfied (Figure 3A). Of note, informal peer mentorship shines, as satisfaction was widespread (81.0% satisfied or very satisfied). In contrast, students report low satisfaction on career planning advice from faculty (27.3% satisfied or very satisfied, Figure 4B) and program transition guidance from faculty (25.0% satisfied or very satisfied, Figure 5A). Current levels of dissatisfaction with faculty mentorship is noteworthy, considering the critical role this form of mentorship plays in trainee development. It has been argued that the future of mentoring clinician-scientists must involve cohesive teams of transgenerational, dedicated mentors who can provide committed (and possibly compensated) time to this critical component of trainee success [2]. Interestingly, the National Institute of Health in the United States provides an award, called the K24, that is a salary-based award designed to help physician-scientists carve out protected time to mentor the next generation of clinical investigators. Perhaps a similar funding structure should be established in Canada in order to establish these mentors, in addition to procuring financial support by medical schools through internal awards or funding.

Program transitions later in the program are more difficult

Nationally, improving transitions in training is a key priority for MD/PhD trainees [18]. When we examined respondents' satisfaction with program transition guidance, an interesting trend emerged—student satisfaction decreased with program transitions that were temporally later in the program (Figure 5A). While transition guidance may not be as adequately developed for later program transitions, it is also possible that transitions later in the program are inherently more difficult and thus warrant more attention by program administration. Indeed, such an observation is corroborated by the current approach by many MD/PhD programs when addressing integration, which commonly focuses on the transfer from graduate to clinical studies. A number of schools in the United States have employed Re-immersion Programs targeted to help MD/PhD students navigate the

transition into the clinical setting [31,32]. Our finding that students are least satisfied with the guidance received when transferring to clerkship is evidence that support for targeted programs at this critical juncture, such as the introduction of a Re-immersion Program. At the time of this writing, all uOttawa MD/PhD students had the option of participating in a Clinical Skills Support Program, but student uptake and efficacy was variable.

Career planning advice for future clinician-scientists must be multidimensional

Both Canadian MD/PhD trainees and program directors have identified targeted career planning and development support as a priority [18]. However, identification of the most effective means of delivery remains elusive. In our survey, only 28.6% of the students indicated satisfaction with career planning advice, confirming this as a critical area to address (Figure 4A). To our surprise, there was not one clear source of career planning advice that students collectively agreed should be a top priority for amelioration (Figure 4B). We therefore emphasize that future improvements to MD/PhD career planning must take a multifaceted, flexible approach that provides development support from a variety of angles. The relatively few students in the MD/PhD programs, in comparison with the total number of medical students and graduate students enrolled at any given faculty in Canada, limits the resources that can be applied to the topic of career planning. Improvements at the national level would assist in addressing this critical need of the MD/PhD students.

Students are amenable to dedicated clinician-scientist curricular programming

Program structure and degree of integration has been noted to vary widely across Canadian MD/PhD programs, with only few programs offering concurrent training structures or other forms of clinical and research integration as options for students [18]. Despite the idealized goal of achieving integrated medical-scientists training, most institutions simply provide tandem medical-graduate training. In a single institution study in 2011, at the University of Toronto, the majority of MD/PhD trainees (58%) reported that integration of PhD and MD training needed improvement, as only 6% considered the program already well integrated [19]. When querying our students, the majority of respondents (78.3%) indicated interest in taking a course designed specifically for clinician-scientist trainees (Figure 6A). In addition, most respondents (82.6%) expressed interest in an MD/PhD program-specific workshop that would cover topics such as career planning, program

transitions and scholarship applications (Figure 6B). Taken together, we emphasize that program integration through dedicated curricula would be an approach amenable to our students.

Limitations

Naturally, as a single-institution study, transferability of these results is limited, and results must be extrapolated only within the context of individual schools. Despite a high response rate, the overall sample size is low due the small cohort sizes of the MD/PhD program. At the time of the survey, only one cohort of students had completed the program (and a second was within months of completion), therefore outcome data, such as residency matching success, career choices and so forth, could not yet be assessed.

Conclusion and perspective

This work contributes to the growing body of knowledge surrounding the challenges encountered by MD/PhD programs in Canada and the key areas that can be addressed to further facilitate success. We have established a survey platform that will enable other schools to query their students and identify critical areas for programmatic improvement. As a relatively young program, we plan to assess the outcome of our graduates once we have established a sufficient alumni base.

Of significant note, several of the findings in this study underscore a more global dialogue surrounding the need for improved support for clinician-scientist trainees, covering domains of financial support, intergenerational mentorship and career guidance. It is well-established that the number of physician-scientists has dwindled, yet their role in the healthcare system remains invaluable. In a recent article by Jain et al. elucidating strategies for reinvigorating clinician-scientist training, they commented "...innovations [are] the result of smart and motivated people positioned in supportive environments that allowed them to ask hard questions and pursue hard problems" [33]. Much more work needs to be done in Canada, and quite urgently, to foster the supportive environment necessary to achieving healthcare innovation. MD/PhD programs are ripe for elevation and offer an instrumental training pathway for the next generation of clinician-scientists.

In addition to ongoing and future program investigations, more effort needs to be focused on the national leadership and funding bodies: to ensure the present and future needs of the Canadian health research environment are adequately met, further efforts must be dedicated towards improving physician-scientist training in

this country and effectively deploying the range of skill sets acquired by our MD/PhD graduates to the maximum benefit of Canada's population.

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References

1. Mirmira RG. Editorial: The Vulnerable Physician-Scientist. *Mol Endocrinol*. 2014;28(5):603-606. doi:10.1210/me.2014-1085
2. Schafer AI. The Vanishing Clinician Scientist? *Transl Res J Lab Clin Med*. 2010;155(1):1-2. doi:10.1016/j.trsl.2009.09.006
3. Wyngaarden JB. The Clinical Investigator as an Endangered Species. *N Engl J Med*. 1979;301(23):1254-1259. doi:10.1056/NEJMJ197912063012303
4. Goldstein JL, Brown MS. The clinical investigator: bewitched, bothered, and bewildered--but still beloved. *J Clin Invest*. 1997;99(12):2803-2812.
5. Group P-SWW, Ginsburg D, Mills S, Shurin S. Physician-Scientist Workforce Working Group Report. Natl Inst Health Bethesda MD. 2014.
6. Whitcomb ME. The Need to Restructure MD-PhD Training. *Acad Med*. 2007;82(7):623-624. doi:10.1097/ACM.0b013e318065b4ba
7. Rosenberg LE. MD/PhD Programs—A Call for an Accounting. *JAMA*. 2008;300(10):1208-1209. doi:10.1001/jama.300.10.1208
8. Bradford WD, Anthony D, Chu CT, Pizzo SV. Career characteristics of graduates of a Medical Scientist Training Program, 1970-1990. *Acad Med J Assoc Am Med Coll*. 1996;71(5):484-487. doi:10.1097/00001888-199605000-00019
9. Frieden C, Fox BJ. Career choices of graduates from Washington University's Medical Scientist Training Program. *Acad Med J Assoc Am Med Coll*. 1991;66(3):162-164. doi:10.1097/00001888-199103000-00008
10. Schwartz P, Gaulton GN. Addressing the Needs of Basic and Clinical Research: Analysis of Graduates of the University of Pennsylvania MD-PhD Program. *JAMA*. 1999;281(1):96-99. doi:10.1001/jama.281.1.96-JPU2-2-1
11. McClellan DA, Talalay P. M.D.-Ph.D. training at the Johns Hopkins University School of Medicine, 1962-1991. *Acad Med J Assoc Am Med Coll*. 1992;67(1):36-41. doi:10.1097/00001888-199201000-00008
12. Harding CV, Akabas MH, Andersen OS. History and Outcomes of 50 Years of Physician-Scientist Training in Medical Scientist Training Programs. *Acad Med J Assoc Am Med*

- Coll.* 2017;92(10):1390-1398. doi:10.1097/ACM.0000000000001779
13. 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. *Acad Med J Assoc Am Med Coll.* 2010;85(4):692-701. doi:10.1097/ACM.0b013e3181d3ca17
 14. American Association of Medical Colleges. National MD–PhD Program Outcomes Study; 2018.
 15. Zhou TE, Savage PA, Eisenberg MJ. Canadian M.D.-Ph.D. Programs Produce Impactful Physician-Scientists: The McGill Experience. *Journal of Biomedical Education.* doi:10.1155/2016/3836467
 16. Skinnider MA, Squair JW, Twa DDW, et al. Characteristics and outcomes of Canadian MD/PhD program graduates: a cross-sectional survey. *CMAJ Open.* 2017;5(2):E308-E314. doi:10.9778/cmajo.20160152
 17. Bau JT, Frolkis AD, Nathoo N, Yipp BG, Hollenberg MD, Beck PL. Career and research outcomes of the physician-scientist training program at the University of Calgary: a retrospective cohort study. *CMAJ Open.* 2017;5(2):E395-E401. doi:10.9778/cmajo.20160103
 18. Jones AA, Ng E, Deguise M-O, et al. MD/PhD Training in Canada: Results from a national trainee and program director review. *Clin Invest Med.* September 2016:E132-E139.
 19. Ballios BG, Rosenblum ND. Challenges Facing Physician Scientist Trainees: a Survey of Trainees in Canada's Largest Undergraduate and Postgraduate Programs in a Single Centre. *Clin Invest Med.* October 2014:E268-E283.
 20. Michael G. Schlossmacher, Monique Lalonde, Jean-Marc Renaud, Gary Hollingworth, Richard L. Hebert, Ruth Slack. The M.D./Ph.D. program at the University of Ottawa: Overview and first performance report for 2009-2012. *Univ Ott J Med.* 2012;2(1):11-14.
 21. Twa DDW, Squair JW, Skinnider MA, Ji JX. The Canadian clinician-scientist training program must be reinstated. *J Clin Invest.* 2015;125(12):4317-4319. doi:10.1172/JCI85194
 22. Appleton CT, Belrose J, Ward MR, Young FB. Canadian Clinician Investigator Training in the 21st Century. *Clin Invest Med.* August 2013:E163-E169.
 23. Association of Faculties of Medicine of Canada. Canadian Medical Education Statistics. *AFMC.* 2017;39:2.
 24. Andriole DA, Whelan AJ, Jeffe DB. Characteristics and Career Intentions of the Emerging MD/PhD Workforce. *JAMA.* 2008;300(10):1165-1173. doi:10.1001/jama.300.10.1165
 25. Andriole DA, Jeffe DB. Predictors of full-time faculty appointment among MD–PhD program graduates: a national cohort study. *Med Educ Online.* May 2016. <https://www.tandfonline.com/doi/abs/10.3402/meo.v21.30941>. Accessed November 6, 2018.
 26. Jeffe DB, Andriole DA. A National Cohort Study of MD–PhD Graduates of Medical Schools With and Without Funding from the National Institute of General Medical Sciences' Medical Scientist Training Program. *Acad Med J Assoc Am Med Coll.* 2011;86(8):953-961. doi:10.1097/ACM.0b013e31822225c5
 27. Jeffe DB, Andriole DA, Wathington HD, Tai RH. Educational outcomes for students enrolled in MD-PhD programs at medical school matriculation, 1995-2000: a national cohort study. *Acad Med J Assoc Am Med Coll.* 2014;89(1):84-93. doi:10.1097/ACM.0000000000000071
 28. Yoon J-Y, Appleton T, Cecchini MJ, et al. It begins with the right supervisor: Importance of mentorship and clinician-investigator trainee satisfaction levels in Canada. *Clin Invest Med.* December 2013:E269-E276.
 29. Lander B, Hanley GE, Atkinson-Grosjean J. Clinician-Scientists in Canada: Barriers to Career Entry and Progress. *PLOS ONE.* 2010;5(10):e13168. doi:10.1371/journal.pone.0013168
 30. Lockyer JM, Brzezina S, Thake J, et al. Clinician Scientists in Canada: Supporting Innovations in Patient Care through Research. 2016.
 31. Goldberg C, Insel PA. Preparing MD-PhD Students for Clinical Rotations: Navigating the Interface Between PhD and MD Training. *Acad Med J Assoc Am Med Coll.* 2013;88(6). doi:10.1097/ACM.0b013e31828ffeeb
 32. Bills JL, Davidson M, Dermody TS. Effectiveness of a Clinical Intervention for MD/PhD Students Re-entering Medical School. *Teach Learn Med.* 2013;25(1):77-83. doi:10.1080/10401334.2012.741539
 33. Jain MK, Cheung VG, Utz PJ, Kobilka BK, Yamada T, Lefkowitz R. Saving the Endangered Physician-Scientist — A Plan for Accelerating Medical Breakthroughs. *N Engl J Med.* 2019;381(5):399-402. doi:10.1056/NEJMp1904482