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Career transitions: actionable recommendations by graduate students and postdoctoral scholars on achieving research independence in biomedical sciences

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Academic research in the U.S. is managed through and driven by principal investigators overseeing independent research programs, often with a goal of training researchers in the process. The theoretical path to becoming a principal research investigator consists of developing research skills during a PhD, followed by "apprentice"-style research experiences as a postdoctoral researcher, ultimately leading to independent leadership of research projects (and teams) as a faculty member. Early career researchers looking to climb this career ladder therefore need to develop research "independence", or independence of thought. Workshops conducted with graduate students and postdoctoral researchers in biomedical sciences at multiple universities revealed barriers to research independence. Through these workshops, early career researchers identified solutions to achieving research independence, which revolve around intellectual contributions, training and mentorship, career development and progression, compensation and benefits, work-life balance and mental health, and finally immigration and visas. We propose that systemic changes in these areas will lead to the development of a healthy and productive research enterprise that can build future leaders in the field through developing independent researchers who can advance scientific research.

KEYWORDS

research independence, early career researchers, biomedical, graduate students, postdocs

Introduction

Academic research "independence", and how to attain it, is a topic of critical importance for early career researchers (ECRs, broadly graduate students and postdocs), and to the wider academic and scientific communities. In attempting to grapple with the issue of "independence", the National Academies of Sciences, Engineering and Medicine report The "Bridges to Independence" (National Research Council, 2005) report concluded that: *"The definition of 'independence' as a researcher in a tenure-track faculty position who has received his or her first R01 research project grant is* outdated and

needs to be redefined as *an 'independent investigator' is one who enjoys independence of thought*" (McDowell, 2017). This report specifically stated that "independence" should not be considered as "isolated" or "solitary" or to imply "self-sustaining" or "separately funded", but rather that independent researchers should be in a position to make unique intellectual contributions to research discoveries. The current idealized path to becoming a principal research investigator consists of developing research skills during a PhD, followed by "apprentice"-style research experiences as a postdoctoral researcher, ultimately leading to independent leadership of research projects, and scientific teams, as a faculty member. In addition to conducting experiments, researchers are also involved in scholarly activities such as writing manuscripts and grants, along with preparing and presenting work at national and international conferences, all of which are important for development of their critical thinking about research projects.

However, the training goals for ECRs become conflicted with incentives to demonstrate productivity, not only for themselves, but for those they work for (namely their faculty mentors and academic institutions). When ECRs are primarily funded from research project grants secured by their faculty mentors, they are, in reality, staff carrying out the goals of someone else's grant instead of trainees being supported by it to develop their own directions. Consequently, they are left with little time to focus on generating and developing independent research ideas. This situation can lead to burnout (Nature, 2024 based on the recent book "Slow productivity: The lost art of accomplishment without burnout") and conflict related to not being able to take projects with them to their own laboratories (Barres, 2017), which can ultimately have lasting impacts on their careers (Patsali et al., 2024).

In order to understand the struggles that ECRs face in achieving research independence, it is necessary to discuss the current hypercompetitive academic environment, which is particularly acute in the U.S. biomedical science ecosystem (Alberts et al., 2014). Given that the U.S. scientific enterprise and research workforce are heavily dependent on fluctuating trends in federal funding (Teitelbaum, 2014; Hur et al., 2015, 2017), in a highly hypercompetitive and unstable funding scenario that researchers often find themselves in, the priority becomes maximizing the amount of scientific research output at minimal cost and at the expense of training future scientists.

This is true both for graduate students and postdocs, who albeit are in different stages of their careers, may be faced with similar pressures to publish and obtain grant funding independently from their advisors. While these issues are likely to overlap for the two groups, it is also important to consider unique challenges that they each face. For graduate students, lack of training and mentorship may be perhaps more problematic given they are learning the ropes of how research works and may need to publish several first author publications, which are required for graduation in many universities and for securing competitive postdoctoral positions of their liking.

Conversely, postdocs often encounter well-documented challenges related to compensation and benefits, as well as difficulties in maintaining work-life balance and managing multiple competing demands—issues that graduate students may not typically face. Both postdocs and graduate students are likely to experience limited independence in leading research projects and may be unable to take their projects with them when they transition to new roles. Additionally, international scholars within both groups may face further barriers. For postdocs aiming to transition into faculty positions, this shift brings added responsibilities, such as securing grant funding, hiring staff, and purchasing equipment once they establish their own laboratories.

In both cases, the practical labor of STEM research is carried out by ECRs. The number of PhD degrees awarded in biomedical sciences from U.S. universities has increased in the last three decades (National Center for Science Engineering Statistics, National Science Foundation, 2021; National Science Foundation, 2018, 2014). Data collected in 2016 through a seminal study of research scientists (Sauermann and Roach, 2016) & in 2017 (Kahn and Ginther, 2017) showed that 80% of doctoral degree graduates went on to do a postdoc, and many do so as a default, and this leads to an increase in the number of postdocs in these disciplines. However, the number of academic tenure-track faculty positions has not increased correspondingly (NASEM, 2018a).

Additionally, to make matters worse, much of the faculty hiring was frozen due to effects of the COVID-19 pandemic (Chemjobber, 2020; Langin, 2020). Other studies also showed that during the COVID-19 pandemic, postdocs were particularly in a bind (Park, 2020), since most of them wanted academic faculty positions, but they also recognized that there were few of these roles to be had. Postdocs have traditionally been incentivized to focus on academic research outputs and productivity, and not on developing professional development skills they need to succeed in academic careers. Sadly, this type of skill development is not a focus of faculty hiring processes (van der Weijden et al., 2016; Nowell et al., 2020; NIH 2023 Advisory Committee to the Director Working Group Report) despite its importance for career training.

One of the aftermaths of the COVID-19 pandemic-induced faculty hiring freeze and the declining research positions was that graduating PhD students, particularly U.S.-citizens, were skipping postdoc training altogether (Langin, 2022) and choosing jobs outside academia. This trend created a reported paucity of postdocs in academic research, to the point where even high profile faculty claimed to be struggling to recruit qualified postdocs into their research labs (Woolston, 2022). While the faculty job market survived the COVID-19 pandemic and rebounded in 2022 (Kozik et al., 2022), the ripple effects were felt in the form of "the great resignation" where mid-career level faculty members were reported to leave the research track for higher paying jobs outside of academia (Gewin, 2022).

These faculty researchers attributed their departure from academia to the decreasing rewards and increasingly frustrating experiences they had, despite arguably being in the most secure (i.e., "tenured") part of their careers when they left. To our knowledge, there are no existing reports of a substantial resignation trend for senior-career level scientists, despite this phenomenon having been predicted since the 1980s as an imminent source of relief on the pressure (i.e., "bottleneck") of those competing for tenure-track faculty positions.

The academic system must move away from a decreased reliance on temporary trainees or ECRs, and the problem of a hypercompetitive environment needs to be fixed or at least

partially alleviated, in order to allow the enterprise to move toward developing a more sustainable research workforce (Ålund et al., 2020) that relies on resource-sharing and more permanent staff scientist positions (National Institutes of Health, 2023). This shift will require a change in the definition of research "independence" (National Research Council, 2005) to be more inclusive of the various groups engaged in performing basic research. This change can be achieved by taking into account the multiple roles that ECRs play in the research enterprise, the diverse funding mechanisms through which they may be compensated, and the broader systemic changes necessary to foster their independence in a collaborative research environment (NRC, 1969).

Fostering independence of thought for ECRs within a positive scientific environment will be important not only for their ability to develop research directions for their own laboratory, but also for designing more efficient mechanisms for the research enterprise to function as a whole (NASEM, 2018c). This change will help support future generation of scientists in STEM fields. A shift in the culture of science toward a practice where collaboration and creativity are valued over individual gain to the faculty member may incentivize ECRs to pursue academic careers instead of leaving academia because of a misalignment of personal values with those of the academy (Gibbs and Griffin, 2013).

Finally, not all academic scientists desire to become "independent" in terms of research (but may desire to become independent thinkers). Likewise, "independence" should not be so prized a quality in academia that it disincentivizes collaboration and participation in team science within research laboratories. In addition, not all independent researchers want to become faculty members. This should not be taken as a question of their motivation or scientific ability, but rather an understandable dedication to a particular kind of valuable role in the research enterprise. Therefore, there is a need for a research enterprise which broadly encourages career independence besides traditional faculty roles (National Institutes of Health, 2023).

Study conducted

In order to capture the barriers which ECRs have in their research independence and the solutions they propose, we organized a series of workshops at research-intensive universities in the U.S. and Japan: University of Chicago (2017, private university, $n = 50$), University of Illinois at Chicago (2017, public university, $n = 20$), Okinawa Institute of Science and Technology (Japan, 2018, private university, $n = 10$), University of California Irvine (2020, public university, $n = 43$) (McDowell, 2018, 2019). Each of these workshops included a range of 10–50 ECR participants, with around 120 total for all events.

After an initial overview discussion of the facts and figures underlying the hypercompetitive nature of the academic environment, GSM facilitated group discussions amongst participants to identify and describe barriers to research independence, followed by discussions on ways to address those barriers. Participant groups recorded collective ideas on sticky notes, and these ideas were then presented to the whole group, collected by GSM and are recorded in the Supplementary material.

TABLE 1 Barriers identified and solutions proposed to achieving research independence from workshops conducted.

Barriers to achieving research independence	Solutions for achieving research independence
• **Research and research roles.** Lack of independence in terms of research projects and ideas. • **Training and career progression.** Lack of career training for roles outside of academia. • **Mentorship.** Lack of mentorship guidelines from funding agencies, and mentorship training for faculty. • **Compensation and benefits.** The variation in salaries and benefits among ECRs, including postdocs. • **Work-life balance and mental health.** Lack of emphasis on work-life balance and mental health in academia. • **Immigration and visas.** Challenges faced by international scholars due to temporary immigration and visa status.	• **Research and research roles.** ECRs taking charge of their own research projects and academic careers. • **Training, career progression and progression.** Mandatory coursework for careers outside of academia. • **Mentorship.** Required mentorship training for research faculty supervisors. • **Compensation and benefits.** Higher salaries and improved benefits for ECRs including postdocs. • **Work-life balance and mental health.** A greater emphasis on work-life balance and mental health by institutions. • **Immigration and visas.** Decreased exploitation of foreign-born ECRs based on immigration and visa status.

While our interest is broadly in STEM fields, these workshops focused on trainees in biomedical sciences.

Workshop goals included:

1) informing ECRs of changing trends in the academic and scientific enterprise;
2) helping ECRs identify barriers they may face in developing research independence;
3) assisting ECRs in proposing solutions to attain research independence; and
4) enabling ECRs to make better informed decisions and take charge of their careers in research.

These workshops highlighted several themes around common barriers that ECRs face in achieving research "independence" and academic career growth, and solutions which different stakeholders could undertake (Table 1) to improve the scientific enterprise and support future generations (NASEM, 2007). Detailed data and quotes from these workshops can be accessed in the more extensive online pre-print published earlier (Singh et al., 2020).

Study limitations

The study outlined in this publication was not intended to be a comprehensive investigation but rather a pilot initiative aimed at supporting ECRs participating in specific workshops. As a secondary outcome, Future of Research collected and utilized ECR data to gain insights into the real-world challenges within academia, identifying potential reforms to help steer the academic system in the right direction. We acknowledge that the data gathered from these workshops may not be exhaustive, it provides a meaningful snapshot of the issues faced by individuals who were engaged enough with the workshop topics to dedicate time in discussing them.

This also highlights the caveat that data obtained comes from those who were self-motivated to come to the workshops, which is only a subset of all ECR voices at that particular institution. Nevertheless, responses from the workshops highlight well-known issues in the academic system, which is interesting in itself to reflect on the fact that opinions of our sample size represent trends that have been documented in the field. While the conclusions drawn in this publication are on the academic enterprise, they are primarily based on or are limited to our data. We believe the workshops provide the basis for a broader discussion on systemic changes that need to occur in academia, particularly given that responses we obtained come from trainees themselves and represent multiple types of institutions both in the U.S. and abroad.

Discussion

Cultivating academic researcher independence requires intellectual contributions and agency for ECRs over their own research ideas. This is in addition to training mechanisms needed to facilitate ECR research project development and mentorship preparation for ECRs by academic advisors. Another important element is including career training and education for ECRs when transitioning to the academic job market, and providing them with resources for career progression, adequate compensation and benefits to retain research talent in STEM, prioritization of work-life balance and assistance with mental health needs, and finally immigration and visa support for foreign-born ECRs to showcase their importance to the scientific enterprise and workforce (Department of Homeland Security STEM OPT).

Below, we expand on the role that each of these areas plays in cultivating research independence for ECRs and facilitates broader academic systemic change, based on barriers identified and solutions proposed from the workshops we conducted (Table 1). These events resulted in recommended actions for different stakeholders to foster research independence, including ECRs themselves, research groups and faculty mentors, and funding agencies (Table 2). All three of these groups play critical roles in achieving a sustainable research enterprise.

TABLE 2 Recommended actions for stakeholders to foster research independence, including early career researchers, research groups and faculty mentors, and funding agencies.

Stakeholder-specific recommendations
Early career researchers
• Keep track of PI's expectations for working hours, goals and milestones • Use the Individual Development Plan (IDP) to track progress • Find a good mentor who encourages research independence • Apply for grants and fellowships to be financially independent • Participate research peer to peer networks • Attend career and professional development events • Become aware of the immigration landscape and rules • Stay informed of institutional salary and benefits before accepting job offer • Track NIH salary scales for postdocs and graduate students • Seek work-life balance and mental health resources available on campus
Research groups and faculty mentors
• Mentors should be mentored (e.g. "train the trainer") • Encourage and participate in collaborative research projects • Allow independence for ECRs in writing grants and fellowship applications • Provide career development opportunities for ECRs in their labs • Incorporate professional development elements into graduate coursework • Include postdocs in career growth opportunities • Enhance job security for postdocs and create staff scientist positions • Increase transparency in institutional salary data and mentoring practices • Standardize institutional guidelines and policies for salaries, benefits • Support immigration and visa sponsorship policies for foreign-born researchers • Ensure working habits supporting work-life balance and mental health
Funding agencies
• Provide incentives to grantees for providing independence to their trainees • Relax restrictions on grants for foreign-born researchers • Allow postdocs to take their grants with them • Provide grant funding for supporting career development and mentorship training • Incentivize and reward faculty mentoring plans in the grant review process • Provide visa sponsorship fees in awarded grants for trainees • Make work-life balance and mental health training mandatory for institutions applying for grant funding • Support training for "the whole scientist" instead of only for research • Provide transparency and accountability for harassment and bullying

Research

The path toward independence for ECRs involves academic training while simultaneously helping them develop an area of interest, in order to carve out a niche allowing them to sustain and elevate their own research careers. In the current academic system, the faculty mentor carries out most of the intellectual labor of generating novel research ideas and writing grants, meanwhile delegating much of the practical labor to ECRs, with the purpose of generating data to advance the laboratory's publications and grants portfolio. This division of intellectual vs. practical labor prioritizes productivity toward the benefit of the laboratory and the university, while diminishing the focus on fostering research independence for ECRs in academic laboratories. Focusing on someone else's practical labor rather than their own intellectual development may prevent ECRs from critically thinking about their own research ideas, and reduce the level of intellectual conversations taking place within the laboratory, especially if the division of labor becomes entirely intellectual on the part of the faculty mentor, and entirely practical on the part of the ECR (Nature Editorial Board, 2024).

In order to take these factors into account toward academic reforms, we propose an all-encompassing definition of an independent researcher for postdocs that should be developed from what currently exists. This new definition of independence states that an independent researcher is "*a researcher involved in generating scientific ideas with freedom of thought and designing and conducting experiments to test them.*" Particular thought should be given to how this issue of lack of independence affects the retention of minoritized researchers (Layton et al., 2016), given it is known that women and minoritized populations have a harder time gaining access to research opportunities including grants (Ginther et al., 2011, 2016; Pickett, 2018). Some of these barriers may be attributable to implicit biases in academia (League of European Research Universities, 2018), but explicit systemic biases also exist in research ecosystems (Hoppe et al., 2019) particularly within the division of intellectual and practical labor which has a gendered history in science (Jardins, 2010).

This definition would allow graduate students to develop their own research directions while learning how the scientific system

works, and to differentiate themselves intellectually from other lab members and their advisors. This would also cultivate their ability to determine which projects they would like to pursue and go through the inevitable process of failing before succeeding in their experiments. Having independence to develop these research ideas early in their careers would ensure later success in postdoctoral and potential faculty roles. Conversely, having this definition of independence adopted by the academic community could contribute to long-term research success for postdoctoral scholars, especially when transitioning into faculty roles (Alberts et al., 2018). In these roles, additional expectations are placed on postdocs including the expectation to lead others.

Therefore, it would be important for postdocs to have a standardized lab environment and experience in terms of title, expectations and position duration (National Institutes of Health, 2023), and this could eliminate existing barriers and biases toward retaining talent in STEM. These principles could also be applied more broadly to other populations of early career researchers. Contrasting the ability of postdocs to pursue independent research directions with their current reality as staff on somebody else's research proposal will be an important part of reforming the system to better support trainees in general. This is beneficial particularly when they are hired on their advisor's grant after it has been awarded, at which point trainees have had no intellectual input into its design, and that can diminish their ability to develop independent research directions.

Training

The lack of adequate training mechanisms for ECRs to protect the time spent on, and the development of individual research project development and career progression, is a significant barrier to their research independence. Independent grants and fellowships could provide the protection of time and provision of resources (including financially) to foster research independence for both graduate students and postdocs. Generally across U.S. institutions, most ECRs are funded on research project grants from their faculty mentors, which supports the labor of research and materials needed to perform the work, but does not include their academic and career training in the process. As a result, a large number of ECRs are unable to take independent projects with them into their own laboratories (Barres, 2017).

A few of the solutions that can address these barriers include having ECRs keep track of the expectations from their faculty mentors, and being aware of additional burdens placed upon them. The nuts and bolts of running a laboratory are often hidden from graduate students and postdocs, and making these best practices more transparent could foster their professional transitions into running their own laboratories in the future. Additionally, it is important for ECRs, including postdocs who are more advanced in their career trajectory, to identify opportunities for fellowships in the first year of their training which can later help them attain independence.

It is therefore critical for ECRs to find faculty who are also mentors, and who encourage their own independence of thought and research ideas (Woolston, 2018), and can help support them in developing independent fellowship proposal submissions (National Science Foundation, 2009). This is particularly important for graduate students who are learning how science works in their first few years, but also for postdocs who are looking to transition into faculty roles, a transition that will require additional skills and balancing multiple responsibilities.

Research roles

Academic departments play a critical role in enhancing research independence for ECRs at a particular institution, and should also provide oversight and expectations for protecting their training and professional development. While this is an important need for both graduate students and postdocs, part of the issue is that many postdocs in particular are working as *de facto* staff scientists, but providing the benefit of doing so on low salaries and are often on temporary contracts. Compared to the dissertation and graduation requirements of graduate students, postdocs also do not have any formal requirements for undergoing training and yet they are claimed as "trainees", which often come with lower salary requirements driving valuable talent away from research.

One role for academic departments in solving this issue could be to provide different types of support and necessary structures for graduate students and postdocs including salaries and financial support for research studies similarly to investments in core department equipment. Some of the existing issues in academia when it comes to retaining talent could be solved by employing more staff scientists (Hyman, 2017). However, currently, institutions have little incentive for such positions, given that hiring postdocs costs them much less financially overall and postdoc hiring results in an already trained workforce when coming into academic roles.

Mentorship

Academic training uses an apprenticeship model, where ECR training is provided by faculty supervisors who are further ahead in their careers. In the U.S., these supervisors are incorrectly automatically referred to as "mentors". In reality, this is not always the case, in particular when it comes to faculty members training their graduate students who may need more guidance and different types of support as opposed to postdocs with more research experience. Therefore, the mentorship style should be different for each of these populations.

Faculty supervisors can also be mentors, but this is inherently complicated by the existence of the employer-employee relationship (Johnson, 2007). In order for both ECRs and faculty members to succeed in productive laboratory environments, faculty should supplement their supervisory duties with required mentorship training. However, the lack of institutional resources and specific career preparation programs that train current and future generations of faculty supervisors as effective "mentors", combined with little to no requirement on their part for a demonstration of formal mentorship skills and best practices to support ECRs (which may be required more at the graduate level), or commitments in hiring processes and grant applications (which

might impact postdocs more), means that faculty are expected to acquire mentorship skills by doing, not by learning.

In addition, with no formal requirements or oversight of mentorship ability, there is often no incentive for faculty supervisors to be good mentors, as this practice is not incentivized in funding mechanisms or career progression when it comes to tenure and promotion. In practice, therefore, faculty test and develop their mentorship skills by experimenting on those they supervise (ECRs in their labs), impacting future generations of researchers. Such experiments affect the career aspirations or trajectories of ECRs within the mentoring relationship. Poor mentorship by anyone in a supervisory role, including faculty, should not be a determining factor for who gets to stay in research.

Meanwhile, ECRs are often advised to seek the best mentors in their departments or institutions, although time pressures on faculty and their responsibilities may be different in public vs. private institutions and that could make a difference in their ability to train others. This can be a poor solution to a difficult problem, also because effective mentors may often be asked to overextend themselves to trainees in other labs, in order to make up for the lack of supervision they should be receiving from their direct faculty supervisors. Ironically, this allows poor mentors to out-compete good mentors, since without spending their time on mentoring, they are free to focus on meeting productivity incentives for their research labs which are often incentivized for career progression over mentoring practices. Meanwhile the effective mentors who are overburdened have less time for activities rewarded by tenure and promotion, such as research productivity. Thus, we drive good mentors out of academia, and retain ineffective ones who willthen hire ECRs into their labs, and that can dismantle the system as these ECRs will likely choose to leave research careers.

ECRs need to increase their focus on learning about and managing reasonable expectations set ahead of time by faculty supervisors, in a process referred to as "mentoring up" or "managing up" (Lee et al., 2016; Harvard Business Review Guides, 2013). This is an important skill for an academic career, which may need to be handled differently at the graduate vs. postdoc levels. However, given that the postdoc-to-faculty transition is one of two major checkpoints hindering the diversification of the biomedical professoriate (Meyers et al., 2018), particular attention should be given to mentorship at this critical juncture, as this is the only point in an academic trajectory where a single person hires, and fires, the researcher.

This is in contrast to undergraduate, graduate and faculty application and program or tenure committees. An evidence-based case for centering mentorship in academia has been previously made (NASEM, 2019), with mentoring resources provided by NASEM, Center for Improvement of Mentored Experiences in Research (CIMER), and National Research Mentoring Network (NRMN), including with NRMN/CIMER mentor training including a specific module called "Fostering Independence" addressing these topics. Therefore, a curriculum-based approach (similar to CIMER) would be important for ensuring effective mentoring training for ECRs aspiring to become future mentors or transitioning into supervisory roles in academic job sectors.

Career development

There is a lack of awareness of the current state of the academic job market by ECRs. This is likely to be true at the graduate level when trainees are entering the system, and there is a general lack of resources provided for their professional development. Academic institutions excel at providing excellent subject matter training and help produce a large pool of PhDs in specialized STEM fields, with vast technical knowledge and a good track record of academic publications. However, at both the graduate and postdoctoral levels, academic training does not translate into a workforce rich in independent thinking and professional skills, which are required at multiple stages in their careers in order to solve real world problems in society. This issue points to a gap between the skills that early career trainees hold and those required in the labor market (Mason et al., 2016; Bosch and Casadevall, 2017; Bosch, 2018).

To address this gap, incorporating professional skills into the academic training for ECRs is necessary, and this includes science communication, mentorship, leadership and business acumen (Roach, 2017). Providing ECRs with such training may decrease the phenomenon of PhD graduates defaulting into postdoc positions and remaining in long, underpaid, and overworked academic jobs when they could better utilize their talents elsewhere. This training could in turn also help retain more postdocs in academia and enable their preparation for these roles. Another potential solution could come from funding agencies, some of which are moving toward prioritizing career development for ECRs.

For example, the National Institute of General Medical Sciences (NIGMS) requires institutions to include a career and mentorship training plan in T32 Training grant applications and subsequent reports. Additionally, through the Common Fund, NIH supported the Broadening Experiences in Scientific Training (BEST) pilot program, which previously funded professional development programs for ECRs at seventeen institutions across the country as another mechanism (Meyers et al., 2016). These developments can help retain talent in STEM fields at various levels in the academic career ladder.

Career and professional development is critical to academic research training and preparation for ECRs to enter the workforce. Institutions should provide graduate students and postdoctoral researchers with ownership over their training and ensure alignment with their career goals. Mechanisms to achieve this goal include through encouraging the faculty members to discuss the Individual Development Plan (IDP) with ECRs in their lab on a regular basis and providing them with necessary career resources. In addition, federal agencies should also support career and professional development opportunities for graduate students and postdoctoral scholars by expanding necessary infrastructure needed for dissemination of these resources and programs (adapted from National Institutes of Health, 2023). These trainings can help promote research independence for ECRs in academic laboratories.

Career progression

In recent decades, the number of available tenure-track faculty positions in STEM has stagnated, while the number of PhDs

awarded every year across multiple disciplines has increased significantly (Cyranoski et al., 2011; NASEM, 2018b). Additionally, ~80% of the U.S. PhD recipients begin subsequent postdoc positions (Kahn and Ginther, 2017), suggesting that a large number of graduate students default into postdoc positions (Coalition for Next Generation Life Science; Blank et al., 2017). While the majority of PhD graduates intend to stay in academic research following degree completion (Sauermann and Roach, 2012; Roach and Sauermann, 2017), only ~50% of postdocs intend to do the same after their research training (Gibbs et al., 2015), indicating that interventions at the graduate level are likely needed most immediately impacting the entire pipeline in a positive manner.

Indeed, the hypercompetitive academic environment (Alberts et al., 2014) and glut of postdocs (Bourne, 2013a) may lead graduate students to become "permadocs." These are individuals undergoing multiple postdocs, where a quarter of them leave their position to do another postdoc (Coalition for Next Generation Life Science data) in the hopes to one day become faculty members (Bourne, 2013b; Powell, 2015). Alternatively, for many biomedical PhD degree holders is transitioning into non-academic, non-research positions (NASEM, 2018a). Both of these data points signify an inefficiency in preparing graduate students in PhD programs for both academic and non-academic careers. While data are more limited, this is also likely to be true at the postdoc level given an overall decline of researchers staying in academia overall (Roach and Sauermann, 2010). Some of this is likely due to the lack of faculty positions available for them to pursue.

In order to advance in their career trajectories and obtain research independence, ECRs need to have faculty buy-in to participate in career and professional development programs. However, many faculty members currently discourage ECRs from taking time out of the laboratory to attend events that will enhance their future careers. Within universities, ECRs should have the liberty to take charge of their own careers and the ability to regularly attend career and professional development events to enrich their training and career progression (McDowell et al., 2019). While these events may be different based on the career stage, both graduate students and postdocs likely need a broad variety of trainings to be successful (Watts et al., 2019). To encourage career progression for postdoctoral scholars in particular, NIH should provide grant extensions for significant life events (e.g., childcare, health issues) and major setbacks (e.g., natural disasters) (National Institutes of Health, 2023), and these measures could also more broadly apply to other career stages in the research pipeline.

Providing an adequate level of knowledge to ECRs on institutional policies impacting them would be an important factor enabling them to take advantage of institutional resources for their own career progression. This requires data collection on career trajectories to be conducted both by federal agencies, and by institutions themselves (adapted from National Institutes of Health, 2023). These data would be beneficial for enabling ECRs to make decisions about their own careers in academia.

Compensation and benefits

A major issue faced by ECRs toward attaining research independence is the inadequate provision of salaries and benefits, which can prevent graduate students and postdocs from being able to afford to stay in academic positions. While graduate student stipends could come from grants or fellowships encompassing multiple mechanisms, this issue is particularly prevalent in the postdoc population, which has been studied to date when it comes to low salaries and inadequate benefits provided for their research expertise and knowledge.

NIH funds a large portion of postdocs in biomedical sciences. Although the agency has been steadily increasing the postdoc salary ranges for all the postdocs on NIH grants (Langin, 2024), this compensation has never reached standards recommended by blue-ribbon panels, and is now even being surpassed by salary minima set by universities. Most recently, it is called into question whether salary increases will be honored by NIH after trainees won their first union contract at a federal agency (Langin, 2025). In addition, as NIH guidelines only legally affect NIH trainees, i.e., those on NRSA training mechanisms, and not the majority of NIH-funded ECRs who are staffing research project grants, PIs can and do dictate their own salary scales for postdocs, ignoring institutional postdoc salary guidelines, which are only as good as their enforcement. Universities struggle to identify and administer their postdocs, with the large number of titles and designations leading to confusion in postdoc classifications (Schaller et al., 2017). This issue makes it difficult to identify postdocs within institutions (Pickett et al., 2017) and to ensure that institutional salary policies are being enforced (Ferguson et al., 2017) and are held equitable across the board.

Postdoc salaries vary across the U.S. and do not take into account cost of living (Woolston, 2017). To address the issue of a wide range of salaries and a postdoc gender pay inequity in the Northeast and South U.S. Census regions (Athanasiadou et al., 2018), NIH recently updated the NRSA postdoc stipends (National Institutes of Health, 2024). However, this still does not account for cost of living index difference adjustment (Sainburg, 2022). This critical problem for the academic community could be solved by putting into action the repeatedly made recommendations that postdoc salaries should be raised to a level that incorporates cost-of-living and years of experience, and actively avoid pay inequities in the system (NASEM, 2014, 2018a; Greider et al., 2019).

Increased transparency in pay scales for ECRs at the institutional level is necessary. To this end, resources for sharing graduate school stipends (http://www.phdstipends.com/), postdoc salaries (https://postdocsalaries.com/) and information on benefits (https://bostonpostdocs.org/advocacy/benefits; Cijsouw et al., 2017) are examples of ways to increase information on and awareness of these issues. Institutional actions such as publishing standard salary guidelines, and increasing transparency on postdoc salary data are also recommended actions. This could include publishing aggregate postdoc salary data to ensure no gender pay inequity exists.

At the federal level, discrepancies in postdoc salaries arise based on whether ECRs are paid from training grants such as from NSF, or from faculty research project grants, such as from NIH. Confusion on this point has existed for many years as to the employee vs. trainee status for postdocs, with widespread reporting of the loss of employee benefits, such as childcare and healthcare, when a researcher moves from being "staff" on a research project grant to a "trainee" on a training grant (Ferguson et al., 2017). Increased clarity from funding agencies, or adjustments at the institutional level to address these issues, are recommended actions.

Work-life balance and mental health

Mental health issues are on the rise among PhD students, and their work-life balance satisfaction has been declining (Bleasdale, 2019; Evans et al., 2018; Loissel, 2019; Krause and Harris, 2019; Levecque et al., 2017; The Graduate Assembly, 2014; Nagy et al., 2019). A NASEM study suggested ways in which higher education can provide support for mental health and wellbeing of STEMM students (NASEM, 2021). ECRs are also taking the matter into their own hands, by starting several initiatives (such as https://www.phdbalance.com/ and http://dragonflymentalhealth.com/) to raise awareness on these issues and advocate for improved academic mental health policies. However, while many of these initiatives are geared toward ECRs, the mental health and wellbeing are critical and should be prioritized at all levels in academia, including faculty (Lashuel, 2020). However, if we do not take the necessary steps to address this problem at the graduate level (or even earlier), it will impact researchers later on in their academic careers including at the faculty level, when they will need to support their own students and may not have the resources or knowledge to do so (Newport, 2024).

In the current research environment, work-life balance for ECRs is often not prioritized. While this aspect may be often difficult to achieve in general, for academics it can be even harder to do so due to the demanding nature of this work, and the incentive structures driving this hypercompetitive environment (Alberts et al., 2014; Edwards and Roy, 2017). Whether work-life balance for academics can actually be achieved is a difficult thing to assess (Gould, 2014; Owens et al., 2018), especially for those who not only have to balance mental health issues and their impacts on work and life, but also other responsibilities or additional barriers faced while pursuing an academic career (Nzinga-Johnson, 2013; De Welde and Stepnick, 2015; Hardy et al., 2016; Antecol et al., 2018). While mental health issues may exist at both the graduate and postdoctoral levels, postdocs looking to transition into faculty roles may face additional barriers.

At all career levels, ECRs could benefit from peer-to-peer support networks, as well as clearly delineated working hours and time off to support work-life balance. These actions are important for fostering research independence for ECRs, and they can be encouraged through improved financial security and mentorship, both which are critical to maintaining a healthy and productive research enterprise. Academic departments and institutions should allow for healthy working habits in order to mitigate burnout (Cannizzo et al., 2019). Funding agencies could also play an important role by enhancing support for trainees and researchers by incentivizing independence by providing career development funding, a required mentorship training. Additionally, funding agencies should require institutions to address work-life balance, mental health, and harassment prevention, ensuring holistic training for scientists.

Immigration and visas

Foreign-born scientists constitute 25% of tenure-track faculty roles and are first authors on 44% of U.S. papers in science-related topics (Stephan, 2010; Heggeness et al., 2016, 2017). While the U.S. research system benefits from this international flow of knowledge and personnel (Regets, 2001), their immigration and visa status can limit their ability to develop research independence (Roach and Skrentny, 2019). The exploitation of foreign-born ECRs in U.S. labs, illustrating the position of power that faculty supervisors have over them, has been documented and discussed extensively (Stephan, 2013; Nature Editorial Board, 2018; Hayter and Parker, 2018). Immigration and visa-related issues affect many ECRs in the research enterprise, adding significant burdens to their ability to attain research independence. This is an issue for both graduate students and postdocs. Data suggest that two-thirds of U.S. postdocs are estimated to be foreign-born (Ferguson et al., 2017), posing a particular challenge for them.

The salaries of postdocs who are U.S. citizens vs. foreign-born and on temporary visas vary significantly (National Science Foundation, 2017). This is only one of the issues faced by international scholars in U.S. labs. Unfortunately, a limited number of mechanisms are available to protect foreign-born researchers working in U.S. laboratories from certain measures of discrimination. Institutions should do more to protect international scholars including through providing clearly defined visa sponsorship and immigration policies (NASEM, 2015; U.S. Government Publishing Office, 2018). Funding agencies should also ease restrictions on their eligibility requirements for international scholars to apply for U.S. federal grants and fellowships that can benefit their research independence by having their own funding.

Some positive grant examples exist. For example, NIH's Career Development (K) awards are controlled by the NIH Director, under authority granted by the Public Health Service Act, and have no citizenship restrictions. The National Research Service Awards (NRSA, F and T awards) are governed by the 1974 National Research Act, and no citizenship restrictions are stipulated within the legislation, and could be modified by an update to the Code of Federal Regulations to include foreign-born researchers [42 Code of Federal Regulations (CFR) Part 66] (Department of State, 2005). Given that half of the first-time faculty recipients of NIH's research independence grants (R01s) in 2017 were faculty (i.e., U.S. Citizens and Permanent Residents) who were eligible for, and had received, one of these training awards (Pickett, 2019), exclusion of researchers solely based on immigration status from accessing career-defining awards flies in the face of a "meritocratic" system for academic career success.

While our data did not address this point, we know from other studies performed by Future of Research (Jorgensen et al., 2022) that these issues were exacerbated by and had been highly prevalent during the COVID-19 pandemic, when foreign-born ECRs in the United States experienced negative impacts on their mental health, academic life, flexibility to leave and enter the United States, as well as their sense of belonging. During this time, several executive actions (EAs, including Executive Orders, proclamations and directives issued by the executive branch) were released which impacted foreign-born ECRs.

These include banning non-U.S. citizens from entering the U.S. from China, and later banning entry of non-resident foreign aliens into the U.S. from Europe and other nations. At a slightly later point, a temporary rule prohibited F-1 and M-1

international students from returning to or remaining in the U.S. if online instruction was adopted. Although this rule was eventually rescinded, it negatively impacted international student applications, as well as mental health issues and financial burdens on international scholars already in the U.S. (Jorgensen et al., 2022) looking to do research at academic institutions. Reforms related to immigration and visas supporting foreign-born ECRs in U.S. laboratories necessitates universities and employers taking steps to mitigate the negative effects of such national policies on their academic experiences.

Conclusion

Research independence for academic scientists requires reforms in a number of aspects which can help build the future STEM workforce. Within each of the areas highlighted in this publication, significant barriers are encountered preventing the biomedical workforce from growing and driving our nation forward in research innovation. Recommendations and solutions proposed for various stakeholders by graduate students and postdoctoral researchers highlight the need for multiple players in this ecosystem to engage in long-term systemic reform through efficient mechanisms to facilitate sustainable research independence in academia.

Data availability statement

The original contributions presented in the study are included in the article/Supplementary material, further inquiries can be directed to the corresponding author.

Author contributions

HS: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Project administration, Resources, Software, Supervision, Validation, Visualization, Writing – original draft, Writing – review & editing. AB: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Project administration, Resources, Software, Supervision, Validation, Visualization, Writing – original draft, Writing – review & editing. GM: Conceptualization, Data curation, Formal analysis, Funding acquisition, Investigation, Methodology, Project administration, Resources, Software, Supervision, Validation, Visualization, Writing – original draft, Writing – review & editing.

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Conflict of interest

GM carried out this work while working at The Future of Research, Inc. GM now works at Lightoller LLC, a sole-proprietor consultancy providing expertise on early career researchers. HS contributed toward organizing the workshops while at the University of Illinois at Chicago and then at the University of California Irvine. The data collected for this publication do not represent the views of either of the institutions presented but are only extrapolations of responses given by early career researchers at these institutions. These workshops were conducted in his capacity as a member of the Board of Directors at The Future of Research. AB is the former President and CEO of Bankston Policy Consulting, LLC, a consulting firm in Washington, DC, which provides a variety of services to stakeholders and individuals invested in and working toward building the next generation STEM workforce through policy change across a number of industries within the science, technology and innovation ecosystem. AB contributed to this publication as a member of the Board of Directors at The Future of Research.

Publisher's note

Supplementary material

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/feduc.2025.1477016/full#supplementary-material

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