

## Current and future challenges in interdisciplinary Ph.D. education as perceived by students

Aina Gallemí-Pérez <sup>1,3</sup>✉ & Venecia Chávez-Medina <sup>1,2,3</sup>

Göttingen is home to the Third Infinity conference, a biennial event organized by Ph.D. candidates that aims, beyond discussing complex systems physics, at providing a platform to discuss themes central to doctoral life and education. As part of the organizing committee of Third Infinity 2020, in this comment we would like to raise attention on the main issues faced by today's European interdisciplinary Ph.D. students as we learnt them from direct experience during the organization process, as well as from discussion with our peers during the event.

In the middle of Germany there is a small city of contrasts, Göttingen. This city showcases a rampant-ringed medieval center that rivals with a highly science-forward life as, though small, Göttingen is home to a renowned university, five Max Planck Institutes, and dwells in a history of several Nobel Prizes<sup>1</sup>. It is in this scenario that the Third Infinity conference for the Physics of Biological and Complex Systems (PBCS) takes place every 2 years since 2013. The event, organized by Ph.D. students from the International Max Planck Research School for the Physics of Biological and Complex Systems (IMPRS PBCS), targets Ph.D. fellows as the main audience. Therefore, alongside scientific research, the conference is tailored to discuss relevant themes in Ph.D. education; aspects that are critical to interdisciplinary education, and specifically in the PBCS field. Even though this may limit their impact to a German scenario, many issues discussed are relevant at an European, and even an international level. The image of the Ph.D. candidate, for example, is slowly shifting from that of a student to that of a worker, and with it, their role as researchers. At the same time, there is still a lack of opportunities that affects differently men, women, members of the LGBTQ+ (Lesbian, Gay, Bisexual, Transgender/Transsexual, Queer, plus other groups, such as asexual, intersex, questioning, etc.), and ethnic minorities. More in general, careers in academia seem to be in crisis, affected by yearly cuts to research funds and by an increasing uncertainty toward the possibility of achieving a permanent position<sup>2-4</sup>. These issues have been magnified by the current COVID-19 pandemic<sup>5</sup> and, when addressed, will

<sup>1</sup> Max Planck Institute for Dynamics and Self-Organization, Am Faßberg 17, 37077 Göttingen, Germany. <sup>2</sup> Faculty of Physics, University of Göttingen, Friedrich-Hund-Platz 1, 37077 Göttingen, Germany. <sup>3</sup> These authors contributed equally: Aina Gallemí-Pérez, Venecia Chávez-Medina. ✉email: [aina.gallemi-perez@ds.mpg.de](mailto:aina.gallemi-perez@ds.mpg.de)

necessarily impose changes into graduate programs, not only for students and young researchers, but also for thesis advisors, institutions, and universities themselves. As members of the Third Infinity 2020 organization committee, in the following, we ought to highlight the concerns that are relevant to today's Ph.D. students, and hopefully to tomorrow's researchers, as we learned them from this organizational adventure, from the feedback of the attendees, and from an exciting and fruitful panel discussion. In particular, the panel discussion on "The future of doctoral education in Physics" proved how the topics that we develop ahead are of common interest, and concern all members involved in science, from coordinators to supervisors, including, of course, us students.

### **Multidisciplinary careers in the canyon between depth of content and diversity of topics**

The first challenge we faced during the organization of the conference was to set the central topic of this 3-day event. Particularly due to the highly multidisciplinary background of the PBCS research school, where students from physics, biology, chemistry, life sciences, and medicine work on research topics that in their diversity go from biomolecular dynamics to pattern formation, passing by neuronal information processing, turbulence, and tissue regeneration. Specialization within physics, due to the mere nature of its subject matter, is therefore a hard nut to crack. At the same time, a wider knowledge in terms of topics, which might not even strictly belong to physics, but might include biology or social sciences, sometimes comes at the cost of giving up depth in most of them. This trade off is necessarily reflected in the structure of interdisciplinary conferences, such as Third Infinity. A Ph.D. in Europe is theoretically completed in 3–4 years. Being Third Infinity a biennial conference, we are thus aware that a student will generally attend a maximum of two editions. Should all the topics included in the PBCS program be covered every 2 years, then? Truth is, there are hundreds of specialized conferences every year; those are the ones that should be targeted in order to go deeper into a specific field of study. What we learnt from organizing Third Infinity was that the main purpose of this type of conferences organized by, and for students, is precisely to offer a platform for these students to showcase their own work and exchange ideas (Fig. 1). Speaking to an audience is an experience that all Ph.D. students should have and practice, not only as a skill, but also as a tool for networking. Yet, too many Ph.D. candidates still finish their education speaking to the fullest room on the day of their thesis defense. And while this is true for many institutes across Europe, in some cases Ph.D. students defend their thesis only in front of a few experts in the field, further delaying the experience of public speaking. Student talks should be something to promote, not to bear before the lunch or coffee breaks. Of course, this does not mean students should have the largest share of talks at all conferences; we all have those headliners—the science Rock Stars—to whom we want to listen from the first row in these events (Fig. 2). However, when Ph.D. candidates are ready, they should be trusted to present their work, as well as to represent their group's research. Until we reach a situation where students' talks are more common, and even when that milestone is achieved, conferences such as Third Infinity are essential to give Ph.D. candidates a platform to speak in front of their peers, as well as of more senior researchers.

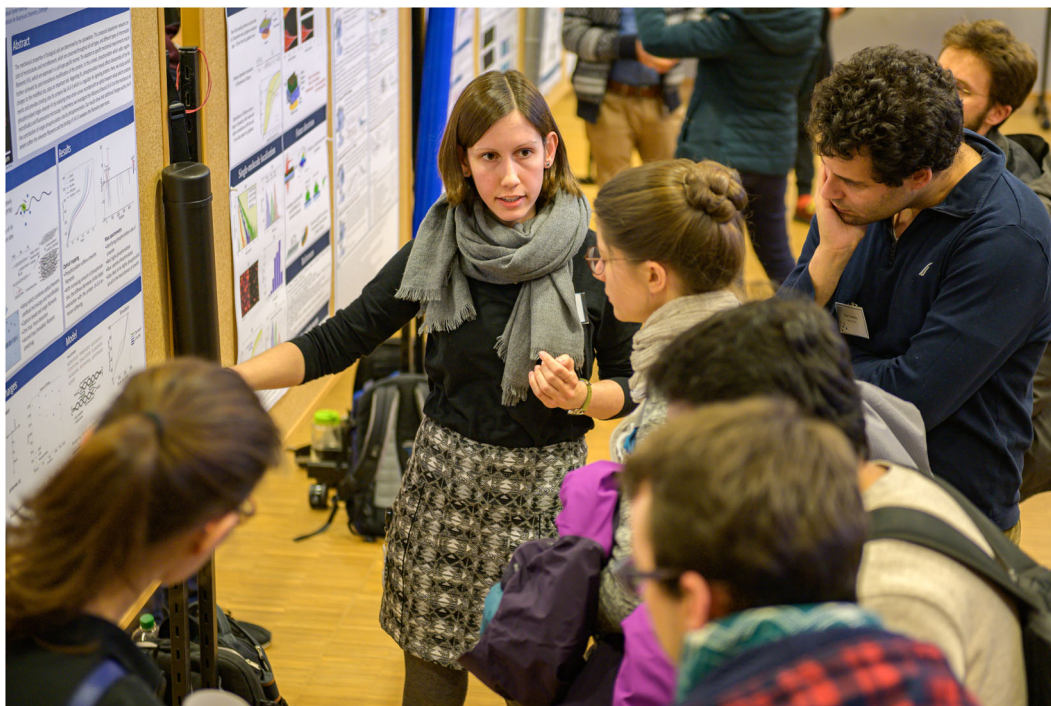
### **The Ph.D. candidate role in between student and worker**

In a field such as physics, where the role of the Ph.D. candidate is shifting from that of a student to that of a worker<sup>6,7</sup>, we believe that the development of these personal skills and the attention to networking take extra relevance. Nowadays, most students who

start a career in research will end up working in the private sector<sup>8</sup>. Indeed, a fast search of "physics job prospects" on any browser results into an endless list of websites and forums, where the future of the education in physics is questioned again and again, and where a number of job options, required skills, or hiring companies are advertised. This reality is in surprising contrast with our current vision of a Ph.D. student, and of an academic researcher<sup>9</sup>. Even though it may sound as a paradox, science has been always tinted by romanticism. In our minds, the image of a scientist is that of someone driven by passion, who works tirelessly and spends restless nights trying to uncover the innumerable secrets of nature. However, this vision turns out to be severely distorted with respect to reality as shown by the aforementioned browser search, causing many students to struggle, with increasing stress and anxiety, toward achieving an ideal that rather belongs to science fiction<sup>10</sup>. Of course, some students still manage to partially conform to such a distorted ideal, which worsens the issue for the others who do not. How can one compete with the work done by someone who spends nights and weekends in the lab? The problem of being in love with physics is that you can lose perspective very quickly. We all have had to stay late at work in order to finish a project or meet a deadline, but when this becomes the norm, you are probably neglecting yourself or your social life. A good work–life balance is essential for our mental health and, in the long run, this might be the key to avoiding a burn out<sup>10,11</sup>. Of course someone could argue: but I work on what I love, it is my hobby and it is what I enjoy! We think this is a delicate point, as there is a difference between working over the weekend and enjoying yourself. Such difference being that the former, while appearing a purely personal choice, actually affects all Ph.D. students by increasing competition, and thus pressure to achieve similar results. For this reason, we believe that doing extra hours should be discouraged by supervisors and administration, rather than rewarded. This is the only option to guarantee that students and researchers with other responsibilities, such as parents, can carry out their research in a healthy environment, without being pushed to juggle their life or to produce more than what can realistically be done during regular working hours.

### **Changes in institutions and supervision**

All these issues orbit around the same topic: what should be imparted, and how should this content be delivered, so that Ph.D. candidates are prepared not only for the practical aspects of scientific research, but also for a successful career? Interestingly enough, a 2019 *Nature* survey<sup>12</sup> over 6300 Ph.D. students showed that even though 60% believed that a Ph.D. formation would improve their job prospects, only 26% of the respondents felt that they were being prepared very well for a satisfying career. Within the Max Planck Institutes, home to the IMPRS PBCS, the satisfaction with a Ph.D. education slightly increases to the 71% (ref. 13). At the same time, even though 56% of students said that academia would be their first career choice, the number of students aiming for a job in industry has increased over the past 2 years from the 22% to the 30% (ref. 12). It is worth mentioning that even though many Ph.D. candidates wish for a career in research, they are also aware of the unlikelihood of succeeding due to the extremely limited number of available positions and the large number of students who graduate every year<sup>3,4</sup>. Furthermore, in many European countries, the number of temporary postdoctoral contracts has increased due to labor market reforms aiming to increase the flexibility of employment<sup>14</sup>. Altogether, this generates insecurities that too often add to the strain on the Ph.D. candidate shoulders<sup>13</sup>. As a matter of fact, 36% of the respondents to last year's *Nature* survey<sup>12</sup> admitted that they have



**Fig. 1 Poster session.** Ph.D. students from the International Max Planck Research School for the Physics of Biological and Complex Systems, and other institutions, presented and discussed their work with their peers, and with more experienced researchers, over two split sessions due to the amount of contributions received. Photo from Irene Böttcher-Gajewski; Public Relations Office and MediaService at the Max Planck Institute for Biophysical Chemistry.



**Fig. 2 Keynote lecture by M. Cristina Marchetti on The Physics of Active Matter.** “This is the first time I have attended a conference organized by students. They did a phenomenal job and I enjoyed it enormously” said Prof. Marchetti, who was happy to talk to Ph.D. candidates upon listening to their talks. Photo from Irene Böttcher-Gajewski; Public Relations Office and MediaService at the Max Planck Institute for Biophysical Chemistry.

sought help for anxiety or depression related to their Ph.D. studies, a number that could still be underrepresented due to the remainings of the stigma on mental health. This already worrying percentage is likely to have further increased over the current pandemic emergency. Hence, acknowledging the importance of mental health has never been this urgent: sudden changes require institutions and universities to react quickly, in order to support

students in facing the present circumstances without having to choose between research and their well-being.

This last observation points straight to our third subject of discussion: Ph.D. students should be able to count on supportive supervisors and institutions. But, are supervisors ready to be supportive? Let us take the current pandemic as scenario. Supervisors have been exposed to the same constraints as students, being mentally challenged in ways we would have never



imagined a few months ago. Still, they had to deal with the same expectations and responsibilities. Most supervisors have been doing their best, remotely managing their team as they would do in normal circumstances. However, being confined at home, an environment that usually does not fulfill the expected requirements of an office, it is just easy to fail. In addition, they must now invest time in recording lectures and reshaping presentations to make them suitable for online posting. Almost all of them have been obliged by the current situation to take crash courses, and learn how to keep up with teaching and project management, using video calls and other tools<sup>15</sup>. Quite successfully, we must add, based on our own personal experiences. Hence, since academia and research are always changing, we believe supervisors should be encouraged to take courses that aim at updating teaching and supervising practices on a regular basis: it is a short-sighted choice from the institution side to train principal investigators on supervising methodologies only in situations of extreme need, or not considering such skill set in the hiring process. Therefore, we celebrate the appearance of initiatives that want to tackle this issue, even though we feel they are still at very young stages<sup>16</sup>.

On a more general level, the relationship between Ph.D. students and their supervisors is crucial for academic, professional, and even personal development<sup>12,17</sup>. It is likewise important to acknowledge that the nature of such relationship is of dependence, and with a clear hierarchy. It is therefore worrying that 24% of students would change their supervisor had they the chance to start over<sup>12</sup>. This data supports our belief that a strong investment in supervising and teaching courses from the side of institutions would generally benefit both Ph.D. students and supervisors, ensuring a synergy that would be positive for all parts involved.

### Human challenges in academia

An effective student-supervisor relationship is of crucial importance when it comes to topics as serious as harassment, gender bias, and discrimination. Referring to *Nature's* Ph.D. survey<sup>12</sup>, almost 40% of the interviewed Ph.D. students had experienced gender-related discrimination or harassment in an academic context. Most gender-related issues that academia must tackle at a global level (women leaving scientific careers in disproportionate numbers at every stage<sup>18</sup>, less recognition of female scientist achievements, and less rate of employment<sup>19</sup> or particular underrepresentation in “mathematically intensive” fields<sup>20</sup>, to name just a few<sup>21–25</sup>), seem to be correlated with the fact that female Ph.D. students are also more prone to suffer of “stereotype threat” and “impostor syndrome”, particularly in the natural sciences<sup>26,27</sup>. The former defines the apprehension of being judged through the negative stereotype that women have weaker math abilities, which consequently disrupts women’s math performance<sup>26</sup>; the latter occurs when a person perceives oneself as a fraud, undeserving of her or his professional achievements. Interestingly, women are 82% more likely to suffer of the impostor syndrome than men<sup>27</sup>. Considering these premises, and using once again the COVID-19 pandemic as a social magnification glass, it should not be surprising that paper submissions from women to journals have been dropping with respect to submissions from men during the last months<sup>28–31</sup>. Of course, this is also the reflection of a wider problem at the level of society, where women, on average, are still the main responsible of family duties<sup>32,33</sup>. Not to mention that parental leave for fathers remains, up to these days, a big challenge<sup>34,35</sup>. A viral Twitter post from a woman and researcher, in the context of this pandemic, reads: “The next person who tweets about how productive Isaac Newton was while working from home gets my 3-year-old posted to them!”, portraying in a funny but straightforward way

how different personal life, but also gender-life conditions, impact research, and productivity. In this frame, the work performed by initiatives, such as the Minerva-FemmeNet, a mentoring network for young female researchers set up by the Max Planck Society<sup>36</sup>, or figures like the Central Gender Equality Officer and her team<sup>37</sup>, who support the fulfillment of gender equality objectives, is essential and should be promoted by all institutions.

Further than gender-related discrimination, we have to remember, as students and institutions, that it is our duty to fight for an inclusive and unprejudiced academia as part of a bigger transformation at the level of society overall. As recently pointed out by the #Strike4BlackLives, organized by a group of physicists led by Brian Nord and Chanda Prescod-Weinstein, who proposed to #ShutDownAcademia and #ShutDownSTEM in solidarity with Black colleagues<sup>38</sup>, or the 500 Queer Scientists visibility campaign for LGBTQ+ people and their supporters working in STEM and STEM-supporting jobs<sup>39</sup>, it is essential to understand that the injustices that prevail in academia are an extension of those occurring at the society level, and therefore need to be tackled. Hence, we believe that our duty of participating in what we consider crucial social movements, such as the Feminist movement, the Black Lives Matter movement, and the LGBTQ+ movement should be supported, and encouraged by research institutions and universities. Discrimination is a problem way beyond what we had the chance to discuss during the conference, yet it is clear to us that academia has still a lot of work to do in this direction, and we believe Ph.D. students will be key actors in shaping a tolerant and diverse environment as the future normal.

### A concluding appeal

Ultimately, by participating to the organization of Third Infinity 2020, we placed ourselves into an exceptional position to learn, from experience and from the exchange of ideas and concerns with attendees and guest speakers, the flaws and strengths of doctoral education in physics. Events such as Third Infinity are a great platform for Ph.D. candidates to showcase their work and to grow as researchers. Therefore, we encourage fellow Ph.D. candidates to take active roles in this kind of events, to aim at constantly improving their research practice, and to evolve as well-rounded academics by raising education and society-related issues. The role of Ph.D. students and their career destinations are changing, and with them should also change the content and the form of Ph.D. education. Supervisors should strive to achieve a level of communication and synergy that facilitates advancing research without burdening the student’s mental health. Institutions should take a forward-looking position, providing opportunities for supervisors to access proper training, and opening the dialogue with Ph.D. students to support them in their first steps inside academia. Successful solutions can be achieved only by working together, and even though there is a perception that Ph.D. students are already in a very privileged position<sup>12</sup>, we all know that there is still a lot of room for improvement.

### Methods

The authors affirm that the informed consent for publication of the images in Figs. 1 and 2 was obtained from the identifiable individuals.

Received: 13 August 2020; Accepted: 13 November 2020;

Published online: 04 January 2021

### References

1. Elmar Mittler. Das Göttinger Nobelpreiswunder <http://webdoc.sub.gwdg.de/ebook/a/2002/nobelcd/html/intro.htm> (2002).

2. The Guardian. Enough of Exploiting Academics - Now Pay us Fairly <https://www.theguardian.com/higher-education-network/2017/jul/14/enough-of-exploiting-academics-now-pay-us-fairly> (2017).
3. Smaglik, P. Beating the odds to secure a permanent contract. *Nature* **562**, S49–S49 (2018).
4. Larson, R. C., Ghaffarzadegan, N. & Xue, Y. Too many phd graduates or too few academic job openings: the basic reproductive number  $r_0$  in academia. *Syst. Res. Behav. Sci.* **31**, 745–750 (2014).
5. BERA, British Educational Research Association. The coronavirus crisis: what support for early career researchers? <https://www.bera.ac.uk/publication/the-coronavirus-crisis-what-support-for-early-career-researchers> (2020).
6. Else, H. Phd students: time to make them university employees. <https://www.timeshighereducation.com/news/phd-students-time-to-make-them-university-employees> (2017).
7. Kroeger, T., McNicholas, C., von Wilpert, M. & Wolfe, J. The state of graduate student employee unions: Momentum to organize among graduate student workers is growing despite opposition. <https://www.epi.org/publication/graduate-student-employee-unions/> (2018).
8. Bailey, C. Your pathway to industry. *Phys. World* **30**, 46 (2017).
9. Maren, L. The Chronicle of Higher Education Wood. Odds are, your doctorate will not prepare you for a profession outside academe. <https://community.chronicle.com/news/2223-odds-are-your-doctorate-will-not-prepare-you-for-a-profession-outside-academe> (2019).
10. A phd state of mind. *Nat. Cell Biol.* **20**, 363 (2018).
11. Seaborne, R. An academic identity crisis. *Nature* **578**, 327 (2020).
12. Woolston, C. Phds: the tortuous truth. *Nature* **575**, 403–406 (2019).
13. Wu, C. M. Perceptions of publication pressure in the max planck society. *Nat. Hum. Behav.* **3**, 1029–1030 (2019).
14. Castellacci, F. & Viñas-Bardolet, C. Permanent contracts and job satisfaction in academia: evidence from european countries. *Stud. High. Educ.* **0**, 1–15 (2020).
15. Elisabeth, P. How early-career scientists are coping with covid-19 challenges and fears. *Science* <https://www.sciencemag.org/careers/2020/04/how-early-career-scientists-are-coping-covid-19-challenges-and-fears> (2020).
16. Georg-August-Universität Göttingen. Training Doctoral Supervisors <https://www.uni-goettingen.de/de/609585.html> (2020).
17. Ashton, P. & Pintor-Escobar, L. Five ways to tackle phd research anxieties triggered by covid-19. *Nature* <https://www.nature.com/articles/d41586-020-01898-1> (2020).
18. Rees, T. Mainstreaming gender equality in science in the european union: the 'etan report'. *Gender Educ.* **13**, 243–260 (2001).
19. Sheltzer, J. M. & Smith, J. C. Elite male faculty in the life sciences employ fewer women. *Proc. Natl Acad. Sci. USA* **111**, 10107–10112 (2014).
20. Ceci, S. J., Ginther, D. K., Kahn, S. & Williams, W. M. Women in academic science: a changing landscape. *Psychol. Sci. Public Interest* **15**, 75–141 (2014).
21. O'Brien, K. R. What is gender equality in science. *Trends Ecol. Evol.* **34**, 395–399 (2019).
22. Olsthoorn, L. H. M. et al. Executive summary of the 2019 Phdnet survey. <https://www.phdnet.mpg.de/survey> (2020).
23. Saucerman, J. & Vasquez, K. Psychological barriers to stem participation for women over the course of development. *Adulspan J.* **13**, 46–64 (2014).
24. Corneille, M., Lee, A., Allen, S., Cannady, J. & Guess, A. Barriers to the advancement of women of color faculty in stem: the need for promoting equity using an intersectional framework. *Equal. Divers. Incl.* **38**, 328–348 (2019).
25. Settles, I. H. Women in stem: challenges and determinants of success and well-being. *Am. Psychol. Assoc.* <https://www.apa.org/science/about/psa/2014/10/women-stem#> (2014).
26. Spencer, S. J., Steele, C. M. & Quinn, D. M. Stereotype threat and women's math performance. *J. Exp. Soc. Psychol.* **35**, 4–28 (1999).
27. Rojas, M. Las mujeres son susceptibles al síndrome del impostor porque creen que no son capaces. *Contra R. eplica* <https://www.contrareplica.mx/amp/nota-las-mujeres-son-susceptibles-al-sindrome-del-impostor-porque-creen-que-no-son-capaces-20203311?twitterimpression=true> (2020).
28. Alessandra, M. The pandemic and the female academic. *Nature* <https://www.nature.com/articles/d41586-020-01135-9> (2020).
29. Flaherty, C. Inside Higher Education. No room of one's own: early journal submission data suggest covid-19 is tanking women's research productivity. <https://www.insidehighered.com/news/2020/04/21/early-journal-submission-data-suggest-covid-19-tanking-womens-research-productivity> (2020).
30. Viglione, G. Are women publishing less during the pandemic? here's what the data say. *Nature* **581**, 365–366 (2020).
31. Frederickson, M. Women are getting less research done than men during this coronavirus pandemic. <https://theconversation.com/women-are-getting-less-research-done-than-men-during-this-coronavirus-pandemic-138073> (2020).
32. Sullivan, O. in *Handbook of the Sociology of Gender*, 377–392 (Springer, 2018).
33. Adams, M. in *Handbook of the Sociology of Gender*, 351–363 (Springer, 2018).
34. European Institute for Gender Equality. Gender equality index 2019. Work-life balance. <https://eige.europa.eu/publications/gender-equality-index-2019-report/parental-leave-policies> (2019).
35. Grose, J. Why dads don't take parental leave. <https://www.nytimes.com/2020/02/19/parenting/why-dads-dont-take-parental-leave.html> (2020).
36. Minerva FemmeNet. Mentoring - career advancement for women. <http://www.minerva-femmenet.mpg.de> (2010).
37. Max-Planck-Gesellschaft. Defining the range. <https://www.mpg.de/central-gender-equality-officer> (2020).
38. Durrani, M. Physicists come out in support of today's strike for black lives. *Phys. World* <https://physicsworld.com/a/how-physics-world-is-supporting-todays-strike-for-black-lives/> (2020).
39. 500QS. 500 Queer Scientists. <https://500queerscientists.com> (2020).

### Acknowledgements

We would like to thank Kristian Blom, Martin James, and Maximilian Vossel, with whom we worked in the organization of the successful Third Infinity 2020, for their sensational work. We would also like to thank Michael Wilczek and Marco Tarantola for creating an excellent work environment, and for being great examples of how supervisors should be.

### Author contributions

A.G.-P. and V.C.-M. contributed equally to the manuscript.

### Competing interests

The authors declare no competing interests.

### Additional information

Correspondence and requests for materials should be addressed to A.G.

Reprints and permission information is available at <http://www.nature.com/reprints>

**Publisher's note** Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.



**Open Access** This article is licensed under a Creative Commons Attribution 4.0 International License, which permits use, sharing, adaptation, distribution and reproduction in any medium or format, as long as you give appropriate credit to the original author(s) and the source, provide a link to the Creative Commons license, and indicate if changes were made. The images or other third party material in this article are included in the article's Creative Commons license, unless indicated otherwise in a credit line to the material. If material is not included in the article's Creative Commons license and your intended use is not permitted by statutory regulation or exceeds the permitted use, you will need to obtain permission directly from the copyright holder. To view a copy of this license, visit <http://creativecommons.org/licenses/by/4.0/>.

© The Author(s) 2021