From challenges to perspectives

Reflections of young scientists on the current state of academic research

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At the Flemish Institute for Biotechnology (VIB), the PhD students organize an international symposium every 2 years. The authors of this article were all members of the organizing committee this year, and we are proud of the programme on offer, which includes a Nobel Prize winner and many other eminent speakers. Organizing the symposium has been a valuable experience for us, and a worthy addition to our CVs, but not everyone we have spoken to feels that way about extra-curricular activities. When we advertised the symposium among our fellow PhD students, we often received comments that people were “too busy” to attend, or “had no time for these things,” or, perhaps worst of all, that their supervisor “would not allow them to come.” Those who did manage to come along this year showed a great deal of interest in one of our optional workshops: “How to stay sane during your PhD?” Overall, the behavior of our peers suggests to us that PhD students are under an unhealthy amount of pressure.

When students experience so much pressure that they cannot make use of career-enhancing opportunities, their workloads are clearly out of control and the output that their supervisors

and universities expect of them might not align with what is best for the student's own career. Do we expect PhD students to be data-generating publication machines, or is there room to cultivate a broader set of professional and cognitive skills, and to nurture the curiosity that brought them into science in the first place? The answers to these questions are complex and involve different aspects of current scientific practice, including publishing, policy, and funding. In this article, we summarize various imbalances in the current academic research system that we believe disadvantage young researchers; we discuss what this means for research in general; and we propose ways to restore the equilibrium. We hope to encourage young scientists to challenge the status quo, leading the way to a research environment that is healthier for everyone in the long term.

The current generation of young scientists, in our view, experiences increasing competition and pressure. The number of biomedical graduate students and postdocs is growing rapidly, while the available funding and tenure positions are not keeping pace [1]. This growing imbalance is a major risk for young students in search of a sustainable career, particularly given that graduate school will have cost them a great

deal of time and money, and especially because gaining a PhD is often only the start of the biggest career challenges.

The scarcity of resources—funding and secure employment positions—also exacerbates two other problems that further worsen the disequilibrium: the difficulty of identifying “good” projects to fund and the amount of time put into writing grant proposals. Because relative funding levels are historically low in Europe and the USA, and because there are so many active researchers, it is becoming increasingly difficult for funding agencies to select the “best” researchers and projects. Reviewers are forced to make subjective choices about which applications to fund as “distinguishing the top 5 or 10% means asking peer reviewers for a level of precision that is simply not possible” [2]. As a consequence, scientists at all levels have to put more time and energy in writing grants because so few get funded, and this is a waste of resources that could otherwise be invested into research.

In theory, a doctoral education should cultivate young scientists, equipping them with the tools and skills they will need to conduct their own independent research. In practice, however, many PhD students do not have the luxury of time to learn their trade, and

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instead have to start publishing papers almost immediately in order to already be competitive by the end of their PhD. This pressure to publish is often frustrating even for experienced people, and it can become an overwhelming and demotivating experience for students taking their first steps in research. In large part, the root of the problem is with how the scientific community evaluates its members. The Journal Impact Factor—designed to judge the value of a journal—has come to be used as a crucial part of the evaluation of individual scientists, even though it says very little about the merit of any given publication, and nothing at all about a scientist's wider skill set and contribution in terms of communication, leadership, teaching, and management, which are crucial to a successful career.

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But what constitutes a successful career in academic science? The traditional sequence of events after a PhD was that you would do a few postdocs, until finally finding a position as an independent group leader. Unfortunately, this career track is completely outdated. In reality, a faculty position has become the *de facto* alternative career option for PhD graduates, as less than 8% of students starting a PhD in the life sciences eventually reach tenure-track faculty positions in the USA (http://report.nih.gov/investigators_and_trainees/ACD_BWF/). According to a study by the Royal Society, only 0.45% of PhD graduates will ever become professor. In contrast, more than half of graduating students *do* aspire to gain a professorship (https://royalsociety.org/~media/Royal_Society_Content/policy/publications/2010/4294970126.pdf), and are told repeatedly that doing so is the only “correct” way to succeed. As such, PhD training only addresses the professional needs of a minority.

This discrepancy between ambition and opportunity stems from the imbalance between the size of the

scientific labor force and the resources available to support it, including most relevantly the discrepancy between the number of PhD students and postdocs, and the number of principal investigator (PI) positions available. Even after several successful postdocs, ambitious scientists have no guarantee that they will be able to secure a tenure-track position because there just are not enough to go around. Before you know it, your career spirals into a seemingly never-ending cycle of uncertainty.

Switching to industry at this point also becomes increasingly difficult, as companies value scientists with relevant industry experience or cheap new graduates far more than they do expensive specialized academic researchers. Many scientists who choose to pursue jobs in industry have great difficulties to find stimulating work that fits their expertise and interests (<http://www.theguardian.com/higher-education-network/blog/2014/may/23/so-many-phd-students-so-few-jobs>). Employers, on the other hand, complain about the lack of certain essential skills among PhD holders. There is a striking imbalance between the contents of the doctoral education and the needs of the private sector.

So who succeeds in becoming a successful independent researcher? A recent study in *Current Biology* set out to answer that question. The authors studied the influence of 50 different factors for academic success. The results suggest that academic career achievements are indeed predictable and depend on the number of publications, their citations, and the impact factor of the journals they are published in. But gender and university rank also have an important effect [3]. Although this study is retrospective—mapping the career paths of current PIs—it seems that the publish-or-perish mantra still holds true.

We cannot neglect the inevitable impact of these fundamental problems and the pressure they cause on science, scientists, and society. The pressure to obtain scarce grants and to publish in high impact factor journals has become so high that it has driven some scientists to lie about their results with varying degrees of severity. A current exemplary case is the publication of two papers on the cellular reprogramming of stem cells by acid-bath treatment: the work turned out to be too good to be true. Other groups failed to reproduce the results, and some images

in the paper were found to be duplicated from the first author's doctoral dissertation. As a result, both publications have now been retracted (<http://retractionwatch.com/2014/06/04/obokata-agrees-to-retract-both-stap-stem-cell-papers-report/>). Most tragically, the case appears to have led to the suicide of the group leader involved, Yoshiaki Sasai, who was not complicit in the fraud, but was criticized for lax supervision (<http://www.bbc.com/news/science-environment-28658269>).

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The previous example highlights an extreme case of scientific misconduct, but there are other failures of scientific integrity. Many cases of retraction seem to come from unintentional mistakes or poorly chosen tools and analytical methods. Some scientists retract papers voluntarily to preserve their integrity, but the majority of retraction comes after inquiries from other scientists, and many cases of fraud probably go unnoticed. Editors, publishers and researchers alike are confronted with the challenge to react rigorously to scientific misconduct, while avoiding witch hunts and leaving room for doubt and reinterpretation.

On the other side of the spectrum lays a huge amount of data, including negative, unfashionable, or untimely research results, which, unfitting for a journal of high impact, remain unpublished and therefore unavailable to the scientific community. While the publication of a positive finding obviously contributes to knowledge, each negative result is also valuable in the sense that it can help others move forward more quickly. Every well-executed study with a clear result should be deemed worthy of communication, irrespective of the implications of the outcome. Any combination of currently unpublished results could become the basis for groundbreaking science.

Thus, the current culture of publish-or-perish, as well as the lack of proper

career options for research scientists not only damage scientific credibility, but also waste precious time and money that could be better spent on innovation and invention. Worse still, shoddy or dishonest research can also lead to serious health-related problems. Last year saw British scientist Steven Eaton sent to prison for his role in falsifying the results from anti-cancer drug research (<http://www.bbc.com/news/uk-scotland-edinburgh-east-fife-22186220>), which could have jeopardized the lives of patients. The result of such scandals will be that if the public begins to lose trust in science, public support for research funding will dwindle and the competition for money will become even worse. It is up to us, as scientists, to avoid such a dire future.

In the last 200 years, humankind has grown from 1 billion to 7 billion humans on this planet, and our species is projected to peak at 9 to 10 billion before the end of this century. At the same time, the world is looking at centuries of climate change and its environmental consequences, potential new plagues and diseases, and the need to find new ways to feed so many more people. Science will play a fundamental role in addressing these problems, and if society collectively invests more resources into the scientific endeavor, beginning with education, we believe that these challenges can be met by science—indeed, by our generation.

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True innovations and inventions come from skilled, educated people with enough resources to realize their ideas. The impact of MOOCs (Massive Open Online Courses) cannot be understated in this context, as worldwide access to quality teaching is allowing anyone with access to the Internet to access an education. But there is more to do, and part of that is giving newly educated people the time, money, and support they need to find their feet and make their own contribution to the world. Sadly for those who would be

scientists, funding for research is stagnating, and the pressures are so great now that young researchers are giving up on research not because they want to contribute in another way, but because it is too hard to get anything done or find any job security.

So what can be done? The private sector only addresses and invests into a small subset of the needed innovations and inventions as companies are mainly interested in the things that will generate profit. It therefore falls to governments to step in, but the question is how best they can spend their money, and what structures and systems they should put in place to foster innovation and progress. Others have argued that reducing the number of doctoral students could be a solution [1; https://go8.edu.au/sites/default/files/docs/the-changing-phd_final.pdf], but we believe that these claims are rooted in a false understanding of how scientific competition works. Research competition exists between two parties competing to get their results published; financial competition exists when two parties compete for funding. While many funding bodies seem to believe that financial competition creates appropriate research competition—that is, suitably incentivizes scientists to do their best work—we believe that the two are mutually destructive. Research competition can only prosper in a climate that stimulates diversification and creativity and supports risk-taking. Financial competition leads to the exact opposite: the elimination of ambitious and risky projects, lower subject diversity, and underappreciation of fundamental research. Sadly, we have evolved a grant system that increasingly favors conservatism, fueled by the major imbalance between resources and researchers.

More and better funding will have to go hand in hand with political change. We need a sustainable, dependable, and robust equilibrium between financial resources and the actors in science. As the number of people involved in research grows, the monetary support should grow at least comparatively. Granting organs should preferentially support young PIs, because this should generate more research groups and more diversity. It should also increase the number of academic career opportunities available to young scientists, as more positions will be available. Similarly, reaching the top of the

academic career ladder should no longer depend only on the publication record, but also on leadership and mentoring capacities. The creation of stable, mid-level research positions—not (necessarily) leading to professorships or dependent on competitive funding—would allow researchers to focus on their talents and preferences. This would lead to more qualified group leaders, smaller laboratories, and smaller classrooms, enabling group leaders to better manage and adequately mentor their staff and students.

At the same time, we think that science should actually abandon the idea of the “default” academic career track of PhD followed by postdoc followed by independent group leader and ultimately tenure. This track hemorrhages talent at every stage, and in reality, the vast majority of PhD graduates find jobs in very different sectors. Society clearly benefits from people with PhD-level training as, for example, policymakers or entrepreneurs. Creativity and critical thinking, combined with a thorough understanding of a specific scientific discipline, provides added value for many different sectors.

“...it is our ethical responsibility to report all research findings to the taxpayers, the major funders of our research, if we want to justify an increase in financial investment in science”

During the past decade, many institutes have started to invest in skill development programmes for their young researchers, with a particular focus on communication and management. We support this trend, but concurrently observe a lack of incentives, as supervisors often underappreciate or even discourage the investment of time in teaching and outreach. We believe that everyone involved in training PhD students should actively stimulate these efforts and take them into account when evaluating a PhD candidate.

We agree that the merit of a scientist should be judged by the contribution he or she has made to his or her field and, more broadly, to society. But, how can the scientific community

judge scientists in their early or mid-career stages, since the merit often only becomes apparent after many years? The truth is young scientists are still judged on the number of papers they have and the impact factor of the journals in which they have published. As such, self-preservation plays a strong role in keeping the impact factor alive and “luxury journals” in business. Thus, despite abundant critique, only a few scientists, organizations, and journals are actually making an effort to change the system. A recent example is the boycott call of “luxury journals” by Nobel laureate Randy Schekman. However, one could argue that he has little to lose but a lot to gain as Editor of *eLife*. Another notable effort is the San Francisco Declaration on Research Assessment (DORA; <http://am.ascb.org/dora/>), which aims to reduce the value placed on the impact factor and focus

instead on other measures of assessing a researcher’s performance. These might include the h-index, which is based on the number of papers and their citation rate, and article-level metrics, as proposed by *PLoS*. It is clear, however, that no single metric is sufficient to properly evaluate the work of scientists. Other initiatives stimulate scientists to publish unfashionable results or negative data. These initiatives are gaining increasing support, as they fit a general demand to create more openness and transparency in science. We believe it is our ethical responsibility to report all research findings to the taxpayers, the major funders of our research, if we want to justify an increase in financial investment in science.

Rome was not built in a day; this gradual change in scientific culture will require time and, more importantly, commitment

from researchers at all levels, including PhD students. We cannot hide behind the excuse of having a wrong system imposed upon us, when in fact we ourselves partially constitute it and can choose to sustain it or not. It is in society’s best interest to encourage the brightest of our young people to become successful scientists, because well-trained and motivated PhDs are the most important resource for future scientific excellence.

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