Advocating a radical change in policies and new models to secure freedom and efficiency in funding and communication of science¹

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A moving landscape

Threats and obstructions to scientific freedom, fairness and efficiency are commonly perceived as surrounding the scientific world. However, bottlenecks can also occur from within the system itself as some of the current regulations and forces shaping research (referred to here as ‘science policies’) substantially decrease the freedom and motivation of scientists. Indeed, inadequate policies can restrict the ability to perform research, the breadth of the fields of study, the methods of carrying out investigations and the dissemination of findings. Conversely, virtuous policies can have a positive impact on the freedom, quality of work and satisfaction of individual scientists. Importantly, from the societal perspective, the more scientists work freely, broadly and with motivation, the more they produce knowledge, data and innovation for the benefit of society, collectively ameliorating the scientific research system.

Unfortunately, ‘science of science’ is in its infancy. There has never been awareness of the importance of policies nor consistent interest in studying them, and specialised journals and articles are very few for several possible reasons. First, many researchers do not perceive the importance of policies for the functioning of science or may simply dislike ‘science of science’ studies and prefer to focus on their discipline. Second, many feel that their individual contribution would not be sufficient to affect the system and see no purpose in sacrificing their time and energy, as in the so-called ‘paradox of voting’ (Downs 1957: 25). Third, or a consequence of all the above, with few academic positions and funding opportunities, the field is at the moment not profitable with regard to career returns.

Nonetheless in order to promote research and discussion on policies with a view to improving them, it is of great importance that science policy experts reach out to the rest of the scientific community. It is key to spread awareness of the many possible changes (however small or big) that can affect the freedom, fairness and efficiency of scientific work. Moreover, it

is crucial that public scientific agencies incentivise investigations by mobilising funding and nurturing opportunities. In this regard, it is advisable that scholars approach this area, combining a thorough and systematic analysis of the current situation with new perspectives including radical and 'out-of-the-box' approaches. There are several aspects of the process of sourcing, obtaining and sharing scientific research that can be improved by implementing effective policies. In this chapter, we focus on two main areas: funding and communication. We discuss the current situation, highlighting what we believe are the problems and the ongoing efforts to find solutions, and then moving to propose paradigm shifts that, albeit radical, appear to us as the natural progression of the existing trends. We concentrate on research in life sciences, our area of expertise, proposing that the matters treated can extend to broader areas of investigation.

Funding of science: ideas for an alternative system

Scientific research, especially when it requires costly equipment as most modern biomedical research does, is an expensive endeavour and good funding is key. There is a very broad consensus over the fact that research is currently underfunded all over the world. The relationship between the funding of specific research fields and their deliverables is a matter of constant debate. Basic research in particular is resistant to evaluation in terms of impact (and thus return on investment), intrinsically requiring long timescales and a dose of serendipity, and often incompatible with the current system of resources and careers. In fact, human beings are consciously and unconsciously biased towards valuing the present more than the future, and inherently show preference for certain outcomes over uncertain risks. Furthermore, the allocation of funding is usually under the direct or indirect influence of politicians, who favour rapid and visible returns over long-term strategies due to short-term electoral cycles. Altogether, these factors have a profound influence on the availability of resources and the efficiency of scientific research. While maintaining the need for increasing investment in scientific research overall, we focus in this section first on describing the current system and subsequently on proposing changes in funding distribution.

At the present time, scientists receive monies to perform their research largely through the submission of proposals to governmental or private funding bodies. These recruit panels of other scientists, usually indicated as 'peers', to evaluate whether the proposed projects are worth consideration. To prepare a proposal, a considerable amount of time is spent in writing and on associated paperwork. After submission, the peer-review process can take several more months. At the end of this process, if the project is approved, a certain amount of money is allocated to that specific project. On the contrary, if the funding is not approved, that project does not receive any money. An increasing trend in Western countries is that most

proposals are not funded. For example, the rate of success for grant proposals submitted to the NIH (the National Institute of Health in the US) is less than 20 per cent (Alberts et al. 2014). The total grant success rate in the MRC (Medical Research Council, UK) is 23 per cent (MRC 2014–15). Submitting more than a few proposals per year is generally prohibitive for a principal investigator. Given the limited number of opportunities and the time and energy costs, missing even two funding attempts in a row could have significant impact on a research group. Indeed in such cases investigators, particularly younger ones, often have to quit their research and disassemble their team.

The acceptance of this model by the scientific community appears to us surprising. In our experience, voicing discontent beyond private conversations is perceived as an implicit admission of failure and the poor quality of research, when coming from young researchers, or an unnecessary attempt to obtain extra publicity when coming from established ones. Unfortunately, this ‘all-or-nothing’ scheme does not do justice to the gradual distribution of merits and skills among scientists. In addition, the prediction of success is elusive, as in most cases the research plan can differ substantially from that proposed, as milestones and deliverables, where present, can be reformulated. Furthermore, the edge that established scientists have over younger ones is well known under the name of the ‘incumbency advantage’ (Ballabeni et al. 2016). This phenomenon has several different causes. The complexity of the procedures for grant applications might be a handicap for newly established scientists who are less experienced or cannot afford assistants (Daniels 2015). Grant applications are commonly centred on the assessment of a significant amount of preliminary data, which obviously favours established investigators and bigger laboratories (Alberts et al. 2014; McDowell et al. 2014; Daniels 2015). Moreover, there is evidence of bias in favour of the ‘insiders and the familiar’ over the ‘unknown’ (Daniels 2015; Fang and Casadevall 2009; Kirwan Institute 2014; Nicholson and Ioannidis 2012) and against unconventional and unorthodox ideas, which are more likely to be proposed by newly established scientists. The latter are also less likely to be involved in large research programmes, which can be favoured over small ones by ‘inertia’ and ‘financial dependency’ biases (Alberts et al. 2014). Finally, the evaluation of proposals usually takes into consideration the record of publications, which is itself affected by ‘incumbency advantage’ (see below). In essence this scenario not only entails reduced freedom of research and significantly sustains inequality in the system, but it also instils stagnation of ideas. Importantly, it produces ‘overfunded’ (i.e. inefficiently funded) laboratories that experience diseconomies of scale (Berg 2010; Stephan 2012; Alberts et al. 2014; Woolston 2015) and diverts funding from innovative projects, forcing many junior scientists to quit research. The dire consequences of this are difficult to fully capture for the community and society.

Some routes to alleviate these problems are being explored. The changing scenery includes examples of crowdfunding (e.g. Cancer Research UK 2014; Vachelard et al. 2016; Crowd Science 2017; Crowdhelix n.d.) and numerous public–private ventures that coexist as non-canonical ways to support research. In parallel, interesting new tools are being developed that use big data mining to allow more transparent access to the research grants and fellowships awarded to laboratories (e.g. Symplectics Research Information Management System). However, the vast majority of funding for basic research continues to be assigned through proposals submitted to funding agencies and evaluated by the mechanism of the ‘peer review’. To tackle the incumbency advantage of this system a few ideas have been tested or proposed. One is capping the amount of funding to a research group with a view to funding more scientists, which has been thoroughly discussed within the scientific community (Alberts et al. 2014; McDowell 2014; Ballabeni et al. 2016). Furthermore, a small number of agencies have been assigning funds by evaluating the overall quality of scientists rather than the research project (Alberts et al. 2014; Daniels 2015; Ballabeni et al. 2016). Importantly, the latter change tackles the problem of the long and time-consuming research proposal preparations and the tendency to disproportionately prefer incremental mainstream projects over more risky and radical ones. Data from a recent broad survey (Scita et al. 2016) show that a consistent majority of life scientists, regardless of their career stage, are in favour of these policies. Assigning funding based on general reputation rather than on project proposals might appear to increase the detested ‘incumbency advantage’. On the contrary, we believe it is likely, as a recent survey indicated (Ballabeni et al. 2016), that promoting caps on funding and a more gradual allocation of funding would be effective in reducing the ‘incumbency advantage’. Another criticism comes from the fact that salesmanship may be favoured, although arguably no more than in the existing grants scenario.

These ideas for new policies might therefore significantly increase fairness by giving everyone similar initial opportunities and by judging the relative merits of scientists through a more proportional lens. In general, the advantages of having an additional number of rewarded scientists and a more widespread distribution of resources are perceived as greater than the disadvantages of decreasing the average funding per scientist. In addition, providing funding to the scientists rather than to the projects would increase efficiency by cutting the time and energy spent on proposal writing and by supporting riskier and potentially ground-breaking research. Additionally, these transformations might also increase the efficiency of the system, as setting caps for investigators or research groups would increase the pool of funded scientists, especially among the younger ones. And by keeping young researchers in the system, it would develop a well-structured workforce for the next decades.

However, is it possible to imagine an even more radical change, a leap into a totally different system? A peer-review system based not on panels of scientists but on collective wisdom? (Bollen 2014; Ballabeni et al. 2016). This ‘lateral thinking’ idea is very recent and not yet common knowledge in the scientific community. It is based on a highly decentralised system in which the wisdom of the whole scientific community is used to allocate funding by avoiding the current ‘all-or-nothing’ approach. Here, being a researcher (for which minimal criteria should be satisfied, for example, a specific certified degree and/or some form of entry-level check) gives one the right to be considered equally with all other researchers under the same funding initiative. The funding agency would give all scientists under its competence an equal amount of funds per year. However, scientists would be required to allocate a fixed percentage of their last year’s funding to colleagues whom they think deserve it. As a consequence, each year researchers would receive a fixed basic amount of money from a funding agency plus an elective contribution decided and donated by their colleagues. While still requiring human judgement, this system would nonetheless cut substantially the huge operating costs of panel-based peer review, and might also neutralise the biases and inefficiencies of the current system. Clearly, the assumption is that most scientists would allocate funding on a purely meritocratic basis, with the greatest interest in maximising fairness, the advancement of knowledge and the improvement of society. Basically, those scientists who are anticipated to lead the best science would accumulate more. On the other hand, scientists who receive more must in turn distribute a larger amount of money; their prominence would therefore give them greater influence on how resources are used. And the constant yearly basic grant would ensure more stability and provide greater autonomy, while it still might be limiting in isolation, encouraging meritocratic advancements. In addition, as the preferences of the scientific community evolve, so the pattern of funding would adapt according to the wisdom of the scientific crowd, giving the possibility of fine-tuning funding levels to where they are most needed.

There are some foreseeable criticisms of this idea. It might at times be difficult to claim that one defined research outcome has been funded by one funding body in particular, so this system might not apply to charities or foundations. Moreover, anonymity, a key element in this system, would need to be enforced to avoid illegitimate practices such as, for example, the creation of circular schemes. However, one could argue that concerns about circular schemes have already been voiced in the current system (e.g. Ghosh 2010). In addition, assigning funding based on general reputation rather than on project proposals might appear to increase the ‘incumbency advantage’. On the other hand, it is likely that promoting a more gradual allocation of funding would be effective in reducing this. Indeed, contrary to the panel-based peer reviews based on panels, which are often composed of established scholars, in this more horizontal system junior investigators

would have a bigger role in deciding how to allocate funding, and thus might plausibly be more likely to know and credit their peers. Furthermore, despite the amount of paperwork involved, some scientists value writing grant proposals as a way of ‘crystallising’ thoughts into a defined plan of action. Yet we contend that the milestones and deliverables of a project could still be present, and would probably better mirror the reality of scientific projects than in the current system.

In any case, we believe that the benefits outweigh the possible drawbacks. Indeed, this system would not only decrease the financial and time costs of panel-based peer review, but it would also cut the time taken up by writing grant proposals, as it is conceivable that such proposals would be less and less important; indeed, much more emphasis would probably be placed on the overall evaluation of a scientist’s scientific and delivery skills. What’s more, it would not involve an ‘all-or-nothing’ allocation of funding and this would guarantee a more proportional, and thus more meritocratic, distribution of resources. Likewise, this system would assure a safety buffer for difficult times. It would dynamically and finely adjust the allocation of funding according to the community interests. Additionally, it would be based on the potential evaluation of more people than those present in a panel, guaranteeing a broader, more unbiased and continuous examination. Finally, it might promote profound changes in scientific communication, as scientists will more openly share past achievements, current data and future plans.

In conclusion, we see the mindset around the funding of science as beginning to change. New and ongoing paradigm-shifting initiatives, like the ones we describe, will lead to a potentially complementary, more functioning and beneficial research system.

Communication of science: ideas for an alternative system

Similar to and possibly more so than in the funding arena, the way science is communicated is constantly debated. At its core, the current system of science publication is over 350 years old. Scientists present the results of their research in the form of scientific articles (papers) sent to journals that are owned and managed by publishing corporations. The format is generally locked into the undoubtedly beneficial logic of an introduction–methods–results–discussion stream. Upon receiving a paper, the editors of a journal can reject it immediately or send it to peer reviewers (also known as referees). These are generally anonymous to the authors of the papers, and the process is therefore referred to as single-blind peer review. The editors use the peer review produced by referees to decide between the following options: immediate rejection, requests for improvement or (anecdotally) immediate acceptance of the article. The entire process normally takes several months (or sometimes years) from the first submission, and an article can frequently go through multiple rounds of peer review and revision. After a paper is

accepted it is published sometimes weeks or months later, and then it usually cannot be peer reviewed, corrected or generally even commented on any more. Only in rare circumstances are mistakes corrected and only very rarely is a paper retracted if major flaws or actual frauds are proven. Papers help the dissemination of findings and ideas while advancing the scientists' careers. More papers being published in the most read journals translates into more opportunities for funding and promotion. This system has for decades served scientific research while granting to successful publishing corporations the luxury of selecting a very small fraction of scientific output from authors, simultaneously sourcing the scientific output of a pool of reviewers at no cost. Thus, especially in recent times an increasing number of problems have arisen around both the reviewing process and access to publication.

As a matter of fact, peer reviewing can be at times a pretty sloppy process. Anonymity and lack of incentives anchor the acceptance of the role and the quality of a referee's work to their awareness of prepublished science and loyalty to a greater good, respectively. In a minority of cases, because of rivalry, sympathy or dislike, unfair peer reviews are deliberately provided. Also, it does happen sometimes that the referee privately reveals her or his identity to the authors, and in fact some journals compel or allow reviewers not to be anonymous.

Whereas scientific progress is dynamic, by definition the publication system is static. Papers cannot generally be improved once they are published. In some cases, editors can offer the possibility of publishing corrections. Continuous improvement to create new versions (a process also referred to as 'versioning', which is extremely common for software and scripts) does not exist except for very few exceptions (e.g. Singh 2015). In very rare circumstances, if the data are proven to be simply wrong or if fraud is demonstrated, an article can be retracted. However, it is now increasingly evident that fraudulent behaviour is spotted and signalled very rarely, and that the very small number of retracted papers represents only a fraction of *de facto* unreproducible results (Baker 2016). This is because neither editors nor reviewers nor (obviously) authors have any interest in spotting flaws after a paper is published. In essence, there is no further peer review after publication. So, the paper is first peer reviewed by just two to four reviewers before publication, whereas afterwards it does not receive any further similar peer review. And without the possibility of post-publication peer review and open commenting on papers, flaws are even less likely to be spotted and signalled. This is unfortunate considering that hundreds of (not anonymous) scientists might be willing to provide their views. Open commenting on papers (comments from scientists or laypeople, similar to what happens in blogs) happens extremely rarely.

The consequences of this publication landscape are perceivable in the fake sense of the official quality and validity of publications, which scientists have learned to take for granted when they are not able to reproduce results

from a colleague's publication. Moreover, many readers, and less so the general public, tend to perceive published articles positively only because these articles are in journals, especially journals with a high impact factor. Scientists who want to stretch or overemphasise their data only have to pass the test of a few people before their message enters a comfort zone in which it will probably never be scrutinised directly again.

Furthermore, there is a predominant culture in academia of novelty over thoroughness and of creativity over robustness. There are fashions and trends in scientific fields that influence perceived importance (Pfeiffer and Hoffmann 2009). There is a diehard snobbery regarding 'negative results' (Goodchild van Hilten 2015), even in clinical trials where debate is raging (AllTrials 2015). In addition, the constrained format pushes some research out of the 'publishable' area. Our brains are wired to the narrative of a 'story' and this makes it more difficult for entire fields of research (research involving different types of 'screening' is a good example) to be considered 'scientific' and not merely 'technical'. Furthermore, the economic model of publishing prescribes a return for the shareholders, and sustains very expensive subscription fees or tariffs for single-article access. This is obviously a major problem for the scientific community as accessing scientific literature can drain a lot of financial resources and fuel the 'incumbency advantage'. It is also unfair for the general public as it precludes access to research, including in some cases research funded via taxation.

Shockingly to us, limiting the number of published papers, irrespective of quality, is a policy choice of established journals even when the actual throughput could be much higher. The strengths of a scientific study in terms of novelty, elegance, reproducibility and impact have in some respect more to do with art than science, and *where* (i.e. in which journal) often matters as much as *what* (i.e. what study) is published. Can the queue outside an exclusive club be a better measure of success than the number of people on the dance floor or their ability?

We contend that the internet has pushed forward the revolutionary change of publishing 'virtually' as opposed to 'on paper', at a fraction of the cost. Scientists can therefore opt to disseminate research in a more open, flexible and collective way (and are beginning to do so). In the last few years more and more articles have been published that are freely accessible to anyone, either in fully 'open access' journals or in hybrid models. Yet surprisingly, and even for small specialised journals, the majority of newly published articles are still 'closed access' (Lewis 2012). Beside 'open access', another change that is driven by the internet is the so-called 'preprint publication'. These are articles published by journals or on websites (e.g. ASAPbio, bioRxiv, PeerJ, F1000Research, Figshare) that do not require any previous peer review. Yet the vast majority of data that makes it to the scientific community is hampered by the long lead times (usually several months to several years) required to complete the submission and peer-review process, and in many cases still has restricted access.

We believe that open access and the avoidance of peer review before publication, as in preprints, is having an impact. Yet offering flexibility in formats, the possibility of post-publication peer review, versioning and incentives for peer reviewers could lead to even more radical strategies at the system level that should be trialled and could make a real difference. A key element of the system we propose is a central international repository held as a reference for each scientist, to enable evaluation for funding, hiring and promotion by assessing all their activities. Here, peer review and original research publications would have complementary value and legitimacy and this will naturally incentivise the reviewing process. The technical, financial and political capacity to establish and maintain such an infrastructure is already within reach. In this system scientists would publish their data and ideas freely, without restrictions of style and format, choosing whether to have peer review before publication or to publish without any previous peer review. However, publications could be effectively open to peer review after publication. The people who perform this type of peer review, also called ‘post-publication peer review’, could be investigators proposed by the authors, investigators proposed by evaluators of the article or the authors (hiring panels, funding agencies, prize committees etc.); or simply investigators who are interested in providing their peer review. Peer review will, then, be fully transparent. The reviewers would be identified and their comments made public. The reviewers, being fully accountable, would have a genuine incentive to produce fair and accurate comments and recommendations. Articles could be easily modified through ‘versioning’. Each version (including the original) would have to remain online with a unique date of publication and digital object identifier (DOI). Each version would be open to peer review and possibly also comments from the general public (similarly to what happens in blogs and social media). In this scheme it is conceivable that once an article is published, it would not have the possibility of being retracted. Scientists would modify their articles through versioning, with each version open to the scrutiny of the scientific community, rendering actual retraction redundant.

At first these proposals might look utopian or naive to scholars who have grown up in the current system. We believe it would not be so in a mutated cultural framework and that the scientific community should have the courage and ambition to offer radically new opportunities to the present system that could serve science and society. Admittedly, what we suggest presents some problems too. It is, for example, possible that some publications could simply present preliminary data. Moreover, the increase in format and design options would make publications more difficult to read, especially in the beginning. An additional potential problem could be the possible deluge of information that would be poured on to the internet as a result of the lack of prepublication gates. However, we believe that in the long run continuous scrutiny and versioning as well as the incentive of being an ‘active reviewer’ would push forward more accurate, complete and effective

science communication paradigms. The ‘authority’ of an ‘active review’ may also be weighed against its author’s previous work (as proposed in Brewer 2014). Our perception is that many low-ranking journals (with poor or, even worse, arranged peer reviews) are already flooding the internet and the proposed change would not have such a dramatic impact on the total number of publications. The best research studies will naturally emerge with profiles of views and citations over time. We contend that the advantages would be far greater than the disadvantages, especially in the long run. We obviously do not propose that this system should abruptly replace journals that have served well for decades, and that may well continue in parallel with a complementary role.

This radically different publishing structure, based on the full use of the internet’s capabilities, could change the system of incentives for scientists and reviewers and would tackle the problems listed above associated with the contemporary system born in a pre-internet and pre-computer era. It would provide much more freedom in format and design, easing scientists’ work and guaranteeing that more data would be published and disseminated, significantly decreasing publication time. Also, as peer reviewers would be identified and evaluated on their peer-review work as much as for their primary research work, the current sloppiness of the peer-review process would be avoided or significantly decreased. Thus, unfair peer reviews would be prevented as well as the private disclosure of the identity of referees to authors. Moreover, peer review and open commenting for all articles would be incentivised after publication, increasing both scientific discussion and scrutiny. In addition, there would be the possibility of producing improved versions of an article. As each version would remain online, authors would still be discouraged from publishing wrong or poor information. Shoddy or fraudulent behaviour would be policed by the possibility of open post-publication scrutiny. Furthermore, contrary to the current system, the publication in itself would not convey any fake sense of validity or quality to an article. In this new system the publication would have less value and the focus would instead be shifted on to the content of the article and the peer review. Finally, this truly ‘open access’ system would be accessible to lay persons and would allow scientific institutions to save a lot of money that could be used to advance science more effectively. This is especially deserved when taxpayers have funded the research.

In this chapter we have proposed two radical system-level changes for the funding and communication of scientific research. Although other, alternative, complementary, small or big changes could also be possible, we believe that these two propositions would have a significant impact on scientists and society. To build momentum it would first be necessary to raise awareness about the current problems and the feasibility of a radically different system through more public debate, online as well as in meetings. As awareness raising by itself will not be sufficient, it will be also crucial to promote more policy-focused research and discussion. Understanding

the motivations, goals and views of scientists will be key to designing policies that can increase freedom and motivation as well as maximising the advancement of knowledge and practical benefits to society (Ballabeni et al. 2014; Scita et al. 2016).

In conclusion, we believe that these paradigm-shifting proposals are an example of how the freedom and quality of work of scientists as well as the fairness and efficiency of the research system can be significantly improved by designing far-reaching and ground-breaking policies.

Note

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