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Hypercompetition in biomedical research evaluation and its impact on young scientist careers

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Summary. Recent years have seen tremendous changes in the modes of publication and dissemination of biomedical information, with the introduction of countless new publishers and publishing models, as well as alternative modes of research evaluation. In parallel, we are witnessing an unsustainable explosion in the amount of information generated by each individual scientist, at the same time as many countries' shrinking research budgets are greatly increasing the competition for research funding. In such a hypercompetitive environment, how does one measure excellence? This contribution will provide an overview of some of the ongoing changes in authorship practices in the biomedical sciences, and also the consequences of hypercompetition to the careers of young scientists, from the perspective of a tenured young faculty member in the biomedical sciences. It will also provide some suggestions as to alternate dissemination and evaluation practices that could reverse current trends. [**Int Microbiol** 18(4):253-261 (2015)]

Keywords: biomedical publications · excellence evaluation· research competition · young scientists careers · information overload

Introduction

Recent years have witnessed an explosion in the amount of scientific output produced by each individual researcher [12, 43,56], creating major challenges for both scientists eager to keep up with the scientific literature, as well as for grant panels and recruitment and promotion committees as they attempt to assess growing volumes of researcher productivity. These challenges were foreseen to some extent by Toffler [79]. This author introduced the concept of "information overload", and we are very clearly witnessing this information overload in practice in the biomedical sciences today. For example, in any year in the period 2003–2012, there were about 3000–4000 biomedical journals scholars had available to choose from when deciding where to send their works [28].

In 2009, there were 25,400 journals in science, technology and medicine [9], with a projected annual growth of 3.5% [84] (which is probably currently larger due to the unfortunate explosion in predatory publishers [8]) and publishing about 1.5 million scientific papers a year [9]. Additionally, as of 1st October 2015, PubMed contained >25 million citations to the biomedical literature [59]. This explosion in the total number of papers is in turn coupled with the increasing granularity of publications and of journals' focus, leading in turn to a growing number of new journals targeting highly specialized subfields of each discipline.

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However, even though the amount of information we are required to follow and keep up with has exploded, the speed at which we can read the literature has not. For example, it has been suggested that the average specialist only would manage to read 322 papers a year [76]. However, based on both my personal experience and discussions with colleagues, I would venture to believe that the real number is most likely far lower. This impacts the modes of dissemination of information, such that not only does readership become a collective effort [33], but also this can lead to many scientists becoming authors first, and readers second. This also means that being ignorant of 100% of the literature in your field is not actually very different from being ignorant of 98% of it [33], and the problem with this is that a lot of extremely valuable research can be lost in the noise.

The American Chemical Society (ACS) summed up the zeitgeist of the times in a recent article [5], and the ramifications of this change in publishing culture are dramatic for all scientists, and for young starting scientists in particular. Tying in with this, there has been a tremendous science policy push towards using "excellence" as a criterion in determining funding [15,37,40,49,70]. This in turn affects reward outcomes for young researchers, and, in its path, establishes an essentially new "social contract" for science [75]. For example, within Europe, both national and European level policies to promote excellent research have affected the organization of research [19–22,70], making it increasingly project-based.

This also affects the development of academic careers (which is increasingly directly correlated to grant income [72]) and the definition and operationalization of research excellence within universities. The latter is, again, increasingly, based exclusively on assessment criteria such as the amount of grants received, and on the number of highly cited articles in high-impact journals [38,41]). In such an information-flooded environment, therefore, how then do you measure and reward excellence, in biomedicine or any other discipline?

Author placement and research rewards

At the heart of all forms of scientific dissemination is authorship. Whether it is of scientific publications, reports, technical notes, or presentations, authorship is, in essence, the "currency" of academia [82]. It is used to measure research productivity, it is also used as a basis for funding decisions and professional appointments, and it also brings direct rewards to the author, in terms of dissemination of work, new collaborations, and greater collegiality. As such, therefore, the core aims of authorship are laudable and greatly beneficial to the scientific community. There are many cases, however, when the monetization and incentivization of authorship becomes questionable [21,22], as for example, in reports of Chinese universities that provide impact-factor-based monetary bonuses upon the publication of manuscripts. These can be several times higher than the average urban wage [60], which provides a tremendous incentive for fraud for even the most ethically oriented of researchers, although publication ethics are the responsibility of all parties involved in the publication process [83].

Other examples of problematic incentivization include personal accounts from several colleagues working at departments across Europe, whose departments have introduce arbitrary requirements of *N* publications before promotion to full Professor, without even taking into account differences in the publishing practices of various subfields (names and identities withheld for confidentiality). The biggest problem to arise out of this monetization of authorship, whether through direct financial rewards or through using it as leverage for tenure and promotion, is that it encourages an explosion in the amount of scientific output, creating a drive towards the "least publishable unit" [17] style of publication, and completely overwhelming the readership in the process.

The tight links between authorship and the reward system then also impacts the research process itself [62], turning the choice of what projects and collaborations are selected to a decision based on where the work is likely to be ultimately publishable, while optimizing for the minimum amount of work in a fixed time that will lead to the highest impact. This, in turn, affects the very core of *doing* research [39,62], as publication pressures affect study designs (non-risky topics, increasing chances of false positives), and convert scientific exchanges into a process designed mainly to secure a competitive advantage [51,52,62], even in supposedly collaborative settings or in venues intended to advance the shared knowledge of a field. As a result, the core work of knowledge production is being cropped and tweaked to fit a narrow metric-based evaluation system [19,29,62].

The next major challenge facing the assessment of individual researchers is the fact that despite changes in research practices, author placement still drives many if not even most recruitment, tenure and funding decisions. In biomedical sciences, this typically means that most credit is given to the first

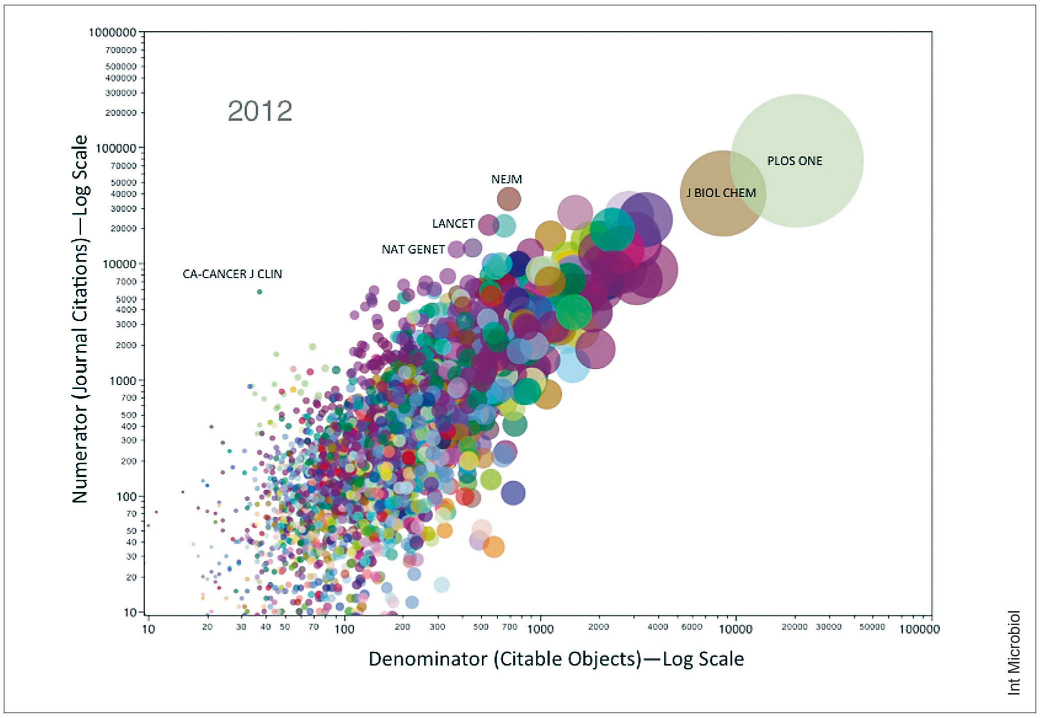

Fig. 1. Bubble plot illustrating the impact of biomedical journals in the years 2003–2012, on a logarithmic scale. The numerator of the plot shows the number of journal citations in 2012 to articles that were published in the years 2010 and 2011, and the denominator of the plot is the absolute number of articles published in 2010 and 2011. All data were taken from Thomson Reuter's Journal Citation Report. The figure has been kindly provided by Phil David from the Scholarly Kitchen, and was originally published at http://scholarlykitchen.sspnet.org/2013/07/24/dynamic-visualization-of-biomedical-journals-2003-2012/

and last author, although author positioning is very field dependent. Additionally, and despite improvements, ghost authorships are still a major problem in biomedicine [53,74,86]. However, Science is not a solo enterprise, and with the increasing importance of interdisciplinarity [54], it is increasingly common to see papers in the literature with dozens if not hundreds of authors on it, following a long ongoing trend of increasing numbers of authors on scientific publications [61,80,91]. For instance, a 2007 publication in the journal *Science* listed 28 authors, 7 of which were marked as having contributed equally [90]. However, one of these "authors" was the Wellcome Trust Case Consortium, which in fact brings the total author listing up to over 200 authors. An even more extreme incarnation of this can be seen in a recent paper in *Physical Review Letters*, which set the current authorship record with no less than 5154 individual authors [1], comprising of 9 pages of actual science, and 24 pages of author names and institutions. A final example of direct relevance to biomedical research is a 2015 genomics paper that involved contributions from 900 undergraduate students and listed 1000 authors in total [44].

Clearly, with author lists of these lengths, it can be extremely difficult to distinguish the added value each individual author brings to the manuscript, and yet biomedical research assessment still puts a majority of emphasis on the contributions of first and last authors, including elite grants that only allow you to list your "main author" papers. This is particularly problematic taking also into account the fact that the number of authors on individual papers is constantly growing [61,80,91]. In addition, especially in interdisciplinary research, even if there are only a few authors on the paper, the contribution of individual researchers from the different disciplines can be equally critical to the success of the project, and yet only one person can be first or last author respectively. One easy way around this might seem to be to just move to an alphabetical author listing, however, even here there is trouble in paradise, as it has been demonstrated that in disciplines such as economics, where alphabetical author listing is the norm, each letter close to an A gives an increased chance of tenure at a top US department (and the associated professional recognition) [30]. Therefore, highlighting researcher contributions in an effective way is absolutely critical [53,74, 80,82,86]. There have, however, been positive moves in this direction. One example is the fact that an increasing number of institutions explicitly require applicants for recruitment or promotion to explicitly list their contributions to each of the publications on their publication lists. If executed with honesty, this practice should reduce the incentive for ghost and honorary authorships.

Additionally, an increasing number of journals are requiring that not just author lists but also individual author contributions be provided upon submission of an article, for publication with the final manuscript. The taxonomy for this can be as simple as "analyzed data", "wrote paper", "performed experiments", but it can also become quite complex, as was for example the case in a 14-role taxonomy suggested by the publication *Nature* in 2014, which was based on correspondence with 1200 authors and publishers of leading life sciences journals [4]. Examples of this taxonomy include, for example, "**Study conception:** ideas, formulation of research question, statement of hypothesis", or "**Data curation:** management activities to annotate (produce metadata) and maintain research data for initial use and later re-use". According to *Nature* [4], this was generally well received, but is of course a small sample size and a very preliminary study. However, this is a promising direction that provides a much more streamlined template with which to assign author contributions and give appropriate credit where credit is due, rather than the rigid first/last authorship model being used in a lot of natural sciences today. By demanding explicit author contributions on published papers, the corresponding journals are significantly contributing to helping reduce the problem of "ghost" and "honorary" authorships, which make it even harder to assess genuine contributions on multi-author papers [82,83,86]. This move towards transparency should be lauded, as it will, hopefully, over time, create a scientific assessment model that allows interdisciplinary research to be properly assessed [60], as well as fostering an environment of greater collaboration rather than competition for the most coveted positions on the author list.

Changing publication culture and moving away from bibliometrics

A 1987 manuscript, by one of the most eminent enzymologists of the 20th century, opens with the following text: "We report here an examination of the mechanisms of general acid and general base catalysis of the reactions of water and alcohols with acetaldehyde. These two mechanisms of catalysis are entirely different and are discussed separately; *however, the work is described in a single long paper for economy of presentation of the experimental data*" (italics mine for emphasis) [69]. For any scientist working in the life sciences today, no further comment is necessary to illustrate just how much publication culture has changed in the past three decades. There has been much discussion in the recent literature about the uses and abuses of quantitative metrics such as the total number of citations, journal impact factors, or the ever-ubiquitous H-index (see e.g., refs. [13,14,18,29,45,50, 65,68,85,89], among many others). Additionally, in chasing to publish their work in the highest impact journal possible, few researchers outside of the field of scientometrics are aware that the original purpose of journal impact factors (JIF) was never to assess individual researchers, but rather, to help librarians decide what journals to purchase for institutional collections [7] (see also ref. [34] for further information about the history of the JIF).

Despite the concerns about uses and misuses of JIF, the information overload facing biomedical researchers in and of itself creates overdependence on bibliometrics, with JIF becoming synonymous with quality and being used to reduce complexity in the evaluation process by acting as an information filter in search of relevant papers [26,87]. Recent research [62] has shown that the JIF is not only used in assessing of individual researchers, but also (and worryingly), impact factor considerations kick in at a very early stage in the research process long before researchers start to think about publishing results. That is, JIF considerations have begun to structure work processes at the epistemic level, for instance affecting choices of which project to work on, or which laboratories to collaborate with, and so forth.

This makes moving away from bibliometrics-based criteria complicated, and although much work has been done on the misuses of impact factors, things evolve in use when they are taken up in different research practices. As such, it is promising to see increased awareness of the problems with arbitrary metrics among scientists and research institutions, initiatives such as the San Francisco Declaration on Research Assessment (DORA) [64], and the push towards the development of alternative metrics by which to assess researchers [10,11,14,57,67,88]. Additionally, citation counts and metrics such as the H-index are inherently flawed because they do not tell you how many people are citing this paper as an example of bad work (they take into account negative as well as positive citations), and they can both over-exaggerate and harm the track records of achievements of scientists working at the interface of multiple disciplines with very disparate publishing practices, depending on which discipline is performing the assessment. Therefore, quantitative metrics start having more limited usage in the assessment of interdisciplinary research, if discipline-dependent context is not taken into account.

In addition to flooding the literature by pushing scientists to produce an inordinately large number of publications, such hypercompetition does not come without a cost to young scientists. That is, as commented on recently by Alberts and colleagues [3], current Western research and authorship models are based on post-World War II concepts of constant growth. However, most biomedical research is done by an increasing number of graduate students and postdocs, leading to an explosion in scientists at the bottom of the professional "pyramid", and the amount of science that needs assessing. Therefore, scientific output has shot radically upwards at a time when research funding has gone down, and this has led to a toxically hypercompetitive environment, which can both put off even the most outstanding young scientists from an academic career, and puts undue pressure on established scientists, taking their attention away from the goal of producing the highest quality research (see the discussion in ref. [3]).

From the perspective of the entire science system, this makes research over-dependent on what is essentially a huge PhD and postdoc "factory" [27,36,58] of cheap labor services [72,73], where only a very small portion of these researchers have the possibility to move up the academic ladder (for example, according to the Royal Society, the figure for the UK for progression to professorial level in the natural sciences is only *ca.* 0.5% of all granted PhDs [77]. This is problematic in and of itself, because not everyone can or should be at the "top" of the research pyramid. Rather, we need an ecology of researchers working on different systems, and research group levels with different expertise and ambitions (to use a sports analogy, one would not want an entire football team to consist only of forward strikers).

Finally, while competition in general is good for science, as it leads to higher quality research, when taken too far, it suppresses creativity, collegiality and risk taking, characteristics that are all essential for groundbreaking discoveries [3]. In addition, the growing pressure to publish in top journals leads more and more scientists to cut corners, exaggerate findings and overstate the significance of their work [3], as is observed not just in the explosion of journal retraction rates [25,71,81], but is also diligently covered in the popular blog Retraction Watch [http://retractionwatch.com]. The main impact this has had on my work, and that of my colleagues, is that it also kills collaborative environments among one's own team members, as graduate students and postdocs develop an "if I'm not first author what's in it for me?" mentality, and it makes it harder and harder for them to work together. Clearly, this is not sustainable in the long term, and something has to change towards a healthier and more productive system if we, as a scientific community, want to continue producing excellent science and training well-balanced young researchers.

How to identify and assess excellent young scientists?

A term that is increasingly used in grant applications and recruitment panels is "excellence", although this term in itself is quite vague. How does one define *excellence*? [55]. And, more critically, how does one get it right when assessing young scientists at the start of their careers, who may have little or no independent track record to draw on as of yet. In an aptly titled recent article [47], Loeb pointed out the problem that many prestigious universities are plagued with "dead wood" faculty who were exploding with promise when they were initially hired, while in parallel, there are many stories of scientists who do not receive tenure at their initial institutions, move to "lesser" institutions, and still end up carrying the day. He argued that this is for a number of reasons, including the tendency of senior scientists to push forward junior candidates who best replicate their own research and ideas, the fact that early career achievements are just a frozen snapshot of a researcher's career, as well as over or under appreciation of a faculty applicant that is a former graduate, due to again a frozen memory of the applicant's achievements [47]. Hopefully, despite these problems, we do still manage to get recruitment of young candidates right most of the time. However, in light of the changing dynamics in publication and dissemination practices, current productivity-based assessment criteria clearly need re-addressing and updating to match current modes of authorship and interdisciplinarity.

As a thought experiment, I propose the reader to consider two potential candidates that have made it to the very last stage of your hypothetical faculty search, both of whom are research compatible with your top research department, and who have made a positive impression on the entire search committee. The first candidate is a postdoc from a world-leading University, with a roster of famous mentors, extensive publication record, and several high impact publications. The second candidate comes from a smaller University, and from a country where funding for equipment and other research expenses is scarce, and therefore has fewer publications, but has several nationally prestigious prizes and put in an exciting and novel research proposal. Who, then, would you pick for this faculty position?

The knee-jerk response, of course, would be to take the first candidate. But at the start of their career, and with excellent mentors, how much of a contribution did they really make to that work? Also, in the case of the second candidate, what if their lower output is due only to resources, and if you scale up to the resources that were available, what if they actually produced more when scaled for resources than the first candidate? If so, how much could they then achieve with a well-funded start-up package and excellent graduate students? The choice is not straightforward, but it highlights the need to take into account contextualized researcher profiles when assessing candidates for recruitment or high-profile grants and awards, rather than quantitative metrics. Clearly, fewer very good publications are superior to a large number of mediocre ones, and therefore it is important to actually read at least the top five publications flagged by the candidates to get a better idea of their research achievements (see also DORA). Mandating author contributions on publications lists submitted with tenure and promotion packages, and grant applications, allow the candidates to outline their contributions to each individual publication, in the case of multi-author papers.

Additionally, in terms of impact on the field, not just publications should be taken into account, but also other metrics such as patents, speaker invitations, awards, distinctions and also collaborative ability (“is this person going to be a good colleague?”). Finally, despite the push to always recruit the highest profile researchers that fulfill the criteria for (a very fluid definition of) excellence, once again, the need for an ecology rather than pyramid of researchers needs to be taken into account, as it is within such multi-dimensional research environments that the best quality research thrives and progresses.

There are, increasingly, other forms of dissemination of material, such as a new preprint server for the life sciences, bioaRxiv [http://bioRxiv.org], which has been modeled on the well-established and successful arXiv server in physics and mathematics [http://arXiv.org]; new modes of publication and peer review experimented with by for instance PLoS One [http://www.plosone.org/], F1000Research [http://f1000research.com] and others, which include publishing based on soundness rather than impact, allowing reader comments and open peer review; new forms of metrics as implemented for example by new forms of measuring impact such as those provided by Impact Story [https://impactstory.org] and AltMetrics [http://altmetrics.org, http://altmetric.com], and, recently, a comprehensive manifesto on research evaluation, the “Leiden Manifesto” [42], which outlines a 10-point list to be taken into account in the evaluation of research. Irrespective of what particular direction the field takes, change needs to be made, and fast, to protect the futures of the next generation(s) of outstanding young researchers.

Summary and outlook

I have written this Perspective not as a practitioner in scientometrics, but from the personal perspective of a biomedical researcher very interested in questions surrounding research evaluation strategies. For economy of space there are many topics I have not touched on here, but as is the case also for other young scientists, I am personally affected by increasing hypercompetition. I am also, in particular, highly alarmed by the speed at which this is increasing, such that purely subjectively, it appears that the pressure on the current generation of postdocs seeking faculty positions is already tremendously larger than the already large pressure I faced only half a decade ago. The most tragic consequence of our current models, however, may well be how the current evaluation and reward system is eroding the “social” aspects of science [3,6,22,23,48], e.g., the collegiality principle, increasing competitive struggles, blistering “benchmark masculinity” [78], and decreasing service to the scientific community [31]. In particular, some of the authorship and evaluation practices that have become central to academic work are in great tension with fostering innovative, collaborative and societally relevant science. Similarly, in the current research assessment models, even when the research comes from large charity funds (such as for instance cancer research foundations), the potential societal impact of the research (e.g., the effects on the clinic, potential new treatments) is usually not the main assessment criterion for determining the “value” of the research, or whether the money was well-spent. These tensions play a great role in creating the disillusionment and elevated stress levels facing academics [2,3,35,46,48,51,52,63], which surely contribute to driving some the best young scientists from the field.

There has been strong concern voiced by many others about the direction the field is taken, and as starting points I would recommend readers to turn to refs. [26,28,68,83,84] and references cited therein for further reading on this topic. Nevertheless, despite the great cause for concern, it is also promising to see the field take proactive measures to correct itself. The Leiden Manifesto [42] and DORA [64] are examples of this, as is proactive work to address these problems by many leading research organizations. Another promising step is that an increasing number of funding agencies request to see only a fixed number of your top publications, which creates a push towards quality over quantity in scientific publishing. Therefore, signs of change do exist, and there is cause to be hopeful. Ultimately, I have written this perspective because, while sustainable biomedical research can only come about at this stage through a major system overhaul at *every level* (research, funding, dissemination), *we*, the practitioners, are ultimately the ones who decide what Science will look like, and it is in our hands to fix it.

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Gaudí's dragon, at the entrance of Park Güell, Barcelona, with its bright scales of small tiles, represents Python, Delphian guardian of the underground waters, the source of knowledge. Python, Gaia/Earth's son, spelled oracles, early symbol of the dissemination of knowledge and science.

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