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The future of scientific publishing

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The beginning

Scientific publishing began thousands of years ago when the Greek philosophers started to write books about the creation of the world and the position of humans in it. Initially, philosophical thoughts and scientific concepts and discoveries were published in books and only much later in papers. Scientific journals, in the proper sense, are more recent and were developed in the seventeenth and eighteenth centuries. Since then, the number of scientific journals has increased tremendously with an ever increasing number of journals appearing worldwide publishing over 2.5 million papers annually. Indeed, it is anticipated that, with the rise in research in China and India, the number of scientific journals and, as a consequence, of scientific publications will increase further.

What is good scientific publishing?

The major principles of good scientific publishing are: (1) honesty, (2) precision, (3) novelty, (4) stringency and (5) timing **(Table 1)**. Scientific findings should obviously be reported exactly how they were obtained[1]. Only honestly reported findings will survive the test of time and will not be falsified by later publications[2]. Indeed, the truth of scientific discovery is mainly determined by conjectures and refutations, as Sir Karl Popper put it, rather than the currently hotly debated conflicts of interest[3].

Table 1. Major principles of good scientific publishing.

Item	Requirements
Honesty	Report only what has been measured as it has been measured. Be aware of the limitations of your study
Precision	Use state-of-the-art tools, report numbers with range and deviations, provide proper statistical analysis
Novelty	Check PubMed on what has been previously published, focus on incremental and/or true novelty of findings
Stringency	Write clearly and logically
Timing	Be in time, only timely findings can be novel

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Precision is another principle of science, as it is – contrary to theology and philosophy – quantitative in nature. Scientific papers primarily report measured parameters, their mean values and standard deviations and a statistical analysis of the obtained numbers that support or disprove a preconceived hypothesis. Today, not a single paper will be published in respected journals without a proper statistical review.

Then, novelty is a crucial element, as only novel findings deserve to be published; science stands for progress and progress requires novelty. Certainly, confirmation (or rather lack of falsification, if we follow Sir Karl Popper) is equally important, but this should be done with novel insights and/or larger numbers, respectively. Nevertheless, the third and fourth confirmation will not make it into a prime journal and the rest should not even be published at all.

Furthermore, scientific papers must be convincing. Only stringent arguments in the discussion section will convince reviewers and editors that the findings deserve publication. As Ludwig Wittgenstein put it, "What can be said at all, can be said clearly"[4]. The discussion of a paper should provide a logical flow of arguments and focus on the results of the study and not on speculation.

Finally, timing is crucial, as competition has never been as fierce as it is now. Of note, most scientists who ever worked in history work today. Thus, with declining acceptance rates in most first-line journals, the life of most scientists becomes increasingly stressful.

The peer review system

While ancient writers published their work as it was written in the first place, in the Middle Ages the Catholic Church censored any publication or authors self-censored their thoughts and writings to avoid any deviation from canonical teaching. The aims of peer review, however, are completely different and historically much more recent. Peer review was introduced to help readers to obtain the best information according to the aforementioned criteria. Henry Oldenburg (1618-1677) is considered the inventor of peer review during his time as secretary of the Royal Society[5]. When he was an editor of the Philosophical Transactions he felt uncomfortable as a theologist to assess the quality of submitted papers from different areas of science and medicine. He therefore relied on the judgement of colleagues of standing in fields other than his own. As such, he invented the peer. A peer is an individual, if we follow the definition of the American College Dictionary, of the same civil rank or scientific standing as the author of the submitted work, an equal before the law. This has remained as such ever since, and even today we select peers with a particular reputation, experience and standing in a given field to assess submitted papers. However, in contrast to the medieval censorship, the peer review system does not intend to suppress thoughts or findings, but rather to improve the quality of submitted work thanks to suggestions of expert peers and more recently statistical reviewers.

The question is: how perfect is peer review? Many disappointed authors whose work has been rejected are critical of peer review. However, although peer review might not be perfect, it certainly improves the quality of submitted papers that make the bar of a particular journal. Indeed, reviewers are asked to assess methods, the statistics and data and whether the conclusions are supported by the results. Papers of interest that are revised after constructive review are certainly better than the original version. Thus, although peer review may have overlooked some unusual or even innovative findings, overall it does provide a service to authors and to science at large – nothing is perfect, nor is peer review, but it certainly fosters reliable scientific reporting.

Will this system survive in the future? Most scientists would agree that peer review is here to stay and distinguishes high-quality journals from the rest of the crowd. Indeed, a lot of low-quality and in particular open access journals do not provide proper peer review and many cannot even afford state-of-the-art statistical reviewing with their business model. Nevertheless, as Churchill stated for democracy (in his speech to the House of Commons on November 11, 1947), peer review may be imperfect, but we do not yet know of any better system. And indeed it is necessary: who could read the thousands of papers published today? What is more, it is a service to readers in order to provide publications of certified high quality.

Journal rating

Humans love to compete: this starts in school and is the main attractiveness of competitive sports – we want to know who the winner is. Scientists are no different: we have citation indices, the h-index for researchers and various impact factors for journals. In particular, the altmetric score introduced a completely new aspect, i.e., the impact a paper has in social media, newspapers and blogs. Hence, for some papers the altmetric score may be huge, but citations in the scientific literature low or vice versa. Indeed, altmetric scores are particularly high for findings on emotional topics, diet and nutrition, environment among others. Thus, they all measure a different aspect of science – in short, they measure the unmeasurable[6]. Whatever these ratings measure, they are highly influential: they determine the visibility and reputation of scientists and journals, and they are important in academic promotion and not least for the self-esteem of editors and authors. There is no question about it – they are here to stay. We may argue which of the factors is most important, but in the end we all want them and will also want to use them in the future.

Changing environment

Over the last few decades scientific publishing has changed considerably due to cultural, logistic, technical and political factors:

(1) **The internet has changed our life**. Thirty years ago this year, Sir Tim Berners-Lee came up with the idea of joining up hypertext with the early Internet of the time, creating a system for sharing and distributing information not just within a company, but globally. He named it the World Wide Web. Since then, the world wide web has had an unforeseen influence on our culture, on business and technology

by providing near-instant communication by electronic mail, voice transmissions, video conferencing and online shopping. As a consequence, the flow of information has been dramatically accelerated and expanded with discussion fora, blogs and numerous social media products. In science and beyond, growing amounts of data are transmitted at higher and higher speed. The electronic platform of journals has become more important than the printed version. Indeed, the European Heart Journal alone enjoys around 10 million downloads per year from its platform.

(2) **The speed of discovery** is continously accelerating. As an example, the discovery of gain-of-function and loss-of-function mutations of the PCSK9 gene in 2003[7] led in less than a decade to novel drugs, the PCSK9 inhibitors[8] and 14 years later to proof of their efficacy on clinical outcomes[9] – a true record in research and development. In contrast, it took decades from the discovery of Mycobacterium tuberculosis by Robert Koch in 1882[10] to the proof of an effective treatment in the seminal streptomycin trial by Austin Bradford Hill in 1948[11]. With the ever increasing number of scientists working worldwide, due largely to China and India, speed – and in turn competition – will increase further.

(3) **The expectations of readers, reviewers and editors** fly higher and higher. Indeed, while years ago it was sufficient to report an interesting finding, today reviewers and editors expect in-depth characterisation of molecular pathways. Randomised studies carry more weight than registries and larger and larger patient populations are expected in order to support the claims of a paper. Big data, machine learning[12-14] and artificial intelligence[15] will change science and medicine further.

(4) **The reading behaviour** of the new generation has changed as well. Today's young readers are less prepared to read long texts and expect more visual content. Indeed, not only have papers become shorter over the last few decades, but they are also more extensively illustrated with tables and figures as well as supplemental files. Some journals now also provide videos or even online lectures of their papers and interviews with prominent scientists.

(5) **The conflict of interest policy** has also affected publishing. Although pharmaceutical and device industries have made important contributions to the progress of medicine at large and cardiology in particular, their involvement is increasingly seen as a problem affecting unbiased data reporting. Similarly, the trustworthiness of authors working with industry has increasingly been brought into question, mainly by media, but also by the public at large[16]. To address this, many societies have produced standards to handle the issue – with moderate success[17].

(6) **The business model** of publishing is also under scrutiny. While most prestigious journals publish using the subscription model where the reader, or his/her institution, pays for access to content, an increasing number of journals use the open access system. Open access is a new business model where the author pays, while the reader gets free access to published articles. In principle, although this is not the rule, open access allows proper peer review; it is primarily a different business model. In addition, there are hybrid journals such as the European Heart Journal among many others, where selected papers are the "editor's choice", i.e., they are freely accessible, while the rest can only be downloaded by subscribers. However, in most journals, authors who wish to have their article published with open access may pay for that, if they wish to do so.

Is speed quality?

In the age of the internet, speed has become a quality factor in its own right. Indeed, some even announced the end of journals as they would be too slow in reporting the progress of science[18]. However, whether new forms of digital publishing would be faster and better than today's peer-reviewed journals remains unproven. To speed up publishing further, prepublication has been proposed[19] or even declared mandatory. Many journals are now accepting work that has been made public on an institutional platform, and some proponents of this strategy have even suggested making every version of the manuscript available. This, however, has several downsides: first, it produces a number of, potentially differing, revised versions of a manuscript with in some cases even differing conclusions. Secondly, this will create confusion and may even damage the credibility of science among the public at large. Third, who will have the time to read up to five versions of a single manuscript at a time when 50 million articles are available since the inception of science? Finally, is speed a quality marker of science or is it rather reproducibility of content? It took William Harvey years to produce De Motu Cordis, but it made history[20]; stem cell research developed exceedingly fast and ended up in a scandal. The lesson is: good scientific publishing requires time and we should allow for that.

Certainly, there is a sweet spot: we should not follow the example of the dark lady of DNA. Indeed, Rosalind Franklin made groundbreaking discoveries on the structure of DNA, but was shy of publishing them[21]. When a certain James Watson visited her lab and showed extreme interest in her radiographs, she ended up in the footnote of a landmark paper where it reads, "We have also been stimulated by … the unpublished experimental results and ideas of … Dr. R. E. Franklin"[22].

Plan S

The discussion over whether subscription or open access is the right way to publish has heated up with the presentation of the Plan S in 2018[23]. It all started with the recognition that publishing companies make astonishing profits by publishing findings they do not pay for, but have been supported by charities and foundations, federal institutions and by researchers working for free. For instance, Elsevier, one of the largest publishing companies, apparently makes several hundred millions of dollars profit every year. Understandably, this has led to a lot of criticism by scientists, governmental agencies and the media. As a consequence, an

increasing number of funding bodies are supporting the so-called Plan S which is also supported by the European Commission and the European Research Council (ERC). Plan S aims to change the system of scientific publishing completely to open access (https://www.coalition-s.org/why-plan-s/). Importantly, Plan S does not allow the hybrid model discussed above, but intends to force scientific journals to publish only open access as of 2020 **(Table 2)**.

What are the advantages and disadvantages of open access publishing? Basically, the two models are different business models: in the subscription model the reader pays, while with open access the author pays **(Table 2)**. But there is more to it: the Budapest Open Access Initiative (BOAI) published in 2002 took the position that all scientists and scholars should publish their research in journals without payment on internet platforms to allow rapid and unrestricted dissemination of their results to the community at large. So, the primary argument for open access is dissemination – certainly something that most would agree with. Secondly, the enormous profits of publishing companies fostered the determination of open access enthusiasts to recommend only this way of publishing and not any other. Indeed, the enormous profits of publishing companies are a foreign body in academic life.

Four major questions remain unanswered that need to be considered. (1) Is open access living up to its promises? (2) Is the quality equal to that of subscription publishing? (3) Is it affordable for scientists from less affluent countries? (4) Could it lead to new conficts of interest for editors and publishers?

Table 2. Modified and shortened summary of the principles of plan S (Source: https://www.coalition-s.org/why-plan-s/).

– Authors retain copyright of their publication without restrictions
– All publications must be published under an open access
– The funders will establish the criteria and requirements for the services that compliant high-quality Open Access journals must provide
– If high-quality Open Access journals do not yet exist, the funders will, in a coordinated way, provide incentives to establish and support them
– Support will also be provided for Open Access infrastructures where necessary
– Open Access publication fees are covered by the funders or universities, not by individual researchers
– All scientists should be able to publish Open Access even if their institutions have limited means
– When Open Access fees are applied, their funding is standardised and capped across Europe
– The funders will ask universities, research organisations, and libraries to align their policies and strategies, notably to ensure transparency
– The 'hybrid' model of publishing is not compliant with the above principles
– The funders will monitor compliance and sanction non-compliance.

(1) **Is open access more effective in terms of dissemination?** Obviously, this is not easy to measure, particularly since first-line subscription and hybrid journals such as the New England Journal of Medicine and the European Heart Journal among others have millions of downloads from their platform every year reflecting massive dissemination. The same applies to citations: by far the best cited journals are those which publish using the subscription or hybrid model and not open access. Although the Budapest Open Access Initiative (BOAI) is 17 years old, this has not changed much[24]. Indeed, in medicine and in cardiovascular medicine in particular, none of the open access journals has reached a sizeable impact: the Journal of the American Heart Association (JAHA) has an impact factor score of 5.117, PLOS ONE of 2.766 and ESC Heart Failure is still waiting to receive one – only PLOS Medicine stands out with an impact factor of 11.675.

(2) **Does open access improve the quality of scientific publications?** Proper peer review is a costly process. First, it requires a team of editorial managers handling manuscripts, checking format and overlap with published work and a team of competent statistical reviewers (who, unlike content reviewers, do not work for free). Second, professional publishing requires an attractive platform with changing content, news section, links and movies. Third, a first-line journal needs a press officer, a social media officer and medical writers for the news section. Finally, an ethics committee to handle issues of scientific malpractice should be standard. All of this has to be organised and coordinated by a sizeable editorial team – this requires an appropriate budget.

Can all this be financed within an open access model? Yes, if the publication rate is high enough. High-quality peer review is costly and there is a limit for affordable registration fees that make running an open access journal at the prime journal level challenging.

(3) **Who pays for open access publishing?** The funding bodies supporting open access have promised to provide resources to pay for publication rates – but how much will this be? Currently, 1,500 to 3,000 euros is the cost of publishing a single paper. What if an unusually productive scientist publishes five papers per year? What if he/she works in a country with a less affluent economy where physicians' salaries are in the range of 3,000 euros or less? What if a paper gets rejected and the authors have to try two or three other journals to get published? Who will cover these costs? Yes, Plan S promises that funders will pay everything – almost a fairy tale **(Table 2)** – but is this credible? What about research paid by universities, by funders not signing up for Plan S? Undoubtably, this will lead to a further discrimination of countries that are desperately trying to develop their academic activities to the level of Western societies.

(4) **Who loses with open access publishing?** Currently, many journals are official organs of scientific societies such as the European Society of Cardiology, the American College of Cardiology and the American Heart Association. All these

societies receive considerable income from their published products that they reinvest in educational activities, grants for young scientists among others. A first estimate of these societies suggests that they will lose considerable income with open access compared to the current subscription model, something which will affect the medical community at large.

(5) **A new conflict of interest.** Finally, the open access system creates a new conflict of interest for publishers and editors alike as their profit and income will depend on how many papers they accept and how little they spend for a high-quality peer review process to select only high-quality papers. Most first-line journals such as the New England Journal of Medicine, The Lancet or the European Heart Journal publish relatively few, but high-quality papers. They publish a large part of the 1% most cited papers in their field because they rigorously select for quality and novelty and have acceptance rates of only 4 to 8%. Such quality selection is not optimally compatible with an open access business model, but it certainly is a necessity in a world that is flooded with more than 100,000 papers a year.

(6) **Accessibility and dissemination.** No doubt there are advantages of open access publishing, the most important one being unrestricted accessibility of information for readers around the world. Therefore, newly gained knowledge should spread faster and more effectively compared to subscription journals. However, current data suggest only a small advantage for open access journals compared to subscription publishing[25]. This may be due to the fact that most open access journals lack high impact and reputation. Also, most first-line subscription journals run a hybrid model whereby some articles are open access (e.g., in the European Heart Journal usually two per issue) and open access can be purchased, if desired. Furthermore, all papers are made fully accessible after a period of time (e.g., usually 12 months). Thus, hybrid publishing seems to be the model of choice. Not Plan S but "Plan B" should be the solution **(Table 3)**.

Conclusions

Scientific publishing is at a turning point where we have to choose between speed and quality and have to take a position for or against Plan S. Quality must remain the gold standard and only proper peer review can ensure that. In the current flood of publications, prime journals provide a service as they select those papers that must be read. The current focus on maximal speed is toxic for science; we have to acknowledge that reproducible scientific discovery requires time. Finally, dissemination of science is indeed important and should be fostered. However, rather than an ideological approach as Plan S proposes, we should support flexible models of publishing as provided by hybrid journals and allow full open access for those who choose that path[26].

Conflict of interest statement

The author is the editor-in-chief of the European Heart Journal, a hybrid journal. He has no conflicts of interest related to this article.

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Table 3. Comparison of the three models of scientific publishing.

Subscription model ("the reader pays")	Hybrid model ("you get what you want")	Open Access model ("the author pays")
– Subscription access only	– Access by subscription	– Completely free access
– Individual subscribers	– Paid open access	– High submission fee
– Institutional subscribers	– Editor's choice free	– Peer review possible
– Submission free	– Individuals, libraries	– Unrestricted publishing
– Peer review the rule	– Submission free	– No publishing company
– Restrictive publishing	– Peer review the rule	– Funders are said to pay
– Publisher profit	– Restrictive publishing	– Highly regulated
– Professional society profit	– Publisher profit	
	– Professional society profit	

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