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OPINION PIECE

Open access publishing: a service or a detriment to science?

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ABSTRACT: The unintended negative consequences of the drive towards open access publishing are becoming increasingly apparent. This paper examines the nature of open access publishing from the perspectives of authors and readers, considering issues of payment and ownership, and the question of open access for data. It discusses the origins of open access, its costs and the extent to which delivers on its aims, and reviews its advantages and disadvantages, including economic restrictions on access to publishing, the rise in predatory journals and degradation of quality control, and the consequent potential of open access to damage the standing of science in society. Given the recognised importance of 'crafting the message', i.e. communicating scientific results to each category of end-users in the most appropriate way, it should also be asked why the 'one size fits all' solution of publishing results in open access journal papers (which usually follow the standard format of scientific papers, which remains off-putting to the casual reader) is considered necessary. There is a need for greater rigour in choice of publication outlets, avoiding predatory journals and promoting benign open access options, and ensuring that funding bodies and policymakers are aware of the unexpected negative impacts of unregulated open access publishing.

KEY WORDS: Open access · Perception · Reputation · Costs

INTRODUCTION

Scientists and policymakers may believe they are setting the open access agenda and thereby providing a valuable service to society. Some are optimistic that 'the route towards a more democratic fashion of making the results of scientific research openly available is mapped out' (Boero 2017) and that 'granting readers full re-use rights unleashes the full range of human creativity for translating, combining, analyzing, adapting, and preserving the scientific record' (Carroll 2013). Others are less sure; Beall (2012) flagged up the growth of predatory 'counterfeit' journals while Beninger et al. (2016) argued convincingly that the spread of predatory open access journals is 'a threat to science itself'. Nevertheless, the gravity of such threats seems not to be widely appreciated, perhaps because there are few studies providing empirical evidence of the problem, and the 'frequent, aggressive solicitations from predatory publishers are generally considered merely a nuisance for scientists from rich countries, not a threat to scholarly

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integrity' (Moher et al. 2017). To echo the concerns of Beall, Beninger et al. and Moher et al., the present study argues that the integrity of science is jeopardised by the dissemination of poor science, pseudoscience and special interest advocacy in publications purporting to be open access science journals. Using Krizhanovsky & Choong (2014) as an example, Beninger et al. say: 'ask yourselves if you really want this article to come up on a computer screen next to your own, or have your article cited in it'. More worryingly, how is a layperson, a member of the public, supposed to know that this is in fact what we might, to adapt current idiom, call 'fake science'?

What is becoming clear is that the open access framework has opened Pandora's box, by creating a new market opportunity which, far more than the old academic publishing model (under which authors were not paid for their writing but at least did not have to pay to publish it), allows unscrupulous publishers to exploit authors' vanity and ambition and the pressure to publish from authors' employers and funding bodies. The open access framework has thus set in motion processes that already appear to be damaging the reputation of science (see Beall 2012, Haug 2013, Beninger et al. 2016, Moher et al. 2017).

WHO WRITES SCIENTIFIC PAPERS, WHAT DO THEY WRITE, AND WHY?

Science, like other human endeavours, is not immune to the vagaries of fashion, or political and financial patronage, and is certainly not immune to subtle (or other) economic incentives. Scholars of the 19th century and early 20th century (e.g. Charles Darwin, Thomas Henry Huxley, John Maynard Keynes, Karl Marx, John Stuart Mill) wrote books and/or published in journals run by universities, learned societies (e.g. the Royal Society, the Royal Economic Society) and other respected publishers, as charitable or non-profit enterprises. Academics published relatively infrequently, describing major research outcomes, after careful peer review. This model prevailed well into the second half of the 20th century, with lengthy monographs still being relatively common.

University and research ethos changed in the 1980s and 1990s, subjecting academics to 'free market' competition policies, using quantitative and comparative assessment measures to identify 'research-active' individuals for promotion and punish 'non-researchers'. These pressures increased the volume of research output and encouraged such questionable concepts as the 'minimum publishable unit', and shorter papers, offering incremental gains to knowledge, increasingly replaced the old-fashioned monograph. This, in turn, put pressure on both journals and referees, and provided an opportunity to 'for-profit' publishers to make significant inroads into the refereed journal market. Subsequently, a series of for-profit publisher mergers occurred, effectively creating monopolisation of the publishing market, and university non-profit publishing houses disappeared, most of them absorbed by the for-profit publishers. At the end of this process, the small number of 'for-profit' publishers, enjoying effective monopoly power, were able to charge extravagant prices to libraries. At the same time, more research was funded by private (for-profit) donors and by political entities pursuing political ends and policies. Most of these funding bodies expected researchers to deliver publications about the work. The scope for conflict of interest thus increased and the pressures arising were not necessarily conducive to ensuring the quality of the science published.

More recently, research ethos has shifted again, with the emergence of what Butler & Spoelstra (2014) call 'the regime of excellence', whereby 'decisions about what to research and where to publish are increasingly being made according to the diktats of research assessments, journal rankings and managing editors of premier outlets'. Under this model, the majority of scientific endeavour essentially becomes irrelevant to how scholars and institutions are judged, with only the 'best' research being rewarded, as though it could somehow exist in isolation and, indeed, as though it were straightforward to identify the best research. Long before open access came along, the way scientists approached their research and its publication was already shifting due to subtle and less subtle pressures; it became usual to make judgements based on artificial indicators of quality rather than quality per se. For example, despite various known biases, it has become commonplace to use impact factor (based on citation rates) as an indicator of journal quality (see e.g. Saha et al. 2003, Elliott 2014). Of course, this does not necessarily indicate that the journal's impact factor is a good indicator of the quality of an individual paper, since the correlation between citations of individual papers and the journal impact factor has become weaker in the digital age (Lozano et al. 2012). Butler & Spoelstra (2014) further explore the perverse consequences of research assessments in some detail. In relation to open access, the point is that scholars had become accustomed to jumping through more or less

meaningless hoops to advance their careers, and as such, open access was probably more easily accepted than would otherwise have been the case. Would 19th and early 20th century scholars have been so accepting?

There had long been an unspoken rule, at least in some academic circles, that science should be judged on the novelty of the ideas tested and discussed, with their relevance to society being a secondary consideration expected to take care of itself in the process of societal or historical discourse, sooner or later. After all, if scientific results were in the public domain then they could be acted upon by interested parties if they so wished. Indeed, to suggest societal actions, based on scientific results, was to step outside the remit of the scientist. For example, as the late George Dunnet (then head of the University of Aberdeen's Culterty Field Station) once remarked, ecology is not the same as conservation: it is the ecologist's job to do the research, not to tell someone else how to use the information, however important the ecologist thinks it is to advance the cause of conservation. Of course, if research results were patentable, and the researcher and/or the employer could turn them into a profit, a different attitude might apply.

Over the last 2 decades, several research-funding bodies (notably the European Union [EU]'s 'framework' funding programmes) have increasingly required applicants to directly address the subsequent use of research results, through a requirement to present dissemination plans and 'impact' statements, explicitly stating how their results would be communicated to end-users (although this did not necessarily imply that end-users should be reading original papers in scientific journals) and how the results would be used to achieve societal goals. Furthermore, in the 21st century in the UK, academic publication in the university sector has been increasingly driven by a government-mandated research assessment process (currently known as the Research Excellence Framework). Similar government-mandated research assessment processes, with various levels of formal assessment, are applied elsewhere. Within this process, while great emphasis has been on 'high-impact' papers that supposedly represent significant *scientific* advances (exactly what is being measured is the subject of some debate, e.g. Butler & Spoelstra 2014), societal impact is also gaining traction as an important component of the assessment process.

Individual scientists write papers to fulfil requirements of funding bodies, to enhance their CVs and those of their students and in doing so, enhance their promotion prospects and the prospects of their students of getting a permanent job (e.g. Ware & Mabe 2015). In principle, scientists publish their research work because they believe (or would like to believe) that they have something worthwhile to say, at least to other scientists, but hopefully also to society. However, in the current climate, very few working scientists will be able to devote the time to write long treatises such as Keynes' 'The general theory of employment, interest and money' or Darwin's 'On the origin of species by means of natural selection, or the preservation of favoured races in the struggle for life', even if many would like to do so.

WHO READS SCIENCE AND WHERE?

By and large, scientific papers were and are read by other scientists and by university students. Communicating science to the public was the job of others, such as university press officers, who prepared potted summaries to send to local newspapers, and scientific journalists, who translated erudite and/or hard-to-read technical papers into easily digested articles for publications like *New Scientist*. Of course, some scientists also published 'popularised' versions of their work and a few became 'media stars'. Many others occasionally talked directly to journalists about their work and often wished they had not done so, when the said journalists cherry-picked some detail that they thought might excite the readers, whether or not it had anything to do with the main message of the original journal paper. Nowadays, increasing numbers of popular science books provide ready digested and very readable accounts of science for public consumption — and governments employ scientific advisors to effectively do the same for the policymakers. However, perhaps the key point is that papers in front-line science journals were and are part of the scientific discourse, neither aimed at the general public nor directly read by the general public. Part of the issue is the deliberately (and arguably necessarily) dry and detached, third-person, writing style that scientists are trained to use, in part reflecting the esoteric nature of scientific discourse but also aiming to be objective and present the facts in an unbiased and unadorned manner. Of course, there are ways to introduce bias (or 'spin') even within such a style, and some authors have argued that science would be better served by adopting a more reader-friendly prose style (e.g. Doubleday & Connell 2017).

WHAT MAKES A SCIENTIFIC PAPER DIFFERENT FROM ANYTHING ELSE YOU OR I MIGHT WRITE AND PUBLISH?

The key to respectable scientific publication was, and mostly still is, peer review. A paper may be misleading or wrong, but it must have convinced one or more reviewers and an editor, all of whom are normally scientists working in the same field or a related field, that it was worthwhile (see British Ecological Society 2013 for a detailed critique of peer review). This system of course depends on the goodwill of scientists to undertake reviews for free and, crucially, on the quantity of the submitted papers in relation to the number of available reviewers. Like all forms of reciprocal altruism, it is subject to 'gaming'[1] but it always used to provide a form of quality assurance. Of course, some people tend to exaggerate the importance of their work in their manuscripts and/or to suggest their friends as reviewers, but it is not in the interests of science (or ultimately of scientists) to allow this to prevail, and editors tend to be alert to the issue. By and large, this system has served science well. Of course, in one sense, science is almost always wrong in the sense that it is incomplete — science is always moving onward, but good scientific publications are way-markers, showing current progress and suggesting ways forward.

WHO PAYS FOR SCIENTIFIC PUBLICATION?

Before the marketisation of the universities, a process that developed in parallel with increasing use of university rankings, erosion of academic freedom[2] and reductions in central government funding (e.g. Robinson 2014, Tsikliras et al. 2014, Lynch & Ivancheva 2015), university libraries and other public libraries were publicly funded to buy academic journals and books from the publishers. To the extent that this funding came from general taxation, both universities and libraries could be considered public goods (as used to be the case for university education). The public had free access to the library material either free or for a small fee. In this way, scientific knowledge was disseminated not only to the scientific community but to other interested readers and the public. Latterly, some journals sought to supplement their income by asking authors to pay 'page charges' for the privilege of being published. Ultimately, public institutions are publicly funded, so if the institution pays to stock the journals and hence indirectly pays for publication, the public pays. And of course the public probably also ultimately paid for the research.

WHO OWNS SCIENCE THEN?

Scientists naturally feel they have intellectual property rights to their work, while their employers may beg to differ. While acknowledging that this is ultimately a legal issue, excluding systems of slavery and feudal societies, the intellectual property right should rest with scientist. Clearly though, to the extent that the university pays the salary and provides the laboratory and other facilities, it too should have a claim — although the precise division is also a legal issue. Contrary to current practices, it can be argued that ultimately, the property rights rest with society. The progression of science is founded on the previous scientific developments that in turn were an outcome of social and scientific processes. As Isaac Newton put it in 1675, 'if I have seen further, it is by standing on the shoulders of giants' (a metaphor that can be traced back to John of Salisbury in 1159).

Nevertheless, when a paper is published, the journal assumes legal copyright, so that the material cannot be republished elsewhere and helping to ensure that, if used, it will be appropriately cited. While not necessarily claiming ownership (although this may arise when research is privately funded), funding bodies may strongly encourage publication. They may even specify the form of publication, and may apply penalties in relation to future research funding (of the individual and the institution) if these recommendations are not followed.

Similar issues arise of course in relation to the research samples and data on which scientific publications are based. Scientists, employers and funding bodies may all feel they have a claim to ownership. One key question is whether data and/or samples can be considered to form part of the 'foreground intellectual property' generated by a project or indeed as 'background intellectual property' that a scientist and/or institution brings to a future project. Funding bodies may (and increasingly do) stipulate that samples and data collected during a project should be deposited in a data/sample bank and be-

[1]Game theory is about analysing situations to identify the course of action which delivers maximum benefit to the individual; gaming is the process of doing this (von Neumann & Morgenstern 1953)

[2]A process which has, incidentally, progressed faster in the UK than in the rest of the EU (Karran & Mallinson 2017)

come freely available to other researchers. Yet for many institutions, especially but not only for small nongovernmental organisations (NGOs), samples and/or datasets may be the key assets that facilitate their entry into collaborative research projects. In addition, from the point of view of the scientist and the employer, loss of control of data and samples reduces the value of undertaking research in the first place and could mean that the research is not carried out at all; this may be a particular issue for long time-series of data and samples which yield useful results only over a relatively long time period. On the one hand, open access provides increased opportunities for scientists to work on existing data and samples, thus shifting efforts away from generating new data and samples. On the other hand, it increases incentives to find novel ways to comply with the letter of the law while still protecting ownership (for example by placing samples in a sample bank but attaching restrictive access conditions).

Increasingly, the prevailing view that publicly funded research belongs to the public, which clearly has merit, has been used to justify a move towards 'open access publishing' (the main focus of the present essay) and 'open access data'. There is an argument that with subscription-only journals, society effectively pays twice, once for the research to be done, and then again in order to view the results. However, unless research funding increases to cover the cost of open access publishing, the result of a shift to open access is a de facto cut in science funding — and indeed an indirect tax on scientific writing that is not directly publicly funded. Support from scientists for open access publishing arises at least partly because traditional journals are seen as profiteering, although again there are counter-arguments. Thus, for example, lower prices lead to reduced editorial quality and furthermore, there is no good reason to assume that open access journals would be less prone to profiteering (e.g. Van Noorden 2013). Finally, correctly identifying an issue does not in itself imply that the proposed solution is the best one or even that it is fit for its purpose. The potential damage caused by unintended consequences of open access, as detailed below, may ultimately outweigh the benefits.

SO ALONG CAME OPEN ACCESS

Regardless of the rationale for open access, it would not have happened without the internet (Carroll 2013, Haug 2013, Wolpert 2013). In her account of the origins (and inevitability) of open access, Wolpert (2013) points to the disruption of the old system of scientific publication caused by the advent of the internet and digital formats. The internet is basically a global public library and huge swathes of content are free to the user, whether or not files are notionally legally protected by copyright law. The availability of mechanisms to bypass copyright essentially destroyed the popular music industry and threatens traditional book and newspaper publishing, so it could be argued that open access was a logical response for academic publishing. Having said that, academic papers seem less likely targets of illegal file sharing than, say, songs by Metallica. In any case, in 2002, the Budapest Open Access Initiative[3] was the first of several initiatives in the move towards open access publishing. Its intentions could not have been nobler: 'An old tradition and a new technology have converged to make possible an unprecedented public good', and the associated forum remains active today (see Guédon 2015 for a detailed history, also Wolpert 2013).

Given the presumption of open access, that scientific papers should be free at the point of access, i.e. free to the reader, apparently an alternative business model was needed to ensure this. The solution was for the author to pay for publishing his or her research or, if he/she were lucky, for his or her institution to pay for publication. Ultimately the funding body pays. However, this all comes at a cost, for example the cost of setting up repositories for papers ('green' open access) and the cost of supporting 'gold' open access (i.e. instant free access to journal papers) (Frank 2013). Among other figures, Frank estimates that it would cost Harvard Medical School almost $10 million annually to switch all its publications to open access and argues that, when resources are limited, taking such sums from the research budget is not justified. Thus, under open access, the public pays more for scientific publication and gains instant free access to scientific papers, by diverting significant sums of money from research.

Taking a step back, the logic of this argument is questionable. Firstly, it is not clear that open access delivers anything new. Before open access, anyone with access to library had access to all the content for which the library had a subscription. It is true that not all libraries subscribed to all journals and that, as a member of the public, one would need to join a good library, possibly implying payment of a usually small fee, but scientific papers could then be accessed free

[3]www.budapestopenaccessinitiative.org/read

of charge. At worst, an email to the author to request a pdf copy would normally solve the problem. Secondly, while open access ensures that the public can access scientific publications without the need to belong to a library, the science that is available to them is starting to look very different to that available under the old model.

Under the old model, the demand for published material was coming from the readership. The universities and public libraries were funded by the public via taxation but which books or journals were in demand was determined by the readership. In the case of scientific papers, demand was mainly from scientists and researchers. Publishers were subject to some market discipline and repercussions due to pressures from university and public libraries, and due to public/government control. Publishers could price their products subject to these controls. Since scientists were not directly paying to publish, they could select journals according to their relevance, quality and/or prestige. Here we should note that journal quality indicators are themselves a source of controversy, not least when used by evaluators as performance metrics to judge the impact of an individual's scientific outputs (e.g. Browman & Stergiou 2008, Lawrence 2008, Anon 2013). However, while non-specialist readers might struggle to determine journal quality (given the profusion of journal quality metrics, between-discipline differences in indicator values, geographical and language-related biases, and so on), it can still be argued that scientists and libraries would tend not to support poor journals — and that peer review also helped to maintain quality. The process of peer review is itself currently under threat, even at the 'respectable' end of the journal spectrum. As pressure to publish increases, the numbers of papers submitted to journals increases, and editors are apparently finding it harder to find appropriate referees. A recent study by Fox et al. (2017) provides some empirical support for this, although the authors suggest that this relates to other pressures on researchers' time rather than 'reviewer fatigue'.

Open access has different mechanics. In view of the pressure on academics to publish, publishers can price their services according to what the market can bear, depending on a host of factors not under public control. Public money (received via public funding bodies) is now transferred directly from scientists to publishers without any attendant market mechanism, so publishers can enjoy monopoly rents via unregulated open access fees. The advent of open access also created the opportunity for journals to charge authors a fee to publish their papers with little or no quality control (Haug 2013).

As academics are under severe and increasing pressure to publish, a trend that is linked to increasing marketisation and reduced job security, there is an increasing quantity of manuscripts (and potentially lower average quality) of manuscripts submitted. This means that more and more manuscripts tend to be rejected by 'respectable' journals. From an author's perspective, the quality of the journal may then become less important (and indeed, perceptions of quality can easily be manipulated by advertising), and the cost of publishing becomes more important. This market opportunity has led to the appearance of 'predatory' journals which have, to varying degrees, dispensed with scientific, legal and moral norms, up to and including publishing of plagiarised articles (Beall 2012). A number of such journals have usurped the names of genuine but small-scale existing journals. An indication of the proliferation of open access journals, predatory or otherwise, is provided by the increasing numbers of emails received by any scientist with an email address, with 'invitations to submit papers to newly established journals, join their editorial boards, or even apply to serve as their editors-in-chief' (Haug 2013). Such invitations often show zero knowledge of the recipient's discipline and not infrequently promote an implausible interdisciplinary topic area.

Whether a direct consequence of the open access business model or simply due to the increasing number of papers being written, there has been a degradation of the peer review process associated with some open access journals. Thus *PLOS ONE* has instigated rapid peer review based on 'soundness not significance' (Ware & Mabe 2015). In some ways, this is laudable — it aims to reduce the impact of subjective judgement in the review process — but it could also be argued that in practice it leads to a reduction in rigour. Predatory journals have taken this further by (apparently) reducing peer review to a box-ticking exercise.

Whereas libraries and institutions had exercised some quality control, now it is left to individual readers to judge, even if they lack the knowledge to make that judgement. The various journal quality indicators are subject to manipulation by the publishers and indeed may be substituted by essentially fake indicators. This, together with the above-mentioned degradation of peer review, opens the door to work of highly questionable content being passed off as good science. This is not to say that senior scientists are unable to recognise good science, but younger scien-

tists need to be trained to distinguish between good and bad science — and perhaps also to understand the logical and moral imperative of favouring the former over the latter.

WHAT OPEN ACCESS MEANS FOR WRITING PAPERS

Put bluntly, the 'pay to publish' model implies that scientific publication is increasingly becoming the preserve of the rich or, at least, the well-funded. The gentleman scholars of the 18th and 19th centuries may not have come back in force but an author increasingly needs institutional backing or some other form of finance in order to publish. Hence, vested interests (e.g. the pharmaceutical industry, those promoting their financial or political interests, such as climate-change deniers, etc.) have increased opportunities to control the kind of research that is undertaken, and the flow of information from that research.

If you are a student, or work for an NGO, or you are simply a scientist who doesn't have any big grants and/or who carries out research in an area considered inappropriate by funders or your employer, you may have a problem in getting published, regardless of the quality of your work. In other words, as Tsikliras & Stergiou (2013) put it, in a fully open access 'publishing world', scientific output not supported by grants will never get published. Thus, in addition to promoting vested interests, open access facilitates censorship, explicit or otherwise.

To be fair, the old system hasn't entirely collapsed: there are still excellent journals running on the old business model and good science can still get into a good journal — unless of course your funding body insists on open access publishing, which many now do; see for example the EU's H2020 programme. As a consequence of the latter, traditional journals typically now offer an open access publication option, paid for by the author (or the author's funders). However, there are also very many new open-access-only journals. As a writer of science, you now have a choice: you can follow the traditional route of writing a good paper, sending it to a good journal and submitting to meaningful peer review or you can go along the open access route. As mentioned, there are open access publication routes that are entirely respectable, but also many others.

Of course, the publication process has always involved elements of gaming and, indeed, questionable behaviour. The pressure to publish may encourage the submission of flawed or otherwise substandard science or simply overstatement of the importance and generality of the work. Most experienced editors and referees are wise to this kind of thing. However, the limited scrutiny of submissions by some open access journals offers an opportunity to less-able and/or more-cynical scientists to publish lesser works. The above-mentioned paper by Krizhanovsky & Choong (2014), describing a 'significant effect of activated mattresses on the human psychophysiological and energy', is a paradigmatic example of something which would not be allowed anywhere near a genuine ecology journal. In 2016, *PLOS ONE* published a paper by Liu et al. (2016) on the biomechanics of hand coordination, later retracted, which claimed that the results revealed the 'proper design by the Creator to perform a multitude of daily tasks in a comfortable way'. While this kind of claim may have been prevalent in the 19th century (e.g. Paley 1802) and has some present-day followers through so-called scientific creationism (or 'intelligent design'), it clearly has no place in modern evidence-based science (see Dawkins 1986 for a modern-day response to Paley).

At this point it is important to acknowledge that the refereeing and editorial process is never perfect: even the most respected journals, open access or otherwise, make mistakes — and mechanisms exist to deal with these mistakes. Papers which are found to be seriously flawed, including those involving misconduct and plagiarism, can be retracted. Indeed, retraction tends to be more prevalent in higher-impact journals (Fang & Casadevall 2011). The paper by Liu et al. (2016) is retracted. Thus, its publication is an example of both a lapse in standards (the referees of *PLOS ONE* are specifically asked to judge whether submissions are 'technically sound') and an appropriate procedure to correct this kind of mistake.

WHAT OPEN ACCESS MEANS FOR READERS

It is all very well having free access to scientific papers, but one thing society does not lack currently is access to information, not least via television, social media and the internet in general. It is probably an understatement to say that the general public is not going to be queuing up to read papers in open access science journals, neither literally nor figuratively.

At this point it may be pertinent to point out that the public has probably never read many scientific papers due to esoteric subject matter and the unex-

citing writing style. Doubleday & Connell (2017) justifiably ask why we can't write science in a style which actually communicates (rather than obscures) the message. Indeed, at least some scientific papers have likely been written more for career advancement than for communication (or, in the words of the Archchancellor of the Unseen University: 'Oh, I don't think it was for reading. It was for having written'; Pratchett 2005). Thebaud et al. (2017) offer one possible solution in their paper on 'Managing marine socio-ecological systems: picturing the future' which, to follow the vernacular, does exactly what it says on the tin. Another possibility, in existence for over a decade, is the video journal, as exemplified by the *Journal of Visualized Experiments*, which publishes papers simultaneously in video and pdf formats.

For the professional end-user, open access does not necessarily make access very much easier: as we noted above, large institutions probably already subscribe to the journals needed and, at worst, a copy of a paper is only an email away: you write and ask the author. Since, nowadays, citations of papers seem to count for almost as much as writing papers in the first place, when building a scientific career, nobody neglects to publicise their own papers, with many providing access to their papers on their personal websites — not always legally, since often only the accepted version, prior to formatting by the journal, may be posted (as we all know, having read the copyright transfer form).

For both the lay reader and the professional, open access has arguably not only failed to significantly improve access to good science, but it has reduced the signal-to-noise ratio by facilitating publication of lower-quality research, from the merely second rate to the bizarre and the sinister. Ignorance or inability to adequately distinguish 'fake' from serious research is endemic in an unregulated system such as open access. Some might argue that all research findings should be published and that open access journals offer a publication route to those who for reasons of language or geography or simply through doing 'low-impact' science are (or feel) unable to publish in top journals. While there is merit in this argument, one should not expect that low impact is automatically associated with low quality. Studies of narrow or local interest are still capable of scientific excellence. Flawed studies, e.g. those with imperfect experimental designs, may still be useful, provided that the limitations of the study are clearly stated and the results are not over-interpreted. The concern is that a gateway has been opened to publish work that is seriously flawed, fraudulent and faked.

HOW OPEN ACCESS WILL CHANGE THE PUBLIC PERCEPTION OF SCIENCE

There is another side to the impact on the readership. Under the old model, when reading a scientific paper, especially if you knew something about the system, you would tend to assume that it had been thoroughly peer-reviewed and, even if the review system was never foolproof, you had some sense of quality assurance. Reading a paper in an open access journal, however, you may reasonably think that, since somebody paid to have this published, is it simply vanity publishing? Worse, how can you be sure it is not some kind of political lobbying, religious evangelism, commercial marketing or crackpot conspiracy theory? In short, why should you trust it? In the vernacular, is it 'fake news'?

We must acknowledge that at least some (and probably all) of the above sins — along with a bias against publishing less interesting and less exciting 'negative' results — found their way into the scientific literature before open access. As Stephen J. Gould highlighted in 'The mismeasure of man' (Gould 1981), racist biological determinism coupled with poor science underpinned many studies of, for example, human cranial structure and IQ in the mid-20th century. Ben Goldacre exposes both the way alternative medicine has been promoted through cynically selective use of evidence and how mainstream medical literature has been hijacked by pharmaceutical companies, who fund the research and expect positive outcomes to be published (Goldacre 2008, 2012). One might also point to the politicisation to be found in some branches of economics. However, with the advent of open access, it is now open season. The imperfect obstacles to publishing bad science have simply been swept away.

Finally, making all scientific papers freely accessible potentially has another (presumably) unintended and undesirable consequence. If something is free, we often value it less or not at all.

THE CONSEQUENCES OF THE OPEN ACCESS BUSINESS MODEL

Open access has created a business opportunity and predatory, rogue and/or junk journals have not been slow to seize it. Many others have highlighted the growth of predatory journals, which, for example, mimic or steal the names of existing journals, and junk journals which offer quick publication with minimal peer review or editorial control, at a price. This

puts economic pressure on the bona fide journal publishers and at least some editors see the writing on the wall. It also debases science (Beninger et al. 2016, Moher et al. 2017). It certainly creates a better environment for lobbyist 'journals' which promote special interests such as climate change denial and the like.

Guédon, one of the originators of the Budapest Open Access Initiative, acknowledges that the category of predatory pseudo-journals needs to be mentioned, and that they have negative effects, namely 'a pollution of the scientific archive' and creating doubts about the quality of all lesser-known titles (Guédon 2015). He notes that 'a market exists for this lunacy, but only because many authors feel their careers depend on publication at all costs' — although, finally, these concerns are covered in a single paragraph within a 38-page paper. This threat deserves more attention. There is a stark warning in figures presented by Shen & Björk (2015): they recorded 53 000 articles published in predatory journals in 2010 and around 420 000 such articles in 2014, published by around 8000 active journals. The underlying concern here is not that a lunatic fringe will discredit real science but that, in relative terms, real science will dwindle to form only a small fraction of the 'scientific' literature, barely noticeable amid a sea of mediocrity, prejudice, greed and irrationality.

WHO WINS AND WHO LOSES?

Obviously, unscrupulous and predatory journals, which prey on individual vanity and the need to advance scientific careers by publishing, are benefitting economically from the open access model. Tsikliras & Stergiou (2013) point out that the majority of open access journals do not copy-edit their articles and that neither members of their editorial boards nor referees are paid for their work (although it should be said that very few journals pay referees for their work), thus 'only editor-in chief, administrative, secretarial and typesetting expenses remain on the menu' and these journals can thus achieve very high profit margins.

The proliferation of papers delivering poor science, pseudoscience and/or support for vested interests makes it harder to sort the wheat from the chaff. Politicians whose agenda does not conform with science can now more easily dismiss science (assuming they can distinguish it from pseudoscience or naked self interest in the first place), or at the very least, more easily cherry-pick papers which support their position. In short, one might suggest that some of those who advocate open access may have been thinking more of themselves than of the public good when foisting open access publishing upon the scientific community.

Scientists lose. In the short term, some may be able to build careers on numerous publications in dubious journals, but long-term prospects look bleak. Increasingly, PhD students will not be able to afford to publish and will no longer have careers in science ahead of them, except of course the lucky few who have adequate funding behind them. Science will be less valued and less respected both because it is 'free' to the end-user and because people will recognise that the content has been selected by vested interests rather than representing the pursuit of truth. Of course, science has always required funding and, at least to a degree, research funding is based on perceived merit. However, what is being lost includes, among other things, a route for brilliant young scientists to emerge from poorly funded research groups and a barrier against publication of well-funded pseudo- and fake science.

Experimental subjects (animals and humans) lose. In a recent analysis of the content of around 1900 biomedical research papers from 'potential, possible, or probable' predatory journals, it was noted that, among those papers that studied humans or whole animals, only 40% acknowledged approval from an ethics committee, a much lower figure than is normal for mainstream journals (Moher et al. 2017). One implication is that the health of human subjects is being put at risk and thousands of animals are being sacrificed in vain, for studies of little or no scientific merit.

Ultimately, society loses. Science may not always have a strong moral compass, but it tells us things we need to know; it advances our understanding of the world. If that voice is silenced or reduced to the status of an astrology channel on night-time television, we are all worse off. Nor do we benefit from vested interests treating 'scientific' publication as a product placement opportunity, nor from the effective censorship of science not backed by big money.

HOW STRONG IS THE EVIDENCE?

From our own experience, we believe that much of what we have said here is self-evident, in terms of both the issues and the consequences. There is empirical evidence that predatory journals publish a disproportionately high amount of poor science. Moher et al. (2017) compared papers in mainstream

and predatory biomedical journals and found the latter had a much lower rate of compliance with guidelines such as registration of clinical trials or ethical approval. It could be argued that the failure was in the reporting and not in the conduct of the research but that would be both over-optimistic and missing the point: the results of such papers cannot be trusted. Moher et al. are very clear that such journals 'erode the integrity of scientific scholarship'.

Across much of the world, policymakers seem to treat science as a greater or lesser inconvenience, to be used, ignored or denied at will. Policy often ignores evidence and defies rational decision-making. Svancara et al. (2005) review examples of policy-driven and evidence-driven targets for percentage of the areas of a country or a region that should be conserved and showed that the latter were almot 3 times higher. Mann & Toles (2016) describe in excruciating detail just how far climate-change deniers are prepared to go to ensure that climate science does not inform policy. Protecting the integrity of scientific publication will not make this kind of problem go away, but failure to do so will help to ensure that the voice of science is lost from public discourse. Let us be clear, open access is not the root of all this evil — but neither is it on the side of the angels.

WHAT CAN WE DO ABOUT IT?

There is an increasingly frequently expressed suspicion that whatever measures we take, we are fighting a losing battle, now that Pandora's box has been opened. However, there are various measures which could help and one or two that could kill off the problem once and for all.

Firstly, and most obviously, academics need to cut off the supply of manuscripts to illegitimate journals, by not submitting their work there, insisting that students do the same, and encouraging others to follow this lead. There is a need to alert funding bodies and policymakers to the dangers of unregulated open access publishing, and ask them to issue explicit warnings against rogue publishers.

Academics need to devise and promote a reasonably foolproof mechanism to identify the bona-fide journals[4], and draw up a code of ethics for science publishing (see Moher et al. 2017). This should ensure that research follows, and is seen to follow, legal, ethical and other good practice requirements, not least in relation to animal experiments. As shown by Moher et al., although papers in predatory journals performed poorly according to such criteria, mainstream journals also failed to enforce reporting requirements.

In any process of research evaluation or when recruiting, publications in questionable journals should be treated with appropriate scepticism. Those working in higher education can do more to provide students with training in critical thought.

More benign forms of open access can be also promoted. Tsikliras & Stergiou (2013) refer to profit-making open access journals as 'pseudo'-open access, pointing out that several non-profit journals (e.g. *Scientia Marina*, *Acta Adriatica*, *Mediterranean Marine Science*, *Turkish Journal of Zoology*), mainly journals which are supported by institutes, universities and/or governments and whose editor-in-chief works on a voluntary basis, offer 'true' open access — nobody pays to publish in them or to read them — and we should strongly support them. Where such 'true' open access journals do not exist (or have lapsed), institutions and learned societies should be encouraged to instigate them. It is appropriate to note here that the journal in which this article appears, Ethics in Science and Environmental Politics, publishes on this basis, i.e. it is freely accessible to all users and articles are published at no cost to authors.

PLOS journals have long offered full or partial publication-charge waivers to all authors who request them, 'no questions asked' (Doyle et al. 2004). Such waivers are increasingly widespread, albeit usually with a reasonable requirement for authors to offer some justification. Waivers should be routinely available to all those who genuinely have little or no funding for publication. In endorsing such schemes and supporting the "true" open access model of scientific publication we acknowledge that publication costs cannot simply be treated as "externalities" by both readers and authors; real costs are incurred in the publication process and a mechanism is needed to cover those costs.

Institutions who are judged on published output have established green open access repositories for publications, so as to fulfil the letter (if not entirely the spirit) of open access requirements, for example by making available the final pre-publication version of a paper. Those journals holding out against this kind of workaround, justified by appeal to the primacy of copyright law, might do well to look over their shoulders at the alternative reality creeping up on us and them.

[4]Beall's list (https://beallslist.weebly.com/) provides information on predatory publishers and journals

Social media (see Bik & Goldstein 2013) and numerous other forums already offer mechanisms to communicate science directly to the general public (and indeed a range of other audiences). The push for open access is at odds with the simultaneous push to ensure that results are delivered in formats which reflect the needs of the end-users. If one believes in the value of 'crafting the message' according to the target audience, is there also a need for a 'one size fits all' approach whereby scientific papers in learned journals are freely accessible to everyone in their original format? Scientific papers are the ultimate repository of knowledge but they are generally not a suitable medium for mass communication — nor would they be even after improvements in writing style to increase readability. If scientists succeed in reaching people through social media and press releases, those who are interested may then seek out more information, perhaps by consulting the original papers, whatever the mode of publication (as previously noted, for non-open-access papers, an email to the corresponding author should suffice).

Finally, it should be demonstrated (through action as well as word) that excellent means to communicate science to the public and to end-users of science already exist, and that science is already accessible, without the need for a business model for publication that indirectly promotes bad science, pseudoscience, fake science, vested interests and censorship.

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LITERATURE CITED

Anon (2013) The maze of impact metrics. Nature 502:271
Beall J (2012) Predatory publishers are corrupting open access. Nature 489:179
Beninger PG, Beall J, Shumway SE (2016) Debasing the currency of science: the growing menace of predatory open access journals. J Shellfish Res 35:1–5
Bik HM, Goldstein MC (2013) An introduction to social media for scientists. PLOS Biol 11:e1001535
Boero F (2017) Open access revolutions. Ethics Sci Environ Polit 17:1–8
British Ecological Society (2013) A guide to peer review in ecology and evolution. British Ecological Society, London
Browman HI, Stergiou KI (2008) Factors and indices are one thing, deciding who is scholarly, why they are scholarly, and the relative value of their scholarship is something else entirely. Ethics Sci Environ Polit 8:1–3
Butler N, Spoelstra S (2014) The regime of excellence and the erosion of ethos in critical management studies. Br J Manage 25:538–550
Carroll MW (2013) Creative commons and the openness of open access. N Engl J Med 368:789–791
Dawkins R (1986) The blind watchmaker. W. W. Norton & Company, New York, NY
Doubleday ZA, Connell SD (2017) Publishing with objective charisma: breaking science's paradox. Trends Ecol Evol 32:803–805
Doyle H, Gass A, Kennison R (2004) Who pays for open access? PLOS Biol 2:e105
Elliott DB (2014) The impact factor: a useful indicator of journal quality or fatally flawed? Ophthalmic Physiol Opt 34: 4–7
Fang FC, Casadevall A (2011) Editorial: retracted science and the retraction index. Infect Immun 79:3855–3859
Fox CW, Albert AYK, Vines TH (2017) Recruitment of reviewers is becoming harder at some journals: a test of the influence of reviewer fatigue at six journals in ecology and evolution. Res Integr Peer Rev 2:3
Frank M (2013) Open but not free — publishing in the 21st century. N Engl J Med 368:787–789
Goldacre B (2008) Bad science. Fourth Estate, London
Goldacre B (2012) Bad pharma: how drug companies mislead doctors and harm patients. Fourth Estate, London
Gould SJ (1981) The mismeasure of man. W. W. Norton & Company, New York, NY
Guédon JC (2015) Open access: toward the internet of the mind. www.budapestopenaccessinitiative.org/boai15/Untitleddocument.docx
Haug C (2013) The downside of open-access publishing. N Engl J Med 368:791–793
Karran T, Mallinson L (2017) Academic freedom in the U.K.: legal and normative protection in a comparative context. Report for the University and College Union. https://www.ucu.org.uk/media/8614/Academic-Freedom-in-the-UK-Legal-and-Normative-Protection-in-a-Comparative-Context-Report-for-UCU-Terence-Karran-and-Lucy-Mallinson-May-17/pdf/ucu_academicfreedomstudy_report_may17.pdf
Krizhanovsky EV, Choong LK (2014) Study of the influence of subtle energetic changes in environment on the productivity of the process of sleep. Open J Ecol 4:693–702
Lawrence PA (2008) Lost in publication: how measurement harms science. Ethics Sci Environ Polit 8:9–11
Liu MJ, Xiong CH, Xiong L, Huang XL (2016) Biomechanical characteristics of hand coordination in grasping activities of daily living. PLOS ONE 11:e0146193 (retracted)
Lozano GA, Lariviere V, Gingras Y (2012) The weakening relationship between the impact factor and papers' citations in the digital age. J Am Soc Inf Sci Technol 63: 2140–2145
Lynch K, Ivancheva M (2015) Academic freedom and the commercialisation of universities: a critical ethical analysis. Ethics Sci Environ Polit 15:71–85
Mann ME, Toles T (2016) The madhouse effect: how climate change denial is threatening our planet, destroying our politics, and driving us crazy. Columbia University Press, New York, NY
Moher D, Shamseer L, Cobey KD, Lalu MM and others (2017) Stop this waste of people, animals and money. Nature 549:23–25
Paley W (1802) Natural theology or evidences of the existence and attributes of the deity. J. Faulder, London

Pratchett T (2005) A collegiate casting-out of devilish devices. Times High Educ Suppl, 13 May 2005

Robinson D (2014) The mismeasure of higher education? The corrosive effect of university rankings. Ethics Sci Environ Polit 13:65–71

Saha S, Saint S, Christakis DA (2003) Impact factor: a valid measure of journal quality? J Med Libr Assoc 91:42–46

Shen C, Björk BC (2015) 'Predatory' open access: a longitudinal study of article volumes and market characteristics. BMC Med 13:230

Svancara LK, Brannon R, Scott JM, Groves CR, Noss RF, Pressey RL (2005) Policy-driven versus evidence-based conservation: a review of political targets and biological needs. Bioscience 55:989–995

Thebaud O, Link JS, Kohler B, Kraan M and others (2017) Managing marine socio-ecological systems: picturing the future. ICES J Mar Sci 74:1965–1980

Tsikliras AC, Stergiou KI (2013) What's on the (publication fee) menu, who pays the bill and what should be the venue? Mediterr Mar Sci 14:363–364

Tsikliras AC, Robinson D, Stergiou KI (2014) Which came first: the money or the rank? Ethics Sci Environ Polit 13: 203–213

Van Noorden R (2013) Open access: the true cost of science publishing. Nature 495:426–429

von Neumann J, Morgenstern O (1953) Theory of games and economic behavior. Princeton University Press, Princeton, NJ

Ware M, Mabe M (2015) The STM report: an overview of scientific and scholarly journal publishing, 4th edn. International Association of Scientific, Technical and Medical Publishers, The Hague. http://digitalcommons.unl.edu/scholcom/9

Wolpert AJ (2013) For the sake of inquiry and knowledge — the inevitability of open access. N Engl J Med 368: 785–787

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