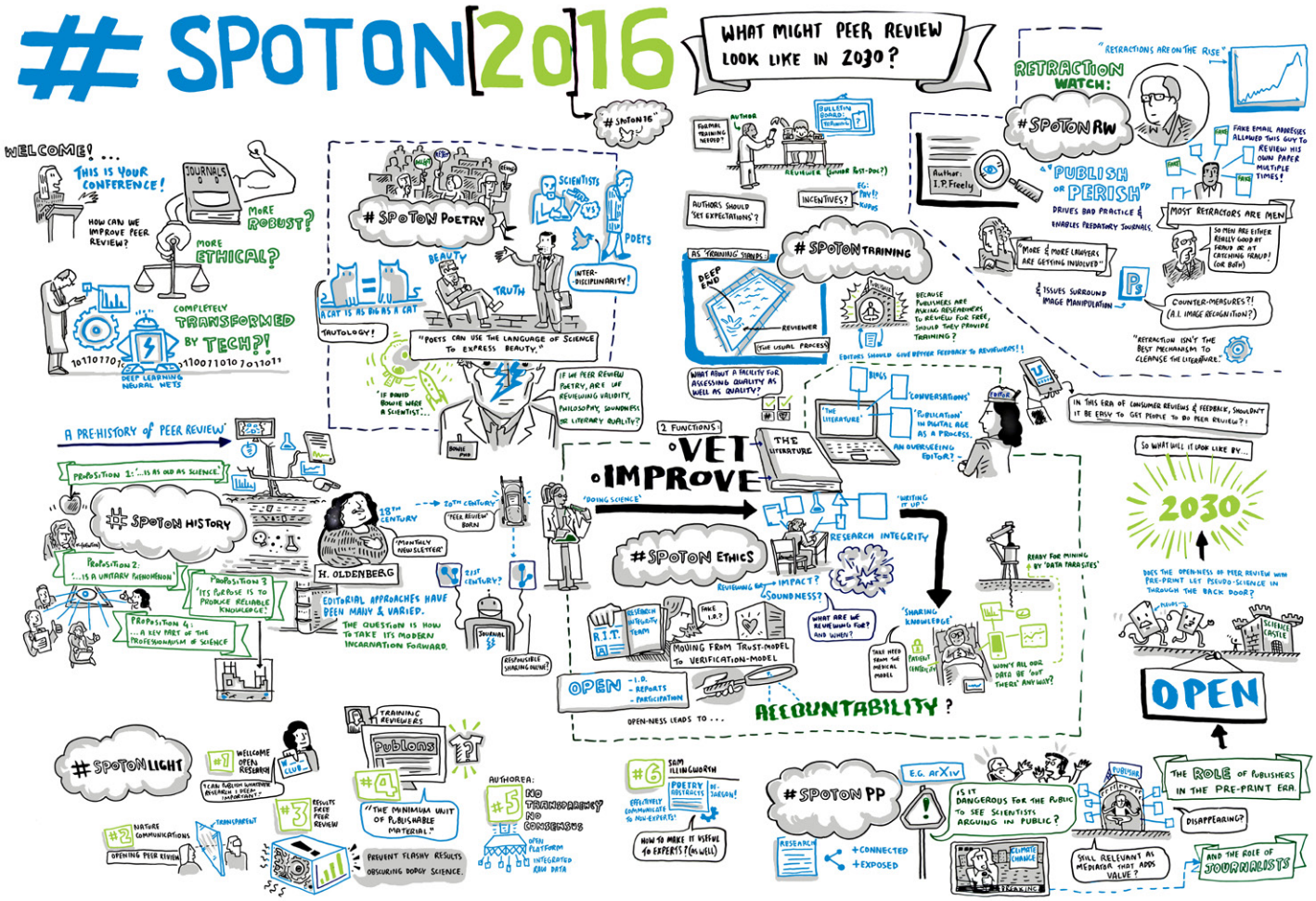

SpotOn Report

What might peer review look like in 2030?

A report from BioMed Central and Digital Science

Foreword by Rachel Burley and Elizabeth Moylan

APRIL 2017

SpotOn | DIGITAL science | BioMed Central

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Foreword

Rachel Burley, Publishing Director, BioMed Central

Elizabeth Moylan, Senior Editor (Research Integrity), BioMed Central

Peer review presents one of the greatest opportunities, and challenges, in advancing discovery. Various methods of peer review have been in existence for the last 350 years, but only formally used by journals since the 1960s. Despite all its perceived flaws — that it can be slow, inefficient, biased and open to abuse — peer review retains its pivotal role in validating research results, typically prior to, but also post, publication.

While there have been a number of advances in peer review in recent times — including new models and improvements to existing systems — truly transformative change has not been widely adopted.

In November 2016, SpotOn London asked 'What might peer review look like in 2030?' with a one-day conference at the Wellcome Collection, hosted by BioMed Central and Digital Science, and sponsored by River Valley Technologies. The aim was to bring together individuals across various communities including research, publishing, funding, communications, technology and policy to collaborate on feasible and innovative ways to improve peer review.

Can technology make peer review faster and easier? Will increased transparency make peer review more ethical? Should there be provision for training in peer review? How will the increasing presence and importance of preprint servers impact on peer review and publishing? Will crowdsourcing make the process of inviting peer reviewers more elective? Will advances in artificial intelligence make the future entirely peer-less? Is there a role for the living article? How could we recognize the work peer reviewers do?

These issues (and many others) were discussed on the day, and developments in six key areas are shared in this report. We hope that you will find the perspectives contained within this report, from publishers, a researcher, a librarian and others, informative and thought-provoking.

In reflecting on the themes presented here, particularly in a climate of ever-increasing research output, it is clear that the publishing and peer review landscape will continue to evolve, and perhaps more rapidly than it has in the past.

At BMC we introduced open peer review in 1999, and we continue to experiment with new models such as results-free peer review. We are still exploring ways in which we can improve the process of peer review, and in some cases, affect radical change to methods, processes and supporting systems. But of course we are not the only ones, and publishers will have to proactively partner with the wider community if we are to see real industry-wide improvements.

Our recommendations as we head towards 2030 are that the research community:

- Find and invent new ways of identifying, verifying and inviting peer reviewers, focusing on closely matching expertise with the research being reviewed to increase uptake. Artificial intelligence could be a valuable tool in this.
- Encourage more diversity in the reviewer pool (including early career researchers, researchers from different regions, and women). Publishers in particular could raise awareness and investigate new ways of sourcing female peer reviewers.
- Experiment with different and new models of peer review, particularly those that increase transparency.
- Invest in reviewer training programs to make sure that the next generation of reviewers are equipped to provide valuable feedback within recognized guidelines.
- Work towards cross-publisher solutions that improve efficiency and benefit all stakeholders. Portable peer review has not taken off at any scale, but could make the publishing process more efficient for all involved.
- That funders, institutions and publishers must work together to identify ways to recognize reviewers and acknowledge their work.
- Use technology to support and enhance the peer review process, including finding automated ways to identify inconsistencies that are difficult for reviewers to spot.

We want to start a conversation with the ambitious aim of ultimately improving peer review for millions of working academics.

We're calling on the research community to take part and take on the challenge.

Whether you're a frustrated scientist, a peer reviewer, an editor, a publisher or a librarian, we would love to hear your views. Tweet us using #SpotOnReport, email us (spoton@biomedcentral.com) or comment online. And we hope to see you at #SpotOn17.

Artificial intelligence applications in scientific publishing

Chadwick C. DeVoss
Founder and President, StatReviewer

Artificial Intelligence (AI) is a term that has become popular in many industries, because of the potential of AI to quickly perform tasks that typically require more work by a human. Once thought of as the computer software endgame, the early forms of true AI are now being used to address real world issues.

AI solutions underway

Scientific publishing is already using some of the early AI technologies to address certain issues, for example:

- **Identifying new peer reviewers**: Editorial staff are often responsible for managing their own reviewer lists, which includes finding new reviewers. Smart software can identify new potential reviewers from web sources that editors may not have considered.
- **Fighting plagiarism**: Many of the current plagiarism algorithms match text verbatim. The use of synonyms or paraphrasing can foil these services. However, new software can identify components of whole sentences or paragraphs (much like the human mind would). It could identify and flag papers with similar-sounding paragraphs and sentences.
- **Bad reporting**: if an author fails to report key information, such as sample size, which editors need to make informed decisions on whether to accept or reject a paper, then editors and reviewers should be made aware of this. New technology can scan the text to ensure all necessary information is reported correctly.
- **Bad statistics**: If scientists apply inappropriate statistical tests to their data, this can lead to false conclusions. AI can identify the most appropriate test to achieve reliable results.
- **Data fabrication**: AI can often detect if data has been modified or if new data has been generated with the aim of achieving a desired outcome.

These are just a few of the big challenges that AI is starting to meet. Additional tasks, such as verification of author identities, impact factor prediction, and keyword suggestions are currently being addressed.

At StatReviewer[1] we use what is more strictly defined as Machine Learning to generate statistical and methodological reviews for scientific manuscripts. Machine Learning takes a large body of information and uses it to train software to make identifications. A classic example of this is character recognition: the software is exposed to (i.e. trained on) thousands of variations on the letter A. and learns to identify different As in an image. Machine Learning is thought of as the precursor to true AI.

In the not-too-distant future, these budding technologies will blossom into extremely powerful tools that will make many of the things we struggle with today seem trivial.

"In the not-too-distant future, these budding technologies will blossom into extremely powerful tools that will make many of the things we struggle with today seem trivial."

The full automation quandary

In the future, software will be able to complete subject-oriented reviews of manuscripts. When coupled with an automated methodological review, this would enable a fully automated publishing process - including the decision to publish. This is where a slippery slope gets extra slippery.

On the one hand, automating a process that determines what we value as "good science" has risks and is full of ethical dilemmas. The curation that editors and reviewers at scientific journals provide helps us distil signal from noise in research, and provides an idea of what is "important". If we dehumanize that process, we need to be wary about what values we allow artificial intelligence to impart. Vigilance will be necessary.

On the other hand, automated publishing would expedite scientific communication. When the time from submission to publication is measured in milliseconds, researchers can share their findings much faster. Additionally, human bias is removed, making automated publishing an unbiased approach.

In the end, if science marches toward a more "open" paradigm, the ethics of full automation become less tricky because the publishing process no longer determines scientific importance. That will be left to the consumers and aggregators of scientific information.

"When the time from submission to publication is measured in milliseconds, researchers can share their findings much faster."

Why use AI then?

Our current publishing model creates an opportunity for potential predatory journals /publishers to take an author's money and publish their work without scrutiny. The fact that this happens as frequently as it does, tells us that there is not enough capacity within the publishing community to process the amount of scientific writing that is being generated. AI solutions will help to address this shortage in two ways. First, AI will increase the overall capacity to publish quality works by finding new reviewers, creating automated reviews, etc. Second, using AI technologies will make it possible to take an automated retrospective look at published works and quickly identify organizations that are not fulfilling their obligation to uphold appropriate standards.

Skynet - How much automation is too much?

Today, we already have automated consumers of scientific information (I've written some of them), and in the future we will have advanced AI consuming it as well. These 'AI consumers' will have the history of science at their disposal. They will take in the newly published information and note how it adds to previous information. Before long, the AI may suggest new experiments to continue research on a given subject. In some industries, experiments are conducted mechanically and they are automatically initiated by the AI... and you can see how this might get out of hand.

The point, at which an unsupervised AI determines the direction of scientific research, is one we have to be wary of. True discovery should be an entirely human idea.

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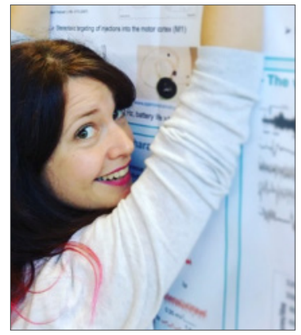
Peer review, from the perspective of a frustrated scientist

Elodie Chabrol, Postdoctoral Research Associate in Neuroscience at University College London



"I know that some of the papers I read are old news by the time they reach me. No one would read the news with months of delay, but that's what we scientists do."

A scientist's fairy tale might go something like this: gather enough significant data, publish your paper, the end. However, far from a simple 'happily ever after', the story of what happens between the collection of great data and publication is far more complex.

First-time authors are usually a bit naïve, thinking the publication process is going to be quick and easy as long as they target the right journal and their paper is well written. But once you discover peer review and the struggle to publish, you realize that having gathered your data was actually only the beginning. I'm in the middle of the process myself right now.

Even before submission, you may have lengthy discussions with your co-authors, because suddenly everyone claims that they deserve a better spot than you on the authors list. Once you have agreed on the details of authorship and submitted your paper, you start the lengthy and complicated process of peer review.

I'm not an expert on peer review or an editor. I'm just a frustrated scientist. Getting published is essential to building a career and it's not easy. It is frustrating to know that my research won't be published for months. I know that some of the papers I read are old news by the time they reach me. No one would read the news with months of delay, but that's what we scientists do.

Science often uses state-of-the-art modern technologies, yet the publishing process hasn't changed in decades. It is subject to numerous flaws, so in the following I am going to concentrate on the ones that stood out for me – as a non-expert in publishing – in the discussions at #SpotOn2016.

- **Single-blinded peer review**: with this type of peer review, the names of the reviewers are hidden from the authors (the authors are 'blinded' to the reviewers' identities) but the reviewers know who the authors are. A potential issue could be that some reviewers may see the authors as competition and thus review a paper more harshly than may be warranted. This may lead to an unfair disadvantage for the authors based on things like the history between 'competing' labs. A way around that would be either double-blinded peer review (where both reviewers and authors remain anonymous) or, even better, open peer review where

"A junior scientist might not feel comfortable reviewing a more senior scientist's work if they know that their name is going to be published alongside their review."

reviewers are not anonymous and their comments are openly available. But open peer review comes with problems of its own. For example, a junior scientist might not feel comfortable reviewing a more senior scientist's work if they know that their name is going to be published alongside their review.

- **Incentive to review**: Many reviewers make an effort to judge manuscripts honestly and on merit. However, peer review is a lot of work and reviewers don't get rewarded for it. Initiatives like Publons[1] are trying to change that.
- **Early-career researchers and peer review**: Meanwhile, early-career researchers who may make great reviewers don't get invited to review because they are not known by editors as experts in their field. These issues suggest that a system change may be in order – not just changes to peer review itself but also to how peer reviewers, authors and their work are evaluated.

"I would like to see double-blinded review introduced as standard so that I wouldn't feel that I was being judged based on my boss's, my colleague's or my name but only on the work I present in the paper I submit"

These changes involve all of us and #SpotOn2016 was a great opportunity to share ideas on how this could be achieved. For me personally, it also opened my eyes to the fact that other people are struggling with the publishing process too – and in many different ways.

Before I came to #SpotOn2016, I hadn't realized how many people were already working on new initiatives such as Authorea[2], Overleaf[3] and Paperhive[4], to improve peer review and publishing, and to facilitate collaboration between researchers.

Change may not happen overnight but it certainly feels like it's coming.

As a first step towards that change, I would like to see double-blinded review introduced as standard so I wouldn't feel I was being judged based on my boss's, my colleague's or my name but rather on the work I present in the paper I submit. Maybe a change like that could lead the way towards more complex changes. Also, maybe publishers could find ways of allowing researchers to apply to be reviewers, so that junior scientists not yet known to the editors would be given the opportunity to become reviewers.

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The history of peer review, and looking forward to preprints in biomedicine

Frank Norman, Information Services Manager, Crick Institute

Peer review is not as old as you might think

Peer review is often regarded as a 'touchstone of modern evaluation of scientific quality'[1] but it is only relatively recently that it has become widely adopted in scientific publishing. The journal *Nature*[2] did not introduce a formal peer review system until 1967. Before then some papers were reviewed, others were not. Michael Nielsen suggests that with the 'increasing specialization of science...editors gradually found it harder to make informed decisions about what was worth publishing'[3].

Aileen Fyfe has pointed out that 'peer review should not be treated as a sacred cow ... rather, it should be seen for what it is: the currently dominant practice in a long and varied history of reviewing practices'[4].

Challenging the status quo

The widespread adoption of the Internet as a means of scholarly interaction began in the mid to late 1990s. Even back then discussions raged about the benefits and disbenefits of challenging the publishing status quo. Tony Delamothe, writing in 1998, summed up the arguments thus:

At one extreme were enthusiasts for electronic preprints, who regard them not as scientific papers in evolution but as near enough finished articles. To these respondents, the current long process of peer review and paper publication is detrimental to science and the public health: any way of getting scientific advances into the public domain fast is worth supporting.

At the other extreme were respondents who thought "too much junk" was already being published. Lacking the skills to distinguish between "valuable material and garbage" journalists and the public could be misled.

More recently the realization has been growing that researchers will use electronic preprints because of their benefits—however much journals may rail against them.[5]

"If most research articles are posted first as preprints then access to research findings becomes possible as soon as an article is completed rather than, as at present, when the article is accepted and published in a journal."

The following year it seemed that the world was really changing when the US National Institutes of Health published its E-biomed proposal but this proved too radical for many in the biomedical research community.

Scientific reports in the E-biomed repository would be submitted through either of two mechanisms... (i) Many reports would be submitted to editorial boards. These boards could be identical to those that represent current print journals or they might be composed of members of scientific societies or other groups approved by the E-biomed Governing Board. (ii) Other reports would be posted immediately in the E-biomed repository, prior to any conventional peer review, after passing a simple screen for appropriateness[6]

That last part seemed too big a departure from peer review, and the proposal was watered down, leading to the establishment of the PubMedCentral[7] repository for published papers. The proposal indirectly stimulated the creation of two new publishers – the commercial BioMedCentral[8] and the not-for-profit PLOS[9].

The early impact of open access on peer review

Early proponents of open access took pains to make it clear that their immediate goal was to improve access to research literature, and not to challenge peer review practices. They were careful not to lose the support of those who held peer review dear.

However, as new open access journals were established they did provide opportunities to experiment with enhancements to peer review. *PLOS ONE*[10], launching in 2006, famously popularized the idea of a 'megajournal' with its mission to publish "scientifically rigorous research regardless of novelty". This model was followed by a swathe of other megajournals. The *Frontiers*[11] series of journals launched in 2007 and introduced 'interactive collaborative review', which aimed to turn the peer review process into a "direct online dialogue, enabling quick iterations and facilitating consensus". In 2012 *eLife*[12] launched with the aim of 'taking the pain out of peer review', again by a more collaborative approach. Gradually, the role of peer review was challenged and the practice changed. *PLOS ONE* introduced the idea that dissemination of research was at least as important as validation of research.

Happily, these challenges have not caused the whole world of research communication to come crashing down. In recent years there has been a bit of a rash of retractions, but these are more strongly associated with high end journals than with megajournals[13]. The strong positions that *PLOS ONE* and *Scientific Reports*[14] have achieved suggest that megajournals are here to stay[15].

A few journals have sought to modify peer review further – *F1000Research*[16] and *Wellcome Open Research*[17] make preprints of articles available almost immediately after submission, and then invite post-publication open peer review.

Preprints

A preprint is "a scientific manuscript uploaded by authors to an open access, public server before formal peer review"[18]. Currently proponents of preprints are following the same strategy as the early OA advocates. Preprints are advocated as a route to better access rather than as a challenge to peer review. The ASAPbio[19] initiative is all about faster access to research findings – 'Accelerating Science and Publication in Biology'. If most research articles are posted first as preprints then access to research findings becomes possible as soon as an article is completed rather than, as at present, when the article is accepted and published in a journal.

Challenges to the current practice of peer review will surely follow the wider adoption of preprints.

Preprints have been widely adopted by physicists through the ArXiv server, but publishing practices and sharing cultures vary greatly between different research fields and biomedical researchers did not show much enthusiasm for preprints until recently. ArXiv has provided a home for computational biology preprints, and this helped to pave the way for the establishment of bioRxiv[20] – a preprint server for biomedical sciences.

Most articles uploaded to bioRxiv are also submitted to journals and subsequently peer-reviewed and published. But some also see bioRxiv as a permanent home for research results. One researcher has declared[21] that one of his bioRxiv preprints is the "final version" and that he will not submit it for publication in a journal. Partly this is because the article is a response to a previously published article, rather than a full article in its own right. But the researcher also wanted to experiment with how preprints are perceived by researchers."[22]

Preprints are still a tiny fraction of the total output of biomedical research papers. If there is widespread adoption, and researchers become accustomed to reading research reports that have not been peer-reviewed, we may increasingly question the value of peer review as a means of screening all research reports. Bernd Pulverer has suggested that:

"If preprints should attain the dominant role they have in physics, publishing papers in journals may remain attractive only in journals that add real value to the scientific communication process."

He suggests that it will be worthwhile only for quality journals "to invest time and effort to add reliability and reproducibility assurances to research findings through careful peer review and prepublication quality control and curation processes."[23]

We may be moving to a world where some research is just published 'as is', and subject to post-publication peer review, while other research goes through a more rigorous form of review including reproducibility checks. This will be a gradual process, over a period

of years. New tools such as Meta[24] and Yewno[25], using artificial intelligence, will help by providing new ways to discover and filter the literature. A new set of research behaviors will emerge around reading, interpreting and responding to preprint literature. The corridors of science will resound with *caveat lector* and *nullius in verba*.

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"In 2015, Web of Science indexed nearly 1.8 million articles and reviews, while Scopus indexed 1.7 million. These numbers reflect what has been identified by some as an exponential growth in scientific literature."

The sustainability of peer review

Alicia Newton, Senior Editor, Nature Research

The extent of STEM literature has become truly staggering. In 2015, Scopus identified over 2.45 million citable items published in that year alone[1]. This number includes books and conference abstracts as well as journal articles. In terms of journal articles, in 2015, Web of Science indexed nearly 1.8 million articles and reviews, while Scopus indexed 1.7 million. These numbers reflect what has been identified by some as an exponential growth in scientific literature[2].

All of these 1.7 million manuscripts were assessed and peer reviewed prior to publication. A Taylor and Francis survey[3] found that peer reviewers spend between four and six hours reviewing a paper. Assuming that each manuscript is seen by two reviewers, the amount of research time spent on peer review may have been on the order of between 13 and 20 billion person-hours in 2015. This is of course a rough calculation, as some fields rely on one peer reviewer and the editor's own comments, while other journals try to find three reviewers. The estimate doesn't account for papers that were sent for review at multiple journals, papers that were sent out for review but never published, or time spent on a second (or third) review.

It is thus clear that reviewing papers is a large burden on researchers' time. A recent survey of professors at Boise State University[4] found that peer review comprises 1.4% of academic work-time. Although this value is low in terms of absolute time spent working, it is comparable to the amount of time spent on writing (2.2%) and research development (1.8%), suggesting that peer review is an important component of these researchers' ' core research/ publication work time.

But are these efforts equally distributed among researchers? The answer is generally no, and it varies by publisher. Wiley's 2015 reviewer survey found that US scientists reviewed 33% and 34% of health and life science papers, respectively, while publishing 22% and 24% of papers[5]. A similar divide exists at two Nature Research titles, *Nature* and *Nature Communications*. In 2016, Americans contributed 50% of reviews, while comprising 36% of corresponding authors of submitted papers at *Nature*. At *Nature Communications*, scientists from the USA make up 40% of reviewers and 24% of corresponding authors. UK reviewers are slightly overrepresented in both the Nature Research and Wiley titles surveyed, while scientists from countries such as Germany and Japan submit and review manuscripts roughly in proportion.

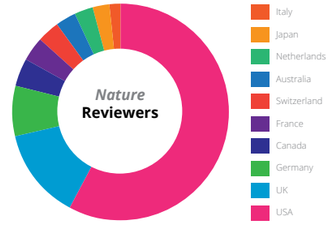
Meanwhile, scientists from countries such as China and Korea are submitting to Nature Research titles, but not reviewing as frequently: Chinese scientists were corresponding authors on 21% of *Nature Communications* submissions and 11% of *Nature* submissions, but they made up only 4% and <1% of reviewers, respectively. Although the geographic provenance of submissions may not exactly reflect the geographic distribution of papers sent for review or accepted, contributions from China nonetheless represent 9% of papers published in *Science* and *Nature* in 2015 (compared to 30% for the USA)[6], suggesting that competence is not the limitation to finding reviewers from China.

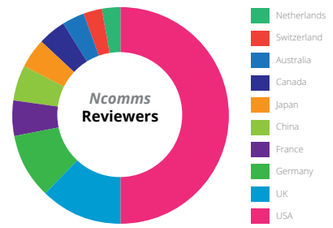
There is also a noticeable gender bias in reviewer pools. A subset of Wiley journals – those published by the American Geophysical Union (AGU) – found that 20% of reviewers were female, whereas 27% of first authors and 28% of AGU members were female; this disparity persisted over all career stages[7]. The authors of this survey attributed this result in part to a strong gender imbalance in reviewer recommendations. At *Nature*, where editors may rely less heavily on recommended reviewers, 22% of reviewers across all disciplines were women in 2015; a strong imbalance in the gender of recommended reviewers was also recorded[8].

The amount of scientific literature published is growing, with one estimate suggesting a growth rate of 8-9% per year[2]. This means that the amount of time spent reviewing is growing too. If peer review is going to be sustainable, editors and publishers will have to find ways to reach new reviewers. Looking at the AGU journal data, one initial solution may lie with authors: asking authors to provide suggestions that reflect varying gender, location and career stage would not only help editors, but also encourage researchers to actively seek out literature that may be missing from their standard citation lists. With the amount of new literature entering the field each year, it can be all too easy for researchers to limit their reading to certain journals or author groups, potentially to the detriment of the base their own work stands on.

Training editors on unconscious bias and setting targets for reviewer diversity across journals and publishers would be another avenue that could be explored with relative ease. But editors are ultimately responsible for what they publish, and they need to be able to know and trust their reviewers' expertise and broader knowledge of the field. For reviewers with a long list of discoverable publications, this is easy to assess. But for reviewers with a commonly-found name that thwarts easy Web of Science searches, or a relatively short publication list, editors may feel they are taking a risk inviting these individuals to review. Better ways of tracking people who are already reviewing for other journals such as tying ORCID numbers to reviews, or recording reviews on Publons could help match editors to experienced referees.

"If peer review is going to be sustainable, editors and publishers will have to find ways to reach new reviewers."





Percentage of reviewers and authors for Nature and Nature Communications

"For peer review to remain sustainable in an era of ever-growing scientific output, we must ensure that our base of peer reviewers becomes as global and diverse as the pool of scientists publishing their work."

Percentage breakdown of Science and Nature Publications

For those who have never reviewed before, a panel at the 2016 SpotOn conference[9] suggested that a reviewer training program could be helpful, especially if it ended in some sort of well-recognized accreditation. Such a program would provide students (or those further along in their careers) with hands-on experience of reviewing combined with feedback from one or more mentors. A database of credentialed individuals could provide an additional avenue for editors to find diverse, competent reviewers.

But opening up reviewing to all scientists is not just about meeting journal targets. Reviewers report that they enjoy feeling that they are playing their part in the academic community, and that they like to see new works and help improve them[10]. Moreover, they feel that reviewing improves their own reputation and standing in the community.

Amongst scientists, peer review is seen as key to inducing confidence in the literature[3]. And despite technological advances in, for instance, automated checks of statistics, few envision a publishing model without pre-publication peer review[3]. But for peer review to remain sustainable in an era of ever-growing scientific output, we must ensure that our base of peer reviewers becomes as global and diverse as the pool of scientists publishing their work.

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Improving integrity through openness

Elizabeth Moylan, Senior Editor (Research Integrity), BioMed Central

"Identity is important, we built everything on trust previously and we are moving away from trust to verification."

Editors and publishers are constantly grappling with ways to address the criticisms levelled at peer review: that it can be slow, biased and open to abuse. As a result, peer review is evolving and many initiatives are exploring ways to increase the efficiency and transparency of the process[1].

Editors are also facing new and more challenging situations. These can range from ethical lapses involving individual manuscripts[2] to large-scale manipulations and fraud[3]. Looking ahead to 2030 and faced with these challenges, how can we maintain the integrity of the peer review process? Are there ways for publishers, editors, peer reviewers and authors to work together more transparently and ethically?

> *"Identity is important, we built everything on trust previously and we are moving away from trust to verification."* Matt Hodgkinson, Head of Research Integrity, Hindawi

The peer review system was founded on trust. Trust that a submitted manuscript is an original piece of work, and that the authors, peer reviewers and editors are real people who act with integrity. However, in recent times we are witnessing a rise in misconduct on an industrial scale[4] fuelled by an increasing pressure on authors to publish[5]. As a result, in approaching 2030 we are likely to see a rise in publishers using technology, such as that provided by ORCID[6], to verify that researchers are who they say they are, that manuscripts are not plagiarized[7] and that figures and results are free of inconsistencies[8][8].

> *"How can we bring the principles of open science into peer review – principles of transparency, accountability, inclusivity, and accessibility of results, work, and methods for the sake of reproducibility and better science?"* Tony Ross-Hellauer, Scientific Manager, University of Göttingen.

A number of initiatives have already implemented ways of improving the integrity of the peer review process through transparency, for example, by naming the handling editor and/or peer reviewers[9], sharing the content of the reviewers' reports (transparent peer review)[10], or sharing content and reviewer names (open peer review) [11]. Such developments make peer review more accountable by allowing the reader to identify and consider potential bias. They also enable editors and reviewers to take credit for the work they do. However, open peer review is not without its challenges, reviewers are less willing to undertake open peer review (particularly early career researchers) and it is not uniformly embraced across all subjects[12].

"How can we bring the principles of open science into peer review – principles of transparency, accountability, inclusivity, and accessibility of results, work, and methods for the sake of reproducibility and better science?"

But there are other ways in which to open up the peer review process. For example, reviewers can comment on each other's reports (termed collaborative peer review or cross-reviewer commenting), reviewers and authors can exchange ideas (interactive peer review) and reviewers can choose what manuscripts they review (open participation). Initiatives investigating these various approaches will gather evidence into which work best and bring about improvements in the process[13-15]. Journals[16] and conferences[17] are encouraging such evidence-based research.

> *"Peer review ties into all sorts of other issues around the scholarly communications ecosystem that are going to be hard to resolve by just focusing on peer review."* Theodora Bloom, Executive Editor, The BMJ.

Of course, peer review does not exist in isolation but relates to other aspects of its environment, such as academic life, research, data, publishing, people, behavior, trends, training and technology (**Figure 1**). It can be complex and challenging, involving multiple stakeholders with various competing interests. Improvements to peer review will thus need to look beyond the process itself.

Figure 1

There is a recognition that the 'old ways' of publishing i.e. submitting a manuscript to a journal, followed by peer review, revision, acceptance and publication of a "final" article are out of step with the 21st century. Published articles do not remain unchanged forever, and we need a system that facilitates post-publication changes[18]. Many individuals are converging in advocating a "living" article[19,20] where sharing what researchers are going to do (pre-registration) and how they do it (data) in addition to the narrative that is their research article could radically reshape the publishing landscape. However, it remains to be seen where peer review would fit into this new landscape; alongside preprints, pre-publication or post-publication or at all stages of the publishing process...

This piece reflects the discussion[21] which took place on this topic at SpotOn in November 2016. I would like to thank and acknowledge Theo Bloom, Matt Hodgkinson and Tony Ross-Hellauer.

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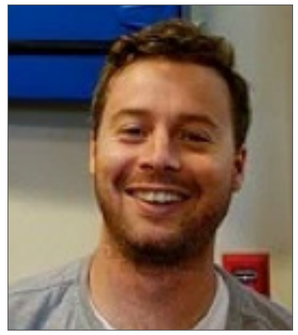

Formal recognition for peer review will propel research forward

Andrew Preston, CEO and Co-Founder, Publons

Tom Culley, Marketing Director, Publons

"Science has the potential to address some of the most important problems in society and for that to happen, scientists have to be trusted by society and they have to be able to trust each other's work."

The research enterprise is plagued by a series of disturbing problems. A reproducibility crisis[1], significant delays in publishing and disseminating peer reviewed findings[2], a surge in the volume of retractions[3] and admissions of fraudulent or questionable research practices[4], to name a few. All of these issues are, quite rightly, leading to increasing public and media skepticism as to the quality and integrity of research[5].

This matters because, as Ferric Fang, a professor at the University of Washington School of Medicine and Editor-in-Chief of the journal Infection and Immunity rightly points out: "Science has the potential to address some of the most important problems in society and for that to happen, scientists have to be trusted by society and they have to be able to trust each other's work."[6]

In other words, if the system is not working in a credible and efficient manner, we put both people and our potential for progress at risk.

At the heart of this problem is an opportunity. In the era of 'fake news' and distrust in reporting, evidence-based decisions are arguably more important than ever. If we can solve some of the issues with the current system, science and research can and will provide massive gains for all of humanity.

Peer Review: The pillar of research quality and integrity

Peer review is at the heart of the research ecosystem. It is the gold standard for ensuring the quality and integrity of published research. Peer review plays the essential role of validating findings, qualifying their importance and filtering out misleading or fraudulent work. Thorough peer review can be relied on to mitigate most of the issues in research, and in fact improve the quality of research papers before they are published.

So why do problems exist? The answer is complex, but one thing is very clear. The way the research establishment treats peer review, the primary mechanism relied upon to prevent flawed or incomplete research being disseminated, has not changed in 350 years. The result is a system that is overburdened and under-developed.

The economics of the research ecosystem

Research is overrun by a debilitating 'publish or perish' culture. Researchers are, for the most part, rewarded with funding and career progression based on their publication and citation records. This compels researchers to publish as much as possible in journals renowned for delivering citations. Add to this the increasing competition for shrinking government funds and you have an environment that fosters temptation to fudge results, ignore inconvenient data, slice and self-select submissions into as many 'novel' publications as possible and generally undermine the truth-seeking goals of research. Thankfully the system has a mechanism for safeguarding the quality and integrity of published research, namely: peer review.

"In the era of 'fake news' and distrust in reporting, evidence-based decisions are arguably more important than ever."

Peer review is a voluntary exercise. Researchers are expected to review for the intrinsic incentive of 'giving back' and a quid-pro-quo understanding that others will review their work. This approach may have been appropriate before the Internet when there was no way to accurately measure anonymous peer review contributions and when scientists worked in tight communities. But the research ecosystem has changed remarkably. We now have the Internet, globalization, interdisciplinary research and mega-publishers. These developments drive the pressure to publish higher, placing increasing stress on a voluntary and unrewarded peer review process.

To summarize, the system almost exclusively rewards experts for publishing at nearly any cost. The same system then offers no formal incentives to the same experts relied upon to filter out the false, fraudulent or misleading submissions through peer review.

Bringing balance back to the system

There is no silver bullet that will resolve all the issues, but there are simple steps that can be taken to bring balance back to the system. An obvious starting point is to formally recognize and reward peer review efforts so it stands a chance against the disproportionate rewards for publishing.

Recognition for review is not a new concept. For years a number of academic publishers and journals have published the names of their reviewers on an annual basis. Others have begun to provide certificates to reviewers acknowledging their valued contributions. Researchers can then reference these efforts in their performance evaluations as proof of their service. This approach, while better than nothing, does have its shortcomings:

1. Academic publishers and journals are not the ones making funding and career advancement decisions for researchers or institutions. A certificate is nice, but if funders and institutions don't give it any credence when evaluating performance or allocating funds, it's no more than a wall decoration.
2. The fragmented and imprecise nature of the recognition (i.e.: no standardized measure or centralized hub for tracking outputs) does not provide a basis for funders, world ranking bodies or institutions to incorporate peer review contributions into their evaluation methodologies, as there is no way to benchmark the peer review outputs.
3. Publisher acknowledgement by itself means the system is still relying on the good nature of individual researchers to contribute to the peer review system. Altruism and a thank you is a tough bet when pitted against the very tangible rewards for publications and citations.

Some have argued that publishers should start paying reviewers or offer in-kind benefits. After all, in monetary terms, publishers benefit the most directly from the scholarly publishing system. The jury is still out as to whether this will help, but a few points to keep in mind regarding a publisher payment solution include:

1. Previous psychological studies[7] suggest that offering a monetary reward for a piece of work can "crowd out" the intrinsic, non-financial incentives for performing a task well. If paying referees without measures to control for the quality of reviews led to bad peer review, it would defeat the purpose of the intervention.
2. A Wiley survey[8] of over 3,000 reviewers suggests researchers prefer formal recognition to cash or in-kind payment for reviewing. The same survey found that "reviewers strongly believe that reviewing is inadequately acknowledged at present and should carry more weight in their institutions' evaluation process."
3. Researchers value career advancement and institutions (not publishers) make career advancement decisions.

To square the incentives ledger, we need to look to institutions, world ranking bodies and funders. These parties hold either the purse strings or the decision-making power to influence the actions of researchers. So how can these players more formally recognize review to bring balance back to the system and what tools do they need to do it?

Institutions

Quite simply, institutions could give greater weight to peer review contributions in funding distribution and career advancement decisions. If there was a clear understanding that being an active peer reviewer would help further your research career, then experts would put a greater emphasis on their reviewing habits and research would benefit.

Funders

If funders factored in peer review contributions and performance when determining funding recipients, then institutions and individuals would have greater reason to contribute to the peer review process.

World Ranking Bodies

Like researchers, institutions also care about their standing and esteem on the world stage. If world ranking bodies such as THE World University Rankings and QS World Rankings gave proportionate weighting to the peer review contributions and performance of institutions, then institutions would have greater reason to reward the individuals tasked with peer reviewing.

More formal weighting for peer review contributions also makes sense, because peer review is actually a great measure of one's expertise and standing in the field. Being asked to peer review is external validation that academic editors deem a researcher equipped to scrutinize and make recommendations on the latest research findings.

Researchers

Researchers will do what they have to in order to advance their careers and secure funding. If institutions and funders make it clear that peer review is a pathway to progression, tenure and funding, researchers will make reviewing a priority.

Tools

In order for peer review to be formally acknowledged, benchmarks are necessary. There needs to be a clear understanding of the norms of peer review output and quality across the myriad research disciplines in order to assign any relative weighting to an individual's review record. This is where the research enterprise can utilize the new data tools available to track, verify and report all the different kinds of peer review contributions. These tools already exist and researchers are using them. It's time the institutions that rely on peer review got on board too.

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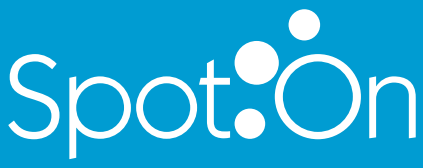
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