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THE ROLE AND RESPONSIBILITIES OF PUBLISHING

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INTRODUCTION

An essential purpose of scientific publishing is: "to make the conclusions, and the evidence (the data) on which a scientific truth claim is based, accessible to scrutiny by peer review and post-publication analysis so that method and logic can be validated or invalidated, conclusions scrutinized, and any observations or experiments replicated."[1] This process is the foundation of the 'self-correction of science' that, in turn, is a bedrock of the integrity that underpins the public value of science and ultimately trust in science and the scientific method.

Research Integrity is weakened by practices that range from sloppy research methodology through poor data handling and analysis and unethical practices to plagiarism and deliberate fraud. The ultimate responsibility for such breaches lies with the researchers involved. However, the act of publishing and the processes involved can—indeed should—play an essential role in detecting their possible occurrence and thus acting as a significant deterrent. Unfortunately, there is increasing and compelling evidence[2] that publishing is not fulfilling this role as well as it could. While significant changes in the culture and expectations of both publishers and researchers are necessary, modest reforms are feasible and warranted. This note, designed to spur discussion, suggests that focussing on two modest reforms while pursuing a more significant reform of scientific publishing would be beneficial.

RETRACTIONS

Publishing's ultimate sanction is retraction. However, while retraction removes a paper from the record of science, it does not eliminate the paper from existence. Such articles live on in the world of misinformation.[3] Indeed, the act of retraction can lead to enhanced media attention[4] and continued citation[5]. The retraction of Wakefield's infamous (and fraudulent) paper linking measles vaccination to autism is now cited by extreme anti-vaxxers as evidence of a so-called conspiracy[6] to suppress Wakefield's views. Reducing the number of retractions would be beneficial to the overall trustworthiness of the record of science.

On the other hand, scientists are human and can make honest mistakes. Thus, it is also essential that authors are encouraged to self-retract or publish corrigenda or errata if they discover errors in their publications or the underlying data after publication. Pleasingly, there is some evidence that such actions are recognized positively and do not stigmatize the author(s) involved[7]. When retracting a paper, journals should accompany the retraction with a statement explaining why it was retracted and who instigated it.

Retractions are systematically recorded by Retraction Watch[8]. This database is valuable for research and analysis of retractions, their cause, and possible mitigation. Whether the apparent increase in retractions in recent years is a result of increasing malpractice by researchers, or better detection, or a combination of the two is open to debate[9]. However, from an inspection of the list of retractions, it is hard not to conclude that many of the most egregious should have been picked up on review and never published.

The recent retraction of a study[10] on hydroxychloroquine from *The Lancet* is a telling example. It is surprising—indeed disappointing—that before publication, no one—authors, referees, or *The Lancet* editor—appears to have questioned the provenance or veracity of the underlying data. Yet within days of publication, serious questions were being raised[11] on social media about the underlying data, ultimately leading to the formal retraction by *The Lancet* when it became clear that the data didn't exist. While it could be argued that this was the self-correction of science at work, examples such as *The Lancet* case undermine trust in science at a time when many already distrust science[12]. They also have implications beyond weakening the record. In The Lancet case, the initial publication caused the World Health Organization to suspend temporarily other clinical trials on hydroxychloroquine.[13]

REPLICABILITY AND REPRODUCIBILITY

A different set of issues arises from papers that pass peer and editorial review and are formally published but contain results or claims without sufficient information to enable the results or claims to be replicated, reproduced, or even potentially retracted.

As emphasized by the US National Academies of Sciences, Engineering, and Medicine (NASEM) in a recent report, *Reproducibility, and Replicability in Science*,[14] this failure goes to the heart of science: "Repeated findings of comparable results tend to confirm the veracity of an original scientific conclusion, and, by the same token, repeated failures to confirm throw the original conclusions into doubt." The failure is not just of importance to science. As the NASEM report continued: "When a scientific study becomes the basis of policy or has a direct or indirect impact on human well-being, scientific reliability becomes more than an academic question." As a result, the NASEM recommends that researchers, institutions, funding agencies, and journals take action to improve the reproducibility and replicability of scientific research.

The two terms are often confused or conflated.[15] In scientific research, *reproducibility* refers broadly to the ability to repeat the experiment, computation or conclusion reported using the same data and methodology as in the original report. On the other hand, *replicability* refers to the ability to arrive at the same conclusions by different methods, analysis, etc., ideally by independent researcher (for a succinct summary, see page 9 with an infographic *10 Things to Know About Reproducibility and Replicability* reproduced from the NASEM Report[16] .) Both are important for post-publication analysis, evaluation, and confirmation of published research.

It would be naive to believe that every scientific study worthy of publication will be valid and not overturned or at least amended by subsequent work. That is the fundamental nature and process of science. However, this requires results that enter the scientific record to be accompanied by sufficient detail and information to allow this to occur. Unfortunately, again there is sufficient evidence[17] to suggest that the publication process is failing more often than is reasonable to ensure this.

The importance of reproducibility and replicability in science (and the role of journals) was brought into sharp focus by the crisis that erupted in the early 2010s in psychology. The crisis was initiated by the publication (in reputable journals) of studies with conclusions that were at best implausible. It was compounded by refusals by many journals to publish subsequent studies challenging the initial findings.[18] The crisis rocked psychology and led to profound reform of its research practices.[19, 20]

Concerns with reproducibility and replicability are not restricted to psychology. Other notable examples include:

- In biology, a 2016 *Nature* survey found that over 70% of researchers were unable to reproduce the findings of other scientists, and approximately 60% of researchers could not even reproduce their own findings;[21]
- In organic chemistry, the editorial board of *Organic Synthesis*' attempts to replicate in their own labs the results of every paper submitted resulted in the rejection of 7.5% of submissions;[22]
- In oceanography, serious questions have been raised concerning the replicability of major and influential studies of the effect of ocean acidification on the behaviour of fish;[23]
- A recent preprint[24] examined preprints related to COVID-19 research deposited on major pre-print servers and concluded that the majority did not to make available the underlying data and code to enable replicability.

The emergence of powerful data analytics such as machine learning (ML) and artificial intelligence (AI) are exacerbating issues with reproducibility and replicability. Indeed, there are claims that ML and AI face a reproducibility crisis comparable to that which rocked psychology in the early 2010s.[25, 26] Computer science is beginning to recognize the seriousness of this issue, and some ideas are being explored.[27] With ML and AI tools becoming commoditized and used more widely in research, it is a critical debate.[28, 29]

Publishers are not blameless. Recently, thirty-one scientists criticized[30] *Nature* for publishing a study[31] from Google Health that relied on Google's proprietary AI system. In response, the original authors published an addendum[32] and made available more information on the training of the deep learning system concerned. Notwithstanding this response, this case illustrates genuine issues concerning the transparency of AI tools that a commitment to open-source software would ameliorate.[33]

WHY DOES THIS MATTER? MERMIN'S TAPESTRY—THE NATURE OF CONSENSUS IN SCIENCE

As acknowledged in *Opening the Record*, the record of science is not static but rather expands and evolves as new knowledge enters the record and as new techniques, new theories and understanding allow the reanalysis and reinterpretation of existing results and conclusions. While the record is built up from individual publications and findings, scientific consensus on a particular issue ultimately emerges, often over years, as individual results are debated, analysed, retested, and combined with other ideas and theories. Some years ago, David Mermin, a theoretical physicist at Cornell, described consensus in science as a tapestry[34]. While built up from individual threads, the picture depicted by a tapestry is not dependent upon any particular thread, nor by the presence of weak spots, or even the occasional hole.

Mermin's tapestry is also an apt metaphor for how people may view scientific consensus or why facts don't change our minds[35]. Research in cognitive psychology suggests that if the 'big picture' conflicts with one's worldview, social group thinking, religion, or other belief, one focuses on the weak spots: the contrary arguments. Conversely, if one agrees with the overall picture, these are overlooked.[36] Thus, papers in the record reporting a result from a poorly designed study at 5% confidence, with insufficient information to allow replication, may not be as benign as sometimes supposed.

Of course, there are examples where a single paper—pulling on a single thread in Mermin's tapestry—changed, even destroyed, consensus. Barry Marshall and his discovery[37] (with Robin Warren) of *H. Pylori* as the cause of stomach ulcers is a classic example. When first proposed, Marshall's idea was met with scepticism and even derision. Twenty years later, he and Warren were awarded the Nobel Prize. It is thus vitally important that such revolutionary ideas enter the record. However, it is equally important that such ideas enter the record with sufficient information to allow them to be tested, refined and even refuted. Arguably, a 'finding' that cannot be replicated is more insidious than one subsequently proved wrong and retracted.

WHAT CAN PUBLISHERS DO? TWO (MODEST) BUT SIGNIFICANT REFORMS

Publishing's–and publishers'—role in ensuring research integrity and hence trustworthiness in science is limited but critical. However, as discussed earlier, there is sufficient evidence to suggest that publishing is not fulfilling this role to the extent it could.

This is particularly so for those journals for which the cachet of publication is seen as exceptionally meritorious in the academic community and perceived to imply credibility more widely. The scientific community and such journals should set higher standards to ensure that the published record is as trustworthy as possible, that opportunities for scientific claims to be misconstrued are minimized, and that research misconduct is deterred to the greatest possible extent. Surprisingly, little opprobrium appears to attach to a journal publishing a retraction, particularly one that should have been picked up on review, given that coordinating peer review is the contribution that journals claim they make to the scientific process and a justification for their publication charges.

While a more radical reform of scientific publishing[38] may be desirable, action by publishers in two areas could have a significant impact in a relatively short time:

1) MANDATING THE CO-PUBLICATION OF DATA.

Since data issues are a feature of many retractions, universal adoption of co-publication of data and the ensuing publication would do much to avoid such cases and act as a significant deterrent. Achieving this should be a priority for policy reform. The model[39] developed by the earth and environmental sciences (and involving publishers) should be considered seriously by other disciplines. For computer science and data science, this consideration should clarify requirements to enhance reproducibility and replicability for publications involving advanced data analytics such as machine learning and AI.

While open data is a laudable objective, FAIR[40] —Findable, Accessible, Interoperable, and Reusable—is, for some disciplines, more appropriate and reasonable. FAIR allows regulation of access, for example to sensitive or indigenous data, the critical issue being that a pathway to access exists and access cannot be unreasonably withheld.

As an interim step towards universal adoption of co-publication (or linkage via emerging online exchanges such as Scholix[41]) journals should articulate clear statements relating to data. For research based upon a clinical trial, journals should require that the trial was pre-registered, as recommended in 2017 by the International Committee of Medical Journal Editors (ICMJE)[42] but yet to be universally adopted by all journals. The requirement for pre-registration should be extended to all research involving trials such as nutrition and the behavioural sciences, as advocated by AllTrials[43]. Indeed, there is a case[44] to extend pre-registration to include data analytic procedures prior to examining data, thereby discouraging inappropriate data selectivity and improving replicability and reproducibility[45].

Even under current practice, editors can, and should, be more active with regard to ensuring the veracity of data in underpinning papers that their journal publishes. In 2020, the Editor-in-Chief of *Molecular Brain* wrote an editorial describing how he had requested the raw data in 41 of the 180 manuscripts he had managed since 2017[46]. Of the 41, 21 were then withdrawn by the authors, and he rejected a further 19 "because of insufficient raw data," suggesting as he concluded, "a possibility that the raw data did not exist from the beginning, at least in some portions of these cases."

One of the problems with *The Lancet* hydroxychloroquine case was the use of a large and complex data set from a third party that some authors did not validate. Following the retraction, *The Lancet* announced new guidelines for the review of papers involving large and complex data sets[47] and now requires that “more than one author has directly accessed and verified the data reported in the manuscript.” While an improvement, *The Lancet* guidelines do not go far enough and would not have prevented the issues that have recently become apparent with data released to researchers by Facebook[48]. Some form of independent validation of data sets from non-academic third parties before use by other researchers is overdue.

2) STRENGTHEN CONSIDERATION OF REPLICABILITY/REPRODUCIBILITY DURING PEER AND EDITORIAL REVIEW.

Peer review has traditionally been the gatekeeper of the record of science, playing a vital role in ensuring the quality and integrity of the record both before publication and post-publication.

Prior to publication, peer review, as practiced by most journals, attempts to assess two different things: the professional competence of the paper and the “novelty” or “importance” of the work. The reproducibility crisis in psychology arose when the second consideration became almost exclusively the criterion for publication and was then misused to reject subsequent papers negating the original findings.

A simple reform would be to require referees, backed by journal editors, ask two simple questions:[49] “Is there enough detail given of the methods involved and, if necessary, is the data available, so that, if I wanted to, I could replicate this work?” If the answer to either question is unclear from the submitted paper, ‘revise and resubmit’ should be the appropriate response and could lead to a significant reduction in the number of potentially dubious studies.

There may be situations in which referees and editors agree that the reported findings warrant publication despite weaknesses in methodology or potential data issues. In such cases, the journal should explicitly welcome and publish (following appropriate review) studies that replicate the research. More generally, more journals and research funders need to recognize the importance of replicative studies and null results[50].

Since the appropriateness of statistical tests is often the issue in questions of reproducibility and replicability, it is surprising that many editors do not use statistical experts to evaluate submitted papers. A recent survey of 307 biomedical journals (of whom 107 responded) found that only 23% of respondents used specialized statistical review for all submitted papers, and 34% rarely or never used it.[51] Given the increasing complexity of data being used in research, this finding is concerning.

More systematic approaches to test data validity in randomized trials exist and should be more widely used.[52] Statistical methods have also been developed to detect fraud in crystallography[53] and numerical data.[54] Even more sophisticated automatic methods to assess replicability may become available, see, for example, a recent exploration of the potential of AI tools to predict replicability.[55]

Journals are taking action. Recently eight major publishers issued guidelines in a preprint on the detection and treatment of doctored or fraudulent images.[56] However, in order to be effective such developments will need wide adoption.[57] Since such methods require access to the underlying data, the co-publication of the underlying data needs to become universal.

A more formal process could be instigated based on a recent proposal of a tool to assist the assessment of the trustworthiness of a paper.[58] Augmenting such a tool with more disciplinary-specific criteria would be appropriate, for example, in biomedical research.[59] Such a checklist could easily be made mandatory for authors submitting papers. The existence of such a checklist on submission would have most likely prevented a concerning recent Australian case[60].

Reforming peer review to focus more prominently on assessing methodological competency and particularly ensuring replication and reproducibility would potentially have four further benefits:

- It would create greater separation and distinction between 'peer-reviewed papers' and preprints. Preprints are an important mechanism to rapidly communicate research, as shown during the COVID-19 pandemic. However, that value comes with an increased risk of spreading unvalidated claims, with many media reports, particularly on social media, not mentioning that the reported research had not been scrutinized by peer review[61].
- Since most preprints are still intended for journal publication, it would encourage authors to address reproducibility and replicability more clearly as a matter of course. At the same time, preprint servers should look closely at adopting screening tools as demonstrated by the Automated Screening Working Group[62].
- Increase transparency around peer review[63] and allow the ranking or badging of journals against more objective criteria based on their quality control of peer review and less on the subjective assessment of future impact. The development of peer review taxonomies[64] is an important step which warrants further consideration.
- Finally, if publication in a "high-impact journal" required authors to address reproducibility and replicability more clearly, that could significantly moderate some of the perverse incentives and assessment protocols that currently drive behaviour by researchers that, in turn, threatens research integrity.

Ultimately, responsibility for the trustworthiness of the record of science lies with those whose work builds it. However, journals can take action to ensure the integrity of papers they publish after peer and editorial review. It would be a pyrrhic victory if opening the record of science led to a decrease in trust in science or, worse, the weaponization of preventable failures against science more generally.

Extract from *Reproducibility and Replicability in Science*, National Academies of Sciences, Engineering, and Medicine, Washington, DC: The National Academies Press. (2019)
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