

Academic Fraud: Solving the crisis in modern academia

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Abstract

Academic fraud is a rising threat. Schemes to defraud funding bodies, institutions and researchers for personal gain are not a modern invention within academia but one that threatens to topple the integrity of research practice. These manifest in the form of internal research misconduct and external predatory practice, the former perpetrated by the over-ambitious and the latter by organizations preying on unsuspecting researchers. Such academic fraud can undermine academic integrity, profoundly influence key legislation, and cause societal damage. Major reform of the academic system is required to overcome these difficulties. These measures are discussed and can be divided into detection and prevention methods. Detection methods include peer-review, replication, whistleblowing, external review bodies, digital solutions, and incentivization. Prevention methods include awareness, data repositories, institutional and editorial policies, punishment and deterrence, transparency indices, and changes to the 'publish or perish' mentality. These solutions are as of yet immature, flawed or in need of major revision but do have some potential in overcoming the rising threat of academic fraud.

Keywords: academic fraud; research misconduct; predatory publishers; fraud solutions; peer review

Academic Fraud: An Overview

Fraud is something of an ancestral condition in human society. The fabrication of precious stones in ancient societies, including Mesopotamia and Egypt, is long-established along with Pliny the Elder's use of diamonds to detect fake gems (**Ruffell et al., 2012**). Hegestratos in 360 BC, perhaps the first case of insurance fraud, was caught in the act of scuttling his boat transporting a pre-paid shipment of corn, being chased off the ship and drowning in the process (**Johnstone, 1999**). Wherever an industry exists, so does fraud. Academia is no exception.

Every academic no doubt has grown accustomed to the constant barrage of emails in their inbox, hundreds of poorly written invitations to present, publish or review for any number of obscure organizations of dubious origin. Some fall for this ruse, being extorted by predatory publishers and conference organizers of ill-repute. Even more sinister are the scandals that emerge from the world of academia all too frequently. Long-term cases of research fraud frequently erupt into the news, such as the infamous Stapel case in psychology (**Stroebe et al., 2012; Stapel, 2014**), the mass fabrication of the promising physics post-doc Schön (**Stroebe et al., 2012; Carafoli, 2015**) and the MMR vaccine fraud purported by Wakefield (**Godlee, 2011; Carafoli, 2015; Mavrogenis et al., 2018**) (Table 1). Each of these high-profile cases sent shockwaves through their respective disciplines, whose impact can cause irrevocable societal damage.

Academic fraud is by no means a modern trend. Babbage (1830) lamented the 'decline of science in England' and described the methods of fraudulency employed by less salubrious researchers at the time. Many will also be familiar with the classic case of Piltdown man, the 'missing-link' discovered in 1912 and later debunked in 1953 (**Goldstein, 2010; de Groote et al., 2016**). Many other giants of science have also been accused of misconduct. For instance, it is suspected that Galileo never actually carried out many of his experiments, Newton to have manipulated his results to better match his theories and Mendel to have 'cooked' his data by presenting only the best results (**Carafoli, 2015; George and Buyse, 2015**). Mendel has been more or less absolved of these accusations however, while the former are mere suspicions lacking serious evidence. These are few and far between compared to now, however. The forms in which modern academic fraud takes are varied but can be considered as belonging to one of two families. The first is 'internal', instigated by researchers and often called 'research misconduct'. The second is instead 'external', fraud instigated through predation, wittingly or unwittingly, on researchers, also called 'predatory practice' (Fig. 1).

Event	Occurrence	Subject Area	Summary	Source
Pittdown Man	1912 - 1953	Archaeology	Infamous case of object forgery of 'missing-link' between man and ape found in England.	Ruffell et al., 2012; Gross, 2016
The Darsee Affair	1966 - 1983	Medicine	Long-term fabrication of data on research in medicine.	Shewan and Coates, 2012; Gross, 2016
Summerlin's 'Painting the Mouse'	1974	Biology	Successful transplantation of skin from black to white mice found to just be black permanent marker.	Gross, 2016; Eisner, 2018
Breuning Ritalin Affair	~1978 - 1988	Psychology	Falsification of evidence proving that Ritalin was an effective treatment for hyperactivity in retarded children.	Goldstein, 2010
Fujimura Jomon Archaeology Scandal	1981 - 2000	Archaeology	An amateur Japanese archaeologist with 'the hands of god' found to be planting artefacts to be found.	Pellegrini, 2018
Fujii Anesthesiology Scandal	1993 - 2012	Medicine	Mass fabrication of data in 183 papers in anesthesiology, the current record holder for retractions.	George and Buyse, 2015; Pellegrini, 2018
Reuben Pain Management Fraud	1996 - 2009	Medicine	Long-term falsification of clinical trials that were never carried out on pain management.	Stroebe et al., 2012; Carafoli, 2015
Stapel Scandal	1996 - 2011	Psychology	The career-wide fraud of Diderick Stapel, in which he fabricated data for himself and for his students.	Crocker and Cooper, 2011; Gross, 2016
The Schön Affair	1997 - 2002	Physics	Industry-changing research into organic crystalline electronics turns out to be completely falsified.	Stroebe et al., 2012; Carafoli, 2015
MMR – Autism Vaccine Scandal	1998	Medicine	Wakefield found to have taken payments to fabricate and falsify a study linking vaccines to autism.	Carafoli, 2015; Mavrogenis et al., 2018
"Archaeoraptor liaoningensis"	1999 - 2000	Palaeontology	A new bird-dinosaur missing-link turns out to be a composite of two fossils combined together.	Rowe et al., 2001; Ruffell et al., 2012
Ninov's 'Element 118'	1999 - 2002	Physics	Claims of the creation of Element 118 by Ninov and his team turn out to be fabricated.	Goldstein, 2010; Carafoli, 2015
Hwang Woo-Suk Stem Cell Scandal	2005 - 2006	Medicine	Novel research into stem cell cloning turns sour due to data fabrication and bioethical violation	Carafoli, 2015
The Plagiarism of Spivak	2010 - 2014	Mathematics	Multiple counts of plagiarism of a single article written by former postdoctoral adviser and colleagues.	Pellegrini, 2018
Chen Peer-Review Scandal	2014	Engineering	The discovery and mass-retraction of 60 papers published through a 'ring' of fake reviewers owned by author.	Haug, 2015
STAP Cell Scandal	2014	Biology	An easy way of creating stem cells is falsified, resulting in retraction and suicide of a co-author.	Pellegrini, 2018

Table 1: High Profile Research Misconduct Cases

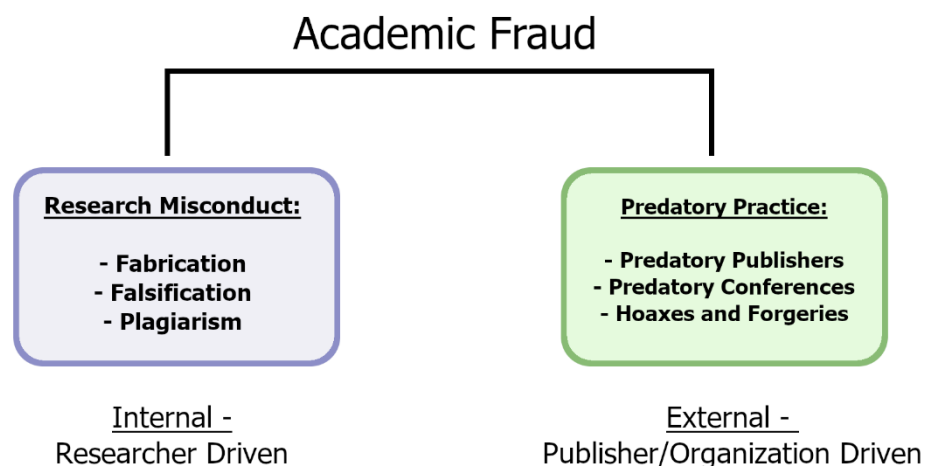


Figure 1: The Nature of Academic Fraud: Academic fraud can be divided into two different categories. Research misconduct involves fabrication, fraud and plagiarism and is internally-driven by researchers. Predatory practice by comparison involves the parasitic I

Research Misconduct

The first, 'internal' source of fraud is that of research misconduct. Research misconduct refers to cases of poor, manipulative or fake research that breaches ethical conduct. The issue is mostly documented in the physical sciences, as evidenced by the breadth of publications on the subject (Goldstein, 2010; Gross, 2016; Hesselman et al., 2017). While few articles address the issue in the humanities, the problem is certainly present. The suspected fraud of Castaneda, author of the infamous 'Teachings of Don Juan', is a high-profile case of putative anthropological fraud in the invention of the titular 'Don Juan', whose authenticity is of dubious veracity (de Mille, 1990). Likewise, the renowned amateur Japanese archaeologist Fujimura was found to have been planting his Jomon 'archaeological finds' for his team to find for many years (Pellegrini, 2018). Plagiarism is known to be a problem in the humanities, although certainly one endemic to all academic disciplines (Loui, 2002; COPE, 2019a). Most authors define research misconduct as 'FFP', or 'Fabrication', 'Falsification' and 'Plagiarism'. These constitute serious research misconduct with the caveat that the infraction is committing knowingly and intentionally rather than in error (Gross, 2016; Mavrogenis et al., 2018; ORI, 2019) (Fig. 2). This has been widely adopted by many bodies in the US to classify cases of research misconduct, including the National Science Foundation (NSF), the US Public Health Service and the National Institute of Health (NIH) (George and Buyse, 2015; Gross, 2016). This definition is not unanimously accepted, however. For example, the definition previously adopted by the Committee on Publication Ethics (COPE) states that research misconduct is "behaviour by a researcher, intentional or not, that falls short of good ethical and scientific standard" (White, 2000). The UK Research Integrity Office (UKRIO), formed in 2009,

mirrors the definition of the ORI, highlighting fabrication, falsification and plagiarism along with breaches in ethical protocol, mishandling of private data and the misrepresentation of data or interests (UKRIO, 2009).

'FFP': Defining Research Misconduct

- **Fabrication:** The creation of non-existent data and results and the act of recording and reporting them.

- **Falsification:** The manipulation of research materials, equipment or processes or omitting data and results so that the research is not accurately represented in the research record.

- **Plagiarism:** The appropriation of another person's ideas, processes, results or words without giving the appropriate credit.

Figure 2: Defining Research Misconduct: The definition of research misconduct as outlined by the ORI (ORI, 2019). Fabrication, falsification and plagiarism are the core tenets of their definition.

The prevalence of research misconduct has also proved difficult to measure. Surveys on observed research misconduct are inconsistent, reporting values between 9% and 27% of respondents who reported seeing potential cases of misconduct among their colleagues (Titus et al., 2008; George and Buyse, 2015; Gross, 2016). A particularly high value of 92% was reported by New Scientist from a survey, but this value appears to be an outlier (George and Buyse, 2015). Self-reporting surveys show smaller values, Fanelli's (2009) meta-analysis of surveys on the subject between 1987 and 2008 finding that 2% of respondents admitted to some form of severe research misconduct and 34% on less serious practices. Other estimates from such surveys for serious research misconduct range from 0.3 – 2% (George and Buyse, 2015).

More popular are studies looking into trends in article retraction notices. These studies show that retractions make up 0.02% of all articles and that their frequency has risen steadily from the 70's until the early 00's, followed by a rapid increase until today (Steen, 2011; Fang et al., 2012; Hesselman et al., 2017). Geographical distribution depends on whether or not the values are normalized to the total of publications, the US having higher raw values followed by Germany, China and Japan (Fang et al., 2012; Grieneisen and Zhang, 2012) but normalized values have higher retractions values for China and India (Van Noorden, 2010; Hesselman et al., 2017). Retractions appear to be highest in the sciences, particularly in biomedicine, life sciences and chemistry (Carafoli, 2015), appear to be higher in high impact factor (IF) journals (Grieneisen and Zhang, 2012; Carafoli, 2015) and also appear to be dominated by men (Fanelli, 2013).

Predatory Practice

The second source of academic fraud arises from ‘predatory practice’ in which publishers, conference organizers, scammers and agencies seek to gain profit by exploiting researchers for their research and funding. These manifest in the form of predatory conferences, who extort unsuspecting authors for high attendance fees (**Berger and Cirasella, 2015; Beall, 2016**). Another trend has been the rise of open-access predatory journals, often named after more prestigious journals to present a thin veneer of authenticity (**Carafoli, 2015; Beall, 2016**). Authors are charged large sums for the right to publish in such journals after ‘peer-reviews’ that are anything but, insights gleaned through the numerous sting operations carried out against them (**Bohannon, 2013; Roberts, 2016**).

The victims are not always unwilling. Other schemes also include barely-legal publishers and agencies who help to expedite the careers of researchers willing to pay. The latter has seen a rise in countries with emerging academic communities, India and China being particularly vulnerable (**Hvrstendahl, 2013; Sabir et al., 2015**). Hvrstendahl (**2013**) highlights an enlightening sting operation into such agencies in China, offering services ranging from paid authorship on accepted papers (up to \$26,000 USD) to purchasing pre-written papers and reviews. Others involve schemes to defraud unsuspecting researchers or organizations. The infamous Bre-X scandal and other mining frauds represent conscious efforts to deceive unsuspecting investors by ‘salting’ mining prospects with small quantities of ore, which inevitably turn up dry when the prospect is sold (**Ruffell et al., 2012**). Others prey on researchers, such as in palaeontology where exciting new finds turn out to be clever forgeries. The bird-dinosaur missing link, ‘Archaeoraptor liaoningensis’, represents such an infamous example, a composite fossil sold to an unsuspecting amateur (**Rowe et al., 2001; Ruffell et al., 2012**).

The extent of predatory practice is difficult to estimate. It is arguably modern, triggered by the arrival of the open-access format throughout the 90’s and 00’s, spurred by the rise of the internet and its role as a rapid distribution medium (**Berger and Cirasella, 2015; Shen and Björk, 2015**). Open access sees the publisher as a service provider to authors, charging them a one-time article processing charge (APCs) for publication, to cover the costs of distribution for the article. The format was popularized by well-reputed publications like PLoSOne and BMJ and has now become a dominant publishing platform for distributing academic content quickly with short article turnaround times (**Bowman, 2014; Carafoli, 2015; Shen and Björk, 2015**). However, in the lee of this emergence came a swathe of pseudo-publications that promise quick publication for fees that under-cut their more reputable rivals in both price and content (**Beall, 2016; Watson,**

2017). This practice has grown explosively within the last decade, evidenced anecdotally through the dearth of spam mails received by even early career researchers (Shen and Björk, 2015).

Few studies have attempted to estimate this growth, although Shen and Björk (2015) give an estimate of ~11,873 journals that met the criteria of the infamous Beall's list (Balehegn, 2017). They also found that the active number of open access journals jumped from 1,800 in 2010 to 8,000 in 2014 and that the majority were based in India (27%). The authors in these publications were mostly Indian (35%), Nigerian (8%) or from the US (6%). This note on geographical distribution agrees with the work of Xia et al., (2015), who also found that the majority of authors in several pharmacological predatory journals came mostly from India, Nigeria and Pakistan respectively. The proliferation of predatory journals has been accompanied by the rise of predatory conferences who operate in a similar manner, enticing naïve scholars to exotic locations only to provide non-existent or poorly provisioned shams in their stead, although no estimates on their growth are available in the wider literature (Bowman, 2014; Beall, 2016; Cress, 2017). Other forms of predatory practice, such as the selling of fake specimens to unwitting researchers, a timely issue in Chinese palaeontology (Wang, 2013), cannot really be measured due to their stochastic nature. Certainly then, at least according to the limited estimates available, predatory practice is a growing threat within the sphere of academia.

Overcoming Academic Fraud

Academic fraud is thus perpetrated internally by researchers through research misconduct, but also externally through organizations that interface with academia to both support dubious practice and gull the unsuspecting. The degree to which these practices occur is another question entirely. It would appear at face value that such fraud is on the rise in academia but the evidence is unfortunately scant.

One major question in all of this is whether or not academic fraud represents merely the tip of the iceberg. Titus et al., (2008) estimate 2,325 potential research misconduct cases a year, far outstripping the yearly number of cases reported to the ORI by a factor of nearly two. Shen and Björk's (2015) towering estimate of 11,873 journals that meet Beall's stringent criteria highlights the volume of publications attempting to muscle in on an industry thought to be worth \$74 million (Roberts, 2016). Countering it is also difficult. Each academic or predatory publisher caught is one of hundreds more that remain undetected. As academia has proliferated over the past few decades and new academic centres have emerged in China and India, the scope for fraudulent practice has only gotten wider. Both China and India are known to be susceptible to

research fraud due to the way their funding, career paths and reward schemes rely on the quantity of publications produced by a researcher (Hvrstendahl, 2013; Sabir et al., 2015; Patnaik, 2016). As academic funding becomes ever more scarce, research misconduct will only proliferate. In tandem with this competition rises a market for predatory organizations to make money, preying on academics desperate for recognition and publications to advance or secure their careers. Such fraudulence has dire ramifications on the perception, significance and purpose of academic practice (Table 2). It needs to be curbed in order to ensure that academia remains rigorous, open and trustworthy to the public and policy-makers. However, doing so may be a near impossible task, complicated by three major drivers.

Impact	Description	Example
Loss of Funding	The act of ‘embezzling’ money from funding bodies takes valuable funding away from meaningful projects.	Eminent psychologist Diederick Stapel was thought to have wasted over €2 million in research funding over the course of this fraudulent career (Stroebe et al., 2012)
Career Destruction of Research Associates	Supervisors, co-authors and other associates have their careers damaged or ended by association with the fraudster.	Mongeon and Lariviere (2016) found that 27.6% of innocent collaborators in biomedicine had their careers ended as a result.
Damage to Reputation of Fields	Single or multiple fraud cases lead to a field being associated with fraud and poor practice.	The scandal of Fujimura and his fake Jomon archaeological findings caused worldwide scepticism of Japanese archaeology for some time after (Pellegrini, 2018).
Academic Retrogradation	The reintroduction of false ideas and ‘pseudo-scientific’ cults propagated through fraudulent research and publication avenues.	Carl Baugh and his faked human footprints in fossil trackways has encouraged the proliferation of Creationism around his Creation Evidence Museum (Ruffell et al., 2012).
Agenda-Driven	The manipulation of the truth by interested parties through bribery to publish false articles or the obfuscation of true evidence.	The Glaxo-Smith-Kline anti-depressants scandal in which the company bribed researchers and manipulated trials to obfuscate the negative effects of paroxetine and increase sales (Doshi, 2013)
Death	The death of the researcher or their associates by suicide or other means.	Associated with the Fujimura scandal, the reputational shame and accusations of fraudulence against Mitsuo Kagawa, an eminent figure in the discipline, led to his suicide (Pellegrini, 2018).

<p>Societal Harm</p>	<p>The harm caused by fraudulent research to individuals and wider communities by false or misleading research.</p>	<p>Breuning’s falsified research supporting the use of Ritalin in treating hyperactive behaviour in mentally retarded children, having dire state-wide influence on treatment of such conditions (Byrne, 1988).</p>
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Table 2: The Impacts of Academic Fraud on Academia and Society.

The first is that the autonomy given to academics to pursue their research without any form of audit or review enables this behaviour. This gives researchers the freedom required for cutting-edge research but ultimately enables opportunities to commit research fraud, close colleagues trusting them to hold true to the intrinsic values of academic rigour. This issue is made particularly acute by the comparative size of modern ‘mass academia’, meaning that it is extremely difficult to keep track of what any individual researcher is doing. This naturally makes it far easier for individual fraudsters to slip through the cracks.

The second, as discussed by Goldstein (2010), is that academia does not reward the scrutiny of existing research. While a rebuttal of a controversial paper may be welcomed by a few authors, it is unlikely to accrue the prestige and academic merit that a metaphorical ‘cure for cancer’ would have. In simple terms, novelty trumps scrutiny. This ultimately runs counter to the principles of so-called ‘Popperian science’, the disproving of and replacement of flawed theories with better ones through empirical investigation, the ideal practice in the sciences (ibid). Thus, rather than delicately chipping away at ignorance, the only way to accrue academic merit in the modern age is to fundamentally change how fields operate (Pellegrini, 2018). However, there are only so many innovative ideas to go around, driving the most ambitious to cut corners on the road to success and secure their own slice of eponymy, as attested by Stapel (2014).

The final driver is that of the ‘publish or perish’ paradigm. A great many authors have taken note of the modern trend towards IF in academia and its importance career progression (Carafoli, 2015; Eisner, 2018). Bibliometric index and IF targets must be met at critical career points if one wishes to stay within academia. In the UK, the run up to the Research Excellence Framework has rapidly become a time of stress in which high-quality papers must be published in bulk if an institution wishes to secure a greater proportion of future funding (Research Excellence Framework, 2019). Failure to provide often places one’s career in jeopardy. The situation is exacerbated in developing scientific communities, such as China and India, where publication quantities and the IF of journals are critical to even survive in the competitive academic climate, on top of the cash bounties offered for publishing in foreign journals for Chinese researchers (Hvristendahl, 2013; Patnaik, 2016). Researchers may seek to

keep up with the competition by fabricating positive results to force a publication while others may employ the services of predatory publishers to expedite their career. The up-front costs for such ‘publications’ are small change compared to the rewards of a tenured position. Thus, the academic rat-race is an eternal driver of fraudulent practice, a self-reinforcing cycle in which the push for ever higher bibliometric standards results in those who fall behind resorting to underhanded tactics to keep up.

Between these three drivers, incentive to defraud becomes an irrevocable part of academia unless major reform is actuated. As academia has proliferated, old systems of ensuring quality research are straining to keep up with the rate at which new research is being carried out. It is this continual deluge of research that makes research fraud particularly difficult to detect. This is not to say that this academic fraud cannot be fought. On the contrary, such fraud can be mitigated through a number of means. These will now be explored, and their advantages and shortcomings discussed. These can be broadly divided into methods of detection and method of prevention.

Detecting Academic Fraud

The ‘gaze of relentless honesty’, as Goldstein (2010) terms it, is the ultimate tool in academic practice. This paradigm asserts that fraud will ultimately be detected regardless of the lengths gone to hide it. Eventually, some truthful researcher will scrutinize the work or its derivatives, find the error and trace it back to the source and out its fraudulence. By sheer weight of evidence, the unstoppable behemoth of academia will inexorably resolve its own inherent issues, a popular idea in the sciences. Unfortunately, in reality, this is not the case (Stroebe et al., 2012). Many fraudsters remain undetected for the majority of their careers and are then not found out because of the ‘gaze of honesty’, but because someone with inside knowledge knew that they had faked it. Thus, academia is not as self-corrective as one would hope and must be assisted by enabling research communities to more readily detect fraud. Here, these measures will be scrutinized.

Peer Review

Peer review is regarded as the ethical fulcrum of academia (Goldstein, 2010; Das, 2016), a vigilant guardian that confers the seal of integrity upon a piece of research. Unfortunately, the guise of peer-review is exploited by predatory journals to protect themselves from suspicion, many practitioners faking positive reviews on flawed research (Berger and Cirasella, 2015). Even under proper peer-review, many cases of fraudulence still slip through the net, driven by a lack of understanding of

the subject, haste or conflicts of interest (**Smith, 1988**). Long-term research misconduct can also be surprisingly difficult to detect. Stapel's submissions to APA journals went through 25 different editors, making it unsurprising that no-one thought something was off (**Crocker and Cooper, 2011; Stroebe et al., 2012**).

The system has been criticized heavily for its slow pace, its lack of transparency, the unrewarding nature for reviewers, the potential for unethical practice by both reviewers and editors and, most importantly, its inability to detect fraudulent behaviour (**Smith, 2006; Stroebe et al., 2012; Das, 2016**). Ultimately, these shortcomings lie with the fact that the editorial system is overwhelmed by the 'publish or perish' mentality that dominates wider academia. Editors are faced with difficulties in finding expert reviewers, coupled with a need to maintain a rapid turnaround on an overburdened review process. This can lead to the assignment of an unsuitable reviewer, resulting in rejection due to a lack of knowledge or conflict of interest, or even blind acceptance without scrutiny (**Haug, 2015; Das, 2016**). Many publishers request that authors recommend reviewers, inviting peer-review fraud all too easily (**Haug, 2015**). This can be abused, as proven by the fabrication of hundreds of reviewers by Peter Chen for sixty of his own articles (**Ibid**). In terms of predatory practice, the slow nature of peer-review conflicts with bulk acceptance to quickly harvest APCs for profit. Many faux-editors fabricate peer-reviews with light comments to expedite the publication process and thrust surprise charges on the unfortunate authors (**Beall, 2016**). Some editors utilize faster forms of publication, such as post-publication review or portable review, to shorten the process. This sacrifices article quality to save time, with the expected consequences (**Das, 2016**). There is also little incentive for reviewers to comply, save advance knowledge of upcoming research, consigning the task to the lowest priority. Guest editors are also problematic, often allowed to invite their own reviewers without vetting. The Indian publisher Hindawi came under fire for this, three editors inventing reviewers which resulted in the publication of 32 articles via falsified review (**Haug, 2015**).

While peer review may be under strain, its problems can be mitigated. Reviewer fraud can be mitigated by verification procedures for reviewers and the development of databases containing trusted, subject experts willing to carry out proper peer review (**Das, 2016**). Even offering greater rewards to reviewers, like free subscriptions, cash bounties or employing reviewers as staff may encourage greater scrutiny of articles, although does potentially encourage poor peer-review practice to simply reap the rewards (**Ibid**). Others advocate the return of open review, that in which the identities of both reviewer and author are openly declared (**Das, 2016; Polka et al., 2018**). However, this introduces strong potential biases in

review as a result, particularly if the two parties have conflicting interests. Other alternatives include services that enable faster reviews and publications. Services like Faculty of 1000 Research (F1000Research) enable near-instant publication on their platform with completely open review. All readers may see reviewer comments, rebuttals and user comments on the article, the author being strongly encouraged to revise continually. The service PubPeer also enables researchers to anonymously comment on research papers and authors to respond to their queries. A quick perusal immediately yields many discussions on the authenticity of figures. While publication before review is risky, such transparency enables a poorly rated paper to be discarded by a research community. Such a service for general review may provide a positive future for peer review, enabling the wider academic community to more readily dissect research and detect malpractice.

Replication

Replication is considered to be the cornerstone of scientific practice. When a ground-breaking new result is announced, other researchers flock to attempt to replicate and test their validity. This approach has been fundamental in detecting many cases of research misconduct and pathological science. For example, the fabrication of Victor Ninov's Element 118 was uncovered when others with more sophisticated equipment failed to find similar results via the same method while the excitement over cold fusion was cooled by an inability to replicate the same heat release (**Goldstein, 2010**). Replication is one of the best ways to detect research fraud in the sciences but can be challenging. Medicine is thought to be prone to research misconduct due to the difficulty of replicating trials and studies, given the natural variation among research participants (**Eisner, 2018**). Many fraudulent researchers thus seek to abuse this under the expectation that their work will never be deeply scrutinized. There is also little incentive to replicate studies. Due to the fact that innovators accrue greater academic merit, replication studies are of little interest and are unlikely to have much impact in their respective discipline (**Stroebe et al., 2012**). There is also a prejudice against replication studies by both editors and authors, the former not wanting to waste editorial space on low impact papers and the latter due to the relative waste of time in pursuing them (**ibid**). The result is that fraudulent research may never be uncovered due to a lack of interest in its verification. Replication is also very difficult for some fields. Studies in the social sciences, particularly in qualitative research, are by their nature unreplicable. For example, an interview study leveraging unstructured interviews would require the exact same interviewees to follow an identical line of conversation. This is naturally impossible. Replication is also a difficult task in psychology, an issue for which it has come under

considerable fire for the prevalence of questionable research practices and the low statistical power of many studies (**John et al. 2012; Stanley et al. 2018**).

The issues with replication are mostly a product of publication politics. Therefore, the solution is simply to incentivize the practice of replication or provide special dispensation to articles that replicate previous work in attempt to validate them. Rewards for doing so may help, but again may encourage authors to produce low effort replication studies to reap the rewards *en masse*. More beneficial is that such studies find a home away from editorial prejudice. The rise of OA has enabled such practice as journals no longer have to worry about space/impact ratios, allowing the publication of papers that might be of lesser interest. PLOS One advocates this particular standard in its journal information, as do many other OA publishers (**PLoSOne, 2019**).

Whistle-Blowing

In the battle against research misconduct, ‘whistle-blowing’ is often regarded as the ultimate weapon (**Crocker and Cooper, 2011; Stroebe et al., 2012; Gross, 2016**). The majority of cases of research misconduct are not uncovered by review but by colleagues or students of the perpetrator. For Stapel, suspicions were first raised by post-doc students which went unheeded for some years before being properly addressed (**Stroebe et al., 2012**). In the case of Breuning’s research fraud on Ritalin treatments, Sprague of the University of Illinois, a former mentor, raised the issue due to his realization that Bruening could not have physically done his claimed experiments (**Sprague, 1993; Stroebe et al., 2012**). As in most situations, however, whistle-blowers are often treated badly and suffer heavy career penalties. A study by the ORI showed that 69% of whistle-blowers suffered negative outcomes as a result and 43% reported that their institutions discouraged them from reporting it (**Titus et al., 2008; Gross, 2016**). Sprague himself suffered for his accusations, initially being investigated and later having his NIMH funding cut (**Sprague, 1993**). Institutions will often defend their prized researchers, particularly if the accusing party is fairly low in the hierarchy (**Eisner, 2018**). If such individuals are discouraged from reporting misconduct, a valuable tool in the fight against research misconduct may be forever lost.

Many authors advocate whistle-blower protection as a solution (**Titus et al., 2008; Stroebe et al., 2012; Mavrogenis et al., 2018**). The whistle-blower should be able to anonymously report their suspicions to a relevant institutional body who will then carry out an investigation free from bias into the report. The ORI fully endorses the protection of whistle-blowers, ensuring that their reports are taken seriously and are safe from retaliation from other staff (**ORI, 1995**). The ORI only has power in cases where the

research is federally funded and thus has little jurisdiction outside of the US. COPE provides some insight into how publishers should investigate claims of research misconduct but outside of this there is little legislative power to protect academic whistle-blowers elsewhere in the world.

External Review Bodies

The foundation of external bodies that exist outside of institutional grounds has been a positive move to deal with research misconduct. The first of these 'arbiters of academia', the ORI, have long worked to investigate cases of research fraud since 1992 (**Goldstein, 2010; Gross, 2016**). The ORI has done sterling work in reviewing cases of research fraud, but few other governmental bodies have emerged in support. COPE was created some years later in 1997, a non-profit organisation focussing more broadly on publication ethics over investigation. It instead advocates outreach and informing the academic community on ethical practice and has no real power to directly tackle research misconduct (**COPE, 2019b**). The UKRIO provides similar support, specialising in the provision of advice and guidance for bodies regarding poor research integrity (**UKRIO, 2019**). These groups ultimately provide academics, institutions and potential whistle-blowers with the tools they need to process reported cases of research misconduct. Since the establishment of the above organizations, the majority of European and North American countries now have established national ethical bodies for science (**Shewan and Coats, 2012; Mavrogenis et al., 2018**). To move forward, such bodies also need to be established in emerging science capitals in the developing world to help raise awareness and curb the rise of scientific misconduct.

However, the establishment of these organisations and the time for individual investigations can be time-consuming. Many cases, despite obvious research misconduct, may never result in retraction of the fraudulent work (**Fang et al., 2012**). For instance, Grieneisen and Zhang (**2012**) report that only 38% of their noted retraction cases were ordered by the ORI. Thus, these external bodies, particularly those with lesser power to investigate, may require more legal power to pursue, investigate and forcibly act on cases of severe research misconduct. India's problems with research misconduct represent the issue with the lack of such a body, as highlighted by Patnaik (**2016**). Powerful institutional figures are, in effect, immune to accusation as their influence is too powerful to cause any form of change from within the institution. As a result, these external bodies are necessary to mediate the investigation process.

Digital Solutions

Academic fraud can also be prevented using digital tools, databases and services that can help editors identify more egregious cases of fraud. Plagiarism software, such as commercial services like TurnItIn, are a defence against simple plagiarism via text matching, but require human-input to confirm whether or not this is truly the case. These solutions also do not have access to every academic source ever created, meaning that some blatant plagiarism may evade detection. While such solutions are useful in detecting low-effort plagiarism, they are less effective in the face of translated article flipping, a practice in which the same paper is published in multiple languages as detailed by Hvristendahl (2013). Author identification services, such as ORCID, are also a useful tool that allow editors to run quick identity checks on authors, their affiliated publications and the veracity of their submission. These services expedite the initial screening process for editors and assist in weeding out poor quality research. Of course, these tools are unable to properly combat more insidious attempts at falsification and fabrication if they are not accompanied by scrupulous peer-review. The widespread use of such tool can also lead to adversarial relationship between student and teacher or indeed author and publisher. If harsh scrutiny is the baseline, trust among academia becomes negligible to the detriment of all.

To this end, more effective tools are required. Some researchers are creating new and innovative solutions to research fraud, such as tools to identify fraudulent publications by their writing style. Markowitz and Hancock (2015) found that fraudulent writers used considerably more jargon, included greater quantities of citations and generally had lower readability, properties that hinder readability and the likelihood of detection. Braud and Søggaard (2017) attempted to apply this knowledge algorithmically, their solution showing identification rates on fraudulent papers of up to ~70%. Others have also developed solutions to identify doctored images, a common form of falsification in fraudulent papers (Bik et al., 2016; Mavrogenis et al., 2018). For instance, Bucci (2018) carried out a meta-analysis of open access papers in the Pubmed database, finding that 6% of the sampled papers had some form of manipulated image. Likewise, Bik et al., (2016) carried out an analysis on over 20,000 articles from biomedical papers from 1995 – 2014, finding that 3.8% had doctored images, at least half of which appeared to be suggestive or deliberate. These solutions at this stage are relatively immature but, with time and refinement, will become essential tools in detecting research fraud.

Incentivization

Another method of tackling research misconduct and predatory practice would be to establish a body, a group of funded 'anti-researchers', whose primary purpose is simply to scrutinize the research of others or investigate and identify suspicious publishers. Obviously, the sheer volume of research produced per annum far outstrips what a small body could feasibly cover but it could help to unmask the most obvious cases of academic fraud and act as a deterrent against future fraud.

This idea is ultimately flawed, however. These 'anti-researchers' would need to be perfectly unbiased or else introduce the rabid pursuit of work that contradicts their specific viewpoint. The act of rewarding the disproving of poor-quality research also invites a 'witch-hunter mentality', where all research starts to be viewed as poor quality to reap the rewards. Such practice would invite a community of scepticism into academia, where the default reaction to innovation is immediate suspicion. For the good of all academic practice, this should be avoided at all costs.

Preventing Academic Fraud

As in all things, perhaps the best method of curbing academic fraud is to prevent it in the first place. Achieving this would require changes in academic attitude and practices, a process that would take considerable time to achieve. The net result of this would be a community of researchers who instinctively look for the tell-tale signs of misconduct but ideally not one of pure scepticism to every novel finding. These measures shall now be examined.

Awareness

Spreading the awareness of academic fraud is a tool with potential. Making researchers aware of the signs of research misconduct enables research communities to police themselves. As discussed above, whistle-blowers are a major source of reporting research misconduct and providing researchers with this knowledge arms the wider community with the tools to act. This can be enabled through training courses carried out by universities, labs and institutions that make researchers aware of the existence of misconduct and mandate the maintenance of records of experiments and data sources (**Gross, 2016**). Ensuring that students and staff are all trained with a solid understanding of research ethics and publishing will ensure that the next generation of researchers are aware of how to avoid and detect misconduct (**Crocker and Cooper, 2011; Gross, 2016**). The number of institutions carrying out such training is growing, the National Institute of Health (NIH) for example having enforced mandatory attendance on responsible research conduct courses since 2011 (**Gross,**

2016). The effectiveness of these awareness approaches is however unclear. Bretag et al. (2013) for example report a survey of academic integrity among students at six Australian universities. They found that while most students were satisfied with the information provided on avoiding breaching academic integrity, many did not feel confident in how to avoid such breaches. This was low particularly for both international students and postgraduates. This suggests that spreading awareness does not necessarily translate into an avoidance of academic fraud. Moreover, perhaps spreading awareness indirectly gives students the gateway to academic fraud, providing knowledge of forbidden strategies to success.

Awareness of research misconduct and specific cases can also be spread more colloquially through blogs, websites and discussion. Retractionwatch is a well-regarded blog which makes its mission to spread awareness of cases of research misconduct to the wider scientific community by reporting cases of article retraction (Gross, 2016; Retractionwatch, 2019). Forums and discussion boards based around academic practice, like ResearchGate, also enable researchers to discuss major cases and spread awareness. This highlights fraudulent research to other disciplines, who may inadvertently cite the paper in error, particularly as many papers are never retracted and continue to accrue citations (Fang et al., 2012; Griensen and Zhang, 2012; Gross, 2016).

Spreading awareness is also essential in dealing with predatory journals and conferences, who prey on less-experienced researchers. The former champion against predatory practice was Jeffrey Beall, publisher of the infamous 'Beall's list' since 2008, which listed many predatory publishers to be avoided at all costs (Bohannon, 2013; Beall, 2016). Beall's list was a useful tool in recognising blacklisted journals but was the subject of much controversy. Many authors claimed that Beall was biased against foreign journals and that some were not outright fraudulent, just guilty of sloppy editorial practice (Berger and Cirasella, 2015; da Silva, 2017). Regardless of his legacy, Beall's list has not been updated by the author since 2017, although the cause is uncertain (da Silva, 2017). His work still provides a good basis for future efforts and has at least highlighted the depth of publisher malpractice. Predatory conferences have proven more difficult to keep track of. A list of guilty conferences was kept by the website 'Scamorama' under the webpage title 'Con-ference', although this list has seemingly been abandoned since 2013 (Bowman, 2014). Another site, the 'Dolos list' run by Prof. Alexandre Georges, also lists a great many predatory publishers and conference organizers and still appears to be being maintained.

Awareness of the issue has also been spread in part due to a number of high-profile sting operations into suspicious journals. The first of these was carried out by Bohannon (2013) of the journal *Science*, who sent off a paper on a miraculous cancer-curing lichen to 304 open access journals. The paper was written to contain many fatal errors that would never survive proper peer-review. Alarmingly, over half of them accepted it, 60% offering no peer review and belonging to big name publishers like Elsevier and Sage. Others have attempted such operations, including the charmingly titled 'Get me off your fucking mailing list', accepted but not published in the *International Journal of Advanced Computer Technology* by Mazières and Kohler (Carafoli, 2015). Alternatively, 'Cuckoo for Cocoa Puffs? The Surgical and Neoplastic Role of Cacao Extract in Breakfast Cereals' by Pinkerton LeBrain and Orson G Welles, an article consisting of five pages of randomly generated gibberish, was accepted by 17 out of 37 open access journals (Carafoli, 2015). These sting operations raise awareness of the threat of predatory publishers but ultimately do little to stem the tide as more emerge in their stead. While awareness highlights the issue, many will still inevitably succumb to such under-handed tactics.

Data Repositories

Data repositories serve an important role in both allowing detection and acting as a deterrent towards those considering data falsification and fabrication. Many publishers now encourage authors to submit their datasets to data repositories and archives to facilitate replication by others and aid data transparency (Crocker and Cooper, 2011; Stroebe et al., 2012), including services such as Dryad or figshare for general data among many other more subject specific repositories: Nature provides a list of approved databases (Nature, 2019). This deters fraudsters from trying to submit false data, as they can easily be detected at a glance. In many high-profile misconduct cases, the perpetrators claim to have lost, deleted or misplaced the original data, as in the cases of Stapel, Darsee and others (Stroebe et al., 2012).

Mandatory implementation of this practice could be advantageous but comes with its own set of difficulties. Submission to digital databases is a rare practice due to many author's unwillingness to share their data. This may be due to natural fears of scrutiny but also due to the possibility of scooping, in which other authors may appropriate the data prior to full publication and publish it themselves (Stroebe et al., 2012; Gross, 2016). This threat is exacerbated by predatory publishers and, while little documentation of such abuse can be found, there is likely an illicit trade of data scooping and paid publication in poor quality journals. It also runs into conflict when dealing with data from human participants. Ethical approvals typically mandate a maximum data storage time, which under

the General Data Protection Regulation (2018) in the UK requires justification of long-term storage, typically for no longer than is necessary. This means that such data is impossible to store beyond the time of the initial study, which could in turn be used as an excuse for fraudsters to cover up their acts and prevent replication.

Institutional and Editorial Policies

A major foundational issue in dealing with research misconduct historically was that institutions had no idea how to deal with it. Many did not want to antagonize their prized academics, taking a substantial amount of time to act when concerns were raised. The fraudulence of Vijay Soman at Yale was a drawn-out affair in which the accuser, Brazilian physician Helena Wachslicht-Rodbard, demanded an audit of a plagiarized manuscript by Soman and his mentor Felig in 1978 (**Broad and Wade, 1982; Gross, 2016**). The accusations took until 1980, in which time Wachslicht-Rodbard left for hospital practice, to be properly audited. The review, carried out by Jeffrey Flier, revealed both plagiarism and fabrication in the work of Soman and Felig, vindicating Wachslicht-Rodbard (**Lock, 2001**). Similarly, Sprague's accusations against Breuning began in 1983 and the investigation took until 1988 to be completed, ending in a prison sentence for Breuning (**Sprague, 1993**).

These large delays in acting were mostly in part due to a lack of a formal procedure for receiving and investigating reports. As heard by Al Gore in the misconduct hearings that established the ORI, researchers believed that misconduct was to be dealt with in an informal fashion by the scientific community (**Gross, 2016**). The issue with this approach is that it relies on the personal involvement of researchers with the free time to investigate, resigning the task to the bottom of a list of competing priorities. In the Soman case, the main delay was that the auditor, Joseph Rall, was too busy at the time. As the need to review research misconduct grew, it became necessary to introduce institutional policies to deal with these accusations. These outline the process by which institutions receive reports of misconduct and how and when they will be investigated in an official capacity. This creates an institutional impetus to resolve the issue quickly, rather than relying on researchers to sort it out themselves. This places a higher priority on resolving cases of misconduct and expedites the overall process.

Similar problems are encountered by editors with regards to fraudulent research. Most journals stipulate that the author is responsible for retracting their papers by request (**Shewan and Coats, 2012**). This is reasonable, considering that journals do not have the manpower or expertise to investigate potentially fraudulent articles and force their withdrawal. The issue is that most fraudulent authors rarely go to the

effort of retraction. This means that many papers exist in limbo, outed but not retracted, as the journal has little power to forcibly remove it. This problem is being solved by the introduction of editorial policies that contain contingencies that allow the editor to retract articles in cases where an article breaches their standards. Shewan and Coates (2012) for example supply a series of eight principles of ethical publishing (Table 3) for the International Journal of Cardiology that enable forced retraction in the case of research fraud. The adoption of editorial policies in handling research misconduct is common in journals, many adopting the recommendations of bodies like COPE, and remains a key defence against research fraud (BMC, 2019; NatureResearch, 2019).

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1. That the corresponding author has the approval of all other listed authors for the submission and publication of all versions of the manuscript.
 2. That all people who have the right to be recognized as authors have been included on the list of authors and everyone listed as an author has made an independent material contribution to the manuscript.
 3. That the work submitted in the manuscript is original and has not been published elsewhere and is not presently under consideration of publication by any other journal other than in oral, poster or abstract format.
 4. That the material in the manuscript has been acquired according to modern ethical standards and has been approved by the legally appropriate ethical committee.
 5. That the article does not contain material copied from anyone else without their written permission and that all material which derives from prior work, including from the same authors, is properly attributed to the prior publication by proper citation.
 6. That all material conflicts of interest have been declared including the use of paid medical writers and their funding sources.
 7. That the manuscript will be maintained on the servers of the journal and held to be a valid publication by the journal only as long as all statements in these principles remain true.
 8. That if any of the statements above ceases to be true the authors have a duty to notify the journal as soon as possible so that the manuscript can be withdrawn.

Table 3: Editorial Policy of the International Journal of Cardiology (Shewan and Coats, 2012).

Punishment and Deterrence

Arguably, one of the main drivers of academic fraud is that it is not normally punished. From the perspective of the honourable academic, the shame of being caught in the act of fabricating data or abusing unscrupulous publishers is punishment enough. Some do get more severe punishment. Stapel was hounded by the media for years following news of his fraudulence being broken (Stapel, 2014) while the infamous Darsee

moved into a clinical position in a hospital before having his medical license revoked a few years in the State of New York (**Gross, 2016**).

Others get caught in the act and comparatively get punished lightly for academic malpractice. This problem is common among Indian universities, as documented by Patnaik (**2016**). The author highlights that the power of these individuals protects them from severe punishment. Gupta represents such an example, an earth scientist who is thought to have fabricated images, stolen specimens and lied about palaeontological finds over his career. After being accused by Talent (**1989**) and Lewin (**1989**), who first brought the fraud to attention, it took nine years, including a four-year enquiry, to prove his falsehood. Yet the only punishment received was a denial of further promotion and being stripped of any administrative responsibilities, continuing at Panjab University until his retirement in 2002 (**Ruffell et al., 2012; Patnaik, 2016**). The price for such mass fraudulence should have a heavier cost, which is likely a motivator for research fraud. A similar driver can be elucidated for predatory publishers. What they do technically is not illegal. They may provide a service for an extortionate cost at a poor level of quality, but the outcome is still a published paper or a 'legitimate' conference event.

This highlights the major problem with academic fraud. There is no legislative power that enables its practitioners to be charged and tried. There are a limited number of researchers that have been convicted of research misconduct. Reuben, Poehlman and Breuning all received prison sentences. Reuben received six months in prison on top of \$415,000 in fines and payments, Poehlman one year in prison and Breuning 60 days in a halfway house along with a repayment of \$11,352 (**Sprague, 1993; Stroebe et al., 2012**). Hwang Woo-Suk, formerly of Seoul National University, was sentenced for two years for embezzlement, falsification of stem-cell research and breaking bioethical laws (**Cyranoski, 2009; Stroebe et al., 2012**). All of these examples however include major breaches of law rather than just falsification, highlighting that only the most heinous acts can be legally punished. Many cases are never pursued further and proving that the law has been broken is difficult in cases of research misconduct, as highlighted by Stroebe et al., (**2012**). Perhaps introducing legislation that allows research misconduct to be punishable under law could provide a more threatening deterrent to fraudsters.

The disadvantage of such an adversarial approach is the breakdown of trust between academics. The linchpin of training among academics is the relationship between the supervisor and their student. This relationship relies on some modicum of trust. When that trust breaks down through suspicion, careers are put into question and futures at stake, as evidenced by the Stapel case. If research fraud becomes a punishable crime, the risk

is greater. The relationship may shift to that of the policeman and the criminal, the supervisor scrutinising the student for signs of misconduct. Little meaningful development can happen under such conditions.

Transparency Indices

Another interesting concept is the introduction of Transparency Indices, an externally judged value of the veracity of a journal's publishing practice, as envisaged by Marcus and Oransky (2012), the authors of the RetractionWatch blog and discussed by Sabir et al., (2015). Such a metric, much like IF, would be an identifier of the journal's review capabilities. Marcus and Oransky (2012) highlight that such a metric should ideally cover whether or not it is peer-reviewed, the average number of reviewers, the review time, acceptance rates and details of appeal processes. They would also highlight other variables, such as the names and expertise of the editorial board, costs, data availability, details of review plagiarism checks, its policy on dealing with misconduct and the structure of its corrections and retraction notices. Many journals do supply some, if not all, of these criteria. For example, PLOS ONE provides much of this data in its journal information (PLoSOne, 2019).

Such transparency indices would have an obvious effect in mitigating the impact of predatory publishers by using peer-review and editorial transparency as a proxy for journal quality. The first layer of protection is the fact that well-meaning journals who wish to keep a good image would accept such a metric, while those less salubrious would prefer to ignore such a metric, providing an immediate 'black spot' on that journal's veracity. Secondly, the value is a useful tool in identifying poor editorial practice and encouraging improvement among innocent but sub-standard journals. Inevitably such indices would need some form of centralization to an organization which can verify and assess them, or else predatory publishers would merely advertise a false value. However, for now a transparency index is not forthcoming. The conversation continues, albeit slowly, on the RetractionWatch website but its emergence remains to be seen (RetractionWatch, 2019).

An End to 'Publish or Perish'

Perhaps the ultimate end to research fraud is simply to ease the metaphorical gas pedal on the race for IF and citation metrics. As many authors have argued, the acquisition of bibliometric domination is a major driver of academic fraud (Davis et al., 2007; Carafoli, 2015; Haug, 2015; Sabir et al., 2015; Das, 2016; Eisner, 2018). In the vast majority of research misconduct cases, the perpetrator has admitted that they were under career pressure, Stapel by his own self-admission (Goldstein, 2010; Stapel, 2014; Gross, 2016). In a similar manner, predatory publishers are fed by

researchers looking to enhance their profile with more publications. The rise of services to feed this illicit trade of poor quality research as highlighted by Hvristendahl (2013) in China is a symptom of the depth of this problem within academia and one that needs to be mitigated to stem the tide of research fraud.

How this can be achieved is a much harder question. IF and citation metrics are now an irrevocable part of academic practice and necessary for justifying the value of research funding. To ignore such metrics, however noble, is to risk losing ever-elusive funding or being passed over for promotion, a fact that almost assures the continued dominance of the 'Publish or Perish' paradigm (Carafoli, 2015). Removing such metrics from the equation is advocated by many (Carafoli, 2015; Haug, 2015; Gross, 2016). However, even if IF was to be discarded as a metric little would change. The advantage of IF is that it provides a quick, informative value of the research quality of a journal, allowing rapid judgement of its worth. If IF were to be removed, another metric would simply take its place. Certainly a number of these would-be replacements are already in common usage. The h-index, a value that relies more on article quality through frequent citation than simple mass publication, is becoming a standard metric. Altmetric also factors in impact beyond academia, the score being tied to news articles, social media interaction, blog posts and citations. These values are arguably better than IF, but ultimately the same. Another number to quote that boils down the complex nature of academic practice into a basic, readable metric.

Some authors and journals are beginning to move away from a dependence on bibliometric indices, however. Many researchers and organizations have signed the Declaration of Research Assessment (DORA), numbering 1553 individual organizations including the University of Oxford, the Public Library of Science (PLOS) and BioMed Central (BMC) and over 15,000 individual researchers (DORA, 2019). Developed in 2012 during the Annual Meeting of the American Society for Cell Biology in San Francisco, DORA advocates that IF is not an accurate or transparent measure for assessing research quality. They recommend to funding agencies, academic institutions, journals, organizations and researchers that; 1) journal-based metrics should not be considered for funding, appointment or promotion; 2) that research be assessed on its own merits rather than where it was published; 3) we need to capitalize on the opportunities provided by online publication to overcome spatial limitations on journal space and the exploration of new indicators of significance and impact. While the impetus behind this scheme grew rapidly after its inception, its impact on publishing and funding practice remains to be seen. Among these signees are many journals, such as eLife, who completely reject the use of bibliometric indices. Its former editor-in-

chief, Randy Scheckman, gave an impassioned statement in 2013, claiming that high IF publications were in effect dominating scientific thought and progress (Carafoli, 2015). Regardless of whether or not this statement is true, minimising the reliance on bibliometric indices is certainly an important first step in mitigating the worst of research fraud.

Summary

Over the course of this review the world of academic fraud has been explored, consisting of the internal realm of research misconduct and FFP, fabrication, falsification and plagiarism, and the external predatory realm of predatory publishers and conferences. Both practices appear at the surface value to be on the rise, although research into analysing their temporal trends give mixed results. What is certain is that it represents the tip of an iceberg of incalculable menace that threatens the very foundation of academia as a practice.

However, tackling the issue is complicated by a number of facets. The first is that academic practice is guided by freedom of thought, enabling calculating fraudsters to easily evade detection. Next is that the reward system of academia, success and eponymy through big ideas, directly opposes academic ideals, by repeating and confirming results in additive fashion to refine theory and practice. Finally, the bibliometric machine is the engine that drives academic fraud and is a system that encourages researchers to cut corners to achieve publication in high IF journals for job survival, funding and promotion.

Methods of both detecting and preventing academic fraud were then explored. For detecting academic fraud, the flaws inherent in peer review were highlighted and potential solutions outlined, alongside the importance of placing principles of replication at the centre stage of academic practice. The importance of whistle-blowers as a key identifier of academic fraud was also highlighted in addition to the importance of external review bodies for investigating and acting on charges of research misconduct. Other resources like digital tools, such as plagiarism and image alteration detection software, can be vital in detecting low effort spam while incentivization could promote the active pursuit of research fraud rather than passive indifference.

To prevent academic fraud, interventions centring on changes of attitudes were described. The primary tool against research fraud was that of awareness, spreading the knowledge of such practices so researchers can recognise the signs of research misconduct and predatory publishers. The importance of data repositories to deter the falsification of data was also explored, although mandatory provision would risk the 'scooping' of data. Institutional and editorial policies could also be a useful tool, ensuring that

institutions and journals have established workflows to deal with cases of misconduct and order their retraction if necessary, removing fraud-based taint from academic knowledge. Deterrence through severe punishment is also an option, but one needing the introduction of national legislation to fully criminalize research fraud. Transparency indices also represent a way of mitigating research fraud, enabling authors to easily verify the editorial process of a journal and identify predatory publishers. Finally, the most effective deathblow to research fraud would be the end of the 'Publish or Perish' paradigm, the never-ending rush to publish big or fast to stay in the academic rat-race.

Overall, a bleak picture of research fraud is painted. This is not something to be sat upon, however. Rather, it represents a realization that the current path of academic practice is untenable in order to maintain the high standards of the past. It will require concerted effort to mitigate and stamp out research fraud from academic practice and likely the hard work of many generations of academics to correct the errors that have crept into the academic record. Given time, awareness and advances in methods of detecting, dealing with and preventing academic fraud, a brighter future can be built for academia free from the taint of the omnipresent fraudster.

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