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The crisis of peer review: Part of the evolution of science

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Abstract

Peer review in journals is in crisis, and its current situation and sustainability are increasingly concerning for academics and scientific communities. We identify this crisis as part of an evolutionary step in the continuous development of science, arguing that peer review maintains a central role. We analyse the emergence and historical development of peer review, identifying its role as crucial to the legitimisation of global science, particularly in guaranteeing quality control in the scientific process of massification—despite its flaws. We then focus on the crisis as part of the recent second wave of massification stemming from 'publish or perish' dynamics, which overburden those involved in peer review management and activities. Based on this crisis and given that the alternative models to peer review rely on the same core ideals, we argue that the current scenario represents a golden opportunity for the peer-review process to adapt by correcting some of its known biases, becoming more inclusive and relevant, and gaining recognition for its crucial role in career progression and in the training of the researchers of tomorrow.

1 | INTRODUCTION

It is now commonplace to consider higher education to be in crisis or in a multitude of crises (e.g., Blumenstyk, 2015). Such crises may be related to partial or total changes to established values, norms and behaviours, forming new systems that guide and structure action (Oliver, 1992). The concept of crisis is closely related to the concept

of change because novelty brings a sense of unease, uncertainty, and need for adaptation until it becomes legitimised, interiorised and thereby normalised (Holton, 1987). This concept is well-known in the philosophy of science and is part of the process of scientific evolution (Kuhn, 1962). The transition to newer paradigms or social systems reflects a state of crisis because change is not always easy or beneficial and may even be incompatible with established thinking, routines, and behaviours (Shapere, 1964). The same is true in higher education systems; fundamental cultural and societal aspects of these systems are threatened or perceived to be threatened by new policy or institutional or processual modalities. This is particularly evident when these modalities critically undermine or seek to replace an order that has been in place for a long time (Szadkowski & Krzeski, 2019) and that continues to be accepted as fundamental to the existence and functioning of core activities in such systems (Slaughter & Rhoades, 2004).

This is the case of peer review in contemporary academia and science: it is perceived as critical for scientific practice but faces growing challenges and critique and is therefore in a state of crisis (Petrescu & Krishen, 2022). The difference between other higher-education crises and the peer-review crisis is that while other new paradigms emerge to replace previous paradigms, peer review is recognised as being in a state of crisis without a new paradigm having emerged that can adequately replace it. Peer review has two main roles. One relates to knowledge gatekeeping and the quality control of submitted research findings; that is, peer review strives to ensure that sound, novel and rigorous findings from the research are published and attempts to prevent erroneous findings from driving the advancement of knowledge or being used to design and implement policies and practices that are damaging to societal progress (Severin et al., 2021). The other role of peer review is developmental and relates to the contribution to new research by the authors' peers, involving a collaborative process of interaction between authors, reviewers and editors to improve the overall research effort (Mason & Chong, 2023). Peer review is the golden standard of science and a fundamental pillar of scientific research (Gonzalez et al., 2022), but it faces substantial strains and challenges.

In this article, we analyse the challenges that peer review faces and the possible outcomes of the current crisis.[1] We analyse the peer-review crisis as part of an evolutionary pathway of science and academia. We first identify peer review as a paradigm that broke a previously established paradigm, thus representing an evolution. This follows Malcolm Tight's (1994) assessment of crises in higher education in the 1990s, wherein he argued that such crises are part of an evolutionary process bringing important developments to the higher education system as well as to other systems. We then present and discuss the peer-review crisis based on evidence provided in the literature. Finally, we argue that any new paradigm attempting to replace the role of peer review will be a compromise between existing peer-review practices and new formats rather than a completely new system. The new paradigm is likely to represent a gradual innovation in the peer review system rather than a disruptive transformation and the emergence of something entirely new.

2 | PEER REVIEW AS A NEW PARADIGM

Peer review can be, understandably, mistakenly assumed to be a longstanding component of academic research and science, similar to the scientific method, as both are part of the regular research practice of thousands of researchers (McNaugthon, 1999). Both the application of the scientific method and peer review are activities now taken for granted, regulated by the norms and ethos of scientific practice, and both are closely linked to the expectation that their use leads to scientific breakthroughs and innovation (Spier, 2002). Peer review is a mechanism that represents a stepping stone in the evolution of science, a change that has permitted the development and establishment of science as we know it today in an evolutionary process of continuity and transformation (Shinn, 1999).

The pre-developmental stage of the peer-review practices known today occurred in the mid-17th century, when the Royal Society of London, in its journal, *Philosophical Transitions*, introduced the practice as an informal

process whereby scholars inspected their peers' studies and made recommendations for improvement at the request of the editor, and only when the editor deemed it necessary (Spier, 2002). The practice changed in the mid-18th century, when research materials submitted to the society could be sent to a selected number of members for their appraisal and the decision of the editor was influenced by this appraisal (this practice was also adopted by other societies and their journals, such as by the Royal Society of Edinburgh; Farrel et al., 2017). It is important to note that the authors had no access to the reviewers' reports; all of the relevant information and decisions were centralised with the editor, and editorial decisions were limited to accepting or rejecting the submitted articles (Baldwin, 2017). Some informal correspondence took place between researchers before the submission of articles; however, once the articles were submitted, the majority of authors were not aware of who the reviewers were, whereas the reviewers tended to know who the authors were (a single-blind review process that is still used in journals today). The double-blind review process, whereby neither the authors nor the reviewers know who the others are, was implemented at a much later date. It was only in 1955 that a journal established double-blind reviews as its main form of peer review. According to Pontille and Torny (2014), this pioneering journal was the *American Sociological Review*, which implemented the practice with the aim of minimising author bias. Double-blind peer review was aligned with an increasing consensus in the mid-20th century that a submitted article should be evaluated based on its content, including its novelty and rigour, independent of the reputation of the author(s) and the prestige of their institutional affiliation(s). The double-blind review was gradually adopted in other disciplines of the social sciences and the humanities from the mid-1970s onwards (Cressey, 2014), but it continues to be less adopted in specific disciplines and fields of the natural sciences, engineering, and medicine even today (e.g., Garvalov, 2015). Apart from the single- and double-blind peer review processes (Peh, 2022), the other practices described above remained unaltered, for the most part, for the next 100 to 200 years, underlining the stability of some peer-review practices since the early stages of the system's development. It is important to underline that the peer-review process was extremely slow at this time; there was only one version of the submitted article, and copying it to share with other reviewers was not easy to achieve before the invention and commercialisation of the typewriter. According to Spier (2002), boards of assistant editors were formed, but their main task was to solicit articles to be submitted to the journals, as the journals had more space than articles to be printed.

Not until the mid-20th century did peer review as we know it today become the norm. Between the 17th century and the mid-20th century, reviewers were all internal to the societies running the journals. However, their role gradually changed from gatekeeping the scientific quality and reputation of what was published by the journal of a society (and therefore, the society itself), to gatekeeping the trustworthiness and quality of the entire scientific literature in their respective fields of knowledge (Baldwin, 2017). This ideal was gradually applied to external reviewers as well in the early 20th century, but their use by journals was a slow process (Clarke, 2015). The journal *Science*, for example, only started to use external reviewers after 1940, and this practice did not spread widely until the Xerox photocopier became commercially available in 1959 (Nicoll, 2018). The development of this technology facilitated the participation of external reviewers in the review processes. However, a more pressing reason for journals to resort to external reviewers was the increasing number of submissions to journals that resulted from the mounting resources invested in science and the growing number of researchers in the post-Second World War era (Powell et al., 2017), causing the number of article submissions to rise steadily and the previously vacant space in journals to decrease rapidly, forcing the acceptance of submitted manuscripts to be more selective. The peer review process took a long time, from an article's submission to the publication decision, until the widespread use of the Internet in the 1990s. Articles were submitted to journals, received by the editors and sent to reviewers, sent back to the journals' editors and, finally, returned to the authors, all by post. This took several months, and some articles were lost midway through the process (Lyman, 2013). The negligible replication costs and high speed of exchange permitted by the development of information and communication technologies in the late 20th century reduced the duration of peer review (Lyman, 2013). However, growing scientific specialisation and the increased diversity of topics submitted to journals also prompted journal editors to engage greater

numbers of external reviewers, many from shared and adjacent scientific fields, thereby expanding the disciplinary scope of journals (Spier, 2002).

These changes did not mean, however, that peer review—a practice taken for granted today—was favoured by all. A well-known example of opposition to the practice is Albert Einstein's negative reaction to his first experience of anonymous peer review in *Physical Review*, a leading journal in the field of physics. After receiving the reviewers' comments, Einstein withdrew his paper and never again submitted a paper to *Physical Review*. He remained critical of peer review thereafter (Kennefick, 2005). Thomas Wakley, the founder of the prestigious medical journal *The Lancet*, also had little appreciation for peer review; the journal only started to take peer review seriously in the 1970s (Burnham, 1990). This change was related to practitioners' lack of trust in the quality of the papers published in the journal (Fox, 1991). The rules governing scientific publication changed due to external pressure by practitioners for quality control and assurance to lend credibility and legitimacy to the research produced in universities and was thus supported by academics (Spier, 2002). This contributed to peer review's becoming an essential element of the scientific endeavour and a prerequisite for scientific best practices, and it led to the broad institutionalisation of peer review as an essential practice (Burnham, 1990). The societal and governmental pressures for accountability in higher education and science—particularly those able to impact funding and related policies—and the desire of researchers to be able to influence research funding decisions further stressed the central relevance of peer-reviewing in ensuring the credibility of science (Baldwin, 2018). Peer review has helped science and academia to progress by increasing its perceived legitimacy among both internal and external stakeholders, and the practice continues to be the 'golden standard of scientific publication' (Kovanis et al., 2017: 652). However, it faces challenges that are not exclusive to it but also affect scientific and higher education systems and institutions; specifically, driven by various incentives and adaptation, there is a mounting lack of trust in science, academia, and in the peer review process that ought to be addressed (Horta, 2022).

3 | PEER-REVIEW CRISIS

The peer-review crisis relates to several issues. One of the most frequently mentioned issues pertains to the length of time from submission to decision. Although there has been a substantial decrease in the duration of the review process since the 1980s due to the successive emergence of e-mail and online journal platforms (Lyman, 2013), the review process tends to be long, which causes dissatisfaction among authors. Huisman and Smiths (2017) found that authors tend to rate the peer-review process more positively, even if the decision is a rejection, if the article spends only a short time (vs a long time) under review. Longer review periods and multiple rounds of review cause authors to consider peer review to be inefficient, sometimes biased and painful (Mulligan et al., 2013). The issue concerning the length of time from submission to decision is not so much related to a lack of effort by editors and reviewers in the service of journals and their scholarly communities. A recent study by Aczel et al. (2021) found that the amount of time dedicated to peer review in 2020 was equivalent to over 15,000 years, with an estimated monetary value of 1.5 billion US dollars, in the US alone. The authors of the study recognised that their projections were underestimated and designated the overall effort as a massive donation that reviewers make to global science on a yearly basis (Aczel et al., 2021).

The core of the problem is dual. First, the growth rate of researchers engaged in research and submitting to journals is higher than that of reviewers,[2] thus creating backlogs in the review process. The urge to publish, particularly in international journals indexed by companies such as Clarivate (owners of the Web of Science platform) and Elsevier (owners of the Scopus platform), is due to related incentives. Research is the most valuable element of an academic's reputation and career progression, and publications are evidence of research proficiency and excellence (Altbach et al., 2010; Oleksiyenko, 2014). Public funding to research must show accountability in terms of 'bang for the buck' (output for the money invested in research), and publishing in highly visible international journals is a perfect way to demonstrate the outputs of such investment (see Chou, 2014). This effect has

been complemented recently by an impact dimension (Watermeyer & Chubb, 2019). Publishing in international journals—which are usually controlled by privately owned global multinationals, such as Clarivate and Elsevier—also offers a benefit for institutions and governments in that it boosts the university profile in global university-ranking competitions and is attuned with academic capitalism, which serves to commodify science funded by public funds, foster scientific oligopolies and reinforce competition between institutions (Larivière et al., 2015; O'Donovan, 2019). All of these actors—universities, governments, publishers and even authors—reap the rewards, but not the reviewer, who does this work for free (Copiello, 2018).

The second major part of the problem is that these incentives are definitely skewed toward a 'publish or perish' dynamic that negatively affects the sustainability of peer review. There are clear incentives to publish and little to no incentive to review. This leads to many publishing but not necessarily reviewing, which counters the prosocial and volunteer behaviour ideals grounded in the practice of peer review. This has led to arguments that a peer-review debt index should be put in place to counter selfish behaviours (Fiedorowicz et al., 2022). While these behaviours are known and hint at flaws in the instruction of researchers concerning the fact that peer review is a responsibility for those who publish, they may also underline the prioritisation of tasks supporting survival and progression in a researcher's career, as well as fatigue (Breuning et al., 2015) and the need for editors to engage younger researchers, in earlier stages of their careers, in the peer review process (Nguyen et al., 2015). Furthermore, as the research capability of developing countries improves, allowing them to participate more in global science, researchers from these countries can be invited to participate more frequently in the peer review process. Studies have shown that researchers from developing countries are significantly underrepresented in the global population of peer reviewers (Chawla, 2018a, 2018b). This may be because journal editors—who are overwhelmingly from developed countries—tend to rely on geographical and epistemological homophily when choosing reviewers (Jackson et al., 2018). The underrepresentation of peer reviewers from developing countries can cause them to be largely isolated from global science, a condition that has historically affected several of these countries (Wagner & Wong, 2012). As a result of this underrepresentation, they are also likely to have fewer opportunities to engage in cutting-edge research, learn and improve their own research competencies by critiquing and contributing to submitted articles, expand professional connections with journal editors of international journals, and develop other critical skills in assessing others' works (Smith et al., 2023). Peer review can open international science to indigenous or 'non-Western' knowledge that otherwise may encounter considerable difficulties in being integrated within global science, particularly knowledge of key topics in the social and health sciences and the humanities (Oldac et al., 2023; Tomaselli, 2019; Woods et al., 2023). The same can be argued concerning the need for more female researchers to be engaged in peer review. A recent study combining Publons data and sociodemographic and career data of 2089 researchers working either in or out of academia across the globe found that female researchers conducted 41.6% fewer reviews than male researchers (Horta & Santos, 2023). This echoes the finding of several other studies that women have fewer chances than men to participate in peer review processes—usually because editors less frequently invite them to review, but also because women decline to respond to requests to review more often than men (Fox et al., 2016; Lerback & Hanson, 2017; Squazzoni et al., 2021). Known biases in science regarding its concentration and over-reliance on developed countries and on male researchers are mirrored in peer review. Overcoming these biases can mitigate some of the issues related to both the duration and quality of peer reviews (Chawla, 2018a, 2018b; Lee et al., 2013).[3]

The duration of the peer-review process is closely aligned with another peer-review problem, that of its quality and reliability. The great influx of submissions overloads the capacity of editors and peer reviewers to handle the submitted articles properly. Editors and peer reviewers are increasingly fatigued in handling articles. Editors must find good-quality reviewers in a timely manner, and such reviewers tend to be the most overwhelmed (Lotriet, 2012; Severin & Chataway, 2021).[4] Finding capable and available reviewers has become a challenge, and it is common in some disciplines for editors to invite 10 to 12 reviewers to secure two to review an article (Hazen et al., 2016). Moreover, with the increasing multidisciplinary and interdisciplinary nature of science is a growing number of topics, for which it is difficult to find researchers with the right expertise (Mansilla, 2006). Reviewing is

predominantly voluntary work performed out of duty to the relevant field of research and science and as a service to the scientific community and ideals that it represents (Overall, 2015). It is also extra work that is usually not recognised by researchers' workplaces as a factor in determining salary increases and career progression, and it piles atop other professional commitments that are recognised in such contexts (Lotriet, 2012). Reviewers may be researchers themselves, overworked and facing several pressures, and they may not have the necessary energy and time to produce optimal reviews in the relatively short time span provided to them (Bilalli et al., 2021). One cannot have the best of two worlds in the peer-review process (or in any process), and a lack of agreement on a given article between reviewers, which is typical of scientific culture, can create even greater entropy in the process and heighten the dissatisfaction of all involved by increasing review times (Onitilo et al., 2014).[5] It is possible that reviewer fatigue is also responsible for reviewer reports that are not polite and constructive in nature, as they should be; however, this may also relate to the lack of training that researchers receive in peer review and biases that peer reviewers may have (Jayasinghe et al., 2003; Mavrogenis et al., 2020).

A final issue regards biases that may be related to poor practices and dubious ethical standards. This is a major issue because it relates to the principles of meritocracy, transparency and fairness that guide the overall practice of peer reviewing (Lee et al., 2013; Lee & Schunn, 2011). Concerns with this issue are not new. For example, studies produced in the 1980s addressed the issue of authors' getting lucky or not in the reviewer draw (Cole et al., 1981) and their awareness that 'old boys' networks' were able to exert influence to protect specific cliques (Gillespie et al., 1985). These studies identified these matters as leading to researcher dissatisfaction and compromising the trust researchers had in the peer review process (McCullough, 1989). Practices of conservationism or even evidence of bad faith and manipulation of researchers by competitors in peer review to delay or hamper the publication of their results also seriously undermine the ethos of the entire peer-review system (Campanario & Acedo, 2005). Single- and double-blind review mechanisms have been implemented to mitigate or eradicate these types of biases since the early history of the peer-review process. In recent decades, the double-blind peer review has become increasingly common, because it has the potential to mitigate the possibility of biases related to authors' gender, ethnicity, nationality, institutional reputation, or previous accomplishments (Blank, 1991). Several studies evidence that double-blind peer review is considered the most effective (Mulligan et al., 2013), non-biased, and inclusive form of peer review (Fox, 2023; Seeber & Bacchelli, 2017). However, some studies criticise double-blind peer review, arguing that it provides a false sense of unbiased peer review when well-known authors can be easily identified by the nature of their work, references to the author's own work in the reference list, and even pre-prints that can be easily found by any reviewer (Cressey, 2014; Fatone et al., 2020). In addition, editors (in the case of double-blind reviews) and both editors and reviewers (in the case of single-blind reviews) can see the authors' identities, characteristics, and affiliations and may therefore base their judgements on the authors rather than on the research quality. Nationality and linguistic biases (e.g., better English in the case of international journals) may also exert influence in decision-making concerning articles (Tregenza, 2002). In the end, much is in the hands of the editors, who ultimately make the editorial decisions. They may have an omniscient role in their journals (Overall, 2015) but are not immune to biases and must rely on their sense of moral and ethical integrity and knowledge.

These biases may be further fostered by the growing number of submissions to journals due to the pressure that universities place on academics for the aforementioned reasons related to justifying the universities' investment and to accruing national and/or global prestige and visibility (Bello et al., 2023). Researchers' career progression and sometimes career survivability thus depend on their articles' being published in specific journals (Madikizela-Madiya, 2023), explaining the increase in article submissions. In addition to overloading editorial teams and reviewers, this also leads to the emergence of new biases and poor practices, such as insider bias from editors (Tutuncu, 2023) and predatory journals that conduct fake or no peer review at all but guarantee publication in exchange for a fee. Predatory journals emerge and proliferate because there is a market for them (often sustained by young, inexperienced researchers from developing countries that must publish their research to advance in their careers; Xia et al., 2015). They contribute further to the loss of trust in science and the social system

it stands for, while fostering nationality bias—most reviewers for these journals are from the scientific 'peripheries' and are younger—and other biases (Severin et al., 2021).

4 | PEER REVIEW CRISIS SOLUTIONS

Studies have suggested alternative ways to tackle the current challenges and improve the peer-review system. Some of these suggestions are related to improvements in the procedure of the peer review; others are related to acknowledging the editors' and reviewers' roles by providing incentives and recognition for their service and work. Those solutions are driven by the key challenges of peer review, such as lack of transparency and efficiency, and the often-unrecognised roles of editors and reviewers.

Efforts to improve transparency have led to an open peer review (OPR) system in certain fields, including in medical and other scientific disciplines. OPR is part of the open science movement in the scientific community, and it has encouraged revealing the identities of authors and reviewers and made review reports available to the public (Ross-Hellauer, 2017; Wolfram et al., 2020). OPR is expected to increase the transparency of potential conflicts of interest in the peer-review process and the accountability of reviewers as compared with blind review, although this model is dominant only in a few disciplines and publishers due to the different disciplinary publishing practices (Ford, 2013).

As the number of submissions has exponentially grown, while the number of willing reviewers has not grown at the same pace, an essential part of the peer review crisis discourse is centred around efficiency and sustainability (e.g., Mulligan et al., 2013). The imbalance between the number of submissions and reviewers has made the review process extremely slow, hampering the timely dissemination of research results and creating dissatisfaction among authors (Huisman & Smiths, 2017). Several solutions have been introduced in recent years to improve the efficiency of the peer review process, such as post-publication review, preprint servers and registered reports, described in detail below. They commonly emphasise that the review process should be faster, more accessible and more inclusive.

The post-publication review is based on the idea that authors do not need to wait out the long review period for a journal's decision. Instead, authors publish their manuscripts on open Web platforms, receive an immediate review from a wider audience and formally publish in the journal after the open review process. Reviews can be disseminated in a short period, and discussions with interested individuals can be facilitated (Knoepfler, 2018). Ross-Hellauer (2017) described the post-publication review as an escape from the elitism of the scientific community and a tool for a timely, wide and robust discussion of research results. Similarly, the preprint servers allow authors to post early versions of their articles online, protect their original ideas and results, gather feedback and improve the articles before submission to a journal (Hoy, 2020). Physicists have been using a preprint system to share and discuss their work since the early 1990s (see arXiv.org [pronounced 'archive']; Hoy, 2020). One important advantage of preprint servers is in disseminating articles that might not be accepted in the typical review process, such as those with non-significant results, replications and contradictory findings (Hoy, 2020). Researchers believe that the research process is equally important as the research results, while traditional journal peer review tends to accept only successful and original research with ideal results for publication (often also in accordance with the dominant knowledge paradigm, indicating a conservative science that may reject a counter-narrative leading to research breakthroughs and innovation; Stanley, 2007). Therefore, the registered reports are developed to publish reports regardless of the results, as long as the research protocol is followed correctly. Authors submit a detailed protocol for their research before conducting it, as part of the peer-review process and pre-accept decision (Chambers & Tzavella, 2022). This allows researchers to focus on the research without the fear of failing to obtain 'publishable' results (Nosek & Lakens, 2014). These solutions provide new ways of thinking about the peer-review system. However, such alternatives also present issues, such as reviewers' using these platforms

to spread inaccurate information, information overload (Hoy, 2020) and the avoidance of the constructive review process while maintaining anonymity (Eyre-Walker & Stoletzki, 2013).

There are clear incentives for academics to publish; however, there are few incentives to engage in reviewing. The reviewing task is conducted on a voluntary basis and is unrecognised but requires time and commitment from the reviewers; it often helps authors significantly to improve their submitted papers, in some cases at almost the same level as co-authors (Chambers & Tzavella, 2022). It is not uncommon to find studies arguing for the monetary or non-monetary incentivisation of peer review. For example, one suggestion is to charge authors a fee to submit, which is then used to pay reviewers. However, Squazzoni et al. (2013) showed that such incentives do not work, because the payment only motivates more reviewers to agree to review; it does not necessarily improve the quality of the review and it may pose a moral threat to academic work. Instead of providing monetary incentives, another suggestion is to give official recognition for review work; this notion has been widely shared in recent years with online platforms such as Publons (https://publons.com/). Publons has successfully acknowledged the effort researchers expend on reviewing (Smith, 2016), although there is a risk that this may create another form of competition for metrics and encourage the marketisation of science (Teixeira da Silva & Al-Khatib, 2019). Non-monetary incentives also include connecting reviews and publications, such as certain journals' practice of offering publication credits for their reviewers (Fox & Petchey, 2010) or penalising researchers for declining several requests to review (Hauser & Fehr, 2007). Fox and Petchy's (2010) study introduced the concept of Pubcreds, whereby authors receive credits for reviewing work, which they can use to get their own work reviewed.

The above suggestions are creative and part of an effort to overcome the current challenges that the peer-review system faces; however, it should be remembered that they may disadvantage early-career researchers, who need more experience as peer reviewers, particularly for high-profile journals. Until recently, little guidance was available to peer reviewers, although publishers and journals have started to develop resources for novice and potential peer reviewers (Pierson, 2011). An awareness of the peer-review process may help early-career researchers understand the process better (Ali & Watson, 2016). Perhaps more telling is the fact that the offered solutions—both those addressing the publication process and those focusing on reviewer incentives—continue to centre on the key values and process of the evolving peer-review system.

5 | CONCLUSION

This article provides a critical overview of the rationale for and the role and challenges of peer review as a mechanism of science. It also describes proposals found in the literature to minimise or eliminate the mounting number of challenges affecting peer review. Although it can be argued that the mechanism is indeed facing a major crisis, this crisis is part of the transformative, evolutionary pathway of science (Shinn, 1999). In this article, we take the perspective of Tight (1994), who perceived in the crises of higher education systems certain benefits. As part of its continuous development, peer review has enabled the massification of science with a solid measure of quality and control, and this is why it is considered to represent the golden standard of science (Gonzalez et al., 2022). In the 17th century, when a system somewhat resembling the peer-review process that we know today emerged, scientific research was mostly conducted by amateur researchers and was essentially restricted to a few scientific societies in the most developed countries (Stanford, 2019). That is, science was an extremely elite system based on a relatively low number of researchers. Publications were produced at very low rates by a small number of researchers limited to a few disciplines (Bornmann & Mutz, 2015). The fact that editorial boards were established to fill in journal space is evidence of the small number of researchers and small amount of research being produced (Spier, 2002). Another indication of this was that publication decisions were rendered solely by a journal's editor until the mid-20th century, and the practice of peer review faced serious opposition until the 1960s (Burnham, 1990; Kennefick, 2005). Peer review as we know it is a relatively new concept.

The consolidation of peer review occurred with the introduction of big science, the massification of higher education, the development of the research university and the increased amount of public funding in science (Forsberg et al., 2022; Stanford, 2019). The increasing number of journal submissions and pressures from inside and outside the scientific system consolidated the practice of peer review as we know it today. Single- and double-blind reviews rendered peer review more impartial, meritocratic and fair (although this is debated today, and single-blind review in particular seems more problematic and prone to biases; see Tomkins et al., 2017). External rather than internal reviewers also contributed massively to the characterisation of peer review as fair (Baldwin, 2018). When peer review became more of a dialogue between authors, reviewers and editors and reviewers gained influence over final editorial decisions, the developmental side of peer review emerged. As publications became collaborative, so did peer review become a more collaborative process. The expected allocation of submitted articles to experts to critique the research and provide comments in an effort to improve the rigour of the research established the two main missions of peer review: information gatekeeping and improvement (Mavrogenis et al., 2020; Severin et al., 2021). This created the foundation for a system providing legitimacy to scientific journals as well as to science itself, gaining the trust of the scientific community and of other stakeholders such as practitioners (Fox, 1991; Spier, 2002). Illustrating the continued power of this system, defenders of Cardano, one of many competing blockchains, state that it is the most trustworthy because its underlying knowledge and technology are peer-reviewed by academic researchers (Junis et al., 2019). The idea that peer review lends legitimacy to and inspires trust in the knowledge produced remains very strong and embedded in the mindsets of those both in and out of the scientific community.

Peer review is thus a pillar of science that has guaranteed a measure of quality control and improvement throughout the massification of science. Thus, although the practice is in crisis, most proposals to come up with alternatives to peer-review are essentially improvements to the 'traditional' peer-review practices. OPR, preprint servers and registered reports are all based on core peer-review principles, even if some may depart from the idea that 'peer review is broken', which many authors consider—correctly—to be an ill-informed generalisation (Tennant & Ross-Hellauer, 2020). Proposed incentives—some already in use in certain disciplinary fields—to foster a fairer, more transparent, rewarding and meritocratic peer-review system also rely on the traditional system, rather than seeking to create a completely different system. The proposals often have mixed results or only work when a complex set of factors is in place (e.g., Garcia et al., 2022), suggesting that departing from the core ideas of peer review is not easy. Overall, the proposals sustain the idea that the benefits of peer review are recognised and its practice is essential to science, but they highlight the need to address its deficiencies. The crisis of peer review was ignited by related factors: the creation of incentives around publishing research, policies aimed at increasing the effectiveness of research funding, the increased competition pervading in academia, the primacy of research vis-à-vis other scholarly activities, and the fact that academic and scientific recruitment and career progression tend to rely on publication numbers (and perceived quality). Such factors served to increase the number of scientific article submissions to the point that editors and reviewers were unable to efficiently cope with them. This became particularly problematic because reviewing is essentially a voluntary, unpaid practice, poorly or not at all recognised by most organisations (especially universities) and is in direct competition for experts' time and energy with the need to publish, among other duties (Overall, 2015). Editorial and reviewer fatigue are symptoms of a crisis, the underlying cause relating to a lack of recognition for engaging in peer reviewing and to a global massification of science underpinned by 'publish or perish' dynamics, which many claim to have increased the number of publications but not to have brought any new scientific breakthroughs (Young, 2015). Rather, such dynamics further fostered the marketisation of public science to the benefit of a few publishers that virtually control the publication-prestige scientific market (Copiello, 2018; Larivière et al., 2015). They also increased poor practices, unethical behaviours, rude or non-constructive referee reports and many other, less savoury practices, including the emergence of predatory journals that exert a negative influence on peer review, emerging scientific communities and science in general (Xia et al., 2015).

Considering that science is undergoing constant transformation, peer review as a practice in science is still part of what Kuhn (1962) designated as 'normal science': it is mainstream, and no viable alternative system is evident. However, peer review must adapt to the challenges it faces, and this requires an effort by the scientific community, practitioners and policymakers. Peer review must be made more transparent in its processes, and clear ethical and procedural guidelines must be established to ensure that the peer-review process retains impartiality and meritocracy (e.g., Seeber et al., 2023). Its sustainability as well as the sustainability of global science must be guaranteed. In the short term, the demands on the peer review system could be reduced somewhat by journals' sharing reviews. Specifically, if a manuscript is rejected by one journal, the reviews conducted on the manuscript for that journal could be used by other journals subsequently considering the manuscript (Fox & Petchey, 2010). Certain journals under the same publisher do share reviews in this way, and this practice should be expanded beyond the domain of individual publishers. On a more fundamental basis, the scientific community must acknowledge peer review more concretely as important scientific work by considering it as a factor in career progression. Furthermore, peer review must become more open to diversity in terms of reviewers; for example, researchers who are female, from developing countries or in the early stages of their careers should be given the chance to review more. By making a sufficient effort to reach a wider pool of researchers who may provide solid reviews if asked, editors may also mitigate certain biases in science (Chawla, 2018a). Finally, peer reviewing should be a component of doctoral training. If we do not impart the importance of and proper values associated with peer reviewing on new generations of researchers, how can we expect peer reviewing to be taken seriously or encourage researchers to engage in it?

AUTHOR CONTRIBUTIONS

Hugo Horta: Conceptualization; investigation; writing – original draft; writing – review and editing; formal analysis. **Jisun Jung:** Writing – original draft; writing – review and editing; formal analysis.

CONFLICT OF INTEREST STATEMENT

The authors declare that there is no conflict of interest.

DATA AVAILABILITY STATEMENT

Data sharing is not applicable to this article as no new data were created or analysed in this study.

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ENDNOTES

[1] In the 1970s and 1980s, peer review was considered a needed and welcome practice to mitigate and curtail scientific malpractice (e.g., Burnham, 1990; Manheim, 1973). This does not mean that during these decades and later there were not concerns about and critiques of peer reviewing (e.g., Alberts et al., 2008), but the current sense of crisis was not prevalent. It was mostly in the 2010s—with 'publish or perish' as a global norm, the acceleration and increasing relevance of academic publication submissions to international peer reviewed journals, and related research evaluation criteria affecting institutions and individuals (particularly their opportunities to obtain funding and progress in their careers)—that imbalances were created that strongly affected the peer-review system and those engaged in or benefiting from it, triggering the sense of crisis that is felt in science and academia today.

[2] Increases in investment and the number of people in science have continued worldwide. Higher-education systems have expanded as part of the massification process, the number of academic staff has increased and such staff have become more qualified, and the doctoral and graduate student population has grown (Powell et al., 2017).

[3] In some fields, such as biomedicine, 90% of the reviews for journals are carried out by only 20% of the researchers in the field, which is unsustainable (Kovanis et al., 2016).

[4] A recent study by Peterson et al. (2022) focusing on the journal *Baylor University Medical Proceedings* shows that over a period of 45 months, only 42% of the invited reviewers agreed to review a submitted article and 6% of these did not complete the reviews. The authors argue that editors' difficulties in finding reviewers arise mainly because reviewers tend to receive an excessive number of review requests from many journals.

[5] This issue is difficult to solve, as the criteria for novelty, rigour, significance and appropriate application of theory and methods are not universal, and different peer reviewers naturally interpret applicable criteria in different ways (see Lamont, 2009).

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