



Cite this: *Mater. Horiz.*, 2024,  
11, 3005

Received 25th October 2023,  
Accepted 19th February 2024

DOI: 10.1039/d3mh01781h

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## Better nanoscience through open, collaborative, and critical discussions

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We aim to foster a discussion of science correction and of how individual researchers can improve the quality and control of scientific production. This is crucial because although the maintenance of rigorous standards and the scrupulous control of research findings and methods are sometimes taken for granted, in practice, we are routinely confronted with articles that contain errors.

### Errors and self-correction of science

The issue of lack of reproducibility and limited translation of research findings is a recurrent concern in nanoscience.<sup>1–3</sup> Since the development of the so-called ‘modern science’ in the 17th century, the scientific enterprise has been founded on the public research dimension.<sup>4</sup> This means that scientific work is not conducted privately but actively involves communities, *i.e.*, groups of people animated by similar aims and shared methods, constituting both the ‘government’ of the scientific enterprise and also its controlling body. Moreover, the collegial and open character of scientific research hinges on the idea that any scientific statement, before it can be recognised and accepted as such, must pass critical scrutiny that is carried out by the scientific community itself. The scientific culture in which researchers are trained and immersed should, ideally, foster the creation of a critical mindset characterised by the need to evaluate research claims based on the internal consistency of experimental hypotheses, models, theories and on methodological rigour. Therefore, the scientific community is not only responsible for establishing the soundness of its studies but also for checking for any flaws, which may have escaped earlier levels of control, and correcting them. This concept is what the sociologist of science, Robert K. Merton, called ‘organized skepticism’<sup>5</sup> by which he emphasises that although it is necessary for theoretical and experimental production to meet methodological criteria, it is not sufficient to establish a ‘scientific fact’.

One of the levels where critical scrutiny takes place is peer review, but that process is often relatively superficial, and it certainly does not involve independently reproducing experimental studies. As a result, errors (both involuntary and, in some cases, intentional) do pass the filter of peer review (see ref. 6–9). The few published studies of the peer review process itself show its limitations. For example, research carried out in the *British Medical Journal* on 607 trained peer reviewers revealed that they detected less than half of the errors regardless of the type of training they had received.<sup>10</sup> Although science is supposed to be self-correcting, once peer-reviewed articles are published, scientists have little incentive to correct or to critically analyse them.<sup>11–13</sup> Indeed, in the contemporary scientific landscape, the incentives that drive researchers play a key role in shaping the trajectory of scientific enquiry and publication practices. These incentives, due to the interests involved, could favour the pursuit of discoveries presented as revolutionary and attention-grabbing over meticulous but less conspicuous work. However, different contexts with different incentive and disincentive mechanisms may indicate that certain dynamics and patterns are not always generalisable and should always be analysed specifically. On the other hand, a research landscape that is still too marked by structural inequalities and working conditions that are not always adequate can exacerbate these situations.<sup>14,15</sup>

One of the main methods of correcting science concerns the possibility of withdrawing a problematic article. However, a recent analysis of this phenomenon shows that, at least as far as chemistry and material sciences are concerned, this is largely restricted to cases of scientific fraud such as plagiarism or data manipulation.<sup>16</sup> Moreover, researchers who attempt to publish a negative study or even challenge the state-of-the-art,<sup>17–20</sup> or to engage critically with the literature, generally find it to be a complex and protracted process (see ref. 21 and 22). Various

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QRPs and factors hindering self-correction	Ref.
Metrics for evaluation and hiring	26
Unextensive (insufficient) knowledge of the literature leading to poor quality of research	27
Academic prestige/authority (Academic leadership)	26
Competition/no will for enemies	28
The fear for the public image of science (Trust in science)	29
Malpractice/sloppiness	30
Pressure to publish	30
Lack of transparency	31–33
P-hacking	34

Critical analysis of articles is everyday work in research laboratories, *e.g.*, to evaluate methodologies, establish new protocols and survey the state-of-the-art. When researchers read an article to formulate ideas for their projects, they may often observe flaws, unclear or incomplete methods, or a lack of data explanation. Usually, those observations are stored as private notes, which are at best shared within a single research group or with a few colleagues.<sup>24</sup> Yet sharing those notes could often save time for other researchers and make the scientific

publication they are reading (or the articles cited) has comments on PubPeer.

We, authors of this paper, are members of the NanoBubbles project, a European Research Council Synergy project that focuses on how, when, and why science fails to correct itself. The project is highly interdisciplinary and, in particular, extends to the human and social sciences but stems from the experience of a nano scientist (RL) struggling to challenge errors and misconceptions in research.<sup>50,51</sup> NanoBubbles includes a post-publication peer review and a replication initiative (amongst others sub-projects). Both aim to help nano scientists, directly and through changes in practices, navigate a field where information bubbles, hype, errors, and misconceptions are common. To demonstrate the benefit of contributing to PubPeer, to-date, we have decided to focus on one specific scientific question of relevance to many proposed applications of nanoparticles: their access to the interior of the cells. We consider, in particular, articles that report nanoparticles-based sensing of cytosolic analytes (mRNAs, ions, pH). In spite of the fact that efficiently delivering nanoparticles to the cytosol is, at best, highly challenging, there are over a thousand articles that report intracellular sensing with nanoparticles. We critically read some of those articles and share our comments on PubPeer, after which authors are

Table 2 Common issues described in NanoBubbles post-publication peer review comments

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notified and have the opportunity to respond. Other scientists can also join in the discussion (anonymously or not). Thus, on this particular disputed nanoscience topic, we are building a common resource (42 comments so far), which we hope would be useful to any scientist in this field or preparing to enter this field. It could also be of interest as a teaching resource for training young researchers.

To maximize transparency and emphasize the scholarly nature of our comments, we sign our reviews and include conflict of interest declarations and author's contributions statements. We start our review with a summary of the article and its main claims to help the reader gain a clear understanding of the study's objectives and findings. We then report our critical observations. Often the response of the scientific community to general concerns about the need for better practices, specifically in nanoscience, has been to insist on higher standards of characterization, *e.g.*, with the introduction of minimum reporting guidelines.<sup>52,53</sup> Whilst our comments do address critical aspects related to materials' synthesis and characterization, they also consider other fundamental issues. These include basic conceptual problems, which are sometimes ignored or minimized, as well as the justification for the study: why is this sensor needed? Is its complexity justified by something else than the need for novelty? How does it compare with other methods currently available? Whilst a detailed analysis of the various points discussed in our comments is beyond the scope of this article, Table 2 highlights some of the issues encountered.

To date, limited but encouraging engagement has taken place with authors responding to our comments. In one case, the authors decided to issue a correction which has been published (Park *et al.*, 2021)<sup>54</sup> whilst in another, authors have announced that they would contact the editorial office to request a correction (comment on Wei *et al.*, 2020).<sup>55</sup> Beyond authors, other scientists added further comments to our post-publication peer reviews.

## Perspective

In this commentary, we argued that scientific self-correction mechanisms need to be improved. Among the practices that can be pursued by any individual researcher, post-publication peer-review, such as that on PubPeer, provides a valid, and above all accessible to anyone, strategy to achieve this goal. Whilst this approach is unlikely to be the method that solves the problem of uncorrected science (since it is a complex issue and touches on other aspects that we have not discussed here), we hope that this article will increase attention to these issues and inspire more researchers in the nanoscience community to engage and participate in this process. Thus, we invite readers to share their thoughts on articles that concern nanoparticle-based intracellular sensing or any other topics of their interest, commenting on methodological issues, but also on other aspects, including the rationale of the research. In our opinion, such commitment could help to move the scientific community

forward, both in terms of shared understanding and common research standards.

## Conflicts of interest

There are no conflicts to declare.

## Acknowledgements

The NanoBubbles project has received Synergy grant funding from the European Research Council (ERC), within the European Union's Horizon 2020 program, grant agreement no. 951393.

## References

- 1 S. Bhattacharjee, Nanomedicine literature: the vicious cycle of reproducing the irreproducible, *Int. J. Pharmacokinet.*, 2017, 2(1), 15–19.
- 2 Committee on Reproducibility and Replicability in Science, Board on Behavioral, Cognitive, and Sensory Sciences, Committee on National Statistics, Division of Behavioral and Social Sciences and Education, Nuclear and Radiation Studies Board, Division on Earth and Life Studies, *et al.* Reproducibility and Replicability in Science [Internet]. Washington, D.C., National Academies Press; 2019 [cited 2023 May 22]. Available from: <https://www.nap.edu/catalog/25303>.
- 3 S. Sharifi, N. Reuel, N. Kallmyer, E. Sun, M. P. Landry and M. Mahmoudi, The Issue of Reliability and Repeatability of Analytical Measurement in Industrial and Academic Nanomedicine, *ACS Nano*, 2023, 17(1), 4–11.
- 4 P. Rossi, *The birth of modern science*, Blackwell, Oxford; Malden, Mass, 2001, p. 276.
- 5 R. K. Merton, *The sociology of science: theoretical and empirical investigations*, University of Chicago Press, Chicago, 1973, p. 605.
- 6 A. Csiszar, Peer review: Troubled from the start, *Nature*, 2016, 532(7599), 306–308.
- 7 H. Bastian 5 Things We Learned About Journal Peer Review in 2022 [Internet]. Absolutely Maybe. 2023 [cited 2023 Apr 10]. Available from: <https://absolutelymaybe.plos.org/2023/01/26/5-things-we-learned-about-journal-peer-review-in-2022/>.
- 8 J. P. Tennant and T. Ross-Hellauer, The limitations to our understanding of peer review, *Res. Integr. Peer Rev.*, 2020, 5(1), 6.
- 9 N. el-Guebaly, J. Foster, A. Bahji and M. Hellman, The critical role of peer reviewers: Challenges and future steps, *Nordisk Alkohol Nark*, 2023, 40(1), 14–21.
- 10 S. Schroter, N. Black, S. Evans, F. Godlee, L. Osorio and R. Smith, What errors do peer reviewers detect, and does training improve their ability to detect them?, *J. R. Soc. Med.*, 2008, 101(10), 507–514.
- 11 B. Alberts, R. J. Cicerone, S. E. Fienberg, A. Kamb, M. McNutt and R. M. Nerem, *et al.*, Self-correction in science at work, *Science*, 2015, 348(6242), 1420–1424.





- 12 C. G. Begley, A. M. Buchan and U. Dirnagl, Robust research: Institutions must do their part for reproducibility, *Nature*, 2015, **525**(7567), 25–27.
- 13 A. D. Higginson and M. R. Munafò, Current Incentives for Scientists Lead to Underpowered Studies with Erroneous Conclusions, *PLoS Biol.*, 2016, **14**(11), e2000995.
- 14 D. Fanelli, M. Schleicher, F. C. Fang, A. Casadevall and E. M. Bik, Do individual and institutional predictors of misconduct vary by country? Results of a matched-control analysis of problematic image duplications. Vousden G, editor, *PLoS ONE*, 2022, **17**(3), e0255334.
- 15 B. Le Maux, S. Necker and Y. Rocaboy, Cheat or perish? A theory of scientific customs, *Res. Policy*, 2019, **48**(9), 103792.
- 16 F. X. Coudert, Correcting the Scientific Record: Retraction Practices in Chemistry and Materials Science, *Chem. Mater.*, 2019, **31**(10), 3593–3598.
- 17 B. Swoger Post publication peer-review: Everything changes, and everything stays the same. Scientific American [Internet]. 2014; Available from: <https://blogs.scientificamerican.com/information-culture/post-publication-peer-review-everything-changes-and-everything-stays-the-same/>.
- 18 PubPeer. PubPeer Blog [Internet]. PubPeer. 2016. Available from: <https://blog.pubpeer.com/publications/AE11BE44CF3-C40A558F3B453BF53C7#14m>.
- 19 P. Jump Slow is no way to go, argues researcher. Times Higher Education [Internet]. 2013; Available from: <https://www.timeshighereducation.com/slow-is-no-way-to-go-argues-researcher/422337.article>.
- 20 L. Besançon, E. Bik, J. Heathers and G. Meyerowitz-Katz, Correction of scientific literature: Too little, too late!, *PLoS Biol.*, 2022, **20**(3), e3001572.
- 21 S. B. Nissen, T. Magidson, K. Gross and C. T. Bergstrom, Publication bias and the canonization of false facts, *eLife*, 2016, **5**, e21451.
- 22 S. Nimpf and D. A. Keays, Why (and how) we should publish negative data, *EMBO Rep.*, 2020, **21**(1), e49775.
- 23 C. Andrade, HARKing, Cherry-Picking, P-Hacking, Fishing Expeditions, and Data Dredging and Mining as Questionable Research Practices, *J. Clin. Psychiatry*, 2021, **82**(1), 20f13804.
- 24 A. A. Ashkarran, J. Swann, L. Hollis and M. Mahmoudi, The File Drawer Problem in Nanomedicine, *Trends Biotechnol.*, 2021, **39**(5), 425–427.
- 25 W. Beker, R. Roszak, A. Wołos, N. H. Angello, V. Rathore and M. D. Burke, *et al.*, Machine Learning May Sometimes Simply Capture Literature Popularity Trends: A Case Study of Heterocyclic Suzuki–Miyaura Coupling, *J. Am. Chem. Soc.*, 2022, **144**(11), 4819–4827.
- 26 A. C. Morgan, D. J. Economou, S. F. Way and A. Clauset, Prestige drives epistemic inequality in the diffusion of scientific ideas, *EPJ Data Sci.*, 2018, **7**(1), 40.
- 27 D. Sarewitz, The pressure to publish pushes down quality, *Nature*, 2016, **533**(7602), 147.
- 28 S. Meirmans, How competition for funding impacts scientific practice, *bioRxiv*, 2022, preprint, DOI: 10.1101/2022.07.30.502158.
- 29 R. Peels and L. Bouter, Replication and trustworthiness, *Acc. Res.*, 2023, **30**(2), 77–87.
- 30 M. Baker, 1,500 scientists lift the lid on reproducibility, *Nature*, 2016, **533**(7604), 452–454.
- 31 J. M. Wicherts, M. Bakker and D. Molenaar, Willingness to Share Research Data Is Related to the Strength of the Evidence and the Quality of Reporting of Statistical Results. ed. R. E. Tractenberg, *PLoS ONE*, 2011, **6**(11), e26828.
- 32 J. M. Wicherts, R. A. Kievit, M. Bakker and D. Borsboom, Letting the daylight in: Reviewing the reviewers and other ways to maximize transparency in science, *Front. Comput. Neurosci.*, 2012, **6**, Available from: <http://journal.frontiersin.org/article/10.3389/fncom.2012.00020/abstract>.
- 33 L. K. John, G. Loewenstein and D. Prelec, Measuring the Prevalence of Questionable Research Practices With Incentives for Truth Telling, *Psychol. Sci.*, 2012, **23**(5), 524–532.
- 34 J. P. Simmons, L. D. Nelson and U. Simonsohn, False-Positive Psychology: Undisclosed Flexibility in Data Collection and Analysis Allows Presenting Anything as Significant, *Psychol. Sci.*, 2011, **22**(11), 1359–1366.
- 35 H. Möhwald and P. S. Weiss, Is Nano a Bubble?, *ACS Nano*, 2015, **9**(10), 9427–9428.
- 36 L. Wang, Z. Sofer and M. Pumera, Will Any Crap We Put into Graphene Increase Its Electrocatalytic Effect?, *ACS Nano*, 2020, **14**(1), 21–25.
- 37 A. Sørensen Excessive funding for popular research creates science bubble [Internet]. Science Nordic. 2013. Available from: <https://sciencenordic.com/denmark-research-policy-society-culture/excessive-funding-for-popular-research-creates-science-bubble/1393546>.
- 38 D. B. Pedersen and V. F. Hendricks, Science Bubbles, *Philos. Technol.*, 2014, **27**(4), 503–518.
- 39 V. F. Hendricks Scientific research can be prone to bubbles too – neuroscience risks being the next one [Internet]. The Conversation. 2014. Available from: <https://theconversation.com/scientific-research-can-be-prone-to-bubbles-too-neuroscience-risks-being-the-next-one-33797>.
- 40 K. L. Chopra, Nanotechnology: hope or hype?, *Curr. Sci.*, 2012, **102**(10), 1364–1366.
- 41 P. Knoepfler, Reviewing post-publication peer review, *Trends Genet.*, 2015, **31**(5), 221–223.
- 42 T. E. Hardwicke, R. T. Thibault, J. E. Kosie, L. Tzavella, T. Bendixen and S. A. Handcock, *et al.*, Post-publication critique at top-ranked journals across scientific disciplines: a cross-sectional assessment of policies and practice, *R Soc. Open Sci.*, 2022, **9**(8), 220139.
- 43 L. O'Sullivan, L. Ma and P. Doran, An Overview of Post-Publication Peer Review, *Sch. Assess*, 2021, **3**(1), 6.
- 44 A. Mlinarić, M. Horvat and V. Šupak Smolčić, Dealing with the positive publication bias: Why you should really publish your negative results, *Biochem. Med.*, 2017, **27**(3), 030201.
- 45 The importance of no evidence, *Nat. Human Behaviour*, 2019, **3**, 3, 197.
- 46 A. W. Brown, T. S. Mehta and D. B. Allison, in *Publication Bias in Science*, ed. Jamieson K. H., Kahan D. M. and Scheufele D. A., Oxford University Press, vol. 1, 2017,



- Available from: <https://academic.oup.com/edited-volume/27956/chapter/211537133>.
- 47 B. Van Steensel, Scientific honesty and publicly shared lab notebooks: Sharing lab notebooks along with publication would increase transparency and help to improve honesty when reporting results, *EMBO Rep.*, 2018, **19**(10), e46866.
  - 48 J. Couzin-Frankel, PubPeer's secret is out: Founder of controversial website reveals himself, *Science*, 2015, <https://www.science.org/content/article/pubpeer-s-secret-out-founder-controversial-website-reveals-himself>.
  - 49 PubPeer. PubPeer Extensions [Internet], PubPeer, 2012, Available from: <https://pubpeer.com/static/extensions>.
  - 50 F. Bordignon, G. Cabanac, Y. J. Erden, W. Halffman, C. Labbé and R. Lévy, *et al.* Nano bubbles: how, when and why does science fail to correct itself? 2023, Available from: <https://zenodo.org/record/7993122>.
  - 51 A. Anirban, How can we make science more rigorous?, *Nat. Rev. Phys.*, 2023, 498–499.
  - 52 M. Faria, M. Björnmalm, K. J. Thurecht, S. J. Kent, R. G. Parton and M. Kavallaris, *et al.*, Minimum information reporting in bio–nano experimental literature, *Nat. Nanotechnol.*, 2018, **13**(9), 777–785.
  - 53 M. Faria, M. Björnmalm, E. J. Crampin and F. Caruso, A few clarifications on MIRIBEL, *Nat. Nanotechnol.*, 2020, **15**(1), 2–3.
  - 54 J. Park, S. Lee, J. Choi and I. Choi, Correction to “Extra- and Intracellular Monitoring of TGF- $\beta$  Using Single Immuno-plasmonic Nanoprobes”, *ACS Sens.*, 2022, **7**(10), 3223–3224.
  - 55 N. Rost, F. Boem, M. Gharib and M. Said Comment on: “Ultrasound-responsive polymersomes capable of endosomal escape for efficient cancer therapy” [Internet]. 2023. Available from: <https://pubpeer.com/publications/C7600CAC35718CE-8A8E9E04FEE1EDB#1>.

