Editor's LETTER

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Deep Impact: Scientific Evaluation by the Numbers

Scientists, administrators, and publishers love numbers. Metrics provide an easy way to assess the performance of a journal relative to others in the field. Of all the metrics used for assessing journals, possibly the most popular is the *Journal Citation Reports* "impact factor" published annually by Thomson Reuters. Essentially, this metric attempts to gauge the impact of a journal from the number of citations received in a year to content published by the journal in the two preceding years. The impact factor has also been used to assess the scientific potential of individual researchers and research institutions (*1*).

With the publication of the 2009 *Journal Citation Reports*, there were movers and shakers, just as there are every year. Intriguingly, a journal focusing on crystallography, *Acta Crystallographica—Section A* had an astronomical rise: this journal had an impact factor of 2.0 in 2008, which vaulted up to 49.9 in 2009 (Figure 1). As a result, this journal is now second only to *CA: A Cancer Journal for Clinicians* in terms of impact factor in the science edition of the *Journal Citation Reports*. What is even more remarkable is that this rise can be predominantly attributed to citations to a single article published in 2008 (*2*). At the time of writing, this highly cited article on SHELX, a set of computer programs relevant to crystal structure determination, received over 6,700 citations in the Thomson Reuters ISI Web of Knowledge database. Had the journal not published this article, the impact factor would have remained under 3.0.

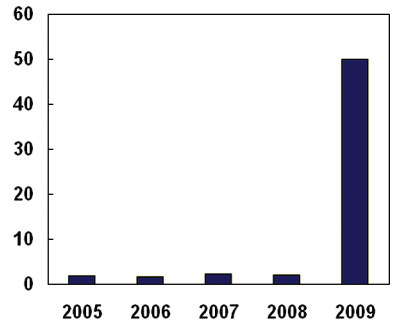

Figure 1. Impact factor (2005–2009) for *Acta Crystallographica—Section A*.

Granted that for other journals changes in impact factor are not as spectacular as the roughly 25-fold increase witnessed for *Acta Crystallographica—Section A*, but it is worth bearing in mind that for many journals, a minority of published articles contribute to the overall impact factor (*1*). For example, *Nature* calculated that 25% of published articles contributed to 89% of the journal's 2005 impact factor (*3*).

Impact factors should not be compared across disciplines, but even within specific scientific areas, certain journal articles tend to garner more citations (*3*). For example, reviews, articles describing new tools and techniques, and research reports describing large data

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sets (such as the sequencing of genomes) may be cited more than other articles published within the same scientific disciplines in the same journals (*4*). By definition, highly cited articles have greater impact, but this may not always correspond to quality, which admittedly is a harder term to define.

It used to be that the impact factor of a journal was only used to assess that particular journal. Now, it is increasingly common to find the impact factor extrapolated to the assessment of individual articles in these journals. In addition, this metric is being used to assess the scientific potential of a researcher. In practice, impact factors are frequently used to decide who gets hired and who gets promoted. Funding levels at many departments are also determined from the analysis of the citations garnered by the researchers in those departments. Consequently, in many institutions around the world, administrators encourage researchers to publish their work in journals with the highest impact factors in order to be favorably evaluated (*1, 5*).

One of the results of over-reliance on this single metric is the unintentional setting of arbitrary criteria for researcher appraisal. For example, in order for an Indian scientist to qualify for the Innovative Young Biotechnologist Award given annually by the Department of Biotechnology of the Indian Ministry of Science & Technology, he or she must have a "cumulative publication impact factor of 10" or "5 with two published Indian patents or one international patent" (*6*). While this standard may have originally been set to filter applicants and reduce bureaucratic burden, it raises the question of what exactly a "cumulative publication impact factor" sets out to measure. Should the author indicate the impact factor at the time of publication or for the current year? Does being a middle author on an article along with fifty others published in a "high" impact factor journal count more toward the cumulative than being the primary author of an article with fewer authors which had been published in a lower impact factor journal? What about situations when there are authors who contributed equally or more than one corresponding author? Surely, there must be better ways to assess scientists other than by relying on arbitrary cutoffs, complex formulas, or tables resembling those straight out of taxation guidebooks!

To be fair, Thomson Reuters has never suggested that impact factors be used in this manner. Indeed, they strongly encourage the use of multiple metrics for assessment. The *h*-index is one such metric, which is often used to assess the research potential of an individual scientist. For example, an author with forty articles each cited at least forty times has an *h*-index of 40. However, there are ways that a researcher can manipulate his or her *h*-index too (*7*).

All metrics have limitations. The goal is not to do away with metrics such as impact factors, but to understand the limitations of each and to use multiple qualitative and quantitative measures as far as possible.

Anirban Mahapatra
American Chemical Society

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