Impact factor impacts on early-career scientist careers

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When I was named the new Editor-in-Chief of PNAS in October 2018, I received hearty congratulations from colleagues from a wide range of disciplines, befitting the intended audience of this venerable journal. The appointment is not my first experience serving as Editor-in-Chief; in 2017, I stepped down after 21 years as Editor-in-Chief of the *Annual Review of Entomology* (ARE). Although ARE is known in entomological circles as the most highly cited journal in the field, even my entomological colleagues readily acknowledge that PNAS is considerably more influential. By one widely used metric, however, the change could be seen as a step down; the impact factor of the last volume of ARE I edited, 13.860, was higher than the impact factor, 9.504, of the journal whose editorial ranks I had just joined.

The irony of the comparison is not lost on me, and I'm hardly the only person who finds journal impact factors (JIF) troubling, even when their values are not calculated to the third decimal point. I'm not even the first person to express concerns about JIF within the pages of PNAS. Four years ago, former Editor-in-Chief Inder Verma (1) cautioned the scientific community against relying on JIF as a surrogate for the quality of any individual article. Before that, Alan Fersht (2), in introducing an alternative metric to readers, reported that, of 39 different bibliometric scales of ranking journals, the impact factor was "at the periphery" (p. 6883). The first to criticize JIF may well have been the person who invented the metric. Although legendary information scientist Eugene Garfield created the concept of science citation analysis in 1955 (3), he did not expand the idea of using "journal impact factor" to evaluate the relative "importance" of a journal until 1972 (4). His concept was to use an "average citation rate per published article" to rank relative journal impact, calculating the average by dividing the number of times a particular journal was cited in a given year by the number of articles it published during a previous specified time period (which today is typically the preceding two years).

At that time, Garfield thought the metric would be of value to librarians managing their journal collections, scientists prioritizing which journals to read, editors evaluating their journal's performance, and science policy analysts aiming to identify new research fronts. By 1998, however, in an article subtitled "Is the tail now wagging the dog?," Garfield (5) noted that his tool had been expropriated for the "frequent . . . misuse of citations for the evaluation of individual research performance. . . . While there are countless legitimate applications of citation data, in the hands of uninformed users, unfortunately, there is the definite potential for abuse" (p. 68).

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Less than 10 years later, Garfield (6) bemoaned the proliferation of those abuses, mostly perpetrated by funding agencies who "often wish to bypass the work involved in obtaining actual citation counts for individual articles and authors" and administrators who decide to "estimate the future impact of a recently published paper by incorporating the impact factor for the journal in which the paper is published" (p. 92). Given the typically long right-tail skew in calculating average impact factor, whereby the majority of citations received by a journal might be earned by a minority of articles, he considered using the impact factor as a predictor of the future impact of a paper "a rather dubious practice."

The JIF was enthusiastically embraced as a reliable predictor of the future citation rate of a recently published paper without robust statistical analysis across disciplinary fields—in fact, evidence of the absence of a significantly predictive relationship has long been available [e.g., Seglen (7, 8)]. I can attest to that lack of relationship with an example from a seemingly low point in my career. Inspired by what I perceived to be a glaring misunderstanding in the nutrition literature relating to honey (that honey, made by honey bees primarily from floral nectar, offers no health benefits beyond those of sugar water, an assertion that ignores honey's rich phytochemical content), with no motivation other than curiosity, I recruited a graduate student and a colleague

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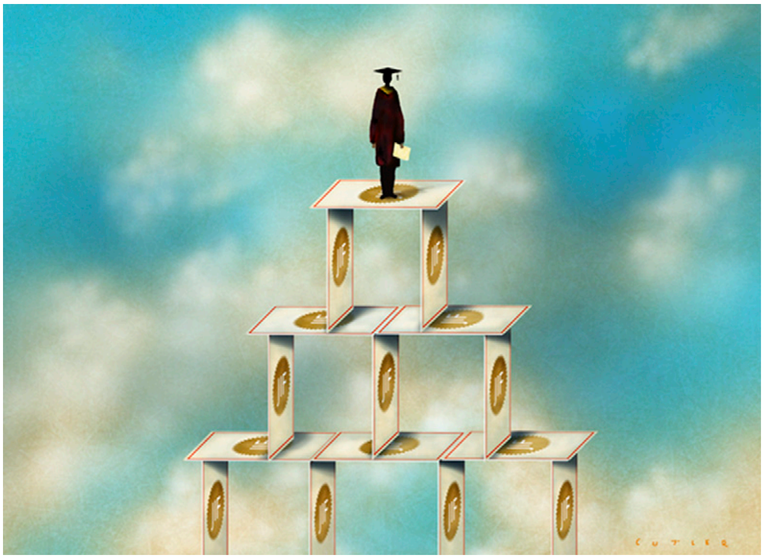

JIF is given too much credence among early-career scientists. Image credit: Dave Cutler (artist).

to collaborate on a modest project. To estimate the effect of differing phytochemical content on one perceived potential health benefit, we measured and compared the antioxidant capacity of an assortment of unifloral honeys (i.e., derived primarily from a single floral source). We were surprised to find 20-fold variation in antioxidant capacity across 14 unifloral honeys and thought these findings merited publication. *Apidologie*, a journal focused on bee biology with an impact factor of 1.2 at the time, seemed to be an appropriate venue. In short order, our manuscript was resoundingly rejected (with a review that included the phrase, "quite without redeeming value"), which was, to say the least, demoralizing. Still convinced of the value of the work, we submitted it to an even more specialized journal with an even lower impact factor—*Journal of Apicultural Research*, with a JIF of 0.6 at the time—where it was accepted. Long story short, according to Google Scholar, Frankel et al. (9) is now among my more widely cited papers, earning more than 372 citations since publication. By comparison, Li et al. (10), a paper I published four years later in *Nature* (2002 impact factor of 30.42), has been cited just 251 times. An editorial in *Nature* (11) revealed that almost 90% of citations in 2004 to papers published in *Nature* in 2002–2003 were attributable to just one-quarter of those papers. Far from being uncharacteristically unheralded, then, mine was among the "great majority" of papers published during that period cited fewer than 100 times in 2004 and an exemplar of the skew that makes using JIF to predict future impact so dubious.

Frankel et al. (9) may have been ahead of its time—the National Academy of Sciences Food and Nutrition Board had defined the term "functional food" for the broad American research community only four years earlier (12), and studies of dietary antioxidant phytochemicals were still in their infancy. Yet the trajectory of Frankel et al. (9) illustrates the potential harm that can be done by equating JIF with future citation rates. There's a time component to citation accumulation; JIF measures citations only on a two-year basis, so citation latencies (which vary across and within disciplines) become a confounding factor. In 1998, I was already a full professor, with tenure (and, for that matter, an endowed chair); my career did not depend on colleagues quickly finding and citing what appeared (to some reviewers) to be a quirky paper with little preexisting scientific context.

Career Impacts

But the situation is entirely different for early-career scientists today. In an increasingly competitive job market, hiring, promotions, grant funding, and bonuses are inextricably linked to a measure, the value of which few people understand completely. Despite the drumbeat of editorials and reviews criticizing its value—Paulus et al. (13) cited 10 examples published between 1997 and 2017—JIF have become increasingly institutionalized around the world. Verma (1) pointed out that, at some universities, job applications lacking at least one first-author publication in a high-impact journal aren't even seriously considered; Abritis and McCook (14) documented the widespread use by universities of financial incentives for scientists who publish in high-impact journals, long known in China but now practiced in more than a dozen countries, including the United States.

JIF use by the scientific community as a predictor of impact has also increased, even while evidence of its predictive value has eroded; both correlations between article citation rate and JIF and proportions of highly cited articles published in high-impact journals have declined since 1990 (15), in part because digitization of journal content and proliferation of open-access articles have profoundly changed how relevant literature is located and cited. Having reviewed its history, I carried out a Web of Science search for articles published last year relevant to JIF; of 88 articles, about half are critiques of JIF, yet the other half, for the most part, are journal editorials touting a new or higher impact factor for the year.

Hiring and promotion decisions are too important to be subject to the influence of a metric so vulnerable to manipulation and misrepresentation. Journals can boost their JIF by encouraging selective journal self-citation and by changing journal composition via preferential publication of reviews, articles in fields with large constituencies, or articles on research topics with short half-lives (16). That the JIF has degenerated into a marketing tool for journals is illustrated by the use of "Unofficial Impact Factors" in promotional material for journals that are not indexed in Web of Science (17); that they are marketing tools for academic institutions is illustrated by the practice of Clarivate Analytics (which now owns Science Citation Index) of awarding paper certificates and electronic "badges" for scientists determined to be Highly Cited Researchers (HCRs, #HighlyCited) by virtue of publishing papers in the top 1% by citations for their field and publication year. Such recognition lacks transparency in terms of the criteria used to calculate citation rates and is not particularly predictive of career trajectory inasmuch as the designation is lifelong

(18). Moreover, this kind of recognition fails to account for the increasing importance of collaborative "team science" that perforce must depend on non-HCRs who, as a consequence of authorship order, don't earn badges or hashtags in recognition of their contributions. Such practices undercut efforts to train and reward early-career investigators who participate in team science (19).

Enacting Change

Again, I'm not the first Editor-in-Chief to point out the adverse impacts of overreliance on JIF for early-career professions. In *Science*, Alberts (20) noted that using JIF as a proxy for scientific excellence undermines incentives to pursue novel, time-consuming, and potentially groundbreaking work: "Only the very bravest of young scientists can be expected to venture into . . . a poorly populated research area." And in *eLife*, Schekman et al. (21) decried the fact that "many pretenure researchers believe that the number of papers in top-tier journals is the key to professional success and happiness." Such a perception isn't entirely without some foundation; McKiernan et al. (22) reported that 40% of research-intensive universities in the United States and Canada mentioned JIF or related terms in their review, promotion, and tenure documents, overwhelmingly positively. Almost two-thirds of these institutions link JIF with quality. Promotion and tenure committees are contributing to publication delays by encouraging early-career professionals to submit manuscripts to journals based not on their appropriateness but rather on the "average popularity" of articles therein. That's a risky way for an early-career investigator to establish a reputation for excellence within a discipline, a criterion ostensibly valued by promotion and tenure committees. Moreover, pressuring early-career scientists to publish in high-impact multidisciplinary journals may also force them to squeeze their best work into a restrictive publication format (limiting page numbers and graphical elements) that, ironically, can reduce its ultimate impact.

As any science journal should be, PNAS is concerned about the vitality and productivity of the community of early-career scientists. We created Brief Reports, in part, to provide a venue for early-career professionals to showcase significant discoveries in their early stages, before full mechanistic details requiring years of additional work are completed. Beyond research reports, we publish Profiles, QnAs, Core Concepts, Inner Workings, and other content relating to the scientific enterprise in general to inform and educate readers, particularly those in the early stages of their career. PNAS editors also have refrained from writing celebratory editorials about any upward movement of our JIF. We have signed on to the San Francisco Declaration on Research Assessment (DORA), issued in 2013 to encourage reforms in evaluations of scientific quality by publishers, funding agencies, institutions, organizations that create and provide metrics, and individual scientists (20).

There are many other reports, manifestos, and pledges to find alternatives to JIF (23), but Garfield (6, 24) was correct in indirectly articulating a fix—granting agencies and university administrators (to which I'll add publishers and individual scientists) can't "bypass the work involved" in carrying out transparent, balanced analysis of the importance of both individual articles and career trajectories. If you'd like to bring about a change at your home institution, feel free to cite this editorial. And, no, I'm not trying to bulk up the impact factor of PNAS; according to the most widely used JIF algorithm, what I've written here is considered "Editorial ephemera" and, as such, isn't even included in the calculation for the JIF for PNAS.

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