Communication of Scientific Information: Is It Time to Reassess?

Moderators: Nader Rifai1,2* and John Sack3
Experts: Michael A. Keller,4 Anurag Acharya,5 Philip E. Bourne,6,7,8 Mike Rossner,9 and Stewart Wills10

The format of communicating scientific, technical, and medical (STM)11 information through professional journals has changed relatively little since the publication in 1665 of the Philosophical Transactions of the Royal Society, the world’s first journal devoted exclusively to science. Although advances in information technology have dramatically altered the search and discovery of scientific information, other aspects—such as migrating from paper to electronic publishing, moving from a “static” to a “living” document, or exploiting social media tools to disseminate STM information—have been slow in coming. The transformations seen in the popular press to better present and relay complex information have undoubtedly raised readers’ expectations of the scientific-publishing community about how to find and use information. In this Q&A article, 5 experts—a librarian, a publisher, a technology expert, and 2 editors representing traditional and new-concept journals—discuss their views on the communication of scientific information.

Why do you think scientific journals, in general, have not taken advantage of technology to the same extent as the lay press?

Michael A. Keller: Actually, scientific journals were early innovators in e-publishing, developing and using features and functions useful in some cases beyond the academic sphere. While I suppose that the assertion of lagging adoption or de novo development of new features by scientific journals with particular regard to social networking functions could be supported in some measure, one rejoinder might be to question whether such functions were pertinent to STM literature. It might also be the case that having been early innovators in the first decade or so of e-publishing, scientific journals have been on a sort of plateau of development recently, which state is about to change as STM journal publishers are starting to explore new possibilities in data archiving and sharing, imaging technologies permitting much higher resolution of views, and advanced modes of navigation and discovery.

Anurag Acharya: Scholarly articles are considered formal archival communications, whereas magazines, newspapers, and such are not. As a result, the focus in scholarly articles has been on the content of the story and not on how it is told. Much of the evolution in the “lay press” has been in terms of improving the presentation quality and interactivity. If, instead, you compare scholarly articles with other formal archival communications, such as books, government reports, and financial submissions, scholarly articles actually take far more advantage of technology than their peers; examples include linking to (1) cited/related articles, (2) other articles by authors, (3) citation/correction alerts, (4) key entities (e.g., proteins, DNA sequences) in widely used databases, and (5) social bookmarking.

1 Departments of Laboratory Medicine and 2 Pathology, Boston Children’s Hospital and Harvard Medical School, Boston, MA; 3 HighWire Press, Stanford University, Palo Alto, CA; 4 University Librarian, Director of Academic Information Resources, Founder/Publisher HighWire Press, and Publisher Stanford University Press, Stanford University, Palo Alto, CA; 5 Distinguished Engineer, Google Scholar, Palo Alto, CA; 6 Associate Vice Chancellor for Innovation and Industrial Alliances, and Professor of Pharmacology, University of California San Diego, La Jolla, CA; 7 Founding Editor in Chief, PLoS Computational Biology, San Francisco, CA; 8 Cofounder, SciVee, Inc., San Diego, CA; 9 Executive Director, The Rockefeller University Press, New York, NY; 10 Editorial Director, Web and New Media, Science Magazine, Washington, DC.

* Address correspondence to this author at: Department of Laboratory Medicine, Boston Children’s Hospital, 300 Longwood Ave., Boston, MA 02115. Fax 617-730-0383; e-mail nader.rifai@childrens.harvard.edu.

Received August 14, 2012; accepted September 4, 2012.

11 Nonstandard abbreviations: STM, scientific, technical, and medical; IF, impact factor.

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Philip E. Bourne: There has been less impetus to change, since the scientific establishment is conservative and slow to change. Open access is probably the single biggest sign of change but as of yet has not led to a complete overhaul of scientific publishing. Nevertheless, I believe that is coming as the business model continues to prove itself.

Mike Rossner: I think most scientific journals—and especially biomedical research journals—have taken advantage of technology to disseminate scientific research and enhance its presentation. As indicated above, in the mid 1990’s biomedical research journals were the very first scholarly publications to adopt web technology to distribute content. The basic narrative and static figures and tables of yesterday have been enhanced with dynamic content such as videos and interactive content such as spreadsheets. Journal news sections now have multimedia elements such as podcasts and videocasts, and journal content and multimedia are often available on mobile devices.

The very nature of the linear scientific narrative limits the options for its presentation, but newer technologies for semantic tagging of text elements and metadata tagging of data elements are beginning to provide links to related content in any format on the web. Other resources, such as CiteULike, Mendeley, and F1000, have grown up around scholarly journals to facilitate storage, sharing, annotation, and evaluation of scholarly articles.

Stewart Wills: I don’t necessarily agree with the premise here. Many lay newspapers and magazines have folded because they couldn’t respond adroitly to changes in the communications landscape. Scientific publishers have made huge investments in the technology of digital delivery; in implementing features such as reference linking, Digital Object Identifiers, and the panoply of other technical efforts spearheaded by CrossRef; in initiatives, such as HINARI, to boost access to research results in the developing world. As a result, scientific content is more widely and immediately available than ever before.

We might reframe the question as: Why haven’t scientific publishers taken more advantage of technology? One answer is that, until recently, the incentives to do so haven’t been there. The revenues associated with technological innovation arguably have been slower to materialize. In addition, the structure of professional rewards in science has proved profoundly resistant to change, remaining largely built around the print-driven construct of traditional scientific papers. This construct has limited the rewards for experimentation by publishers—but that’s starting to change.

What will make readers give up their printed version of a journal?

Michael A. Keller: The principal motivators, I think, are the ease of reading on a mobile electronic device and the use of enhanced features on that same device. A declining portion of reading is now accomplished with printed PDF versions of articles, and more readers are doing so online, so the seismic shift away from the traditional print journal is nearing its conclusion.

Anurag Acharya: I believe this train has long left the station. Few readers still read printed issues of journals. Personally, it has been many years since I consulted any of the printed articles I painstakingly collected. The ease of search and the ability to quickly scan many more articles have been powerful attractors in bringing readers online.

Philip E. Bourne: It is not that the reader is giving up on print—it is more that they are giving up on the notion of a journal. There is always print on demand. In an emerging marketplace of megajournals like PLoS ONE, as science becomes more multidisciplinary, and as we find science by aggregation services such as PubMed and Google, the concept of a journal loses significance, except for those journals that have significant community content, like the front matter found in Science and Nature. Such front matter is expensive and beyond most scientific journals. Otherwise, a research article from one journal is much like another. Of course, there is the different perceived prestige of the journal as measured mostly by its impact factor (IF), but with PLoS ONE having an IF of >4, the system has been seriously perturbed.

Mike Rossner: I think most readers have given up their printed versions of journals. As a result of the transition
to institutional online subscriptions beginning in the late 1990s, we have gone from thousands of print subscriptions to just a few hundred for all 3 of our journals combined at The Rockefeller University Press. What readers have not given up is the printed version of the individual article, a PDF. Readers like the convenience of the layout in the PDF, and many still prefer to read on paper rather than on backlit devices. Many readers still annotate printed PDFs by hand, but better electronic annotation tools will reduce the need for handwritten markup. Tools to share electronic annotations will also move readers in the electronic direction; such tools are under development by innovative companies such as Mendeley and Utopia.

**Stewart Wills:** Many readers already have given up the print versions of journals in favor of online access but have not abandoned printing the article as a PDF. A better question might be: When will publishers give up offering printed journals? The simplistic answer is: when it’s no longer profitable to do so. The reality is more complex. Many readers and authors (and therefore customers) have a strong emotional connection to print; even the most ardent advocates of unfettered electronic content distribution still seem quite pleased when their papers are featured on the cover of the print *Science!* Indeed, traditional publishers currently find themselves in a sort of double bind—they are expected to maintain a high-quality product for a slowly eroding print market, while making not-inconsiderable (and growing) investments in electronic publishing, curation, and distribution across an array of new platforms.

**How can we move from a “static” document to a “living” one, and should we?**

**Michael A. Keller:** In the advanced and most respected journals, the html versions of documents—with all the associated features of the high-end journals—are very much “live” and have been the copy of record for some years. Many readers use those features for research purposes, but some also flip over to reading the static document in PDF printout form.

**Anurag Acharya:** If by “living” document we mean one in which content changes like that of a web page, then I don’t think that would be a suitable model for scholarly articles. Scholarly articles build on each other’s results, citing insights, etc. This allows a new person trying to pursue an evidence/logical chain to follow the evolution of ideas. If articles are malleable rather than archival, it would be hard to construct a similar structure.

If the intent is rather to make it easier to find the current best understanding of the concepts/ideas covered in the article, that would be quite useful to new readers. Some possibilities include: (1) encouraging follow-up articles 3–5 years after the initial publication and linking them to the original one, and (2) automatically identifying articles that represent significant evolution in the understanding of the subject matter of the original article and linking them to the original article.

**Philip E. Bourne:** Wikipedia is perhaps the best example of a living document, and it is a great success. It defies the standard reward system we are accustomed to in science and is more for review material, but GeneWiki, Topic Pages in PLoS Computational Biology, and a number of other efforts speak to the idea of live content being an increasing part of scientific discourse. Better provenance and acceptance of these contributions of scholarship must come if living documents are to gain further popularity.

**Stewart Wills:** I can think of at least 2 definitions of a “living” document—a paper packed with additional interactive material to enable a richer experience of the research, and a paper that evolves over time with changes in the science. Both developments strike me as inevitable. On the first point, the “consumerization of IT,” and the increased facility of a broad swath of users in interactive techniques are already increasing the amount of high-quality material that might extend or complement traditional scientific reports. I see this as a big potential growth area.

The second approach—the evolving paper—is more difficult to envision and achieve, but we see hints of it in the appearance of user-comment streams alongside research results. That’s obviously an imperfect solution; better ones, perhaps with the wiki as a model, may well come along. One big limiting factor for the move from “static” to “living” documents, though, is simply finite time, both for authors and for publishers. Creating, updating, and curating “living” documents are not trivial tasks.

**Mike Rossner:** If we define “living” as dynamic, whereby the reader has access to all of the underlying data and can interact with those data, then we should definitely move to a “living” document. If we define living as “updatable,” so a publication is essentially a working paper, then I am less supportive of such a move. The scientific paper is a historical document—what was the state of a field at a particular point in time that led researchers to ask a particular question? How did the answer to that question advance the field at that time?

I certainly think that an article should be corrected if factual errors are found, or retracted if those factual errors affect the interpretation of the data, but it should not be updated ad infinitum. That would effectively...
create an up-to-date textbook, which might have its uses but which would lose all of the nuance of the progress of science. Although it is certainly possible to use wiki technology to create an updatable document that preserves its version history, how many Wikipedia readers go back and look at the history? There are also practical questions regarding an updatable document, e.g., how much of an advance would warrant an update? How would those updates be reviewed? How would researchers receive credit for updates?

**How do we go about filtering and choosing the high-impact scientific articles?**

**Michael A. Keller:** This is a key question, because articles may not be instantly recognized as pivotal or containing key new concepts. On the other hand, we should find the means to filter out, during the manuscript acceptance process, those articles that are highly likely not to be significant. Those articles should receive minimal treatment and attention until and unless the subject, the article, or the author gains attention, which would then justify more elaborate and labor-intensive treatment by editors and publishers.

**Philip E. Bourne:** Article-level metrics where readers vote with their keyboards clearly have a role in identifying high-impact articles. Gaming is possible, but safeguards are emerging to reduce that risk. Again, I cite PLoS ONE. There are many articles that were rejected by more traditional journals but have done very well in PLoS ONE. This tells us something about our current ability to define innovative science.

**Anurag Acharya:** I have no idea how to predict newly published articles that will have a large impact. However, I believe it is indeed possible to identify newly published articles likely to be of interest to a group of researchers. The key idea here is to use the same features that researchers have long used to identify new articles to read, such as: Who wrote the article? Which lab/group do the authors belong to? Which institution are they from? What do my colleagues say about it? Improved algorithms and increased compute power would allow us to consider these features at a much larger scale than an individual researcher can.

**Stewart Wills:** If the meaning is “How should we . . . ,” this is one of the most exciting questions—indeed, perhaps the central question—in professional scientific communication today. Almost everyone seems aware of the disadvantages of the journal-centric IF in an “article economy.” Yet, when we ask scientists young and old what leads them to choose a publication venue for their results, they invariably cite the journal’s IF. The IF appears too entrenched in the academic reward system to be easily dislodged.

Fortunately, an active community is exploring other possible measures of scientific impact complementary to citation-driven approaches—article-level metrics, web usage, and even influence in social media channels, the press, and other public discussion. All of these measures, like the IF, have their own problems. I believe that, over time, a hybrid approach to measuring impact will emerge, combining the impact of the journal brand, however measured, with robust article-level metrics to provide a more complete picture.

**What do you see as the biggest challenge to scientific publishing today?**

**Michael A. Keller:** The proliferation of minimally interesting articles; articles that convey falsified, fabricated, or plagiarized content (including images and data sets); bottom-feeder writing, editing, and publishing driven by career interests; and the limited distribution of journal articles in languages other than English are serious challenges to scientific publishing.

**Anurag Acharya:** Moving beyond the assumptions and constraints derived from print-based journals. The role of journals as distribution channels for physical copies has resulted in fairly tight page limits and article selection. As a result, articles often don’t have enough information for the reader to be able to replicate the studies, and communication of results is delayed as articles bounce from one journal to another. The move to online distribution removes some of these limitations.

Physical constraints have also resulted in abbreviated bibliographic information and citation styles. Insufficient recording of detailed information diminishes the reliability of identifying sources of articles and the relationships between the sources and between the articles, thus resulting in suboptimal searches.

**Philip E. Bourne:** Reducing the time to disseminate the information and increasing the amount of information disseminated in a usable way by human and machine would seem to be the biggest challenges today, whether you are that author striving for tenure, a patient with an incurable disease, or everyone in between.

**Stewart Wills:** The need to find a new value proposition in an era no longer characterized by information scarcity. In his essay “Better than Free,” Kevin Kelly memorably described the Internet as a sort of vast copy machine and asked what creates value in an environment where free copies of content are so readily available. He found the answer in other value sources that
“can’t be copied”—things like trust, findability, personalization, interpretation, and immediacy.

It’s my view that many publishers are fighting a rearguard action to protect traditional copyright, which may prove increasingly difficult and, perhaps, ultimately futile. We should instead be focusing on new sources of value in an age of networked information: giving authors the best possible presentation of their results and giving readers immediate access to trusted, authentic content when, where, and how they need it—as well as the tools to understand its significance and context in the larger scientific picture. But changing our perspective on how we bring value to the table and maintaining a viable business while doing so represent a huge challenge.

**Should we revisit the traditional peer-review system?**

Michael A. Keller: Like Winston Churchill’s description of democracy, peer review is not as efficient and efficacious as the scientific communication communities would like, but the alternatives are all worse. From my perspective, peer review should be conducted on the basis of high standards of scientific quality, as exemplified in the best general and specialty scientific journals. Peer review should admit novel hypotheses, methods, and findings, provided that there are sufficient experimental, diagnostic, or theoretical indicators of validity. However, consideration of submitted articles should be foreshortened for about half of all articles submitted globally, based on the quality or significance of the research and the findings. The half not receiving full treatment should be published effectively in preprint fashion—without benefit of peer review and copyediting—until and unless some greater value was revealed by use. That approach is, of course, anathema to those needing publication of their articles in any journal claiming peer review for purposes of appointment, promotion, and tenure. Another view of the chain of review by scientists (starting with acceptance of graduate students and post docs for engagement with senior scientists, proceeding with peer review in scientific-journal publishing, peer review in grant proposal processes, and peer review in appointment, promotion, and tenure processes) is that the ecology of peer review is both robust and effective in aggregate. Through the chain of such considerations in scientists’ lives, the quality of any individual’s work is revealed by success in articles published, grants received, and promotions attained in significant institutions.

Anurag Acharya: Traditional prepublishing peer review performs a key, albeit approximate, function—to indicate which articles are acceptable to a community. In some cases, it also helps improve articles. Both of these are desirable functions, and I don’t know of other ways to effectively and comprehensively perform these functions.

The traditional peer-review system, however, provides little additional information for readers as they consider new articles. It would be good to preserve at least some of the comments from the review process for the eventual readers of the articles. Some possibilities include (1) publishing parts of the referee comments, as the European Molecular Biology Organization and other journals have been doing; and (2) explicitly inviting commentary articles that appear at the same time as the original article, or soon thereafter.

Philip E. Bourne: There are different models of peer review out there already—prepublication review, postpublic review, open review, closed review, etc. Different versions seem to work, depending on the communities. Personally, I like the PLoS ONE notion (even if different editors interpret it in different ways). That is, if the science is sound (saves me time filtering as a reader), put it out there without worrying about the level of innovation. Let the community decide—effectively crowdsource the review.

Mike Rossner: The traditional peer-review system has been revisited in the past 10 years. The open-access business model emerged in 2000 through a systematic reduction in the stringency of peer review to feed high-volume publishing. In this system, the studies reported in a scientific article do not necessarily have to represent an advance in the field of study. What, then, is the utility of such a publication? It can provide authors with a venue for publishing negative or repeated data (but how many repeats warrant publication? 2, 5, 10, 50?), or for a relatively easy editorial review of work that does represent an advance in the field. What this approach does not do is provide a substantive filter for readers.

The growing popularity of reduced-stringency review corresponds with a growing and vocal dissatisfaction with the stringent-review process, which many people believe has swung too far in the opposite direction, with excessive requests by reviewers for additional experimentation. This is a valid concern, but this issue can be effectively monitored and alleviated by good journal editors to preserve the positive aspects of high-stringency peer review, through which designated experts provide a trusted authority that filters large volumes of information to find (what in their opinions are) the most significant advances and to present them to the appropriate audience.

Stewart Wills: Nothing is sacrosanct, nothing is perfect, and we should always be willing to revisit assump-
tions and traditional mechanisms. That certainly extends to peer review, and it’s clear that substantial experimentation and rethinking about the best approach to peer review are happening now. This ranges from more “open” approaches to traditional peer review, to postpublication peer-review mechanisms. I tend to think that, whatever the outcome of these efforts, the place for rigorous prepublication peer review in some form will remain secure, given the value that it adds as a primary filter in an information-glutted environment.

Are you optimistic about the future of scientific journals, and why?

Michael A. Keller: I am optimistic about the future of scientific communication, despite perturbations in the business models (including open access as a front of several business models) and the dreary prospect of every article getting published somewhere, no matter how mundane and void of actual contribution. That optimism arises from the sum of qualitative decisions made by scientists in several venues in their totality. These include the insightful and correct identification by STM editors of highly productive minds contributing new insights on a recurrent basis. Quality counts, and decisions about quality must be made within the scientific communities. Publishing the reports of the most productive and promising members of the scientific community is important for the advancement of science and to establish the record of science, thus permitting and supporting decisions about quality. The selection, editing, and association by program of the most respected scientific journal publishers have been, are, and will be predictors in validating the scientists who submit articles. Thus, whether the future of scientific journals lies as much in the journal issues or in branded articles, I am optimistic about the future of scientific communication, because it is an essential element in the advancement of science. There is too much at stake in the commonwealth of knowledge to forswear scientific communication.

Philip E. Bourne: I am very optimistic about the future of scientific communication, but uncertain how big a role the journal will ultimately play. There are a lot of people out there with great ideas for moving us beyond the PDF,” and some of these are sticking. The future will be more about discrete items of research; whether those items are at the level of a research article, a nanopublication, or something else remains to be seen. In my opinion, there is enough entropy in the system to see some new modes appear and take hold. It is an exciting time.

Stewart Wills: To me, the journal as a physical artifact seems doomed, as its costs and inconveniences as a mechanism of information delivery will increasingly tell against it. I also tend to think that even in its electronic incarnation, the scientific journal as an intellectual construct—that is, a collection of articles published weekly, monthly, quarterly, or whatever—will erode as well, albeit slowly, in light of the drive toward ever faster and ever more responsive information delivery.

What I do think will endure, however, is the journal brand as a filter and an indicator of the type and quality of content it embraces. In an environment saturated with information, users increasingly require a quick take on what matters and what’s important to come to grips with, both within and outside of their discipline. The journal brand offers one such filter, and a potentially powerful one, coupled with other longstanding modes, such as recommendations by colleagues and the reputation of author groups. I believe this role of journal brands will endure, irrespective of the fate of journals sensu stricto, as a packaging mechanism.

If we lived in a perfect world, how would you like scientific information to be communicated?

Michael A. Keller: Scientific information would be communicated electronically with healthy portions of interactivity among authors, peer reviewers, readers, teachers, and students through efficiently published articles replete with sharing of data, including image data and open rights for text and data mining. The role of responsible publishers (i.e., those whose main goal is effective scientific communication with profit making subordinated and sustainable publishing) is the norm. Naturally, I see only a few for-profit publishers and many scientific societies self-publishing as the models for this vision of perfection.

Anurag Acharya: We live in a world of rapidly accelerating hard problems. Some are of our own making, and others have been thrust upon us. If we are to survive these adversities, we need to bring together the intellectual abilities of as many people as possible. If I could create my perfect world, researchers from around the world would be able to quickly learn and build upon what their peers have discovered so all those who have the ability and desire to contribute to the solutions have the opportunity to do so. I grew up on a university campus in India where many smart people spent long hours in laboratories and libraries. Sadly, much of that work had little impact because of their limited exposure to what had already been learned and accomplished by others elsewhere.
Philip E. Bourne: What I want is the publication of work flows; I want the data, the methods, and how they were executed all available. Scientific reproducibility is mostly a myth in my opinion; work flows, if done right, would take us much closer to this pillar of science that many scientists seem to think already exists.

Mike Rossner: I think there is still a place for the scientific narrative in a perfect world. The narrative tells the story behind a researcher’s application of the scientific method to answer a particular question. The perfect scientific communication provides the reader with access to all of the data underlying a scientific narrative and with the ability to interact with those data. This is already possible for many types of complex data sets, with databases established by the research community, by funding agencies, or even by journals (e.g., the JCB Dataviewer) to store data, annotate it, present it in a useful and searchable manner, and provide it to users in standardized formats.

Where such data-sharing mechanisms exist, many journals already require that authors use them to deposit data underlying a publication. Funding agencies have begun to mandate access to data, but such mandates must be backed up with the funds necessary for ongoing development of the data-sharing infrastructure as novel types of data sets are introduced, data sets become more complex, and increasing volumes of data are generated.

What are your views on open access compared to the common subscription system?

Michael A. Keller: From my perspective, open access is just another business model. That open-access enthusiasts have demonized all publishers is a shame, heedlessly and needlessly damaging self-publishing scientific societies. University and college librarians have failed to exploit the economic power of their acquisitions budgets but instead have succumbed to the blandishments of the “big deals,” which so obviously could (should?) have been seen to be wasting money on very little used, bottom-feeding journals, money that could have been invested in more relevant titles published by smaller, specialized publishers, including, especially, the scientific societies. Finally, the adverse economic realities of the past few years have awakened skepticism by librarians about the “big deals,” a decade and a half too late for the corrective action that could have been taken, but that approach is still much needed. Thus, the common subscription system—manipulated by the for-profit publishers with the silent approbation of college and university librarians supposedly charged with stewardship of institutional assets—has served only one of the players in the grand scheme well; all the other players—the entire academy—have suffered.

Mike Rossner: The concept of immediate public access to published biomedical research articles was developed by BioMed Central. As I indicated above, it was instituted as a business model, which entails high-volume publishing fed by reduced-stringency peer review. In this model, reviewers are asked only whether the data presented in the work support the conclusions drawn. They are not asked to evaluate whether the work represents an advance for the field. The high volume of papers published, coupled with other cost-cutting measures, such as the elimination of copyediting, keep the costs per paper low. The success of BioMed Central and subsequent ventures like PLoS ONE indicate that there is clearly a desire in the biomedical research community to have such venues for publication, but that does not preclude their coexistence with journals that serve a filtering function by undertaking stringent peer review and publishing a small percentage of submitted papers at a high cost per published paper. These journals are sustained by selling subscriptions, which spreads the cost across a wide readership. Their continued success indicates that the research community still values these functions. Publishers of these journals can provide public access after a short period under access control, during which they sell subscriptions to desirable content.

Can immediate public access work for low-volume, high-stringency journals? Yes. Either funding agencies become willing to pay the actual cost of publishing an article in one of these journals (or underwrite the cost of a whole journal), or the cost per article is subsidized in some way, for example by selling news content or by sharing expenses across a suite of journals, of which one is a high-volume, reduced-stringency journal.

Philip E. Bourne: Having spent a considerable amount of time over the past 7 years cofounding and then being the editor in chief of an open-access journal, my viewpoint is obvious. Open access through the likes of BMC and PLoS has shown itself to be financially sustainable. Given this persistence, what possible reason would there be for not making science freely and openly available? Scientific societies need subscription revenue from their journals to function. This begs the question, what offers more to science—the work of a society or free access to the knowledge by everyone? This then raises the question of the role of scientific societies in a connected world, but that is another debate.

Stewart Wills: Like most editors, I would prefer it if all content could be completely free and thus see a lot of
prima facie value in open access. Author-pays open access does shift the vested interest and paying customer of the publisher to the author, and some have rightly highlighted potential problems in that, with, for example, conflict of interest. But these strike me as growing pains that are inevitable and not insurmountable.

What we haven’t figured out at this point, at least at Science, is how to pay for open access and still operate at the level of breadth and quality that has enabled us to build the reputation we have. In many ways, open access does seem like a model that’s easier for new players who can “break the mold” than for more established organizations that have built their viability around a specific way of doing business.

That said, I think that the question’s phrasing highlights a key point: This issue is too often framed in unsubtle, adversarial ways. Speaking for myself, as an employee in a “traditional” publishing organization, I think that the push for alternative business models and approaches is one of the healthiest things that has happened in scholarly publishing in years, as it has made publishers question their assumptions on how best to provide value for authors and readers. Most of the people I know in this business are there, at least, because they love science and care about scientific communication and advancement. It seems to me that more than one business model can support those goals, but the market will ultimately have to decide.

Author Contributions: All authors confirmed they have contributed to the intellectual content of this paper and have met the following 3 requirements: (a) significant contributions to the conception and design, acquisition of data, or analysis and interpretation of data; (b) drafting or revising the article for intellectual content; and (c) final approval of the published article.

Authors’ Disclosures or Potential Conflicts of Interest: Upon manuscript submission, all authors completed the author disclosure form. Disclosures and/or potential conflicts of interest:


Consultant or Advisory Role: J. Sack, American Chemical Society Governing Board for Publishing; M.A. Keller, numerous scientific societies and libraries; M. Rossner, PubMed Central National Advisory Committee.

Stock Ownership: M.A. Keller, Mondobiotech Holding.

Honoraria: None declared.

Research Funding: None declared.

Expert Testimony: None declared.

Patents: None declared.

Previously published online at DOI: 10.1373/clinchem.2012.194738