Transforming Scientific Communication for the 21st Century

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ABSTRACT. Since its inception in the 17th century the research journal emerged as the formal communication method in the sciences. The last half of the 20th century has seen stresses develop on the journal system due to the explosion of scientific research, increasing subscription costs, and technological advances. New models, taking advantage of digital technology, have demonstrated that great improvements are possible if the scientific community is willing to embrace change. Two methods for significantly changing the model are suggested: adopting an e-print moderator model which decouples the dissemination of information from its review, and shifting the costs of publication from the reader to the author and sponsoring agencies and organizations.

KEYWORDS. Scientific communication, scholarly communication, scientific journals, e-prints.

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Introduction

Much has been written in the last half century about ways to improve the communication of research findings in science and technology. In 1963 a US Presidential Advisory Committee issued a number of recommendations intended to strengthen the communication system for science and technology.[1] Since then the rising cost for information, particularly scientific and technical journals, has exacerbated the problem.[2] The library community has been vocal in recommending solutions to the existing crisis,[3] and it has been joined by many university faculty and administrators in its plea for reform.[4] This paper briefly reviews the factors creating the crisis in scientific communication, examines some of the most promising initiatives that have emerged during the last decade, and recommends two principles any solution must incorporate.

Background

Communication lies at the heart of research.[5] It is a key component in the advancement of science.[6] The emergence of the journal as the efficient method for formal communication in the sciences dates back to the 17th century.[7] Despite its success, problems have been associated with journals: delays in publication due to the time involved in the peer review process, constraints on the length of papers, and packaging papers of interest with papers not of interest.[8] Nevertheless the journal system remains the de facto archive for scientific communication, and scientists continue to consider scholarly journals to be extremely valuable.[9] The threat to this archival system results from a combination of forces which now threaten the roles and blur the lines between the various stakeholders in the scholarly communication process: creators (faculty and other researchers), publishers (commercial and societal), and enablers (universities, companies, governments, and libraries).

Three forces have created the current crisis. The first is the rapid growth in scientific knowledge. Since the 17th century science has grown exponentially.[10] Although it now appears that the rate of growth of the formal scientific literature is declining, the total growth of research information being put into circulation annually, formally and informally, remains formidable.[11]

The second force at work has been the commercialization of scholarly publication in the sciences.[12] The years 1950-1975 saw a marked growth in the importance of commercially published journals.[13] This growth contributed to what has long been known in the library community as the serials crisis, which highlighted concerns that a long-term solution requires a fundamental reconfiguration of the dynamics of scholarly communication.[14] A more recent analysis of journal pricing indicates that mergers among commercial publishers have contributed significantly to ongoing price increases.[15]

The third force at work is technology. Information technology is advancing at a rapid pace and becoming ubiquitous.[16] Predictions that technology can solve the crisis in scholarly communication abound.[17] The demise of the traditional scholarly journal has been predicted[18] and celebrated[19] as inevitable due to technological advances. However, ensuring the long-term preservation of digital materials at a level equal to or greater than paper has achieved in the past is far from certain.[20] Although computer centers have demonstrated that archiving digital data is possible,[21] there is still much uneasiness about archiving electronic journals.

In addition to these three forces, it is important to understand how authors' motives and copyright policies contribute to the current situation.

> A common misconception is that people create materials primarily for the fees and royalties that they generate... Creators whose motive is not financial usually benefit from the widest possible exposure of their work. This creates a tension with their publishers,

> whose business model is usually to allow access only after payment. Academic journals are an important category of materials in which authors' interests (recording their research and enhancing their reputations, both of which benefit from broad dissemination) may be in direct conflict with the publisher's desire for revenue. [22]

In the current system many scientists do research supported by university resources and government funding, and publish the results of that research. Research articles are submitted either to nonprofit academic publishers or commercial publishers. In return for their services publishers typically demand that authors give them copyright ownership of their articles. Publishers then sell these articles back to the scholarly community, either to libraries or to individuals, as journals. In this cycle of publication universities and their libraries expend large amounts of resources at both the front and back end.[23]

The production and consumption of scholarly information in the academic community has been governed by a gift culture marked by faculty members giving away their research to publishers and expecting to be able to access it for free in their libraries. The commercialization of scholarly publishing over the last fifty years has created a dramatic shift from nonprofit to for-profit publishing, creating a hybrid gift/market system. This has been a major contributor to the current crisis caused by the rising costs of scholarly information.[24]

Scientists value library subscriptions to journals because library subscriptions save them time and money, and help them improve the quality of their work.[25] Library budgets have been unable to keep pace with the increasing volume and cost of scientific scholarship.[26] These increasing costs, combined with the current funding situation for academic institutions and the changing communication infrastructure, require a fundamental redefinition of how libraries operate and cooperate in order to contribute effectively to the scholarly communication process.[27]

So what will happen to the scientific journal? Can the status quo be changed in a manner that takes advantage of new advances without harming the careful archival process that has been developed over the ages? Can the promise of cheaper costs and broader access be realized? Developments during the last decade have begun to reveal some answers.

A Decade of Progress

XXX Archive

> In many highly competitive, fast-moving fields of basic science, such as molecular biology, the machinery of publication in standard journals moves too slowly to serve fully the needs of the scientific community. It has therefore become customary for scientists to circulate preprints of articles among their colleagues. Such informal circulation, which harks back to the earliest days of science when new results were communicated by personal letter, has the advantage of speed. But it also has within it the seeds of serious disorders for science... The scientific community must devise ways of retaining the timeliness of the preprint and yet reducing its privateness and irresponsibility.[28]

In 1991 Paul Ginsparg at the Los Alamos National Laboratory began an e-print archive for high energy physics which soon expanded to other areas of physics and even to other disciplines.[29] XXX[30], as the archive is known, remains a vital part of the scientific communication process in physics, and serves as an important model for how the communication process might change in other disciplines.[31] Building on the pre-existing "preprint culture" in high energy theoretical physics which had already become the primary means of communication between researchers in the field, Ginsparg provided a paradigm for improving scientific communication. Using computing and networking advances he provided timely and widely distributed access to important research work. His model has spawned other successful discipline specific e-print archives such as CogPrints[32] for cognitive sciences and RePEc[33] for economics.

Reclaiming Copyright

Responding to perceived unfairness in the copyright system, in 1993 librarians associated with North Carolina's Research Triangle universities led an effort to develop a new publishing and copyright policy:

> As a non-profit institution which relies heavily on government and foundation grants to support its research activities, this university asks its faculty to publish their scientific and technical research results in journals supported by universities, scholarly associations, or other organizations sharing the mission to promote widespread, reasonable-cost access to research information. Where this is not possible, faculty should use the model "Authorization to Publish" form below to ensure that control of copyright in the published results of their university research remains within the academic research community.[34]

This movement toward taking control of one's intellectual output has had some effect. The Association of Computing Machinery copyright policy[35] retains traditional copyright transfer to the ACM but allows authors greater flexibility than in the past, including the right to mount their material on private servers. The American Physical Society has adopted a similar policy.[36]

Highwire Press

In early 1995 Stanford University Library's Highwire Press began online production of the *Journal of Biological Chemistry*, the highly cited journal of the American Society for Biochemistry and Molecular Biology. Soon to follow and partner with Highwire were *Science* and the *Proceedings of the National Academy of Sciences*. Now, in 2000, Highwire produces over 200 journal titles, primarily in the medical and life sciences. Highwire was founded to ensure that its partners, scientific societies and "responsible" publishers, would remain strong and able to lead the transition toward the use of new technologies for scientific communication.[37] It has played a significant role in improving the functionality of electronic journals, pioneering the use of links between authors, articles, and citations, providing advanced searching capabilities, high-resolution images and multimedia, and interactivity. While Highwire should be credited with providing a good model for how to use technology to improve the capabilities of electronic journals, it has had less influence in improving the economic models for the distribution of scientific information. These functional improvements, however, have served to demonstrate how technology can contribute to a positive transformation rather than simply a modernization of the scientific journal.[38]

Scholars' Forum

In March 1997 Caltech held a Conference on Scholarly Communication. At that meeting, attended by university administrators, faculty, and librarians from across the U.S., a consensus emerged that the certification of scholarly articles through peer review could be "decoupled" from the rest of the publishing process, and the peer review process could continue to be supported by the universities whose faculty serve as editors, members of editorial boards, and referees.

> The central idea would have the learned societies expand their role to undertake a certification process for articles, independently of whether they are submitted for, or are eventually published in the standard paper journal system. Under such a system, scholars could submit articles for review (with an agreed-upon submission fee), and the normal refereeing process of the learned society would determine whether the article qualified for their "seal of approval," which, if received, could be affixed to any electronic version of the article as retrieved by others.[39]

The proposal *Scholars' Forum: A New Model For Scholarly Communication*[40] calls for a trilateral partnership between a consortium of universities, professional societies, and authors which would:

1. Support peer review and authentication
2. Support new models of presentation incorporating network technology
3. Permit "threaded" online discourse
4. Adapt to varying criteria among disciplines
5. Assure the security of data
6. Reduce production time and expense
7. Include automated indexing
8. Provide multiple search options

SPARC

The Scholarly Publishing and Academic Resources Coalition (SPARC) was created in 1998. SPARC is a coalition of libraries, initiated by the Association of Research Libraries (ARL), that seeks to partner with scholarly publishers willing to enter markets where journal prices are highest and competition is needed. Through its activities, SPARC intends to reduce the risks to publisher-partners of entering the marketplace and to provide faculty with prestigious and responsive alternatives to current publishing vehicles. Since its inception SPARC has partnered with a number of scholarly societies including the American Chemical Society, Royal Chemical Society, Geological Society of America, and the IEEE.[41] It has also provided grant monies to university initiatives such as Columbia University Press' Earthscape,[42] MIT Press' CogNet,[43] and the California Digital Library's eScholarship.[44] Possibly its most ambitious project to date is BioOne, which will aggregate, link and make easily accessible peer-reviewed research in the biological, ecological and environmental sciences. It hopes to enable leading non-profit journals self-published by scientific societies to remain viable, and offer them a cost-effective alternative to commercial publishers' digital aggregations.[45]

Can SPARC succeed in supplanting journals which are too expensive with less expensive alternatives? While it is having some initial success in introducing significant new journals, in the short term it has created a quandary for libraries which now find themselves having to subscribe to additional titles while convincing faculties that the more expensive titles are no longer necessary. Time will judge whether SPARC will be successful in eliminating, reducing the cost, or making less important the more expensive titles.[46]

NEAR

In October 1998 David Shulenburger, Provost at the University of Kansas, unveiled his proposal for a National Electronic Article Repository (NEAR):

> We must find a way of requiring that when a manuscript prepared by a U.S. faculty member is accepted for publication by a scholarly journal, a portion of the copyright of that manuscript be retained for inclusion in a single, publicly accessible repository, after a lag following publication in the journal… NEAR would see to it that articles are permanently archived, thereby assigning responsibility for the solution to another problem brought to us by the electronic age. NEAR could be funded by universities through "page charges" per article included, by federal appropriation, by a small charge levied on each user upon accessing articles or by a combination of these methods.[47]

E-BIOMED

In May 1999 Harold Varmus, then Director of the National Institutes of Health, proposed E-BIOMED: A Proposal for Electronic Publications in the Biomedical Sciences. Within four months this controversial proposal morphed into PubMed Central: An NIH-Operated Site for Electronic Distribution of Life Sciences Research Reports.[48] PubMed Central has created vigorous debate[49]

and responses from the private sector.[50] The July 2000 *Freedom of Information Conference: The Impact of Open Access on Biomedical Research*, held at the New York Academy of Medicine, represents the most recent round of debate on this topic at the writing of this article.[51] So far the reaction to Varmus' proposal demonstrates the problems associated with the existing copyright structure,[52] a copyright structure which has been described as a Faustian bargain made by scholars to get their work published.[53]

Open Archives Initiative

In October 1999 digital librarians and computer scientists committed to creating a Universal Preprint Service (now known as the Open Archives Initiative[54]) gathered in Santa Fe, New Mexico, for a meeting sponsored by the Council on Library and Information Resources, the Digital Library Federation, SPARC, ARL, and the Research Library at the Los Alamos National Laboratory. The objective of the meeting was to pave the way for universal public archiving of the scientific and scholarly research literature on the Web.[55] Participants concluded that many different archive initiatives were likely to emerge, and, for such initiatives to become part of the scholarly communication system, interoperability was essential. Further, a consensus developed that interoperability hinges on a clear distinction between the archive functions and end-user functions.[56]

Although many technical issues were identified and discussed, social issues concerning scholarly communication also emerged:

1. Will the institution provide or support a departmental or institutional e-print archive of authors associated with the institution? If so, will it adopt the open archive principles agreed to in Santa Fe?
2. How will research libraries package and deliver access to e-print literature?
3. With the resolution of e-print archive interoperability technical issues, what will be the process of resolving the social issues connected with tenure and publishing?[57]

Building Consensus

In March 2000 a conference was held in Tempe, Arizona, sponsored by the Association of American Universities, the Association of Research Libraries, and the Merrill Advanced Studies Center of the University of Kansas.[58] Participants produced a set of *Principles for Emerging Systems of Scholarly Publishing.*[59] In the preface to their principles they state:

> Numerous studies, conferences, and roundtable discussions over the past decade have analyzed the underlying causes and recommended solutions to the scholarly publishing crisis. Many new publishing models have emerged. A lack of consensus and concerted action by the academic community, however, continues to allow the escalation of prices and volume.

Their hope is to build consensus on a set of principles that will inform the design and evaluation of new systems of scholarly publishing. The goal is to provide guidance while leaving open to creativity and market forces the actual development of such systems.

DSpace

In July 2000 Hewlett Packard and the MIT Libraries began a two year research project called DSpace.[60] DSpace aims to develop a scalable digital archive with storage, submission, retrieval, searching, access control, rights management, and publishing capabilities. Its goal is to embrace all of the digital intellectual output of MIT. DSpace is one of the first e-print archive initiatives to focus on capturing an institution's output rather than a particular field of scholarship, and, in addition, it is one of the first involving an industry partner, HP.[61] It hopes to contribute answers to some of the questions raised by the Open Archives Initiative.

eScholarship

In July 2000 the University of California launched eScholarship,[62] dedicated to facilitating scholar-led innovations in scholarly communication. The overall goal of eScholarship activities is to develop an infrastructure for digitally based scholarly communication that:

1. Facilitates the mutual interests of the University, its faculty, and the broader scholarly community.
2. Leverages the capabilities and strengths of UC to provide leadership in this area.
3. Supports and extends experimental reconfigurations of the components of scholarly communication by communities of scholars themselves.

eScholarship sees itself as a core set of disciplinary e-print archives surrounded by functional tools and orbited by value-added scholarly "products" created by scholarly societies, the university, or third parties. It includes the following key components:

1. Disciplinary-based knowledge archives of e-prints.
2. Support tools for submission, expanded peer review, discovery, access, and use.
3. New scholarly products drawn from e-print archives.[63]

E-prints for Chemistry?

At the August 2000 American Chemical Society National Meeting in Washington, D.C., the ACS sponsored a Webcast *Online Preprints: Implications for Chemistry*.[64] Although no consensus was reached, the points raised at this forum effectively highlight many of the questions and issues surrounding the debate over e-prints:

1. The need for effective, efficient means of information dissemination that uses all available technology to reach as many readers as possible.
2. The fact that disciplines have different cultures, e.g., physics and math researchers use preprints as an integral form of communication.
3. The need to determine whether preprint articles are considered "prior publications" and what that means for current society practices for journal publication.
4. The issue of whether proper content and credit fairly applied can be assured without peer review.
5. The relationship between preprints and patent applications.
6. Organizational questions: How to name, archive, and file preprint information to allow for future access.

Changing the Paradigm

XXX represents the most significant change in scientific communication since the establishment of the journal in the 17th century. Although not intended to replace journals, it quickly became used as an electronic journal for obvious reasons of convenience.[65] XXX has shown that simply focusing on the status quo of scientific journal creation and dissemination is shortsighted. It demonstrates that the basic distribution of scholarly papers can be achieved inexpensively while at the same time increasing access.[66] Can its success be transferred to other scientific communities? Or are the cultural differences between disciplines too great a barrier? The World Wide Web is an example of how an innovation developed by the high energy physics community has been quickly adapted by the world at large.[67] Why not e-prints?

The momentum created by XXX, the Open Archives Initiative, and other related projects is spawning a transformation in scientific communication. Clearly the dissemination of scholarly work can be separated from the peer review process. Although the peer review process is not

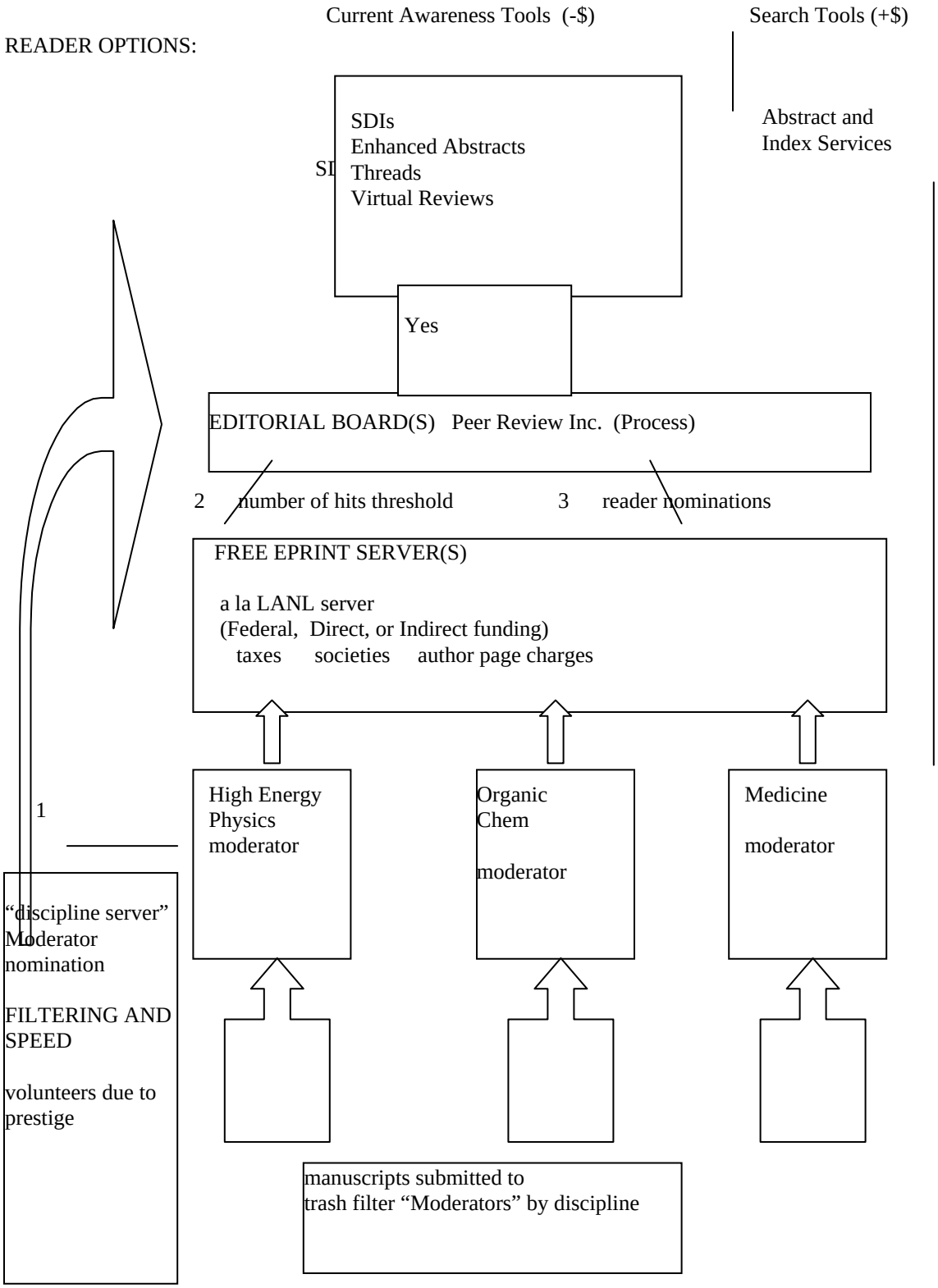
perfect,[68] most scholars, including physicists, value its importance.[69] The American Physical Society has successfully begun to work with xxx to speed up peer review.[70] In addition the initial concern some authors displayed regarding the lack of prestige associated with scholarly electronic journals is eroding.[71]

Serious obstacles remain, however, and one of the largest is convincing publishing stakeholders to change their financial models. Commercial publishers and many scholarly societies have benefited financially from the current model for scientific journals. They are grappling with their mission of advancing knowledge in their respective disciplines versus the dependence they have developed on the income generated by their publishing programs. Another challenge is the social and cultural differences between the different scientific communities, as demonstrated by the previously discussed E-BIOMED proposal and the ACS Webcast on Online. Social issues are often more difficult than technical ones, and can be hard to overcome.[72] Although scientists pride themselves on their belief in logic and rational thought, old traditions do die hard and university communities are not noted for rapid change.

I believe the most promising strategy for improving the flow of scientific communication involves a combination of two ideas. The first is moving to an e-print moderator model [see figure 1]. This has the potential to allow the widest range of scientific manuscripts to be archived, searched, and distributed electronically with the lowest possible cost.[73] It will take cooperation between authors, editors, reviewers, societies, universities, and responsible publishers.

Second, the costs for publication must shift from the reading community to authors and the funding agencies/institutions sponsoring their research either by direct support or through overhead costs.[74] In fact it is argued that open access publishing is becoming a permanent feature of the Internet, and that an economic model is emerging where the costs are paid for by the suppliers of the information. [75] Certainly the costs borne by current subscription models are counterproductive to the goal of disseminating scholarly work as far as possible. For years librarians and others have decried the increasing costs of journals and been forced to cancel subscriptions, thus impeding access to scholarly work. By reverting to a funding system more akin to page charges authors and the organizations sponsoring their research will be more aware of the costs associated with disseminating their work, and will be more responsible in determining where their work is published. In their exhaustive work on electronic journals Tenopir and King comment that reverting to a page charge system would be a great gain from a system economic standpoint.[76] Although they acknowledge that the basic research funders would bear a larger burden of the costs associated with publishing, they go on to state “society would benefit because more use, and, therefore, value would be derived from the basic research findings.” Is this not a goal worth fighting for?

Figure 1 E-print moderator model (from *Guide to Information Sources in the Physical Sciences* by David Stern ©2000 Libraries Unlimited)



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