

Electronic Publishing in Science

Invited contribution for Conference held at UNESCO HQ, Paris, 19-23 Feb 1996, during session *Scientist's View of Electronic Publishing and Issues Raised*, Wed 21 Feb 1996:

Winners and Losers in the Global Research Village, P. Ginsparg

- [Abstract](#)
 - 1. [Introduction](#)
 - 2. [Some History](#)
 - 3. [Scholarly vs. Trade Publication](#)
 - 4. [The Current Role of Physics Journals?](#)
 - 5. [Potential Pitfalls](#)
 - 6. [Problems and Possibilities](#)
 - 7. [Who needs it?](#)
 - 8. [Cloudy Futures](#)
-

Abstract

I describe a set of automated archives for electronic communication of research information that have been operational in many fields of physics, and some related and unrelated disciplines, starting from 1991. These archives now serve over 35,000 users worldwide from over 70 countries, and process more than 70,000 electronic transactions per day. In some fields of physics, they have already supplanted traditional research journals as conveyers of both topical and archival research information. Many of the lessons learned from these systems should carry over to other fields of scholarly publication, i.e. those wherein authors are writing not for direct financial remuneration in the form of royalties, but rather primarily to communicate information (for the advancement of knowledge, with attendant benefits to their careers and professional reputations). These archives have in addition proven equally indispensable to researchers in less developed countries.

A major lesson we learn is that the current model of funding publishing companies through research libraries (in turn funded by overhead on research grants) is unlikely to survive in the electronic realm. It is premised on a paper medium that was difficult to produce, difficult to distribute, difficult to archive, and difficult to duplicate -- a medium that hence required numerous local redistribution points in the form of research libraries. The electronic medium shares none of these features and thus naturally facilitates largescale disintermediation, with the resulting communication of research information both more efficient and more cost-effective. A correctly configured fully electronic scholarly journal can be operated at a fraction of the cost of a conventional print journal, and could for example be fully supported by author subsidy (page charges or related mechanism, as already paid to some journals), ideally allowing for free network distribution and maximal benefit both to authors and readers.

Another lesson is that authors are unlikely to accept "electronic clones" of print journals (i.e. electronic versions identical in content, functionality, methodology and appearance, to paper versions), whether transmitted via CD-ROM or via the network. The electronic medium should not be constrained by any former print incarnation and, in particular, easily implemented quality appraisal mechanisms in the electronic realm will be dramatically superior to the binary (i.e.

one-time, all-or-nothing) procedure employed by the print medium, which in turn frequently conveys inadequate signal. Moreover, authors and their funding institutions will be empowered to insist upon retaining the right to distribute electronic research documents and attachments in the format produced by the authors. Authoring tools already allow a highly sophisticated end-user format, including automatic network linkages, and will continue to improve.

The essential question at this point is not **whether** the scientific research literature will migrate to fully electronic dissemination, but rather **how quickly** this transition will take place now that all of the requisite tools are on-line. Secondary open questions include determining the most effective means of cost recovery for the disseminators of this information, what agencies will be responsible for insuring the long-term archival integrity, indexing, and cross-compatibility for the various research databases, and how peer review will be organized for those disciplines that depend on the value-added it can in principle provide.

Finally, I describe some of the major improvements, enhancements in functionality, and other expansions projected over the next few years for the existing archives.

1. Introduction

Electronic publishing in science has recently become the focus of an increasing number of workshops and conferences, typically including representatives from professional societies and other scholarly publishing concerns, and members of the library community; but only a small or vanishing participation from actual researchers. This is ironic since the average scientist provides the lifeblood of scientific publication on a daily basis as reader, author, and referee, frequently as editor, and also as organizer of conferences, schools, and workshops. Scientists consequently understand research publication from the inside-out as few non-researchers ever could, and many have grown frustrated at patronizing attempts to assure them that unthinking preservation of the status quo is in their best interest. It is clear that many traditional roles will be shifted by the electronic medium, and new roles will emerge, though precisely which players will acquire the competence to fill which roles, and when, remains to be determined.

In principle, the new electronic medium gives us the opportunity to reconsider many aspects of our current research communication, and researchers should take advantage of this opportunity to map out the ideal research communication medium of the future. It is crucial that the researchers, who play a privileged role in this as both providers and consumers of the information, not only be heard but be given the strongest voice. In particular, we need to dislodge definitively the curiously prevalent notion that the future electronic medium will strictly duplicate, inadequacy for inadequacy, the current print medium.

2. Some History

Rather than relate here the full history of the "e-print archives" and whatever has occurred since mid 1991, instead I will concentrate only on some highlights that serve to illustrate the major lessons learned to date, and suggest their implications for the future. (For additional background information, see my [article](#) *First Steps Towards Electronic Research Communication*, **Computers in Physics**, Vol.8, No.4, Jul/Aug 1994, p. 390, originally adapted from a letter to **Physics Today**, June 1992. For some of the more recent publicity, see **Computers in Physics**, Vol.10, No.1, Jan/Feb 1996, p. 6; and **Science**, Vol.271, 9 Feb 1996, p. 767.)

The first database, hep-th (for High Energy Physics -- Theory), was started in August of '91 and was

intended for usage by a small subcommunity of less than 200 physicists, then working on a so-called "matrix model" approach to studying string theory and two dimensional gravity. (Mermin [Reference Frame, Physics Today, Apr 1992, p.9] later described the establishment of these electronic research archives for string theorists as potentially "their greatest contribution to science.") Within a few months, the original hep-th had quickly expanded in its scope to over 1000 users, and after a few years had over 3800 users. More significantly, there are numerous other physics databases now in operation (see [xxx](#) physics e-print archives) that currently serve over 35,000 researchers and typically process more than 70,000 electronic transactions per day (i.e. as of 2/96; see the [weekly stats](#) for an overview of growth in WorldWideWeb usage alone at [xxx.lanl.gov](#)).

These systems are entirely automated (including submission process and indexing of titles/authors /abstracts), and allow access via e-mail, anonymous ftp, and the WorldWideWeb. The communication of research results occurs on a dramatically accelerated timescale and much of the waste of the hardcopy distribution scheme is eliminated. In addition, researchers who might not ordinarily communicate with one another can quickly set up a virtual meeting ground, and ultimately disband if things do not pan out, all with infinitely greater ease and flexibility than is provided by current publication media.

It is important to distinguish the form of communication facilitated by these systems from that of usenet newsgroups or garden variety "bulletin board" systems. In "e-print *archives*," researchers communicate exclusively via research abstracts that describe material otherwise suitable for conventional publication. This is a very formal mode of communication in which each entry is archived and indexed for retrieval at arbitrarily later times; Usenet newsgroups and bulletin boards, on the other hand, represent an informal mode of communication, more akin to ordinary conversation, with unindexed entries that typically disappear after a short time.

While the high energy physics community did have a pre-existing hardcopy preprint habit that had already largely supplanted journals as our primary communication medium, this is not a necessary initial condition for acceptance of an electronic preprint archive, as evidenced by recent growth into other areas of physics and mathematics, and even to [computation and linguistics](#). The economics for all this remains favorable, with a gigabyte of hard disk storage currently averaging under \$500 (i.e. roughly 25,000 papers including figures can be stored for an average of less than 2 cents apiece). Finally, politically correct elements typically fret over leaving the third world in the dust -- but the reality is that less developed countries are *already* better off than they were before: researchers in eastern Europe, South America, and the far East frequently report how lost they would be without these electronic communication systems, and how they can finally participate in the ongoing research loop. It will always remain easier and less expensive to get a computer connected to the internet than to build, stock, and maintain conventional libraries -- the conventional journal system had always been much less fair to the underprivileged.

To summarize, to date we've learned:

1. The exponential increase in electronic networking usage has opened new possibilities for formal and informal communication of research information.
2. For some fields of physics, the on-line electronic archives immediately became the primary means of communicating ongoing research information, with conventional journals entirely supplanted in this role. Researchers will voluntarily subscribe and make aggressive use of these systems which will continue to grow rapidly. The current levels of technology and network connectivity are adequate to support these systems. (Though we anticipate the need for increases in transcontinental network carrying capacity to catch up with the recent explosion in non-academic usage -- otherwise scientific usage will require either priority routing on the shared network or an independent network.)

3. For some fields of physics, open (i.e. unrefereed) distribution of research can work well and has advantages for researchers both in developed and undeveloped countries.

3. Scholarly vs. Trade Publication

Before continuing, we must distinguish at this point between two very different types of publication, formerly grouped together only due to accidental similarities in their modes of production and distribution. Understanding this distinction is crucial to the future of scholarly publishing endeavors. (My comments here have been strongly influenced by e-mail discussions with Stevan Harnad and correspondents, some of which are available at [this ftp url](#). Other relevant discussions of electronic publishing issues by Harnad, with further references, are available at [this http url](#) or equivalently at [this ftp url](#)).

In scholarly publication (a.k.a. "Esoteric Scholarly Publication"), we are writing to communicate research information and to establish our research reputations. We are not writing in order to make money in the form of royalties based on the size of a paying readership. We have every desire to see maximal distribution of our work (properly accredited of course), and would fight any attempt to suppress that distribution. In trade publication, on the other hand, authors write specifically to sell their articles and books, and have direct financial remuneration in mind from the outset. It is consequently in their interest as well to maximize distribution, but at the same time to insure that each reader pays per view; for this the intermediation of a publishing company to maintain an infrastructure to exact money from paying customers and to root out bootleg distribution may well remain welcome.

So in scholarly publication, we have a situation wherein authors can joke that they would pay people to read their articles. (N.B. this potential paucity of readership for any given article must not be used as an argument that support of basic research is intrinsically wasteful -- it simply results from the naturally restricted size of a highly specialized community, and does not directly measure the ultimate utility of the research.) So the essential point is now self-evident: if we the researchers are not writing with the expectation of making money directly from our efforts, then there is no earthly reason why anyone else should make money in the process (except for a fair return on any non-trivial "value-added" they may provide; or except if, as was formerly the case in the paper-only era, the *true* costs of making our documents publicly available are sufficiently high to require that they be sold for a fee). Now we are ready to consider the current role played by publishers of physics research information (at least in certain fields).

4. The *Current* Role of Physics Journals?

It is ordinarily claimed that journals play two intellectual roles: a) to communicate research information, and b) to validate this information for the purpose of job and grant allocation.

As I've explained, the role of journals as communicators of information has long since been supplanted in certain fields of physics, so let's consider their other role. Having queried a number of colleagues concerning the criteria they use in evaluating job applicants and grant proposals, it turns out that the otherwise unqualified number of published papers is too coarse a criterion and plays essentially no role. Researchers are typically familiar with the research in their own field, and must in any event independently evaluate it together with letters of recommendation from trusted sources. Recent activity levels of candidates were mentioned as a criterion, but that too is independent of publication per se: "hot preprints" on a CV can be as important as any publication.

So many of us have long been aware that certain physics journals currently play NO role whatsoever

for physicists. Their primary role seems to be to provide a revenue stream to publishers, a revenue stream invisibly siphoned from overhead on research contracts through library systems.

5. Potential Pitfalls

So this goes a long way to explaining how it could possibly be that a system whose primary virtue is instant retransmission is able to supplant entirely established journals as a credible information source in certain fields. (Though it is true that e-print archives are technologically somewhat ahead of what established publishers are offering in ease of use and functionality, and are likely to remain so for the foreseeable future.)

With an example of an electronic system that physicists will voluntarily and actively use in hand, it is illuminating to consider how a poor understanding of the properties and potentialities of the electronic medium can lead to badly mistaken implementations. An example of this was an American Physical Society (APS) "request for proposals" for an on-line version of Physical Review Letters back in autumn 1993. Its superficial problem involved asking that the electronic version be identical in appearance to the printed version --- in other words to clone electronically every unnecessary artifact of the paper version. Its more profound problem is that the entire journal structure and organization needs to be reconsidered in light of the electronic format. In an era of instantaneous communication, why is there still a need for a letters journal with its draconian page limits and atavistic claims of rapid publication? As is well-known to potential physicist readers, artificial constraints result in articles too telegraphic to be useful either to experts or to non-experts.

While I have used familiarity with the situation within one small sector of physics publishing to illustrate these points, feedback from researchers in other fields indicates that there is a generic and growing frustration at the slowness of existing publishers to recognize that the needs of researchers can potentially be served in an electronic format in novel and creative ways. The current problem consists both of misguided selection criteria and of misplaced goals: publishers may measure the success of their journals by the number of pages published, whether certain artifactual and unnecessary constraints are met, and whether they're published "on time" (i.e. with regularity, not with speed). "Useful", "readable", "innovative" are not necessarily primary criteria in this established framework.

Even benign, nonprofit organizations and learned societies can easily become addicted to the amenities of scholarly publishing and lose track of their original mandate: thus placing the revenue-generating potential of their established publishing enterprises above the need to furnish creative intellectual services to their constituents. Until recently, there were few effective options for physicists or other researchers to break into an intellectually void closed loop involving only publisher and library systems. The resources necessary for production and distribution of conventional printed journals allowed publishers to focus on their mechanics, and avoid any pressure to rethink the intellectual content and quality of their operations.

6. Problems and Possibilities

Why is it that the current implementation of peer review, as employed by paper journals, needs to be entirely rethought in view of new possibilities afforded by electronic publication and dissemination?

A most obvious problem in the current scheme is that as the number of researchers in any given field has grown (both due to global population increase and increased cold war funding for the sciences), the number of papers published in journals for any given field has vastly exceeded the ability of any one researcher to read and absorb. While perhaps there once was a time when a physicist could pick

up a single journal each month and read it from cover to cover to remain abreast of all of physics, this idyllic state of affairs is not even a distant memory for any recent generation of physicists. Nonetheless, this outmoded methodology effectively remains the basis for many aspects of the current implementation of peer review, in physics and in other fields.

Once the mere fact of publication in a journal no longer gives a particularly useful guide, readers are forced to perform the majority of the selection on their own by some set of additional criteria, and their primary need is simply access to the information as quickly as possible. For this reason, a systematic preprint system was set up for high energy physics institutions in the early 70's and largely usurped the role of conventional journals as conveyors of topical information. This widespread preference for rapid access over the limited filtering provided by peer review was even more dramatically reinforced with the advent of the electronic preprint (e-print) archives in the early 90's, which quickly grew to supplant as well the conventional archival role of journals in many fields.

This is not, however, to argue that peer review cannot in principle provide substantial added-value to the reader. One of the foremost problems at present is the large amount of information lost in the conventional peer review process, with the end result only a single one-time all-or-nothing binary decision. Although this may somehow be adequate for the purpose of validating research for job and grant allocation, it clearly provides little benefit to the average reader.

A variety of superficial improvements can easily be implemented immediately in the electronic realm. Since there are no financial or physical barriers to widespread dissemination, we can imagine a relatively complete raw archive unfettered by any unnecessary delays in availability. Any type of information could be overlaid on this raw archive and maintained by any third parties. For example the archive could be effectively partitioned into sectors, gradated according to overall importance, quality of research, or other useful criteria, and papers could be shifted retroactively as dictated by additional information or follow-up research. And rather than face only an undifferentiated bitstream, the average reader could benefit from an interface that recommended a set of "essential reads" for a given subject from any given time period. There could also be retroactively added descriptive information, "this paper was important since it drew upon a,b,c [hyperlinks to sources] and led to new developments x,y,z [more hyperlinks]" to provide a further guide to the literature. Or the interface could point to a specific paper as having been important, but warn the beginner to go first to a later paper by the same (or other authors) that subsumes, extends, or corrects the same results in a more understandable fashion; or this paper generated much attention but skip it since the fad played itself out and people returned to more serious pursuits. The literature need not be frozen in time as in the paper medium, but can remain as fluid as the research itself. Even interdisciplinary research (for example if I as a particle physicist wished to peruse the recent literature in biophysics or even biochemistry) can be easily facilitated by an interface that allows rapid identification of papers that provide pedagogic review material or are otherwise likely to be of specific interest to outsiders. Further possibilities such as moderated comments threads attached to specific points in papers together with more exotic features can be added in successive stages as desired.

7. Who needs it?

Will the enthusiastic use of the instant communication provided by free access to unreviewed electronic archives ultimately emerge only as an artifact, preferred only in isolated subsets of the scientific community? This is to a certain extent an experimental question, answerable only after all the bits have settled. But it is worthwhile to speculate on features that may characterize those scientific sub-communities most likely to find it practical and efficient in the future to sidestep the conventional peer-review structure for rapid access to new results, while still maintaining some form of electronic peer-review system to provide validation of and guidance to their archival literature. In

other words, looking beyond current experience drawn from a well-defined and highly interactive community of voracious readers with a pre-existing hard-copy preprint habit, with a standardized word processor and a generally high degree of computer literacy, with a rational means of assigning intellectual priority (i.e. at the point of dissemination rather than only after peer-review), and with little concern about patentable content --- all of which may be regarded as momentary historical accident --- is there some more abstract characterization of the required autonomy that allows a circumscribed community to flourish rather than suffocate in its own unreviewed output stream? Again it will be easier to argue these issues in retrospect someday, but at least one noteworthy feature can be identified: in my own research discipline, the author and reader communities (and consequently as well the referee community) essentially coincide. Such a closed peer community may signal a greater intrinsic likelihood for acceptance and utility of free electronic dissemination of unreviewed material.

Research communities comprised of a relatively small number of authors and a much larger number of readers *could* ultimately settle on a very different model, wherein the institutions that support the research assert copyright privilege, assume the role of publishers, and disseminate material produced in-house for a fee to those institutions that only consume it. Though this would upset proponents of free electronic access to all publicly supported research material, it would at least be a logical system, in which the real risk-takers --- namely the institutions that support research by way of investment in salary and equipment --- are able to profit from and protect the products of that investment. The current system, which cedes full copyright of high-quality content to low-risk publishers who step in at the last moment and provide at most a comparatively insignificant few hundred dollars of added-value (in most cases even selling it back at high prices to the initial sponsoring institution), has never been particularly sensible.

8. Cloudy Futures

For the moment, conventional publishers have continued to express their unbridled enthusiasm for open electronic dissemination systems, despite an intrinsic potential for subversion. As long as their bottom line is unaffected, they can afford to be arbitrarily magnanimous in their desire for peaceful coexistence: "After all we have long been in the business of propagating research information, we would never dream of trying to suppress it in any way..."

But ever financially pressed research libraries are poised for triage of their journal subscriptions. And as pointed out by [Quinn \(1994\)](#), there's a potential explicit mechanism to encourage preferential cutting of subscriptions to physics journals: Libraries, faced with difficult choices, may decide that physicists already have an alternate information feed from the raw global electronic database; and physicists may well complain the least (or not at all) when their journals are threatened with cancellation. (Indeed this is already reported to be happening in India and other places with severely limited financial resources -- as argued above, the less developed countries stand to benefit at least equally from recent technological developments).

The physics and math archives now offer a variety of choices of high quality output formats (TeX source, [hyperdvi](#), gzipped hyperPostScript with choice of font resolution or type 1 PS, or pdf, ...) and will be able to support higher level formats as they become available. With this aspect of end-user accommodation thus trivialized, the near-term concerns have shifted to the continued development of a robust global mirroring system, and to better means of handling meta-level indexing information. Additional mirror distribution sites and caching proxy servers will give better response times, especially to international users whose access is increasingly impeded during times of day when their national networks and transcontinental links suffer from the congestion caused by recent increases in non-academic network traffic. In the long-term, they also provide a global backup system resistant to

localized database corruption and/or loss of network connectivity. The problems of indexing and categorization of information in principle lie within the purview of the library and information science communities, but to date theirs has been a curiously low profile in the electronic realm, while various amateur brute-force indexing schemes are running dangerously amok. It would be remarkable if centuries of ostensibly relevant experience will find little applicability in the network context.

We should also be alert to risks borne by authors who may find themselves prematurely encouraged to abandon "chemicals adsorbed onto sliced processed dead trees" in favor of an electronic-only archival format. There is a certain leap of faith involved here, since every once in a while one does after all get lucky and write a paper that could still attract readership a century from now. The physical format, with a worldwide system of institutional libraries serving as a multiply redundant distributed archive, has proven robust on the timescale of centuries to anything short of global cataclysm (in which case we'd probably have more pressing concerns). No current electronic format has proven similar longevity --- for the simple reason that all have been in existence for little more than a decade if that. Few claim to know what will be the preferred electronic format a century from now, but I'm willing to go out on a limb and assert that it will be none of TeX, PostScript, PDF, Microsoft Word, nor any other format currently in existence. On the other hand, this is certainly not a fundamental problem of principle, and perhaps scientists will eventually come to rely on much-needed logistical assistance from future librarians in their role as archivists: just as endangered material on decaying acid paper is currently migrated to microfilm, automated translation to newer and more general electronic formats should always be possible during transition periods, provided there is an acknowledged need to prevent our living research archives from becoming data cemeteries.

One possibility is that some consortium of professional societies and institutional libraries will ultimately acquire the technical competence to provide umbrella sponsorship of the global raw research archive. Those societies that are as well non-profit publishers may continue to organize high-quality peer-reviewed overlays (though perhaps no longer as a means of generating income to subsidize other non-publishing ventures), and certain commercial publishers accustomed to large pre-tax profit margins on their academic publishing activities will probably have to learn to compete in more realistic marketplaces.

In the long term, it is difficult to imagine how the current model of funding publishing companies through research libraries (in turn funded by overhead on research grants) can possibly persist. As argued by [Odlyzko \(1994\)](#), it is premised on a paper medium that was difficult to produce, difficult to distribute, difficult to archive, and difficult to duplicate -- a medium that hence required numerous local redistribution points in the form of research libraries. The electronic medium shares none of these features and thus naturally facilitates largescale disintermediation, with attendant increases in efficiency benefitting both researchers and their sources of funding. As described above, recent developments have exposed the extent to which current publishers have defined themselves in terms of production and distribution, roles which we now regard as trivially automated. But there remains a pressing need for organization of *intellectual* value-added, which by definition cannot be automated even in principle, and that leaves significant opportunities for any agency willing to listen to what researchers want and need.

FAIR USE: I reserve the right to distribute this electronic document in any way I so desire. It is publicly posted to the internet on my server, and anyone is free to establish a link to it from a subsidiary server (but not to copy it for public posting on a remote server, since that could lead to an undesirable proliferation of obsolete versions). It should not be reprinted for inclusion in any publication for sale without my explicit permission.