

Reforming Scholarly Publishing in the Sciences: A Librarian Perspective

Joseph J. Branin and Mary Case

Introduction: The Librarian's View of the Scholarly Publication System

Research librarians—that is, librarians who work in large college, university, and private research libraries—today face the difficult challenge of managing their collections and information services during a period of crisis and profound change in scholarly publications. This crisis and change affect all fields of knowledge, but the sciences, including mathematics, are front and center in defining the stresses and innovations that are shaking the foundations of the established, scholarly publication system. Research librarians at present are particularly concerned about three issues in scholarly publishing. First, there is the very specific but seemingly intractable problem of reversing, or at least containing, the rapidly rising cost of scientific journal subscriptions. Librarians often describe this as the “serials crisis” in scholarly publications. Second, there is growing concern among research librarians that revisions to local, national, and international information policies and procedures governing intellectual property rights may threaten the free flow of information in scholarly communications. And finally, there is the overriding librarian preoccupation with the applications and effects of new information technology. Will the new digital information system fundamentally change the scholarly publication system

and the research librarian's role in it? Will new information technology help solve troubling current economic and structural problems in scholarly publication or merely exacerbate these problems?

The sheer volume of scholarly publication, the rising cost of this scholarship (particularly in the sciences), and the dizzying array of new options brought about by advances in information technology all conspire to make this an exciting and difficult time to be a research librarian. Underlying this tumultuous change and challenge is the fundamental question of who owns scholarly publications. Ownership is key to both the cost and accessibility of scholarship in the traditional print information system as well as in the emerging digital information system. Research librarians, as this essay will document, are increasingly troubled by the growing commercialization of scholarship in the sciences, where authors assign their copyrights to commercial publishers. By placing ownership of publications outside the circle of the academy, scholars run the risk of making their works unaffordable and unavailable to research libraries.

Research librarians and their concerns, of course, form only a subset of the players and issues in the overall scholarly publication system. The librarian perspective on problems and solutions in scholarly publication is important, but this perspective must be viewed in the context of an overall system which, at least until the present time, has depended on the interplay of authors, publishers, librarians, and readers in a highly interdependent process. The potential, in light of the new digital information system, for changing the roles of the respective players in the process is, in fact, one of the underlying stresses in scholarly

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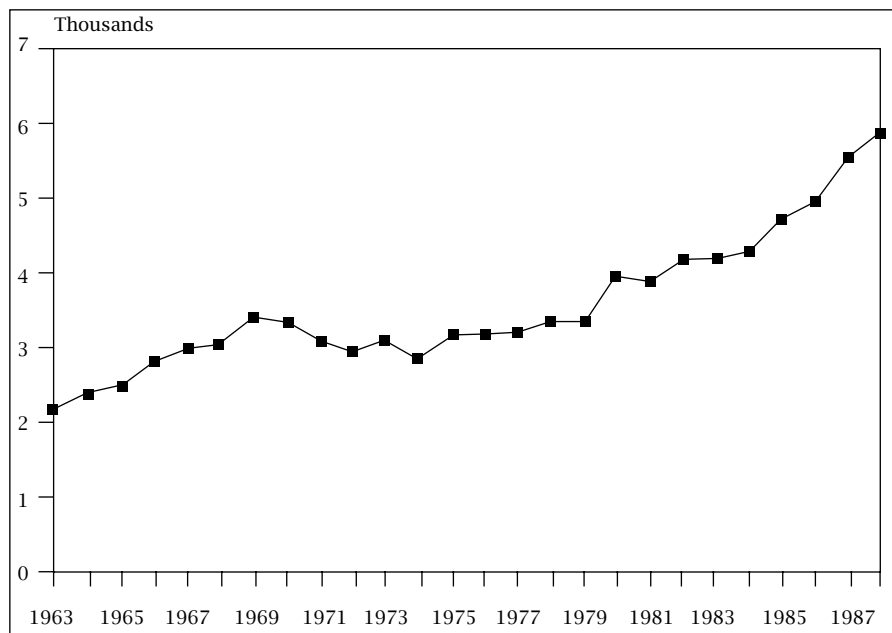


Chart 1. Number of university press books published annually.

publishing today. With desktop publishing software, client-server technology, and the Internet, do authors need publishers to produce and distribute their scholarship anymore? With mass digital storage, broadband telecommunications, and electronic document delivery to the desktop, what is to become of traditional library services to readers that have been built around decentralized, local print collections?

Defining the Crisis in Scholarly Publishing: Too Much at Too High a Cost

Whose Crisis Is It?

To oversimplify, the established formal scholarly publication system is made up of three major constituents: scholars who create, describe, and use new knowledge; publishers who evaluate, edit, package, and distribute this knowledge; and librarians who collect, organize, preserve, and share this published knowledge. Depending on your constituency group, you may or may not believe there is a crisis in scholarly publishing. Research librarians certainly think there is one, for they have been finding it increasingly difficult to keep up with the quantity and cost of new scholarship in the last quarter of the twentieth century. These may be the boom years for scholars and for certain types of publishers, but for research librarians, who collectively have the responsibility for preserving and sharing the complete record of scholarship, the overload of information is crushing. Rutherford D. Rogers, the retired director of the Yale University libraries, observed a number of years ago that information overload was the number one challenge facing scholars and research librarians. In a *New York Times* article entitled "Torrent of print strains the fabric of libraries" [1], Rogers commented that

"we're drowning in information and starving for knowledge."

The Growing Imbalance between Scholarly Output and Library Resources

Starting about twenty years ago, research librarians in the United States began complaining about the growing imbalance between scholarly output and the resources necessary to collect, preserve, and share this output. In 1979 a Board of National Enquiry composed of publishers, librarians, and university faculty and administrators issued a report entitled "Scholarly Communication" [2]. In it the board describes how librarians in major research centers are "facing the difficult task of allocating increasingly scarce dollars among the vast and steadily growing number of books, journals, microforms, and other materials of scholarship." According to the Board of National Enquiry major research libraries are "no longer able to develop or maintain comprehensive, self-contained collections". In 1991 the Andrew W. Mellon Foundation sponsored a study and report entitled "University Libraries and Scholarly Communication" [3]. The report documents the tremendous growth in the number of scholarly books and articles published over the last forty years. For example, Charts 1 and 2, which are reproduced from the Mellon study, show the increase in book titles issued by American university presses between 1963 and 1987. Except for some dips in the 1970s, university presses have generally issued more new titles annually, on average 3% more each year. In 1994 the Association of American Universities (AAU) in cooperation with the Association of Research Libraries (ARL) shared the results of its analysis of current challenges in scholarly communication. Again, the system is described as being out of kilter. According to the "AAU/ARL Research Libraries Project Report" [4] worldwide book production increased by 45% between 1980 and 1990, yet during the same period there was an "aggregate decline in the number of titles acquired by libraries."

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Growth of Journal Literature in the Sciences

While the growth of scholarship can be seen in all fields of knowledge and in all formats of publication, increases are most dramatic in the sciences and in the journal literature of the sciences. Chart 3, which is drawn from *Science Citation Index* source publications, illustrates the number of new scientific journals founded from 1700 to the end of the 1980s [3]. Since World War II there has been an explosion of scholarly information published in journals, particularly in scientific and technical journals. John Naisbitt, author of *Megatrends* [5], estimates that 6,000 to 7,000 new articles are writ-

ten each day and that scientific and technical information increases by 13% per year, which means a doubling in output every 5.5 years. Andrew Odlyzko, a mathematician at AT&T Bell Laboratories, believes scientific scholarly literature is growing at an exponential rate, in the mathematical meaning of the word. He estimates that the number of scientific papers published annually has been doubling every 10 to 15 years for the last two centuries. According to Odlyzko, in 1870 there were 840 papers published in mathematics; by the middle of the 1990s, there were 50,000 new mathematics articles being published annually [6].

The High and Rising Cost of Scientific Journals

The statistics on the volume of scholarly publishing may not be exact, but the trend is clear: more is being published each year, especially in scientific fields where the journal article is the formal medium of choice. This has severe implications for research libraries, because scientific journal subscriptions are expensive and the cost for these subscriptions is rising rapidly. The annual "Periodicals Price Survey", published in *Library Journal* [7], lists the recent price history and average cost of journal subscriptions in different disciplines (see Chart 4). According to the survey the most costly journals in 1997 are all in scientific fields. Physics journals, at an average price of \$1,494.47 for a library subscription, are the most expensive, followed by journals in chemistry, astronomy, biology, math and computer science, engineering, technology, geology, botany, and zoology. Journals in the humanities and social science fields on average cost much less: \$89.73 for journals in language and literature, \$96.46 for journals in history, and \$238.09 for journals in psychology. Not only are prices higher for scientific journals, but their costs are rising faster than in many other fields. Between 1996 and 1997 library subscription prices increased by 11.41% in physics, 11% in chemistry, and 10.04% in math and computer science, while language and literature increased by only 3.97%, history by 3.88%, and music by 7.57%. Some fields in the social sciences, such as psychology, which saw a rise of 11.43%, and business and economics, which increased by 13.7%, are beginning to rival the sciences for annual price increases in journal subscriptions.

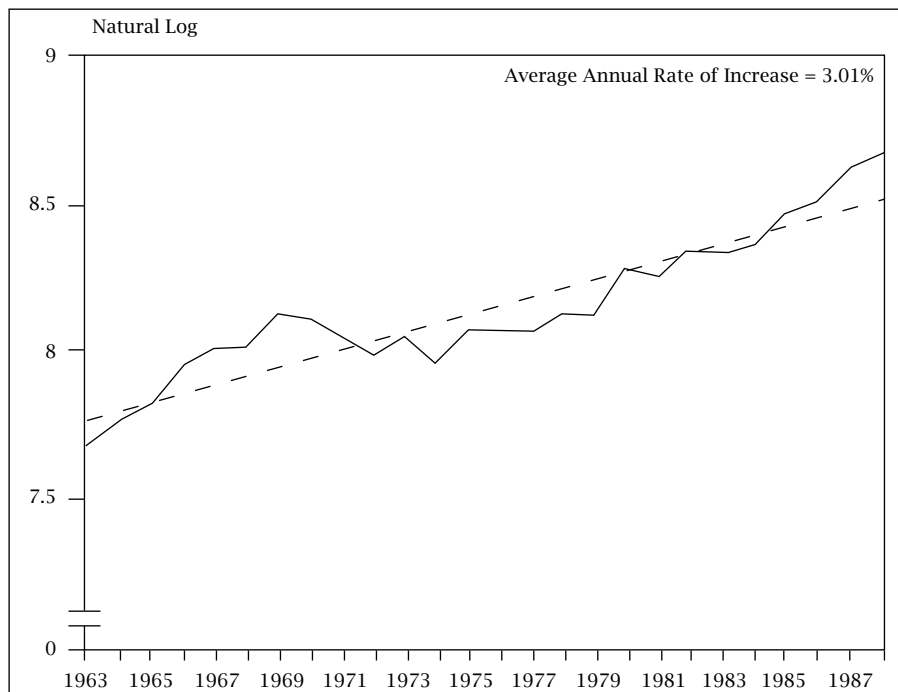


Chart 2. University press books, average annual rate of increase.

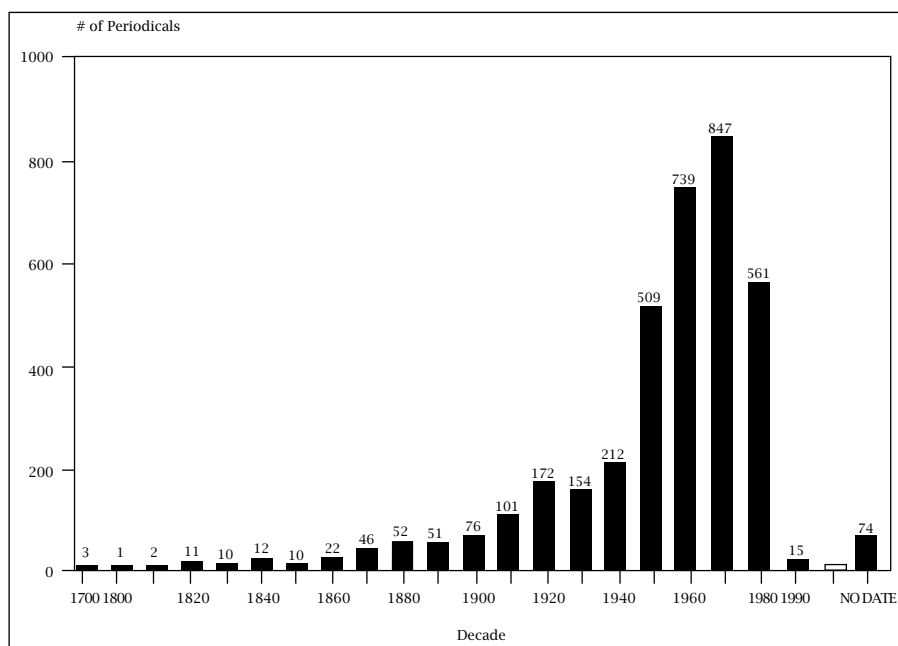


Chart 3. Growth of scientific journals.

Research Libraries Are Acquiring Less Each Year

Library budgets are simply not keeping pace with the increasing volume and cost of scholarship. At a time when research libraries should be acquiring more books and journals to keep pace with the growth of scholarship, they are actually acquiring fewer. Each year the Association of Research Libraries (ARL), which is composed of the 121 largest research libraries in North America, gathers statistics on its members' activities and expenditures. Chart 5 plots the general trend research libraries have found themselves in over the last decade [8].

Subject	Average No. of Titles 1993-97	Average Cost Per Title 1993	Average Cost Per Title 1994	% of Change '93-'94	Average Cost Per Title 1995	% of Change '94-'95	Average Cost Per Title 1996	% of Change '96-'97	Average Cost Per Title 1997	% of Change '96-'97	'93-'97 % of Change
Agriculture	197	\$274.98	\$286.91	4.34	318.68	11.07	\$373.34	17.15	\$402.49	7.81	46.37
Anthropology	38	127.18	138.93	9.24	155.55	11.96	174.08	11.91	186.44	7.10	46.60
Art & Architecture	67	91.46	93.01	1.69	98.14	5.52	103.88	5.85	108.21	4.17	18.31
Astronomy	22	829.55	755.95	-8.87	855.81	13.21	1,005.71	17.52	1,084.32	7.82	30.71
Biology	231	536.19	555.75	3.65	621.64	11.86	732.98	17.91	824.05	12.42	53.69
Botany	58	416.02	427.85	2.84	482.01	12.66	560.97	16.38	612.78	9.24	47.30
Business & Economics	238	190.95	204.90	7.31	236.64	15.49	280.80	18.66	319.26	13.70	67.20
Chemistry	186	933.88	940.88	0.75	1,035.01	10.00	1,224.50	18.31	1,359.22	11.00	45.55
Education	89	123.33	128.76	4.40	140.58	9.18	155.29	10.46	169.12	8.91	37.13
Engineering	241	491.36	534.98	8.88	591.13	10.50	718.91	21.62	814.38	13.28	65.74
Food Science	16	328.07	351.00	6.99	398.09	13.42	456.60	14.70	501.73	9.88	52.93
General Science	76	342.47	368.10	7.48	410.11	11.41	471.40	14.94	530.39	12.51	54.87
General Works	76	61.68	67.40	9.27	72.98	8.28	84.04	15.15	89.73	6.77	45.48
Geography	62	277.62	297.58	7.19	334.51	12.41	382.52	14.35	442.90	15.78	59.53
Geology	81	444.69	461.13	3.70	511.99	11.03	615.08	20.14	692.83	12.64	55.80
Health Sciences	1373	355.34	372.29	4.77	414.75	11.41	487.34	17.50	543.32	11.49	52.90
History	198	73.31	77.86	6.21	85.40	9.68	92.86	8.74	96.46	3.88	31.58
Language & Literature	328	67.48	69.37	2.80	75.87	9.37	86.30	13.75	89.73	3.97	32.97
Law	87	93.39	95.85	2.63	103.49	7.97	115.75	11.85	119.83	3.52	28.31
Library & Information Science	59	144.34	152.94	5.96	170.30	11.35	187.99	10.39	198.04	5.35	37.20
Math & Computer Science	169	526.84	582.34	10.53	631.04	8.36	743.09	17.76	817.72	10.04	55.21
Military & Naval Science	9	99.00	111.44	12.57	129.33	16.05	142.00	9.80	154.67	8.92	56.23
Music	45	53.59	55.07	2.76	59.24	7.57	62.59	5.65	67.33	7.57	25.64
Philosophy & Religion	140	86.28	87.21	1.08	97.55	11.86	108.28	11.00	112.70	4.08	30.62
Physics	184	994.93	1,020.57	2.58	1,130.57	10.78	1,341.46	18.65	1,494.47	11.41	50.21
Political Science	57	117.52	123.55	5.13	139.89	13.23	161.71	15.60	178.30	10.26	51.72
Psychology	134	152.87	167.98	9.88	188.67	12.32	213.67	13.25	238.09	11.43	55.75
Recreation	18	71.44	76.73	7.40	79.14	3.14	88.45	11.76	92.72	4.83	29.79
Sociology	242	145.64	155.83	7.00	172.63	10.78	196.90	14.06	215.20	9.29	47.76
Technology	196	430.22	474.47	10.29	531.37	11.99	631.07	18.76	706.95	12.02	64.32
Zoology	106	402.83	424.30	5.33	474.57	11.85	545.88	15.03	599.11	9.75	48.73

Chart 4. Cost history of periodicals by subject.

Between 1986 and 1996 the largest research libraries in the United States and Canada saw their serials purchases decline by 7% and monograph purchases decline by 21%. (In librarian terminology, "serials" are publications that are issued in successive parts, usually at regular intervals. Publications such as periodicals, newspapers, annuals, memoirs, proceedings, and transactions of societies are "serials". "Monographs" are single books on specific subjects.) While the number of scholarly serials and monographs purchased declined, research libraries spent 29% more on monographs and 124% more for serials during this same time period. The monograph unit price rose by 63%, and the serial unit price by 147%. These numbers are not adjusted for inflation, but since 1986 the annual average increase for a serial subscription has been 9.5% and for a monograph purchase 5.0%, both of which are higher than the general inflation trends in North America during this same period. In the last decade research libraries purchased fewer books each year than they did in 1986, and by 1991 serials subscription cancellation projects were becoming standard operating procedure.

The Commercialization of Scholarly Publication in the Sciences: At the Core of the Economic Problem

Blame the Publishers

As a result of the high cost and continuing double-digit annual price increases for scientific journals, research librarians have had to shift ever-larger portions of their acquisitions budgets into science journal subscriptions, even as they cancel journal titles and buy fewer books. With growing frustration and boldness, librarians are blaming the scientific community, particularly the commercial publishers of scientific journals, for this unfortunate situation. Librarians write about the expensive science journal as a "Doomsday Machine" or as "The Journal That Ate the Library" [9]. A headline in a recent issue of the *Wisconsin State Journal* proclaims, "Librarians rebel against publisher" [10]. The publisher in question is Reed Elsevier, the world's largest commercial publisher of academic and scientific journals. Its most expensive journals, such as *Brain Research* and *The Journal of Chromatography*, can cost as much as \$15,000 a year

for a library subscription. According to the news report in the *Wisconsin State Journal*, librarians are “fed up” and “quite desperate” over the high and rising prices that Reed Elsevier and other scientific publishers are charging for their journals. In a recent *New York Times* article entitled “Concerns about an aggressive publishing giant” [11], a group of professors and librarians at Purdue University is reported as telling Reed Elsevier that its “must have” journals had become “can’t afford”, and “don’t need” journals. Research libraries have simply not been able to retain their purchasing power for acquisitions in the face of these high costs for scientific journals. The result has been massive cancellation of library subscriptions and the steady erosion of new book purchasing. For example, the University of Wisconsin at Madison library, the fourteenth largest research library in North America, has cancelled more than 7,000 subscriptions to academic journals over the last ten years.

Blame the Librarians

While research librarians complain, some scholars and publishers express differing sentiments about the state of scholarly publishing in the sciences. Albert Henderson, editor of *Publishing Research Quarterly*, in a recent letter to *The Chronicle of Higher Education* [12], took issue with Robion Kirby, a mathematics professor at the University of California, Berkeley, over who is to blame for declining library acquisitions. Kirby, in April of 1997, sent an e-mail survey report on the cost of mathematics journals to his colleagues around the country [20]. Kirby describes the plight of mathematics libraries like that at Berkeley, where acquisitions funds are not keeping pace with the 13% rise in annual subscription costs for mathematics journals. Kirby points a finger at high-priced, commercially published mathematics journals and predicts that if the current situation continues, Berkeley’s math library will see its purchasing power cut in half in three years. While Kirby urges mathematicians to start publishing their work in less expensive journals, Henderson

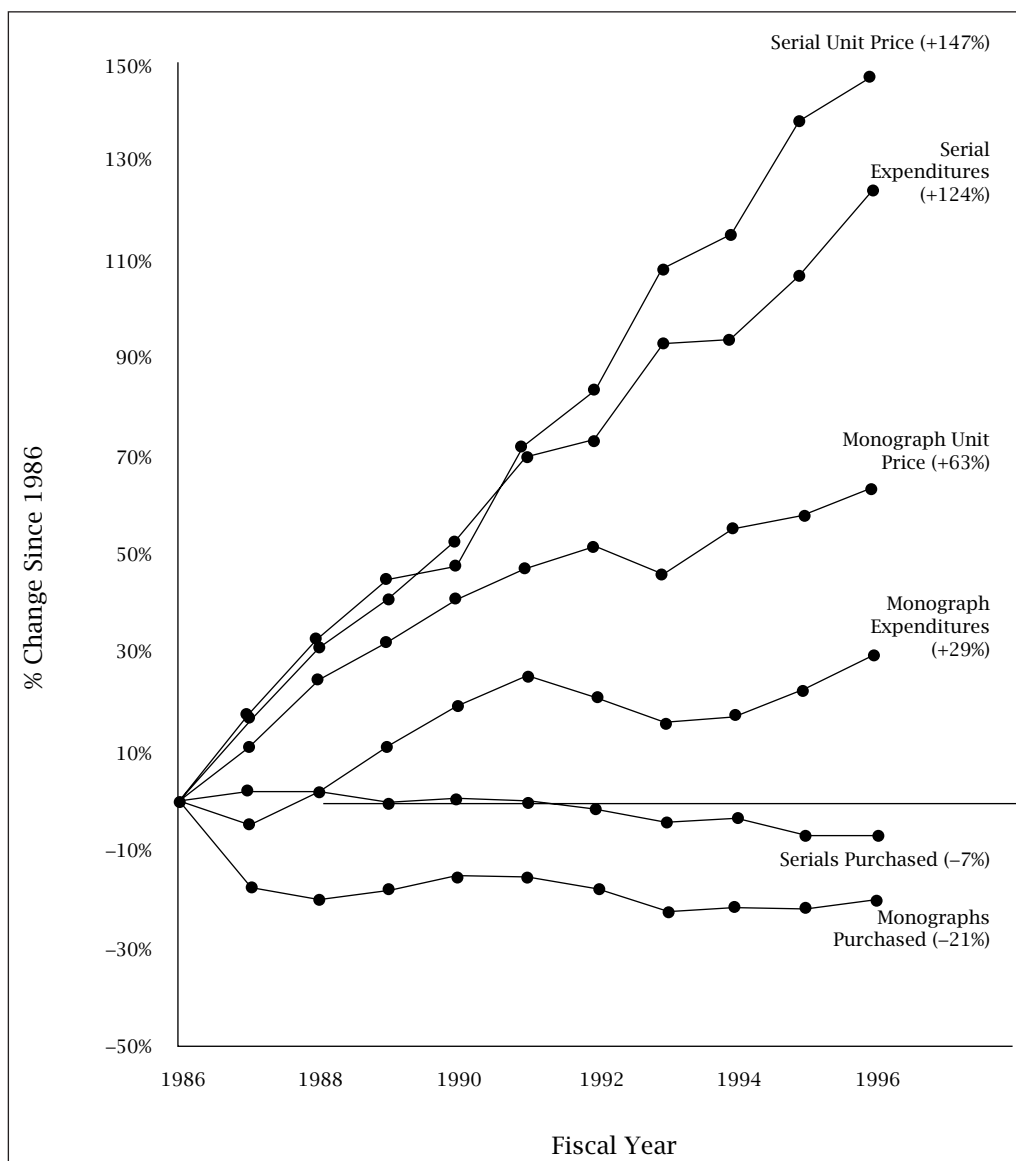


Chart 5. Monograph and serial costs in ARL libraries, 1986–1996.

makes a different recommendation: simply increase library funding. According to Henderson, “If library budgets matched the growth of research expenditures, we would not be having this discussion.” Henderson is right about the anemic state of research library budgets. As Chart 6 shows, the library percentage of university education and general expenditures has decreased almost 17%, from 3.91% in 1982 to 3.26% in 1995 [13].

But can research librarians and the academic community realistically expect that library acquisitions budgets will increase by 10% to 15% a year? At Berkeley, for example, where the expenditure for mathematics journals was approximately \$250,000 in 1997 and subscription increases are averaging 13% a year, the institution will have to commit over \$360,000 to math journal subscriptions in the year 2000 just to retain the same purchasing power. The provost at the University of Kansas recently told the Kansas faculty that the uni-

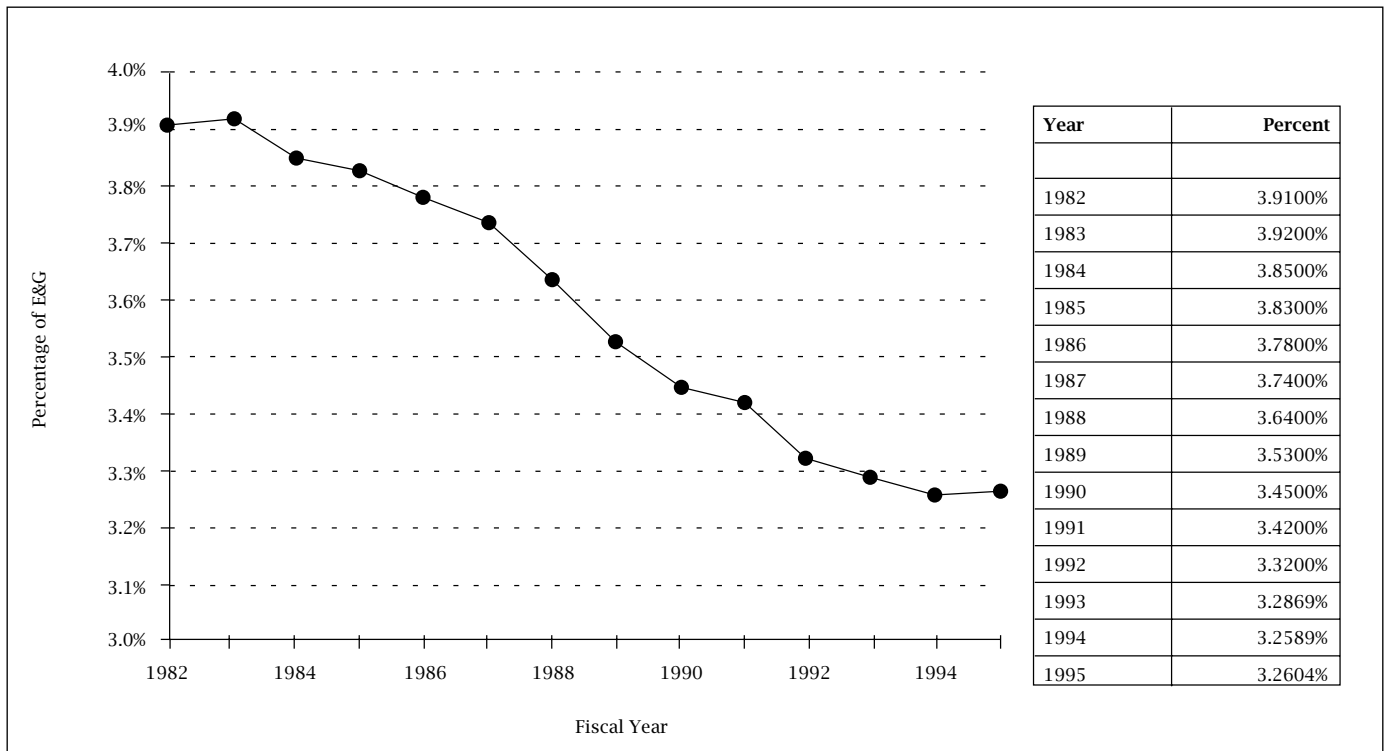


Chart 6. ARL library percentage of university education and general (E&G) expenditures.

versity library there would need an acquisitions budget of \$9.4 million to purchase the same proportion of published scholarship as it did in 1986 [14]. This is 2.5 times more than its current acquisitions budget. To have achieved this total, the acquisitions budget at the University of Kansas libraries would have had to increase by 9.6% a year during a time when the university's operating budget increased by only 2.6% a year. Research librarians certainly want to strengthen the library economy, but few would expect, in either public or private universities, the massive infusions of funds necessary to keep pace with current inflation rates for scholarly scientific publications.

Why Do Science Journals Cost So Much?

Why do science journals cost so much, and why do subscription prices for these journals continue to rise at double-digit rates each year? Could the reasons be the growth of science literature, fewer subscribers, and higher production costs or profits for publishers? These are not easy questions to answer, because publishing data are notoriously slippery and sensitive. As one publishing industry analyst put it, "Book industry statistics may be likened to a handful of wet spaghetti. They may be more or less digestible, even a bit nourishing; but they are messy, slippery, elusive, never tidy" [15]. One scientist who tried to get a better handle on the cost of science journals paid dearly for his efforts.

The Barschall Study

In 1986 and again in 1988 Henry Barschall, now deceased but at the time a physics professor at the

University of Wisconsin and an editor of *Physical Review*, published a series of studies on the cost and cost effectiveness of scholarly journals in several scientific disciplines [16, 17]. Barschall determined the cost, based on library subscription price, per 1,000 characters for a sampling of journals in physics, optics, mathematics, and philosophy. He found that the cost-per-character ratio could be more than 40 between the most expensive commercially published journals and the least expensive scientific society- or association-published journals. In physics, for instance, Barschall's study revealed that in 1985 the *Journal of Applied Physics*, published by the American Institute of Physics, cost .7 cents per 1,000 characters, while *Particle Accelerators*, published by Gordon and Breach, cost 31 cents per 1,000 characters. In mathematics, using the American Mathematical Society's (AMS) "Survey of American Research Journals" of 1982, Barschall found that a library subscription to the *Journal of the American Statistical Association* cost .8 cents per 1,000 characters, while *Applicable Analysis*, published by Gordon and Breach, cost 35 cents per 1,000 characters [16].

Barschall then went on to add another factor to his analysis: "impact", the frequency with which articles in journals are cited, as measured in *Science Citation Index*. By combining cost and impact Barschall developed a cost-effectiveness test which he applied to 200 journals in physics. His analysis led him to conclude that "All the publishers whose journals have low average costs per character or low ratios of cost to impact are scientific societies or associations, while the publishers

whose journals have high costs per character or high ratios of cost to impact are commercial firms" [17].

Blame the Commercial Publishers of Science Journals

Barschall's findings confirmed the experience of many research librarians: commercial publishers in the scientific disciplines were at the core of their economic woes. One commercial publisher, Gordon and Breach, who came out at the bottom of Barschall's survey of cost effectiveness, disagreed and sued Barschall, the American Physical Society (APS), and the American Institute of Physics (AIP) in West Germany, Switzerland, France, and the United States over the publication of the journal cost surveys [18]. Gordon and Breach later obtained an injunction in West Germany, barring the AMS from distributing surveys in which Gordon and Breach journals were included. The injunction still stands. Gordon and Breach contended these surveys were conducted in a poor manner and constituted unfair comparative advertising. Nevertheless, courts in West Germany, Switzerland, and the United States upheld Barschall's right to say what he did and the rights of the APS, AIP, and AMS to publish surveys on journal cost. A French trial court did find in favor of Gordon and Breach under strict French comparative advertising laws. The AIP/APS is appealing that decision. In the U.S. case, decided on August 26, 1997, Judge Leonard B. Sand found in favor of AIP/APS, affirming that "Barschall's methodology has demonstrated to establish reliably precisely the proposition for which defendants cited it—that defendants' physics journals, as measured by cost per character and cost per character divided by impact factor, are substantially more cost-effective than those published by plaintiffs" [19]. When notified of Judge Sand's decision, Gordon and Breach immediately announced their intention to appeal the decision.

Gordon and Breach's legal tactics are a disappointment to the scholarly community, and they have not stopped further analysis of cost differentials among science journals. As mentioned earlier, in the spring of 1997 Robion Kirby distributed widely an e-mail message to his colleagues [20] that reported on a survey he conducted on the cost of mathematics journals in the University of California, Berkeley, library. Kirby's findings are similar to Barschall's: prices, in this case cost per page, charged for journals in mathematics can vary greatly. Kirby's exact figures are subject to more dispute than his qualitative conclusion: commercial publishers, such as Gordon & Breach, Elsevier, Springer-Verlag, Birkhäuser, Wiley-Interscience, de Gruyter, Baltzer, Kluwer, and Academic Press account for most of the expensive journal titles published in mathematics. In his e-mail Kirby encourages "all mathematicians to pledge that they

will not submit papers to, nor edit for, nor referee for, high priced journals." Kirby characterizes the current situation in mathematics scholarly publishing as "crazy." He states that "even if we can survive with the status quo, we owe it to the math community at large to vastly improve our efficiency in disseminating mathematics."

Finding Solutions: Owning and Sharing Scholarly Publications in the Digital Age

Who Owns Scholarly Publications?

Research librarians share Professor Kirby's view that the current situation in scholarly publishing in mathematics and in all the sciences is untenable and must be changed, but how? In the current system scholars, in most cases supported by a university and in many cases also supported by governmental grants, do research and write manuscripts about their research findings. They submit their manuscripts to nonprofit academic publishers—that is, university presses, scholarly societies, or scientific association publishers—or to commercial publishers who evaluate, edit, package, and distribute worthwhile articles in their journals. Publishers usually ask or demand that authors give copyright ownership of their articles to them. Publishers then sell their journals to individual scholars and to research libraries. North America's largest universities, through their research libraries, spent more than \$386 million on current serials in 1996 to buy from publishers this record of scholarship produced by their faculty of scholars [21]. In this cycle of writing, editing, and archiving scholarly information, universities and their libraries spend a great deal of money at the front and back end. Scholars, who create the articles, make little or no profit and in some cases pay the publisher through a practice of "page charges" to package their work. Scholarly publishing may be a precarious occupation, but to librarians publishers seem to end up in control of this cycle, with the ownership of scholarship and with the right to sell it as a commodity.

Scholarship As a Specialized Commodity

Scholarship is an interesting type of information commodity in that it has a very limited market and no "elasticity of demand", which means that without competition owners can charge what they want [22]. Occasionally a scholarly article or book will appeal to a broad audience and even become a best seller, but in most cases scholarship is highly specialized, obtuse, and meant for a small target audience. Andrew Odlyzko makes this point in his article "Tragic Loss or Good Riddance? The Impending Demise of Traditional Scholarly Journals" [6]. According to Odlyzko, "Research papers are written by specialists for specialists," and the typical number of serious readers for any given research paper is under twenty. Because of the sheer size (number of pages issued annually) and the high

subscription cost of many scientific journals, library or institutional subscriptions have largely replaced individual subscriptions. Research librarians then are primary buyers of science journals and other specialized scholarly publications.

High-Cost, Low-Use Scholarship

Research librarians have known for some time that portions of their collections receive very limited use. In 1979 Allen Kent issued a rather controversial study on the use of library material in the University of Pittsburgh library [23]. Kent examined circulation records and in-house use of library material over a seven-year period at Pittsburgh and found “that any given book purchased had only slightly better than one chance in two of ever being borrowed.” As books on the shelves aged and did not circulate, their likelihood of ever circulating diminished to as low as one chance in fifty. Journal use was also discovered to be low. Subsequent use studies have confirmed Kent’s general finding of underutilization of scholarship in research libraries. In 1991 and 1992 staff at the State University of New York at Albany library gathered data on the use of their journal collection [24]. In science and mathematics they found that of the 1,403 current journal titles in their collection, 229 could be described as “low-use” titles, that is, titles for which there were five or fewer uses in a year. These 229 low-use titles were tracked as having 522 uses during the year. Their total subscription cost to the library was \$103,758; therefore, cost per use—and this excludes any overhead cost for processing, managing, and storing these titles—was \$198.77.

Journal Cancellation Projects As a Coping Strategy

Scholarship may have no “elasticity of demand”, but under the current scholarly publication system research librarians are finding it necessary to say no to a growing number of high-cost, low-use journals and monographs. Tina Chrzastowski and Karen Schmidt, librarians at the University of Illinois at Urbana-Champaign, tracked the cancellation of journal subscriptions in five Midwestern research libraries (Illinois, Iowa, Michigan State, Ohio State, and Wisconsin) over the five-year period from 1988 to 1992 [25]. During this period the five libraries canceled a total of 13,021 serials titles, which represented a 5.7% reduction in total serials holdings. Science titles and non-U.S.-published titles dominated the serials cancellation lists. One approach then to managing the scholarly publication system is to follow a marketplace model. This is what research librarians are doing: buying what they can afford and cutting back where necessary. Scholarship that is expensive or that has a small readership is the first to go. As a result, specialized science journals and foreign-language material are becoming less available in research libraries.

Canceling journals and buying fewer monographs are just coping strategies and not really solutions to the crisis in scholarly publications. In fact, buying fewer items only deepens the crisis for publishers and scholars. Publishers raise their prices as revenues decline with fewer sales, and scholars find it harder to locate the scholarship they need in their less robust local library collections. What research librarians would ideally like to see is a reform, a restructuring, of the scholarly publication system itself. Such reform revolves around two issues: the digitization and the ownership of scholarly information. Moving from print to digital will be much more than just a format change for scholarly publication. The way information is created, organized, stored, and retrieved will be transformed. But more fundamental than the potential of technological transformation will be the perennial question of ownership, for in the digital age owners will exert greater control over the access to and cost of scholarly information than they ever did in the print environment.

Reform through New Information Technology

The digital information system is still quite immature, but its potential as a vehicle or tool for revolutionary change in library service and in scholarly publishing is becoming clear and startling. While print is place and time bound, networked digital information is not. With a computer workstation networked to the Internet and with the proper passwords or clearances, scholars from any location and at any time of the day can now gain access to a growing array of online library catalogs, reference works, newspapers, business and government reports, and electronic journals. Scientific scholarly publishers are leading the way in this transition from print to electronic communications. The AMS, the American Physical Society, the American Institute of Physics, the American Chemical Society, Elsevier, Springer-Verlag, and Academic Press have been some of the first scholarly publishers to offer many of their journals online. The AMS is now publishing three journals in electronic form only: *Conformal Geometry and Dynamics*, *Representation Theory*, and *Electronic Research Announcements*.¹

A recent survey of the penetration of online journals into the core of scholarly literature uncovered that 24% (665 of 2,729) of journals listed in *Science Citation Index*, 19% (546 of 2,866) of journals listed in *Social Science Citation Index*, and 10% (118 of 1,135) of journals listed in *Arts and Humanities Citation Index* were available online [7]. Web sites on the Internet abound with gateways to scientific information in the digital medium. In mathematics several such interesting Web sites can be found at the

¹These electronic journals can be found at the AMS home page, <http://e-math.ams.org/>.

AMS home page (<http://e-math.ams.org/>), the European Mathematical Information Service (<http://www.emis.ams.org/>), and Web-based Mathematics Sources maintained by the University of Pennsylvania (<http://www.math.upenn.edu/MathSources.html>). Not only is current literature becoming available in the electronic medium, but older information is also being digitized. The J-STOR Project, a non-profit organization with initial sponsorship from the Mellon Foundation, is digitizing complete backfiles of scholarly journals and making them available to its customers over the Internet.² Thus far the backfiles of 34 journals have been converted, including 6 in mathematics (*Annals of Mathematics*, *Journal of the AMS*, *Mathematics of Computation*, *Proceedings of the AMS*, *SIAM Review*, and *Translations of the AMS*).

The Beginning of More Fundamental Change in Scholarly Publishing

In these early days of the emerging digital information system, digital formats are serving primarily as substitutes for or enhancements of print formats. The fundamental structure of the scholarly publications system has yet to be altered in any significant way. Authors still submit their manuscripts, now more often than not in electronic form, to publishers. Publishers take ownership of the manuscripts, turn them into both print and electronic books and articles, and sell them to individuals and libraries. Research librarians are loath to give up their print collections and journal subscriptions until the digital information system, particularly in its archival function, is more stable and mature, so libraries tend to use electronic resources as access enhancements to their local print collections. But more fundamental changes are certainly in store. The traditional book and journal as organizing frames for scholarship will likely change, as will basic production, distribution, and archiving functions.

Paul Ginsparg, a physicist at the Los Alamos National Laboratory; Andrew Odlyzko, a mathematician at AT&T Bell Laboratories; and Ross Atkinson, a research librarian at Cornell University, have all written provocatively about the demise of the traditional scholarly communication system and what its replacement might look like. Taking full advantage of desktop publishing capabilities, networking, and powerful computer servers, Ginsparg envisions the development of an electronic "global raw research archive" managed by a consortium of professional societies and research libraries [26]. Odlyzko believes the new digital information system will allow scholars to become their own publishers and archivists. According to Odlyzko, "publishers and librarians have been the middlemen between the scholars as producers of infor-

mation and the scholars as consumers, and are likely to be largely squeezed out of this business" [6]. Atkinson predicts the design of new network-based hypertext document structures that may "represent fundamental revisions in the very modality of communications" and that "may affect and alter some of our basic assumptions about the nature of information itself" [27].

Scholars, publishers, and librarians, of course, may not agree with all or part of these future scenarios, and they will strongly resist any diminished role in a newly evolving digital scholarly publication system. But these futurists should not be dismissed out of hand, for they point to some potentially fundamental changes that can help reform scholarly publishing. The nature and structure of scholarly archives, for example, need to be changed to manage better the growing quantity, specialization, and cost of scholarship. Rather than a highly decentralized system as exists today, with duplicative print collections spread across the country, digital technology can be used to centralize information storage and distribute access quickly and cost effectively when and where it is needed by scholars. Digital technology can also foster the integration of the various components and sources of scholarly publication. Researchers will no doubt use hyperlinks to move quickly online from index or bibliographic citations to abstracts to full multimedia documents with the click of a button. Such integration is already happening on the Internet's World Wide Web platform and through the efforts of library and scientific information services such as the Online Computer Library Center's (OCLC) *FirstSearch* (<http://www.oclc.org/>) and the Institute of Scientific Information's (ISI) *Web of Science* (<http://www.isinet.com/>). The ability to use hyperlinks to integrate scholarship online is an extraordinary driving force for the adoption of the new digital information system, a force with which the print format cannot compete.

Restructuring the Scholarly Archive

Research librarians are just at the beginning of making broad, organizational change in the management of the archives of scholarship. Librarians are starting to provide more access to digital information not from files stored in their own libraries or on their own campuses but from centralized servers that are networked to publishers, government agencies, universities, and scholarly societies that can be located anywhere around the world. Rather than selecting scholarly resources on an item-by-item basis, librarians are turning to a new breed of "aggregators" for collection development at a macro and integrated level. Reference tools, electronic journals, and digital archives of historical material now come in a variety of bundled packages. Johns Hopkins University Press, Elsevier, Academic Press, and the American Chem-

²J-STOR, <http://www.jstor.org/>.

ical Society, for example, now all market their entire line of electronic journals as a complete package to individual libraries, local library consortia, and even statewide or regionwide groups of libraries. And libraries are beginning to aggregate themselves by creating “virtual libraries” at the state or regional level to pool resources and services. The Ohio Library and Information Network, Georgia Library Learning Online, and the Midwest’s Committee on Institutional Cooperation (CIC) Virtual Library are just three examples of the new virtual library consortia that are emerging across the country.³

What these new organizational developments in libraries have in common is the strategy of using digital information services to gain economies of scale, end unnecessary duplication, and provide scholars with more information resources at less cost. This pattern of networked, integrated access to central stores of electronic scholarly material seems inevitable in the new digital scholarly communication system. Finally the limitations of print collections may be overcome: self-sufficiency was never really possible in the traditional campus or departmental library, and at the same time there was always a great deal of waste in the form of underutilized material in these decentralized archives. The new is affecting the old too. Research librarians, running out of space for local collection storage and seeing new access opportunities through improvements in document delivery services, are beginning to consolidate their print archives both on and off campus, with regional storage facilities in operation or under construction in many parts of the country [28]. Scholars accustomed to having their separate discipline-based libraries in their departmental buildings—and mathematicians are an exemplar of this approach—are finding it disconcerting to see this convenient approach to library-collection organization end. But the high cost of maintaining decentralized archives along with the new approaches to access that digital information technology offers are making the traditional departmental library an anachronism. A recent report on “Mathematics Research Libraries at the End of the Twentieth Century” in *Notices of the AMS* [29] found that the number of mathematics libraries that are part of a general library or science and engineering library is increasing, while the number of mathematics libraries located in the same building as the mathematics faculty is declining.

³Information about these virtual library projects can be found at <http://www.ohiolink.edu/> for *Ohiolink*; <http://galileo.galib.uga.edu/Homepage.cgi/> for *Galileo*; and <http://ntx2.cso.uiuc.edu/cic/cli/velnew.html> for the *CIC Virtual Library*.

The Library Model in the Digital Scholarly Publication System

The new opportunities for improved access to scholarly information, from a technical standpoint, look wonderful in the digital networked environment. However, ownership issues and their effect on the control and cost of scholarship are still quite problematic for research librarians. Libraries are usually thought of as places, collections, and services that provide needed information, but underlying this construct is an economic model for funding and sharing information services that is often taken for granted. In the print information system, libraries buy books and journals that can be borrowed any number of times or that can be copied within the limits of copyright law and fair-use guidelines. This traditional library model for the central funding and communal sharing of information, depending on your perspective, can be seen as either a key advantage or a serious obstacle to scholarly communication in the new digital environment.

Both access to and control over information take on powerful new dimensions in the digital age. The “circle of gifts” model that characterized the first years of the Internet was an idyllic time for pioneering electronic citizens. Information was freely shared over the network, and those with proprietary interest in their writing or databases stayed away. Some of the early electronic journals such as *Psycoloquy* and the *Electronic Journal of Combinatorics* and Paul Ginsparg’s groundbreaking *Los Alamos Physics E-Print Archive* were, and in some cases continue to be, gifts to the scholarly Internet community [30]. And why not? If scholars receive no compensation for their work in traditional publishing, they might as well spread their own word for free through electronic self-publishing.

For those who wanted to conduct commerce on the Internet and receive payment for their work, the “circle of gifts” model was unacceptable. Through the development of firewalls, encryption techniques, authentication devices, and cyber-cash the Internet has become a much more secure environment today for a marketplace model of scholarly publishing. In fact, controls on the use of information can be much more powerful in the digital information system than they were in the print system. The Association of American Publishers in partnership with the Corporation for National Research Initiatives has designed a new persistent identification device called the “Digital Object Identifier (DOI) System” [31]. The DOI System, by identifying digital content and the content owner, is intended to enable easy customer and publisher communication and payment exchange over the Internet.

As the digital information system has evolved from a free-for-all into a highly controllable envi-

ronment, librarians have become more concerned about restrictions on the sharing of scholarly information. The library model is not the same as a “circle of gifts”, for it assumes that publications are not free. On behalf of a community—in the case of research libraries on behalf of the scholarly community—the library compensates the owner of information for the right to share it. This economic model can be carried forward into the digital environment if authors, publishers, and librarians cooperate with each other. But if the owners of scholarly publications limit sharing by charging high prices or by restricting fair-use copying, all the advantages of a more effective digital scholarly archive will be blocked.

Research librarians are trying to preserve the best of the library model by being proactive when it comes to funding and ownership issues of scholarly publishing in the digital age. In North Carolina, for instance, librarians in 1993 led an effort to engage scholars in the Research Triangle universities in the development of a policy regarding faculty publication in scientific and technical scholarly journals [32]. Concerned about the “relatively small number of very large commercial publishing conglomerates, many based in Europe” that dominate science scholarship and believing that there is “incompatibility between [the] non-economic goals of academic researchers and the largely economic goals of commercial and some not-for-profit publishers,” the North Carolina group urged scholars to consider initial publication of peer-reviewed and edited research in “journals supported by universities, scholarly associations, or other organizations sharing the mission to promote widespread, reasonable-cost access to research information.” At Johns Hopkins University and at Stanford University, librarians have pushed efforts to keep science publishing within the circle of the academy. Johns Hopkins developed Project Muse, which was one of the first university press efforts to publish established science journals on the World Wide Web.⁴ HighWire Press, the Internet imprint of the Stanford University Libraries,⁵ has as one of its aims to “insure that the nascent marketplace for electronic communication among scholars does not develop along the semi-monopolistic lines of current STM [Science, Technical, and Medical] publishing.” HighWire’s first project has been the digital publication of *The Journal of Biological Chemistry*. And finally, the Association of Research Libraries has mounted an aggressive lobbying effort among scholars, scholarly societies, higher education associations, and federal government agencies to influence both intellectual property rights policies and the structure of scholarly publishing in the digital environment. These efforts culminated in 1997 in the Associa-

tion’s creation of the Scholarly Publishing and Academic Resources Coalition [33], whose mission is to be a catalyst:

- to create a more competitive marketplace for research information by providing opportunities for new publishing ventures; endorsing new publications and information products; and recruiting authors, editors, and advisory board members;
- to promote academic values of access to information for research and teaching; the continuation of Fair Use and other library and educational uses in an electronic information environment; and the ethical use of scholarly information;
- to encourage innovative uses of technology to improve scholarly communications by collaborating in the design and testing of new products; advancing new publishing models as appropriate applications of electronic networks, such as Internet2; and developing systems and standards for the archiving and management of research findings.

Sharing Scholarship: The Scholar’s Choice

Will the promise of improved access to scholarship in the digital age be blocked by restrictions to fair use or by the high cost placed on publication by its owners? Scholars themselves are really the only ones who can answer this question, for it is scholars who create and have first ownership rights to their own scholarship. If they pass their ownership rights to their scholarship to publishers outside the circle of the academy, they must realize that they have turned their work into a commercial commodity. If scholars keep their publications within the academy, they should also realize that some nonprofit organizations use publication revenues to support more than publication based expenses. In either case, scholars may be placing their works and the ownership rights to their publications with publishers who will limit access to their scholarship through high cost or restrictions to library sharing or educational uses of these works. Publishers, of course, serve a critical function in the scholarly publication system, but the best edited, produced, and marketed publication can be severely limited or useless if it cannot be widely shared with other scholars and students. If it is true that one of the fundamental missions of the modern university and the scholarly community is to promote the free exchange of ideas and research results, then authors, publishers, and librarians must work more in partnership to ensure that this happens. At the end of the twentieth century many research libraries are in serious trouble because they can no longer afford to acquire scholarship they need to share with their communities. The commercialization of science publication is at the core of this problem for research librarians. By bringing scientific scholarly publishing back into

⁴Project Muse, <http://muse.jhu.edu/>.

⁵Highwire Press, <http://www-jbc.stanford.edu/>.

the circle of the academy, the scholarly publication system can be reformed to take full advantage of the archival and distribution potential of new digital information technology.

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