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The Cost Implications of Open-access Publishing in the Life Sciences

WILLIAM H. WALTERS AND ESTHER ISABELLE WILDER

Open-access journals are growing in number and importance. Because they rely on revenue from publication fees rather than subscriptions, these journals have important economic implications for the institutions that sponsor, produce, and use research in the life sciences. This article shows how the wholesale adoption of open-access pricing would influence institutional journal costs in the field of cell biology. Estimating prices under two open-access models, we find that a switch to open access would result in substantial cost reductions for most institutions. At the same time, the top universities would pay up to 10 times as much as they currently do. Institutions with fewer than 4.29 million library volumes would be likely to save money under either open-access model. The long-term viability of open-access publishing in the biosciences may depend on the establishment of an environment in which the top research institutions are willing and able to pay a greater share of the total systemwide cost.

Keywords: cell biology, journals, libraries, open access, scholarly communication

Unlike conventional journals, open-access journals provide free, immediate online access to scientific research. In most cases, the revenue to support these journals is generated through a combination of external funding and publication fees (paid by authors' institutions) rather than through subscriptions. The life sciences are of special interest to open-access publishers, accounting for more than a third of the several thousand active open-access journals (Kaufman-Wills Group 2005, Lund University Libraries 2007, NIH 2007a).

Although several authors have investigated the potential advantages of open-access publishing—including increased readership and enhanced citation impact (Lawrence 2001, Antelman 2004, Eysenbach 2006, Davis and Fromerth 2007)—only a few have examined the economic implications of open-access pricing. Early cost estimates suggested that the largest research universities would pay more under an open-access model than under the current subscription-based model (Davis 2004, Davis et al. 2004, Holmström 2004). Subsequent research has revealed that a wholesale shift to open-access publishing would bring cost savings for most colleges and universities while increasing the proportion of the total cost paid by the top universities and research institutions (Dominguez 2006, Walters 2007). The economic implications of open-access pricing are important because they influence (a) the long-term, large-scale feasibility of open-access publishing, (b) the perception of open access as a fair or unfair mechanism for allocating costs, and (c) the amount of funding that colleges and universities can devote to other, competing scholarly initiatives.

This study builds on earlier research by presenting conventional and open-access cost estimates for cell biology journals at 24 US colleges and universities. Cell biology was chosen because of its relatively high levels of research activity, its importance as the foundation of many bioscience disciplines, its attractiveness to commercial publishers, and its potential as a field in which new open-access journals are likely to emerge. Nearly 30 cell biology journals are listed in the *Directory of Open Access Journals,* including 8 established since 2005 (Lund University Libraries 2007).

This article presents institutional journal cost estimates for three distinct pricing models: (1) the conventional model (the current subscription model); (2) the Public Library of Science (PLoS) open-access model, with costs based on the publication fees currently charged by *PLoS Biology* and *PLoS Medicine;* and (3) the equal-revenue open-access model, with costs based on higher publication fees to ensure that pub-

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lishers' total systemwide revenue is equal to that received under the current subscription model.

The stratified sample of 24 colleges and universities allowed us to evaluate the impact of open-access pricing on the entire range of postsecondary institutions, from the largest universities to the smallest two-year colleges. Our data also permitted the development of a simple regression model that uses institutional size (number of library books and journal volumes) to predict the expected change in journal costs associated with the widespread adoption of open-access pricing.

Three journal pricing models

We used the 2004 Academic Libraries Survey (NCES 2007) to prepare a stratified random sample of 24 colleges and universities. Each selected institution represents all of the colleges and universities within a particular size range—that is, all those with a roughly equal number of library volumes. For example, one institution (Harvard University) was selected from among those universities with 12,792,001 to 15,392,000 library volumes. At the other end of the spectrum, one institution (Lakeshore Technical College) was selected from among those colleges with no more than 30,000 library volumes.

The conventional model. Cost estimates for the conventional model were prepared for each of the 154 cell biology journals in the *Science Citation Index* (SCI; ISI 2006a). Under the conventional model (the current subscription model), scientific journals have three primary sources of revenue from colleges and universities: subscriptions (print and online), page charges, and submission fees.

We began by searching the online library catalogs of the 24 institutions in the sample, noting which cell biology journals were accessible in print or online format at each institution. Journals accessible only after a delay of months or years were excluded. In calculating costs under the conventional model, we were interested only in those forms of access that resulted in subscription fees or other journal-related expenditures. Free online access to a journal after 12 months, for example, does not represent an expenditure on the part of the institution.

In calculating subscription costs, we assessed each journal at its 2006 list price, accounting for the type of access (print, online, or both) and the relevant characteristics of the subscribing institution (enrollment, Carnegie classification, number of life sciences faculty and staff, etc.). If multiple subscription options were available, we chose the least expensive option consistent with the information presented in the library's catalog. We made two exceptions to the list-price rule, however. First, institutions with current access to more than half the cell biology journals offered by any of four major publishers (Blackwell, Elsevier, Springer, and Wiley) were credited with a 33 percent discount for those titles. Although the terms of large-scale licensing arrangements are generally confidential, our experience with both consortial and single-institution licensing suggests that a 33 percent discount is not unreasonable. Second, the cost of each journal received through the BioOne collection was calculated as the total cost of the collection (for the institution) divided by the number of journals in the collection.

Page charges were assessed at 2006 rates based on the number of pages published in cell biology journals by the authors at each institution (ISI 2006a). Data for a five-year period (2000 through 2004) were divided by five to minimize the effects of annual variations in publication rates. We accounted for variable page charges (e.g., no charge for the first eight pages but $100 per page thereafter) and assessed each page charge at the lowest possible rate (the member rate, for journals published by scholarly societies). Each page charge was assigned to the first author's institution.

Only three journals in the sample charged submission fees. We assessed these fees on the assumption that each published article was the result of 1.6 submissions, an assumption consistent with recent publication data (APS 2007).

The PLoS open-access model. The nonprofit PLoS publishes several open-access journals in biology and medicine. Their flagship journal, *PLoS Biology,* has a 2005 impact factor of 14.7, placing it first among the 64 journals in SCI's general biology category. Likewise, *PLoS Medicine* ranks seventh in the general medicine category (ISI 2006b). PLoS is the best-known open-access publisher, and the only one to have established top-ranked journals in the life sciences. For these reasons, we developed our initial open-access cost estimates in accordance with the publication fee schedule currently in use at *PLoS Biology* and *PLoS Medicine.* Our PLoS-model estimates are the amounts that would be paid if all publishers abolished their subscription charges, made their journals freely available online, and charged a publication fee of $2500 per article (the current PLoS fee).

PLoS-model cost estimates were prepared for each of the 154 cell biology journals indexed in SCI (ISI 2006a). Specifically, we used SCI to identify those articles written by authors at the 24 colleges and universities in our sample. Five-year publishing totals (2000 through 2004) were divided by five to arrive at annual figures. We limited our results to research articles and notes, excluding editorials, book reviews, and similar items. Each $2500 publication fee was assigned to the first author's institution, a practice consistent with the billing policies of most open-access publishers. Previous research has shown that this method produces results nearly identical to those achieved when an equal fraction of the cost is allocated to each author's institution (Walters 2007).

The equal-revenue open-access model. The equal-revenue model is based on the assumption that neither commercial nor nonprofit publishers would willingly accept less money than they currently receive—that within the system as a whole, total open-access publication fees must equal conventional (current) subscription revenue. Unlike the PLoS model, the equal-revenue model is likely to be regarded as realistic by those who contend that open-access publishing offers no incentive for publishers to accept reduced income

(Ewing 2004, Mabe 2004, Morris 2005). Although we did not account for the loss of subscription income from nonacademic sources, the available evidence suggests that personal subscriptions generate relatively little revenue for most scientific journals (Tenopir and King 2000). Likewise, we did not account for any possible increase in advertising revenue associated with higher readership in an open-access environment. Subscription income from nonacademic institutions, while potentially substantial, could not be included in our cost estimates because of the absence of reliable data on corporate subscriptions.

The cost for each institution under the equal-revenue model was computed as 4.96 times the equivalent PLoS-model cost, since the total revenue generated by the conventional model ($40,737,702) is 4.96 times the total revenue generated by the PLoS model ($8,210,000). Table 1 shows these calculations, which account for the number of colleges and universities within each institutional size category. For example, the 25 institutions with 2,365,001 to 2,865,000 library volumes were assumed, on average, to have the same subscription costs and publishing productivity as the University of Oregon.

As table 1 indicates, 1107 colleges and universities did not report the number of volumes in their libraries when responding to the Academic Libraries Survey. Because the institutions that declined to report their library holdings may have had various reasons for doing so (very small collections, lack of current information, institutional policies that prohibit disclosure, etc.), we evaluated a separate random sample of 20 nonresponding institutions to ensure that their publishing productivity and library holdings were consistent with the data for National American University, the institution representing the "not reported" category in our analysis.

Table 1. Calculation of aggregate journal costs (publishers' revenue) under the conventional (subscription-based) pricing model and the Public Library of Science open-access model.

Size range (number of library volumes)	Representative institution	Number of institutions in range	Conventional-model cost ($)		PLoS-model cost ($)	
			Representative institution	All institutions in range	Representative institution	All institutions in range
12,792,001–15,392,000	Harvard University	1	249,936	249,936	504,500	504,500
9,337,001–12,792,000	University of Illinois (Urbana-Champaign)	3	130,492	391,476	52,500	157,500
8,220,001–9,337,000	University of Texas (Austin)	2	142,209	284,418	34,500	69,000
7,106,001–8,220,000	University of Michigan (Ann Arbor)	6	207,361	1,244,166	198,000	1,188,000
5,320,001–7,106,000	Princeton University	7	107,512	752,584	44,000	308,000
3,740,001–5,320,000	University of Oklahoma (Norman)	14	123,930	1,735,020	27,500	385,000
2,865,001–3,740,000	University of Kentucky	31	133,477	4,137,787	53,500	1,658,500
2,365,001–2,865,000	University of Oregon	25	106,115	2,652,875	24,000	600,000
1,916,001–2,365,000	University of North Texas (Denton)	23	100,988	2,322,724	9500	218,500
1,457,001–1,916,000	Florida International University	28	93,087	2,606,436	2000	56,000
1,109,001–1,457,000	Brandeis University	51	109,420	5,580,420	33,000	1,683,000
782,001–1,109,000	Carnegie Mellon University	69	67,607	4,664,883	14,000	966,000
513,001–782,000	Grinnell College	119	27,878	3,317,482	0	0
401,001–513,000	Millersville University	81	36,096	2,923,776	0	0
280,001–401,000	St. Bonaventure University	132	4274	564,168	0	0
228,001–280,000	Augustana College (Sioux Falls)	105	4029	423,045	0	0
165,001–228,000	SUNY College at Old Westbury	208	29,447	6,124,976	2000	416,000
122,001–165,000	West Virginia Wesleyan College	190	3827	727,130	0	0
102,001–122,000	Peru State College	172	200	34,400	0	0
81,001–102,000	John F. Kennedy University	197	0	0	0	0
56,001–81,000	Clark College	328	0	0	0	0
30,001–56,000	Union Institute and University (Cincinnati)	444	0	0	0	0
1–30,000	Lakeshore Technical College	878	0	0	0	0
Not reported	National American University (Rapid City)	1107	0	0	0	0
Total	All institutions	4221	—	40,737,702	—	8,210,000

Note: SUNY is the State University of New York.

Cost projections

Under either open-access pricing model, the institutions that produce the most scientific research would pay a larger share of the total systemwide cost. The two models differ substantially, however, in the actual dollar amounts that the most productive institutions would be expected to pay.

The PLoS open-access model. Within the field of cell biology, a wholesale switch from the conventional model to the PLoS model would result in lower journal expenditures for nearly all of the institutions in our sample; only one institution would pay more. For instance, the University of Illinois would pay publication fees equal to just 40 percent of its current journal expenditures (see table 2). Smaller schools would achieve even greater savings, and 11 of the 24 institutions in the sample (representing 89 percent of all colleges and universities in the United States) would pay no publication fees whatsoever in the field of cell biology. Those institutions, like the general public, would receive online access to all 154 cell biology journals without incurring costs of any kind (other than the cost of Internet access).

In more general terms, a switch to the PLoS model would have two major effects. The first is an overall reduction in systemwide costs. As noted earlier, the PLoS fee schedule ($2500 per article) generates only 20 percent as much revenue as the conventional model. Consequently, it requires aggregate payments equal to only 20 percent of current subscription expenditures.

The second effect is a redistribution of costs. Because institutional disparities in research output are far greater than institutional disparities in library holdings, any shift from a pricing model based on subscriptions to a model based on publishing productivity will reduce the proportion of the total cost paid by most institutions and increase the proportion paid by the largest research universities. Within this sample, two universities (Harvard and Michigan) would each

Table 2. Institutional journal costs and availability under three pricing models: the conventional (subscription-based) model, the Public Library of Science open-access model, and the equal-revenue open-access model.

Institution	Number of library volumes	Annual cost ($)			Percentage change in cost in comparison with conventional model		Percentage increase in number of journals available under either open-access model
		Conventional model	PLoS model	Equal-revenue model	PLoS model	Equal-revenue model	
Harvard University	15,392,000	249,936	504,500	2,502,320	102	901	32
University of Illinois (Urbana-Champaign)	10,192,000	130,492	52,500	260,400	–60	100	66
University of Texas (Austin)	8,482,000	142,209	34,500	171,120	–76	20	54
University of Michigan (Ann Arbor)	7,958,000	207,361	198,000	982,080	–5	374	14
Princeton University	6,253,000	107,512	44,000	218,240	–59	103	91
University of Oklahoma (Norman)	4,387,000	123,930	27,500	136,400	–78	10	77
University of Kentucky	3,093,000	133,477	53,500	265,360	–60	99	75
University of Oregon	2,636,000	106,115	24,000	119,040	–77	12	101
University of North Texas (Denton)	2,093,000	100,988	9500	47,120	–91	–53	110
Florida International University	1,738,000	93,087	2000	9920	–98	–89	119
Brandeis University	1,176,000	109,420	33,000	163,680	–70	50	107
Carnegie Mellon University	1,042,000	67,607	14,000	69,440	–79	3	352
Grinnell College	522,000	27,878	0	0	–100	–100	728
Millersville University	503,000	36,096	0	0	–100	–100	684
St. Bonaventure University	298,000	4274	0	0	–100	–100	2880
Augustana College (Sioux Falls)	261,000	4029	0	0	–100	–100	3625
SUNY College at Old Westbury	195,000	29,447	2000	9920	–93	–66	964
West Virginia Wesleyan College	135,000	3827	0	0	–100	–100	1763
Peru State College	108,000	200	0	0	–100	–100	14,800
John F. Kennedy University	96,000	0	0	0	—	—	—
Clark College	65,000	0	0	0	—	—	—
Union Institute and University (Cincinnati)	46,000	0	0	0	—	—	—
Lakeshore Technical College	14,000	0	0	0	—	—	—
National American University (Rapid City)	Not reported	0	0	0	—	—	—

Note: SUNY is the State University of New York.

pay a greater share of the total systemwide cost under the PLoS model. The other 22 institutions would pay not only lower dollar amounts but a lower proportion of the total cost.

The preeminence of Harvard and Michigan in the life sciences has a major impact on the distribution of open-access journal costs within this sample. For instance, Harvard authors publish an average of 202 papers in SCI-indexed cell biology journals each year—roughly 6 percent of the total national research output in this area, and more than the authors at the other 23 institutions combined (ISI 2006a). Both Harvard and Michigan are among the top 15 recipients of funding from the National Institutes of Health (NIH 2007b). Likewise, a recent guide to graduate programs ranked Harvard 2nd and Michigan 12th in the Biological Sciences (PhD) category. Harvard was ranked 1st, and Michigan 11th, in the Medical (Research) category (US News and World Report 2006).

The data in table 2 suggest a three-group typology of academic institutions. Specifically, Harvard and Michigan—the universities that would pay a larger share of the cost under the PLoS model—can be regarded as primary producers of research in the field of cell biology. They would gain access to additional journals in an open-access environment, but not in proportion to their share of the total cost. Sixteen other institutions in the sample—those with significant expenditures under the conventional model but savings of 50 percent or more under the PLoS model—can be regarded chiefly as consumers of cell biology research. They are the institutions that stand to gain the most from the widespread adoption of open-access pricing. Finally, six colleges in the sample—those with costs of $200 or less under both the conventional model and the PLoS model—are neither producers nor consumers of research in cell biology (see table 1). The impact of open access on these institutions is difficult to predict. On the one hand, these colleges currently operate without access to any of the 154 cell biology journals indexed in SCI. On the other hand, free online access might encourage faculty and students at these institutions to make greater use of the scientific literature. That is, improved access to scholarly work may itself encourage greater research productivity.

Our PLoS-model results suggest that fewer than 10 universities in the United States can be regarded as primary producers of cell biology research. (That is, fewer than 10 schools fall into the same size ranges as Harvard and Michigan; see table 1.) About one-fourth of all postsecondary institutions are net consumers of cell biology research, and roughly three-fourths are neither producers nor consumers—that is, they neither subscribe to cell biology journals nor publish in them.

The equal-revenue open-access model. As mentioned earlier, universities such as Harvard and Michigan can expect to pay a far higher proportion of the total systemwide cost under any pricing model in which expenditures are linked to research productivity. Under the equal-revenue model, their absolute costs would increase dramatically as well, by 901 percent at Harvard and by 374 percent at Michigan. As table 2 shows, a switch from the conventional model to the equal-revenue model would bring increased journal costs for 10 of the institutions in the sample: the 8 largest universities—those with more than 2.5 million library volumes—plus Brandeis and Carnegie Mellon. In terms of library size, those 10 institutions represent about 5 percent of the colleges and universities in the United States (see table 1).

The other 95 percent of all postsecondary institutions would achieve cost savings under the equal-revenue model. Even top liberal arts colleges such as Grinnell would spend far less on cell biology journals than they currently do. This finding is especially significant when considered in combination with the potential for improved access to the scientific literature. For example, the 26,000 students at Florida International University would gain access to all 154 of the SCI-indexed cell biology journals rather than the 68 that are currently available to them. At the same time, Florida International would cut its cell biology journal costs by 89 percent.

How many institutions would pay more? The financial viability of the equal-revenue model is likely to depend on the number of institutions that would experience substantial increases in their journal expenditures. Our sample data suggest that 5 percent of US colleges and universities would pay more than they currently do, and that a handful (perhaps a dozen) would pay far more. At the same time, the idiosyncrasies of this particular sample may mask some of the more general relationships between library size (as a proxy for research productivity) and institutional journal costs. For example, the University of North Texas has a library twice as large as Carnegie Mellon's but would experience a 53 percent decline in journal costs, whereas Carnegie Mellon's would increase 3 percent. The University of North Texas is bigger, but Carnegie Mellon's faculty are more productive.

To illustrate the more general relationship between institutional size and open-access journal costs, we used bivariate regression to estimate the number of institutions that would pay more under the equal-revenue model. Specifically, we used institutional size (number of library volumes) to predict equal-revenue cost as a percentage of conventional-model cost.

The ideal measure of institutional size would be effective as a predictor, valid over the entire range of institutions, and publicly available. This last criterion facilitates the estimation of open-access journal costs for those colleges and universities that do not have convenient access to their own institutional publication data through SCI. We considered a number of predictor variables, including full-time enrollment, graduate enrollment, federal research funding, medical school ranking, and biology program ranking, before choosing the number of library volumes (NCES 2007) as the only measure that met all three criteria. Within the sample of 24 institutions, the number of library volumes is correlated with both current subscription costs (polynomial $r^2 = 0.81$) and publishing productivity (polynomial $r^2 = 0.85$).

As figure 1 shows, the best-fitting regression model is polynomial. Specifically, $y = 3.6354x^2 + 1.8841x + 24.869$, where x is the number of library volumes, in millions, and y is

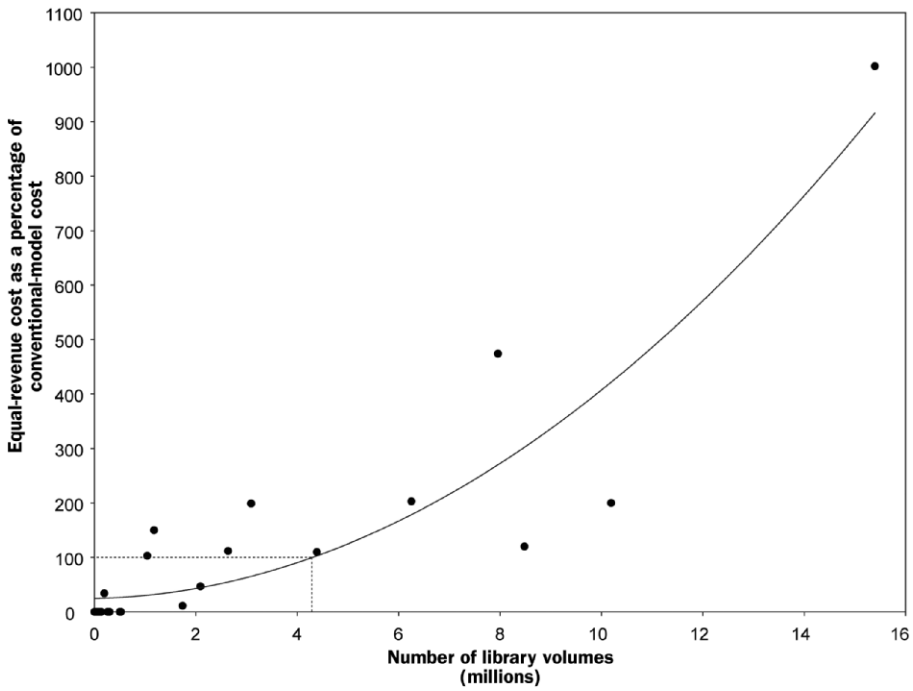

Figure 1. Expected relationship between the cost to colleges and universities under the conventional (subscription-based) journal pricing model and under the equal-revenue open-access model, by library size (number of volumes). Most institutions with fewer than 4.29 million library volumes can expect lower costs under the equal-revenue model.

equal-revenue cost as a percentage of conventional-model cost. The regression model has high predictive power ($r^2 = 0.84$), and y equals 100 when x equals 4.29 million. This suggests that only those institutions with more than 4.29 million library volumes—30 of the 4221 colleges and universities in the United States—would pay more for cell biology journals under the equal-revenue model.

Because the PLoS-model cost for each institution is 20 percent of the equivalent equal-revenue cost, we can further predict that only those institutions with more than 11.18 million library volumes would pay more for cell biology journals under the PLoS model (since y equals 500 when x equals 11.18 in the equal-revenue equation). Only two US universities, Harvard and Yale, have libraries that large.

Implications of open-access pricing

While these findings are generally consistent with previous research, our data reveal a potential shift in journal costs that is somewhat greater than earlier studies have indicated (Davis 2004, Dominguez 2006, Walters 2007). Within the field of cell biology, the wholesale adoption of either the PLoS model or the equal-revenue model would result in a major redistribution of systemwide expenditures, reducing the proportion of the total cost paid by most institutions and increasing the proportion paid by the major research universities. Under the PLoS model, only a few universities would pay more than they currently do. Under the equal-revenue model, approximately 30 institutions would pay more.

Some proponents of open-access publishing have been critical of cost estimates such as these (Suber 2006). First, they argue that authors' institutions do not necessarily pay the publication fees charged by open-access journals—that research grants can often be applied toward these costs. This argument is specious to some degree, since universities can use grant money to pay for open-access publishing in exactly the same way they can use tuition money or government funding. The funds can come from any of several sources, but it is ultimately the university that must pay, often with money that could have been used for other purposes. To the extent that foundations support open access through direct grants to the journals themselves, that support is implicitly incorporated into the PLoS model. As our results show, the PLoS model generates publication fees equal to only 20 percent of current subscription revenue. PLoS journals therefore rely heavily on grants from outside agencies—grants that allow them to charge lower fees than they otherwise would. In 2005, PLoS's income from fees and advertising covered just 35 percent of its operating costs (Butler 2006).

A second criticism is that estimates such as these do not account for the fact that many open-access journals do not charge publication fees at all (Kaufman-Wills Group 2005, Suber 2006). This assertion is valid when evaluated on a title-by-title basis. Of the 25 fully open-access cell biology journals listed in the *Directory of Open Access Journals,* 10 do not charge publication fees (Lund University Libraries 2007). It is important to note, however, that many of the no-fee journals publish only a handful of papers each year. In the case of cell biology, 4 of the 10 journals published fewer than 20 research articles in 2005, and all 10 together published 412 articles—less than half the number that appeared in *PLoS Biology* and *PLoS Medicine* that same year. While no-fee journals make up a significant proportion of open-access journals, they account for only a small proportion of open-access articles. The recent launch of several new PLoS titles may further reduce the proportion of open-access articles that are published in no-fee journals.

The long-term feasibility of open-access journal publishing depends on the extent to which colleges, universities, and funding agencies can generate adequate revenue without resorting to mechanisms that would limit access to scientific information. (Some publishers maintain both conventional and open-access journals, relying on subscription income to support their open-access initiatives. Of course, such a busi-

ness model would not be sustainable in a purely open-access environment.) From a publisher's perspective, the equal-revenue model may appear more sustainable than the PLoS model. Among other things, we cannot be certain whether the PLoS model generates sufficient revenue in the long run—whether the funding agencies and philanthropic organizations that contribute to PLoS and other open-access initiatives are willing and able to support those same initiatives on a broader scale or over an extended period of time. From the perspective of many colleges and universities, however, the PLoS model may appear more sustainable. Institutions that are able to pay the PLoS publication fee ($2500 per article) may be less able to pay the costs associated with the equal-revenue model ($12,400 per article). In any event, the true institutional costs of open-access publishing are likely to fall somewhere between these two estimates. Moreover, many publishers have chosen to support hybrid models that combine aspects of open access with aspects of the current subscription model—journals that provide free online access after 12 months, for example. These hybrid models are likely to have institutional cost implications less dramatic than those presented here.

Either of the two open-access models presented here (PLoS or equal-revenue) would make the full range of scientific literature accessible to faculty and students at all kinds of colleges and universities. Either model would reduce expenditures at most academic institutions, potentially freeing up funds for other scholarly initiatives such as internal grant programs and improved lab facilities. Grinnell College, for example, would increase its holdings of cell biology journals by more than 700 percent while saving nearly $28,000 in subscription costs. Other colleges—those that currently send few students on to graduate programs in the life sciences—might enhance their training capabilities through improved access to the research literature and through greater funding for instructional resources other than library subscriptions. Overall, these developments have the potential to enhance research activity at the smaller colleges and universities; to encourage scholarship that explains, interprets, and synthesizes earlier work; and to promote greater exposure to the journal literature among students in the life sciences. However, the full potential of open access can be realized only if open-access pricing models prove sustainable on a large scale. As these results suggest, the long-term sustainability of open-access publishing is far from certain.

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