SSIC Report 9/2015

Open Access: Publishing, Commerce, and the Scientific Ethos

Report to the Swiss Science and Innovation Council SSIC

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Swiss Science and Innovation Council

The Swiss Science and Innovation Council

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Open Access: Publishing, Commerce, and the Scientific Ethos

Report to the Swiss Science and Innovation Council SSIC

by
Professor Dr. Bruno J. Strasser, University of Geneva & Yale University
Professor Dr. Paul N. Edwards, University of Michigan

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E

Access to published scientific claims is essential for the production of new scientific knowledge, because science builds on previous claims and establishes its validity through collective scrutiny. Traditionally, scientific claims are made public through journals, proceedings, and books produced largely by commercial publishers.

In the 1990s, the prices charged by publishers for academic content rose sharply at the same time as electronic distribution costs decreased. These prices became prohibitive for many research institutions, threatening the access to scientific knowledge. As a result, researchers began to advocate for a transformation in scientific publishing: "open access".

In the case of journals, instead of limiting access to those who purchase subscriptions, open access (OA) makes articles freely available to anyone. On the OA model, costs of publication are funded by author fees or subsidies. Both commercial and non-profit publishers have created new OA journals ("gold road"). Some existing journals have switched entirely to open access, while others have adopted a hybrid approach, allowing their authors to pay for open access if they so choose. Alternatively, open access can be achieved by making published scientific content available, immediately or after a delay, in an institutional repository ("green road"). Open access has dramatically increased the availability of scientific knowledge, most significantly for poorer institutions and developing countries.

Overall the rise of open access among commercial publishers has not reduced the cost of scientific publishing. Non-profit, open access journals, on the other hand, offer reduced author fees with potentially identical impact factors. In both cases, open access has mainly shifted the financial burden from libraries to authors, who are generally subsidized by science funding agencies.

Market forces alone are unlikely to expand open access further or to reduce publishing costs. Since individual researchers choose their publication venues based on expected social rewards, institutional incentives that help to restructure these rewards are most likely to succeed. For example, institutions might adopt a policy of considering only OA publications when evaluating researchers for funding, promotion, and tenure. Financial support for author fees should become a standard element of science funding. Some journals currently provide important editorial and news content, which will need to find financial support as well. However, the deeper problem represented by the dominance of commercial publishers with profit margins around 30 %, and the resulting costs for the scientific community, will require a different set of policies than those aimed at increasing OA.

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Der Zugang zu veröffentlichten wissenschaftlichen Erkenntnissen ist für die Produktion von neuem wissenschaftlichem Wissen entscheidend, da dieses auf früheren Erkenntnissen aufbaut und seine Gültigkeit durch die Wissenschaftsgemeinschaft geprüft und bestätigt wird. In der Regel werden wissenschaftliche Erkenntnisse durch Zeitschriften, Berichte und Bücher bekannt gemacht, die grösstenteils von kommerziellen Verlagen herausgegeben werden.

In den 1990er Jahren stiegen die von den Verlagen verlangten Preise für akademische Inhalte deutlich an, während gleichzeitig die Kosten für die elektronische Verbreitung sanken. Die Preise der Verlage wurden für viele Forschungsinstitutionen unerschwinglich, was den Zugang zu wissenschaftlichem Wissen gefährdete. In der Folge begannen sich die Forschenden für einen Wandel im wissenschaftlichen Publizieren einzusetzen, nämlich für das Modell des «Open Access» (offener Zugang).

Bei Zeitschriften sind die Artikel über «Open Access» (OA) allen frei zugänglich und nicht nur auf Abonnenten und Abonnentinnen beschränkt. Im OA-Modell werden die Publikationskosten über Artikelbearbeitungsgebühren oder Fördermittel gedeckt. Sowohl kommerzielle als auch gemeinnützige Verlage haben mittlerweile neue OA-Zeitschriften geschaffen («goldener Weg»). Einige bestehende Zeitschriften sind komplett auf «Open Access» umgestiegen, während andere einen gemischten Ansatz verfolgen, bei dem ihre Autorinnen und Autoren für «Open Access» bezahlen können, wenn sie dies wünschen. Alternativ kann «Open Access» über die unmittelbare oder verzögerte Veröffentlichung von wissenschaftlichen Inhalten auf institutionellen Dokumentenservern («grüner Weg»)

umgesetzt werden. Mit «Open Access» wurde die Verfügbarkeit von wissenschaftlichen Kenntnissen stark erhöht, besonders für weniger finanzkräftige Institutionen und Entwicklungsländer.
Durch die Zunahme von «Open Access» bei kommerziellen Verlagen sind die Kosten für wissenschaftliche Publikationen indessen nicht gesunken. Gemeinnützige «Open Access»-Zeitschriften bieten reduzierte Bearbeitungsgebühren, haben jedoch praktisch den gleichen Impact Faktor. In beiden Fällen wurde die finanzielle Belastung lediglich grösstenteils von den Bibliotheken auf die Autorinnen und Autoren überwälzt, die in der Regel von wissenschaftlichen Förderagenturen finanziell unterstützt werden.
Die Marktkräfte alleine dürften nicht ausreichen, um «Open Access» weiter zu verbreiten oder die Publikationskosten zu senken. Da einzelne Forschende ihre Publikationsform nach der erwarteten sozialen Anerkennung auswählen, versprechen institutionelle Anreize, die zu einem diesbezüglichen Umdenken beitragen, am meisten Erfolg. So könnten Institutionen beispielsweise die Strategie verfolgen, im Hinblick auf eine Finanzierung, Förderung und Anstellung von Forschenden bei ihrer Evaluation ausschliesslich OA-Publikationen zu berücksichtigen. Finanzielle Unterstützung für Lizenzgebühren sollte standardmässig zur Wissenschaftsförderung gehören. Einige Zeitschriften liefern derzeit wichtige Nachrichten und redaktionelle Inhalte, für die ebenfalls finanzielle Unterstützung gefunden werden muss. Das tiefer liegende Problem der Dominanz von kommerziellen Verlagen mit Gewinnmargen von rund 30 Prozent und der dadurch anfallenden Kosten für die Wissenschaftsgemeinschaft wird jedoch andere Strategien erfordern als jene, die auf eine Erhöhung der Anzahl von OA abzielen.

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L'accès aux résultats de la recherche qui sont publiés est essentiel pour le développement de nouvelles connaissances scientifiques, car la science progresse en se basant sur les découvertes antérieures et sur leur validation par la communauté scientifique. En général, les résultats de la recherche sont rendus publics par le biais de revues, rapports et ouvrages publiés en grande partie par des éditeurs commerciaux.
Dans les années 1990, les prix facturés par les éditeurs pour les contenus académiques ont considérablement augmenté, alors que dans le même temps les coûts de diffusion par voie électronique diminuaient. Devenus prohibitifs pour un grand nombre d'institutions de recherche, ces prix remettaient en question l'accès aux connaissances scientifiques. Les chercheurs ont alors commencé à préconiser un nouveau mode d'édition scientifique, à savoir le libre accès.
En ce qui concerne les revues, le libre accès permet à tous d'accéder gratuitement aux articles, contrairement aux abonnements qui réservent l'accès aux seuls abonnés. Dans le modèle du libre accès, les frais de publication sont financés par les auteurs ou par des subventions allouées aux éditeurs. Quelques éditeurs commerciaux et non commerciaux ont créé de nouvelles revues en libre accès («voie dorée»). Les éditeurs de certaines revues qui existaient déjà ont opté pour le libre accès total tandis que d'autres préfèrent une approche «hybride» où les auteurs peuvent payer pour que leurs articles soient disponibles en libre accès. Un autre type de libre accès consiste à rendre les articles scientifiques accessibles au public immédiatement ou de manière différée en les déposant sur un serveur institutionnel («voie verte»). Le libre accès a largement augmenté les possibilités d'accéder aux connaissances scientifiques, principalement pour les institutions dotées de moyens modestes et les pays en voie de développement.
Reste que la généralisation du libre accès parmi les éditeurs commerciaux n'a pas fait baisser le coût de l'édition scientifique. Les revues non commerciales en libre accès proposent des frais de publication à la charge de l'auteur moindres, tout en ayant un impact pratiquement identique. Dans les deux cas, le libre accès a surtout déplacé la charge financière des bibliothèques vers les auteurs, qui reçoivent en général des subventions des agences de financement de la recherche.
Il est peu probable que les forces du marché puissent à elles seules étendre le libre accès ou réduire les coûts de publication. Etant donné que les chercheurs choisissent les supports sur lesquels ils vont faire publier leurs articles en fonction de la reconnaissance sociale escomptée, les incitations institutionnelles qui permettent de restructurer le cadre de cette reconnaissance ont le plus de chances de porter leurs fruits.

Les institutions peuvent par exemple décider de tenir uniquement compte des publications en libre accès lorsqu'elles évaluent les profils des chercheurs en vue d'un financement, d'une promotion ou d'un emploi. Accorder une aide financière aux auteurs pour les frais de publication devrait devenir un élément standard du financement de la recherche. Certaines revues fournissent actuellement un volume important de contenu éditorial qui devra également être financé. Néanmoins, le problème majeur posé par l'hégémonie des éditeurs commerciaux qui réalisent une marge de bénéfice d'environ 30 % et par les coûts qu'elle induit pour la communauté scientifique demandera un ensemble de stratégies autres que celles visant à augmenter le libre accès.

L'accesso alle ultime scoperte scientifiche è essenziale per la genesi del sapere: la scienza, infatti, si fonda su conoscenze acquisite, frutto di un processo di conferma collettivo. Di solito i risultati delle ricerche vengono pubblicati da case editrici commerciali in riviste accademiche, articoli, atti di conferenze e libri.
Negli anni Novanta i costi di pubblicazione dei contenuti scientifici sono saliti alle stelle, mentre quelli per la diffusione elettronica sono invece calati. Per molti istituti di ricerca questi prezzi sono diventati addirittura proibitivi, tanto da pregiudicare l'accesso a conoscenze e scoperte scientifiche. Oggi molti ricercatori chiedono una svolta ed esigono che le loro ricerche siano pubblicate in modalità ad accesso aperto («open access», OA).
Diversamente dal tradizionale abbonamento, l'OA mette i singoli articoli a libera disposizione di tutti; i costi di pubblicazione vanno a carico degli autori stessi o sono finanziati mediante sussidi. Le case editrici, commerciali e non-profit, hanno creato nuovi periodici OA (la cosiddetta via d'oro o «gold road»). Alcune riviste già esistenti sono passate completamente all'OA, mentre altre hanno scelto una via di mezzo, un approccio ibrido che consente agli autori di pagare per l'accesso aperto, se lo richiedono. In alternativa, i contenuti scientifici possono essere pubblicati in appositi archivi istituzionali (la via verde, «green road»), immediatamente o dopo un determinato periodo a partire dalla pubblicazione in una rivista. Il fenomeno open access sta agevolando notevolmente la condivisione del sapere scientifico, a tutto vantaggio degli istituti meno facoltosi e dei Paesi in via di sviluppo.
Nel complesso, tuttavia, l'editoria commerciale OA non ha ridotto i costi delle pubblicazioni scientifiche, mentre i periodi OA non-profit offrono prezzi di abbonamento ridotti con un fattore di impatto potenzialmente identico. In ambedue i casi l'OA ha principalmente trasferito gli oneri finanziari dalle biblioteche agli autori, i quali sono generalmente sussidiati da enti di finanziamento della ricerca.
È poco probabile, comunque, che le sole dinamiche di mercato contribuiranno a promuovere ulteriormente l'open access o a ridurre i costi di pubblicazione. Tuttavia, dato che numerosi ricercatori scelgono i loro canali di pubblicazione in funzione del prestigio sociale che ne possono trarre, gli incentivi istituzionali volti a promuovere l'OA hanno buone probabilità di successo. Gli istituti interessati possono ad esempio decidere di considerare esclusivamente le pubblicazioni OA dei candidati a una cattedra o a un posto di professore con "tenure track" o di chi presenta una domanda di finanziamento. Gli aiuti finanziari a copertura delle spese di pubblicazione addebitate agli autori dovrebbero diventare un elemento standard nell'ambito del finanziamento della ricerca. Attualmente alcune riviste pubblicano notizie e contenuti giornalistici importanti che dovranno anch'essi fondarsi su un modello di sostegno finanziario adeguato. Il problema più spinoso – ossia la posizione predominante delle case editrici commerciali con i loro margini di profitto attorno al 30 per cento che per la comunità scientifica si traducono in costi eccessivi – richiederà una serie di politiche diverse da quelle adottate per promuovere l'open access.

1 Introduction

"The organization of science consists of an exchange of social recognition for information."

Warren O. Hagstrom, *The Scientific Community,* 1965

"In order to promote the success of their ideas, and hence themselves, scientists must adopt a strategy of both competition and collaboration, of altruism and selfishness. Each must balance his or her behaviour, in relation for example to sharing information."

Lewis Wolpert, *The Unnatural Nature of Science,* 1992

The conditions of access to scientific knowledge largely determine the success of the scientific enterprise. Because the production of new knowledge relies on previous knowledge, and because new knowledge must be validated by the community of scientists, science depends on access to data, results, and interpretation. Since the Scientific Revolution in the 16th century, the conditions of access have continually evolved along with intellectual, technological, sociocultural, political, and economic circumstances. Today, once again, structures of access to scientific knowledge are undergoing radical change.

Starting in the last decade of the 20th century, under the heading of "open science", an intense debate has taken place among stakeholders in the scientific enterprise to define the conditions of access to scientific data and to the scientific literature. This debate has already had profound consequences resulting, overall, in an increased openness of science. It has also led to the creation of new scientific journals and archives, publication models and incentives, funding regulations and institutional norms, deeply affecting researchers, publishers, funding and science policy agencies.

The consequences of these transformations for science's ability to produce new knowledge of social, cultural, and economic value are still unknown because, paradoxically, science requires concealment as much as openness. Indeed, the entire reward structure in science rests on rewarding individuals not so much for *producing* knowledge, which takes time to develop and test, but rather for *disclosing* knowledge after testing is completed. Without concealment to guard producers' interests while they work, there could be no disclosure. Thus, scientific knowledge production rests on finding an optimal balance between promoting and limiting access to scientific knowledge within the complex ecology of actors, norms, and values that govern science today. Just as patents were created to make trade secrets public, while granting legal protection to their owner for their commercial exploitation, open access seeks to balance public disclosure with intellectual ownership in the scientific community.

2 Origins of Open Knowledge Production: The Scientific Ethos

The scientific enterprise is unlike almost any other, in that both the producers and the consumers of its main product, knowledge, belong to the *same* community. Artists and art buyers, for example, play different roles and form distinct communities, and only the art buyers determine the value of a piece of art. The same is true of any industry: most car buyers are not themselves car manufacturers. In science, not so. All researchers are both consumers and producers of knowledge. They, and they alone, determine its validity (through peer review), as well as its value for creating further knowledge (through use and citation). Scientists constantly evaluate and certify, or disprove, other scientists' claims about nature. Publishers play two key roles in the political economy of this process: first, they organize the peer review process prior to publication, and second, they expose certified results by publishing them. Until a knowledge claim has been peer-reviewed and published, it belongs not to science, but to speculation and personal opinion.

For these reasons, scientific publishers function very differently from other publishers. Literary authors submit manuscripts to publishers whose staff evaluate their merits and potential markets. Literary publishers thus base publication decisions on *internal* evaluation. Scientific authors, by contrast, submit their manuscripts to publishers who *delegate* the evaluation of their merits to other scientists, typically in a blind or double-blind process organized by an editor or editors who are themselves scientists and are not usually directly employed by the publisher. These *external* evaluations and editorial decisions govern almost all choices about content. For scientific publishers, then, the large majority of the labor involved

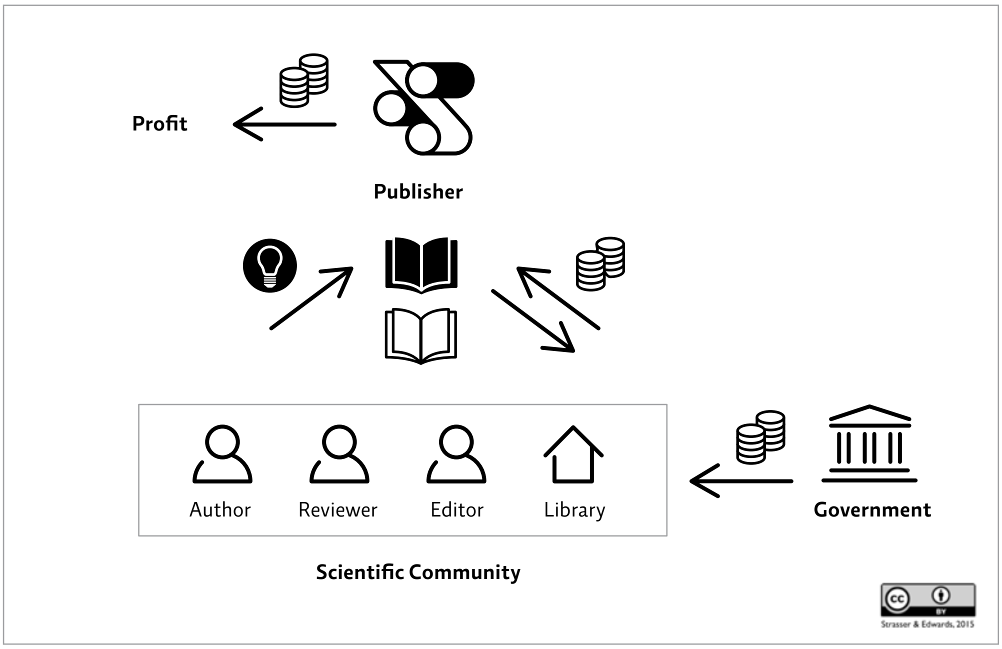


Figure I **Commercial scientific publishing**

The scientific community provides knowledge, expertise, and funding to publishers in exchange for scientific publications. Funding flows from government (science funding agencies) to the scientific community (libraries or authors) to publishers.

bringing a paper to press, from peer review to editorial decisions, is accomplished at *no cost* by scientists who justify their work as a service *to their community*. The corollary is that scientists spend a significant amount of their time reviewing manuscripts, work for which they are unpaid and unacknowledged, since the review process is generally anonymous. But this process does have a major benefit for the scientific community: publishers offer a *filtering* of knowledge claims, making public only those that other scientists have deemed reliable. The end result, for the scientific community, is a more reliable, searchable, and usable body of scientific claims. By publishing a scientific manuscript, an article or a book, publishers vouch for its scientific validity, and by doing so, they turn researchers into scientific authors. The scientific community also uses the publisher's author-making function as a proxy for individual researchers' accomplishments. In short, scientific publishers are central to the scientific enterprise because they *certify knowledge* and *accredit people (scientists)*.

2.1 Publishing cultures

There exist three distinct scholarly publishing cultures, centered around journals, conference proceedings, and books respectively. The predominant publishing mode in the natural sciences, mathematics, and medicine is the peer-reviewed scholarly journal. Journal cultures also exist in the humanities and social sciences, where they often share priority with book cultures. The second publishing culture, archival conference proceedings, is central to disciplines such as computer science and engineering. Professional societies solicit manuscripts to be presented at their conferences. Submissions are forwarded to large committees of scholars, divided by subdiscipline, which evaluate and rank papers for inclusion. After being presented and discussed at the conference, accepted papers are published in proceedings without further review. Conference cultures are optimized for speed, with the submission-to-publication cycle lasting just 3–6 months, versus 6–18 months for most journals. As with journals, low acceptance rates are interpreted as marks of rigor and prestige.

The third publishing culture, based on books (monographs and edited volumes), is most important in the humanities and qualitative social sciences. Book production is slow; after years in the writing process, 18–24 months can elapse between manuscript submission and publication. Like journal publishers, book publishers vary in their reputation, but there is no formal metric analogous to journal impact factor or acceptance rate for comparing book publishers. In general, books are viewed almost negatively in the natural sciences, mathematics, and medicine, where their principal roles are as textbooks or popularizations rather than as vehicles for research results.

Since the open access debate has revolved mainly around journals, and since journal cultures are also the most widespread in academic research, they are the principal focus of this report.

2.2 Why do scientists publish?

Why does the culture of scientific inquiry place such enormous value on making knowledge claims publicly accessible to a broad audience? In 1942, the sociologist Robert K. Merton characterized four imperatives, or "norms and values" comprising the bedrock "ethos of science": *universalism, communism, disinterestedness,* and *organized skepticism.* Each of these norms carries implications related to open access. According to "universalism", scientific claims are to be evaluated through universal or impersonal criteria. Thus, the evaluation of scientific claims requires that they be made publicly available. According to "communism" (later renamed "communalism"), scientific knowledge belongs to the community, not to individuals. The only right of individual scientists over knowledge is a claim to intellectual property, granted through authorship – which requires the disclosure of knowledge. According to "disinterestedness", science rewards impartiality and punishes partisan or self-aggrandizing approaches; potential conflicts of interest must be avoided, or else fully disclosed. Finally, according to "organized skepticism", the community of scientists skeptically evaluates and re-evaluates all claims; this requires, once again, that both claims and evidence be made fully available for evaluation.

Why did these values, and the disclosure of knowledge they required, become intrinsic to the scientific culture? Initially, knowledge was spread by exchange of letters among scholars, but these had very limited reach. Over time, scientific publishing moved increasingly toward broader dissemination. As printing costs declined and literacy and education levels generically increased, print communication replaced letters as the fundamental mode of scholarly interaction.[1] The creation of the Royal Society of London (1662), the Académie des Sciences in Paris (1666), and other scientific societies institutionalized the witnessing of experimental performances among a (still small and select) community of natural philosophers. These academies printed accounts of their discussions in journals such as the Royal Society's *Philosophical Transactions,* the oldest extant scientific periodical, or the *Mémoires de l'Académie des Sciences.*[2] These institutions and their periodical publications, in contrast to books, bound the diffusion of knowledge to its *accreditation* by a community of scholars, laying the foundations of the current peer-review system.[3] Thus the academies became gatekeepers for validated scientific knowledge, and their journals became the primary means of scholarly communication. By publishing the (experimental) methods used to obtain scientific results, they made possible, at least potentially, the replication of experiments and the validation of results. The 19th century witnessed a tremendous growth in the number of scientific journals, most of which were tied not to scientific societies, but rather to commercial publishers.[4] Academic libraries, always at the center of higher learning, became repositories for scientific journals, making them available to students, scholars, and others.

1 Eamon 1985; Eamon 1994; Johns 2009.

2 Kronick 1976.

3 Biagioli & Galison 2003.

4 Meadows 1980.

2.3 The role of publication in the reputation economy of science

Scientists' principal rewards for discovery and innovation have always been prestige, authority, and career advancement, with financial gain typically only a secondary motive, often foregone. In the 20th century, these rewards developed into a quasi-standardized reputation system based largely on publication in peer-reviewed scientific journals. As the sociologist Warren O. Hagstrom puts it, "the organization of science consists of an exchange of social recognition for information," i.e. for the disclosure of methods, evidence, and reasoning. Authorship of published work recognizes intellectual ownership of this "information" (knowledge).[5] Thus intellectual authority is inextricably bound to scientific journals, because they only publish work that has been favorably reviewed by peers. In this sense, journals mimic the roles of academies where a body of selected scientists evaluated scientific claims made by one of its members.

With the massive growth of the scientific workforce in the 20th century, competition to improve one's reputation emerged as another incentive for publishing. Yet this same competition also created incentives not to disclose their knowledge. For individual researchers, the costs of disclosure are many: exposure to public criticism, advantages given to competing researchers, and the time and resources spent preparing a publication and responding to peer review. A single blockbuster result, fully developed, could be worth far more to one's career than a series of small, incremental publications, which might risk revealing one's ultimate research targets or hard-won methodological innovations to competitors. These contradictory incentives – to publish, and to conceal – only made the journals more powerful in the scientific enterprise.

5 Hagstrom 1965: 13.

2.4 "Impact factor": publications as a measure of scientific value

In the second half of the 20th century, scientific reputation systems began to deploy quantitative assessment methods. These techniques were borrowed from library bibliometrics, used to evaluate holdings and purchasing decisions, and academic scientometrics, which was used in science policy to measure national scientific outputs.[6] Published articles are easily counted, but for reputation, what matters more is how much one's results are *used* by other scientists. In 1955, the American linguist Eugene Garfield developed the Science Citation Index, a publication listing the number of citations every scientific article received in a given year (and cumulatively over multiple years). More-cited articles presumably had a higher "impact" on the scientific community. Hence Garfield named this measure the "impact factor" of an individual article.[7]

Given the crucial role of journals as the "containers" for individual articles, Garfield later defined "journal impact factor" as the average number of citations per article published in that journal in the two years following publication.[8] Journals could thus be attributed an impact factor for a given year, ranging from 42.351 for *Nature* in 2014, to 0 (zero) for the *Journal of Avian and Poultry Biology* (among many others). The quality and quantity of a given researcher's work could then be measured simply by weighting each publication by the "impact factor" of the journal.

These metrics have been widely criticized. Of two articles, each cited only a few times, for example, the one published in a "high impact factor" journal would receive more credit. Conversely, an article that was widely cited, but published in a low "impact factor" journal might receive less credit. These flaws have not prevented the widespread use of impact factors to evaluate individual scientists. More individualized metrics, such as the "h-index," assess a scientist's productivity based on the number of citations to his/her publications, or combinations of the number of papers and their citations.[9] These indices have also been criticized: a paper later refuted or retracted would still make a large contribution to an author's citation index, while papers in large disciplines, such as biochemistry, are naturally cited more often than those of smaller ones, such as stratigraphy, which have fewer scholars, leading to lower overall h-indexes in smaller fields.

Nonetheless, these indices have become a standard element of academic resumés, especially in the natural sciences. They are now widely believed to determine many scientists' publishing practices, leading to ever larger quantities of less important publications.[10] Despite their serious flaws these metrics remain widely used in academic institutions, driving careers and behaviors. Some analysts speak of an "economization of science," in which competition to "produce" (publish) at all costs leads to incentive structures that reduce the quality of knowledge production in favor of quantity. Today, over half of the 1 million papers published each year are never cited at all.[11]

6 Wouters 2006; Polanco 1995; Gingras 2008; Archambault & Larivière 2009.

7 Garfield 1955.

8 Garfield 2006; Archambault & Larivière 2009.

9 The H-index, proposed in 2005 by physicist Jorge E. Hirsch, purports to measure both productivity and presumed impact. A scholar has an h-index of *n* if she has published *n* articles which have each been cited *n* times by others.

10 Weingart 2005.

11 Folkers 2013.

3 Rise of the Open Access Controversy

The open access controversy that arose in the 1990s resulted from two dramatic transformations in scientific publishing: commercialization and digitalization.

3.1 Commercialization

The first transformation saw an increasingly concentrated journal market dominated by a handful of large, for-profit publishing houses. From the 17th century to the early 20th century, academic journals in the English-speaking world were published mainly by non-profit professional societies, scientific academies, and (later) university presses. Commercial publishers also participated in the journal system, but at this time they were motivated more by prestige than by profits, since scientific journals did not yet enjoy very large circulations.[12]

In the aftermath of World War II – sometimes called "the scientists' war" – national governments became much more deeply involved in the funding and promotion of scientific research.[13] In the Western states, non-military government funders struck a bargain with scientists. The state would pay for basic research, which scientists would direct; in exchange for relative independence from government oversight, scientists would maintain transparency and accountability by publishing their work. Others could then build and/or profit on this knowledge as a public good. Higher levels of public funding also accompanied the broad-based expansion and democratization of university systems in the 1950s and 1960s; along with them, research libraries grew rapidly in both size and number. Together, these developments created a larger, and also more reliable, demand for scientific journals.

This larger, expanding, and more stable market therefore became more attractive to commercial publishers, who took an increasing share of academic journal publishing beginning in the 1960s.[14] In most cases, however, for-profit publishers did not interfere with the essential editorial and peer review elements of scientific journals. Both scientific editors and peer reviewers continued to work as volunteers; only the infrastructure and ownership of journal production and distribution changed. By the 1990s, economies of scale and rising profits allowed these publishers to offer sophisticated editorial management systems, high visual quality, additional content such as news and opinion pieces, and (crucially) broad distribution and marketing. Many professional societies found it cheaper and easier to contract their journal publishing operations to these large enterprises.

3.2 Digitalization

The second major transformation, the 1990s shift from print to electronic media, dramatically altered both the calculus of subscription pricing and the role of libraries in the provision of journals. Previously, libraries provided print journals for shared use. Library patrons could browse journals, then xerox personal copies of individual articles (albeit at a substantial cost in time and inconvenience). The physical library offered centralized, highly organized storage as well as catalogues, essential for maintaining access to paper materials. Electronic media rapidly diminished the marginal cost of copies nearly to zero, while the Internet provided an increasingly convenient mechanism for sharing these nearly-free copies. Meanwhile, these media required much less storage space, in different forms (servers, disk drives), as well as new cataloguing and distribution techniques. By the early 1990s, some library patrons had already switched from xeroxing to digital scanning. Around the same time, some publishers began to provide journals in both print and electronic formats.

The notion of "electronic publishing" dates to the mid-1980s and even before, but only with the rise of Adobe PDF (Portable Document Format) a decade later did electronic formats become a serious proposition for established journals.[15] PDF allowed page images to be displayed identically across platforms, permitting publishers to retain their traditional print page formats in digital form. The mid-1990s also saw an explosion of plans and ideas for "digital libraries," including

12 From about 1850–1933, German scientific publishers such as Springer enjoyed considerable success, including a large export market. They suffered declines following the rise of Nazism and the post-WWII dominance of English as the scientific *lingua franca*. Elsevier, in the Netherlands, benefited from the pre-war exodus of German-speaking Jewish scientists, and established an English-language beachhead in the USA in 1939 (Fredriksson 2001).

13 Kevles 1997.

14 Guédon 2001.

15 Adobe released version 1.0 of PDF in 1993.

early all-electronic publishers such as HighWire Press, an initiative of the Stanford University Libraries, which hoped that the potentially lower costs of all-electronic publishing might relieve the relentless pressure on research library budgets. Virtually all publishers moved quickly to the new medium, with about 90 percent of journals available online by 2005.

These two changes took place in a context of steady growth in the number of scientists, all of whom needed access to published research and peer-reviewed outlets for their own publications. Over time, the sciences have expanded into new areas and also splintered into increasingly fine-grained subdisciplines. Both of these phenomena led to new journals. This growth has a very long history: since the 1700s, the number of peer-reviewed journals has grown at an annual rate of about 3.5 %, doubling roughly every 20 years, while the number of articles published per year has grown at about 3 % per year – aligning closely with growth in the number of practicing scientists.[16] Research libraries had struggled for decades to keep up with this growth. They faced particular difficulty after the mid-1980s, when library budgets flattened even as subscription prices rose and new journals proliferated.

In the 1990s, the availability of easily-shared electronic copies correlated with a steady decline in print journal subscriptions by individuals, who could now access the journals online through their libraries. Revenues from individuals plummeted; one survey showed that whereas in 1990 46 % of respondents used personal subscriptions to access articles, by 2002 only 15 % did so; the rest preferred electronic access through libraries.[17] This provided publishers with a reason – justified or not – to raise their prices to libraries.[18] At the same time, for-profit publishers began to consolidate the industry, buying up journals and merging into ever-larger conglomerates. Today, just five commercial publishers (Reed Elsevier, Springer, Wiley & Sons, Blackwell, Taylor & Francis) produce almost 40 % of all journal titles, with Reed Elsevier publishing around 25 % alone and owning almost 2,200 journals. Those commercial companies are in a powerful position to negotiate bundle subscription contracts with libraries, which are often their primary source of income. Given the substantial "long tail" of small, low-circulation journals, this figure conceals the true extent of commercial dominance; a better measure appears in a 2012 study which reported that commercial publishers, including those contracted to handle publishing for professional societies, accounted for 64 % of all published articles. Most of the remainder were produced by non-profit professional societies (30 %) and university presses (4 %).[19]

3.3 The "serials crisis"

Between 1990 and 2000, these trends created a new stage in what librarians began to call the "serials crisis".[20] Research library budgets remained relatively flat, yet journal prices began to rise dramatically. A notorious example is the *Journal of Comparative Neurology,* whose subscription price was $1,920 in 1985, but reached $15,000 in 2000 following takeover by a commercial publisher – an increase of 780 % over 15 years. In response, members of the North American Association of Research Libraries cut their monograph purchases by an average of 21 % and their serials (journal) purchases by 7 % between 1986 and 1996, even as the proportion of their budgets going to acquisitions rather than salaries increased.[21]

Commercial publishers also initiated the practice of "bundle pricing". Journal impact factor – originally used by libraries to decide which journals to purchase – now were deployed by publishers to "bundle" high-impact with lower-impact journals, many of which were not of interest. Libraries were presented the choice of buying the bundles containing their preferred journals, or paying much higher *à la carte* prices for individual subscriptions. During this period, profit margins of the large commercial publishers reached an estimated 35 %, versus about 20 % for professional society publishers and 25 % for university presses.[22] These trends

16 Ware & Mabe 2012: 23.

17 Boyce et al. 2004.

18 For example, in 2001 the price of an institutional print subscription to *Science* was $370, while an electronic site license for the same journal cost between $1500 and $5000 (Bergstrom & Bergstrom 2004).

19 Ware & Mabe 2012: 33.

20 McGuigan 2004.

21 Branin et al. 2000.

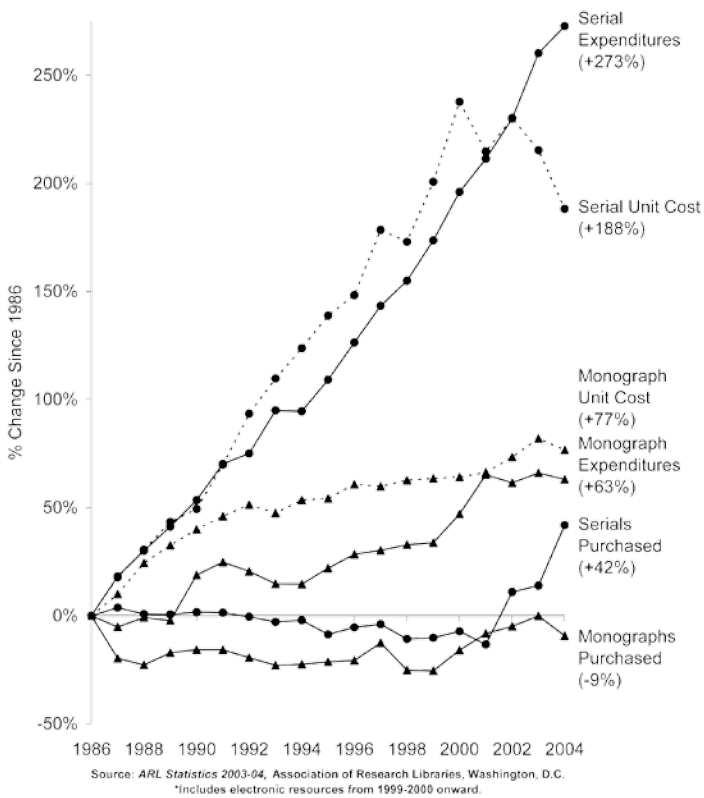
22 Swan & Brown 2008.

continue. In 2012, the Harvard University Library, the largest and one of the best-endowed academic libraries in the world, declared that prices charged by "at least two [unidentified] major [commercial] providers [...] are now prohibitive," citing subscription rates as high as $40,000 per journal as well as bundling practices and high profit margins.[23]

For many, the spiraling prices to libraries flew in the face of hopes for price reductions from the ostensibly lower production costs of electronic media. Instead, the average cost per journal article has remained remarkably stable at $4,000–5,000 since the 1990s.[24] The reasons for this are many and complex; they include not only the rising profits of publishers, but also the

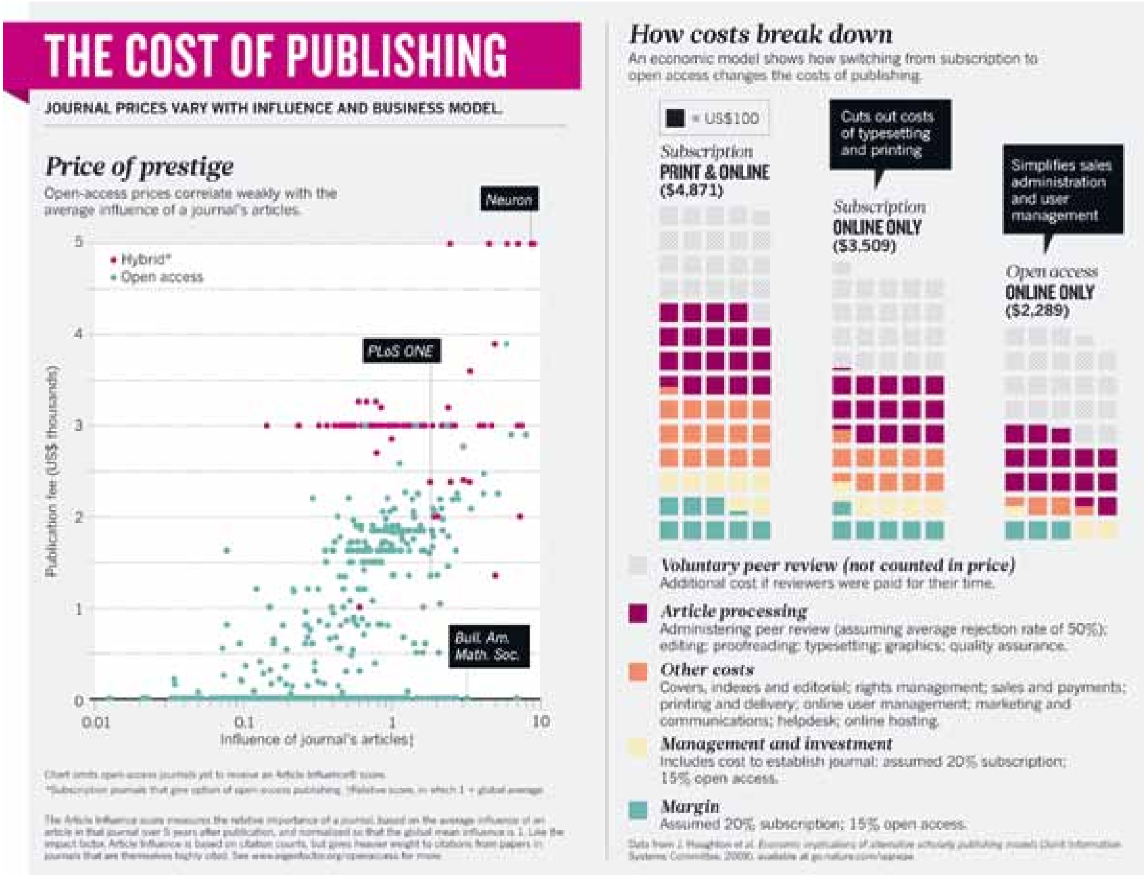
23 Faculty Advisory Council 2012.

24 Ware & Mabe 2012; Odlyzko 2014; Swan & Brown 2008. Researchers have developed several different ways to measure how much it costs a publisher to produce an article. These include first-copy cost, per-article cost (including indirect costs and profits), and others. Due to averaging across large numbers of very different journals, these measures can serve only as general indicators.



Graph. 1 **Monograph and Serial Expenditures in ARL Libraries, 1986–2004**

Source: ARL 2005. For the period 1986–2004, this chart shows the steep rise in journal (serials) prices and the much lower rate of increase in monograph costs. The decline in price per journal (serial unit cost) in the early 2000s reflects the introduction of bundle pricing.



Graph. 2 **The Cost of Publishing. Source: Van Noorden 2013**

increasing array of auxiliary products and services publishers provide, such as data deposit, “articles that cite this article” displays, digitization of backlists, and supplemental materials published online.

Online journals and internet search engines have changed researchers’ reading practices in significant ways. Today’s researchers read almost twice as many articles per year as their colleagues of the mid-1970s. They also read in twice as many different journals.[25] At the same time, a marked decline in correlation between journal impact factor and citations since about 1995, and even more steeply since 2010, has been attributed to the newfound ability to search for individual articles, or even individual elements of articles, directly by means of Internet searches.[26] These phenomena are reducing the importance of journals as coherent collections of community-valued resources – as well as the value of impact factor for library purchasing decisions.

These transformations were, arguably, partially mitigated by new developments. Notable among these were the so-called “Big Deals” and various forms

25 Ware & Mabe 2012: 37.

26 Lozano et al. 2012; Brembs et al. 2013.

of differential pricing. The "Big Deal" is a very large bundle of subscriptions, up to all of a publisher's titles. Only a minority of research libraries have accepted the "Big Deals".[27] Meanwhile, starting in 2001, some for-profit publishers introduced "tiered pricing" dependent on the type and/or size of the institution.[28] Although commercial publishers keep the prices of these bundles secret under nondisclosure agreements, a recent study has uncovered large differences in how much libraries pay for the same bundle. In one case, the University of Michigan paid almost $2 million for the same Elsevier bundle sold to the University of Montana for $442,000. The new differential pricing schemes were heavily driven by the economics of digital media, which render delivery of additional titles trivial. These trends reflect larger societal shifts, also driven by information technology. Differential pricing of services, from taxi rides (Uber) to airfares, is becoming ubiquitous. Even more importantly, though, they reflect the hollowing out of research libraries, many of whose services are being taken over by the combination of publisher platforms and internet search.[29] The "Big Deals" have resulted, in some universities, in much greater availability of the overall scientific literature to research scholars, funded by their libraries, a situation that (somewhat ironically) approximates the main goals of open access.

27 Bergstrom et al. 2014.

28 Bergstrom et al. 2014.

29 Odlyzko 2014.

4 Open Access to Published Literature

Today, scientific journals play the most important role in making knowledge accessible. They also represent the cornerstone of science's reputation system. Thus access to scientific knowledge requires access to scientific journals.

4.1 Diffusion of knowledge and the scientific publishing industry

The diffusion of scientific knowledge has been hindered by the limitations of cataloguing and reference systems, the copyrights held by publishers, and the cost of publication. Although none of these factors are new, the rise of the Internet has profoundly changed how each factor affects the diffusion of knowledge. The expansion of electronic reference systems, such as PubMed, WorldCat, and Web of Science, together with the growth in the number of existing titles, has made ever more journals and articles "visible" to scholars – often, however, limited to titles and possibly abstracts, rather than full content. Finally, the increasing prices of scientific journals – a growing burden for research institutions – have led many libraries to cancel some of their subscriptions, especially in less wealthy universities and in developing countries.

These limitations to the diffusion of scientific knowledge have created a growing resentment in parts of the scientific community. Although copyrights cover both printed and electronic documents, digital files can be shared so easily that publishers' "right" to control their circulation now seems almost unnatural. The practice of sharing copyrighted digital materials has spread widely, despite its uncertain legality. In this environment, scientists increasingly resent publishers' active attempts to restrict the availability of published work.

The unusual structure of the scientific publishing industry, discussed previously, plays a key role in this widely shared antipathy. Unlike non-academic books and magazines, where editors and other staff contribute substantial value to publications, most of the labor involved in science publishing is provided for free by scientists. Yet these same people must pay substantial fees to access the content they and their peers have helped to produce. On top of that, in many cases scientists who wish to publish their work must pay "article processing charges" to journals – often hundreds, even thousands of dollars – supposedly to offset publication expenses. While these fees do cover part of the production costs of the journals, they are also widely believed to enrich publishers' large profit margins as well (Figure 1, p. 11). Journal prices have risen much faster than inflation, and profit margins above 30 % are not uncommon.[30]

4.2 Movements for open access publication

To combat these trends, in 2000 a group of scientists led by the biochemist Patrick O. Brown (Stanford University) and the biologist Michael Eisen (Berkeley) founded the Public Library of Science (PLoS), an advocacy group promoting open access to the scientific literature. Their first initiative was to circulate a petition on the Internet to "support the establishment of an online public library that would provide the full contents of the published record of research and scholarly discourse in medicine and the life sciences research in a freely accessible, fully searchable, interlinked form."[31]

Supported by high-profile scientists such as Harold E. Varmus, former NIH director and Nobel Prize winner, and Richard J. Roberts, another Nobel prize winner, the petition garnered over 30,000 signatures within a year, sparking a wide debate in the scientific, publishing, and policy communities.[32] Unsurprisingly, journals such as *Science* and publishers opposed the petition, while a few, more sympathetic, promised to make articles "open access" on their websites within six months of publication.[33]

The Public Library of Science (PLoS) initiative had three major consequences. First, it proclaimed a movement throughout the sciences toward a state of affairs already taking hold in biomedicine. (The PubMed

30 Van Noorden 2013; Bergstrom et al. 2014, http://www.elsevier.com/about/at-a-glance, Ware & Mabe 2012.

31 www.publiclibraryofscience.org/ (December 2001). See Roberts et al. 2001.

32 34,000 according to http://poynder.blogspot.ch/2012/02/oa-interviews-michael-eisen-co-founder.html.

33 The Editors 2001.

Central repository, which made full-text articles in biomedical fields freely available under agreements with publishers, had opened in 2000.) Second, it lent momentum to the Budapest Open Access Initiative, a public statement drafted by the Open Society Institute in December 2001, which became a rallying point for the open access movement and paved the way towards the Berlin Declaration on Open Access to Knowledge in the Sciences and Humanities a year later. Third, and most important, in 2003 the Public Library of Science group launched *PLOS Biology*, its first open access, non-profit journal; it now publishes six additional titles and has inspired a number of other, similar initiatives.[34]

34 Brower 2001; Brown et al. 2003.

4.3 The "green" open access model: authors submit directly to depositories

Advocates of open access defined deposition in digital repositories by authors as the "green road" towards open access (Figure 2). Digital repositories of scientific literature are modeled after libraries and archives. Collections of digital documents are stored in a single place, organized and catalogued, and made freely accessible. Two key differences between libraries containing paper documents and repositories containing electronic articles are: (1) electronic documents, unlike physical books, can potentially be accessed (and copied) by an unlimited number of readers, and (2) the granularity of digital document access can be much finer than for paper documents. In consequence of (1), repositories become, in fact, distributors of material copyrighted by publishers. In consequence of (2), users can seek and find articles or chapters, without regard for the bound journal issue or the book in which they are contained. For these reasons, publishers have, in principle, opposed electronic repositories.

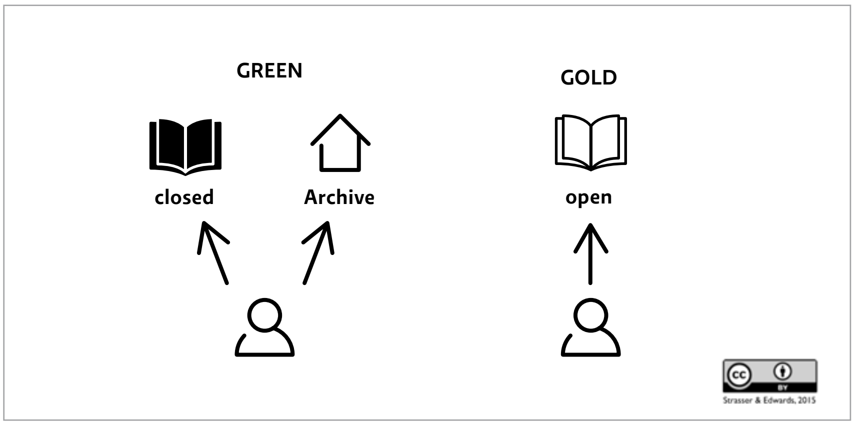


Figure 2 **Open access "green road" and "gold road"**
In the "green road", authors publish in closed journals and make a preprint or published article available in an open access archive. In the "gold road", authors publish in open access (or hybrid) journals.

In 1991, physicists at Los Alamos National Laboratory established an online repository for preprints of research in high-energy physics.[35] The tradition of circulating preprints, or draft versions of articles, predated this initiative. In physics, where articles could take many months, even years, to percolate through the process of peer review and journal publication, dated preprints served not only to keep peers informed of the state of the art, but also to establish priority claims to discovery – thus serving scientists' self-interest as well. Since these were unpublished manuscripts, authors were free to distribute them. The Los Alamos repository, renamed "the arXiv," later moved to Cornell University and enjoyed immense success. Within five years, authors were submitting more than 1000 articles to the arXiv every month. In 2014, the arXiv reached the milestone of 1 million articles, with a submission rate now exceeding 8000 manuscripts per month. The cost of providing this service is approximately $725,000 per year, funded by Cornell University Library, the Simmons Foundation, and some 180 "member" institutions (including such Swiss institutions as CERN, ETH Zurich, and the universities of Geneva and Zurich), who pay small annual fees (on the order of $3000) based on usage.[36]

It was no accident that the first major digital repository emerged in high-energy physics, nor that it thrived.[37] The need to share huge, extremely expensive resources, namely particle accelerators such as the Large Hadron Collider at CERN, encouraged cooperative experiments involving hundreds or even thousands of participants, all listed as "authors" on the resulting publications. In contrast to, say, molecular biology, this cooperative behavior extended to greater openness about results prior to publication. The field had also come to recognize authorship, not only through publication in peer-reviewed journals, but also in public communication, either through preprints or even oral presentations. Thus, for this specific community, the arXiv perfectly served the twin purposes of facilitating the diffusion of new knowledge while also establishing authorship and priority.[38]

Perhaps surprisingly, the fear that a manuscript's availability in the arXiv would decrease journal sales proved unfounded.[39] Libraries and researchers still purchased journals, which added value to the arXiv's preprints by submitting them to peer review; only the published version was definitive.

The arXiv's success inspired the second major digital repository for science, PubMed Central.[40] Instead of a collection of preprints, PubMed Central was established as a "free digital archive of biomedical and life sciences journal literature", i.e. an open access collection of *published* articles.[41] Initially, PubMed Central, like the arXiv, was envisioned by Harold Varmus (then director of the NIH) as a repository of *both* published papers and preprints. However, as a result of the vocal protests of the publishing industry, PubMed Central was established as a more modest repository containing published articles only.[42] Hosted at the NIH National Center for Biotechnology Information, PubMed Central was integrated with PubMed, the major bibliographic database in the biomedical sciences. PubMed Central embodied the goals of open access but ran directly into conflict with the goals of journal publishers. Because these held the copyright of the articles they published, PubMed Central was dependent on the voluntary participation of journal editors.[43] At first, only a few journals participated, and agreed only to a delayed release of their content (typically 6 or 12 months after publication). Authors who held the copyright on their papers (a rare situation) had no real incentive to deposit their papers in PubMed Central, since they were already available (at a cost) through the publishers and their authorship had already been established. PubMed Central, a generous (or "naïve" according to its founder) idea, was thus entirely dependent on publishers' good will.

35 Ginsparg 2011.
36 Porciello 2015.
37 Ginsparg 2011.
38 Biagioli & Galison 2003.
39 Willinsky 2006: 63.
40 Kling et al. 2002.
41 PMC 2001.
42 Varmus 2009.
43 Varmus 2009.

4.4 Policies mandating repository deposition

The promoters of PubMed Central attempted to enroll science funding and policy agencies to support their goals. In 2005, two years after its mandatory data sharing policy came into force, the NIH began requesting that its grantees submit the accepted versions of their manuscripts to PubMed Central no later than twelve months after publication.[44] This new policy posed no problem for open access journals, such as *PLOS Biology*, but represented a serious policy, if not economic, issue for all the others. However, just like the NIH's early calls to deposit gene sequences in GenBank, compliance remained limited: only one in six grantees systematically submitted articles. In 2004 the United States House Appropriations Committee (which provides the NIH budget) voiced its concerns that "insufficient public access to reports and data resulting from NIH-funded research [was] contrary to the best interests of the U.S. taxpayers who paid for this research" and recommended that the NIH require "that a complete electronic copy of any manuscript reporting work supported by NIH grants or contracts be provided to [PubMed Central] upon acceptance of the manuscript for publication in any scientific journal".[45] Twenty-five US Nobel laureates wrote a letter supporting the NIH plan. Similar statements were made in Europe, for example by the Research Councils UK and the Wellcome Trust, all not merely recommending, but *mandating* that final versions of published articles be made available within 6 to 12 months of publication.[46]

In 2007, the US Congress examined a bill proposing to make submission to PubMed Central mandatory within 12 months of publication for all federally funded research.[47] The key argument being that the sharing of scientific information was in the best interest of the taxpayers, since it would stimulate the research. A group of large journal publishers hired a powerful public relations firm to combat the proposal, claiming (strangely) that "public access equals government censorship," but to no avail.[48] Congress passed the bill, and the ensuing NIH Public Access Policy went into effect the following year, on April 7, 2008. By then, mandatory submission to PubMed Central was widely supported by elite scientists, professional organizations, science funding agencies and governmental science policy bodies. PubMed Central's current budget of about $4.5 million per year works out to about $50 per article deposited, most of it spent on converting and editing the relatively small number of author-submitted articles (about 20 % of the total).[49]

Despite strong language, the manuscript-deposition mandates generally lacked any incentives, means for enforcement, or sanctions. By 2012, compliance with the NIH policy leveled off at around 70 %; in other words, about one-third of NIH-funded articles were still unavailable on PubMed Central. As a result, the NIH threatened those who did not comply with restrictions on their "future awards for a specified period".[50] Two years later, in 2014, the NIH together with the Wellcome Trust actually took action, the latter withholding grant payments to over 60 researchers.[51]

Research institutions also began mandating that published papers be deposited in institutional archives, often under Creative Commons licenses. Harvard led the way, in 2008.[52] But like most institutions that followed, it included an "opt-out" provision, which allows researchers not to participate in the program. For this reason, when the University of California, the world's largest public university, adopted an open access policy in July 2013, where UC California researchers are required to deposit their manuscripts in an institutional repository under "creative commons" license, the policy was criticized by open access advocate Michael Eisen as "toothless", no more than a "symbolic gesture – a minor event in the history of open access".[53] Indeed, a number of leading journals, such as *Science* and *Nature*, actually *require* that authors from institutions with such policies opt out – while at the same time authorizing them to deposit,

44 NIH 2005.

45 Department of labor 2005.

46 Suber 2012; http://legacy.earlham.edu/~peters/fos/newsletter/07-02-06.htm.

47 http://grants.nih.gov/grants/guide/notice-files/NOT-OD-08-033.html.

48 Giles 2007; Dyer 2007.

49 Anderson 2013.

50 http://grants.nih.gov/grants/policy/nihgps_2012/nihgps_ch8.htm#_Toc271264977.

51 Van Noorden 2014.

52 Ledford 2008.

53 Check 2013; Eisen 2013.

immediately after publication, the author's copy (final submitted draft) of the manuscript.[54] The University of California has issued around 300 waivers in the policy's first 18 months, most of them required by Nature Publishing Group. Around 5 % of faculty have decided to opt out. More troublesome for open access advocates, the policy lacks any incentives for researchers to comply and the actual proportion of researchers who do comply is unknown.

An alternative institutional repository model was established by the University of Liège, Belgium in 2008. The university mandated deposition in its Open Repository and Bibliography (ORBi), while simultaneously requiring that assessment of researchers for promotion and tenure be based exclusively on publications present in the archive. This strong incentive led to widespread compliance.[55] The Higher Education Funding Council for England recommended a similar policy, but it was not implemented.[56] The key elements of this policy are: 1) require immediate deposit, but allow delayed open access, and 2) make the evaluation of researchers dependent on (timely) deposition. Researchers thus have a direct incentive to deposit their manuscript in an institutional repository. This model thus ties open access to the existing "ethos of science", a solution which has proved very effective for open access to data.[57]

4.5 "Gold" and "platinum" open access: pay to publish

The 2001 PLoS petition demonstrated a strong feeling among scientists that open access should be promoted. Those who signed the petition pledged not to "publish in, edit or review for, and personally subscribe to" journals which were unavailable in PubMed Central. Yet the call to boycott most major scientific publishers seems to have had little effect, as many broke their pledge when given an opportunity to publish in *Science* or *Nature*. The prestige (and resulting benefits) of publishing in these journals was just too great to resist. For this reason, the Public Library of Science decided to compete directly with publishers by starting its own journal, hoping to make it eventually as attractive to prospective authors. Its goals were unambiguous: "Our aim is to catalyze a revolution in scientific publishing by providing a compelling demonstration of the value and feasibility of open access publication."[58]

In 2003, it launched *PLOS Biology* a peer-reviewed, open access journal, all of whose content was "freely available to anyone, anywhere, to download, print, distribute, read, and use without charge or other restrictions, as long as proper attribution of authorship is maintained".[59] In addition, the journal adopted an open review process and innovative ways to measure articles' impact. The editorial work that goes into publishing is funded exclusively through author fees (and an initial grant from a philanthropic foundation), which amounted to $2900 per article in 2015.[60] This model of publishing – directly into an open access journal – has been named "gold open access" (Figure 2, p. 24). The Public Library of Science went on to organize seven more journals. Measured by the standard impact factor, PLOS journals rapidly acquired excellent reputations (impact factor 11 for *PLOS Biology* in 2014), though they remain below the top journals like *Science* (31) or *Nature* (42).

The PLOS journals have also demonstrated, according to supporters, that open access journals managed by the scientific community are financially viable, while keeping open access publishing fees relatively low. The number of open access journals has grown exponentially, either through the creation of new journals or through subscription journals who converted to open access.[61] The independent Directory of Open Access Journals, sponsored by universities, research libraries, and major publishers, currently lists 10,240 "quality" open access journals (defined as peer-reviewed journals providing full text access), in 136 countries,

54 MIT Libraries 2015; AAAS 2015.

55 Rentier & Thirion 2011.

56 Harnad 2013, http://openaccess.eprints.org/index.php?/archives/987-The-UKs-New-HEFCEREF-OA-Mandate-Proposal.html.

57 Strasser 2011.

58 Brown et al. 2003.

59 Brown et al.2003; Bernstein et al. 2003.

60 PLOS 2015.

61 Open Acess Directory 2015.

across all scholarly fields including the humanities.[62] Of those, approximately 6,000 are in science, medicine, or technology, excluding the social sciences. Estimates of the total number of scientific journals vary, but many put the figure at about 28,000 in total; a rough estimate, then, would put the number of open access scientific journals at around 20–25 % of the total number.

Journal publishers, whether for-profit or non-profit, have responded to the rise of open access journals in three different ways. First, some have offered an immediate open access option for authors willing to pay processing charges. These journals are thus called "hybrid" in that they publish open access articles along with articles available only by subscription. Second, other journals have transitioned entirely to the open access model,[63] usually supported mainly by author fees. By means of their efficient manuscript processing procedures, some of these journals (offered by for-profit publishers) manage to keep article processing charges even lower than the non-profit journals

62 Directory of Open Access Journals 2015.

63 Open Acess Directory 2015.

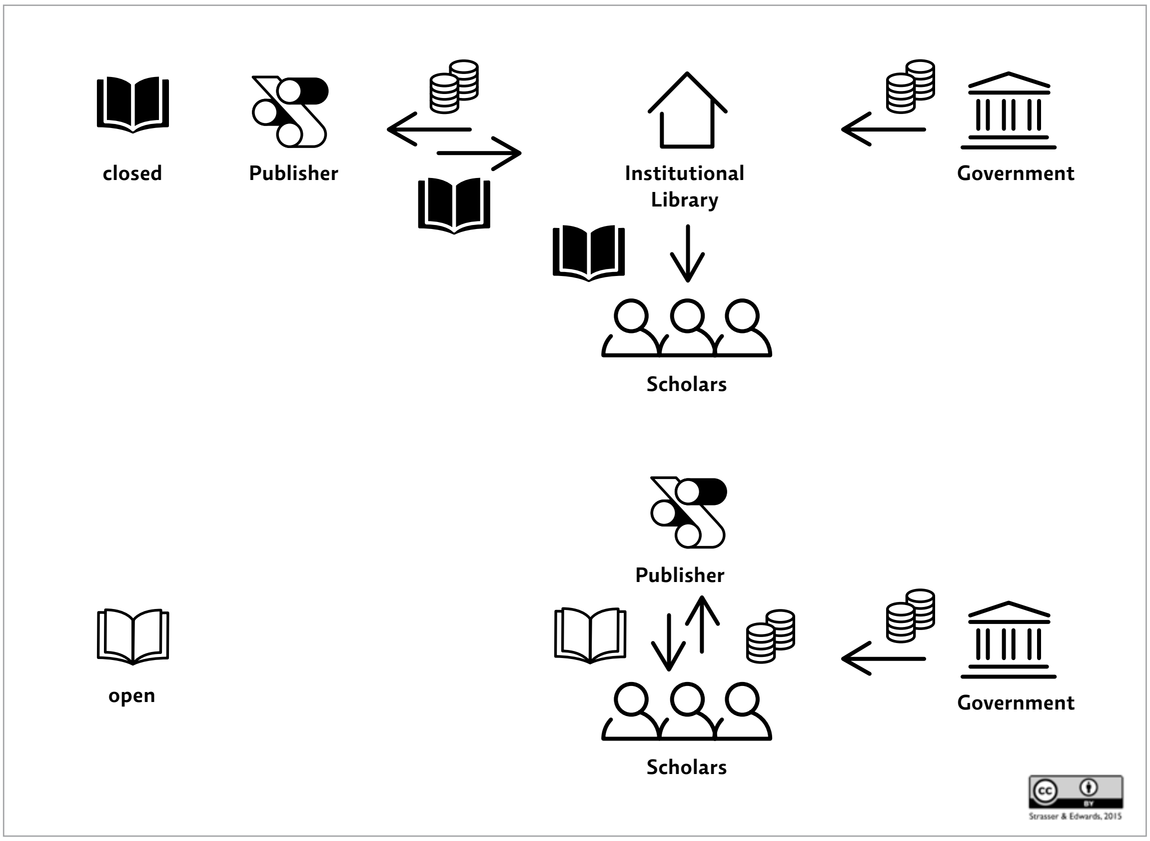


Figure 3 **Comparison of closed access and open access scientific publishing**
With open access, libraries are being disintermediated, since readers can access journal content directly from publishers' websites, without passing through a library subscription. With open access, government funding for publishing transits through authors (article processing charges) instead of libraries (subscriptions).

such as PLOS. However, most for-profit publishers, whether open access or not, charge higher processing fees than non-profits.[64] Third, some for-profit publishers have adopted a delayed open access policy, permitting these publishers to sell access to the journal content for a given period (typically 12–24 months) after initial publication. After that, the content is freely available, either on the publisher's website or in a repository such as PubMed Central.

A disturbing unintended consequence of the gold open access models is the rise of "predatory" open access journals.[65] These journals, generally only electronic, appear in most respects to be ordinary scientific journals – with prestigious editorial boards, peer-review procedures, etc. – and provide open access in return for article processing fees. In fact, however, they exist primarily to profit from scientists' powerful incentives to publish their work, often backed by research funding agencies willing to pay author fees. Many effectively *promise* to publish any submission. Levels of peer review vary from slim to none at all. In the worst cases, once processing charges are paid, the "journal" simply disappears, along with the money.[66] More generally, there is no correlation between the quality of a journal and how much it charges its authors for open access.[67]

The rise of open access publishing represents a profound change for scholarly communication. It has increased access to cutting-edge science for a vast

64 Solomon & Björk 2012.

65 Butler 2013.

66 Bohannon 2013.

67 Corbyn 2013.

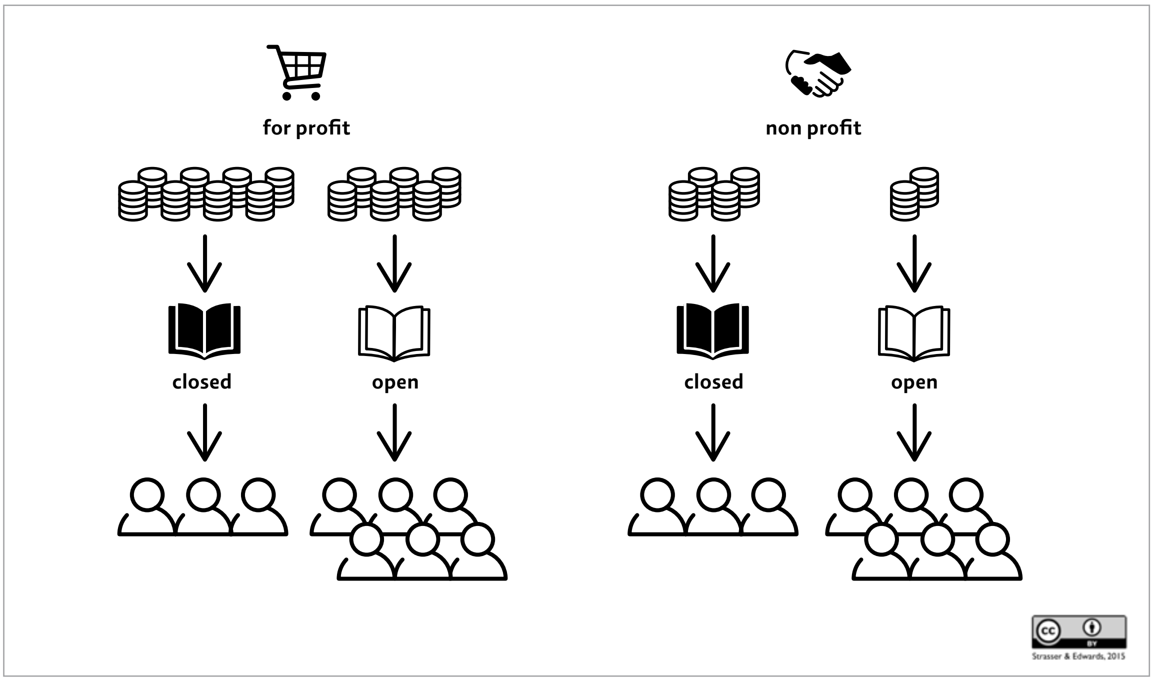


Figure 4 **Comparison of costs and audience in different publishing systems**
Open access can reduce overall costs, but mainly increases audience. Non profit, open access or not, significantly reduces publishing costs.

audience that goes far beyond the restricted academic circles. Yet to borrow Richard Stallman's famous slogan about open source software, open access is "free as in speech, not free as in beer". In other words, open access publishing liberates the *consumption* of knowledge, but has not changed the costs of *producing* and *disseminating* it. Instead, it has simply shifted the cost burden from one payer to another (Figure 3). Rather than academic libraries paying for journal subscriptions, a cost effectively diffused throughout the larger research institutions of which they are part, it is now increasingly individual authors (and their research grants) who pay to provide access for readers. It is far from clear that the open access models presently in vogue will reduce significantly the overall cost of publishing, unless they contribute to a major shift towards non-profit journals (Figure 4).

Ironically, while open access has made the content of academic publishing much more widely accessible, especially in developing countries, the new regime of author-paid processing charges may end up restricting the possibilities for scientists from those same countries to publish in open access journals. Aware of this defect, some journals, such as *PLOS Biology,* waive author fees (or reduce them) for researchers from the poorest nations.[68] Some open access advocates have criticized "gold open access", suggesting a "platinum open access" where open access journals would be free for both readers *and* authors. On the "platinum" model, sponsors – usually science funding agencies – would support all publishing costs. The most visible example of this approach is *eLife,* a non-profit open access journal launched by the three major science funding organizations – the Howard Hughes Medical Institute, the Max Planck Society and the Wellcome Trust – in 2011.[69] *eLife* represents a growing trend of science funding agencies entering the publishing arena with the hope of promoting low- or no-cost open access. The logic of this is clear: since these agencies end up paying the author fees of their grantees, their best interests are served both by keeping fees low *and* by promoting open access more generally. *eLife* has adopted the "platinum model," providing high-quality peer review and editorial processing at no cost for authors. In Switzerland, *Swiss Medical Weekly,* for example, follows the same model.

However, it is important to note that profits from subscription revenues or author page charges are not always diverted from scientific research funding to commercial publishers' pockets. Some professional research organizations, such as the European Molecular Biology Organization (EMBO), have drawn substantial revenue from subscriptions (and now author publication charges) to their journals *(EMBO Journal, EMBO Reports)*, which they have used to support research in their field. In fact, scientific professional societies opposed E-BioMed (the precursor to PubMed Central) because of fears it would reduce membership and revenue (a journal is often a scientific society's only "product," delivered solely to dues-paying members).

The economics of open access scientific publishing are not, however, zero-sum. As non-profit publishers take an increasing share of the publishing market, the overall cost of publishing will likely drop (Figure 4). To further reduce costs, some open access advocates recommend eliminating pre-publication peer review – letting readers decide for themselves on the scientific value of a paper. This would be a radical step, since it would greatly reduce the value of journals as filtering and certifying mechanisms; further, attempts to introduce post-publication peer review, whether to supplement or to replace pre-publication peer review, have not been successful.[70] High-quality peer review and publishing remains an expensive enterprise. If cost reduction is pursued above all other goals – especially the all-important aim of carefully vetted, collectively endorsed reasoning and evidence – open access could decrease the quality of scholarly publishing.[71]

4.6 Open data

Open access to scientific knowledge increasingly includes not only the text and figures of a published article, but also the supporting data, published or not. A number of policies in favor of open access to the

68 PLOS 2015.

69 Aguzzi 2015; Wellcome Trust 2011.

70 Neylon & Wu 2009.

71 Van Noorden 2013.

scientific literature were modeled after open data policies. Most attempts to encourage voluntary data submission achieve at best partial compliance. However, starting in the 1990s, many scientific journals began to require deposit of research data, accessible along with the article, as a condition for publication. This model has greatly improved the accessibility of scientific data in many fields.

The experience of open data can serve as a useful model for open access to the literature. Although the main questions of open access to scientific data have largely been solved, there remain several tensions and unresolved issues. Open data clearly offer many potential benefits, especially increased efficiency, reproducibility of results, and innovation of previously unknown uses. "Big data" techniques for finding patterns and anomalies in data have already led to numerous breakthroughs. Transparency has always been valued by democratic societies, and open data may contribute to democratizing science. Yet, like anything else, open data also present costs and tradeoffs that must be reckoned with.

Cooperation vs. competition. Sociological studies clearly show that researchers increasingly endorse at least the concept of open data, indicating a broad-based shift toward the communalist aspect of the scientific ethos. Yet as previously observed, science also retains a strongly competitive aspect, whose incentives militate for keeping data private. The highest-impact open access initiatives were precisely those, such as journals' requiring data deposit with article submission, that were embedded within the *existing* reward system. Conversely, initiatives that called for (cultural) revolutions in science – satisfying the communalist impulse without simultaneously addressing scientists' self-interest within existing career structures – seem to have had little impact.[72]

Usefulness vs. usability. Furthermore, the ideal of open data tends to conceal practical difficulties and issues of cost. For one thing, *useful* data are not necessarily *useable*; open access is not at all the same thing as genuine transparency. *Usability* requires not only clear and sufficient metadata, including descriptions of how, when, where, by whom, and with what instruments data were collected, but also readily accessible data formats appropriate to the desired use. In the context of inter- and trans-disciplinary problems such as climate change, where scientists from many traditions seek to make use of data from distant disciplines, metadata and data formats can never be perfectly resolved in advance. Increasingly, these problems are compounded by the existence of many similar datasets and many versions of the same data.[73]

Costs vs. benefits. Managing data requires time, energy, and attention from human beings. Digital data may be inexpensive to store, copy, and deliver, but they are not free. Storage, in particular, requires hardware that must be maintained and frequently replaced as technology evolves. The energy required for "cloud" storage and data delivery is enormous; if cloud computing were a country, it would have been the world's 6th largest electricity consumer (after China, the USA, Japan, India, and Russia), according to Greenpeace.[74] That was in 2011, and the growth curve is exponential. The drive to open data reflects a supply-side ideology, in the sense that it assumes a demand that very often does not exist. The fact that half of all published articles are never cited strongly suggests that at least half of all published scientific data will never be used, raising the important question of whether norms and/or policies that require data deposit are in fact worth their costs in time, effort, and money. Finally, most data policies, such as the mandatory Data Management Plan, provide for data preservation, but do not address the question of data deaccessioning: when, and by what criteria, should decisions be made to delete aging data, or data that are rarely or never used? With the amount of stored data currently increasing at exponential rates, cost-benefit analysis should be a high priority for future policy research.

72 Strasser forth. 2016.

73 Edwards 2010; Rood & Edwards 2014.

74 Greenpeace 2014.

5 Policy Options

Academic publishing is currently undergoing a profound transition, making it difficult to predict how the new system will stabilize. However, a certain number of changes now seem irreversible. All the actors in the academic publishing system – researchers, universities, libraries, science funding and science policy agencies, and even commercial publishers – acknowledge that the scholarly communication system is moving inexorably toward generalized open access. The remaining questions are how fast the transition will occur, at what cost, in what countries and disciplines, and with what consequences.

As this report has shown, the scientific communication system is driven mainly by researchers' choices about how and where to publish, guided by considerations of audience, exposure, and reputation effects. Incentives that can modify the basis of those choices thus represent the best opportunities for public policy.

5.1 Incentivizing open access

5.1.1 Open access mandates

Academic institutions and science funding agencies can choose to mandate open access publication for their employees and grantees. At present, the choice between green (repositories) and gold or platinum (OA journals) should be left to individual researchers due to field-specific norms.

5.1.2 Monitoring

Numerous examples show that policy mandates are insufficient to guarantee OA publishing. Some form of monitoring, tied to a system of incentives and/or sanctions, is necessary. Non-monetary rewards such as badges or certifications might have incentive value.

5.1.3 Researcher evaluation

Since a researcher's choice of publication venue largely depends on the expected social returns (audience, exposure, reputation effects), it is crucial to increase the social benefits of publishing in OA outlets. In evaluation processes for grants, appointments, promotions, or tenure, a policy of considering only the researcher's OA publications (green or gold) would be a strong motivator. Such a policy could be introduced gradually (e.g. only for publications after date X).

5.1.4 Research funding

Science funding agencies could withhold further funding if publications stemming from previous grants have not been made OA. The US NIH and the Wellcome Trust enforced this policy in 2014.

5.1.5 Author fees

Increasing open access will result in a transfer of charges from readers (individual subscribers) or libraries (institutional subscribers) to authors (usually supported by funders or academic institutions). In fields such as physics or mathematics, where most readers are also authors, science funders and academic institutions should cover at least part of this cost. Some funders limit the author fees they will support to a fixed amount; this policy encourages authors to publish in lower-cost venues. Some funding agencies, such as the DFG or the Norwegian Research Council, only support publication fees for fully OA journals, not hybrid OA journals.

5.1.6 Submission fees

Some OA journals charge modest fees ($100–250) to defray the up-front costs incurred during submission and peer review (whether or not an article is eventually published). Such fees help to discourage frivolous or premature publication, but journals, funders and institutions alike must ensure that they do not become prohibitive for less-well-off researchers and institutions, using discounts or reimbursements to offset these fees.

5.1.7 Raising awareness

Although most scientists recognize OA principles, their implications for researchers and for science are much less widely understood. Raising awareness of the economic issues, cost-benefit tradeoffs, and social value of OA may increase scientists' propensity to publish in OA journals.

5.2 Increasing accessibility

5.2.1 Repositories (green route)

Electronic repositories are replacing libraries in making scholarly content accessible to readers. To serve the goals of scholarly research, repositories need to make their material readily findable, searchable, downloadable, and comparable with other repositories, while ensuring long-term preservation of their content. The most cost-effective way to reach these goals is arguably to support *public disciplinary* repositories (such as PubMed Central or arXiv), rather than local institutional repositories. Localized document repositories were warranted for printed documents, when access required readers and documents to be physically in the same place. As reading practices have evolved towards electronic documents, comprehensive disciplinary repositories make much more sense than incomplete, idiosyncratic local repositories. Disciplinary repositories can be (and often are) funded through international consortia of science funding agencies.

5.2.2 Delayed release

The value of a publication to further research decreases rapidly over time; most articles are accessed primarily in the first months after their publication. Therefore, maximizing the benefits of OA for research requires that publications be made accessible as quickly as possible. Policies can aim at making preprints immediately OA, and published versions as soon as possible (but no later than 1 year after publication).

5.2.3 Right of secondary publication

The ability of commercial publishers to charge high prices rests on their claim of copyright in the published work. A number of science funding agencies have required either that their grantees retain copyright, or that copyright be under a Creative Commons license, which provides the right of secondary publication.

5.2.4 International law

The legal basis of green OA is not entirely clear due to ambiguities in copyright law. Government and university guidelines should clarify repositories' responsibilities under the Berne Convention for the Protection of Literary and Artistic Works (1886), in order to place OA initiatives on a more secure legal basis.

5.3 Reducing costs

5.3.1 Support non–profit OA journals

Research funding institutions bear an increasingly large share of publishing costs (through author publishing fees and support for repositories). Therefore, they have a growing incentive to reduce these costs while maintaining quality. In general, non-profit OA journals offer the lowest costs and fees. Science funding agencies can support the creation of non-profit OA journals, or the transition of existing non-profit journals to an OA model.

5.3.2 Negotiate reduced prices

In the UK, some institutions whose authors pay OA author fees to commercial publishers have negotiated for equivalent reductions in the prices they are charged for subscriptions to those journals. This principle could be widely extended.

5.3.3 Insist on market transparency

Differential or negotiated pricing based on ability to pay is a society-wide trend that may be unavoidable (and is sometimes desirable). In the case of commercial scientific journals, transparent pricing – even if differentiated – is essential to understanding the social distribution of costs.[75]

5.3.4 Consider a general exit

A radical, but potentially cost-effective approach would be to abandon commercial journals altogether in a phased exit. Some researchers have calculated that funds recouped by canceling commercial subscriptions entirely would more than pay for the transition to non-profit OA journals, at least in some circumstances.[76]

5.4 Maintaining quality

5.4.1 Quantity vs. quality

Currently, both authors and publishers have strong incentives to increase the number of articles submitted. These quantity-maximizing incentives produce deleterious effects on science, including higher costs, "peer reviewer fatigue," reputation judgments based on dubious quantitative measures, and burgeoning numbers of insignificant, never-cited articles. Striking the right balance between productivity incentives and high-quality science is therefore an important policy goal.

5.4.2 Publisher side: retain editorial judgment and stringent peer review

"Publish everything" norms – such as *PLOS One's* policy of publishing "all papers that are scientifically and technically sound, regardless of their perceived impact or importance"[77] – can be attractive to publishers in the open access environment because they boost submission numbers for journals. These norms risk downgrading journals' function as filters and certifying mechanisms. They should be tempered with more stringent criteria.

5.4.3 Limit the number of publications considered in evaluations

Funders and academic institutions could emphasize quality over quantity by limiting the number of publications taken into account when evaluating researchers, who would then submit only their highest-quality publications. Appropriate limits would need to be set on a field-by-field basis.

75 Estelle 2014.
76 Neylon 2014.
77 PLOS ONE Editors 2013.

Abbreviations

ARL	Association of Research Libraries
DFG	Deutsche Forschungsgesellschaft
EMBO	European Molecular Biology Organization
ETH	Swiss Federal Institute of Technology
NIH	National Institutes of Health
OA	open access
ORBi	Open Repository and Bibliography
PDF	Portable Document Format
PLoS	Public Library of Science
USA	United States of America

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Swiss Science and Innovation Council SSIC
Einsteinstrasse 2
CH-3003 Bern
T 0041 (0)58 463 00 48
F 0041 (0)58 463 95 47
swir@swir.admin.ch
www.swir.ch

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Swiss Science and Innovation Council SSIC
Einsteinstrasse 2
CH–3003 Bern

T 0041 (0)58 463 00 48
F 0041 (0)58 463 95 47
swir@swir.admin.ch
www.swir.ch