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## The Access/Impact Problem and the Green and Gold Roads to Open Access<sup>[1]</sup>

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**Abstract.** The research access/impact problem arises because journal articles are not accessible to all of their would-be users, hence they are losing potential research impact. The solution is to make all articles Open Access (OA, i.e., accessible online, free for all). OA articles have significantly higher citation impact than non-OA articles. There are two roads to OA: the "golden" road (publish your article in an OA journal) and the "green" road (publish your article in a non-OA journal but also self-archive it in an OA archive). About 10% of journals are gold, but over 90% are already green (i.e., they have given their authors the green light to self-archive); yet only about 10-20% of articles have been self-archived. To reach 100% OA, self-archiving needs to be mandated by researchers' employers and funders, as they are now increasingly beginning to do.

The research *journal-affordability problem* and the resulting university libraries' journal budget crisis were what first brought the research *article-access/impact problem* to light, but the journal-affordability problem and the article-access/impact problem are not the same. According to *Ulrichsweb* [<http://www.ulrichsweb.com/ulrichsweb/analysis/>], about 25,000 peer-reviewed research journals exist worldwide, across all disciplines and languages, publishing about 2.5 million articles per year. But because journal prices keep rising and library budgets are limited, each university can afford only a small portion of that total. That means their users have access to only a fraction of those articles, even though, in the online age, we would have expected otherwise. This is the research journal-affordability problem.

What the journal-affordability problem unmasked was a further problem: As a consequence of the fact that most of their would-be users at most universities cannot access most of the 2.5 million articles published yearly (because their universities cannot afford the journal access-tolls), a significant portion of the potential research impact of those inaccessible articles is being lost. An article's research impact is the degree to which its findings are read, used, applied, built-upon and cited by researchers in their own further research and applications. Research impact is a measure of the progress and productivity of research. That is the reason why researchers' careers (their salaries, promotions, tenure, funding, prestige, prizes) depend on their impact; it is also why their universities (which co-benefit from the research funding, progress and prestige) as well as their research funding agencies (which are answerable for the way they spend tax-payers' money) reward research impact.

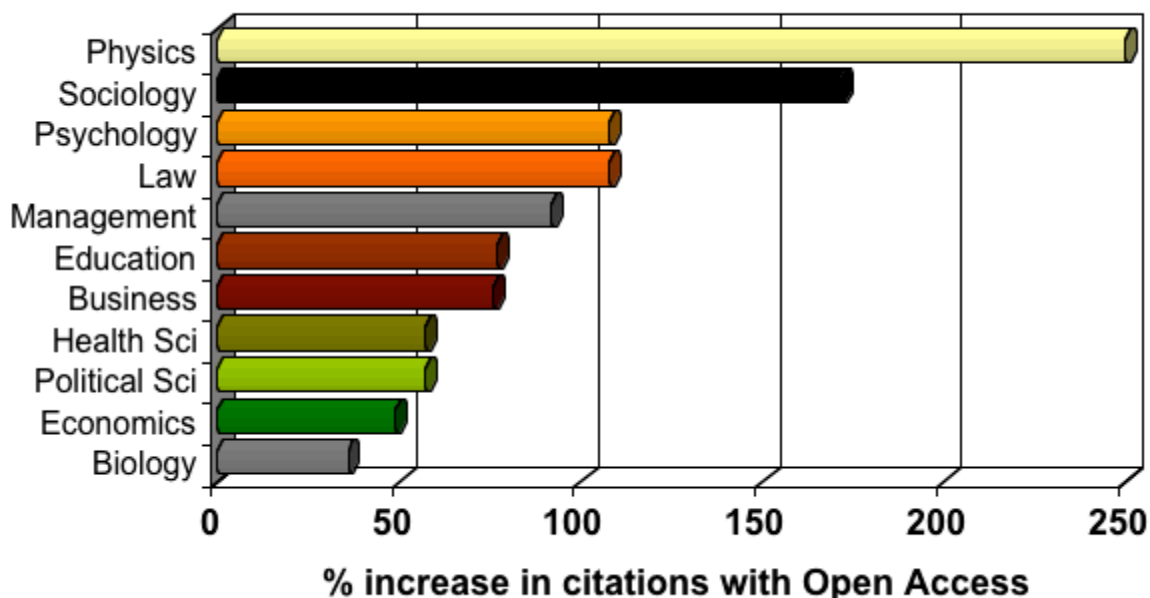
Merely to do the research and then put your findings in a desk-drawer is no better than not doing the research at all. Researchers must submit their research to peer review ([Harnad 1998](#)) and then "publish or perish," so others can use and apply their findings. But getting findings peer-reviewed and published is not enough either: Other researchers must find the findings useful, as proved by their actually using and citing them. And to be able to use and cite them, they must first be able to access them. That is the research article access/impact problem.

To see that the journal affordability problem and the article access/impact problem are not the same one need only note that even if all 25,000 peer-reviewed research journals were sold to universities at cost -- i.e. with not a penny of profit -- it would still be true that almost no university has anywhere near enough money to afford all or even most of the 25,000 journals, even at minimal access-tolls: <http://fisher.lib.virginia.edu/cgi-local/arlibin/arlib.cgi?task=setuprank>. Hence it would remain true even then that not all would-be users could access all of the yearly 2.5 million articles, and hence that that potential research impact would continue to be lost.

So although the two problems are connected (lower journal prices would indeed generate somewhat more access), solving the journal affordability problem does not solve the research access/impact problem.

How big is the access/impact problem? Estimates are emerging, and their consistency and size are quite striking. Lawrence (2001) reported that in computer science the citation impact of conference articles whose full texts are accessible online toll-free -- let us call that "Open Access" (OA), in line with the definition provided in 2001 by the Budapest Open Access Initiative: <http://www.soros.org/openaccess/read.shtml> -- is 336% higher than the impact of non-OA articles. Kurtz et al. (2004a, 2004b) have reported similar effects in astrophysics, and Odlyzko (2002) in mathematics.

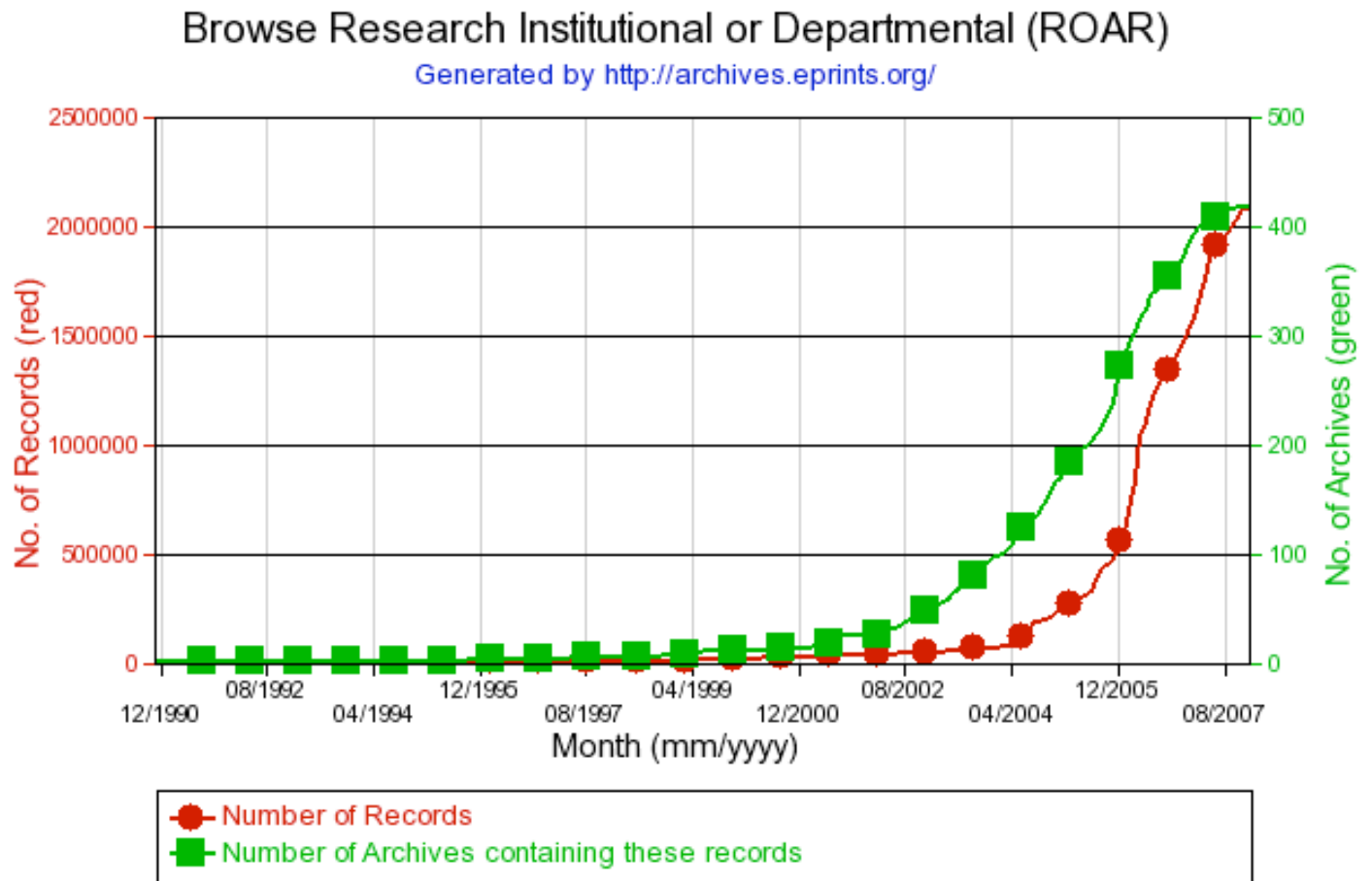
We have charted this OA-impact advantage across all disciplines as well as across time in a study using a 12-year sample of 14 million articles from the Institute for Scientific Information (ISI) database. We compared the matched citation counts of OA versus non-OA articles by trawling the Web to find which of the 14 million articles within the same journal and year are and are not OA. In field after field, the results confirm what Lawrence reported (Figure 1, Harnad & Brody 2004, Hajjem et al 2005).



**Figure 1.** Average citation ratios for articles in the same journal and year that were and were not made OA by author self-archiving. Date span: 1992-2003 Source: , [Harnad & Brody 2004](#), [Hajjem et al 2005](#)

How did some of the articles in those non-OA journals become OA? Because their authors "self-archived" them on the Web (i.e., made them accessible online toll-free for all would-be users): <http://www.eprints.org/self-faq/>. Physicists have been self-archiving in growing numbers since 1991, in a central archive called Arxiv ([http://arxiv.org/show\\_monthly\\_submissions](http://arxiv.org/show_monthly_submissions)), as have computer scientists on their own Web sites, which are then harvested by Citeseer: <http://citeseer.ist.psu.edu/cis>.

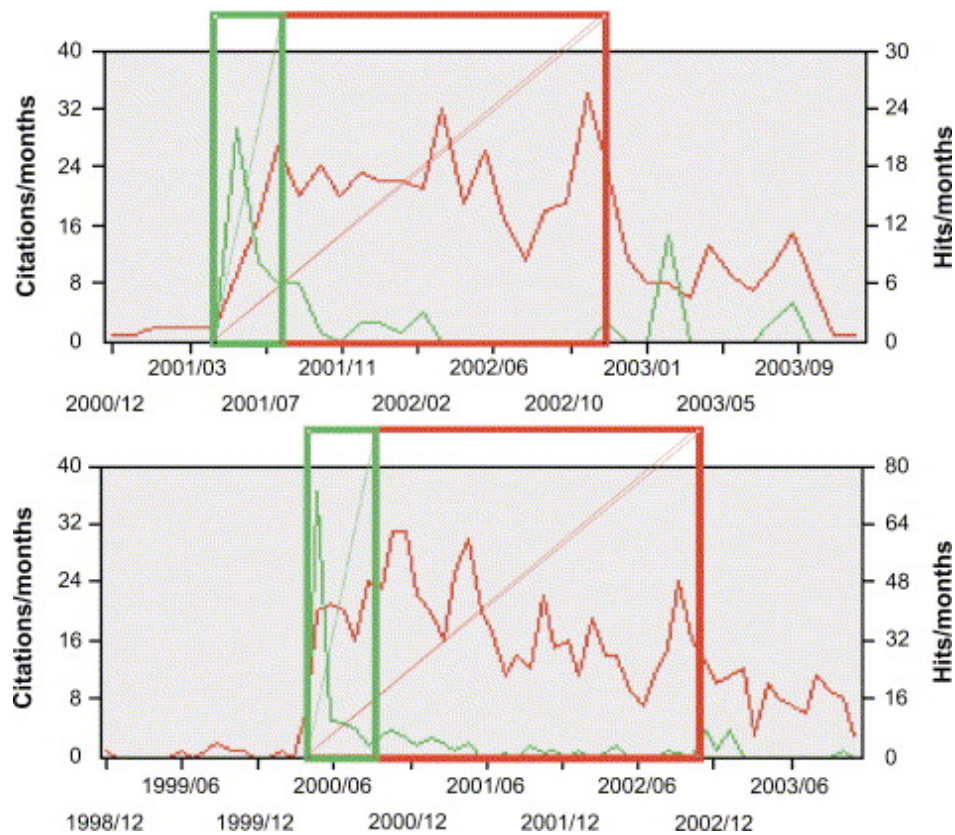
But the self-archiving method with the greatest potential to provide OA is self-archiving in one's own university's OAI-compliant Institutional Repositories (IRs; ). There are already over one hundred such institutional archives worldwide (<http://roar.eprints.org/>) and they are growing rapidly, but not yet rapidly enough: see Figure 2)



**Figure 2. Growth of Institutional Archives and Contents.** Displays a graph of all archives that have been flagged as 'Research Institutional'. The date-stamps of records as exported by the archive's OAI-PMH interface is used to plot a cumulative graph of records over time. The date of the earliest OAI-PMH record is used to show the number of cumulative archives over time (green, scale right). The number of metadata records exported by an archive may not reflect the number of full-text, publicly accessible documents (red, scale left).

OAI-compliance means using the Open Archive Initiative's metadata-tagging protocol to tag the critical information (author, title, date, etc.) in a uniform way (<http://www.openarchives.org/OAI/openarchivesprotocol.html>). OAI-compliance makes those many distributed archives "interoperable", so that they can all be harvested by cross-archive harvesters such as OAIster (<http://oaister.umdl.umich.edu/o/oaister/>) or BASE (<http://base.ub.uni-bielefeld.de/>) into a single, global seamlessly-searchable virtual OA archive

This global OA archive can then be enhanced with a harvester for the research literature such as Google Scholar or Citebase (<http://citebase.eprints.org/>), which counts citations instead of links and can rank articles by either the citation impact or even the "usage impact" (downloads) for the article or the author (Brody & Harnad 2004; Hitchcock et al. 2003). Early-days measures like the citebase download/citation correlator (<http://citebase.eprints.org/analysis/correlation.php>) can even predict eventual citations two years later from the number of downloads today (See Figure 3 for an area of physics in which the correlation between downloads and citations is about 0.4.).



**Figure 3. The Download/Citation Cycle Across Time.** In most areas of physics the correlation between downloads and citations is between 0.3 and 0.4; (Brody et al. 2006) These graphs show the time-course of downloads (smaller left box) and citations (larger right box) that would be included in calculating the correlation for two papers, where downloads were included up to 4 months after deposit and citations up to 2 years. The effect is cyclic, downloads generating citations and citations generating further downloads.

Such performance indicators and predictors can be included in standardized university OAI CVs ([http://paracite.eprints.org/cgi-bin/rae\\_front.cgi](http://paracite.eprints.org/cgi-bin/rae_front.cgi)) and then harvested by research assessors and evaluators to chart the progress and direction of research as well as to help make decisions on promotion and funding (Smith & Eysenck 2001; Harnad et al. 2003, Harnad 2007):

There is evidence that perhaps as many as 39% of authors are already providing OA for *at least one* of their articles by one or the other of the three means of self-archiving (arbitrary Web sites, central disciplinary archives, distributed university archives; Swan & Brown 2004): This 39% now needs to be systematically increased to 100%, *for all articles*, and the institutional self-archiving route is the most promising way to achieve that because universities and their researchers share in the benefits of maximizing research impact and share in the costs of lost impact.

All signs are favorable: There has been a great increase in OA consciousness in the past year, with many Declarations and Statements in support of OA worldwide such as:

- Berlin Declaration:** <http://www.zim.mpg.de/openaccess-berlin/berlindeclaration.html>
- WSIS Declaration:** [http://www.itu.int/wsis/documents/doc\\_multi-en-1161|1160.asp](http://www.itu.int/wsis/documents/doc_multi-en-1161|1160.asp)
- Bethesda Statement:** <http://www.earlham.edu/~peters/fos/bethesda.htm>
- Budapest Open Access Initiative:** <http://www.soros.org/openaccess/view.cfm>
- Public Library of Science:** <http://www.plos.org/about/history.html>
- Wellcome Trust Statement:** <http://www.wellcome.ac.uk/en/1/awtvispolpub.html>
- IFLA Statement:** <http://www.ifla.org/V/cdoc/open-access04.html>

In response to the research community's expressed desire for OA, the latest JISC/Romeo survey of nearly 10,000 journals indicates that over 90% are already "green," that is, they have given their official green light to author self-archiving (<http://romeo.eprints.org/stats.php>) (Cox & Cox 2003) .

Almost 3000 journals (i.e. about 10% of all journals) are even "gold," that is, they are OA journals, making all their own contents OA: <http://www.doaj.org/>. To cover their costs, however, some of these gold journals have had to adopt the OA journal cost-recovery model (Harnad 1995): Instead of the user-institution paying the journal access-tolls for incoming articles, the author-institution pays the journal peer-review and publication costs per outgoing article.

Currently the riskiness and untestedness of this gold journal cost-recovery model makes publishers more willing to go green rather than gold in response to the research community's demand for OA. Publishers note that physics journals have been green since 1991, and yet there still has not been any cancellation pressure (Swan 2007). Universities that can afford to pay for the official non-OA version do so. Users at universities that cannot afford the non-OA version use the authors' self-archived OA versions. One prominent "born-gold" journal -- Journal of High Energy Physics (<http://www.iop.org/EJ/journal/1126-6708>) has even successfully made the transition backwards from gold to green in order to make ends meet after a few years of being toll-free. Yet its contents remain 100% OA because 100% of its authors self-archive them.

Publishers have done their part in response to the research community's demand for OA by giving their green light to author-institution self-archiving. It is now time for more of the research community to take them up on it. It is not enough to sit and wait for all 25,000 journals to convert to gold (<http://www.eprints.org/self-faq/#31.Waiting> ). And it certainly isn't fair for researchers to demand that publishers make all the sacrifices and take all the risk upon themselves while the research community does not bother to take the risk-free step of providing OA (which they purport to want and need so much) for their own articles -- by simply self-archiving them (Harnad 2006).

The research community is ready at last to do update its existing "publish or perish" mandate to require also providing Open Access to the articles it publishes in the online era. The UK Parliament Science and Technology Committee (<http://www.publications.parliament.uk/pa/cm200304/cmselect/cmsctech/399/39903.htm>) has recommended (and the US Congress <http://www.taxpayeraccess.org/> has already voted in favor of) legislation to the effect that as one of the conditions for receiving research funding it should be mandatory for the fundee not merely to publish but also to self-archive all the articles resulting from the funded research. Six of the seven UK Research Councils, eight further research councils, and 13 universities worldwide have already implemented an Green OA self-archiving mandate and numerous other mandates are at the proposal stage (<http://www.eprints.org/openaccess/policysignup/> ).

In an author survey, Swan & Brown (2004a, 2004b) report that the vast majority of their author sample indicated that *they would self-archive willingly if their employer (or funding body) required them to do so!* Hence, universities and research-funders are in the best position to usher in the OA era by adopting and implementing their own institutional Green OA self-archiving mandates (<http://www.eprints.org/signup/sign.php>).

More than 500 universities worldwide already have Institutional Repositories. The adoption of official university OA self-archiving mandates will help to maximize the number of such archives, as well as the number of articles in them -- by incentivising self-archiving not only for the sake of the enhanced impact it has been shown OA will generate (Harnad & Brody 2004, Hajjem et al 2005) and the rewards of enhanced impact in assessing, crediting and rewarding research productivity and progress (Harnad 2007), but for the rich potential of e-science and e-scholarship on the Open Research Web (Brody et al 2007, Shadbolt et al 2006).

Along with the substantial recent rise in OA consciousness worldwide there has also been an unfortunate tendency to equate OA exclusively with OA journal publishing (i.e., the golden road to OA) and to overlook the faster, surer and already more heavily travelled green road of OA self-archiving. This oversight is probably a spin-off of conflating the journal-affordability problem with the access/impact problem. Let us hope that the mounting evidence of the powerful impact-generating effects of OA, plus incentives from their employers and funders, will at last induce the 61% of authors who have not yet done so to take to the green road so that we can all enjoy the benefits of 100% OA at last.

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