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A new mandate highlights costs, benefits of making all scientific articles free to read

By [Jeffrey Brainard](#) | Jan. 1, 2021, 12:01 AM

[Science's guide to the new open-access landscape](#)

In 2018, a group of mostly European funders sent shock waves through the world of scientific publishing by proposing an unprecedented rule: The scientists they funded would be required to make journal articles developed with their support immediately free to read when published.

The new requirement, which takes effect starting this month, seeks to upend decades of tradition in scientific publishing, whereby scientists publish their research in journals for free and publishers make money by charging universities and other institutions for subscriptions. Advocates of the new scheme, called Plan S (the "S" stands for the intended "shock" to the status quo), hope to destroy subscription paywalls and speed scientific progress by allowing findings to be shared more freely. It's part of a larger shift in scientific communication that began more than 20 years ago and has recently picked up steam.

Scientists have several ways to comply with Plan S, including by paying publishers a fee to make an article freely available on a journal website, or depositing the article in a free public repository where anyone can download it. The mandate is the first by an international [coalition](#) of funders, which now includes 17 agencies

and six foundations, including the Wellcome Trust and Howard Hughes Medical Institute, two of the world's largest funders of biomedical research.

The group, which calls itself Coalition S, has fallen short of its initial aspiration to catalyze a truly international movement, however. Officials in three top producers of scientific papers—China, India, and the United States—have expressed general support for open access, but have not signed on to Plan S. Its **mandate** for immediate open access will apply to authors who produced only about 6% of the world's papers in 2017, according to an **estimate** by the Clarivate analytics firm, publisher of the Web of Science database.

Still, there's reason to think Coalition S will make an outsized impact, says Johan Rooryck, Coalition S's executive director and a linguist at Leiden University. In 2017, 35% of papers published in *Nature* and 31% of those in *Science* cited at least one coalition member as a funding source. "The people who get [Coalition S] funding are very prominent scientists who put out very visible papers," Rooryck says. "We punch above our weight." In a dramatic sign of that influence, the Nature and Cell Press families of journals—stables of high-profile publications—announced in recent weeks that they would allow authors to publish papers outside their paywall, for hefty fees.

Other recent developments point to growing support for open access. In 2017, for the first time, the majority of new papers across all scholarly disciplines, most of them in the sciences, were published open access, according to the Curtin Open Knowledge Initiative. More recently, most major publishers removed paywalls from articles about COVID-19 last year in an attempt to speed development of vaccines and treatments.

Despite these and other signs of momentum, some publishing specialists say Plan S and other open-access measures could be financially stressful and ultimately unsustainable for publishers and the research institutions and authors who foot the bill. As debate continues about just how far and fast the movement will go, *Science* offers this guide for authors readying to plunge in.

How does open access benefit authors?

Authors who make their work open access may reap benefits, but their magnitude depends partly on what you measure.

One yardstick is a paper's impact. Some studies have reported up to triple the number of citations for open-access articles on average compared with paywalled ones. But authors may be likely to publish their best work open access, which might bring it more citations. A recent analysis that used statistical methods to control for this tendency found **a far more modest citation advantage** for open access—8%—and only for a minority of "superstar" papers.



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Mark McCabe of SKEMA Business School and Christopher Snyder of Dartmouth College studied how citations to articles changed when their journal volumes moved from behind paywalls to entirely open access, and compared them with citations for articles that remained paywalled. For each article in their sample of more than 200,000 papers in ecology and other fields, the researchers accounted for other characteristics that affect citations, such as a paper's age: Newly published papers usually receive a burst of citations at first but fewer later. The modest citation advantage from open access accrued only to high-quality papers, defined as having

already garnered 11 or more citations during a 2-year period before the paper became open access, McCabe and Snyder reported in November 2020.

Other studies have found that open-access articles have a larger reach by other measures, including the number of downloads and online views. They also have an edge in Altmetric scores, a composite of an article's mentions on social media and in news stories and policy documents.

These nonscholarly mentions buttress reports that open access enables a broader audience, beyond the core scientific community, to read research findings. In November 2020, Springer Nature and partners released findings from a survey of 6000 visitors to its websites. They reported that **an “astonishing” 28% were general users**, including patients, teachers, and lawyers. Another 15% worked in industry or medical jobs that required them to read but not publish research.

Even for faculty members who can read subscription-based journals through their institution's libraries, open access could allow quicker access to articles in journals to which the institution doesn't subscribe. Some 57% of academics surveyed said they “almost always” or “frequently” had trouble accessing the full content of Springer Nature's articles.

How does open access work for authors?

Open access comes in different varieties, or colors, each with its own costs and benefits.

In what's called gold open access, articles carry a license making them freely available on publication. Typically the publisher charges a fee to offset lost subscription revenue and cover the cost of publishing. In recent years, the median paid, after discounts, was about \$2600, according to a 2020 study by Nina Schönfelder of Bielefeld University. More selective journals, such as *The Lancet Global Health*, have charged up to \$5000. The Nature Research family of journals has set its top open-access fee at €9500 (about \$11,600), and Cell Press will charge \$9900 for its flagship, *Cell*. Some journals are entirely gold open access; other, “hybrid” journals offer authors a choice between free publication behind a paywall or open access for a fee.



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A growing number of universities and research institutions, especially in Europe, are striking deals in which they pay a publisher a single fee that covers open-access publishing by their authors and also lets people on their campuses read content that remains behind paywalls. The **largest such agreement** was reached in 2019 between Springer Nature and 700 German research institutions and libraries. Since the first such deal in 2015, the number grew to 137 in 2020, according to the ESAC Transformative Agreement Registry. However, the deals last year covered publication fees for only 3% of papers produced globally.

A variant called green open access allows authors to avoid publication fees. In this arrangement, authors publish in journals—even ones that use paywalls instead of charging authors—but also make their article freely available in an online repository. U.S. policy already requires the final, published versions of papers developed with federal funding to be deposited within 12 months in a repository such as the National Institutes of Health's PubMed Central, and many publishers do this automatically. Other authors can use online tools to find repositories. The Directory of Open Access Repositories lists more than 5500 of them.

Publishers typically impose a 6- or 12-month embargo before authors can deposit the final, peer-reviewed version of a paywalled article, but this runs afoul of the Plan S requirement for immediate open access. (The embargo policies of thousands of journals globally are listed in a database called Sherpa/Romeo.) As a compromise, many publishers including the *Science* family of journals allow authors to immediately post a nearly final, peer-reviewed version of a paper in an institutional repository. Plan S accepts this form of green open access, but has added a controversial provision that these accepted manuscripts be licensed for free distribution. Some publishers have complained that this approach threatens their subscription revenues because it could widen free reading of these articles.

Rooryck says Coalition S canvassed major publishers and found none was planning to routinely reject submitted manuscripts funded by Coalition S members because of the prospect that the authors would immediately post them when accepted. A spokesperson for publishing giant Elsevier told *Science* that all its journals will offer authors funded by Coalition S members the option to publish open access for a fee, allowing authors to comply with Plan S without violating embargoes.

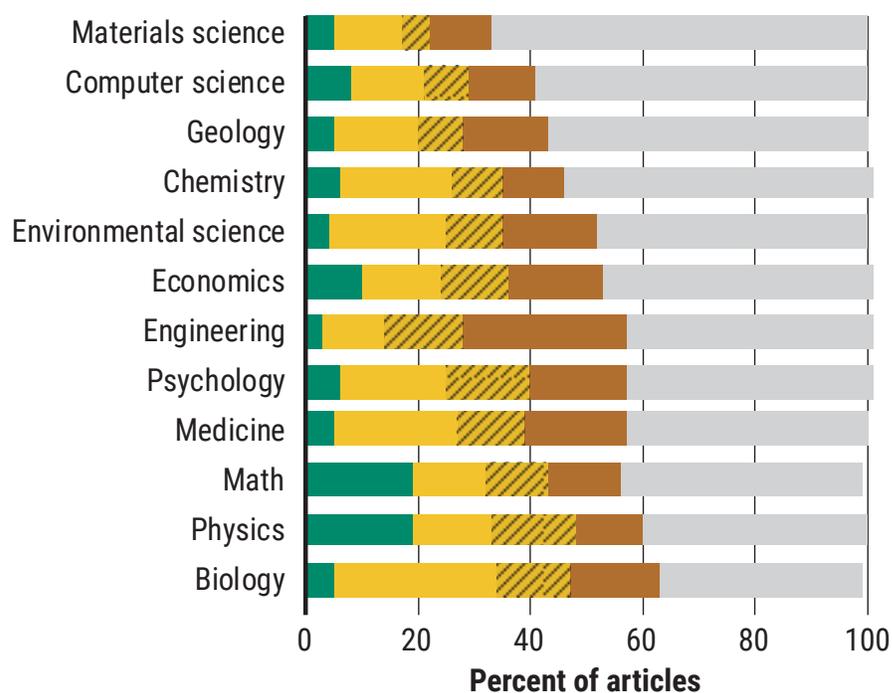
The many colors of open access

A variety of business models have evolved to support the publication of scientific journal articles that are free to read, and their prevalence differs by field.

The Curtin Open Knowledge Initiative performed the analyses using the CrossRef, Microsoft Academic, and Unpaywall bibliometric databases.

Differences by discipline

The higher rate of gold open access in biology may reflect higher funding levels that cover publication fees. Physics has a long tradition of posting manuscripts in green open-access repositories.



● Green

Authors or publishers deposit articles in a public repository, where they are free to read. But journal embargoes can delay posting. Numbers shown for green are undercounts because they exclude articles that were also published in other categories of open access (below).

● Gold

Articles are published with a license making them immediately free to read. Authors or institutions typically pay journals for this service. Gold journals publish only gold articles.

● Hybrid

Hybrid journals offer gold open-access publication but also publish other articles behind a paywall and continue to charge for subscriptions.

● Bronze

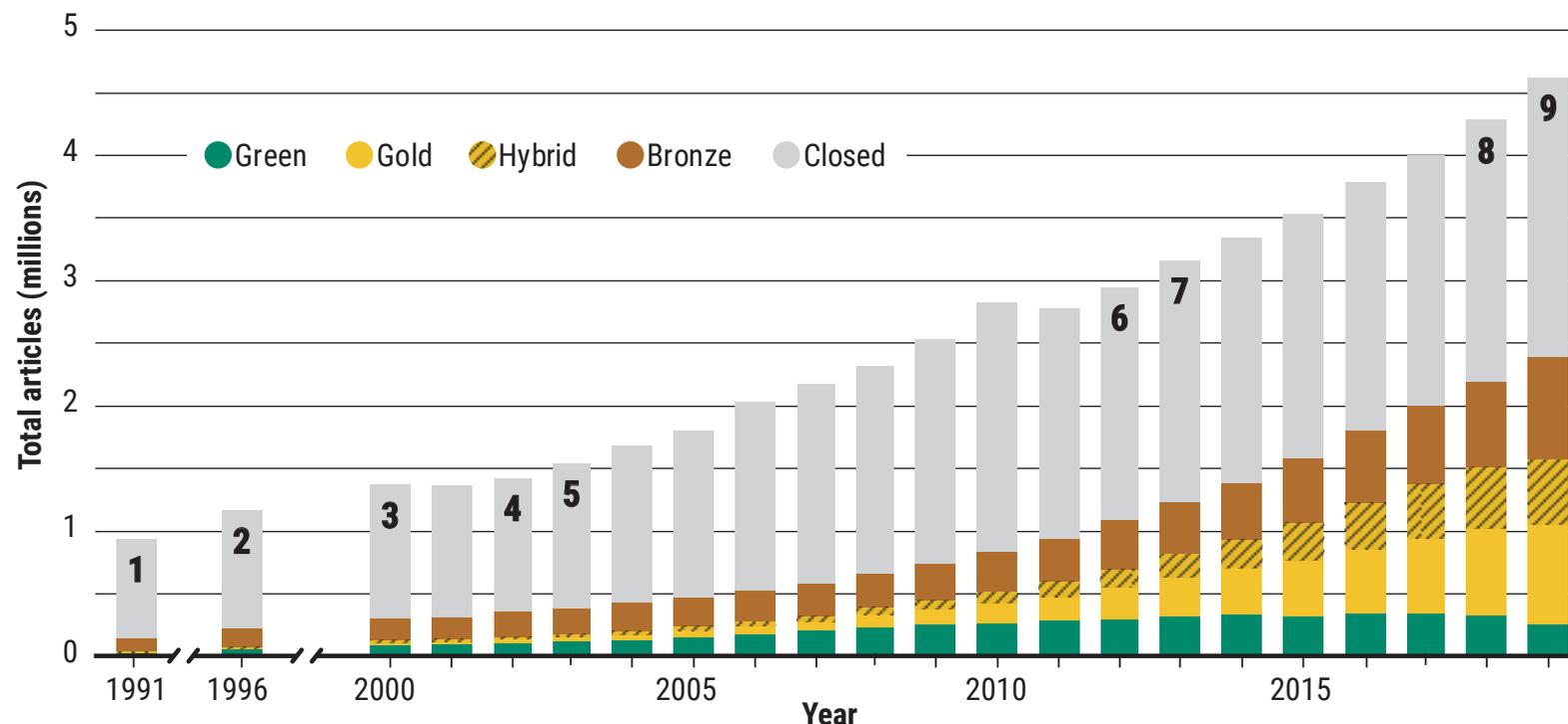
Articles are free to read on publishers' websites, but the papers are not licensed as open access, allowing publishers to place the articles behind paywalls later.

● Closed

Journals keep articles behind subscription paywalls.

A gradual opening

In 2017, the percentage of new scientific literature published open access surpassed 50% for the first time. Decisions by authors, publishers, and research funders have helped drive the growth.



1. 1991 ArXiv, the preprint server that posts papers in physics and other fields, publicly debuts, allowing free online reading of manuscripts.

2. 1996 The Journal of Clinical Investigation becomes the first prominent journal to provide its content free online, as public use of the internet increases.

3. 2000 BioMed Central, the first open-access, for-profit scientific publisher, starts.

4. 2002 The Budapest Open Access Initiative defines open-access scholarly articles as allowing the free reuse of the content, with credit to authors.

5. 2003 The Berlin Declaration on Open Access to Knowledge in the Sciences and Humanities expands on Budapest's terms, calling for research findings and data to be deposited in free, public repositories. The PLOS open-access journals are launched.

6. 2012 More than 2600 scientists vow not to publish in or referee for journals of the publisher Elsevier, in part because of its opposition to a U.S. National Institutes of Health requirement for green open access.

7. 2013 The White House Office of Science and Technology Policy requires that researchers who publish findings funded by U.S. grants make them open access within 12 months after publication.

8. 2018 Coalition S, a group of foundations and mostly European funders, announces its Plan S, which requires findings published by its grantees to be immediately open access starting in 2021.

9. 2019 Springer Nature and German institutions sign the largest "transformative agreement." Such deals allow institutions' authors to publish open access without paying per-article fees.

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Are publishing fees affordable for authors?

Where a researcher works strongly influences how much money is available for open-access fees. In Europe, institutions used dedicated internal funds to pay fees for 50% of articles their authors published in hybrid

journals (those that publish both open-access and subscription content), but in the rest of the world, the figure was only 25%, according to a 2020 [survey](#) by Springer Nature. Authors also tap funders and other sources, including their own personal funds. European scholars reported paying out of their own wallets for just 1% of the articles, compared with 16% in other countries.



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In Italy, the Nature group's new €9500 open-access fee has riled some researchers. That figure is "insane, there's no way on Earth to justify that," says Manlio De Domenico, who leads a network science lab at the Bruno Kessler Foundation. The annual research budget for his 10-person lab recently included a total of €8000 for open-access fees for the entire year. "We can spend the money better another way," he says—to pay Ph.D. students and, in normal times, fund travel to conferences and other labs. "To me, the trade-off is clear." (The Nature group says the price reflects its costs to produce such highly selective journals; journals don't normally collect fees for papers they review but don't publish.)

Nor do open-access publication fees hew closely to the laws of demand. One would expect fees to increase with the prestige of the journal, but a recent study by Schönfelder suggests that's not always true. She examined the relationship between fees paid by U.K. funders and the impact factor—a measure based on the average number of citations per article—of the journals where the papers appeared. She found a strong correlation in journals that published only open-access articles but a weaker one in hybrid journals. Hybrid journals tended to cost more than purely open-access journals, too.

In a [paper](#) published last year, Schönfelder suggested her findings reflect the legacy of the subscription prices of large, traditional publishers such as Elsevier and Springer Nature, which publish many hybrid journals. These highly profitable companies with large shares of the publishing market have operated with limited competitive pressure. "If [their] pricing behavior wins through, the open-access transformation will come at a much higher cost than expected today," Schönfelder wrote.

A complete shift to open access could lead publishers to boost publishing fees even further, to try to make up for lost subscription revenues, says Claudio Aspesi, a publishing industry consultant based in Switzerland. Although just over 30% of all papers published in 2019 were paid open access, subscriptions still accounted for more than 90% of publishers' revenues that year, according to Delta Think, a consulting and marketing firm.

Coalition S seeks to exert downward pressure on prices by increasing transparency. When a grantee's research is published, Plan S requires publishers to [disclose to funders](#) the basis for their prices, including the cost of services such as proofreading, copy editing, and organizing peer review. Rooryck says the coalition will share the information with authors and libraries, many of which help fund publishing fees. He expects the practice will increase price competition or provide "at a minimum, confidence that some of these prices are fair."

Who has qualms about open access?

Despite wide acknowledgment by scientists, publishers, librarians, and policymakers of open access' potential benefits, many are reluctant to go all in.

Even in Europe, where the movement for open access has been especially strong, Plan S is unusual. Of 60 funders surveyed in 2019, only 37 had an open-access policy, and only 23 monitored compliance, according to

a **report** prepared for SPARC Europe, a nonprofit that advocates for open access.

Some authors remain hesitant, too. In multiple surveys, authors have ranked open-access publishing below their need to publish in prestigious, high-impact journals to gain tenure and promotion. And they may be wary of a perception among some scientists that journals that carry only gold open-access articles lack rigor. (That view, researchers say, may reflect that such journals are relatively new, which lowers their impact factor.)



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A recent study also hints at inequities, finding that established, funded researchers at prestigious institutions are more likely to pay to publish their work open access. Anthony Olejniczak and Molly Wilson of the Academic Analytics Research Center, part of a data firm in Columbus, Ohio, examined the demographics and publishing patterns of more than 180,000 U.S. scholars. Overall, 84% of biological scientists and 66% in the physical and mathematical sciences had authored or co-authored at least one gold open-access paper between 2014 and 2018. Those authors were more likely to have advanced faculty rank and federal grants and to work at one of the 65 leading research universities that belong to the Association of American Universities, Olejniczak and Wilson report in **an upcoming paper** in *Quantitative Science Studies*.

Olejniczak and Wilson hypothesize that scientists who choose to pay for open access not only need financial resources, but also the sense of job security that tenure confers. “This is a good news, bad news story,” Olejniczak says. “Open access is thriving, and it’s growing.” But, he adds, publishers collecting the fees should consider ways to accommodate a wider diversity of authors.

Are publishing fees affordable for universities?

One tenet of the open-access movement has been that publishing fees can be funded by redirecting money university libraries currently spend on journal subscriptions—but that assumption faces questions. Although the “transformative” agreements that cover both reading and publishing of articles have rapidly increased the percentage of articles published open access at some institutions, the details of these deals (like traditional, subscription-only ones) are often secret and have other features that make it difficult to compare bottom-line costs. Comparing costs across institutions is also challenging because these deals usually involve large packages of journals, with the exact lineup varying by institution.



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Still, it is clear that making most articles gold open access could wallop the library budgets of research-intensive universities whose scientists publish the most papers. Many institutions that publish little research would save money by dropping subscriptions and letting faculty members read articles for free, analysts say, and publishers would look to recoup the lost revenue through publishing fees.

Pay It Forward, a **report** published by librarians at the University of California (UC) and colleagues in 2016, remains one of the most comprehensive analyses of the impact of these shifts on universities. They calculated what each of UC’s 10 campuses and three comparison institutions would have paid to publish as gold open

access all articles from between 2009 and 2013 that listed one of their faculty members as a corresponding author.

A key finding: At most of the research-intensive institutions studied—such as the UC campuses in Los Angeles and San Francisco and Harvard University—simply redirecting funds from journal subscriptions wouldn't cover the open-access fees. Those institutions could charge the difference to federal grants, but they would still have to cover fees on papers from studies done without grant funding. Harvard, for example, might have to boost its total library spending by 71%, or nearly \$6 million.

Rich universities like Harvard could potentially tap their huge endowments and copious research funding to cover these costs, but other universities could struggle. U.S. university library budgets have lagged the rate of inflation in higher education for years and now face cuts because of the coronavirus pandemic.

Some researchers interviewed for UC's study said they were reluctant to spend grant money on open-access publishing fees because they would eat into funds for research. "But in practice, we found [faculty members] are independently spending millions of dollars" from grants on fees, says MacKenzie Smith, university librarian at UC Davis and one of the study's co-authors. UC is conducting an experiment that limits the universities' contribution to per-article publication fees in order to encourage faculty members to consider other funding sources and journals with lower fees. "We want to get authors more engaged in the cost aspect of publishing, or at least mindful of it," Smith says.

Is open access the future of scientific publishing?

If paying for open-access publication becomes the default route for scientists, and publishers hike prices as expected, many analysts worry publishing will become a luxury that only better funded researchers can afford. That could create a self-reinforcing cycle in which well-funded researchers publish more, potentially attracting more attention—and more funding.

If that comes to pass, it could be especially hard on early-career researchers and authors in the developing world who lack their own grants, and on those in disciplines that traditionally receive less funding, such as math. Although publishers offer waivers for authors, many do not always cover the entire publishing fee or disclose what percentage of requests they grant.

Small, nonprofit societies that currently depend on subscription fees from their journals could also lose out in an open-access world, because the dynamics of the pay-to-publish model tend to favor publishers and journals that produce a high volume of articles, which affords economies of scale.

"I am worried that in the zeal to go that last mile" to make a larger portion of articles open access, "we could end up really hurting the scientific enterprise," says Sudip Parikh, CEO of AAAS, which publishes the *Science* family of journals. One of them, *Science Advances*, charges an open-access fee of \$4500, whereas the rest operate on the traditional subscription-only model. Parikh says AAAS is considering other options to make papers free to read, but he wasn't ready to discuss them when *Science* went to press. "I don't pretend to know the answer yet," he says. "But it feels like there are other possibilities" besides publishing fees.



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One model for sustaining open access without relying on per-article publishing fees comes from Latin America. Brazil and other countries have funded the creation of free open-access journals and article repositories, and the region in 2019 had the world's highest percentage of scholarly articles available open access, 61%, according to the Curtin Open Knowledge Initiative.

Debate continues about how to control publishing costs. Many advocates for open access say making it more affordable will require a vast shift in the culture of science. In particular, tenure and promotion committees will need to lower their expectations that authors publish in prestigious, costly journals.

But some argue that even if funders and institutions must cough up more money to help authors publish open access, the potential to accelerate scientific discovery would justify the added cost. The journal publishing industry's annual revenues of about \$10 billion represent less than 1% of total global spending on R&D—and, in this view, it's reasonable to divert more of the total to scholarly communications that are essential to making the entire enterprise run.

It's unlikely, though, that all scientific articles will ever become open access, says Rick Anderson, university librarian at Brigham Young University, who has written extensively about business models for journal publishing. "It just seems to me like the barriers to universal open access are too great," he says. "Every open-access model solves some problems and creates other problems."

"What I think is much more likely in the future, almost inevitable, is a fairly diverse landscape of open-access and subscription models," Anderson adds. "I haven't yet seen anything that has convinced me that toll [subscription-based] access is going to go away entirely."

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