Chapter 3 Opening science

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Abstract
Advances in technology have triggered the emergence of a new generation of science communication forms that are based on Open Science (OS), an umbrella for different movements whose goal is to promote transparency, reusability and connectivity of research. It provides the infrastructure (platforms, tools and services) to make scientific information freely available. OS can mean many different things—open access to publications, open research data, open peer review, open citations, open-source software, open collaboration, open notebooks, open educational resources, open books, and citizen science. This chapter focusses on the movements promoting (1) Open access to publications, (2) Open peer review, (3) Open research data, and (4) Open access to citations. It also looks at how preprints, academic social sites, and new communication formats, such as *Registered Reports*, *Lab Protocols, and Study Protocols,* are challenging the traditional scientific publishing system.

Keywords
Academia.edu, academic social sites, lab protocols, open access, open access journals, open science, preprints, research data, ResearchGate, research output, scientific communication, scientific publications, social media

Introduction

> Now we are witnessing the transition to yet another scholarly communication system — one that will harness the technology of the Web to vastly improve dissemination. What the journal did for a single, formal product (the article), the Web is doing for the entire breadth of scholarly output. The article was an attempt to freeze and mount some part of the scholarly process for display. The Web opens the workshop windows to disseminate scholarship as it happens, erasing the artificial distinction between process and product (Priem, 2013).

Open science, open access, open source, open citations—words often heard now in the scientific community—stirred a discussion about the future of scientific research, publishing, and metrics to evaluate academic impact. The enormous growth of scholarly communication, facilitated by digital technologies, is having a dramatic impact on the scientific publishing field. As the cost of subscriptions is becoming increasingly unaffordable, institutions are looking to Open Access (OA) to maintain access to published research. Governments, funding agencies, llibraries, publishers, and authors have a stake in making scientific information available and discoverable. New open access models and formats of

publishing are challenging the traditional system of scholarly communication in science, technology, and medicine (Baffy et al., 2020).

The push toward open access to scientific publications has increased in the past fifteen years as the relationships between research institutions and publishers have changed. In the 1990s, publishers were offering journal subscriptions as bundles to institutions (usually through their libraries). This has guaranteed publishers constant revenues. The academic institutions also benefitted from these contracts, as they were able to provide access to more publications than they would have been able to do it, if they were subscribing to individual journals. With time, the cost of these packages (known as "The Big Deal") began to rise faster than most academic library budgets. The 'deals' also did not allow flexibility in choosing the content available through these deals, as institutions were getting a lot of journals that were not needed or were not of good quality.

A lot of the research today is publicly funded, and researchers create scholarly content and review the work of their peers at no cost to the publishers. Scholarly publishing has become very profitable for publishers, while the cost of subscriptions has grown increasingly prohibitive for institutions. That has pushed academic libraries to reevaluate these deals and rethink how to make journal access more affordable. Institutions have started actively supporting OA and became proactive in pushing for contracts that would allow them to keep pace with the rising cost of journals without harming their patrons.

This chapter focusses on four dominant movements in OS—open access to publications, open peer review, open access to research data, and open access to citations. It also looks at how preprints, academic social sites, and new communication formats are changing the traditional publishing system.

Open Science

What is Open Science (OS)? Is it a concept, an infrastructure, practices, or maybe something else? OS is an umbrella term for various movements that have set up the goal of removing the barriers for sharing any kind of output, resources, methods or tools, at any stage of the research process and make the primary results of publicly funded research available with no or minimal restriction. OS means many different things—open access to publications, open research data, open-source software, open collaboration, open peer review, open notebooks, open educational resources, open monographs, and citizen science. In the domain of discovering scientific information, the focus is usually placed on two of these movements: Open Research Data (Baffy et al., 2020; Culley, 2017; Eiblmaier et al., 2018; Rousi & Laakso, 2020) and Open Access to scientific publications (Fiala & Diamandis, 2017; Hook et al., 2019; Joseph, 2021).

The Center for OpenScience envisions "a future scholarly community in which the process, content, and outcomes of research are openly accessible by default," detailing the path to achieving those goals (Center for OpenScience, 2021):

- All scholarly content is preserved, connected, and versioned to foster discovery, accumulation of evidence, and respect for uncertainty.
- Scholarly service providers monetize and compete on quality of service rather than by controlling access to content.
- Institutions evaluate researchers based on both the content of their discoveries and the process by which they were discovered, not on where those results are published.

- Funders have full insight into the returns on their research investments for prioritizing future investments.
- Researchers prioritize getting it right over getting it published and will receive credit for scholarly contributions beyond the research article such as generating useful data or authoring code that can be reused by others.
- Reviewers provide feedback at all stages of the research lifecycle and get credit and reputation enhancement for reviewing.
- Librarians apply curation and data management expertise throughout the research lifecycle, not just retrospectively.
- Consumers have direct access to review and primary evidence for scholarly claims.
- All stakeholders are included and respected in the research lifecycle and share pursuit of truth as the primary incentive and motivation for scholarship.

Open Access to scientific publications

> With effect from 2021, all scholarly publications on the results from research funded by public or private grants provided by national, regional and international research councils and funding bodies, must be published in Open Access Journals, on Open Access Platforms, or made immediately available through Open Access Repositories without embargo...The Funders commit that when assessing research outputs during funding decisions they will value the intrinsic merit of the work and not consider the publication channel, its impact factor (or other journal metrics), or the publisher (coalition-s, 2021).

On 4 September 2018, a group of national research funding organizations in Europe, with the support of the European Commission and the European Research Council (ERC), announced the launch of cOAlition S, an initiative requiring that scientific research supported by public funds must be published in alignment with Open Access principles (coalition-s, 2021). The funders of this initiative have agreed to implement the following principles:

- Authors or their institutions retain copyright to their publications
- All publications must be published under an open license, preferably the Creative Commons Attribution license
- The Funders will develop robust criteria and requirements for the services that high-quality Open Access journals, Open Access platforms, and Open Access repositories must provide
- Open Access publication fees will be covered by the Funders or research institutions, not by individual researchers—all researchers should be able to publish their work Open Access
- Governments, universities, research organizations, libraries, academies, and learned societies are encouraged to align their strategies, policies, and practices, to ensure transparency
- 'Hybrid' models of publishing will not be supported, but transitional path toward full Open Access will be allowed within a clearly defined timeframe, and only as part of transformative arrangements (In the 'Hybrid' model of OA, articles are published in a subscription journal but are immediately free to read under an open license, with authors paying an article processing fee).
- When assessing research outputs during funding decisions, those who are making these decisions will value the merit of the work and not consider the publication channel, its impact factor (or other journal metrics), or the publisher

The goal of Open Access is to make research and scholarly work openly available to all, which will benefit society and allow other researchers to use and build new knowledge upon results from previous research. OA journals are most often defined by their inclusion in the Directory of Open Access Journals (DOAJ).

The share of open access journals is rapidly increasing and accessing scientific information has become easier, but there are many challenges and uncertainties about how research can and should be communicated and shared. A large-scale study of the state of OA (Piwowar et al., 2018) used three samples, each of 100,000 articles, to investigate OA in three populations: (1) all journal articles assigned a Crossref DOI, (2) recent journal articles indexed in Web of Science, and (3) articles viewed by users of Unpaywall, an open-source browser extension that lets users find OA articles using oaDOI. The study has estimated that at least 28% of the scholarly literature is OA (19M in total) and that this proportion is increasing, driven mostly by growth in Gold and Hybrid options for OA. This percentage varies according to publisher, discipline, and publication year, with the most recent year analyzed (2015) also has the highest percentage of OA (45%).

The most common models for OA journals are Gold, Green or Hybrid, but the authors found a new category that they called "Bronze"—a category that includes articles to which publishers provide free access, without mentioning an Open license. The study used the following classification for types of OA journals (Piwowar et al., 2018) :

Gold OA: articles are published in an “OA journal,” a journal in which all articles are open directly on the journal website.

Green OA: Green articles are published in a toll-access journal, but self-archived in an OA archive. These “OA archives” are either disciplinary repositories like ArXiv, or “institutional repositories (IRs) operated by universities, and the archived articles may be either the published versions, or electronic preprints.

Hybrid OA: articles are published in a subscription journal but are immediately free to read under an open license, in exchange for an article processing charge (APC) paid by authors.

Delayed OA: articles are published in a subscription journal but are made free to read after an embargo period.

The proliferation of freely accessible journals is changing the citation rates of authors and the impact factors of journals. The results from the study mentioned above showed that open articles received 18% more citations than expected, which confirmed what is called "the OA Citation Advantage" found by other studies. Open access research articles may have a citation advantage (they are cited earlier and more often) than articles published in journals requiring paid subscriptions (Niyazov et al., 2016), but more studies are needed to draw this conclusion. More citations will also benefit journals, as that increases their impact factor.

The types of OA publishing models depend on different factors. There are discipline-specific preferences for the type of peer review used by OA journals. A comprehensive review of the disciplinary perspective on emergent and future innovations in peer review was published in *F1000Research* (Tennant et al., 2017).

The Open Access landscape was analyzed in a report, which compares the countries with highest research outputs with those publishing the highest number of Open Access papers over a 16-year period (Hook et al., 2019). The study found that there is a correlation between countries with higher use of OA and the international collaborations of researchers from these counties. The report used the following classification for Open Access:

- Pure Gold: Version of Record (VOR) is free under an open license from a full OA journal
- Bronze: Freely available on publisher page, but without an open license
- Hybrid: Version of Record (VOR) is free under an open license in a paid-access journal
- Green (Published): Free copy of published version in an OA repository
- Green (Accepted): Free copy of accepted version in an OA repository
- Green (Submitted): Free copy of submitted version, or where version is unknown, in an OA repository
- Platinum open access means permanent and free access to published scientific works for readers with no publication fees for the authors

While the Pure Gold option for OA was the preferred way to publish in Open Access among the top 12 OA-publishing countries, the global trend was slightly different with Bronze being the channel of choice. Bronze and Gold routes were found to be the fastest growing channels.

Although the idea of a journal that is freely available to the public with no financial barriers to access seems great in theory, when it comes time to publish, many researchers struggle with the decision of whether to do so in an OA journal or a traditional (and more well-established) journal. The four main factors that are taken into account when making this decision are prestige, visibility, cost, and speed.

What do researchers think about OA? A study looked at the extent to which open access (OA) publishing models affect French researchers' attitudes (Boukacem-Zeghmouri et al., 2018).. The instrument of the study was a survey designed to answer these questions:

- What place does OA have in attitudes of French researchers in mathematics, biology, and computer science?
- Are French researchers aware of new publishing models? Do they publish in these new outlets? What funds do they use?
- What kind of feedback and satisfaction can we observe?

The findings of the survey show that, when choosing journals to publish their articles, researchers do not consider OA as a criterion but rather take it as an opportunity for impact, prestige, and recognition. Lack of defined policy, guidance, and lack of rewards explain why OA is not a factor that determines the publishing strategies of French researchers. The study found that those who took the risk to publish in OA journals were the biologists, the older and more experienced researchers, and those who were members of editorial teams.

The new opportunities for publishing are also they present many challenges (Baffy et al., 2020). While they have made published research more accessible, they have also led to the proliferation of predatory journals and questionable author and editorial practices (Baykoucheva, 2015; Baykoucheva, 2018; Elmore & Weston, 2020; Markovac et al., 2018; Teixeira da Silva et al., 2019).

For years, the discussion of predatory journals has been based on Jeffrey Beall's list (Beall, 2016). A recent large-scale study systematically examines how predatory publishing is defined in the literature and how predatory journals are characterized by authors who write about such journals (Krawczyk & Kulczycki, 2020). The authors created a list of relevant publications on predatory publishing using four databases: Web of Science, Scopus, Dimensions, and Microsoft Academic. The findings show the profound influence of Jeffrey Beall, who composed and maintained himself lists of predatory publishers and journals, on the whole discussion on predatory publishing. The major themes by which Beall has characterized predatory journals are widely present in non-Beall publications. In 122 papers reviewed in this study, predatory publishing was combined with open access employing strategies similar to those used by Beall. The article discussed "the ways in which predatory journals have been conflated with—or distinguished from—open access journals." The authors conclude that "The overgeneralization of the flaws of some open access journals to the entire open access movement has led to unjustified prejudices among the academic community toward open access."

There have been some concerns that the open access author-pays model is 'ethically flawed,', because it raises the risk that bad science could be widely distributed without being subjected to more rigorous peer review. All journals care about their reputation and are motivated to weed out poor science through peer review. A journal will only attract submissions if it can convince authors that they will achieve credibility by publishing in it. In fact, many open access journals are demonstrating equally high standards as their counterparts. Some have implied that open access journals are tempted to publish more because of the increased revenues they receive from author fees. But what should we say about the traditional publishing houses, which are constantly increasing their prices by more than inflation—justifying it with the increasing number of pages they are publishing.

Open research data

> The new “atom” of scholarly communication, beyond the publication, is profoundly driven by research’s new and emerging relationship with data. This new format for communication will require new infrastructure with reproducibility built in. In this new world, peer review will remain central but will look completely different. With the rise of the post-truth or antiexpert era, it is critical that we develop mechanisms that make research open and reproducible that are beyond reproach (Hook et al., 2019)

Journal publishers play an important role in the open research data ecosystem, promoting transparency and broader access to knowledge. Open research data can be used for secondary analysis or for confirming the accuracy of reported results. While datasets may be an independent form of research activity, they are most often associated with journal articles. Journals are now requiring authors to make all data underlying the findings described in their manuscript fully available and to provide the data as part of the manuscript or deposit them to a public repository. Many journals recommend that authors deposit their laboratory protocols in protocols.io, where they are assigned an identifier (DOI), so that they can be cited independently. *Nature* recently published a list of recommended data repositories, where researchers can archive their data (Nature, 2021).

Because of a lack of standardization in definitions of the types of data that require deposition of data, open data policies vary greatly between journals. The policies should clearly say where and how data

should be archived, whether they should be made publicly available, can they be cited, and who can access them. The data sharing policy of a journal can be *mandatory*, *optional*, or *not required*.

There are many factors that may influence the data sharing policies of a publisher (Rousi & Laakso, 2020). Some large publishers have standardized open data policies for their journals. Taylor & Francis, for example, have adopted data policies that range from encouraging—to making mandatory—open data deposition that may be adopted by their journals. Springer Nature offers different types of data sharing options, depending on the journal (Springer Nature, 2021). Their policy includes sharing via repositories, permissions for citations, peer review of data, data availability statements, public data deposition and dataset identifier.

Academic publishing associations and other related bodies have also issued guidelines on preferred practices for data sharing and citation:

- *Committee on Publication Ethics' (COPE) Principles of Transparency and Best Practice in Scholarly Publishing*
- *Guidelines for Transparency and Openness Promotion (TOP) in Journal*
- *Policies and Practices*
- A joint statement on data accessibility by the International Association of Scientific, Technical and Medical Publishers (STM) and the Association of Learned and Professional Society Publishers (ALPSP)
- *Force 11 Joint Declaration of Data Citation Principles*.

In order to improve the infrastructure supporting the reuse of scholarly data, a group of representatives from academia, industry, funding agencies, and scholarly publishers have come together to create and implement a set of principles that came to be known as the FAIR Data Principles (**F**indability, **A**ccessibility**, I**nteroperability, and **R**euse) of digital assets (Wilkinson et al., 2016). The goal was to use these principles as a guideline for facilitating the reusability of data. The FAIR Principles were designed to make it easier for machines to automatically find and use the data and support their reuse by individuals (GOFAIR, 2021).

Open citations

Citations in published articles, patents, and other works are very important in discovering relevant literature published in the past and keeping up with current research in a more efficient way. For a long time, the only way to obtain citation data was through paid subscriptions to Clarivate's Web of Science or Elsevier's Scopus. This has changed, since PubMed Central (PMC) allowed extracting citations from the life sciences literature. Microsoft's Academic and Digital Sciences' Dimensions are now providing comprehensive citation indexes. Many citations are available in Crossref, but there is a movement to make all citations in articles freely available, which will allow discovering, analyzing and reusing them.

OpenCitations is an independent not-for-profit organization, which provides infrastructure for open scholarship and is dedicated to the publication of open bibliographic and citation data (OpenCitations, 2021a). It uses Semantic Web (Linked Data) technologies and provides open citation indexes (OpenCitations, 2021b). These indexes contain information about the citations themselves, in which the citations, instead of being considered as simple links, are treated as first-class data entities in their own right. Each citation has descriptive properties, such as the date on which the citation was created, its timespan and its type (e.g., whether or not it is a self-citation).

OpenCitations is an active advocate for open citations and is a key founding member of the *Initiative for Open Citations (I4OC)*, is a project supported by publishers, researchers, and other interested parties, which promotes unlimited access to references cited in scholarly papers.

Preprints vs journals

The slow changes in publishing have been attributed to the tight coupling of the journal system—the system's essential functions of archiving, registration, dissemination, and certification that are bundled together (Priem, 2013; Priem & Hemminger, 2012). This tight coupling made it difficult to change any one aspect of the system, stifling out innovation (Priem & Hemminger, 2012). By allowing research communities to make their own evaluation of a work in their field before formal peer review takes place, preprints are accelerating the de-coupling of research from the vetting power exercised by traditional peer review journals.

Researchers present preliminary results at conferences and publish the final results in scientific journals. However, the web has allowed scientists to bypass the traditional way of publishing. Preprints, for example, are becoming increasingly popular option for authors, as they provide visibility, feedback from peers, and greater attention for the final published version (Baffy et al., 2020; Fu & Hughey, 2019; Pagliaro, 2021; Preprints, 2021; Serghiou & Ioannidis, 2018). Preprints have played a major role in disseminating research findings on the COVID-19 pandemic (Sevryugina & Dicks, 2021).

A preprint is a full draft of a research paper that is shared publicly before it has been peer reviewed. Preprints are given a digital object identifier (DOI), so they can be cited in other research papers. In the past, posting a preprint may have caused a journal to reject the submission for prior publication, and some still share this concern. However, the vast majority of journals now acknowledge the benefit of preprints and encourage (or at least allow) their use.

Initially, preprints (sometimes called “working papers”) were a major path for sharing research findings in the physical sciences. Preprints history goes back to 1991, when physicists at Los Alamos National Labs created a central server to share drafts of new research papers. As this practice became more and more popular, the server was relaunched online as arXiv and has since been hosted by Cornell University. With time, other fields embraced the preprint concept and in 2013, Cold Spring Harbor Laboratory Press launched bioRxiv, a preprint server for life sciences.

Subsequently, new preprints have been launched in many other fields, including chemRxiv (Pagliaro, 2021). A wide range of discipline- or subject-specific preprints are supported by the Center for Open Science (https://www.cos.io. The history and current state of preprints were discussed in detail in recent publications (Fu & Hughey, 2019; Pagliaro, 2021; Serghiou & Ioannidis, 2018).

While preprints still constitute a small section of scientific publishing, they are a rapidly growing area of scholarly communication. In about three years since its start in 2016, the multidisciplinary preprint platform of the scientific publisher MDPI , Preprints, reached 10,000 preprints (Preprints, 2021). It took only 13 months to almost double the number of preprints to 17,000 by late October 2020 (Pagliaro, 2021). With the wave of publications on COVID-19, many researchers turned to preprint servers to post their research findings and share their results as soon as possible (Sevryugina & Dicks, 2021). A large influx of manuscripts in the life sciences and medicine went into preprint servers during that period.

Preprint servers in the STEM disciplines include arXiv, Authorea, ChemRxiv, CogNet, medRxiv, OSF Preprints, PeerJ PrePrints, SSRN, Research Square, ResearchGate, TechRxiv, and Zenodo.

The benefits of preprints fall into three main areas: credit, feedback, and visibility. By posting a preprint of research results, authors can make a claim to the work they have done and receive feedback that could help them improve the final version of their paper. The US National Institutes of Health now allow researchers to cite preprints in their grant applications. Posting manuscripts on preprint servers before or at the time of submitting them to peer review journals makes the dissemination of research findings faster. Preprints and providers of infrastructure like CrossRef often link preprints to the final published article, increasing the visibility of the work. The more places this work can be discovered by peers and the public, the more it will be read, cited, and mentioned. Posting a preprint is likely to increase the chances of finding a paper sooner.

Preprints can be very important at critical times for making quick decisions by health authorities and politicians. Since such manuscripts have not been vetted by peer-review, though, there is a possibility that they could contain some methodological errors and incorrect conclusions. The idea of using preprints in biomedicine, though, is still disputed (Kun, 2020). Preprints are driving the changes in scientific publishing, as they present alternative paths for making research available early on, improving the way in which research findings are shared and evaluated.

Academic social sites: Challenging the traditional publishing models

Academic Social Networking Sites (ASNSs) are increasingly used by scholars to obtain full text articles, create academic profiles, share research publications, and interact with peers. ResearchGate and Academia.edu, which appeared almost simultaneously in 2008, are the most highly used of these sites. The other academic social sites are LinkedIn, Mendeley, ResearcherID (on Publons) and ORCID. Researchers are also sharing information and personal profiles through Facebook, Instagram, and Twitter (Klar et al., 2020).

Academic social sites allow researchers to communicate directly with each other through an internal mailing system, add their publications to their profiles and use tools to monitor who is reading their publications. Some of these sites (for example, ResearchGate and SciHub) have been sued by commercial publishers for allowing posting of full text publications, which were protected by copyright. These sites provide benefits that are not available with conventional tools (Boudry & Durand-Barthez, 2020):

- Free and immediate deposit of references and full text publications (sometimes infringing copyrights)
- Significantly increasing visibility of publications, thus contributing to the building of researchers' reputation
- Use of an internal mailing system allowing direct contact
- Automatically alerting users to the addition of new publications considered to be of interest
- Allowing connection and collaboration with colleagues and experts in the field
- Asking and answering questions and even finding suitable job opportunities
- Serving as a source of bibliometric as well as Altmetrics indicators such as publication counts, reads, number of downloads, citations, and profile views

Academia.edu

Academia.edu, established by Richard Price in 2008, is a networking site entirely dedicated to academics. This platform allows users to create personal profiles, upload full text papers, exchange messages with other users, request feedback and see whether their papers were read. Users can also connect with their peers from other social networking sites (e.g., Facebook, Twitter). They can also get alerts through email whenever a researcher on their follow list publishes a paper. Academia.edu has analytic features that allows users to track the use of their outputs.

Google Scholar

Google Scholar is a search engine used to find scholarly information. It allows users to search across a wide range of academic literature from scholarly journals, professional societies, university repositories, institutional libraries, and other academic websites. Users can create a Google Scholar profile, keep in it a list of their publications, see how many times each publication was cited, save their articles in Scholar Library and also import their citations. Google Scholar Citations feature provides a way for authors to keep track of citations to their articles. It also has Metrics feature which provides way for authors to see the visibility and influence of recent articles in scholarly publications. This platform is available on.

ResearchGate

ResearchGate (a company with headquarters in Berlin, Germany) is a social network service founded in 2008 by the physicists Ijad Madisch and Sören Hofmayer together with computer scientist Horst Fickenscher (Manca, 2018). It is an academic social site, where researchers can connect and share information, upload journal articles, conference papers, posters, data and code to an online repository. ResearchGate has analytics feature about users' publications such as the number of times their papers have been read and cited by other users on ResearchGate. It provides its own set of proprietary metrics (RG Score , RG Reach and h-index) for measuring reputation.

ASNs such as Academia.edu or ResearchGate provide very basic search options. The search key is the author's name, which may be written in different ways. The accurate identification of authors is crucial for publishers, funders, universities, research evaluators, libraries, because many actions depend on the accuracy of this information (e.g., promotions, funding, getting credit for publishing or reviewing articles). An article discussed the difficulties in tracking scholarly and institutional publications of a particular author on Academia.edu and ResearchGate (Boudry & Durand-Barthez, 2020). These difficulties could be due to identical or similar names, name changes over time due to marriage, or the use of author groups. Change of researcher affiliations over time, due to researcher changing institution and/or lack of uniformity when stating affiliations in articles are also well-known problems.

Besides traditional citation counts, social media provides many other ways of tracking research impacts by capturing the interest to research through different forms of online engagement, such as views, downloads, bookmarks etc. Collectively, these metrics are called Altmetrics, as opposed to traditional citation metrics used by Web of Science, Scopus and other bibliometric databases.

PlumX (Plum Analytics) is an Altmetrics company (owned by EBSCO), which gathers a wide variety of research metrics for scholarly journal articles, but it also measures attention to other kinds of research artifacts that researchers produce. PlumX collects metrics for 67 different types of artifacts, which include abstracts, articles, audio files, bibliographies, blogs, blog posts, books, book chapters, catalogues, clinical trials, code/software, commentaries, conference papers, data sets, editorials, exhibitions/events, figures, government documents, grants, guidelines, images, interviews, journals, lectures/presentations, letters, live performances, manuscripts, maps, media files, musical scores,

newsletters, news, papers, patents, policy, posters, preprints, press releases, projects, reports, research proposals, reviews, retractions, speeches, standards, syllabi, technical documentation, theses/dissertations, videos, visual arts, web pages, and other items. PlumX divides metrics into the following five separate categories (Plum Analytics, 2021):

Citations include both traditional citation metrics such as those provided in Scopus, as well as citations that indicate impacts such as Clinical or Policy Citations. Citation counts in PlumX are measures of how many times a researcher's work has been cited by others. Examples: citation indexes, patent citations, clinical citations, policy citations Learn more

Usage is an indicator of how many times a work was read or used. Examples: clicks, downloads, views, library holdings, video plays

Captures is a metric that indicates that someone wants to come back to the work. Captures can be a leading indicator of future citations. Examples: bookmarks, code forks, favorites, readers, watching

Mentions is a measurement of activities such as news articles or blog mention about a work or an individual. Mentions shows that people are engaging with the reported research. Examples: blog posts, comments, reviews, Wikipedia references, news media Learn more

Social media is a category that includes tweets, Facebook likes and other signs of interest about reported research. It measures attention. Examples: shares, likes, comments, tweets.

Publishers are constantly adapting and finding new ways to facilitate discovery of their content more easily. Editors want the articles they publish in their journals to be found and they are taking advantage of social media to promote their content. Many journals are now active on Twitter and require authors to provide a “tweetable” abstract.

After threatening to remove millions of papers posted on ResearchGate in infringement of copyright (Jamali, 2017; Van Noorden, 2017), publishers' latest move is to collaborate with the academic social sites to make their content more easily discoverable and allow authors to promote their research (ResearchGate, 2021). Several publishers (Wiley, Springer Nature, Cambridge University Press, and Thieme) have started pilot projects with ResearchGate to make articles published in some of their open access journals available on the ResearchGate platform. Such initiatives will save authors time, increase the visibility and potential discoverability of their research, allow measuring the impact of their work in various ways, and create opportunities for discussing their work and establishing new collaborations.

Disintegrating the scientific article

> Breaking down the research article into more digestible and structured parts—or modules—can provide researchers with more opportunities to reuse and improve research (PloS, 2021a).

In a blog, "Imagining a Transformed Scientific Publication Landscape," PLoS presented their vision for an Open Science model that can only be achieved through collaboration among funders, institutions, publishers and researchers in such areas as dissemination, verification, recognition and community

building (PloS, 2021a). PLoS will be offering opportunities to publish detailed and enhanced methods by launching two article types on PLOS ONE that are the result of a partnership between the journals *Lab Protocols* and *Study Protocols*. *Lab Protocols* will provide step-by-step instructions for verified methodologies and computational techniques, using features of the protocols.io's platform and an input from a peer-reviewed article on PLOS ONE that puts into context the methodology used in the article. This may allow other researchers to replicate the experiments.

Study Protocols would allow readers to see design and analysis plans for a study that have not been performed, yet. This is a new type of article published in PLOS ONE, which describes detailed plans and proposals for research projects that have not yet generated results. The philosophy behind this publishing model is that "Sharing a study's design and analysis plan before the research is conducted improves research quality by reducing the potential for bias, and credits researchers for the work that occurs prior to data collection (PLoS, 2021b).

Study Protocols comes after *PLoS* launched in 2020 another new type of article, *Registered Reports*, which was adopted by other publishers, including *Nature* (Nature, 2021). In this model, scientists submit a detailed plan for a research project, study design and methodology. Their proposal goes through the process of peer review before research is actually performed. Editors need to approve it for peer review and if the reviewers agree that the proposal is well thought and planned, the journal promises to publish the work, regardless of the final product. *Study Protocols* are a stand-alone work, for which there is no commitment to publish. Authors of Study Protocols can publish their results wherever they choose to do it. This is different from *Registered Report Protocols* (RRP), where every RRP is peer reviewed and, if accepted, is being offered an "in principle" acceptance of their results.

As evident from the comments about these new types of articles, researchers have serious concerns about disclosing too much information about a planned research. The following opinion expressed by Jerry Miller in a comment posted on the PLoS blog was shared by other researchers (PloS, 2021a):

"Sharing protocols and research design ahead of executing the research is a recipe for disaster. Other people will steal the ideas. Yes, publications matter in career advancement, but being the FIRST to publish something matters a lot in this competitive environment. Much effort, time and organization– and preliminary research— can go in to developing a study protocol, so why hand it over to others for free? They'll take your work and your ideas and carry out the work with this jump-start done by you for them. They'll beat you to the patent office, so to speak, figuratively or literally. Researchers already know how to design studies without sharing the design with everyone else; or they can consult with colleagues in-house. Bad protocol development surely happens occasionally, but there are always complexities in studies that can only be seen in retrospect. Peer reviewing of protocols probably won't do any better and presents serious risks."

Although the interest to preprints is growing, some researchers have raised valid concerns about them. A legitimate concern is that there is the potential that other researchers could appropriate ideas or repeat an experiment reported in a preprint and publish a paper before the preprint's authors do. With the data and results posted publicly with a DOI, it becomes a permanent part of the scholarly record – one that can be referenced in any dispute over who discovered something first. Thus, preprints can guard against the problem by clearly establishing priority, but there are cases when the "borrowing" of ideas and even of the results could be more skillfully made and difficult to prove. The "borrowers" could slightly change the experimental settings, scope of study, and interpretations, to disguise their unethical

behavior. Authors who have suffered from this happening with their preprint may think twice before submitting another paper to a preprint server.

Conclusion

In an effort to facilitate access to scientific information, academic institutions and funding agencies are now encouraging (and sometimes, mandating) publishing research in open access (OA) journals, posting papers as preprints before submitting them to a journal and use social media, blogs, and web pages, to reach out to the public. Funding institutions are increasingly mandating OA publishing for grantees.

With more and more journals becoming freely available on the Internet, how is this going to affect the commercial publishers, as well as the secondary publishers and what could they do to survive? All commercial and professional society publishers are feeling the pressure from freely available open access journals and other information resources, and they come under greater scrutiny because of the prices they charge. The transparency which open access brings to the costs of publishing will mean better competition and lower margins for publishers. At the beginning of the Open Access movement, open access journals were regarded as category that was separated from those published by commercial publishers. As more and more commercial publishers have started offering fully or partially open access journals, the term "commercial publishers" as a synonym of subscription-based journals is not accurate.

The STEM publishing field is changing quickly, with the open-access mood forcing commercial and societal publishers to provide more public access to their journals. Open Access to information has the power to transform the way research is conducted, having direct and widespread implications for academia, medicine, science, industry—and for society, as a whole.

Opening access to research and the development of freely available tools for collaboration are driving the current progress in science.

Appendix: Organizations promoting Open Access

arXiv
www.arxiv.org
Repository for free e-prints in physics, mathematics, computer science, quantitative biology, quantitative finance, and statistics.

ARL
www.arl.org
ARL (The Association of Research Libraries) is a nonprofit organization that advocates OA. It includes research libraries in the United States and Canada and is one of the original founders of SHARE (Shared Access Research Ecosystem)

bepress (Berkeley Electronic Press)
www.bepress.com
bepress offers communication and publishing services for academic institutions. It has created Digital Commons, the leading institutional repository (IR) platform for universities, colleges, law schools, and research centers.

bioRxiv
www.biorxiv.org
bioRxiv archives and distributes unpublished preprints in the life sciences. Once an article is posted, it can be cited and cannot be removed.

BioMed Central
www.biomedcentral.com
BioMed Central is a pioneer of open access publishing, with a growing portfolio of high-quality OA journals OA peer-reviewed journals in science, technology, and medicine, making articles freely available upon publication.

CHORUS
www.chorusaccess.org
CHORUS (Clearinghouse for the Open Research of the United States) provides tools and resources for discovery and preservation of research data and supports initiatives for increasing public access to peer-reviewed publications with articles based on federally funded research.

CitizenScience
CitizenScience.gov
CitizenScience.gov is an official government website designed to accelerate the use of crowdsourcing and citizen science across the U.S. government.

Coalition for Responsible Sharing
http://www.responsiblesharing.org
The Coalition for Responsible Sharing (CfRS) is a group of publishers whose aim is to bring the practices of article-sharing platforms and scholarly collaboration networks into compliance with copyright to

address the copyright-infringing dissemination of enormous amounts of published journal articles on the largest scholarly collaboration network, ResearchGate.

cOAlition S
https://www.coalition-s.org
cOAlition S is an initiative to make full and immediate Open Access to research publications a reality.

CrossRef
www.crossref.org
CrossRef is an association of scholarly publishers that maintains a citation-linking network covering millions of journal articles and other content items such as book chapters, data, theses, and technical reports. It is involved in developing new tools and infrastructure to support scholarly communications.

Digital Science
www.digital-science.com
Digital Science is a company developing innovative technology whose goal is to make scientific research more efficient. Digital Science produces Dimensions (Dimensions, 2021), a scholarly search platform that allows to search publications, datasets, grants, patents and clinical trials. The free version of the platform allows searching only for publications and datasets.

F1000Research
www.f1000research.com
F1000Research is an OA journal that provides immediate publication of articles and makes them available for open peer review. It uses invited reviewers, but this happens after the article is made available to the public online, and anybody can review and comment on the presented results and raw data.

figshare
www.figshare.com
figshare (figshare.com) is a repository for many different kinds of files (e.g., figures, datasets, media, papers, posters, and presentations), which can be uploaded and visualized in a browser.

FundRef
www.crossref.org/fundref
In FundRef, publishers deposit funding information from scholarly articles and other contents. FundRef Registry uses a taxonomy of international funders' names provided by Elsevier. The funding data are publicly available through CrossRef.

Horizon 2020
ec.europa.eu/programmes/horizon2020
Horizon 2020, an EU Framework Program for Research and Innovation, is the biggest research and innovation program of the European Union, whose goal is to support research and innovation.

Initiative for Open Citations (I4OC)
https://i4oc.org/
I4OC, is a project supported by publishers, researchers, and other interested parties, which promotes unlimited access to references cited in scholarly papers.

IPython Notebook
www.ipython.org/notebook.html
IPython Notebook is an example of the new powerful "direct-to-publish" authoring tools that are changing users' experiences with scientific information. It allows the user to combine code execution, text, mathematics, plots, and media into a single document using interactive Web-based tools.

The Library Publishing Coalition
www.librarypublishing.org
The Library Publishing Coalition is a library-led project aimed at supporting publishing by libraries.

National Center for Biotechnology Information
www.ncbi.nlm.nih.gov
National Center for Biotechnology Information at the National Institutes of Health was created to respond to the rapid developments in molecular biology required different
archiving and publishing models, which led to the creation of the web-based genomic and proteomic databases (GPD), GenBank and Protein Data Bank (Brown, 2003). GPD is used for storage and retrieval, as well as for depositing vast volumes of molecular biology information. GPD is free and the information deposited in it is not subject to peer review.

OpenCitations
https://opencitations.net/
OpenCitations is an independent not-for-profit organization, which provides infrastructure for open scholarship and is dedicated to the publication of open bibliographic and citation data

OSF
https://osf.io/
OSF is a free, open platform to share research, which provides access to public research (projects, data, materials, and collaborators).

OSTP
www.whitehouse.gov/administration/eop/ostp
OSTP (Office of Science and Technology Policy advises the president of the United States on science and technology issues.

OASPA
www.oaspa.org
OASPA (Open Access Scholarly Publishers Association) develops new publishing models that support OA journal and book publishing. Its mission is also to educate researchers and the public on the benefits of OA publishing.

OpenAIRE
www.openaire.eu
OpenAIRE (Open Access Infrastructure for Research in Europe) is an initiative of the European Union supporting a large-scale shared archive network of aggregated digital repositories for datasets and other kinds of scientific outputs from many disciplines.

ORCID
www.orcid.org

ORCID (orcid.org) provides a unique identifier that disambiguates authors' names.

PeerJ
www.peerj.com
PeerJ (peerj.com) is an OA peer-reviewed journal providing low-cost publishing plans to authors. It publishes articles in the biological and medical sciences and allows readers to ask and answer questions, as well as make comments and annotations about them. It also maintains a preprint server, PeerJ PrePrints.

Peerage of Science
www.peerageofscience.org
Peerage of Science is a new model for peer review in publishing, which uses qualified reviewers to evaluate manuscripts before they are submitted to any journal. It also allows the writing of reviews of the peer reviews. Journals that subscribe to this service can accept already reviewed articles, and the authors also have the option of sending them to other journals.

PLoS Labs Open
www.ploslabs.org
PLoS Labs Open (www.ploslabs.org) is building new tools for disseminating and evaluating research.

Publons
www.publons.com
Publons (publons.com) is a platform for reviewers to post their reviews and get credit for them. This social networking website provides a platform for sharing and discussing peer review of academic publications.

PubMed Central
www.ncbi.nlm.nih.gov/pmc
PubMed Central (www.ncbi.nlm.nih.gov/pmc) is a digital repository that archives full-text scholarly articles in the biomedical and life sciences journal literature and makes them freely available. It is linked to other NCBI (National Center for Biotechnology Information) databases. The NIH public access policy requires that research papers reporting research funded by the National Institutes of Health must be available to the public free through PubMed Central within 12 months of publication (publicaccess.nih.gov).

PLoS
www.plos.org
PLoS (Public Library of Science) is an OA nonprofit scientific publisher. It has proposed the model of article-level metrics (ALMs) (SPARC, 2014). PLoS publishes OA journals and blogs in biology and medicine and provides resources and tools to facilitate the understanding and application of ALMs.

PKP (The Public Knowledge Project)
www.pkp.sfu.ca
PKP is a multi-university initiative of for developing (free) open-source software to improve the quality of scholarly publishing. The Open Journal Systems (OJS) is PKP's journal management and publishing system that is freely available to journals. Based on open-source software installed and controlled locally, it is aimed at expanding and improving access to research.

RDA (Research Data Alliance)
www.rd-alliance.org
RDA is an international organization that connects researchers and enables open sharing of data across technologies, disciplines, and countries.

ROARMAP
www.roarmap.eprints.org
ROARMAP (Registry of Open Access Repositories Mandatory Archiving Policies) provides a list of open-access mandates.

Rubriq
www.rubriq.com
Rubriq (www.rubriq.com) is a new form of peer review, which prescreens papers that are submitted for publication before they enter the publication process. It is used by some publishers as the only peer-review evaluation.

SHARE (SHared Access Research Ecosystem)
SHARE is an OA research initiative proposed by the ARL, the Association of American Universities (AAU), and the Association of Public and Land-grant Universities (APLU). Its network of cross-institutional digital repositories will accept papers and associate them with datasets resulting from research funded by federal agencies.

SHERPA/RoMEO and SHERPA/JULIET
www.sherpa.ac.uk/romeo
www.sherpa.ac.uk/juliet
SHERPA/RoMEO and SHERPA/JULIET are organizations that maintain databases with publisher copyright and research funders' policies, respectively.

ScienceOpen
www.scienceopen.com
ScienceOpen (www.scienceopen.com) calls itself a "research and publishing network." in 2013, it was started by scientists in Leipzig (Germany). It is an independent company with offices in Berlin and Boston that is committed to OA.

SPARC
www.sparc.arl.org
SPARC is a nonprofit international organization dedicated to promoting ALMs. The mission of SPARC is to "expand the distribution of the results of research and scholarship in a way that leverages digital networked technology, reduces financial pressures on libraries, and creates a more open system of scholarly communication" (Joseph, 2014).

PubPeer
https://pubpeer.com
The PubPeer Foundation is a California-registered public-benefit non-profit corporation. Its overarching goal is to improve the quality of scientific research by enabling innovative approaches for community interaction. It allows scientists to search for their publications or their peers publications and provide feedback and/or start a conversation anonymously. PubPeer has grown as part of a reaction to the negative influence of editorial conflicts of interest, commercialism, errors and bias in the present system

with its pre-publication review. We do not aim to reproduce it but to complement it with something different. Thus, PubPeer is designed around post-publication review and aims to facilitate open discussion. The philosophy driving the site is that authors should assume responsibility for assuring the quality, clarity, transparency and integrity of their publications.

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