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# **Reassembling Scholarly Communications**

## **Histories, Infrastructures, and Global Politics of Open Access**

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## 9 The Royal Society and the Noncommercial Circulation of Knowledge

Aileen Fyfe

### Introduction

The history of learned society publishing reveals that the philanthropic desire to make scholarship widely available, and free to read and reuse, is a scholarly tradition far older than the current Open Access Movement.<sup>1</sup> The Royal Society of London is the publisher of the world's longest-running scholarly journal, the *Philosophical Transactions*. It was launched in 1665 as a private venture by Henry Oldenburg, secretary to the recently founded Society; and since 1752, has been owned by the Society. The *Transactions* has historically been a useful way for the Society to enhance its reputation, not simply through the selection of interesting papers for publication but also by ensuring that its volumes and papers were widely available to scholars in Britain and the learned world. This was done through an extensive program of noncommercial distribution of printed copies of the *Transactions* and its later sibling, the *Proceedings*; and by encouraging reprinting and reuse of the material appearing in those journals.

For over two hundred years, from around 1750 to 1950, the Royal Society was heavily and successfully committed to funding the wide circulation of scholarly knowledge. The judicious distribution of the Society's publications—as membership perks, gifts to important individuals and institutions, tokens of exchange with other publishing societies, and as offprints circulating in personal scholarly networks—was central to this aim; but so too was a permissive approach to copying, reprinting, and reuse.

The Society's journals did have some paid-for sales, but the majority of the printed copies of the Society's journals prior to ca. 1930 were accessible without the need for payment by the end users. I start by considering how,

in the absence of any significant sales income, the substantial costs of producing and distributing scientific research in printed form were supported. The story reveals that there is a much longer history of using alternative sources of income to support the circulation of research than is usually assumed in discussions of open access.

## Money

It has too often been assumed that scholarly publishing has been a lucrative commercial undertaking for over three centuries, and that open access would be an unprecedented transformation of a well-established business model. Such an assumption would be utterly mistaken.<sup>2</sup>

It is true that back in 1665, Henry Oldenburg had hoped that the *Philosophical Transactions* would find enough paying customers to augment his modest income; and it is true that since the 1950s, the Royal Society's publishing division has generated increasingly large surpluses (£3.6 million in 2015).<sup>3</sup> But for most of the period in between, the *Philosophical Transactions* and the *Proceedings* were seen as legitimate causes for expenditure, not as potential sources of income.

The Royal Society's archive clearly shows that, while Oldenburg did make a little money from the *Transactions*, he was probably the last person to do so for almost three hundred years. His immediate successors as editor bankrolled the *Transactions* from their own pockets. When the Society took over the ownership and management in 1752, its leaders did so in the knowledge that this would involve financially supporting the *Transactions*. Their stated aim was to issue the *Transactions* for "the sole use and benefit of the Society, and the Fellows thereof."<sup>4</sup>

The ways in which that intention to "benefit" was put into action meant that the level of support needed by the publications increased over time: from 1752, Fellows were entitled to claim free copies of the *Transactions* as a membership perquisite; and from the 1760s onwards, the Society used copies as gifts to individuals and institutions. It was only during the difficult economic times of the 1930s, when the cost of the Society's now extensive program of gifts and exchanges became unsupportable, that a series of radical cuts to its generosity was followed by an increase in copies sold. By the 1950s, the Society shifted to a commercial model, in which sales and

subscriptions were both the main source of income, and the main mode of circulation.

How did the Society support its publications financially from the 1750s to the 1950s? For most of this period, publication finances were not separated from the Society's general finances: any income from sales was not earmarked as "publication income," and the publication expenditure was met from the Society's general sources of income. In broad terms, that means that the publications were supported in the eighteenth century by membership fees, with a little help from income from property and investments. In the nineteenth century, investment income became vastly more important than membership fees; and from the 1880s onwards, the Society's activities were also supported by grants and donations received from government, industry, and private individuals.

It is from the 1890s that we can see evidence of specific income streams to support publications. The growth in scientific research over the later nineteenth century had meant that the cost of supporting the publication of research papers was straining the resources of all learned societies, not just the Royal Society. In 1895, therefore, the Royal Society led an appeal on behalf of society publishers for a grant-in-aid of scientific publishing from the UK government.<sup>5</sup> The result was the creation of a fund administered by the Royal Society, using government money, to which learned societies could apply for support for their publications; each year, the Royal Society kept any balance remaining to support its own publications. The government grant was increased at various points over the first half of the twentieth century, but by the 1960s it was more usually used to support occasional book publications rather than research journals. The existence of this mechanism for government support of scientific publishing may explain why UK learned societies do not seem to have adopted the "page charges" used by certain US societies from the 1930s onwards.<sup>6</sup>

During the early twentieth century, therefore, the costs of producing and distributing printed scientific knowledge were being covered from a mix of income streams: the Society's investment portfolio; the annual grant from government (and, from 1925, an annual grant from Imperial Chemical Industries); and the income from modest sales. Together, this was (just about) enough to enable the Society to continue circulating so much research outside the commercial market.

## 1. A Membership Perk

The first of the ways in which Royal Society journals circulated noncommercially was as a membership perquisite. Fellows were entitled to claim a free copy of every volume of the *Transactions*, though they had to do this in person and within five years of publication. The requirement to collect in person protected the Society from postage costs, while the generous time-window assisted those who were only in London occasionally.

The copies for Fellows accounted for a large fraction of the print run. For instance, in the 1840s, the print run of *Transactions* was just 1,000, and there were over 700 Fellows (although only about two-thirds of them actually claimed their copies).<sup>7</sup> By 1947, Fellows could have their copies mailed to them, and this accounted for between 25 percent and 30 percent of the print runs of the several research journals then published by the Society.<sup>8</sup> Fellows were now asked to choose among the journals rather than receiving all of them.

With so many copies destined for the hands of privileged individuals, this may not seem particularly “open” to modern eyes. However, these personal copies were not necessarily as private as we might now imagine. Before the twentieth century, public or university libraries were scarce, and so personal libraries often became resources for the friends, colleagues, and local community of the owner. There are surviving accounts of eighteenth-century scholars consulting books in each other’s libraries, and of nineteenth-century artisans gaining access to knowledge via the library of an employer, patron, or local minister. Further, after the death of their original owners, these personal copies typically entered the secondhand book trade. Thus, while it is difficult to quantify the use that may have been made of these out-of-commerce copies of the *Transactions*, we must not ignore them.

## 2. Institutional Gifts and Exchanges

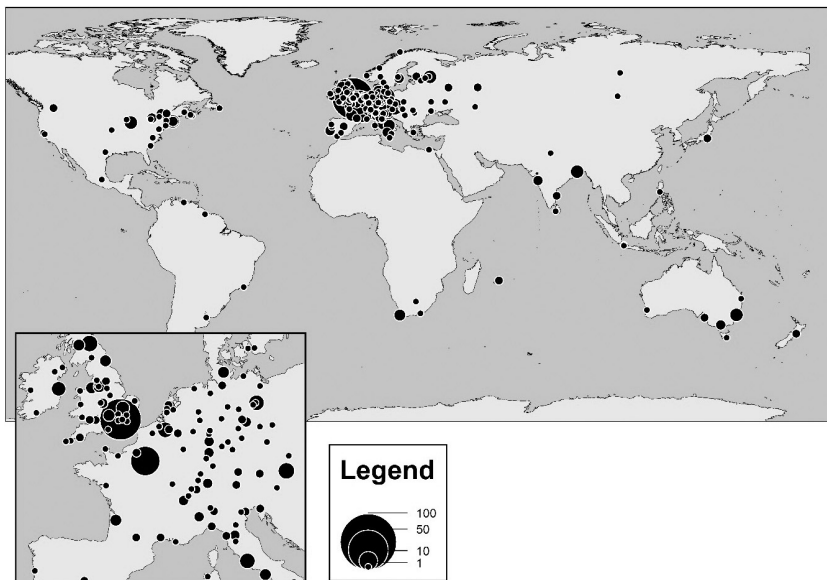
The most striking way in which the Royal Society supported the circulation of knowledge was by using copies of its publications as tokens in gift exchange with other bodies. Some gifts were efforts to enhance the Society’s prestige within Britain, such as regular donations to the King, the British Museum, and the universities of Oxford and Cambridge from the 1760s.<sup>9</sup> Others were attempts to spread the Society’s reputation internationally,

such as the gifts to the Royal Academies of the Sciences in Stockholm, Lisbon, Brussels, and Berlin. Sometimes, they acknowledged a gift received, and sometimes not.

The use of *Transactions* as a gift was relatively small in scale in the late eighteenth century, but by the 1840s, the Society was giving around 60 copies each year to learned societies, observatories, academies, and universities, as well as another 20 or 30 copies as gifts to individuals.<sup>10</sup> By the early twentieth century, there would be over 460 institutions receiving the Royal Society's publications.<sup>11</sup>

Within Britain, the beneficiaries included virtually all the universities and university colleges, as well as national scientific organizations (the National Physical Laboratory), metropolitan scientific societies, provincial societies (the Essex Field Club, Glasgow Natural History Society), and public libraries in Birmingham, Manchester, and Cardiff.

The increasingly long list of beneficiaries was due to the Society's expanding international ambitions over the later nineteenth century, which reflected Britain's expanding political and commercial influence. By 1908, over 70 percent of the gifts were going overseas. As the map in figure 9.1 shows,



**Figure 9.1**

Location of institutions receiving free copies of Royal Society publications in 1908.

the majority of these went to European universities and scientific societies, but significant numbers also went to similar institutions in Canada, Australia, New Zealand, India, and South Africa, and to the US. A handful were sent even further afield—to the observatory at Rio de Janeiro, the university library at Caracas, the imperial university in Tokyo, and the bureau of science in Manila. The distribution pattern combines a commitment to scholarly sharing with cognate institutions anywhere in the world, with a paternalistic vision of the Royal Society's role in Britain and the wider world that included public libraries in Cardiff as well as those in Alexandria and the Cape colony.

This increasing generosity was one of the reasons why the Royal Society sought additional income streams to support its publication activities from the 1890s onwards. The cost of sending copies to more institutions, often at great distance, was exacerbated by the fact that the Society—like other organizations—was publishing more research papers. In the early nineteenth century, the Society had printed about 500 pages of *Transactions* each year; but by the 1930s, it issued about 4,000 pages of *Proceedings* as well as 900 pages of *Transactions*.

An analysis in the 1930s noted that, historically, the Society's main aim in granting gifts had been to get its own publications out in the world.<sup>12</sup> It did, however, often benefit by receiving reciprocal gifts of publications for its library. In the early twentieth century, almost 200 of the institutions that received the Society's publications did reciprocate. They formed an international system of exchanges amongst a group of scholarly institutions that both published research and hosted research libraries. This enabled the creation of (printed) repositories of international scientific publications in national academies and learned societies around the world. The Royal Society was a net funder of this system: a 1954 review revealed that the Royal Society spent £2,300 on the production and shipping of the printed journals it sent out, but only received £800 of journals in return.<sup>13</sup>

In addition to these exchanges, the Society gifted its journals to a substantial list of universities, research institutions, observatories, and public libraries that did not publish their own research journals but did have members or staff seeking access to research from elsewhere. However, in the 1930s, an analysis of the cost of this "free list" swiftly led to the removal of privileges from most foreign universities, research institutions, and libraries. All the universities in Britain and its former colonies were entitled to

retain their place on the free list, and that included over 270 institutions.<sup>14</sup> But after a further review in 1954, universities were expected in future to buy the Society's publications, and only the Queen continued to get the *Transactions* for free.<sup>15</sup>

### 3. Offprints

Bound volumes were not the only ways in which the research printed in the *Transactions* and *Proceedings* circulated. The practice of allowing authors to acquire copies of their papers for circulation among their own friends, colleagues, and correspondents had been already well established by the 1780s.<sup>16</sup> In the days before photocopiers, these copies were valued as the only way to get a copy of the complete text—and tables, images, and formulae—without the labor of hand transcription. Authors sent them to their correspondents as soon as they were available; but they could also expect requests to arrive in the mail from researchers who wanted a personal copy.

These “separate copies” were, therefore, an important means for the circulation of individual articles in the age of print on paper; although, until it became standard practice to include full bibliographic details on the cover or in the header, their use could lead to misleading or inaccurate citations.<sup>17</sup>

The number and financing of separate copies varied over time. In the late eighteenth century, they were merely permitted—but not funded—by the Society: authors could pay for up to 100 copies of their article, directly from the printer.<sup>18</sup> By the start of the nineteenth century, the Society had begun to provide a certain number of copies to authors for free, with additional copies available at a charge; and by the 1840s, it was usually 100 copies for free.<sup>19</sup> This set the general pattern for the next century, although there were repeated attempts both to restrict free copies further and to restrict the number of additional copies that the authors could purchase.<sup>20</sup>

Separate copies facilitated certain forms of reuse, without the expense of recomposing type and hiring a printer, which would have been entailed by reprinting. Some researchers bound up a master set of their own papers, or used offprints received from others to create bespoke volumes on particular topics. Research institutions used the printed pages to create books out of the papers published by their staff. The scale of their requests for copies indicates that these were not just for internal use: in 1910, one author



requested 500 additional copies for binding into his laboratory's "archives"; and in 1950, the Rothamsted Experimental Station sought 400 extra copies to be used in volumes of "memoirs" showcasing the agricultural research of its staff.<sup>21</sup>

Allowing the production and circulation of "separate copies"—and funding the production of a certain number of them—was another means of enabling access to the research papers published by the Royal Society. Like the institutional gifts and exchanges, it was of most benefit to active researchers who were either themselves, or through their institution, well-connected to other active researchers and institutions.

#### 4. Copying, Reprinting, and Reuse

For readers outside the main scholarly research networks, it helped that the Society generally encouraged and enabled the copying, excerpting, reprinting, and summarizing of its research papers, rather than attempting to use copyright to restrict copying.<sup>22</sup> *Philosophical Transactions* itself, of course, is older than copyright, and it was not until the early nineteenth century that UK copyright protection was explicitly applied to periodicals as well as books. By that time, the Royal Society's approach to copying and reprinting was long established, and was based upon custom and courtesy, not legislation.

Throughout the nineteenth century, the Royal Society made generous dispensation to its authors to reuse their material. Authors who wished to reprint their articles were granted permission to do so. The Society also routinely granted permission to authors and their publishers to make use of the engraved metal plates (and later, wooden blocks) that carried the illustrations for their paper. The Society had paid for the images as part of the original publication in the *Transactions* or *Proceedings*, and it cost little or nothing to allow authors to reuse them; but it was a very significant cost saving to those who reused them. Permission to reuse images was also granted to certain third parties, such as the editor of *Nature*, to enable him to illustrate a report on a recent paper.<sup>23</sup>

The Society's willingness to allow third-party reuse of its material had been established in the early eighteenth century, when the Society gave permission to a series of editors, from 1703 onwards, who wished to produce

an abridgement of the back volumes of *Transactions*. These abridgements were sufficiently commercially successful that there were more copies of the abridgements in circulation than of the original journal volumes. Despite the fact that the editors and printers of the abridgements made money, the Society made no effort to interfere, nor to secure a share of the proceeds.

Abridgements of back numbers did not give access to current research, however. Around 1800, this role was taken on by a new group of scientific journals, which carried reports of papers read at Royal Society meetings and summaries of published articles.<sup>24</sup> The Royal Society's own *Proceedings* began in the early 1830s with this function, though it later evolved into a research journal. As with the eighteenth-century abridgements, the Society generally enabled and encouraged the secondary reporting and excerpting of its research papers. In the early nineteenth century, editors depended upon the author circulating some of his separate copies; but by the 1890s, the Society had created a list of journal editors who should receive copies of new articles automatically.<sup>25</sup>

The one point on which the Society stood firm was the timing of any reporting and reprinting. Until the 1890s, all research published by the Royal Society had first been announced at one of its meetings; was then available as separate copies; and was eventually formally published in the volume of the *Transactions*.<sup>26</sup> This meant that there was a real possibility that the key facts of the paper—if not the full details—could circulate through scholarly networks well ahead of formal publication. Thus, well-connected journal editors might, either accidentally or intentionally, report or reprint *before* publication. In 1802, the then-president of the Society had been vehement in his rebuke to an offending journal editor, and this appears to have established the practices of courtesy that governed reporting and reprinting of Society papers for the rest of the century.<sup>27</sup> The Royal Society insisted on having the prestige and credit of being the point of first publication for new research, but after that moment it welcomed efforts to distribute, report, abstract, and index its published papers. It did not seek to use copyright legislation to constrain the circulation of knowledge, and in 1950, it would be the architect of the Fair Copying Declaration, in which over a hundred signatory publishers agreed to allow articles in their journals to be photocopied for the purposes of research and study. This resulted in equivalent provisions in the 1956 UK Copyright Act.<sup>28</sup>

## Conclusion

In the late nineteenth and early twentieth centuries, Royal Society publications were not as easily accessible to global readers as open-access articles are now on the internet; but by the standards of the day, they were very widely available, and few end users had to pay. Until the 1950s, hundreds of copies of the Society's *Transactions* and *Proceedings* were being sent to organizations with libraries where they could be consulted by anyone with access rights to the library. Many university students and staff, and government researchers throughout Britain, Europe, North America and beyond, would have been able to get hold of Royal Society publications. It might involve a trip to a larger city or asking a favor from a colleague with membership in a society—but for individuals within the scholarly community, these publications could be obtained without any need to purchase them.

The Society's efforts were primarily directed toward those who were in some way part of a scholarly community. Copies were sent to public libraries in some of the large industrial cities, but the wider public was expected to learn about the contents of the Society's publications through third-party reporting, commenting, and reprinting. The argument that researchers should make their work publicly available, as a form of giving back to the taxpayers who funded them, is a far more recent development. Even when the Royal Society was presenting the argument for government funding of scientific publications in the 1890s, it focused on supporting the advance of scientific knowledge by aiding the circulation of knowledge among researchers.

By that time, the financial challenges of funding the Royal Society's increasingly ambitious, generous, and international vision for the circulation of printed knowledge were already apparent. For the next half-century, the Society struggled to find ways to keep this vision alive, slashing the provision of free and exchange copies, and seeking additional sources of external funding. In the world of print-on-paper publication, the Society's commitment to the noncommercial circulation of knowledge was ultimately defeated by scale.

It was during the rebuilding of the Society's publication practices after the Second World War that sales income came to be regarded as the preferred form of financial support for circulating knowledge. This is the same period in which a new group of commercially motivated firms moved into the publication of research journals and created a new business model based on the sale of journal subscriptions to international institutions. In

the context of the early Cold War, when budgets for scientific research were generous, this strategy proved highly profitable.<sup>29</sup>

By the mid-1960s, the Royal Society's success in selling its journals to the cash-rich universities of the United States (and also to British universities who no longer received them as gifts) meant that it no longer struggled to cover the costs of publishing. Instead, the Society was beginning to see publishing as an income stream that might support the increased range of scientific, educational, and policy activities it wished to pursue.<sup>30</sup>

Royal Society leaders in the 1940s and 1950s had hoped for a technological revolution that would transform the circulation of what was then called "scientific information," making it faster and more accessible, and bringing costs back to a level sustainable by learned societies. But by the time that revolution arrived, the switch to a commercial model of knowledge circulation meant that new means of sharing research seemed a threat to income, rather than an opportunity. A 1993 committee worried that "we know how to give electronic journals away, but we have no idea how to sell them."<sup>31</sup> The same was true of the Society's initial response to open access, which a 2005 statement described, with a dubious grasp of history, as "the biggest change in the way that knowledge is exchanged since the invention of the peer-reviewed scientific journal 340 years ago."<sup>32</sup>

In 2006, the Society adopted a hybrid model of open access for its existing journals, and since then it has launched two new open access journals (initially supported by the Society's general publishing funds, but now using an article processing charge (APC) model). As at many learned societies, there is an ongoing tension between the desire to retain the useful income stream from publications (dating from the 1970s), and the (much older) desire to circulate knowledge widely.

Much like the Royal Society in 2005, the Open Access Movement's emphasis on making use of new communication technologies has failed to appreciate that we do not need to invent a new world of free-to-read access to scholarly knowledge. Rather, we are seeking to use that technology to revive a traditional and long-standing noncommercial ethos of scholarly publishing.

## Notes

1. The research for this paper was supported by the UK Arts & Humanities Research Council, grant AH/K001841.

2. The following discussion is based on Aileen Fyfe, "Journals, Learned Societies and Money: *Philosophical Transactions*, ca. 1750–1900," *Notes and Records: The Royal Society Journal of the History of Science* 69, no. 3 (2015): 277–299, <https://doi.org/10.1098/tsnr.2015.0032>.
3. The Royal Society, "Trustees' Report and Financial Statements 2015–16," 2016, 111, note 3, <https://royalsociety.org/-/media/about-us/governance/trustees-report-2015-2016.pdf?la=en-GB&hash=82396A1A10887287879D8F973D72A2B0>.
4. The Royal Society, "Council Minutes," March 19, 1751, RS CMO/4.
5. Text of letter in The Royal Society, "Council Minutes," June 20, 1895, RS CMP/7.
6. Tom Scheiding, "Paying for Knowledge One Page at a Time: The Author Fee in Physics in Twentieth-Century America," *Historical Studies in the Natural Sciences* 39, no. 2 (2009): 219–247, <https://doi.org/10.1525/hsns.2009.39.2.219>; Marianne Noel, "La Construction de la Valeur Économique d'Une Revue en Chimie: Le Cas du *Journal of the American Chemical Society* (1879–2010)," *Revue Française des Sciences de l'Information et de la Communication*, no. 11 (2017), <https://doi.org/10.4000/rfsic.3281>.
7. Fellowship claims, from The Royal Society, "Undated Circulation Figures [before 12 Feb 1846]," n.d., RS CMB/86/A.
8. The Royal Society, "Distribution of Royal Society Publications 1947. Officers' Minutes," January 7, 1948, RS OM/2(48).
9. The Royal Society, "Council Minutes," June 25, 1761, RS CMO/4; The Royal Society, "Council Minutes," December 12, 1765, RS CMO/4.
10. See, for instance, list printed in *Proceedings of the Royal Society* (1838).
11. The 1908 list has 467 institutions, of which 260 were receiving the *Transactions*, and the rest the *Proceedings*. See *Year Book of the Royal Society of London* (London: Harrisons and Sons, 1908), 125–142.
12. The Royal Society, "Report of the Library Committee to Council," April 21, 1932, RS CMB/47/5.
13. The Royal Society, "Revision of the Lists of Exchanges and Gifts of the Royal Society's Publications," March 2, 1954, RS OM/14(54). There were 198 institutions on the exchange list at that point.
14. The Royal Society, "Revision of the Lists of Exchanges and Gifts."
15. The Royal Society, "Recommended Reductions in Exchanges and Gifts of the Royal Society's Publications," 1954, RS OM/16(54). An alternative incarnation of the "free list" emerged in the early twenty-first century, when the Society began to participate in the UN Programme for the Enhancement of Research Information, to make scientific journals more easily available to institutions in the developing world. The Royal Society, "Review of the Year," 2003, 9.

16. For example, see Charles Blagden to Erasmus Darwin, September 14, 1786, RS CB/2/34, Blagden Papers.
17. On Darwin's confusion, involving an offprint, see Alex Csiszar, "Seriality and the Search for Order: Scientific Print and Its Problems during the Late Nineteenth Century," *History of Science* 48, no. 3–4 (2010): 399–434, <https://doi.org/10.1177/007327531004800306>. The Royal Society offprints had carried the name of the *Transactions* since the start of the nineteenth century; the date was added in the late 1870s. See The Royal Society, "Council Minutes," March 21, 1878, RS CMP/5.
18. Blagden to Darwin, September 14, 1786.
19. This is apparent from The Royal Society, "Council Minutes," July 15, 1802, RS CMO/8.
20. The Royal Society, "Council Minutes," December 20, 1849, RS CMP/2.
21. On Rothamsted, see FC Bawden to Salisbury, "Application for Reduction in Charge for Reprints," December 7, 1950, RS OM/57(50).
22. For an extended discussion of the Royal Society's attitude to copyright, see Aileen Fyfe, Julie McDougall-Waters, and Noah Moxham, "Credit, Copyright, and the Circulation of Scientific Knowledge: The Royal Society in the Long Nineteenth Century," *Victorian Periodicals Review* 51, no. 4 (2018): 597–615, <https://doi.org/10.1353/vpr.2018.0045>.
23. For instance, William Herschel arranged to use RS plates for the reprint of his papers. See The Royal Society, "Council Minutes," June 22, 1797, RS CMO/8; and the Council Minutes for 20 March 1902 grant permission to several authors as well as to the editor of *Nature*. The Royal Society, "Council Minutes," March 20, 1902, RS CMP/8.
24. On the new journals, see Csiszar, *The Scientific Journal*, chapter 2.
25. "Notes on the Reading and Publication of Papers," in *Year Book of the Royal Society of London* (London: Harrisons and Sons, 1899), 88–89.
26. Aileen Fyfe and Noah Moxham, "Making Public Ahead of Print: Meetings and Publications at the Royal Society, 1752–1892," *Notes and Records: The Royal Society Journal of the History of Science* 70, no. 4 (2016): 361–379, <https://doi.org/10.1098/rsnr.2016.0030>.
27. This episode is discussed in Iain P. Watts, "'We Want No Authors': William Nicholson and the Contested Role of the Scientific Journal in Britain, 1797–1813," *The British Journal for the History of Science* 47, no. 3 (2014): 397–419, <https://doi.org/10.1017/S0007087413000964>.
28. Brad Sherman and Leanne Wiseman, "Fair Copy: Protecting Access to Scientific Information in Post-War Britain," *The Modern Law Review* 73, no. 2 (2010): 240–261.
29. Aileen Fyfe et al., "Untangling Academic Publishing: A History of the Relationship between Commercial Interests, Academic Prestige and the Circulation of Research" (Zenodo, May 25, 2017), <https://doi.org/10.5281/zenodo.546100>.

30. The Royal Society, "Special Meeting of Officers Minutes: 3. Review of the Society's Finances," January 26, 1973, xiv, RS OM/16(73).
31. The Royal Society, "Minutes of the Publications Management Committee," July 21, 1993, RS PMC/24(93).
32. The Royal Society, "Royal Society Position Statement on 'Open Access,'" November 24, 2005, <https://web.archive.org/web/20060207171805/http://www.royalsoc.ac.uk/page.asp?id=3882>.