Hailed as the apotheosis of reason and progress, science became central to defining the meaning of print in the nineteenth and early twentieth centuries. For many readers, cheap periodicals and other products of factory publishing were tangible evidence of spiritual and material progress. Specialist publishing grew rapidly and was often seen as a key sector for innovation. The relation between knowledge and print also changed dramatically, as discovery came to mean previously unknown findings announced in a published journal intended for specialist practitioners. Yet we know surprisingly little about how the press was used after the 1830s to announce novelties and more generally to create images of science and invention.

Since the 1960s, interest in the making of science and technology in the Victorian and Edwardian eras has burgeoned. With a few exceptions, however, the dominant theme of this new literature has been the emergence of the social role of the specialist practitioner. It has been shown how science was transformed through the creation of appropriate institutions, including the British Association for the Advancement of Science and a reformed Royal Society, as well as new educational structures and fresh possibilities for employment in government, industry and the universities. Underlying all these was the emergence of the ‘scientist’ – a term invented in 1833 but which became widely used only towards the century’s end – as gentlemanly, vocational ideals were replaced by the notion that science should be a paid career, independent of church and aristocratic patronage. Although simple teleological models of professionalisation have been rejected, the key questions have continued to involve issues of social organisation and identity.¹

¹ The best surveys of this highly sophisticated literature include Barton, ‘“Men of science”’; Desmond, ‘Redefining the X axis’; and White, *Thomas Huxley: making the ‘man of science’*. I am grateful to Anne Secord, David McKitterick and Jon Topham for exceptionally helpful comments, and to Chitra Ramalingam for allowing me to refer to her unpublished essay.
An approach informed by the history of print shows that this view of the changing structure of science is radically incomplete and sometimes just plain wrong. For it ignores, or at best treats as peripheral, the forms in which knowledge appeared, assuming that publication in specialist periodicals was already established as the only legitimate means for announcing new discoveries, thus downplaying other methods such as conversation, books, letters and museum displays. In this way, it presupposes that specific forums for communicating knowledge were ready to hand, and firmly in the control of a well-defined group of specialists. Except in works devoted to book history, the transmission of knowledge into print is usually treated as relatively transparent. Carrying out procedures in the laboratory, creating scientific organisations and attracting new practitioners: all these are assumed to require work. But the forms of publication, with a few exceptions, have been taken for granted.

What would happen if we considered the story of modern science through the study of printed communication in the widest sense? This chapter will suggest that changes in publishing, printing and readership practices are central to the transformation of science. The debate about the forms knowledge should take was at every point implicated in the making of knowledge. What was the appropriate way for knowledge to appear? Who should be in control of publication? How could technical books and journals – often comprehensible to a tiny minority of not particularly wealthy readers – be financially viable propositions in the volatile publishing market?

To tackle these questions involves considering an extraordinary range of publications, from double-elephant natural history folios to newspapers and ‘wee bookies’ for children. My focus will be on the sciences, with some attention to the very different circumstances prevailing in mathematical and technological publishing. After surveying controversies about knowledge in relation to the machine in the early industrial era, I will first turn to the periodical, which during the nineteenth century emerged as the form characteristically associated with both specialist publication and accessible science journalism. The second half of the chapter will look at the role of the book: reflective surveys, reference works and introductory manuals intended to entice beginners and educate students. The book, as I hope to show, remained significant for the sciences right through the century, far longer than would be expected given the common (but false) assumption that research articles were all that really mattered. Recent historical studies – which have focussed on children’s

2 For ‘wee booky’, see Literary Gazette 8 August 1835.
books, accessible primers and the general periodical press – have provided a far broader and richer picture.

One aim of this chapter is to suggest that works aimed at wide readerships played a vital part in the emergence of specialist forms of publication. It is all too easy to see approaches based on publishing and reading as relevant either to so-called ‘popular’ science, or to the publication of specialist monographs and periodicals, but not as a way of breaking down this easy divide and transforming our vision of the subject as a whole. The forging of the sciences as a distinctive field of enquiry was the product of a much wider contest about access to print and the audiences for knowledge. To set the scene, I want to take us back to 1830 and a virulent debate about the shape of knowledge in print.

The decline of science?

Intellectual debate in the first half of the nineteenth century was dominated by reform agitation and the coming of the machine. Innovations such as the steam press, machine-made paper and distribution by railway were hailed as transforming practices which had changed little since the introduction of printing in the fifteenth century. In previous centuries, the dominance of manual labour in the production of printed works meant, at an extreme, that it was far from certain that two copies of a book were the same. In works such as George Dodd’s *Days at the factories* (1843), industrial production was celebrated for its clarity and lack of ambiguity. The power of print, which had depended on an assumption of fixity, appeared to be enhanced. Uniformity extended to the finest details of the printed page: machine-made types made it more likely that every letter was identical; wood- and steel-engravings did not wear out nearly so fast as copper ones had done; the making of stereotype plates in plaster or laminated paper ensured that different printings of a work could be made without the need for resetting type; machine-made paper was uniform and smooth, unlike the hand-made products of the previous centuries.

It is often assumed that mechanised printing made knowledge more secure, but in fact the early industrial era witnessed the most profound debates about science since the seventeenth century. As the revived Baconian slogan put it, ‘Knowledge is power’, and for many readers that power was epitomised by the manual-operated hand-frame printing press. Relatively inexpensive,

3 Berg, *The machinery question and the making of political economy*.
such presses produced an outpouring of radical literature in the years around 1830. An unprecedented expansion in literacy created audiences who looked for knowledge relevant to Chartism, socialism and other working-class movements. The freethinker Richard Carlile railed against the failure of scientific men to acknowledge the revolutionary power of their discoveries. From this perspective, an understanding of the facts of nature offered tools for undermining clerical authority and state oppression.\(^5\) Opposing this view, middle-class entrepreneurs such as Charles Knight hoped to subvert the use of knowledge for radical ends by flooding the market with safe, reliable and standardised science produced through the new machine-based printing technologies at prices working-class publishers found hard to beat.\(^6\) As publisher for the Society for the Diffusion of Useful Knowledge (f.1826), Knight had extolled the virtues of the *Penny Magazine* (f.1831), the *Penny Cyclopaedia* (1833–43) and other ventures which brought illustrations of natural history, invention and the fine arts to hundreds of thousands of readers.\(^7\) The aim of creating a rational, educated workforce safe from radical temptation also inspired William and Robert Chambers of Edinburgh, whose firm became the nation’s leading publishers of inexpensive part-works and informative tracts.\(^8\) These hopes for the easy diffusion of science as a carrier of moral messages, however, proved a chimera, as readers could not be so easily controlled.

Middle-class publishers and radical agitators alike tended to value science for its propaganda value, using established knowledge to demonstrate the rights or wrongs of the existing order of society. Some working-class readers, in contrast, aimed not so much to find moral messages in science, but rather to participate in its making. Particularly in the north of England, handloom weavers, shoemakers and other artisans became keen observers in esoteric areas of science such as the identification of rare mosses. They demonstrated that labouring people, working in concert, could contribute to the most skilled forms of practice. Their communally held libraries of scientific books, kept in the pubs where they met on Sundays, were potent political symbols of working-class achievement. Works such as the *Penny Magazine* or Carlile’s pamphlets had little place on the shelves of these pub libraries, not so much because they were ideologically charged, but because they lacked the detailed information needed for participating in scientific practice. Instead the artisans valued authoritative works of classification and identification,

\(^5\) Desmond, ‘Artisan resistance and evolution in Britain, 1819–1848’; Johnson, ‘“Really useful knowledge”’.
\(^6\) Topham, ‘Science and popular education in the 1830s’.  \(^7\) Gray, *Charles Knight*.
\(^8\) Cooney, ‘Publishers for the people’.
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such as James Sowerby and James Edward Smith’s *English botany* (1790–1824; 3d edn, 12 vols., 1863–86) which gave access to existing networks of elite practitioners.9

Different answers to the question of how science was to be used and pursued were thus embodied in different forms of print. Chemistry, for example, was for many educated authors a ‘philosophical’ subject centred on disputes about the nature of matter. In such cases, publication traditionally took the form of a theoretical treatise, usually an octavo, aimed at an educated genteel readership. Such works belonged on the shelf with systematic theology, Genesis commentaries and abstract metaphysics. But reprinted in radical miscellanies or reinterpreted by the socialist followers of Robert Owen, they also could be associated with freethinking materialism, with the chemist imagined as a potential agent for political liberation. Others saw chemistry as concerned not with philosophies of matter but with hands-on laboratory or factory experience, and published cookbook-like lists and brief notices of new compounds. During the 1840s, the practical aspects of the subject came to the fore, especially in agriculture, so that Justus von Liebig’s *Familiar letters on chemistry* (1843) became an international best-seller.10

Behind these conflicting views was a fundamental and long-standing question about how knowledge should be related to the act of publication. Across the class spectrum, many settings for science tended to stress the significance of conversation and the delivery of papers at meetings. This was certainly true for many working people, who identified knowledge as embodied skill rather than as words printed on paper.11 At the other end of the social spectrum, the young naturalist Charles Darwin noted that ‘geology is at present very oral’ and the only reason for publishing was ‘proof of earnestness’.12 A good example here is the debate about the discovery of the composition of water. In Britain, the natural philosopher Henry Cavendish was often awarded the contested palm of discovery over the inventor James Watt, despite the fact that the latter had published his findings and the former had not.13 An outstanding collection of books, minerals, fossils or dried plants could place one in the highest rank in certain fields. Those with sufficient wealth could become patrons, encouraging work along certain lines and providing political connections and administrative experience. The botanist Robert Brown and the

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9 Secord, ‘Science in the pub’.
10 The range of different approaches is apparent in Brock, *The Fontana history of chemistry*.
13 Miller, *Discovering water*. 

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geologist George Bellas Greenough published almost nothing and yet were at
the forefront of their respective sciences. The most telling expression of this
attitude was in elections to the fellowship of the Royal Society, which until
changes were introduced after 1847 depended as much upon social status and
a general interest in science as it did upon the number or significance of papers
published. In these circumstances, the great experimenter Michael Faraday’s
celebrated dictum ‘work, finish, publish’ was not only a personal exhortation
but advocacy of a particular way of conducting the scientific enterprise.

Especially in fields relating to practical engineering and technology, the
virtues of publishing were far from obvious. Why should commercially valuable
information be made available to the casual reading public? Such discoveries
were either to be kept secret or to be filed as legally enforceable patent claims.
In such cases, publication in any form was seen to be inappropriate. Impor-
tant initiatives were made in putting the details of new machines into print,
especially in technical encyclopaedias and periodicals such as the Mechanics’
Magazine (f.1825); but, more typically, practical knowledge was passed down
through the apprentice system, and new inventions and techniques were kept
as valuable trade secrets. The leading London chemist William Hyde Wollas-
ton, discoverer of the element palladium, only gave out the receipt for making
it malleable shortly before his death.15

The most trenchant critique of this view of science came from Charles
Babbage. A leading inventor and man of science, active in reforming mathe-
matics in Cambridge, he was best known for developing a government-funded
mechanical calculating engine. Babbage aimed his fire at outmoded publica-
tion practices in his Reflections on the decline of science in England, and on some of
its causes (London, 1830), which argued that science in England was in a bad
way, and had been declining since the late seventeenth century. The long-term
problems had to do with education and with the lack of any inducement to
pursue science as a career. The role of publishing was central. Babbage was
especially shocked that out of 714 Fellows of the Royal Society, only seventy-
two had contributed two or more papers to the Philosophical Transactions; in his
view, membership of the Society should require this as a minimum.16 From
this perspective, appearing in print defined what it meant to be a man of sci-
ence. Babbage’s model for the way science should work was taken from the
continent, especially France, where men of science were given state support
and even occupied high political office. For most British observers and many

16 Babbage, Reflections, p. 155. On the declinist debate, see Morrell and Thackray, Gentlemen of science,
on the continent, this suggested that French savants were subject to jobbery and intrigue. ‘Wealth and dignities’, as one pamphleteer wrote, ‘acquired at such a price, cannot be objects of envy in the eyes of a philosopher.’17 Babbage, however, considered such positions as evidence of independence and state recognition.

Reformers like Babbage were especially appalled that scarce resources for publishing in science were squandered. At least £2,000 of Royal Society funds had been expended on the plates for anatomical papers by one individual, who was on the Council voting for their publication. Five tons of the published data of the Royal Greenwich Observatory were sold as waste suitable for pasteboard, although practising astronomers were not allowed free copies.18 As Babbage was able to show as a result of his intimate knowledge of the printing trade, the publisher John Murray was paid well over the odds to issue the Royal Society’s Presidential Discourses, and yet only a handful were sold. Like many reformers, Babbage felt that the only good thing about the *Philosophical Transactions* was their prompt publication. With their wide margins and hot-pressed paper, they were ponderous and expensive, a waste of precious funds.

At the height of the declinist debate, Babbage confronted the problems created by the public’s lack of access to engineering and industrial information, arguing that the apprentice-based oral culture of Britain’s workshops and factories led to waste and inefficiency. His *On the economy of machinery and manufactures*, published in 1832, made freely available a wide range of hitherto secret practical knowledge. The book’s intended publisher, Benjamin Fellowes, was so outraged by revelations about the costs and techniques of book production that Babbage was forced to look to Charles Knight, who shared many of his attitudes towards the free flow of knowledge.

The comments in Babbage’s *Decline of science*, often vituperative and narrowly focussed, sparked a much broader debate about the state of British science in relation to publishing.Perhaps the most serious accusations were summed up by the novelist and social commentator Edward Bulwer-Lytton in *England and the English* (1833), which told the story of a learned man, of great scientific attainments but little worldly wealth, who showed a manuscript treatise to ‘a publisher of enterprise and capital’. The publisher explained that since only fifty readers would understand profound research in mechanics but little worldly wealth, who showed a manuscript treatise to ‘a publisher of enterprise and capital’. The publisher explained that since only fifty readers would understand profound research in mechanics, that part of the work was ‘mere rubbish’ from a commercial point of view. But if the learned doctor could expand the chapter of elementary exposition into a volume, the publisher would pay hundreds of pounds for that. As a result, the book of

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discoveries remained unpublished, while the familiar principles received yet another retelling. ‘The time is come’, Bulwer-Lytton concluded, ‘when nobody will fit out a ship for the intellectual Columbus to discover new worlds, but when everybody will subscribe for his setting up a steam-boat between Calais and Dover.’

Such stories were not just the fancies of a literary imagination: they expressed actual dilemmas that scientific writers faced every day. Take the case of Mary Somerville, who became an iconic figure of the reformist movement after publication of her *Mechanism of the heavens* (1831) – a densely mathematical redaction of Pierre-Simon Laplace’s great work on celestial dynamics. Her next work, however, was the much more accessible *On the connexion of the physical sciences* (1834), which expanded upon the themes dealt with in the ‘preliminary discourse’. Somerville then completed the manuscript of a concluding volume of the *Mechanism*, which dealt mathematically with topics such as the tides and the rotation of the planets, but this remained unpublished after being rejected by John Murray. From this point onwards she adopted the role of summarising and linking the results of different sciences. Another example is provided by John Vaughan Thompson’s *Zoological researches, and illustrations; or natural history of nondescript or imperfectly known animals*, issued in parts from 1828 to 1834, which had to be stopped for lack of sufficient purchasers.

Yet not all that many great works languished unpublished: more often, they were never begun, or appeared in less imposing forms. Writers were able to take up substantial projects only as time and funds allowed. One of the leading students of optics in the first half of the nineteenth century, the Scottish natural philosopher David Brewster, made a living through editing and scientific journalism. On first hearing of Babbage’s book on the decline of British science, Brewster claimed that he would have written on ‘the heartbreaking subject’ himself, but was prevented from doing so by the press of hand-to-mouth literary labours. His own comments did appear, but as a paying review for the *Quarterly*, which noted with barely concealed irony that many potential discoverers were ‘torn from the fascination of original research, and compelled to waste their strength in the composition of treatises for periodical works and popular compilations’.

21 Brewster to Babbage, 12 February 1830, quoted in Morrell and Thackray, *Gentlemen of science*, p. 47. See also Brock, ‘Brewster as scientific journalist’.
The term ‘popular’, as a way of distinguishing forms of knowledge accessible to the people from those that were not, occasionally began to be used in the early nineteenth century as a way of marking readerships without specific forms of expertise. Brewster, like Babbage and their allies in the declinist debate, attempted to set up a contrast between original research and derivative writing for periodicals and elementary readers. This was a polemical divide that went against much of the way that science was still being done, for openness to a range of participants was a prized feature of many areas of natural philosophy and natural history.

The problem, as the declinists saw it, was that the genteel patronage and diverse readerships characteristic of the publishing system in Britain had failed to maintain specialist science at the highest international level. The publishing of ‘penny’ science was burgeoning, while original research either made tiny sales or languished in manuscript. To a surprising degree, scientific and medical publishing was dominated by a few firms, notably Longman & Co. (who in 1837 controlled nearly a third of the trade), so that decisions by a few entrepreneurs were vital to furthering the scientific enterprise. The Royal Society was filled with genteel fellows who paid their membership fees, but had never published. To end this corruption, the reformers called for state support and educational reform. But the answer they found was a series of commercially engineered transformations in the role of the scientific periodical and the introductory textbook.

The magazine of nature

It is easy to assume that the establishment of the Philosophical Transactions of the Royal Society of London in the 1660s marked the point at which all new findings had to be announced in something approaching the form of the modern scientific paper. In fact, what it meant for something to be a scientific periodical, and the role of periodical publication regimes within the sciences, was radically uncertain right through the middle of the nineteenth century. This is evident even in so basic an issue as defining priority, where the conventions dominating the announcement of discoveries were much less secure (especially in Britain) than is usually thought. The contrast with the patenting of inventions – a system which had developed during the early stages of the industrial revolution – was clear. An obsession with priority in

science was usually identified with France, where publication (usually in the weekly *Comptes rendus* of the Paris Académie des Sciences) became essential for anyone who wished to stake a discovery claim. It was part of the career-oriented, centralised system of science that the reformers such as Babbage wished to emulate. In Britain, priority of discovery in science was traditionally assessed in more flexible ways, involving gentlemanly codes of conduct – the sort of ‘delicate arrangement’ that led to the announcement of the theory of evolution by natural selection by Charles Darwin and Alfred Russel Wallace in the *Proceedings of the Linnean Society*.\(^{25}\) In France, individual priority would have been secured through either quick publication (no genteel Darwinian delay) or a sealed note deposited with the Academy.

The second and third quarters of the nineteenth century in Britain were thus a period of unexampled experimentation in periodical publication and its place in the making of knowledge. Just as ‘science’ and ‘scientist’ were being defined and debated, so too were the very notions of what a scientific publication might be. For almost all of the new specialist organisations founded during the first half of the century, the issuing of printed volumes, usually quarto transactions modelled on those of the Royal Society, was a significant aim. Such publications offered wide margins, large type, good paper and plenty of illustrations, often hand-coloured. Publication was irregular and schedules often stately. Unsurprisingly, the format was expensive, with a single number sometimes costing a guinea. As a result, print-runs were small by contemporary standards, usually 500 to 750, and sales considerably less than that.\(^{26}\) Most purchasers tended to have a general interest in the subject rather than a vocation for research. The organisations they joined were thus less professional ‘learned societies’ in our sense of the term, and more like the Athenaeum and other clubs for those with literary and intellectual interests. In this context, publishing transactions offered a way to associate new and potentially controversial sciences such as geology, zoology, comparative anatomy and stellar astronomy with traditional forms of gentlemanly culture. Luxurious production values made a bound set of transactions a suitable acquisition for a gentleman’s library, implying that the knowledge they contained was of permanent value.

Just at the time when the number of transactions began to increase, they were challenged by an alternative format of monthly octavo journals produced by commercial entrepreneurs.\(^{27}\) These grew out of eighteenth-century periodicals

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\(^{26}\) These figures are based on the Taylor & Francis account books in the St Bride Printing Library.

\(^{27}\) Brock, ‘The development of commercial science journals in Victorian Britain’; also Brock, ‘Science periodicals’. The shift from quarto to octavo was first noted in Cannon, *Science in culture*. 

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such as the Gentleman’s Magazine, which had encouraged informal communication among the learned. Financial considerations, as much as priority, were significant in encouraging the dominance of such periodicals. From the perspective of a commercial publisher or an independent society, commencing a journal was much less risky than issuing books. If sales proved disappointing and subscribers too few, publication could simply cease, without leaving a warehouse full of expensive unsold stock.

A handful of these commercial periodicals proved exceptionally long-lived, notably the Philosophical Magazine, founded in 1798. It did this partly by absorbing the competition but also by becoming more specialised. By the 1830s its scope had already narrowed from the entire circle of the sciences to a primary focus on chemistry and the physical sciences. The Philosophical Magazine was published by one of the key firms in the London scientific book trade, run initially by Richard Taylor and then by William Francis. It had originally included natural history, but pressures of space and an increasingly diverse readership led Taylor to establish the Annals of Natural History (f.1838, from 1840 known as the Annals and Magazine of Natural History). Like the Philosophical Magazine, the Annals emerged the hardy survivor of a much larger group of natural history monthlies, although sales remained relatively small, with a print-run of only 500 copies.28

Despite precarious sales, these commercial monthlies led the way in redefining the meaning of a scientific paper in Britain during the crucial decades of the 1820s and 1830s. By emphasising frequent and regular publication, they stressed timeliness over permanence, practicality over luxurious presentation. They looked and read more like the journals that were appearing across the Channel, such as the Annales de Chimie and Poggendorf’s Annalen der Physik. The papers they published were shorter and focussed on specific new findings: on discovery rather than comprehensive exposition. They were less like monographs, and more like articles in newspapers and weekly periodicals. From the 1820s, the format, frequency and aims of the commercial science journal began to be imitated in scientific clubland, and ultimately at the Royal Society itself. The newer societies, which prided themselves on being progressive and willing to change, were the first to do this; thus the Geological Society began to issue Proceedings in 1826 and the Royal Astronomical Society issued its Monthly Notices from 1827. Usually appearing in issues of between sixteen and thirty-two pages, these offered an account of the meetings for those who had been

28 Brock and Meadows, The lamp of learning, esp. pp. 93–100; Sheets-Pyenson, ‘From the North to Red Lion Court’; Sheets-Pyenson, ‘A measure of success’.
unable to attend, and a printed record of results for establishing international priority. Because they appeared so quickly, the proceedings of organisations such as the Geological Society and the Royal Astronomical Society became a major outlet for quick announcements: a new comet, a unique fossil, the results of a summer’s fieldwork. Only much later did the older societies follow suit: the Linnean Society in 1855, the Royal Society in 1856. Notably, too, when the British Association for the Advancement of Science began to meet in 1831, it offered both opportunities for very quick publication – through newspapers and literary weeklies such as the *Athenaeum* – and the more permanent form of a relatively inexpensive annual report. This was one of the ways that it identified its project with the more general enterprise of reform.

By the mid-1830s, transactions were clearly losing the battle of formats. Only the best-funded elite organisations (the Linnean, the Royal and the Cambridge Philosophical Society) continued with the prestige quartos, albeit in a modified form. Some aspiring new groups, such as the London Electrical Society, made the mistake of issuing a showy volume of transactions that used up all of their resources. In this, they learned the hard way what the leaders of the Geological Society had known for years: it was easy to get fellows to pay the subscription needed to put some letters after their name, but hard to get them to pay for specialist publications. Henry De la Beche drew a caricature of double-entry bookkeeping to make the point (fig. 12.1). On the debit side, an ordinary meeting hears a gloomy report on finances, which are faltering because too few fellows are purchasing the transactions; but on the credit side, they seem eager to applaud the accomplishments made in the science during the year at a costly dinner.

At the same time there were striking changes within the world of commercial science periodicals, challenging the established titles. The 1830s and 1840s witnessed the rise of what was called ‘class’ journalism, appealing to non-specialist readers with specific interests in (say) law, architecture, gardening, economics or art. The focussed appeal of science and invention meant that these subjects tended to lead the way in the development of this genre. Publishers issued a wide range of titles to test the market. The earliest and most successful dealt with mechanical inventions, with a stress on letters to the editor and informal reviews, as in the weekly *Mechanics’ Magazine* (f.1825). Monthlies included the lively *Zoologist* (f.1843) and *Phytologist* (f.1841), both issued by the enterprising

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29 As Morus, in ‘Currents from the underworld’, shows, the Electrical Society went on to issue less expensive proceedings, but it continued to be plagued by a failure to match its publication programme to the potential market.
Quaker naturalist and publisher Edward Newman, who mocked the competing Annals and Magazine of Natural History for its ‘prescriptive technicalities and chartered obscurities’. In the physical sciences, Sturgeon’s Annals of Electricity (f.1837) lambasted the formality of the existing periodicals.

The commercial journals were issued by small publishers and printers, most of whom were religious dissenters hoping to encourage contributions from many hands and open debate. By finding the right mix of material and encouraging discussion, it was just about possible to keep a regular monthly journal of this kind afloat. Labours of love, they almost never made money and usually disappeared without a trace after a few issues. Eschewing politics, their general outlook was democratic and egalitarian. Unlike most of the other journals already mentioned, they did not rely on referee reports, taking pride in

30 Brock and Meadows, The lamp of learning, p. 126.
printing just about everything they received. Advocating a different ideal of the scientific polity, they set themselves apart from the journals emanating from the scientific societies, viewing those as bastions of privilege. They were, it is important to stress, not just journals of popularised science; rather, they created a forum in which distinctions between ‘popular’ and ‘specialist’ were rejected for a more open definition of ‘the people’. In contrast, for many within the elite of British science, chatty commercial journals such as the Zoologist and Geologist were beyond the pale; they did not publish there, unwilling to see their work in such a promiscuous setting. Thus the Geologist’s editor was severely reprimanded for reporting in print the discussion after one of the Geological Society’s celebrated meetings.31

At mid-century, then, different types of periodicals were battling it out for dominance. That these embodied different conceptions of the aim and purpose of science is evident from the fierce debates that occurred whenever one of the scientific societies attempted to change its publication format. The Geological Society adopted a compromise whereby only those papers requiring elaborate illustrations were republished in transactions; otherwise the proceedings were seen as the journal of record. By 1845 even this solution was seen to be unsatisfactory, and a new title, the Quarterly Journal of the Geological Society of London, replaced them both in a move widely welcomed by reformers.32 Change was even more hotly debated at the Royal Society, where (as we have seen) many thought the mode of publication was a waste of money. As a compromise, the Philosophical Transactions remained a large quarto, but from the 1840s used a smaller font, smaller margins and narrower line spacing. In these subtle ways did reform insinuate itself even in the standard-bearer of gentlemanly publication. The Royal Society, with its wealthy fellowship and ties to the state, was unusual in having to face the pressures of commerce only indirectly. For most of those involved, from the Royal Astronomical Society’s council to individual entrepreneurs, keeping a scientific periodical afloat was a constant challenge.

Specialist journals and professional men

The uneasy alliance between the specialist interests of practitioners and a variety of commercially viable genres and formats lasted from the late 1830s through the 1860s. In the decades that followed, a fundamental transformation

32 On the Geological Society’s publications, see Rudwick, ‘Historical origins of the Geological Society’s Journal’.
took place which created, in broad terms, the publishing regime in which British science would operate for the following century.

This change involved three elements. First of these was the impact on the printing and publishing industries of new, science-based technologies, notably photography, machine engineering and scientific management. Photography proved potentially useful in astronomy, physiognomy, physical geography and other fields in which drawings and wood-engravings were generally found to be incapable of producing reliable testimony. By the end of the century, in these fields photographic reproduction by half-tone had largely replaced engraving as the standard method for reproducing illustrations in journals and books. Colour printing, which had emerged in the middle of the century in a few niche markets, was much more common by its end, either in expensive specialist monographs or in works produced for a mass market, such as school atlases and wall charts. Science-based machine engineering made possible new high-speed presses, while chemical technology provided inexpensive paper based on wood-pulp. Typesetting by machine, despite fierce union opposition, replaced hand composition on all but the most technically demanding work. From the 1880s, the American Frederick Winslow Taylor and others concerned with industrial efficiency attempted to apply the lessons of experimental science to the management of production processes. These innovations often involved considerable capital costs and resistance from workers, and were especially important in the production of cheap newspapers and books.

A second change involved the world of specialist science publishing more directly. The older family firms such as Murray and Longman, which had catered for the needs of gentlemanly science, were supplemented by newcomers more in tune with current intellectual trends, such as Routledge, Macmillan and Kegan Paul. Just as the previous generation of publishers had relied on associations with genteel scientific circles, so too did men such as Alexander Macmillan exploit academic connections and other associations with leaders of science.

Third, educational reform led to a rise in demand for scientific textbooks and reference works at all levels. These changes increased the overall significance of scientific and technical works within the publishing industry; and made specialist works depend less upon private patronage and local cultivators, and more upon educational institutions and the state. Forms of publication which had previously depended upon attracting a range of readers could now be undertaken in the expectation (or at least the hope) that they need only appeal to those who defined their interests in the subject as ‘professional’.
The transition is clear from the early history of the weekly periodical Nature (f.1869). For although Nature was supported by the scientific careerists and eventually emerged as the leading international weekly for science in Europe, it initially attempted to appeal to a wider readership. Advertisements stress its attractive illustrations and accessibility, and early issues provided free portraits of famous scientists such as Michael Faraday and Charles Darwin. As Alexander Macmillan explained to William Thomson (Lord Kelvin), the journal was ‘meant to be popular in part, but also sound, and part devoted specifically to scientific men and their intercourse with each other’. In format and content, Nature thus presented itself as continuing the traditions of the Athenaeum, Reader, Illustrated London News and other periodicals intended to encourage topical discussion. Even with this attempt to address a broader public, Nature lost money; the publisher kept it going largely because of the access it provided to the best authors in London. It began to break even only when the number of active practitioners in the sciences increased towards the end of the century.

The outstanding trend in periodicals was specialisation. The refocussing of Nature illustrates the emergence of the ‘scientific periodical’ from the more general intellectual weekly, but it was unusual in attempting to reach the full range of scientific disciplines, which it did largely by combining general scientific news and opinion with specialised research reports. The tightening of disciplinary focus is also evident in the continuing evolution of the commercial Philosophical Magazine, which by the century’s end was a physics journal which published little on what was seen as chemistry, let alone astronomy or geology. It played a dominant role in debates about matter theory during the early twentieth century, with key papers by Niels Bohr, Ernest Rutherford and J. J. Thomson on atomic structure and quantum theory. Across the range of the sciences, founding a journal became a way of furthering new approaches and the work of the academic research schools that were such a characteristic feature of scientific innovation in this period. At Cambridge, the Journal of Physiology (f.1878) provided a channel for publication of work in Michael Foster’s school of experimental physiology, while the Journal of Genetics (f.1910) furthered William Bateson’s attempts to create a new science of heredity. Although these periodicals were the products of private enterprise, they were both printed by Cambridge University Press, which also published

34 See R. MacLeod’s contributions to the ‘Centenary supplement’; Gooday, ‘“Nature” in the laboratory’.

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Karl Pearson’s *Biometrika* (f.1901) and the *British Journal of Psychology* (f.1904).\(^{35}\) By the early twentieth century, such journals increasingly featured an international cast of authors and editors, and a correspondingly world-wide range of subscribers in universities, technical institutes and public libraries. They were, in effect, a natural outgrowth of the earlier tradition of commercial science periodicals, attractive to publishers looking for opportunities to expand the realm of profitable science publishing by using improved postal networks and opportunities for rapid communication.

At the core of the new way of pursuing knowledge was the redefinition of key genres for science. In particular, the scientific article achieved something close to its current form – and certainly its dominance within science – during the final decades of the nineteenth century. The number of scientific periodical titles in Europe and America, as Derek J. De Solla Price claimed in the 1960s, increased exponentially during the nineteenth century, from under a hundred to about 10,000 by its end.\(^{36}\) Although there are obvious problems with Price’s analysis (not least, his use of an unchanging definition of a scientific periodical) it does suggest the scale of change in the century’s final decades. The work that had to go into redefining the relations between science and publishing in this period is clear from one of its greatest monuments, the Royal Society *Catalogue of Scientific Papers*, which began to be published in 1867. The brief, initially to include only articles on chemistry and physics, was soon broadened to include ‘all the branches of Natural Knowledge for the promotion of which the Royal Society was instituted, excluding matter of a purely technical or professional character’.\(^{37}\) Writings in periodicals such as the *Mechanic’s Magazine* and *Scientific American* were definitively excluded, as were reflective essays in the *Edinburgh Review* and the other major quarterly journals. Announcements of new comets and other celestial bodies counted only if they appeared in the Royal Astronomical Society’s *Monthly Notices* or the *Astronomische Nachrichten* – not in *The Times* or other newspapers, which had long played a major role in communication among observational astronomers. Anything in the realm of the ‘literary’ was explicitly excluded. The *Catalogue* was not simply a response to the vast growth in the volume of published science; rather, it retrospectively enforced a rigid and in many ways anachronistic definition of the ‘scientific paper’ on to the entire nineteenth century.

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\(^{36}\) Price, *Little science, big science*.

Bringing the sciences to book

The increasing dominance of periodicals is often seen as something unique to the sciences, but in fact a glance at statistics shows that it was part of a wider trend. By 1907, only 17.1 per cent of the printing industries’ net output involved books, while 28.2 per cent came from periodicals and newspapers. Many of the advantages of periodical publication applied not only to the sciences, but also to other forms of writing. Notably, the serial format made it possible to tailor print-runs more closely to the market than was possible with books. Costs were spread out for booksellers and readers alike; and for those concerned with such matters, publishing in periodicals offered a way to establish priority. In some fields, especially chemistry and experimental physics, these issues dominated to the extent that almost all original research throughout the nineteenth and early twentieth centuries would at first glance appear to have been announced in articles. For all the advantages of this format, however, the book retained specific roles of great significance: as a practical form of reference, as a means for opening out an extended argument, and as a symbol. Periodicals tended to end up in a smaller range of specialist libraries, while books could go on many different shelves and were more often noticed in public debate and discussion.

A broad spectrum of books was issued, the most significant defining entire disciplines and traditions of research. Such ‘reflective’ works, which considered the aims and purposes of knowledge, were especially characteristic of the decade surrounding the first reform bill in 1832. Works such as Mary Somerville’s On the connexion of the physical sciences (1834), Charles Lyell’s Principles of geology (1830–3) and John Herschel’s Preliminary discourse on the study of natural philosophy (1831) offered reflections on the meaning of particular sciences and their wider goals. They were explicitly not textbooks, although modern readers have sometimes mistaken them as such; rather, they invited a broad reading public to think about the overall shape of disciplines and their underlying principles.

Such works drew on a long-standing British tradition of the philosophical treatise, as exemplified by Adam Smith’s Wealth of nations (1776) and Isaac Newton’s Principia mathematica (1687). They borrowed from the French genre of a ‘preliminary discourse’ preceding an extended treatise or encyclopaedia,

38 Eliot, Some patterns and trends in British publishing, p. 42.
39 For further reflection on the continuing importance of books, see James, ‘Books on the natural sciences in the nineteenth century’.
40 Yeo, Defining science; Secord, Victorian sensation, pp. 42–76.
as in the case of Samuel Taylor Coleridge’s ‘Treatise on method’ for the *Encyclopaedia metropolitana* in 1818. Not only did such works often sell well, they were also widely read through extracts in reviews. Such works offered opportunities for considering knowledge of nature in relation to issues of the day – questions that might be considered inappropriate for scientific meetings and specialist periodicals, which attempted to keep aloof from political and religious disputes.

The openness of the reflective genre was especially significant in providing a forum for potentially explosive debates about the sciences of mind and the evolution of species. The London publisher John Churchill, best known for medical textbooks and monographs on anatomy and physiology, found in 1844 that he had an unexpected sensation on his hands in the anonymous *Vestiges of the natural history of creation*, which for the first time combined an encyclopaedic range of sciences into an evolutionary story based on a law of development, the ‘universal gestation of nature’ from gaseous fire-mist to the future elevation of the human race. *Vestiges* brought evolution – a subject that had been canvassed in medical schools and freethought ‘Halls of Science’ – into middle-class homes and the very heart of public debate. By the time *On the origin of species* appeared in 1859, the reaction to an evolutionary origin of mankind was less violent than is usually assumed, not only because of *Vestiges* but also because it was harder to dismiss a respectable author like Darwin appearing under a respectable imprint like John Murray.\(^{41}\) The *Origin*, as Darwin had foreseen, would appeal both to ‘scientific’ and ‘semiscientific’ readers, and it became the leading example of a series of accessible works on evolutionary topics in the latter half of the nineteenth century. This was a vein quarried with great success not only by Murray, but also by Longman, Williams & Norgate, Macmillan, Kegan Paul and many other firms.\(^ {42}\)

Works in the reflective tradition found an easy place on booksellers’ lists alongside titles in philosophy, history, biography and doctrinal theology, fields in which books continued to be a dominant form. John W. Parker, London-based publisher to the University of Cambridge, published many such works, including William Whewell’s three-volume *History of the inductive sciences* (1837), two volumes by the same author on the *Philosophy of the inductive sciences* (1840), and John Stuart Mill’s competing *System of logic* (1843). In the second half of the century, Macmillan emerged as a key publisher in this field, following out the publisher’s personal policy of encouraging a fruitful


\(^{42}\) Secord, *Victorian sensation*; on the later history of the evolutionary epic, see Lightman, *Victorian popularizers of science*, pp. 219–94.
dialogue between science and religion. His firm published many important books on both sides of the Darwinian debate as well as specialised treatises such as William Stanley Jevons’s two-volume *Principles of science* (1874).

The tradition of reflective works continued into the early twentieth century, with frequent reprints of works such as Karl Pearson’s *Grammar of science* (1892) spurred on by the rise of ‘middlebrow’ audiences eager to come to terms with exciting new developments in physical theory, scientific psychology and modern biology. The International Scientific Series, an Anglo-American initiative which published ninety-eight books between 1872 and 1911, aimed to prove ‘an elegant and valuable library of popular science, fresh in treatment, attractive in form, strong in character, moderate in price, and indispensable to all who care for the acquisition of solid and serviceable knowledge’. A similar readership was targeted with reissued ‘classics’. J. M. Dent’s Everyman series included books by Faraday, Huxley and Hugh Miller, all of which were highly successful. Meanwhile Alfred Watts’s Rationalist Press issued books by Ernst Haeckel, John Tyndall and Richard Carlile. After the copyright on Darwin’s *Origin* lapsed in 1909, a wide variety of publishers reprinted it, Murray issuing the work for the first time in paperback. Scientific titles tended to be defined in such lists by the company they kept.

Particularly in more speculative fields, reflective works in science graded into imaginative fiction and poetry. Thomas Carlyle’s *Sartor resartus*, first published as a serial in *Fraser’s Magazine* in 1833–4 and then as a separate book, was explicitly presented as a natural philosophy of clothes and a contribution to the science of man, as well as being a mock autobiography and an introduction to Teutonic philosophy. Throughout the rest of the century it inspired a range of literary treatments of scientific subjects, including the famous evolutionary dream of Charles Kingsley’s fictional working-man’s autobiography, *Alton Locke* (1850). As Alfred Tennyson’s *In memoriam* (1850) and Elizabeth Barrett Browning’s *Aurora Leigh* (1856) suggested, poetry could provide a way of intervening in public scientific debates.

In certain fields books held an overwhelming significance as a way of reporting original results from the laboratory and field. This was not a residual role, but related to the continuing association of science with museums.

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44 Beer, *Darwin’s plots*, and more generally Beer, *Open fields*.

45 Pickstone, ‘Museological science?’
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displayed in public and private cabinets, books provided a form of virtual museum. Publication of a substantial treatise on a single subject, often in several volumes, became the touchstone of an author devoted to learning as a vocation. This model of publication, like so much in nineteenth-century British science, derived from continental models from the late eighteenth and early nineteenth centuries, especially great works such as Pierre-Simon Laplace’s great *Mécanique céleste* (1798–1827) and Georges Cuvier’s *Ossemens fossiles* (1812). In the wider context of the reform debates, maintaining science as a part of polite culture was of considerable political significance. The aristocratic Whigs, notorious in the eighteenth century for dissipation and gambling, were especially anxious to demonstrate moral probity through intellectual leadership. Patronage of fine books and involvement in projects for publishing scientific results were seen as a means towards this end.

Especially in natural history, geology and the study of machines, specialist books of these kinds could be rendered viable by appealing to a constituency wider than that composed of actively researching practitioners. John Phillips’s *Illustrations of the geology of Yorkshire* (1829–36) and Roderick Murchison’s *Silurian system* (1839), with their wide margins, coloured plates and fine printing, explicitly addressed an audience among the country gentry, whose interest in the subject was motivated by a combination of interests in agriculture and mining.46 Such works assimilated the new science of geology into older traditions of local antiquarianism. This was not only a way of making science theoretically and politically safe; it invited potential purchasers to see such books as belonging on the same shelf as works on classics and theology. A large format and attractive hand-coloured illustrations could attract wealthy collectors and bibliophiles. In this way, relatively esoteric works describing new species could reach a larger readership – and hence the break-even point for publishers – than the tiny handful of expert botanists, geologists or zoologists.47

Works describing more specific groups of objects, or requiring substantial illustration, inevitably posed challenges in reaching break-even point, as publication could be expensive and the number of readers using them for research was vanishingly small. Individual entrepreneurs often organised the self-publication of such works, canvassing for subscribers among the aristocracy and gentry and organising production using family members and an inner

46 On the publication of Murchison’s books, see Thackray, ‘R. I. Murchison’s *Silurian system* (1839)’; Thackray, ‘R. I. Murchison’s *Geology of Russia* (1845)’; and Thackray, ‘R. I. Murchison’s *Siluria* (1854 and later)’. These short articles remain among the few serious studies of the production of specific scientific works in the period after 1830.

subscription publishing remained a significant way of attracting patrons in illustrated natural history works long after it ceased to be commonly used elsewhere in the publishing industry. Outstanding examples include John James Audubon’s *Birds of America* (1827–39), James Bateman’s outsized book on orchids (1837–43) and Edward Lear’s *Illustrations of the family Psittacidae, or parrots* (1832), printed by Charles Hullmandel. Lear had begun as an artist working with John Gould, the artist and publisher of works such as the *Mammals of Australia* (1845–53). Even for the wealthy, such volumes were notable acquisitions. Sir Charles Bunbury, an expert on fossil plants, particularly treasured Joseph Hooker’s costly Antarctic flora as a gift from his wife Frances in celebration of their wedding anniversary.

One solution to the problem of cost was to publish in parts, thus assimilating books more closely to a serial format and spreading the costs of production and purchase over a longer period of time. The issues were in many respects similar to those used to market Dickens’s novels, as a way of avoiding the excessive costs associated with the three-decker novel. Subscribers were offered not only the opportunity to purchase a substantial work in instalments; each instalment typically offered an inducement to purchase, often a set number of plates. The attractions were not those of narrative suspense (in fact, parts often ended mid-sentence, sometimes mid-word) but rather those of completion and pleasure in fine printing. By the end of the nineteenth century, many of these connoisseurs viewed natural history plate books as the equivalent of imperial trophies, a manifestation of the triumphs of empire that could be shelved in their homes.

Gorgeous illustrations, which make these works so collectible today, thereby broadened the appeal of visually striking natural history subjects such as mammals, birds and flowers. In a few fields – notably botany, zoology and ornithology – the continuing interest of collectors and bibliophiles made it possible to produce monographs that could also be used by specialists. A sudden blossoming of public interest, as in the fern and seaweed crazes around mid-century, similarly encouraged the appearance of detailed and specialised monographs on groups of organisms that might in other circumstances have been deemed unprofitable. Such works were often issued in both coloured and uncoloured versions, the latter targeted at active practitioners unable to afford the extra cost.

48 For examples of these books, see Desmond, *Great natural history books and their creators*; Blunt and Stearn, *The art of botanical illustration*; and Knight, *Natural science books in English 1600–1900*.
50 Price, ‘Publication in parts’.
51 For these interests, see Allen, *The Victorian fern craze* and Allen, ‘Tastes and crazes’.
Many topics that fascinated practising naturalists, however, did not lend themselves to this kind of treatment. The increasing dominance of classifications based on internal anatomy rather than on external characters tended to make gorgeously coloured books of plates less relevant to working taxonomists (except in fields such as ornithology and mammology) than they had been earlier in the century. The production of beautiful natural history books reached a peak of interest around the end of the century, but such works were typically luxury items marketed to wealthy bibliophiles, part of the extraordinary rise of interest in book collecting more generally during this period. Artists such as Archibald Thorburn (known for his bird plates) found themselves in great demand. At the same time, the contemporary expansion in natural history works for the middle classes had little effect on specialist publication, as such readers were unwilling (and usually unable) to pay for the elaborate works demanded by practising specialists.

Zoology and palaeontology were especially affected by this gradual splitting of audiences. As a result, the 1840s witnessed the foundation of publishing societies, in which like-minded purchasers agreed to pay a subscription to receive all of the works issued during a particular year. The first of these was the Ray Society, founded in 1844, which issued both translations and new work in zoology, including Darwin’s volumes on barnacle taxonomy. In 1847 a group of fossil experts in London established the Palaeontographical Society, for publishing on subjects such as brachiopod shells and vertebrate fossils. For many fields, the most important patron of scientific works, however, was the state, particularly through reports on mineral, botanical and other resources conducted both at home and in the colonies. Government grants also subsidised the publication of the results of many scientific natural history voyages, most notably the fifty massive volumes of the Challenger expedition (1880–95), which became the foundation stone for future work in international oceanography.

Scientific publishing, even on such a grand scale, encouraged a close integration between authors, printers and booksellers. The publication of technical works often made unusual demands not only on authors and readers, but on typesetters, illustrators and printers as well. The production of works in natural history, anatomy and geology was greatly facilitated by lithography, which allowed even a small number of impressions to be produced at a reasonable price. An experienced lithographer such as George Scharf could reproduce delicate variations in shading and nuances of texture. Scientific works were at the forefront of experimental forms of image-making, as in the case of ‘nature printing’ which involved making plates from direct impressions of natural objects. Only a handful of books were made using this method, notably by
James A. Secord

Henry Bradbury in Thomas Moore’s *The ferns of Great Britain and Ireland* (1857) and William Grosart Johnstone’s *The nature-printed British sea-weeds* (1859–60). From the 1830s scientists were at the forefront of the invention of photography as well as its use for illustration. In 1843 the botanist Anna Atkins produced the first photographically illustrated book, a work on algae. In the end, however, photography proved something of a disappointment in many forms of illustration, as it was seen to bring out the accidental qualities of objects rather than their essential characteristics. Even after the new spectroscopy-based astronomy of the 1860s gave photography a central role, the evidence it provided remained ambiguous.

The greatest challenge for printers was the complex and expensive labour of typesetting works laden with technical terminology, species names and mathematical symbols. Although the major printing firms had capabilities for setting simple geometry and algebra, more advanced mathematical works presented challenges not covered in the standard printers’ manuals (fig. 12.2). Much of the work was done at Taylor & Francis and, later, at the University Press in Cambridge, where mathematical typesetting became part of every apprentice’s training. The technological demands of science, technology and mathematics made these significant areas for innovation in the printing industry; conversely, the very idea of being a scientist involved skills in negotiating the complex world of printing and publishing.

**Gateways to the sciences**

The alliance between scientists, engineers, the state and education forged in the final decades of the nineteenth century meant that books on all scientific and technical subjects had a much more secure market niche, relatively independent of other constraints, than they had possessed half a century earlier. This is signalled most tellingly by the ways in which older publishing firms expanded their lists, while several new ones made these areas an important part of their business. Moreover, the proportion of science books was also rising, particularly compared to theology.

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52 Armstrong and de Zegher (eds.), *Ocean flowers*. On the role of photography, see Tucker, *Nature exposed*.
55 I am indebted to the valuable paper by Ramalingam, ‘The mathematician and the compositor’.
56 Eliot, ‘Patterns and trends and the NSTC: some initial observations’ (1998), at pp. 72, 80.
Figure 12.2 Problems in typesetting advanced mathematics, from a report of a committee of the British Association for the Advancement of Science. (‘Report of the committee’, Report of the forty-fifth meeting of the British Association . . . held at Bristol in August 1875 (London: John Murray, 1876), pt 1, pp. 337–9, at p. 338)

Books such as Darwin’s Origin had an obvious symbolic value in this transformation, as well as a practical role in shaping the sciences; but as Thomas Kuhn stressed long ago, the most important genre for doing this job was the textbook.57 In a period when the very definition of science was controversial, such works were not the routine, mechanical summaries of known facts they are often taken to be, but attempts to define disciplines in particular ways. This is evident in a range of examples, from the translation of Sylvestre François Lacroix’s standard treatise on new techniques of French mathematics in 1816

57 Kuhn, The structure of scientific revolutions.
to James Clerk Maxwell’s *Treatise on electricity and magnetism* in 1873.\(^{58}\) Michael Foster’s *Textbook of physiology* (1870) occupied a key role in creating an evolutionary research tradition at the universities,\(^{59}\) while Archibald Geikie wrote his thousand-page *Text-book of geology* (1882) to encourage a broad interdisciplinary and international perspective. In terms of publishing, the sciences were key elements in the increasingly active role taken by the university presses at Oxford and (especially) Cambridge from the 1890s onwards.\(^{60}\) Conversely, the reform and expansion of university education created an unprecedented market for scientific and technical works.

From the point of view of publishers, however, the really significant possibilities were in elementary education. Introductions to the principles of geometry and arithmetic had long been staples of the classroom and the second-hand book trade, playing an important part in debates about education in an era of increasingly widespread literacy. Robert Simson’s edition of Euclid’s *Elements*, first published in 1756, went through a host of Victorian redactions, abridgements and formats for every imaginable audience. For traditionalists such as Charles Dodgson and Isaac Todhunter, an edition of Euclid remained the best-possible introduction to geometry. From the 1870s, however, this view was being challenged by those who believed that a subject central to the industrial economy was not best taught by an ancient Greek.\(^{61}\)

In subjects such as chemistry, geology, physiology and experimental physics, the situation was very different, for most schools taught little in the way of natural sciences until the final decade of the century. One of the few really widely used schoolbooks was the *Fifth book of lessons* (1835), which had introduced science as a way of bridging religious divides in Ireland, and which became a standard text in schools elsewhere in the British Isles. Firms such as W. & R. Chambers of Edinburgh had been active in producing textbooks from the 1830s, but much of their output was employed in self-education. The Education Act of 1870, which standardised a national scheme of secular education, inaugurated two decades of transformation and ultimately led to a huge demand for elementary exposition in the sciences.\(^{62}\) Huxley’s *Lessons in elementary physiology* and H. E. Roscoe’s *Lessons in elementary chemistry*, both first

\(^{58}\) Warwick, *Masters of theory*; Barrow-Green, ‘‘The advantage of proceeding from an author of some scientific reputation’’; Topham, ‘A textbook revolution’.

\(^{59}\) Geison, *Michael Foster and the Cambridge school of physiology*.

\(^{60}\) McKitterick, *A history of Cambridge University Press 3*.


published in 1866, remained on Macmillan’s list for decades, selling 199,845 and 430,000 copies respectively.63

The emergence of textbooks targeted at schools and universities was paralleled by the rise of periodicals and books explicitly targeted as ‘popular science’ for the literate masses. Many of the leading general journals, from the fat quarterlies such as the Edinburgh and the Westminster to nimble literary journals such as the Spectator and Pall Mall Gazette, featured topical essays on all aspects of science, from the origins of humanity to the wonders of electricity. A good barometer of this interest is the middle-class comic weekly Punch, which mercilessly parodied the British Association for the Advancement of Science and other learned organisations. The Illustrated London News, the Graphic and other pictorial periodicals regularly carried accounts of technological and scientific marvels.64

It is not difficult to perceive, however, an increasing anxiety about the accessibility of science during the course of the century. The term ‘popular’ became a selling point, leading publishers to issue attractive volumes including the Rev. David Landsborough’s Popular history of British zoophytes (1852) and Agnes M. Clerke’s Popular history of astronomy (1885). Their production, especially from the 1860s onwards, often took advantage of the latest printing technologies with machine colour printing of frontispieces, elaborate wood-engravings and splendid cloth casings imprinted in gold. Leading firms involved in reaching this market included Routledge, especially active in reprinting classic works; Cassell, which branched out from temperance and religious publishing to embrace other forms of improving knowledge; Jarrold, which focussed on the lower end of the market; and the Religious Tract Society, which promoted evangelical principles through science imbued with what Thomas Arnold had called ‘Christian tone’.65

Accessible illustrated weeklies such as Science Gossip (f.1865) and Chemical News (f.1859) encouraged the development of new roles such as the ‘science writer’ and the ‘science journalist’. Clergymen, Grub Street hacks, science lecturers and many others found they could supplement an income or even make a career out of translating the increasingly inaccessible literature of science for a mass audience. Many of the authors were women. After the death of Lyell, his secretary Arabella Buckley went on to write a sequence of

64 On science in general periodicals, the best place to start is Cantor et al., Science in the nineteenth-century periodical; Cantor and Shuttleworth (eds.), Science serialised; and Henson et al. (eds.), Culture and science in nineteenth-century media.
65 Fyfe, Science and salvation.
best-selling books for children and young adults, providing lively introductions to evolutionary natural history and modern physics. Science authorship, however, was rarely a ready route to fortune. Several of the most prolific authors ended up as broken figures, their health ruined by overwork and insecurity.66

Books that publishers expected to reach a wide range of readers deployed a rich range of literary and visual resources. Strikingly, some of the same rhetorical techniques can be seen at work in Buckley’s writings on scientific ‘fairyland’ or in the ‘Peter Parley’ books for children as in Darwin’s *Origin* and Maxwell’s *Treatise*. Introducing new scientific concepts involved radical changes of perspective, often best explained by analogy, metaphor and anthropomorphism. The Scottish stonemason-turned-newspaperman Hugh Miller was especially effective in employing the language of visual spectacle to recreate ancient landscapes. His books, many of them compiled from newspaper articles, were hugely successful in the half-century after his death in the 1850s.67 Similarly, astronomical writers such as Thomas Dick, John Pringle Nichol, Agnes Giberne and Robert Ball encouraged readers to imagine the grandeur of the nebular formation of the cosmos.68 Accessible books by these and dozens of other commercial authors were the mainstays of publishers’ lists right through the First World War.

If the scientific populariser was a new figure on the scientific scene in the second half of the nineteenth century, another developing role was that of the scientific ‘amateur’, a role that grew in relation with the development of the ideal of the scientific professional. There was an unparalleled proliferation of books in natural history for the urban (often suburban) middle classes, with individuals encouraged to form collections and to make observations of their own. The writings of Philip Henry Gosse, Charles Kingsley and George Henry Lewes attracted readers eager to turn a seaside beach holiday into an improving scientific expedition.69 The size of the audience is indicated by the extraordinary sales of cheap manuals such as the Rev. John George Wood’s *Common objects of the sea-shore* (1857), which sold nearly 100,000 copies in just

66 Lightman, *Victorian popularizers of science*; Fyfe, ‘Conscientious workmen or booksellers’ hacks?’ On women science authors, see in addition Steir, *Cultivating women, cultivating science*, and Gates, *Kindred nature*.


69 Allen, *The naturalist in Britain*. A list of relevant titles can be found in Freeman, *British natural history books*. The output of one of the most prolific authors is detailed in Freeman and Wertheimer, *Philip Henry Gosse*. Many of these figures, along with significant science publishers, have biographies in Lightman (ed.), *Dictionary of nineteenth-century British scientists*. 
four years.70 This spawned a series of manuals, especially popular at railway bookstalls, each intended to encourage the reader to identify the everyday natural history objects around them. Similar books encouraged experiments in chemistry and physics, or provided detailed instructions on how to build various devices, from telescopes and cameras to air-pumps and salt-water aquaria.

These works marked boundaries around popular science in a new way. Earlier in the century, artisans, women, children and enthusiastic cultivators of science had been seen as potentially serious contributors to science. Typically they had bought and read the same books that had been used by the most accomplished experts. Increasingly, self-taught enthusiasts were placed on the margins of the community of active practitioners, which could only be entered through formal education.71 Like scientists themselves, divided by their specialities, these groups now needed to be addressed through separate channels for publication. Books like those of Wood were entertaining and packed with facts, but they were divided by an increasingly deep gulf from the kind of works used by specialists in universities and government institutes. When those pursuing knowledge outside these arenas made contributions, it was often within circumscribed limits, as indicated by the title of one local natural history journal from the Welsh Borders, the *Caradoc Record of Bare Facts* (f.1891). They were ‘amateurs’ pursuing a ‘hobby’.

There was, of course, lively controversy about this process of fragmentation. Thus the popular writer Robert Proctor explicitly founded his weekly *Knowledge* in 1881 as a repudiation of the hierarchical, elitist model of science that was being advocated in *Nature* editorials.72 There was an undercurrent of opposition to scientific exclusionism in many of the other journals, especially those devoted to practical invention and mechanical invention. Mass-market journals such as *Tit-Bits* and *Pearson’s Weekly* carried a substantial proportion of technology and science, mostly of a practical progressive kind, but cared little about specialist priorities.73 In response, men of science continued actively to pursue public education and scientific popularisation. With one hand, authors such as Maxwell, Huxley and E. Ray Lankester wrote works unintelligible to all but the learned; with the other, they contributed prolifically to newspapers, encyclopaedias and textbook series. Rather than retreating from public engagement, as is often assumed, the leaders of science in the early twentieth

73 Broks, *Media science before the Great War*. 
Figure 12.3 ‘Out of the Stone Age into the Wonder Age’, cheaply produced black and white half-tone rotogravure illustration from the *Children’s Magazine* (July 1912), facing p. 417. The accompanying narrative (pp. 417–23) tells the story of Ishi, the last survivor of the Yahi tribe, who walked out of the foothills in northern California in the previous year. In the illustration, a Neanderthal-looking primitive bursts into modern civilisation, typified by telegraph wires and the web perfecting press in the lower left corner. (Bodleian Library, 399.d.694, opp. p.417)
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century served as intellectual celebrities, fulfilling what they believed to be a responsibility in communicating the findings of science in newspapers, magazines and popular books. Among the most successful of these publications were part-work series issued in the years before the First World War, notably the *Self-educator* (1905–7) and *Popular science* (1911–13), both edited by Arthur Mee and published by Harmsworth. Mee’s *Children’s encyclopedia* (1908–10) and *Children’s Magazine* (1911–14) used rotogravure, cheap paper and an international distribution network to bring fantasies of technological evolution to millions of young people (fig. 12.3).

Highlighting the role of science in empire, these publications allowed a combination of freelance science writers and leading experts to reach the working and middle classes.74 As specialised scientific research became less obviously tied to other aspects of cultural life among the English elite, other audiences and other means of maintaining a public presence had to be found. In these ways, the Edwardian era witnessed a new alliance between science and mass journalism.

Conclusion

From the moment in 1814 that steam printing was introduced into the press-rooms of *The Times*, nowhere were questions about the relation between print and knowledge asked with more urgency than in the world of science and technology. What was the role of science, mathematics and technical understanding to be in the emerging age of industry? Who was to have control over these forms of knowledge, and towards what ends? What was the role and status of the author? What was the appropriate medium for communicating uncertain or controversial knowledge? The machine belonged to a new set of social relations, which broke down old assumptions about access to knowledge and the means for disseminating it. Controversies about issues ranging from patent law to workshop practice showed that industrialisation was not so much a cause of a transformation as part of the crisis itself.

These debates began to be resolved only in the final decades of the century. It is not so much that controversy ceased – of course, it continues on many of these questions today. But there can also be little doubt that roles and genres became more clearly defined. For example, the relation between ‘scientific’ and ‘literary’ writing, which had been so fluid in the mid-Victorian era, became relatively clear to most readers.75 The ‘scientist’, ‘engineer’ and ‘man of letters’

74 Bowler, ‘Experts and publishers’. 75 White, ‘Cross-cultural encounters’.

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emerged as identifiable characters. Above all, the radical instability of texts, so evident a feature of early modern printing, seems largely to have come to an end.

Scientific and technological publication in the long nineteenth century could well be depicted as the story of the increasing isolation of an intellectual elite. In fact precisely the opposite is true. By the early twentieth century the sciences had become absolutely central to the workings of modern society, as the leading sectors of industrial development drew increasingly on technologies based in science, notably chemistry and electricity. As I have suggested, this transformation forged a new relation between the printing house and the laboratory, signalled by the coming of machine typesetting, rotogravure and the consequent trends towards large-scale capitalisation and monopoly control. The sciences not only provided the impetus for these new technologies, but also served as a touchstone of rational thought, precision measurement and moral probity.76 From the Cavendish Laboratory in Cambridge to working-men’s reading rooms in the industrial north, science became a symbol of regularity, standardisation and progress.

There is an ironic postscript to this story. At the present time, scientific periodicals, textbooks and monographs published after 1860 are, with a few exceptions, Cinderellas of the library world. The same books and papers that contemporaries placed at the heart of a global economic and social transformation are now typically outhoused and poorly catalogued. Science libraries often do not want them because they seem outdated, while humanities collections view them as space-hungry intruders not really belonging under the same roof with philosophy, literature or history. Only a handful of the most prominent titles have been digitised, which for material with many illustrations and poor bibliographical control is by no means a universal panacea. Yet given the persistent belief that science is outside culture, de-accessioning and disposal all too often appear to be attractive options. I remember discovering a full run of the first genetics journal in the world in a skip outside a university science department some years ago; and that is not an isolated incident. More than any other area of human endeavour, science actively consumes its past, and the single-minded belief in progress that motivated the building of great science libraries in the past can today easily become a justification for throwing things away.

76 Gooday, *The morals of measurement*; Schaffer, ‘Late Victorian metrology and its instrumentation’.
On the issue generally, see Collini, *Public moralists*.