FOCUS

A View from the Industrial Age

*By Jonathan R. Topham**

ABSTRACT

Like the constructivist approach to the history of science, the new history of reading has shifted attention from disembodied ideas to the underlying material culture and the localized practices by which it is apprehended. By focusing on the complex embodied processes by which readers make sense of printed objects, historians of reading have provided new insights into the manner in which meaning is both made and contested. In this brief account I argue that these insights are particularly relevant to historians of science, first, because practices of reading, like those of experiment and fieldwork, are constitutive of scientific knowledge, and, second, because attention to the history of reading provides important evidence of the multifaceted and uneven contest for meaning that occurs when science is mobilized in popular culture. The essay concludes by considering some of the surprisingly abundant sources of available evidence from which a history of scientific reading might be constructed for the modern era.

OVER THE LAST TWENTY YEARS, a new and distinctive history of reading has emerged from a range of disciplines, including literary criticism, cultural history, media studies, and, latterly, book history.[1] Like the constructivist approach to the history of science, it has been characterized by a shift away from an emphasis on disembodied ideas to an analysis of the underlying material culture and of the practices by which that material culture is apprehended in various settings. Where, previously, reading was understood to relate definitively to texts, the new history of reading highlights the recalcitrant materiality of the printed works through which readers encounter texts and the hermeneutical signif-

* School of Philosophy, University of Leeds, Leeds LS2 9JT, United Kingdom.

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[1] See, e.g., Roger Chartier, "Texts, Printings, Readings," in *The New Cultural History,* ed. Lynn Hunt (Berkeley: Univ. California Press, 1989), pp. 154–175; Robert Darnton, "First Steps toward a History of Reading," in *The Kiss of Lamourette: Reflections in Cultural History* (New York/London: Norton, 1990), pp. 154–187; Jonathan Rose, "Rereading the English Common Reader: A Preface to a History of Audiences," *Journal of the History of Ideas,* 1992, *53:*47–70; James Raven, Helen Small, and Naomi Tadmor, "Introduction: The Practice and Representation of Reading in England," in *The Practice and Representation of Reading in England,* ed. Raven *et al.* (Cambridge: Cambridge Univ. Press, 1996), pp. 1–21; and Adrian Johns, "Science and the Book in Modern Cultural Historiography," *Studies in History and Philosophy of Science,* 1998, *29:*167–194.

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icance of that material form. The fact that readers encounter texts in particular material objects—whether books, newspapers, or computer monitors—makes a difference to the meaning they derive from them, because they read more than merely the words. In addition, different kinds of textual objects are typically used in different ways: one cannot annotate a computer monitor as one can a book or a newspaper. These diverse reading practices are a key focus of attention in the new historiography. Such practices, which range from the student's careful note-taking to the lover's impassioned recitation of memorized poetry, are central to the process by which meaning is made. Where approaches to reading based on textual criticism associated meaning primarily with the text, the new approach recognizes it to be the outcome of historically contingent acts of reading. Readers approach books with different expectations and interests, levels of skill, and reading conventions, and these substantially alter the sense they make. What a book means thus frequently becomes a matter of contest between parties engaged in a struggle for cultural authority.

In its attention to material culture and to practice, the new history of reading presents a useful additional tool in the historian of science's armory. In this short account, I begin by arguing that reading practices can be as important for understanding the development of science as experimental or fieldwork practices. I then argue that the history of reading has a particularly valuable role to play in the history of science in popular culture, since its attention to the contest for authority over interpretation that occurs between readers subverts more one-dimensional notions of popularization or "popular" science. Finally, I conclude with some practical pointers about how the history of reading might be brought to bear on the history of science in the industrial age.

READING AND THE PRACTICE OF SCIENCE

One important respect in which the history of reading impinges on the history of science is in the practice of science itself. The recent turn toward practice in the history of science has been based on the conviction that the experimental processes and field techniques through which scientific knowledge is created are constitutive of it and that the wider acceptance of knowledge claims depends on the replication of craft skills as well as on the publication of cognitive claims. Much scholarly attention has consequently focused on the reconstruction of local experimental and fieldwork practices. At the same time, consideration has also increasingly been devoted to the more public rhetorical and communicative practices by which the findings of the laboratory are presented to a wider world. Between these two, however, the role of reading practices in scientific work has tended to be overlooked. In his survey of work in the field, Jan Golinski suggests one incentive for studying them, noting that "scrutiny of the hermeneutical practices in which readers of scientific texts are engaged" would support "analysis of science as rhetoric," but the emphasis here seems to be primarily on exoteric readers. In addition, however, there is a growing awareness that the thinking that scientists do, rather than being purely cerebral, is also a "practical activity, intimately bound up with other kinds of doing."[2] One activity with which thinking has often been closely associated is reading, and the study of it offers

[2] Jan Golinski, "The Theory of Practice and the Practice of Theory: Sociological Approaches in the History of Science," *Isis,* 1990, *81:*492–505, on p. 498; and Golinski, *Making Natural Knowledge: Constructivism and the History of Science* (Cambridge: Cambridge Univ. Press, 1998), p. 9.

valuable insights as historians seek to extend the range of their analysis. Reading practices, too, we discover, are embodied. They also are the accomplishments of localized communities, and they have to be painstakingly acquired. Moreover, like the other practices in which scientists engage, they are constitutive of the scientific knowledge that is produced.

Of course, questions about *what* scientists read, *when,* and with *what effect* often loomed large in the older ideas-led historiographies. However, the insights of the new practice-led historiographies have yet to be widely applied in asking the question of *how* scientists read what they read, at least for the modern era. The issues are well illustrated by the example of Charles Darwin. Through the endeavors of a generation of scholars, we know far more about Darwin's reading than we do about that of most scientists. His reading notebooks—recording books he intended to read or had read—have been transcribed and annotated, as have his marginalia and early theoretical notebooks. From these various sources, we know how important Darwin's reading was for his scientific work, and the often-faint traces of his encounters with books have been adroitly deployed as evidence of the "brainwork" of his theorizing. In particular, his reading of Thomas Malthus's *Essay on the Principle of Population* is still seen as a pivotal moment in his theorizing.[3] Nevertheless, there remain significant aspects of Darwin's reading that have received relatively little attention. How did he set about reading books, making notes, and subsequently storing and using both? Where did he learn those practices? When and how did they change? To what extent were they shared by his scientific peers? In what ways did they shape his scientific work? While the massive Darwin literature contains information on all these points, they have not attracted systematic study.[4] Yet, given that Darwin's reading was a key element of his scientific work, such questions are clearly worthy of serious consideration.

Historians of science interested in earlier periods are generally aware of the need to recover unfamiliar reading practices, ranging from arcane, biblically inspired hermeneutic techniques to the performative notion of reading entailed in using some alchemical texts. However, while it may be more familiar to us, reading in the industrial age also requires detailed historical analysis. For Darwin, as for us all, reading was a bodily activity. As Francis Darwin recalled, his father had "no respect" for books but "merely considered them as tools to be worked on," reading them to pieces or tearing them in half as necessary. Darwin's physical procedures of note-making and annotation were part of a larger method

[3] Charles Darwin, *The Correspondence of Charles Darwin,* 13 vols. to date (Cambridge: Cambridge Univ. Press, 1985–), ed. Frederick Burkhardt *et al.,* Vol. 4, pp. 434–573; Darwin, *Charles Darwin's Notebooks, 1836–1844: Geology, Transmutation of Species, Metaphysical Enquiries,* ed. Paul H. Barrett *et al.* (Cambridge: Cambridge Univ. Press, 1987); and Darwin, *Charles Darwin's Marginalia,* Vol. 1, ed. Mario A. Di Gregorio with the assistance of N. W. Gill (New York/London: Garland, 1990). For a recent analysis of the early notebooks, and the term "brainwork," see Jonathan Hodge, "The Notebook Programmes and Projects of Darwin's London Years," in *The Cambridge Companion to Darwin,* ed. Hodge and Gregory Radick (Cambridge: Cambridge Univ. Press, 2003), pp. 40–68. For the use of Darwin's marginalia to understand the development of his thinking on social evolution see John C. Greene, "Darwin as a Social Evolutionist," *Journal of the History of Biology,* 1977, *10:*1–27. On the reading of Malthus see Radick, "Is the Theory of Natural Selection Independent of Its History?" in *Cambridge Companion to Darwin,* ed. Hodge and Radick, pp. 143–167.

[4] Some consideration has been given to the actual mechanics of Darwin's reading in James Secord, *Victorian Sensation: The Extraordinary Publication, Reception, and Secret Authorship of* Vestiges of the Natural History of Creation (Chicago/London: Univ. Chicago Press, 2000) (hereafter cited as **Secord, Victorian Sensation**), pp. 426–433; Darwin, *Charles Darwin's Marginalia,* ed. Di Gregorio and Gill, pp. x–xxxvii; and Susan Sheets-Pyenson, "Darwin's Data: His Reading of Natural History Journals, 1837–1842," *J. Hist. Biol.,* 1981, *14:*231–248.

of managing information and ideas, involving habitual (if cluttered) spatial-temporal organization. In the Down House study, Francis recalled:

> He had one shelf on which were piled up the books he had not yet read, and another to which they were transferred after having been read, and before being catalogued. He would often groan over his unread books, because there were so many which he knew he should never read. Many a book was at once transferred to the other heap, either marked with a cipher at the end, to show that it contained no marked passages, or inscribed, perhaps, "not read," or "only skimmed." The books accumulated in the "read" heap until the shelves overflowed, and then, with much lamenting, a day was given up to the cataloguing.[5]

In laboratory work, such spatially organized bodily activities are now routinely subjected to historical analysis, but scientific reading in this period has yet to invite the kind of analysis given, for instance, to instrument reading. Nonetheless, Darwin's changing reading practices were closely linked to the theoretical work he was conducting. James Secord, for instance, detects elements of continuity between the meticulous record-keeping he began on the *Beagle* and his keeping of reading notes in the transmutation notebooks, but he also finds a significant shift in Darwin's note-keeping once he moved to Down House and began to build up an "anthology of passages and references" to flesh out his now-established theory.[6] Darwin's theoretical work did not consist simply of acts of cognition, but also of these physical processes of reading.

Similarly, while laboratory practices are habitually seen as the accomplishments of localized communities, reading practices are often treated as being either universal or purely personal. In an influential study, Martin Rudwick has highlighted the social and spatial situatedness of Darwin's scientific work during the years he spent in London following the *Beagle* voyage. Both Darwin's public geological theorizing and his more private theorizing on transmutation were, Rudwick contends, to varying degrees shaped by his involvement in a collective research enterprise centered on key scientific localities and social networks in London. Rudwick contrasts the social nature of his own analysis with Edward Manier's attempt to reconstruct the young Darwin's "cultural circle" from the "merely bookish 'influences' " revealed by his reading notes. Yet the approach taken by Rudwick to Darwin's other scientific practices—including such apparently private ones as note-making—can also profitably be taken to Darwin's reading practices. Rather than being "virtually non-social" (as Rudwick deems Manier's study to be), the analysis of reading should attempt to relate this apparently private practice to the wider but localized communities in which it takes place. As I have argued elsewhere, the experience of scientific reading for Darwin, while in itself solitary, was typically molded by social practices such as formal discussion in society meetings, private conversation and correspondence, and even practical cooperation in research. Just like note-making and theorizing, private prac-

[5] Francis Darwin, ed., *The Life and Letters of Charles Darwin, Including an Autobiographical Chapter*, 3 vols. (London: John Murray, 1888), Vol. 1, pp. 150, 151. By contrast, Darwin typically encountered fiction and other nonscientific works aurally, read aloud by members of the family either in his bedroom during an afternoon siesta or in the drawing room during the evening (*ibid.,* pp. 121–125).

[6] Secord, *Victorian Sensation,* pp. 428–429. Graeme Gooday has exploited the analogy between the reading of instruments and of printed texts in "Spot-Watching, Bodily Postures, and the 'Practiced Eye': The Material Practice of Instrument Reading in Late Victorian Electrical Life," in *Bodies/Machines,* ed. Iwan Rhys Morus (Oxford/New York: Berg, 2002), pp. 165–194, on pp. 166–167. On notions of the physical processes of reading in an earlier period see Adrian Johns, "The Physiology of Reading in Restoration England," in *Practice and Representation,* ed. Raven *et al.* (cit. n. 1), pp. 138–161.

tices of reading were shaped by the localized communities to which scientists belonged. Indeed, the object of reading was often itself social. As Secord has shown, Victorian "gentlemen of science" read books partly in order to discuss them in such diverse settings as learned societies and fashionable conversaziones, and their readings were shaped accordingly.[7]

The reading practices developed within particular communities had to be laboriously learned. Secord considers that Darwin's techniques of close study were typical among gentlemen of science. The question remains, however, of how he learned them. Like experimental practices, reading practices are craft skills, generally learned by ostention rather than by rule, and often as part of a pedagogical process. Yet while we have excellent studies of the manner in which Darwin learned his fieldwork practices while a student, we know little of how he and his peers were trained to read by their university education. One effort in this direction is Aileen Fyfe's study of the reception of William Paley's *Natural Theology* in the University of Cambridge. Correcting the common misapprehension that the work was a "set text" in the university, Fyfe examines how it was actually incorporated into pedagogy (including both university and college lectures and examinations) and the expectations consequently evoked in readers.[8] It is in such studies as these that the shared reading practices of different communities emerge.

One of the most notable accounts of the importance of shared reading practices in shaping scientific work is provided by Andrew Warwick's recent *Masters of Theory,* which examines the practice of late Victorian mathematical physics through a reconstruction of the advanced mathematical pedagogy of the University of Cambridge. Warwick's study is at the forefront of extending practice-based analysis to include theorizing. He argues that, just as the replication of experiments depends appreciably on the reproduction of experimental skills and material resources, so the interpretation and use of abstract theories depends on the reproduction of the theoretician's much less obvious craft skills. The mathematical physicist may only have had "a desk, a few shelves of books, and a large wastepaper basket" to work with, but it took years of training to know how to use them. Warwick uses the example of Newton's *Principia* to illustrate his point: readers of Newton's work, he argues, had to have embodied certain technical skills "through protracted routines of learning using a material culture of books, paper, pens, ink, and mathematical instruments" in order to understand and participate in the new science.[9] For Warwick, understanding the shared practices by which scientists make meaning out of printed matter thus contributes on a grand scale to the historical analysis of scientific change.

Warwick's study particularly emphasizes the importance in Victorian Cambridge of a system of private tutoring, and of problem solving with paper and pen, to which the use of pedagogical devices like textbooks was made subservient. Importantly, he argues that

[7] Martin Rudwick, "Charles Darwin in London: The Integration of Public and Private Science," *Isis,* 1982, *73:*186–206, on p. 186 (the reference is to Edward Manier, *The Young Darwin and His Cultural Circle* [Dordrecht/Boston: Reidel, 1978]); Jonathan R. Topham, "Beyond the 'Common Context': The Production and Reading of the *Bridgewater Treatises*," *Isis,* 1998, *89:*233–262, esp. pp. 250–252; and Secord, *Victorian Sensation,* pp. 410–419.

[8] Secord, *Victorian Sensation,* p. 429; and Aileen Fyfe, "The Reception of William Paley's *Natural Theology* in the University of Cambridge," *British Journal for the History of Science,* 1997, *30:*321–335 It should be noted, however, that some consideration is given to Darwin's reading, as well as to his fieldwork, in James Secord, "The Discovery of a Vocation: Darwin's Early Geology," *ibid.,* 1991, *24:*133–157.

[9] Andrew Warwick, *Masters of Theory: Cambridge and the Rise of Mathematical Physics* (Chicago/London: Univ. Chicago Press, 2003), pp. 16, 17.

these pedagogical practices, and the skills they engendered, resulted, in the 1870s and early 1880s, in a distinctive "collective interpretation and local propagation" of James Clerk Maxwell's *Treatise on Electricity and Magnetism* (1873). This in turn, he claims, "established and sustained Cambridge as by far the most important center in Britain for the development of Maxwell's work." Warwick states that in the early 1870s "only a handful of readers in the world" could have followed Maxwell's *Treatise,* which combined elements from a range of highly technical fields.[10] Over succeeding years, however, a collective understanding gradually emerged in Cambridge. This depended in part on private and collective study, but also on the incorporation of aspects of the book into the system of private tutoring, into college lectures, and into the examination system. Having learned, in this range of distinctive pedagogical contexts, the key skills needed for a "Cambridge reading" of the *Treatise,* Maxwellians like J. H. Poynting and J. J. Thomson built on that distinctive reading in their early contributions to electromagnetic theory.

Work like Warwick's gives clear indications that attending to the reading practices in which scientific practitioners engaged affects our interpretation of their scientific work. Moving beyond the "what" and "when" to the "how" of reading thus promises to extend the insights of practice-based historiography to many more aspects of the history of science.

READING AND THE HISTORY OF SCIENCE IN POPULAR CULTURE

Of course, it is not only practicing scientists who read scientific publications. Whether they are intended to or not, a wide range of other readers use them, and the history of reading consequently offers new insights concerning the role of science in popular culture. Indeed, it contributes to a larger attempt to rethink historiography in this field, along lines outlined by Roger Cooter and Steven Pumfrey. In a now-classic survey paper, Cooter and Pumfrey not only attack the well-known inadequacies of the diffusionist model of popularization but also criticize what they call the "dichotomous model of élite versus popular cultures," in which science is seen as a resource that is "actively mobilized . . . to cross the divide" between two independent cultures. Dissatisfied with the presumed independence and implied homogeneity of elite and popular cultures on this view, they urge the need for a model in which "the relations between science and its publics are configured in a more dynamic interactive fashion." They seek to replace both "top-down" and "bottom-up" approaches with a new kind of cultural history of science that allows for a multifaceted and uneven contest for meaning, and they urge two "precautions" for maintaining this dynamic focus. First, they suggest that historians should be "responsive to a greater plurality of the sites for the making and reproduction of scientific knowledge," such as the pub or the drawing room. Second, they suggest a shift "away from texts and towards a greater plurality of signifiers of scientific activity." They criticize the "papyrocentricity" of much history of popular science and urge the "importance of practice and of non-literary products" ranging from wax models of the human body to world fairs.[11] This does not, they point out, mean rejecting printed sources; on the contrary, they observe that the examination of popular prose and nonscientific texts has much to offer the historian of science. However, they do not make the link between the new cultural history and the history of reading made by some of the cultural historians on whose work they draw.

[10] *Ibid.,* pp. 288, 298.

[11] Roger Cooter and Stephen Pumfrey, "Separate Spheres and Public Places: Reflections on the History of Science Popularization and Science in Popular Culture," *History of Science,* 1994, *32:*237–267, on pp. 251, 252, 254–255.

This link is well illustrated by the work of Roger Chartier. Chartier, too, rejects the notion of an independent "popular culture," pointing out that such an entity is often defined negatively in relation to the dominant culture and that the term obscures manifold social divisions. In addition, he urges that neither material objects nor cultural practices can be definitively associated with particular social groups but that they frequently cross the boundaries between such groups. For Chartier, books are prime examples of such circulating objects, and the diverse readings to which they are subjected in different social and cultural settings provide a key source of evidence for the cultural contest that is under way. As I have shown in a study of the production and reading of the *Bridgewater Treatises,* such an approach readily lends itself to the history of science in popular culture. Reconstructing the diverse readings to which scientific books were subjected can reveal the cultural dynamics of science in just the manner proposed by Cooter and Pumfrey. I argue that individual readings of the *Bridgewater Treatises,* shaped by a range of social and cultural determinants, were expressions of an unequal struggle for hermeneutic control. Frequently, such acts of reading were linked to private or public acts—oral, textual, institutional, ostensive, or physical—that were intended to prosecute the contest for cultural authority more directly. Moreover, the authors had to take cognizance of such readings not only after the fact, in preparing new editions and new works, but also in anticipation, in writing their works in the first place.[12]

The observation that scientific authors respond both proactively and reactively to readers again demonstrates the importance of the history of scientific reading for the history of the scientific enterprise as a whole. As a number of scholars have shown—following the work of Bruno Latour—there is a mutual process of enrollment of interest that occurs when scientific practitioners are successful in urging their claims to knowledge onto wider audiences. When the members of an audience accept the appeal of the scientists, the scientists also to some extent take on board the interests of the audience they have enrolled.[13] Understanding in concrete detail the reading audiences that are so enrolled, and examining the dynamic of the interaction, will consequently reveal much about the development of the sciences. Scholarship on the second scientific revolution, in particular, has emphasized the extent to which the newly emerging scientific specialists were preoccupied with the need to manage their claims to knowledge in the context of an emerging series of audiences, ranging from radical artisans to evangelical activists. A fully historical account of scientific reading in the period will allow these concerns to be analyzed to a much greater extent. In particular, the new history of reading offers an approach that mediates between individual readers and collective formations and wrestles with the question of how individuals identified themselves as members of particular reading communities.

This feature of the history of reading is ably illustrated in James Secord's recent study, *Victorian Sensation.* Secord claims that the "pivotal role" that evolution currently has in the public arena came about because of changes in who read and in what and how they read: "What once made sense as the 'Darwinian Revolution,' " he argues, "must be recast as an episode in the industrialization of communication and the transformation of reading audiences." He begins this recasting by offering, for the anonymous evolutionary book

[12] Chartier, "Texts, Printings, Readings" (cit. n. 1), p. 169; and Topham, "Beyond the 'Common Context' " (cit. n. 7).

[13] Cooter and Pumfrey, "Separate Spheres and Public Places" (cit. n. 11), pp. 250–251.

Vestiges of the Natural History of Creation (1844), "the most comprehensive analysis of the reading of any book other than the Bible ever undertaken."[14] Skillfully interweaving the traces of individual reading events with evidence about the larger social and cultural formations that shaped them, he shows how the various readings to which *Vestiges* was subjected had substantial consequences for the development of Victorian science. One of the most impressive features of Secord's analysis is that, far from describing a mere riot of competing individual readings, he considers how the conventions, the techniques, the expectations, and the competencies of readers varied between different groups—whether between members of London's high society and members of Cambridge colleges or between evangelical activists and freethinkers. The evidence needed to create such historical distinctions ranges widely, from details of educational practices to conduct manuals and from fictional representations of reading to information about the organization of libraries. By moving continually between the individual readings and these larger patterns, Secord is able to provide an astonishingly synthetic account of the reading of *Vestiges* that significantly advances our understanding of the place of science in Victorian culture.

In urging that books and reading should have a significant role in the cultural history of science, I do not mean to detract from the case for attending to other material objects and practices. On the contrary, such an approach must move forward in parallel with work on other aspects of material culture, such as domestic technologies, menageries, public exhibitions, and museums. However, it is sometimes necessary to make a special case for books, since in redressing the "privileging of ideas and texts over practice and object" books are often set aside with the former rather than being embraced with the latter. Moreover, while recoverability is by no means the only argument for using particular primary sources, the disproportionate survival of books relative to other material objects of the past has to be considered. To refuse to exploit such resources would be needlessly impoverishing as well as misconceived. Of course, the relative prevalence of textual matter, and of reading, has differed significantly over the course of time. Only a moment's reflection reveals that most of the textual matter currently accessible to readers of this journal is the product of industrialized communication technologies introduced over the course of the last two centuries, ranging from mechanized printing to the Internet. The commercialization and mechanization of the book trades in the late eighteenth and early nineteenth centuries led to what was, at the time, "the greatest transformation in human communication since the Renaissance." As the first of the mass media, print had a wider significance in the nineteenth and early twentieth centuries than at any period before or since. Indeed, as Secord points out, the coexistence in the first half of the nineteenth century of "gossipy personal letters and private diaries" with "steam-printed books and cheap magazines posted by rail" means that the period is probably better supplied with sources for the history of reading than any other.[15] It is to the interpretation of such evidence that I now turn.

TOWARD A HISTORY OF SCIENTIFIC READING

While the evidence from which a history of scientific reading might be constructed is surprisingly abundant for the modern era, much of it remains unexplored and undevel-

[14] Secord, *Victorian Sensation,* pp. 2, 4.

[15] Cooter and Pumfrey, "Separate Spheres and Public Places" (cit. n. 11), p. 255; and Secord, *Victorian Sensation,* pp. 2, 4.

oped.[16] However, once reading becomes a subject of serious and integrated historical scrutiny, these neglected sources take on a wider significance. What is distinctive about the new history of reading in recent decades is that it brings together forms of evidence that previously tended to be considered in disciplinary isolation. In particular, it combines what Robert Darnton calls the "external history of reading"—the who, what, where, and when of reading—with the "internal" history of how and why readers read. Earlier, atomized approaches inevitably distorted the history of reading by separating out these different features. Alvar Ellegård's famous study *Darwin and the General Reader,* for instance, relied on the publication of articles on evolution in the British periodical press as the sole source of evidence for the "reception" of Darwin's theory. Painstakingly researched as it was, Ellegård's entirely "external" reception study gave no thought to how such articles were read or responded to by readers.[17] At the other extreme, historians of science have often sought to characterize the reading of books solely on the basis of an interpretation of the rhetorical strategies of their texts. However, given that reading is radically underdetermined by the rhetorical strategies that are intended to direct it, such an approach can only be partial and must be combined with other, especially more direct, forms of evidence if it is to provide a genuinely historical account of reading.

It may appear that our knowledge of the "external" history of reading is already well developed. However, historians of science, like students of literature, have become increasingly aware over recent years that their perceptions of the past have been constrained by the existence of a "canon" of familiar publications. In an age in which bibliographical databases like the *English Short-Title Catalogue* and the *Nineteenth-Century Short-Title Catalogue* are giving an ever-improving sense of the output of the scientific press, the opportunities for more systematic study are manifold. Using techniques of bibliometry, the historian can chart on a large scale the rise and fall of particular genres, the changing prevalence of works in different fields of scientific endeavor, and the shifting price distribution of scientific books. Such work can also be combined with archival evidence about edition sizes to give a fuller sense of the prevalence of different kinds of books.[18] Even on a small scale, such gross measures of the history of reading as the number and size of editions can problematize existing perceptions. In *Victorian Sensation* Secord charts the number of copies of *Vestiges* and the *Origin of Species* issued in Britain between 1844 and 1890, revealing—very strikingly—that the latter had not outsold the former by the time of Darwin's death. Aileen Fyfe has subsequently shown that by the same date the numbers of copies of Paley's *Natural Theology* and George Combe's *Constitution of Man* issued in Britain were, respectively, twice and three times those of the *Origin of Species.*[19]

[16] I give more detailed consideration to the practicalities of research in this area in Jonathan R. Topham, "Scientific Publishing and the Reading of Science in Nineteenth-Century Britain: A Historiographical Survey and Guide to Sources," *Stud. Hist. Phil. Sci.,* 2000, *31A:*559–612.

[17] Darnton, "First Steps toward a History of Reading" (cit. n. 1), p. 157; and Alvar Ellegård, *Darwin and the General Reader: The Reception of Darwin's Theory of Evolution in the British Periodical Press, 1859–1872* (Chicago/London: Univ. Chicago Press, 1990). More reader-conscious approaches to the science content of nineteenth-century periodicals are explored in Louise Henson *et al.,* eds., *Culture and Science in the Nineteenth-Century Media* (Aldershot: Ashgate, 2004); Geoffrey Cantor and Sally Shuttleworth, eds., *Science Serialized: Representations of the Sciences in Nineteenth-Century Periodicals* (Cambridge, Mass.: MIT Press, 2004); and Geoffrey Cantor *et al., Science in the Nineteenth-Century Periodical: Reading the Magazine of Nature* (Cambridge: Cambridge Univ. Press, 2004).

[18] I currently have a project under way at the University of Leeds, funded by the Arts and Humanities Research Board, which is designed systematically to sample the output of the British scientific, technical, and medical press between 1800 and 1850. The case for such an approach is made at greater length in Topham, "Scientific Publishing and the Reading of Science" (cit. n. 16).

Such figures are not easy to interpret, but they raise important questions that are otherwise easy to overlook. Indeed, as Fyfe shows, they can prompt the historian to question not only why people might read a given book but also how that reading might change over time.

One reason why sales figures are not easy to interpret is, of course, the fact that the availability and price of a book are no sure guides as to who actually read it. Printed material is well known for getting into the "wrong hands," whether it be artisans using expensive floras in pub-based botanical meetings or Charles Darwin reading the *Gooseberry-Grower's Register* as a source of evidence for his theory of species change. Of course, truly atypical readers are often accessible to the historian only through personal sources, like diaries or correspondence, but attention to the mechanisms of book distribution can yield significant information about patterns of use. For instance, the oft-cited statistic that the first edition of the *Origin of Species* numbered 1,250 copies has obscured the important information that of the 1,192 copies actually put on sale, 500 (42 percent) were bought by Charles Edward Mudie's circulating library. This obviously helps to explain how the edition came to be oversubscribed by 250 copies when the publisher John Murray offered it for sale to the wholesale trade on 22 November 1859. At the same time, however, it suggests that many more and a wider variety of readers had access to the first edition than we might have thought: at its peak Mudie's library had over 25,000 subscribers nationwide and also supplied smaller book clubs and libraries. Moreover, once the immediate demand had diminished, or the copies had become shabby, they were sold off secondhand. As the case of Mudie's suggests, libraries massively increased in number and range during the industrial age. Their assorted records—catalogues, minute books, and even loan registers—provide extensive and concrete evidence of the distribution of scientific books. The records of book wholesalers and retailers are less plentiful but are nonetheless important, for they can indicate patterns of sales that otherwise remain hidden.[20] Particularly fertile in this regard are private subscription lists for individual publications and the distribution records of learned societies and specialist publishing societies.

Such evidence of the "external" history of reading—of who had access to which scientific books and where—clearly needs to be tied in with evidence of the "internal" history of reading: the how and why. One important source of evidence of how readers read scientific publications remains conventional textual criticism. However, to provide a truly historical account of reading, this must be complemented by evidence of at least two further kinds. First, the role of the material form of the printed artefact in shaping meaning deserves attention. It is here that the insights of an Anglo-American tradition of "analytical bibliography"—defined as the study of the book as a physical object—can be brought to bear on the history of reading. The physical form of the book is a semiotic system, which shapes readings in a manner precisely analogous to the semiotics of the text. Scientific

[19] Secord, *Victorian Sensation,* p. 526; and Aileen Fyfe, "Publishing and the Classics: Paley's *Natural Theology* and the Nineteenth-Century Scientific Canon," *Stud. Hist. Phil. Sci.,* 2002, *33:*729–751, on p. 735.

[20] On the unanticipated uses of books see Anne Secord, "Science in the Pub: Artisan Botanists in Early Nineteenth-Century Lancashire," *Hist. Sci.,* 1994, *32:*269–315, on pp. 277–278; and Darwin, *Correspondence of Charles Darwin,* ed. Burkhardt *et al.* (cit. n. 3), Vol. 10, pp. 578–579 (*Gooseberry-Grower's Register*). For the statistics see *ibid.,* Vol. 7, pp. 394, 395; Vol. 8, p. 488; Vol. 11, p. 63. On Mudie's see Guinevere L. Griest, *Mudie's Circulating Library and the Victorian Novel* (Newton Abbott, Devon: David & Charles, 1970). For an example of the use of wholesalers' and retailers' records see, e.g., Jonathan R. Topham, "A Textbook Revolution," in *Books and the Sciences in History,* ed. Marina Frasca-Spada and Nick Jardine (Cambridge: Cambridge Univ. Press, 2000), pp. 317–337.

texts that we know primarily through first editions—sometimes in facsimile or on microfilm—were known to original readers not only through multiple editions but also through a wider process of "literary replication" in which they were excerpted and reviewed in periodicals, books, and advertisements. While the text was often identical, these different physical objects frequently had widely different meanings. As Secord has shown, for instance, the publisher of *Vestiges* was only too aware that issuing it in a cheap "people's edition" would make it potentially far more subversive. Moreover, such multiple materializations were frequently outside the control of those who produced them. Long before its publisher agreed to a people's edition, *Vestiges* was widely known through a cheap "expository outline" published as a supplement to the *Atlas* newspaper.[21] Close scrutiny of this complex process of the physical embodiment and re-embodiment of texts aids the historian in recovering their multiple meanings.

A further body of evidence for the history of scientific reading, of course, relates to the readers themselves and to the actual practice of reading. The most obvious such evidence comes from the abundant records of individual encounters with printed matter found in marginalia, notes, correspondence, diaries, and autobiographies. However, as we have already seen, individual reading practices are profoundly shaped by the shared conventions and interests of particular reading communities, and these too require attention. Identifying and understanding such groupings is, of course, by no means straightforward, particularly since individual readers not infrequently identified themselves with more than one. Nevertheless, there are numerous neglected sources of evidence that can help to elucidate shared reading practices. The history of education at all levels would particularly repay further consideration in this regard. For instance, with a million enrolled scholars in 1835, the Sunday School Union clearly had a major impact on the reading practices of Britain's working class, but it has yet to receive extended consideration in relation to the history of popular science. At the other end of the spectrum, we need more studies of how habits of scientific reading were instilled in grammar school and university students like Darwin. A further important body of evidence comes from those sources, ranging from conduct manuals to sermons, that provided readers with explicit or implicit advice about reading. In particular, the vast bulk of the periodical literature of the last two centuries is replete with evidence of how different groups of readers learned to read scientific books, and it has barely begun to be explored.[22] By using such sources to move beyond the isolated records of individual readings to a larger view of the history of reading, historians can restore the practice of reading to the significant place it occupied in science's past.

When the history of reading is prosecuted in a comprehensive manner, including "all the diverse ways that books and other forms of printed works are appropriated and used," it can justly be considered, in James Secord's phrase, "a study of cultural formation in action."[23] Both at the level of scientific practice and in terms of understanding science as

[21] Secord, *Victorian Sensation,* pp. 111–152.

[22] On the Sunday School Union see Jonathan R. Topham, "Periodicals and the Making of Reading Audiences for Science in Early Nineteenth-Century Britain: The *Youth's Magazine,* 1828–37," in *Culture and Science in the Nineteenth-Century Media,* ed. Henson *et al.* (cit. n. 17), pp. 57–69. On what we can learn from study of the periodical literature see *ibid.*; and Cantor *et al., Science in the Nineteenth-Century Periodical* (cit. n. 17), esp. the introduction and Ch. 3.

[23] Secord, *Victorian Sensation,* p. 3.

part of a wider culture, the study of reading as a practical, situated, and social activity reveals individuals engaged in a complex hermeneutical negotiation, making meaning by continual reference to their own and other reading communities. For the industrial age, dominated as it has been by the culture of print, such analysis has a key role to play in the cultural history of science.