·科学技术史·

十九世纪英国科学和历史大图景

Nineteenth-Century British Science and the Big Picture

伯纳德·莱特曼 /Bernard Lightman

（约克大学人文学系，多伦多，M3J 1P3，加拿大）
(Department of Humanities, York University, Toronto, M3J 1P3, Canada)

摘　要：本文运用《科学史指南》一书中的四个分析范畴来描绘19世纪英国科学的大图景。角色、地方、传播实践和物质材料是目前驱动科学史领域发展的最重要的分析范畴。本文首先回顾1973年新马克思主义科学史家罗伯特·杨提出的19世纪英国科学的大图景，讨论四十多年来的科学史工作对该研究路径的挑战、突破和补充。随后，本文将围绕这四个分析范畴整合19世纪英国科学史研究的新进展。19世纪中叶自然哲学家和博物学家被科学人所替代，笔者将讨论科学角色发生变迁的原因及其影响和意义。接着，笔者考察了科学场所的演变，特别是实验室如何成为发现知识的特权空间。对科学传播中的转变，笔者将着重探讨传播革命带来的廉价科学图书的爆发式增长和新期刊的大量出版。最终，笔者提出一个新的综合的19世纪英国科学的历史大图景。

关键词：科学认同　科学传播　科学空间　科学自然主义　科学职业化和科学普及

Abstract: In this paper I aim to apply to 19 century British science the four analytical categories used in *A Companion to the History of Science* (ed. B. Lightman, John Wiley & Sons, 2016) to introduce the entire field of the history of science. The hope is to produce a big picture of the nineteenth century that is based on a number of the most important analytical categories currently driving the field. The categories are: roles, places, communicative practices, and materials.

The paper will actually begin with an examination of previous big pictures, especially the one developed in 1973 by the neo-Marxist historian of science, Robert Young, in his substantial essay “The Historiographic and Ideological Contexts of the Nineteenth-Century Debate on Man’s Place in Nature.” Here Young outlines

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作者简介：伯纳德·莱特曼（1950–）男，加拿大约克大学人文科学杰出研究教授，美国科学史学会前主席，《爱西斯》前主编。主要研究英国维多利亚时代的科学文化史。最近主编出版的文集有：《重新思考历史、科学与宗教》《19世纪英国的科学期刊》和《世俗时代的身份认同》。他目前正在写一本关于维多利亚时代的科学、宗教与期刊的书。他是“丁铎尔通信项目”的主编之一。该项目致力于收集、整理、编辑、出版和数字化丁铎尔的全部来往书信，是一项国际合作项目。他也是“科学与19世纪文化”系列丛书的主编，该套丛书和丁铎尔书信全集都是由匹兹堡大学出版社出版。

Bernard Lightman is Distinguished Research Professor in the Humanities Department at York University, Past President of the History of Science Society, and past editor of the journal *Isis*. Lightman’s research focuses on the cultural history of Victorian science. Among his most recent publications are the edited collections *Rethinking History*, *Science and Religion*, *Science Periodicals in Nineteenth Century Britain* (co-edited with Gowan Dawson, Sally Shuttleworth, and Jonathan Topham), and *Identity in a Secular Age* (co-edited with Fern Elsdon-Baker). He is currently working on a book on science, religion, and Victorian periodicals, and is one of the general editors of the John Tyndall Correspondence Project, an international collaborative effort to obtain, digitalize, transcribe, and publish all surviving letters to and from Tyndall. He is also editor of the book series “Science and Nineteenth Century Culture,” which, like the Tyndall Correspondence, is published by the University of Pittsburgh Press.

the complicated shift from natural theology to scientific naturalism during the course of the nineteenth century, emphasizing the continuities rather than a Darwinian revolution. I will discuss the limitations of this approach as newer scholarship both challenged, and filled in some of the gaps of Young's analysis.

The rest of the paper will try to group together the newer scholarship within the four analytical categories. For scientific roles, I will discuss how these changed during the nineteenth century, as the natural philosopher and natural historian gave way to the "man of science," as the result of the work of a new generation of men who arrived on the scene in the middle of the century. They defined the scientist in ways that were different from the gentleman of science of the first half of the century, and this had significant implications for the participation of women and others. In dealing with the second analytical category I will discuss the way the places of science changed over time, as the laboratory became the privileged space in which knowledge was discovered. The communications revolution leading to the production of an avalanche of cheap science books and new periodicals will be front and center in my examination of the changing practices in communicating science, the third analytic category. A new synthesis will, I hope, emerge at the end of this overview of the scholarship of the last forty years.

Key Words: Scientific identity; Scientific communication; Scientific spaces; Scientific naturalism; Professionalization and popularization

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In 1993, the eminent Cambridge historian of science James Secord called for the development of "new big pictures" to replace the older ones that focused on important scientific figures like Darwin, Newton, and Faraday whose significance was "defined by an agenda grounded in criteria of heroic discovery (e.g. natural selection, universal gravitation, field theory）." The canon, he asserted, needed to change, especially since the "established stories in the field—from the origins of science in ancient Greece to the Darwinian and Einsteinian 'revolutions'—are in ruins" after having been demolished for years by specialists. Since no new big picture had appeared, the "construct founded on the primacy of method, genius and heroic discovery continues (albeit awkwardly) to organize a body of specialist literature devoted to criticizing the coherence of such concepts." Secord acknowledged that coming up with another kind of account was a difficult challenge but he insisted that it was essential for the future of the field [①]. How have historians of science responded to Secord's challenge over the last thirty years? I suspect the answer is that we haven't completely risen to the occasion. I won't attempt in this paper to pursue this larger issue. That would be far too ambitious. But in order to build a new account for the entire history of science it might be necessary to construct a big picture from the ground up, that is, by connecting together medium sized pictures of specific time periods. My more modest goal is to ask: how have historians of nineteenth century British science responded to Secord's provocative question?

Over the last three decades scholars working on nineteenth century British science have produced some exciting and ground-breaking work that provides a glimpse--maybe more--of what a new big picture would look like for this period. Today I will present a synthetic overview of the key works in the field to see if a clearer shape can be given to what has emerged. What obscures our view is the tendency of historians of science since the 1980's, particularly in the west, to produce thickly textured and specialized studies in their attempt to understand the social, cultural, intellectual, political, and economic contexts that shaped nineteenth century British science. In other words, it is the contextualist approach itself that has led to the fragmentation of the field. But this has been necessary in order to deconstruct the old big picture that dominated the field in the past. The old picture really centered around Darwin and the Darwinian

①James A. Secord, "Introduction," *British Journal for the History of Science* 26 (1993), 387-9. Secord's piece served as the introduction to a series of essays discussing the big picture issue by J. R. R. Christie, Andrew Cunningham and Perry Williams, John V. Pickstone, Andrew Barry, and Ludmilla Jordanova.

revolution.

To put it simply, the narrative lying behind most histories of nineteenth century British science used to be the triumph of Darwin's theory of natural selection and how it revolutionized not only the biological sciences, but all the scientific disciplines. It is understandable why scholars in the past found this an appealing story to tell. Those historians of British science who worked on the early modern period had found great success in building their narrative around Newton's theory of gravity and the seventeenth century revolution that was said to have established a firm foundation for scientific progress. When history of science was more firmly established as a discipline in the middle of the twentieth century the study of the scientific revolution provided a focus for the field. For those who wished to draw attention to the nineteenth century, emphasizing Darwin and his scientific theory seemed like a logical strategy. Hence, Gertrude Himmelfarb's *Darwin and the Darwinian Revolution* (1959), and, later, Michael Ruse's *The Darwinian Revolution* (1979).

But, as some historians pointed out, there were problems with a story that made Darwin and his theory of natural selection the focus of nineteenth century British science. There were questions whether or not a revolution really took place at all. In two of his books, *The Eclipse of Darwinism* (1983) and *The Non-Darwinian Revolution* (1988), historian of biology Peter Bowler pointed out that if there was a scientific revolution it wasn't a Darwinian one. The theory of natural selection was not widely accepted by scientists until the 1920's and 1930's, when the modern synthesis joining Darwin's theory with Mendel's ideas on heredity was formed. So according to Bowler there was no Darwinian revolution within science in the nineteenth century. That was a myth. Neither, as the neo-Marxist historian Robert Young argued in 1985, was there a revolution "outside" science. Young maintained that although a change took place when evolutionary theory was introduced into Britain, it did not amount to a revolution. Instead, Young emphasized the continuity between pre-Darwinian and post-Darwinian frames of thought. The argument between natural theologians and evolutionists was over the "best ways of rationalizing the same set of assumptions about the existing order. An explicitly theological theodicy was challenged by a secular one based on biological conceptions and the fundamental assumption of the uniformity of nature."[1]

Newer scholarship has challenged and filled in some of the gaps in Bowler and Young's analyses, and they have moved the gravitational center of the field away from a focus on scientific heroes and their theories ①. In this paper I aim to apply to nineteenth century British science three analytical categories used in *A Companion to the History of Science* to introduce the entire field of the history of science ②. The categories are: roles, places, and communicative practices. For scientific roles, I will discuss how these changed during the nineteenth century, as the natural philosopher and natural historian gave way to the "man of science," as the result of the work of a new generation of men who arrived on the scene in the middle of the century. They defined the scientist in ways that were different from the gentleman of science of the first half of the century, and this had significant implications for the participation of women and others. In dealing with the second analytical category I will discuss the way the places of science changed over time, as the laboratory became the privileged space in which knowledge was discovered. The communications revolution leading to the production of an avalanche of cheap science books and new periodicals will be front and center in my examination of the changing practices in communicating science, the third analytic category. A new synthesis will, I hope, emerge at the end of this overview of the

① It is worth noting Iwan Morus's fascinating overview of the history of the physical sciences in *How the Victorians Took Us to the Moon: The Story of the 19th-Century Innovators Who Forged Our Future*. New York and London: Pegasus Books, 2022. This is a satisfying big picture of the physical sciences. However my aim is to outline a big picture that moves across the physical and the life sciences.

②Bernard Lightman, ed., *A Companion to the History of Scienc.* Chichester, UK: John Wiley & Sons Ltd., 2016. Due to length constraints I have omitted discussion of the fourth category used in this edited collection: the tools of science. This would involve tracking the changing patterns in the materiality of science, over the course of the century, as new scientific instruments like the spectroscope became important, and older ones, like the microscope, became even more central in the laboratory setting.

scholarship of the last thirty years.

I. Roles and Identities

During the nineteenth century the idea of the "scientist" changed dramatically over time. The term itself was coined in 1834 by the English polymath William Whewell. [2] Whewell did not have in mind the specialized, professional scientist that we are familiar with today. He used the term to question the tendency of his contemporaries to subdivide science into separate disciplines. Creating the term "scientist" was part of Whewell's desire for unity in science and his rejection of specialization. This indicates that what constituted a "scientist" in nineteenth century Britain was hotly contested. For Whewell's generation, the scientist not only ranged over a variety of disciplines, he also understood nature through the lens of natural theology. But in the middle of the nineteenth century a new generation of young scientists that included the biologist Thomas Henry Huxley and the physicist John Tyndall agitated for institutional and intellectual reform. Using the controversy over Darwin's *Origin of Species* (1859) as an opportunity for pushing their agenda, they rejected natural theology as a basis for science and argued that theologians had no authority to determine the fate of new scientific theories. Scholarship in the field since the early 1990's has fleshed out this story about the professionalization of science, complicating it in the process. At the same time there has been increased attention to figures who played a role in the scientific community even though they would not fit the current description of who is and who is not a scientist. Historians examined, for example, the roles of invisible technicians, instrument makers, artisans, scientific illustrators, popularizers, amateurs, and the public in general. This necessarily involved a new appreciation of how women were active participants in the world of nineteenth century science even though there were significant obstacles blocking their path. In sum, historians viewed this period as one in which the concept of professional scientist was not yet set in stone, which allowed for a wide range of individuals to become involved in scientific activity.

Ever since 1978, when Frank Turner discussed how the Victorian conflict between science and religion was a by-product of the process whereby professionally minded scientists attempted to exclude Christian clergymen from science, the concept of professionalization has been intertwined with the group of intellectuals he referred to as scientific naturalists. [3] Scientific naturalists were those men who put forward new interpretations of nature, society, and humanity derived from the theories, methods, and categories of empirical science. They were naturalistic in the sense that they ruled out recourse to causes not present in empirically observed nature and they were scientific in that they interpreted nature in accordance with three major midcentury scientific theories, the atomic theory of matter, the conservation of energy, and evolution. According to Turner, the leading scientific naturalists included the biologists T. H. Huxley and E. Ray Lankester, the physicist John Tyndall, mathematician William Kingdon Clifford, the founder of eugenics Francis Galton, statistician Karl Pearson, anthropologist Edward Tylor, doctor Henry Maudsley, philosopher of evolution Herbert Spencer, and a group of journalists, editors and writers, such as Leslie Stephen, G. H. Lewes, John Morley, Grant Allen and Edward Clodd. Turner argued that these were the men who were engaged in a contest for cultural authority with the Anglican clergy in the second half of the nineteenth century and who used professionalization as a strategy for discrediting the clergy's scientific credentials. [4, 5] Scientific naturalists, then, were seen as the primary agents of professionalization in science. More recent work on scientific naturalism has offered new perspectives on this important group by focusing on issues of community, identity, and continuity. Retaining Turner's term "scientific naturalism," scholars nevertheless now recognize that this category is more fluid and mutable than hitherto acknowledged. [6, 7]

Hand in hand with a re-evaluation of scientific naturalism there has been a rethinking of how historical actors conceived of professionalization. Huxley wanted science to be associated with expertise, laboratory research, and naturalism, and he wanted to break its connection with the Anglican clergy and natural theology. However in the early 1990's scholars were already raising questions about the meaning of the term in general apart from science. Collini discussed the diversity of, and limits to, the professionalization

of intellectual life in the late nineteenth century. He warned that the use of the term "professionalization" to describe what differentiated intellectual life in 1930 from that of 1850 assumed a uniform and complex process that did not exist. [8] Dealing with the issue specifical in science, Ruth Barton persuasively argued that historians had neglected the significance of amateur members of the X Club, such as John Lubbock. [9] In trying to appreciate what it meant to be a professional scientist, at least from the point of view of Huxley and his allies, we cannot simplistically oppose the professional to the amateur. A few years later Desmond observed that professionalization can no longer be seen as triumphal in its "Whiggish inevitability." Huxley does not fit into the mould of the twentieth century professional scientist. When it came to forging alliances, he and his friends were more concerned with an individual's commitment to naturalistic science ① . The newer scholarship has complicated our understanding of the meaning and nature of the process of professionalization in the second half of the century.

Perhaps the most up-to-date scholarly treatment of the issue of scientific professionalization can be found in the chapters on "The Man of Science" and "The Professional Scientist" in *A Companion to the History of Science* ② . Here a firm distinction is made between the identity adopted by the gentlemen of science and the man of science, both from the nineteenth century, and the professional scientist of the twentieth century. Scholars have used the term "gentlemen of science" to refer those men who practiced science in the first half of the nineteenth century, following Jack Morell and Arnold Thackray's usage in their *Gentlemen of Science: Early Years of the British Association for the Advancement of Science* (1982). Relatively few of the gentlemen of science were actually genteel by firth. They were committed to the serious pursuit of knowledge as a vocation, but not for pay.[10] White argues that "man of science" was the "most common generic term for a scientific practitioner in Britain and North America from the middle of the nineteenth century through the 1920's." "The man of science" was not the familiar figure "we now associate with the laboratory and the white coat." Rather, it referred to a mixed community of persons with technical expertise as well as broader interests. A "man of science" was not a paid professional. In Britain a systematic course of training, or a typical career path, was not in place until the last quarter of the century when state-funded, academic research science became more dominant. Science was thought of as a calling, as White puts it, pursued for its intrinsic merits and with a sense of higher purpose that was quite apart from any material or financial gain." The "man of science" was presented as a moral figure standing apart from politics and private interests in order to provide knowledge beneficial to society. According to White, "the man of science" was specific to the United States and Britain as it had no exact counterpart in other countries ③ . The upshot of all this is that care must be taken to understand that the professionalization of science was a lengthy process that did not occur overnight and that the nature of the process varied in different parts of the world. Huxley and his allies may have expressed their desire from the middle of the century on for some kind of professionalization process to take place within the British scientific community, but this was more an ideal to be reached in the future than a reality that existed before the beginning of the twentieth century.

But focusing on professionalization tells only half of the story. At the same time that historians of British science have re-evaluated how the process of professionalization played out during the nineteenth century, they have also maintained that a whole new cast of historical actors should be studied in addition to the members of the scientific elite that were previously the center of attention. Figures that might have previously been considered outside the domain of

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①For discussions of other scientific naturalists and professionalization, such as Karl Perason and Joseph Dalton Hooker, see: Theodore M. Porter, *Karl Pearson: The Scientific Life in a Statistical Age*. Princeton, NJ and Oxford: Princeton University Press, 2004, 4; Jim Endersby, *Imperial Nature: Joseph Hooker and the Practices of Victorian Science*. Chicago and London: University of Chicago Press, 2008, 22-26.

②Paul White, "The Man of Science," in *A Companion to the History of Science*, ed. B. Lightman, 153-163, and Cyrus C. M. Mody, "The Professional Scientist," in *A Companion to the History of Science*, ed. B. Lightman, 164-177

③White, "The Man of Science," 153-155, 159.

the history of science were given careful consideration and incorporated into the stories that historians wanted to tell about nineteenth century science. A few years before Secord's call for a big picture, Adrian Desmond explored the world of working-class science in his *The Politics of Evolution: Morphology, Medicine, and Reform in Radical London* (1989). Desmond argued that historians of nineteenth century British science needed to borrow the methods of social historians to get at a history of biology "from below" instead of being dazzled by elite scientists. In his book he discussed how radical working-class figures exploited Lamarckian evolutionary theory and French anatomy, with its emphasis on self-development, to support a more egalitarian vision of society. Not only did Desmond shed light on a little-known evolutionary tradition in Britain in the early nineteenth century, he simultaneously helped us to understand why Darwin did not publish his *Origin of Species* (1859) earlier: he was afraid that his theory might be appropriated by radicals, particularly during the period of Chartist violence in the late thirties and early forties.[11] While Desmond dealt largely with the incorporation of evolutionary theory into political rhetoric, five years later Anne Secord, in her now classic article "Science in the Pub," explored how artisan botanists did science in the public house through a communal method of learning. To Secord, members of the working class did science in the obscurity of the public house so it could be their own rather than a vehicle for Whig reformers to promote the values of improvement.[12]

Working class scientists were not the only group that historians began to examine. Iwan Morus investigated scientific instrument-makers in his *Frankenstein's Children: Electricity, Exhibition and Experiment in Early Nineteenth-Century London*.[13] He argued that although instrument-making was an essential part of the making of scientific knowledge, and although it had provided the qualifications necessary to be a part of the scientific elite in the eighteenth century, in the nineteenth-century instrument-makers could not be knowledge-makers. John Herschel understood natural philosophy to be open and transparent, but craft, which included instrument-making, was closed and secretive. "The view of how knowledge was properly made and by whom that became dominant during the Victorian period did not accommodate easily the view that knowledge was embodied in its instruments.," Morus asserted ① . Morus has also drawn attention to laboratory assistants and local informants who, along with instrument makers and artisans, played an important role in the making of scientific knowledge. But since they worked behind the scenes, they have until recently remained anonymous and invisible②.

Two more groups that historians began to include in a significant way since the early 1990's within their picture of nineteenth century British science were illustrators and popularizers. Including these groups has provided historians more scope to investigate the participation of women in science, though, of course, there were male illustrators and popularizers. The scholarship in general on women in nineteenth-century British science has been particularly rich and stimulating. Ann Shteir's *Cultivating Woman, Cultivating Science* (1996) discussed the women who wrote about botany from 1760 to 1860, while Barbara Gates looked at the writing, illustrating, teaching, and political activism of women who felt a connection with the natural world in her *Kindred Nature* (1998).[14, 15] Suzanne Sheffield's *Revealing New Worlds* (2001) focused on three Victorian women naturalists, Margaret Gatty, Marianne North, and Eleanor Ormerod.[16] But there have also been studies that have concentrated specifically on women as illustrators and popularizers③. Women may have been excluded from universities until the end of the century, prevented from joining many societies by the men of science, portrayed as intellectually inferior by Darwin due to the evolutionary process, but they nevertheless

①Iwan Rhys Morus, "Invisible Technicians, Instrument-Makers and Artisans," in *A Companion to the History of Science*, B. Lightman (Ed.) 97-110, on p. 101.

②Ibid., 97-110.

③Valérie Chansigaud, "Scientific Illustrators," in *A Companion to the History of Science*, ed. B. Lightman, 111-125, on p. 120; Ann B. Shteir and Bernard V. Lightman, eds., *Figuring it Out: Science, Gender, and Visual Culture*. Hanover, N.H.: Dartmouth College Press, 2006; Bernard Lightman, *Victorian Popularizers of Science: Designing Nature for New Audiences*. Chicago: University of Chicago Press, 2007.

did not allow these obstacles to deter them. Becoming a popularizer of science, or supplying illustrations for scientific texts, became an accessible route to science for many women.

In sum, since the early 1990's, historians of nineteenth-century British science have recognized that the focus of attention should not be solely on the elite figure of the man of science or the process that led to the creation of the professional. Rather, we should also consider the important roles played by artisans, laboratory assistants, instrument-makers, illustrators, and popularizers in the making of knowledge in this period. Only then will we understand both how science was practiced and what it meant to those who belonged to the scientific community.

II. Places and Spaces

Just as a big story about nineteenth-century British science could be told focusing on the diverse roles played by would-be professional scientists, their laboratory assistants, the instrument-makers, the illustrators, and the popularizers in the scientific community, we could also use recent scholarship to tell a connected, but different, story that centers on the places and spaces of science in this period. All scientists, whatever role they assume, must perform that role in a specific space. David Livingstone, a historical geographer of science, has emphasized that space is not a neutral "container" in which social life takes place. Rather, Livingstone insists, space is "constitutive of systems of human interaction."[17] When we are considering critical sites in the generation of knowledge, such as the university, the field, or the laboratory, we always need to ask, who manages that space? What are its boundaries? Who is allowed access? What are the politics of space at play? Paying attention to place means taking into account the local, regional, national, transnational, and global features of science①. This is a matter of scale. Studying the remarkable range of scientific spaces in nineteenth century Britain, as well as deciding which scale we will highlight when it comes to place, opens up numerous possibilities. It gets us away from the emphasis on people, their roles, and their identities. It allows us to see how there were important spaces outside those in which elite scientists operated while looking at a variety of scales provides us with different perspectives on where knowledge was created②.

The spatial organization of British science changed significantly over the course of the nineteenth century. New spaces were created and older ones were refashioned. We can roughly divide up the stages of this process of change into three periods. There is the pre-1820 period, in which the botanist and scientific statesman Joseph Banks controlled three important spaces. Then there is the period between 1820 and 1850, when the gentlemen of science were in command. Finally, there is the post-1850 period when scientific naturalists like Huxley began to exercise influence leading to a transformation of important scientific spaces. However in each stage there were always spaces that operated in opposition to the groups that dominated the scene.

Up till his death in 1820, Joseph Banks was the definitive power broker in British science. He ran the three privileged spaces of science in the early nineteenth-century, the Royal Institution, the Royal Society, and Kew Gardens. They were all spaces of the landed aristocracy and the upper class where the importance of agricultural science was emphasized. At the end of the eighteenth century both George III and the Tories saw agricultural improvement as the path to national prosperity. After Banks was appointed by George III in 1772 to reorganize Kew, it became a great botanical exchange house for the empire. Under Banks the collections at the Royal Garden expanded, and botanists trained there worked on Admiralty vessels, for the English East India Company, and in colonial gardens around the world. The Royal Society,

①In what follows, due to space constraints, I stick primarily to the spaces of science in Britain. But looking at British scientific places in the larger context of empire is, of course, an important theme in recent scholarship.

②For a more detailed discussion of these issues see: Bernard Lightman, "Refashioning the Spaces of London Science: Elite Epistemes in the Nineteenth-Century," in *The Geographies of Nineteenth-Century Science*, ed. David N. Livingstone and Charles W. J. Withers. Chicago and London: University of Chicago Press, 2011, 25-50. From what follows in this section I draw heavily on this piece.

which Banks presided over from 1778 until his death, was devoted to natural history, the study of antiquities, and agricultural improvement. Banks opposed on principle the founding of metropolitan specialist societies as he believed that they undermined the power of the Royal Society. The Royal Institution was first proposed at a meeting in 1799 at Banks's Soho Square house with the goal of applying science to the needs of the nation and especially to agriculture.[18, 19]

After Bank's death, scientific spaces slowly began to shed facets of their aristocratic science. From about 1820 to 1850, old sites were modified and new sites arose as the geography of British science was subtly reconfigured. Reformers wanted to alter the politics of science. The reformers came from two groups, the gentlemen of science and the Utilitarians. The gentlemen of science pushed for change in such new spaces as the British Association for the Advancement of Science. Many of the gentlemen of science in this period were educated at Anglican Cambridge, and they belonged to the Cambridge Network, a loose convergence of scientists, historians, dons, and other scholars. Important scientists such as George Airy, Charles Babbage, John Herschel, George Peacock, and William Whewell were key members of the Network. They worked to modernize the study of mathematics at Cambridge by converting the university from Newtonian mathematics to the new French methods of analysis. They inaugurated a new era in British physical science and moved to undermine the emphasis on natural history, especially the agricultural sciences. [20, 21] The men of science were joined by the Utilitarians in the push to reform aristocratic spaces of science. The Utilitarians saw science as a professional tool to be used to create a body of knowledge useful to the reformers in government and in the professions. This vision of science was embodied in the founding in 1826 of London University. Utilitarian conceptions of science was also to be found at the Royal Institution, through the chemist William Thomas Brande, the Statistical Department of the Board of Trade (found in 1832), and the Geological Survey (established in 1835)①.

The three sites that Banks had controlled were not immune to the winds of change. The reformers refashioned them. At the Royal Institution, Michael Faraday shifted the emphasis from agricultural improvement to natural philosophy and the value of pure research. Kew was also undergoing a metamorphosis from royal to public garden. It became a public institution when William Hooker took charge in 1841. After moving to Kew, Hooker worked to transform it into a center for scientific research as well as a place for the amusement and edification of the nation. Similar developments took place at the Zoological Society of London's Regent's Park Zoo, which became far more open to the public by the middle of the century. Bank's Royal Society was viewed by the gentlemen of science as being tainted by corruption and the cultivation of the nobility. They were opposed to it domination by men who were ignorant of science. Led by Herschel in 1830, reformers failed to make the changes they desired, but by the late 1840's alterations in the statutes of the Royal Society transformed it from an absolute to a constitutional monarchy②.

White older aristocratic sites were being refashioned, the men of science opened up new scientific spaces during this period. The British Association for the Advancement of Science was created in 1831 as a peripatetic organization. The Cambridge Network was central to the BAAS.

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①Morris Berman, *Social Change and Scientific Organization: The Royal Institution, 1799-1844*. Ithaca, NY: Cornell University Press, 1978, 110, 113-123; Peter Alter, *The Reluctant Patron: Science and the State in Britain*, 1850-1920. Oxford: Berg, 1987, 25; Adrian Desmond, *The Politics of Evolution: Morphology, Medicine, and Reform in Radical London*. Chicago: University of Chicago Press, 1989, 26, 28, 33-41.

②Sophie Forgan, "Faraday—From Servant to Savant: The Institutional Context," in *Faraday Rediscovered: Essays on the Life and Work of Michael Faraday*, ed. David Gooding and Frank A. J. L. James. Basingstoke: Macmillan, 1985, 64; Drayton, *Nature's Government*, 168, 180, 184, 188; Harriet Ritvo, *The Animal Estate: The English and Other Creatures in the Victorian Age*. London: Harvard University Press, 1987, 217, 230, 239; David Philip Miller, "Between Hostile Camps: Sir Humphry Davy's Presidency of the Royal Society of London, 1820-1827," *British Journal for the History of Science* 16 (March 1983), 18; Roy MacLeod, "Whigs and Savants: Reflections on the Reform Movement in the Royal Society, 1830-48," in *Metropolis and Province: Science in British Culture*, 1870-1850, ed. Ian Inkster and Jack Morell, Philadelphia: University of Pennsylvania Press, 1983, 55-90.

Whewell, Sedgwick, and Airy were intimately involved in its intellectual and managerial policies. The rapid growth of museums was another signal that scientific spaces were in the process of being reconfigured. The museum was the central scientific institution for much of the Victorian period. The Museum of Practical Geology on Jermyn Street in London (opened in 1851) brought together and displayed materials gathered by the Geological Survey. It defined nature as useful by teaching viewers to understand how natural resources were transformed into commercial products. [22] At the Hunterian Museum at the Royal College of Surgeons, Lincoln's Inn Fields, in London, the prominence of vertebrate paleontology illustrated the scientific epistemology of natural theology. Owen was one of the most active supporters of the movement to expand museum collections and to turn them to educational and research purposes. [23]

But not all sites were scenes of gentlemanly and Utilitarian science in the second quarter of the nineteenth century. For some, the reformist inclinations of gentlemen of science and Utilitarians did not go nearly far enough. The founding of the secular London University provided a hospitable site on Gower Street for Scottish anatomists enamored with French evolutionary theory. From this base of operations, they could use radical Lamarckism to challenge the Tory-Anglican establishment and argue for the reform of privileged aristocratic institutions. But they were also critical of the gentlemen of science, who appeared to them to be too conciliatory in their push for reform and too dependent on natural theology as a framework for their science. London University was not the only new educational institution founded at this time. A number of new "private" or nonhospital medical schools were founded after the late 1820s with close ties to Nonconformism. Disadvantaged both socially and in the medical world, medical Dissenters were receptive to the new Continental anatomies established at London University①.

Scientific spaces were reconfigured once again as a new generation of practitioners arrived on the scene at the midpoint of the century, the scientific naturalists. Their aim was to make scientific spaces hospitable to their goals, which included the secularization of nature, the professionalization of their discipline, and the promotion of expertise. Representatives of the new generation included Thomas Henry Huxley, lecturer at the Royal School of Mines, John Tyndall from the Royal Institution, and Joseph Dalton Hooker, who became the director of Kew. These three men recognized that to accomplish their goals they needed to refashion many of the sites of gentlemanly science and it was imperative to create new scientific spaces. One space of expertise was particularly important to them: the laboratory, where they could engage in systematic experimentation. As Catherine M. Jackson has asserted, "the laboratory is the iconic space of modern science."②

Joseph Dalton Hooker succeeded his father as director of Kew in 1865. Under him a fundamental change took place in Kew's identity as an institution. The younger Hooker by 1872, was presenting the gardens as principally committee to pure research and the imperial economy ③ . Kew could best serve the public interest, according to Hooker, by becoming both a center for botanical research as well as a public garden. In 1876 Hooker open the Jodrell Laboratory, which was designed for research in plant physiology, paleobotany, anatomy, cytology, and other branches of botany requiring controlled laboratory experiments. [24]He continued to allow only serious botanical students and artists into the garden in the morning and resisted all attempts to extend the garden's opening hours for the general public. [25] At the Royal Institution, the mantle of leadership was in the process of passing from Faraday to Tyndall. The Royal Institution was the primary space in which Tyndall practiced his science from his appointment as professor of natural philosophy in 1853 until he retired in 1887. In the Royal Institution's well-equipped laboratory, still a rarity in mid-century Britain, Tyndall continued Faraday's emphasis on original research, though he also delivered public lectures. In his sixty-

① Desmond, *The Politics of Evolution*, 152-153.
② Catherine M. Jackson, "The Laboratory," in *A Companion to the History of Science*, 296.
③ Drayton, *Nature's Government*, 219.

foot biological laboratory in the Science Schools Building at South Kensington, Huxley was free to teach his students to view nature through secular eyes. Built in 1871, the laboratory was based on Berlin and Bonn models. Joined by a team of lab assistants, Huxley could train the science teachers who would return to the factory towns. The South Kensington laboratory became a model of effective practical teaching in botany and physiology that was exported to other academic institutions in the 1870s and 1880s by Huxley's former demonstrators after they left his lab. Huxley's new site signaled the shift from museum display to the lab as the new knowledge-manufacturing space for science.[26, 27]

Although Huxley, Tyndall, Hooker, and their allies successfully refashioned sites in line with their agenda, such as the Royal Institution and Kew Gardens, and although they created new spaces to further their goals, such as Huxley's South Kensington laboratory, vast tracts of the scientific landscape were not under their control in the second half of the nineteenth century. Aristocratic spaces, such as the country-house, continued to be sites of scientific work. Aristocrats, such as Lord Salisbury, William Siemans, William Armstrong, and Lord Rayleigh, built laboratories on their landed estates. Their science was embedded in aristocratic and Christian values. Aristocrats and their country-house science continued to play significant roles in the second half of the nineteenth century, challenging the authority of Huxley and his allies. [28, 29] The museum, one of the key spaces opened up by the gentlemen of science, could serve a similar purpose. The Oxford University Museum, completed in 1860, embedded the principles of the natural theology tradition in its architecture. The Natural History Museum in South Kensington, which opened in 1881 under the direction of Richard Owen, was built along similar lines. Huxley had opposed Owen's plan for a unified museum of natural history since it increased the status of the museum as a site of ongoing research. Huxley believed that the laboratory should be considered the most important space for the practice and teaching of science①.

Thinking spatially about science over the entire course of the nineteenth century gives us a renewed appreciation for how places can become sites of contention as the composition of the scientific elite changes, as the role of that elite is altered, and as new groups attempt to force their way into the charmed circle of power. Behind the formidable and seemingly solid walls of the buildings that house scientific sites, we discover malleable spaces. Sites are refashioned several times over the century to fit the needs of various groups or individuals. New sites are also created to serve the needs of new generations.

III. Communicating Knowledge

A third big picture can be developed if we focus on the changes in how science was communicated during the nineteenth century. Instead of putting the scientist, or the space in which the scientist worked, at the center of things, we can examine how knowledge was transferred between sites through a variety of mediums, including print, visual, and oral. This involves exploring periodicals, books, lectures, museums, and even literature. These mediums were used for scientists to communicate to each other and to the public. But they were also used by popularizers and others who were not scientific practitioners to convey their thoughts about science to the reading audience. The many modes of scientific communication has been a topic of much scholarly interest since the turn of the century, especially after the publication of James Secord's *Victorian Sensation* (2000). In this groundbreaking book, Secord argues that a communication revolution took place in the second quarter of the nineteenth century that represented the "greatest transformation in human communication science the Renaissance." It led to "opening the floodgates to a vastly increased reading public." ② The communication revolution took place in Britain

①Yanni, *Nature's Museums*, 80-84; Paul White, *Thomas Henry Huxley: Making the "Man of Science"*. Cambridge: Cambridge University Press, 2003, 34-35, 56-57, 65; Rupke, *Richard Owen*, 97-100.

②James Secord, *Victorian Sensation: The Extraordinary Publication, Reception, and Secret Authorship of Vestiges of the Natural History of Creation*. Chicago: University of Chicago Press, 2000, 2.

due to the introduction of steam-driven presses, the reduction of the "taxes on knowledge," increasing literacy rates, the lowering of the price on paper, and the development of the railway system. The upshot was an explosion of cheap science books and periodicals in the second half of the nineteenth century, which both contributed to, and reflected, the growing interest in science in Victorian culture.

The communication revolution led to the creation of more specialized periodicals for scientists to convey the results of their research to each other. Many new scientific journals were founded in the second half of the nineteenth century, like *Nature* in 1869, edited by Norman Lockyer. *Nature* became one of the most prestigious scientific journals in the world. Although it began as a journal designed to attract both the public and scientific practitioners, it quickly targeted the latter audience. As Melinda Baldwin has argued, *Nature* "was not simply a vessel for important research articles: it was a site where scientific practitioners could debate about how to define themselves and discuss their place within a wider society."[30] But the latest scholarship on scientific periodicals is not limited to specialized journals for scientists.[31-33] The recently published edited collection *Science Periodicals in Nineteenth-Century Britain* avoids thinking of scientific journals as the "favored genre of legitimated knowledge" and instead examines the role that they played in the construction of scientific communities.[34] It is also important to note that scientific subjects were "omnipresent" in the general periodical press to the point that it has been claimed that they played a far greater role than books in molding the public understanding of new scientific discoveries, theories, and practices.[35] Newspapers are also a topic that have received attention. In his *News from Mars*, a study of how newspapers and popular journalism forged the new astronomy from 1860-1910, Joshua Nall examines the roles played by media in science.[36]

The newer scholarship on science books has tended to emphasize how knowledge was communicated in that form to the British public ①. The new conditions in the world of publishing created by the communications revolution of the early nineteenth century produced a powerful group of scientific authors who opposed a number of the aims of the would-be professionals of science by continuing to incorporate religious themes into their work and by insisting that they spoke on behalf of science. A new polity of readers was created that became the audience for the works written by popularizers of science. By midcentury, publishers were finding that a market existed for these kinds of books ② —at the same time that Huxley and his allies were establishing themselves in positions of power and pushing their agenda of obtaining autonomy for science. Popularizers therefore represented a real obstacle to Huxley and the other scientific naturalists in their attempt to establish the idea of the professional scientist, based on a notion of expertise and special training③.

The topic of how knowledge was communicated to the public through lectures has also been examined extensively by scholars. Here again, attention has not been limited to the practitioners. Finnegan's *The Voice of Science* is the first book-length study of scientific lecturing, and he covers both practitioners, such as John Tyndall, T. H. Huxley, Alfred Russel Wallace, as well as non-practitioners, such as Richard Proctor and Henry Drummond. Finnegan argues that popular science lectures, "understood in performative terms and as thoroughly embedded in a wider lecture culture, were a crucial means for shaping and extending the public authority

① Three central works that together cover the entire nineteenth century are: Jonathan R. Topham, *Reading the Book of Nature: How Eight Best Sellers Reconnected Christianity with the Sciences on the Eve of the Victorian Age*. Chicago: University of Chicago Press, 2022; Secord, *Victorian Sensation*; Lightman, *Victorian Popularizers of Science*.

② The increased attention to the role of publishers in the production of science books and periodicals can be found in Secord, *Victorian Sensation;* Lightman, *Victorian Popularizers of Science*; Aileen Fyfe, *Steam-Powered Knowledge: William Chambers and the Business of Publishing, 1820-1860*, Chicago: University of Chicago Press, 2012; Aileen Fyfe, *Science and Salvation: Evangelicals and Popular Science Publishing in Victorian Britain*, Chicago: University of Chicago Press, 2004.

③ Lightman, *Victorian Popularizers of Science*, 494-496.

affective power and cultural meanings of science."[37] Understanding scientific lecturing requires attention to the crafting of vocal performance, the use of proper body language, and the type of venue in which the lecture was delivered ①. Many of the most well-known scientific lecturers could draw huge crowds due to their use of visual spectacle and experimental demonstrations, such as John Tyndall, Richard Proctor, John George Wood, and Henry Pepper②.

Museums have already been mentioned as spaces in which the gentlemen of science performed their research but which slowly gave way to the laboratory in the latter half of the century when scientific naturalists were attempting to transform the spatial organization of science. Ironically, just as would-be professionals no longer saw museums as important scientific sites, the number of scientific museums and exhibitions began to grow. They became useful for the communication of knowledge to the public. Scientific exhibitions grew due to the success of the Great Exhibition in 1851 while museums increased after the Museums Act of 1845 that enabled civic museums to be established throughout the provinces. Among the new museums devoted to science were the Museum of Practical Geology (1851) and the British Museum (Natural History) in South Kensington (1881). In addition to these museums there was a wide range of more commercial enterprises, ranging from the relatively long term—such as the Polytechnic (1838-1881)--to ephemeral shows, such as the exhibition of so-called Aztec children who took London and Dublin by storm in the summer of 1853③.

Historians of science have studied the large, well-known natural history museums such as the British Museum. Here the emphasis is often on significant nineteenth-century museum curators such as Richard Owen. Owen was the curator of the museum at the Royal College of Surgeons, superintendent of the Department of Natural History at the British Museum, and founder of the Museum of Natural History. For him museums were meant to illustrate the principles of Oxford natural theology and German idealism. Nicolaas Rupke has argued that Owen's career, which lasted from 1827 to 1883, coincided with the "age of museums." The period in which most of Britain's great museums were founded ④. Perhaps the most important development in recent scholarship has been the study of science museums and science exhibitions in relation to each other. Important in this context is Tony Bennett's *The Birth of the Museum*, a good example of the new scholarship of the 1990's. His concept of the "exhibitionary complex" encouraged scholars to think of museums and exhibitions as part of a larger entity sharing similar characteristics. He explicitly grouped the British Museum, as well as other museums, together with more temporary and dramatic exhibitions, such as the Great Exhibition and Wyld's Great Globe.[38] The advantage of Bennett's concept of "exhibitionary complex" makes it clear that both museums and exhibitions are sites of scientific display that developed simultaneously. This means following objects, exhibitors, and theories both within the walls of museums and beyond them, considering not only static displays but, crucially, the performances and theatrical settings that brought knowledge to life. Building on Bennett's approach, the authors in the edited collection *Science Museums in Transition* (2017) explore more deliberately what museums and exhibitions shared in common.[39]

IV. Concluding Thoughts

① Diarmid A. Finnegan, "Lectures," in *A Companion to the History of Science*, 414-427.

② Jill Howard, "'Physics and Fashion': John Tyndall and His Audiences in Mid-Victorian Britain," *Studies in History and Philosophy of Science* 35, no. 4(2004), 729-758; Lightman, *Victorian Popularizers*, 167-218, 305-307; Bernard Lightman, "Lecturing in the Spatial Economy of Science," in *Science in the Marketplace: Nineteenth-Century Sites and Experiences*, Chicago: University of Chicago Press, 2007, 97-132; Simon Schaffer, "Transport Phenomena: Space and Visibility in Victorian Physics," *Early Popular Visual Culture* 10, No. 1(2012), 71-91

③ Rupke, *Richard Owen*, 13-15; Sadiah Qureshi, *Peoples on Parade: Exhibitions, Empire, and Anthropology in Nineteenth-Century Britain*, Chicago: University of Chicago Press, 2011.

④ Rupke, *Richard Owen*, 13.

I have explored how historians of nineteenth-century British science have applied analytical categories to the field in order to formulate three big pictures that are not dependent on an emphasis on the shift in theory represented by the concept of a Darwinian revolution. In the case of the roles and identities of the scientist, the story about the professionalization of the elite scientist has been balanced by the inclusion of a larger cast of characters such as artisans, instrument makers, popularizers, illustrators, laboratory assistants, and women. The focus on the rise of the laboratory as the privileged space in which knowledge was created by elite scientists has been complemented by the recognition that old sites were continually refashioned, new ones created, and sites other than the laboratory, such as the country house, the museum, and the exhibition, continued to be important in the latter half of the century. Finally, paying attention to how science was communicated, has led us beyond a concentration on how elite scientists exchanged knowledge with each other, and towards an understanding of the concept of a communications revolution. Not only did this revolution lead to an explosion of cheap science books and periodicals that were read voraciously by the public, but it also fueled interest in science lectures, museums and exhibitions. These three big pictures could be combined into one meta-picture if we don't ignore the complicated relationship between elite practitioners and public science. We do not have to choose, for example, between the story about the professionalization of elite science and the stories about other scientific figures who were a part of the scientific scene. They are all part of the cast of characters that we should be studying if we wish to understand the dynamics at work in nineteenth-century science. We should never forget that the issue of who was considered to be a scientific authority in the nineteenth century was the very point under discussion in this period. A modern, professionalized body of scientists was still in the making in the second half of the nineteenth century, which left open the questions: In which spaces should science be done? How should it be communicated? What, exactly, was science itself? And which groups could participate in the debates on these questions? If we keep these questions in the back of our minds, then the nineteenth century becomes less familiar to contemporary eyes and, as a result, far more interesting to the historian.

References

1. Robert Young, *Darwin's Metaphor: Nature's Place in Victorian Culture*. Cambridge: Cambridge University Press, 1985, 191.
2. William Whewell, "On the Connexion of the Physical Sciences. By Mrs. Somerville," *Quarterly Review*, 51 (1834), 54-68, on p. 59.
3. Frank M. Turner, "The Victorian Conflict Between Science and Religion: A Professional Dimension," *Isis*, 69(1978), 356-376.
4. Frank Miller Turner, *Between Science and Religion: The Reaction to Scientific Naturalism in Late Victorian England*. New Haven, CT: Yale University Press, 1974.
5. Frank M. Turner, *Contesting Cultural Authority: Essays in Victorian Intellectual Life*. Cambridge: Cambridge University Press, 1993.
6. Gowan Dawson and Bernard Lightman, "Introduction," in Gowan Dawson and Bernard Lightman (Ed.) *Victorian Scientific Naturalism: Community, Identity*, *Continuity*, Chicago and London: University of Chicago Press, 2014, 20.
7. Ruth Barton, *The X Club: Power and Authority in Victorian Science*, Chicago: University of Chicago Press, 2018.
8. Stefan Collini, *Public Moralists: Political Thought and Intellectual Life in Britain 1850-1930*, Oxford: Clarendon Press, 1911, 203, 220.
9. Ruth Barton, "Huxley, Lubbock, and Half a Dozen Others: Professionals and Genletmen in the Formation of the X Club, 1851-1864," *Isis* 89(1998), 410-444.
10. James A. Secord, *Victorian Sensation: The Extraordinary Publication, Reception, and Secret Authorship of "Vestiges of the Natural History of Creation,"* Chicago: University of Chicago Press, 2000, 403-404.
11. Adrian Desmond, *The Politics of Evolution: Morphology, Medicine, and Reform in Radical London*. Chicago and London: University of Chicago Press, 1989, 20, 412.
12. Anne Secord, "Science in the Pub: Artisan Botanists in Early Nineteenth-Century Lancashire," *History of Science* 32(1994), 169-315.
13. Iwan Rhys Morus, *Frankenstein's Children: Electricity, Exhibition and Experiment in Early Nineteenth-Century*

London. Princeton, New Jersey: Princeton University Press, 1998.

14. Ann B. Shteir, *Cultivating Women, Cultivating Science: Flora's Daughters and Botany in England, 1760-1860.* Baltimore: The Johns Hopkins University Press, 1996.
15. Barbara T. Gates, *Kindred Nature: Victorian and Edwardian Women Embrace the Living World*. Chicago: University of Chicago Press, 1998.
16. Suzanne Le-May Sheffield, *Revealing New Worlds: Three Victorian Women Naturalists*. London and New York: Routledge, 2001.
17. David N. Livingston, *Putting Science in Its Place: Geographies of Scientific Knowledge*. Chicago and London: University of Chicago Press, 2003, 7.
18. Iwan Morus, Simon Schaffer, and Jim Secord, "Scientific London," in Celina Fox (Ed.) *London—World City, 1800-1840*. New Haven, CT: Yale University Press, 1992, 130;
19. Richard Drayton, *Nature's Government: Science, Imperial Britain, and the "Improvement" of the World*, New Haven, CT: Yale University Press, 2000, 88.
20. Susan Faye Cannon, *Science in Culture: The Early Victorian Period*, New York: Dawson and Science History Publications, 1978, 30, 33-35, 39-40, 44, 63.
21. David Philip Miller, "The Revival of the Physical Sciences in Britain, 1815-1840," *Osiris* 2(1986), 110.
22. Carla Yanni, *Nature's Museums: Victorian Science and the Architecture of Display*. New York: Princeton Architectural Press, 2005, 52, 58.
23. Nicholas A. *Rupke, Richard Owen: Naturalist*, New Haven, CT: Yale University Press, 1994, 13, 59, 61.
24. W. B. Turrill, *Joseph Dalton Hooker: Botanist, Explorer, and Administrator*. London: Thomas Nelson and Sons, 1963, 136.
25. Jim Endersby, "Hooker, Joseph Dalton," in Bernard Lightman (Ed.) *Dictionary of Nineteenth-Century British Scientists*, Bristol: Thoemmes Continuum Press, 2004, 2: 999.
26. Adrian Desmond, *Huxley: From Devil's Disciple to Evolution's High Priest*, Reading, MA: Addison-Wesley, 1997, 395.
27. Graeme Gooday, "'Nature' in the Laboratory: Domestication and Discipline with the Microscope in Victorian Life Science," *British Journal for the History of Science*, 24(1991), 333-40.
28. Donald Luke Opitz, "Aristocrats and Professionals: Country-House Science in Late-Victorian Britain," PhD Dissertation, University of Minnesota, 2004, 7-10, 33, 101, 109, 256-257.
29. Donald L. Opitz, "'This Hosue is a Temple of Research': Country-House Centres for Late Victorian Science," in David Clifford, Elisabeth Wadge, Alex Warwick, and Martin Willis (Ed.) *Repositioning Victorian Sciences: Shifting Centres in Nineteenth-Century Scientific Thinking*. London: Anthem Press, 2006, 143-153.
30. Melinda Baldwin, *Making Nature: The History of a Scientific Journal*. Chicago: University of Chicago Press, 2015, 5.
31. Alex Csiszar, *The Scientific Journal: Authorship and the Politics of Knowledge in the Nineteenth Century*. Chicago: University of Chicago press, 2018.
32. Aileen Fyfe, "Journals and Periodicals," in *A Companion to the History of Science*. Bernard Lightman, (Ed.) Chichester, UK: John Wiley & Sons Ltd., 2016, 387-397.
33. Aileen Fyfe, Noah Moxham, Julie McDougall-Waters and Camilla Mørk Røstvik, *A History of Scientific Journals: Publishing at the Royal Society 1665-2015*. London: UCL Press, 2022.
34. Gowan Dawson and Jonathan R. Topham, "Introduction: Constructing Scientific Communities," in Gowan Dawson, Bernard Lightman, Sally Shuttleworth, and Jonathan R. Topham (Ed.) *Science Periodicals in Nineteenth-Century Britain: Constructing Scientific Communities*, Chicago: University of Chicago Press, 2020, 1-32, on p. 3.
35. Geoffrey Cantor, Gowan Dawson, Graeme Gooday, Richard Noakes, Sally Shuttleworth, and Jonathan R. Topham (Eds.) *Science in the Nineteenth-Century Periodical: Reading the Magazine of Nature*. Cambridge: Cambridge University Press, 2004, 1-2.
36. Joshua Nall, *News from Mars: Mass Media and the Forging of a New Astronomy, 1860-1910*. Pittsburgh: University of Pittsburgh Press, 2019.
37. Diarmid A. Finnegan, *The Voice of Science: British Scientists on the Lecture Circuit in Gilded Age America*. Pittsburgh: University of Pittsburgh Press, 2021, 4.
38. Tony Bennett, *The Birth of the Museum: History, Theory, Politics*. London: Routledge, 1995, 72, 84.
39. Carin Berkowitz and Bernard Lightman (Eds.) *Science Museums in Transition: Cultures of Display in Nineteenth-Century Britain and America*. Pittsburgh: University of Pittsburgh Press, 2017.

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