Introduction

Building Global Perspectives in History *of* Science

The Era from 1750 to 1850

Patrick Manning

The scholars included in this volume address global parallels and interconnections in the history of science, centering on the period from 1750 to 1850, a time of dramatic worldwide transformations in economy, politics, society, and culture—including knowledge. They follow and extend the active study of scientific interconnections conducted in recent years. The variety of themes discussed here confirms the complexity of that era's scientific discourse and practice, at stations through Europe, the Americas, and in other parts of the world, in what we have identified as an age of revolutions.[1] In our approach we emphasize that a wide range of transformations took place during that century, as seen in both geographical and topical terms, and we focus on scientific study as a field of activity in contact with others in the midst of those revolutions.

Chapters in the opening section give attention to the many characters and numerous levels of participation in the exchange of knowledge—in forests of the upper Amazon, in the hurricane alley of the Caribbean, and among fauna near the rivers of Suriname. The various participants had their own perspectives, interests, degrees of freedom and agency, and particular type of knowledge. Individual knowledge was framed by the collective knowledge that had been passed on within their social groups,

and which under certain circumstances crossed group boundaries. As the authors have emphasized, separating individuals into categories—imperial, colonial, indigenous, slave—is less important than making the effort to trace the processes by which those in any community preserve past knowledge and gain new knowledge in exchange. These chapters highlight connections in knowledge across communities.

A second set of chapters centers on the work of the great classifier Carl Linnaeus, his associates, and their visions of a system of taxonomy for plants and animals.[2] In these studies, including episodes based in Uppsala, London, and Sierra Leone, arguments are presented on the evolution and successful application of binomial nomenclature and also on the balance between taxonomy as the development of knowledge as such and as a device supporting the hope for economic and social advantages that might result from classificatory work.

Description and taxonomy of plant and animal species, however, were not all incorporated into the Linnaean framework. Chapters in the third section of this volume trace divergences and debates in collection, classification, and characterization of various species. The description of hummingbirds—especially their alleged periodic torpor or hibernation—brought major debate between writers based in Mexico and Europe. Parallel debates accompanied the understanding of birds collected from the frontiers of Paraguay and, later, the exchange and classification of remains of a small South American mammal. In one of these cases, the imperial state facilitated the movement and classification of faunal remains; by the nineteenth century, the exchanges were carried out instead by members of a fledgling international scientific community.

The fourth section of the book pursues the expansion of scientific communities. It includes studies in ameliorating the production of sugar in Cuba, a device for the transport of plants over great distances, and the rationalization of postal communication in India. In these cases, the communities developed innovative practices and effective tasks for the spread, sharing, and concentration of knowledge. Only one of these, the postal system, relied primarily on government support.

The essays of the fifth section, drawing on literature within and beyond history of science, assert frameworks for expanding studies of history of science. Each addresses a linkage of economics and science in ways that encompass and yet exceed the boundaries of the great divergence debate. One articulates a labor history of science, addressing race and economics. The other focuses on consumption, extending economic thinking on

consumption to model the production and consumption of data in what became known as Humboldtian science.

This volume results from a collaboration of fourteen scholars working from two disciplinary standpoints. In it, historians of science seek to link specific studies to analysis at a broad scale, while world historians seek to connect their broad scope to issues in history of science. In spatial terms, half of the studies apply to Spanish America, while others apply to Europe, West Africa, India, and Asia more generally. Four authors are based principally in history of science, nine are based in history; in addition, the authors include one biologist and one social scientist. The nine historians include three who specialize in world history, three who specialize in economic and environmental history, and three others. Arguably, the authors are an unusually diverse group for work on a volume such as this. The result is at once a reconsideration of established interpretations and a new intellectual venture.

History of Science and World History: Toward a Fuller Conversation

History of science and world history, two of the many subfields in the wide-ranging discipline of historical studies, have reasons to develop closer contact and fuller understanding of their specific contributions. Each field is fundamentally temporal, focusing energy on reconstructing and problematizing developments in the past. At the same time, both fields focus centrally on developing the implications of past processes for understanding the transformations and dilemmas of the present, that is, world history provides background to rapid globalization in general, while history of science provides background to today's dramatic scientific change.

History of science became an internationally organized field of study at the end of World War II and has since maintained a high level of research and analysis on scientific issues from the ancient world to contemporary times.[3] (Institutionally, it is studied in departments of history of science, in departments of history, and in departments of science and technology studies.) One dimension of the field relies on specialized studies focusing on the details of scientific analysis.[4] At the same time, historians of science participate in a wider discourse that includes the social context of scientific knowledge. At this level, and especially for early modern and modern times, there is great overlap of history of science with economic, political, social, and cultural history. For instance, studies of the Scientific

Revolution overlap significantly with analysis of the Industrial Revolution, capitalism, and empire; Joel Mokyr and Margaret Jacob are well-known both in history of science and in historical studies broadly.[5]

The field of world history developed in later decades; it gained a relatively full set of institutions and programs only at the end of the 1990s. In an overlapping set of processes that has been confusing to some, global and transnational studies in history developed at similar times but in different directions. Transnational history was the eclectic exploration of linkages across national boundaries that took place in virtually all established fields of history for the eighteenth through the twentieth centuries. The result of this work was expansion of the scope of national literatures plus new attention to "entangled" histories tracing the interaction of two or perhaps more national histories.[6] Approaches in world or global history were taken up by a smaller but more organized group of historians. Their approach challenged the notion that the essence of history took place within national units; they sought to identify patterns of economic, environmental, and other changes at the level of a global system, while also including the interplay of global patterns with those at regional and local levels.[7] From the point of view of the many historians who continued to work within national historical paradigms, transnational and world history were much the same because they worked beyond the national level. With time, however, the distinctions and the overlaps of world historiography and transnational historiography have become clearer.

World history, as it expanded, gave only modest attention to global dimensions of the history of science, although it did rely on research results from historians of science working at localized or civilizational levels. Still, an expression of interest in digging more deeply into history of science came with the 2000 award of the World History Association book prize to a survey text on history of science.[8] World historians have focused on political, commercial, and environmental history, and also on migration and travel. World historians have sought to escape the limits of Eurocentric historiography, considering a wide range of inter-regional and global patterns. The writings of world historians focused, as the field gained momentum, especially on political and economic change.[9] The first clear subspecialty within world history was that of global environmental history.[10] The study of migration, especially over long distances, became a subfield of world historical studies because it linked separate regions into common histories.[11] The broader field of social history, though it expanded impressively in the postwar era, had rather little impact in world history,

perhaps because most social-historical documents were organized at local and national levels rather than in transnational terms. Nonetheless, as concerns for global inequality expand steadily, new efforts are being made to address social history, and especially the history of labor, at a world historical level.[12]

World historical writing as seen in both monographs and textbooks has tended to give little attention to history of science. Perhaps this distance resulted from a concern that science was a Eurocentric issue and ought therefore not to be central in world historical interpretations. In any case, existing surveys in world history, when they refer to history of science, tend to provide brief references to major scientific discoveries rather than exploration of the processes of scientific change.[13] In a distinction that is more likely to persist, world historians show more interest in history of technology than do historians of science. Especially in making long-term comparisons among societies, the differences in types and levels of technology stand out and are commonly taken as causal. Thus, a useful contrast emerges, comparing the approaches of history of science and world history to long-term change, through the views of Joel Mokyr and Arnold Pacey. Mokyr's long-term view of developments in knowledge focused especially on comparisons of scientific knowledge and advanced technology in societies over time. Pacey's approach, in contrast, emphasized the interplay and complementarity of basic technology and advanced technology in a sequence of social situations.[14]

Advances in the History of Early Modern Science

Historians of science turned in the 1990s, with the contemporary focus on globalization, to detailed consideration of science beyond Europe. As they did so, they reviewed earlier interventions on this general topic. Well-known among them were George Basalla's classic article, "The Spread of Western Science," and the multivolume studies led by Joseph Needham on science and technology in China. In addition, studies of imperialism produced in the era of decolonization offered implications for the history of science.[15]

Individual scholars turned in the late twentieth century to study of science in colonial territories. For instance, José Maria López Piñero, after years of historical study of science and medicine in Spain, turned in the 1990s to the Americas, analyzing descriptions of American plants, the introduction of American plants into Spain, and *mestizaje cultural*

in the medicine of New Spain.[16] Juan Pimentel, in a 2000 interpretation of Iberian imperial vision, arguably bridged the gap between Iberian and Anglo-American scholarship.[17]

With the coming of the twenty-first century, studies in the history of science turned significantly toward questions about many parts of the world, emphasizing the regional and topical interconnections in knowledge. Nine major collections, published beginning in 1996 and addressing the era from roughly 1500 to 1850, have focused on a mix of metropolitan and colonial science in Europe, the Americas, and elsewhere. The nine volumes focus, in order, on imperial botanic voyages, commerce and science, Renaissance go-betweens, colonial botany, science and empire, inquiry and invention in technology, science in the Spanish and Portuguese empires, the brokered world of go-betweens, and global cotton textiles.[18] This series of collections began with a volume on imperial voyages edited by David Philip Miller and Peter Hanns Reill, concentrating on botanical investigations. It was followed by a volume that focused more on Europe but on a wider range of issues. Pamela Smith and Paula Findlen, in *Merchants and Marvels*, brought together a collection emphasizing the centrality of commerce in nurturing links that advanced "the representation of nature in art and science." Extending this reasoning, also with a European focus but with attention to "go-betweens" (the intermediary figures who facilitated linkages across cultural boundaries), was the volume edited by Andreas Hofele and Werner von Koppenfels, *Renaissance Go-Betweens*.[19] Extension of these approaches to a focus on overseas regions came with *Colonial Botany*, in which Londa Schiebinger and Claudia Swan edited a collection that explored botanical work in English, French, and Dutch colonies. In one of the best organized of this series of collections, James Delbourgo and Nicholas Dew focused on *Science and Empire in the Atlantic World*. Their introductory essay, in reviewing the literature broadly, treated empire more as umbrella than as principal cause of the expanding scientific investigation that is explored in chapters ranging throughout the Americas. Margaret Jacob, in a concluding essay, linked these visions of science and empire to global capitalism.[20] Major collections then extended to similar issues explored on a wider canvas. In a topical expansion, the interplay of technology with science was the focus of *The Mindful Hand*, which explored technology both within and beyond Europe. And in a geographic expansion, the collection led by Daniela Bleichmar and others on *Science in the Spanish and Portuguese Empires* confirms the argument made earlier by Jorge Cañizares-Esguerra that the substantial scientific investigations sup-

ported by the Spanish and Portuguese monarchies were neglected in the print record because most of the key documents remained in manuscript rather than appearing in books.[21] In a decisively cosmopolitan step, the editors of *This Brokered World* selected a theme explored earlier in mainly European context, that of "go-betweens," and presented a widely ranging set of investigations of scientific and other connections nurtured by such intermediaries. As Sanjay Subrahmanyam described this analytical focus, "A place for the go-between was eventually found only in appealing to the possibility that markets might not be characterized by perfect information. The go-between thus emerged in a world of imperfect information, either as someone who enjoyed rents from the information he possessed, or in terms of formal and informal models that portrayed transactions as games, and go-betweens as products of the manner in which these games were played out."[22]

The geographic terrain for study of history of science has been expanding. One important advance is the expansion in publication on science in Spanish and Portuguese imperial realms for the full period from 1500 to 1800. The strong preference of the Iberian monarchies for maintaining the secrecy of the reports they received in scientific as well as political and social affairs brought a contrast with the English, French, and Dutch traditions, for whom publication in book form was common. Until intensive historical exploration of the Spanish archives began, it appeared from published works that the northern European powers were the only ones to pursue scientific investigations beyond the limits of Europe. In fact, multiple copies of manuscripts did circulate among knowledgeable Iberian officials. José Maria López-Piñero began publication of studies based on such manuscripts in the 1990s and recent publications based on archival research now document the steady advance in scientific study in European colonies, beginning with the Spanish and Portuguese.[23] Work continues to appear on English, French, and Dutch explorations and settlements, including a recent expansion of study of the Pacific. Studies on science in India and China are being linked to those of the Atlantic world; studies of scientific investigation in Africa, while still scarce, are appearing.[24]

The numerous issues, perspectives, and connections revealed in these studies make clear that there was no single trajectory for the change and development in knowledge as global and imperial connections tightened. The *Cambridge History of Science*, in its authoritative overview, places the eighteenth century precisely in the middle of its seven volumes, emphasizing the intermediate and transformative nature of the eighteenth- and

nineteenth-century era in history of science.[25] In the eighteenth-century volume, all of the thirty-six chapters are relevant to world history in some sense, and as many as one-third address questions of overseas contacts, commercial networks, and science outside the West. The specificity of the eighteenth century in the history of science literature—when balanced with world historical debates about the Great Divergence in the global economy (1750–1850)—suggests the interest of a conversation between the two fields, one centering on the eighteenth and early nineteenth centuries.

This was an era of such polymaths as Benjamin Franklin, J. W. von Goethe, and Alexander von Humboldt, as well as lesser-known experts and autodidacts in multiple fields. It was an era of relative balance between a developing system of principled, scientific knowledge and a world that operated through eclectic systems of practical or inherited knowledge. This era preceded the full emergence of the industrial complex, modern universities, and systematic scientific advance. It was a time in which global connections were well established but during which people could still claim to be experiencing encounters with previously unknown others. Empires both expanded and shrank—even collapsed—within this century. The notion of science itself was gradually crystallizing during this period, though with the separation of social science from the body of natural science. This century provides a truly interesting time period for considering the key elements of science in societies of all sorts as they overlapped each other increasingly, and for considering the role of science in tightening global interconnection.

Reconsidering Science in an Age of Revolutions, 1750–1850

The presentation in this volume takes place on two basic levels. At the level of principal topic, the chapters are organized into five sections. The sections focus, in order, on exchanges among ways of knowing, especially exchanges across ethnic lines; the evolution of the Linnaean vision as it extended to multiple arenas in science and economy; debates on description and taxonomy, where these debates tended particularly to set European scientists against researchers in the New World; the logistics, management, and planning of agricultural and economic enterprises as these activities relied on scientific knowledge; and, broadly, analyses of labor and economics in the history of science.

At the level of interactions among the contributions to this volume, numerous additional threads of discussion arose among authors and editors,

the traces of which add to the value of these studies in a way that balances and enhances the basic argument of each author. Indeed, in the following introductory summary of the contributions to this book, the chapters are presented not strictly according to their order in the table of contents but according to parallels, links, and contrasts among chapters as they arose in the course of revisions for publication. Readers are encouraged to read the chapters as they are ordered in the text but are also encouraged to pause occasionally, to flip back and forth through the pages, and to identify the discussions among the chapters that appear in various forms.

The remainder of this section discusses, for five interrelated topics, the emphases of the chapters and their interplay, both with each other and with the history of science literature. First is the role of the state—especially the imperial state—in seeking and developing knowledge of the natural world. Second is the role of civil society (including merchants, missionaries, and independent voyagers) in seeking out knowledge of the natural world. Third is the place of encounters and exchanges in knowledge across the social frontiers brought by language, ethnicity, and also social strata. (Of the latter, such social strata as slaves, mestizos, and creoles grew in population through global interaction.)[26] Fourth, the interplay of the economy with scientific knowledge brought shifts, debates, and reorientations in an era in which social science separated itself from natural science and took up the theorization of social and racial hierarchy. Finally, the nature of scientific practices and the gradual expansion of scientific institutions becomes increasingly evident with time. Discussion on these topics developed among participants in successive drafts of chapters and was reinforced in the course of further exploration of the available literature.

The Role of the State

The state, both national and imperial, supported scientific investigation and sought to gain military, economic, or geopolitical advantage from such study. C. A. Bayly, in *Imperial Meridian*, emphasized the influential role of the state in shaping scientific understanding of the colonial world but balanced this view by presenting the state as but one of many influences in the emergence of modernity in *Birth of the Modern World*. States led in eighteenth-century explorations of the Pacific, the creation of botanical gardens, and the collection of botanical samples.[27]

In this volume, Matthew James Crawford argues that the Spanish monarchy and the Viceroyalty of New Granada led a relatively skillful and

orderly campaign to develop production and use of *quina* (with its active ingredient of quinine), though they were limited by various forces: the indigenous planters, the laborers who did the processing, and the limits on techniques of extraction of the drug. Devyani Gupta, addressing a slightly later period, argues that the British-led establishment of a postal system throughout India allowed for exchange of widely ranging types of knowledge (with perhaps policy choices the highest priority within those), but it allowed the development of systems of information management that would have wide application. While her narrative of the developing postal system gives recognition to its basis in the preexisting postal systems (both government and private) of the Mughal state and numerous princely states, she gives prime emphasis to the steady imposition of British initiative in restructuring the postal system.

As military engineer in service to the Spanish crown, Félix de Azara was sent to Paraguay as a member of an expedition to demarcate and describe the frontier of Paraguay with Brazil. According to Marcelo Fabián Figueroa, Azara took up ornithological research as a sideline to his various expeditions to Paraguayan frontiers but then became interested enough in the collection and description of birds to send collections to Spain and later to write descriptions and taxonomies of his findings. In this case, argues Figueroa, the expansion of the scientific literature came largely as an unexpected by-product of imperial administration. Less clear, at this point in the interpretation, is whether indigenous assistants in the process of collection were limited to manual labor or whether they contributed to the classificatory work for which Azara later became known.

Civil Society

The term "civil society," commonly used in political discourse to refer to individuals and social groups beyond the limits of the state, can be appropriated here as a way to note certain parallels among merchants, missionaries, and voyagers whose scientific investigations were not under control of the state. Although empires, with their armies and navies, were important in scientific connections, the recent literature has given considerable attention to nongovernmental dimensions of scientific study and knowledge exchange. Contributions to the volume edited by Smith and Findlen show the interplay of commerce, art, and science in trans-European connections. The contributions of Christian missionaries to scientific study have been documented for the Americas, Asia, and Africa. Further, the term

"go-between" has been explored in depth to consider the various ways in which mediators have facilitated communication, including exchange of scientific knowledge.[28]

Göran Rydén's chapter focuses on the interplay of biological and economic thinking. Thus, he argues that Mary Louise Pratt's 1992 vision of imperial travel and changing biological thinking anticipated the argument of Kenneth Pomeranz in suggesting that "ghost acres" of American land sustained European economic growth; in contrast, he argues that Lisbet Koerner's interpretation of Linnaeus was Swedish-based.[29] In both cases, Rydén explores contemporaneous and interactive transformation in biological and economic thinking in Sweden. In addition, Rydén adopts Koerner's term "contact zone" to refer to the lands in which the Linnaean apostles studied, without defining precisely the nature of that zone. Rydén focuses on the interactions of scientific and economic thinking, however, in pursuing Linnaeus's own hopes for using his knowledge to encourage national development for Sweden. In sum, Rydén proposes various paths of interaction among scientific and economic thinking.

Irina Podgorny narrates the discovery and debate over the *pichiciego*, a small mammal partly covered by a shell, native to the southern Andes. The animal became known to the wider world in the postcolonial 1820s through visits by North American and European observers.[30] Specimens traveled to museums in Europe and North America, and analysis took place entirely in those distant places. Because of decay in the specimens, an immensely confusing debate took place on the character and classification of the *pichiciego*. Podgorny documents the philosophical as well as the practical divisions in the debate and emphasizes the fragmentary nature of the available information: she deconstructs the notion of "centers" of information collecting and rationalizing information from the peripheries. The comedy of errors that resulted from attempts to spread knowledge about unusual mammals around the Atlantic showed the deficiencies both in knowledge and in ways of exchanging it.

The movement of knowledge about the elements of sugar production from one part of the world to another—and focusing on their application in Cuba—was one such exercise. Leida Fernández-Prieto focuses on tropical agriculture in the industrial era, in an archipelago of island science linking Java, the Mascarenes, and the Caribbean. Through the case of sugar in Cuba in particular, she emphasizes the regional and transatlantic exchange of knowledge and argues that the key steps were worked out by those living and working in the tropics—rather than sending data to Europe to be the-

orized and analyzed. In this case, the dedication and entrepreneurship of creole farmers and investigators contributed to a geographical expansion of the scope of scientific knowledge.

In another case, Stuart McCook frames the period from 1700 to 1940 as the "neo-Columbian exchange," in which plants were redistributed in all areas of the world rather than to and from the Americas, as before. His focus is on the Wardian case—a remarkable device for safely transporting plant species long distances that was prominent from 1840 to 1890. He shows how this ingenious device made it possible to convey plants from one climate to another with little loss, thus greatly accelerating the spread of knowledge about them. The developer of the case, an amateur gentleman naturalist, worked to perfect the case and to commercialize it in partnership with professional nurserymen. Ward thus participated in the cosmopolitan world of Victorian horticulture, providing an example of the role of civil society in quietly spreading plants to the metropole and around the colonies in a highly efficient fashion.

Encounters and Exchange of Knowledge

The study of "encounters" draws attention to major social boundaries across lines of ethnicity, language, and social status—in the creation and transfer of scientific knowledge and practice. The most famous encounters are those between groups of people who were completely unaware of each other's existence, as with Spanish-Aztec encounters and the Pacific encounters of the eighteenth century.[31] Of equal importance are repeated encounters across borders that persist despite continuing contact: recurring encounters across civilizational or ethnic lines or across lines of class and status. In these cases, each generation must renew the encounter, with the resulting realizations and misunderstandings.[32] The various possible types of encounters show why a full range of encounters and boundaries—along with such related categories as go-betweens and indigenous knowledge—should be considered together. This is definitely a topic for further investigation, especially as documents are scarce and weak in conveying the various perspectives. At best, however, new studies are showing how to convey the knowledge and learning within communities sometimes labeled with the terms "indigenous" and "subaltern." Thus, Judith Carney's *Black Rice* not only conveys a story of the agency of enslaved Africans but provides a case where a productive new technology was introduced to the Americas by a subaltern group that remained enslaved.[33]

The studies in this volume encounter a dilemma on how best to set the framework for considering the preservation of knowledge within social and ethnic groups on the one hand and the exchange of knowledge across social and ethnic boundaries on the other. Scholars working on the Americas have interest at once in documenting knowledge systems within indigenous societies, in documenting the expansion of European-based knowledge through the labor and creativity of indigenous employees, and in understanding the knowledge and knowledge contributions of enslaved Africans, relatively new to the Americas as were the Europeans.[34]

Eleonora Rohland's chapter begins with the recently arrived French settlers in the Louisiana colony who experienced a severe 1722 hurricane. The author inquires into what they and other Europeans might have learned about hurricanes from Amerindians in Louisiana and gradually from inhabitants in the Caribbean and even from Atlantic sailors. It took a century for Europeans to achieve a broad understanding of the counterclockwise vortex of the storms, their movement, and their varying trajectories. The author considers that the cross-cultural transfer in information may have been gradual and complex: she seeks to trace the interaction of indigenous and European knowledge of hurricanes from the seventeenth to the twentieth century.

In another study for which the analysis is long-term for a different reason, Kay Etheridge traces the creation and analysis of Maria Merian's remarkable painting (in roughly 1700) of a bird-eating tarantula. The author details the artist's artisanal skill, which sustained an approach known best in the seventeenth century. The image, disbelieved by some experts in Europe, gained credibility in part because of the skill of the artist's portrayal. Indeed, Etheridge notes that Linnaeus and his students classified over one hundred species based on their study of Merian's illustrations. Further, as Etheridge emphasizes, Merian's accomplishments were by no means due to herself alone. Her approach, implicitly in mind all along, was to treat her "servants," both African and Amerindian, as skilled informants. (The limit was that Merian never reported the name of any of her informants.) Whether their communication was strictly the conveying of empirical data or whether it also involved conveying their practical or conceptual sense of classification may take more study. That is, the people of Suriname are seen at least to have had "indigenous knowledge" and may indeed have been treated as having systematic local or civilizational knowledge of their region's flora and fauna.

Iris Montero Sobrevilla focuses in exchange of knowledge and debate

among those participating in scientific discourse. She highlights the studies of the Mexican-born polymath José Antonio Alzate and his campaign to overturn the consensus of European scholars that hummingbirds underwent long periods of torpor or hibernation. This debate formed part of the eighteenth-century "dispute of the New World," on whether the Americas had inferior climate, lethargic animals, and sluggish civilization. Alzate argued for the benefits of his fieldwork and direct observation in contrast to European studies based on remnants of specimens drawn from cabinets. Alzate invoked the descriptive power of indigenous Americans in their understanding of hummingbirds, and Montero backs up Alzate's approach with illustrations of pre-Columbian artwork portraying hummingbirds in both natural and supernatural roles.

Economy

Jessica Ratcliff builds on Rydén's inversion of the well-established subordination of scientific knowledge to economic progress, treating scientific knowledge as an end in itself and asking to what degree it is advanced by economic change. To view science as something other than self-generated, as a result of transformations elsewhere in society, is to take one of those steps in contingency and multiplicity of perspectives that is characteristic of world historical studies. Her essay focuses primarily on links of biological and economic practice, emphasizing that influences can be seen passing in both directions. Like Rydén, she emphasizes a synchronous development of scientific method and economic change in Britain. Taking a step further she argues that Humboldian science, with its emphasis on broad and systematic collection of data, resulted from British economic expansion. In restating her framework she emphasizes a distinction between what science produces (theory, knowledge, and technology) and what it consumes (specimens, data, and information).[35]

Daniel Rood, in a different sort of global argument, makes the case for a "global labor history of science." His interpretive vision highlights the centrality of labor processes and labor relations to the development of scientific knowledge and appropriation of the benefits of science. He considers the interactions among elements of scientific thought along with the interplay of science and society, in each case highlighting the links across boundaries of social strata and across the frontiers separating Europe from the colonies and the world beyond. He identifies the interplay of racial knowledge, managerial knowledge, and scientific knowledge, particularly

in experience of industrial plantations. This approach leads him to extend but also to critique the insights of Margaret Jacob and Joel Mokyr, whose works combined to celebrate the "common workers" of Europe who extracted "useful knowledge" out of scientific principles. Rood expresses skepticism about the "frictionless diffusion of knowledge" implied in these theses. In expanding the notion of useful knowledge beyond Europe, he observes that scientific knowledge on race was commonly incorrect and biased, so that the "usefulness" of science could include the deepening of social inequality—though slaves and indigenous people provided useful knowledge of natural science under these circumstances. Rood notes further the "struggles between different knowledge communities"—as white creoles, for instance, emphasized local specificity in observing their own regions in contrast to the Enlightenment universality emphasized among European-based researchers. These are some of the observations that arise from a focus on the labor processes of scientific work as they evolved in the eighteenth and nineteenth centuries.

Scientific Institutions and Practices

The gradual emergence and expansion of scientific institutions may be characteristic of this period, though not limited to this time frame. Academies, archives, gardens, museums, and networks of communication developed to a new level.[36] Kenneth Nyberg traces an *apodemic* tradition, according to which travel with structured observation was taken as central to biological analysis. He focuses on the vision of European specialists traveling abroad as the path for developing global scientific knowledge. This permits the formulation of one notion of scientific labor—in that the time and energy spent traveling and researching may have yielded substantial results. Through the work of Linnaeus himself and then through that of his followers, especially as his approach was taken up seriously in England, one may trace a recurring if sometimes uneven effort at classifying plants and, to a lesser degree, animals.

Hanna Hodacs traces the development of Linnaean natural history partly through analysis within the scientific world and partly with attention to links of science and the economy. She notes Mokyr's focus on the circulation of useful knowledge as an element of economic growth and emphasizes even more firmly the work of Lisbet Koerner, which traces Linnaeus's inspiration by cameralist political economy, aimed at building the Swedish nation. Here Hodacs focuses on how economic theory may have

influenced scientific practice. She then considers the dynamics of scientific practice, especially the role of Salander and Dryander in building British botanical records. She presents the binomial nomenclature, which Linnaeus publicized definitively in his 1753 *Species plantarum*, as having evolved from the classroom interplay of Linnaeus and his students. Nyberg, in contrast, suggests that the key element in developing binomial nomenclature may have been the interaction of Linnaeus with his traveling apostles as they returned from the field. In this regard, the two authors are testing contrasting mechanisms for the perfection of this terminological system.

In sum, the various chapters in this volume fill gaps remaining in previous work, open new perspectives on debates already engaged in, and move on to inquire as to whether a world historical perspective adds new perspectives or even new questions.

Global Dimensions in History of Science

What is different about the interpretation of world history when it is studied in association with the history of science? Does it make sense to imagine the formation of a field of study that might be called "world history of science"? What is different when history of science is studied in association with world history? These are three of the many questions we invite readers to pose as they explore the contributions in this volume. While the previous section has emphasized the close links of chapters in this volume to the expanding analysis within history of science, this section now emphasizes connections between this volume and the world history literature. These world historical dimensions include a systems based approach to history of science, attention to links among multiple scales of human existence and activity, and a critique of civilizational distinctions that minimize parallels and connections among social groupings.[37] The two concluding chapters are most explicit in their introduction of global approaches.

What can history of science do for world history? The field of world history has yet to pay enough attention to history of science. For the period from the sixteenth century on, world historical narratives should give more attention to science and learning. History of science contributes a sophisticated summary of processes in scientific change and their interactions with other segments of society, and a fuller and clearer statement of the role of science in human society—as a source of new ideas bringing understanding and some control over natural processes but also as a reflection of transformations throughout society. For earlier times, in which science

was a smaller part of society, world historical analyses need more attention to links between science and technology, to scientific knowledge and other sorts of knowledge.

What can world history do for history of science? To the history of science, world historical studies should add the additional observations that arise from analysis across borders not usually crossed, at scales larger than usually explored, and with unsuspected linkages. World historical perspectives tend to ensure that the issues under study are considered at multiple scales, and that large-scale patterns are identified and linked to other scales.

World historical studies may contribute to history of science by distinguishing imperial science from science directed by civil society and by showing how scientific advance has consisted not only of creating new knowledge but also by the adoption of existing knowledge across boundaries. Where high social barriers exist, separating one society from another or separating strata within a society, world historical approaches may explore encounters in knowledge across those barriers. For instance, world historians might be skeptical of treating "indigenous knowledge" as a discrete category—separated into subcategories for each ethnic group—and instead consider an ensemble of overlapping communities of knowledge. These overlapping communities might span the boundaries of ethnicity, language, "race," gender, slavery, wage labor, and geographical location—but also the processes of sustaining knowledge within those boundaries and of transferring knowledge across boundaries.[38]

The studies in this volume have given particular attention to transatlantic scientific links from Europe to the Americas and, to a lesser degree, other regions. They show colonial creoles reinterpreting the canons of European knowledge; they unmask some of the subaltern contributions to scientific knowledge; and they reveal the strength of New World science in direct observation, if not in theory. Nyberg and Rydén address the changing scientific methodology of collecting evidence in response to expanding processes of industrial production. Hodacs, Rohland, Etheridge, and Montero pursue the discourse on the exchange of knowledge across social and regional bounds. For the changing relations among science, nation, and empire, Hodacs, Rydén, and Figueroa document countervailing influences. On the transfer of knowledge, Etheridge, Fernandez, McCook, and Gupta show the value of long-established techniques (as of illustration) and also the importance of innovations such as the Wardian case. Ratcliff and Rood, in conclusion, open what promise to be important discussions on

the breadth of scientific documentation and the complexity of the labor history that linked science and society.

Dramatic transformations in scientific knowledge and practice, from 1750 to 1850, reflected and doubtless influenced the broader transformations in global society. The great project of classifying the natural world advanced impressively in biology, in chemistry, and in geology. The sense of time changed greatly, especially as geologic time began to be understood, a longer-term outlook that facilitated the understanding of biological change. The need for observations from many parts of the planet came to be recognized as important for many fields of scientific research, so that notions of center and periphery in the natural world came to be reconsidered. Economic benefits of scientific knowledge arose in additional fields, as with the value of nitrogen for fertilizer.

Yet also in this century, the links of natural science and social science faltered increasingly. Pressures arising in politics, ideology, and economic profitability built up biases in the social sciences, so that ideological notions of race, civilization, and social hierarchy gained in influence during the nineteenth century. The increasingly prejudicial categorization of humans into subcategories, following principles not used elsewhere in classification, should have been a warning. Thus, in the accelerating transfers of knowledge, misinformation came to be transferred along some of the same routes as increasingly valid scientific knowledge. It appears, therefore, that a productive expansion of investigation—both by world historians and by historians of science—would be to explore in more detail the links and contrasts of natural and social sciences from 1750 to 1850 and into the later years of the nineteenth century.