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Author(s): Harold J. Cook

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Moving About and Finding Things Out: Economies and Sciences in the Period of the Scientific Revolution

*by Harold J. Cook**

ABSTRACT

One of the most common arguments about science is that it leads to economic development; it is also commonly argued that the rise of science was a critical factor in the rise of the modern economy. This article explores that theme from the viewpoint of the history of northwestern Europe in the early modern period, arguing that rather than either “economy” or “science” producing the other, they were coproduced. Institutional forms of organization employed by the urban elite to manage their affairs came to place a high value on descriptive matters of fact, which became the chief matters of exchange in their efforts toward both material betterment and reliable knowledge. In giving pride of place to matters of fact in their knowledge systems, which moved relatively easily across cultural boundaries, it also became possible for urban leaders to imagine a universal form of knowledge, which we often call *science*.

One of the chief generalist visions of the history of science has long fallen outside the mainstream of the field, but is virtually a constant in the public forum: the rise of science has caused modern economic development. The positive contributions of science to economic growth have been assumed and discussed not only by many journalists and others involved with political and economic decision making but also by academics beyond the history and philosophy of science. For many good reasons those of us in that field have generally been wary of entering into these discussions. Yet the enduring view that the modern economy owes a great deal to modern science suggests that however mythological some of these statements might seem, it would be worth examining the reasons why this theme has been kept alive over so many generations. Moreover, if the relationships between “economy” and “science” are taken seriously even as they are reformulated, they lead to further questions about the processes of historical change. But in doing so, such investigations require that the history of science be brought into a closer relationship with the history of medicine and technology, and with economic history, than was common in the late twentieth century.

* History Department, Brown University, Box N, 79 Brown St., Providence, RI 02912; Harold_Cook@brown.edu.

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For the purposes of this article, I explore such questions for the period and region with which I am most familiar, the early modern period in Europe and some of the far-flung European enterprises of the era, a time that witnessed the emergence of both modern science and capitalism.¹ The world of commerce and early capitalism not only privileged the mobilization of monetary value in the service of wealth, power, and pleasure but also advantaged certain forms of social interaction and exploitation that placed a very high value on accurate and cumulative information about the material world and its underlying materialistic elements. In taking up this line of analysis, it is necessary to explore not only recent literature in the history of science, medicine, and technology (STM), but some of the new economic history, which in turn offers analytical frameworks that can help us to see old problems in the history of science in new ways. It is likely—as this article will argue—that the modern economy and modern science were not in the kind of relationship in which one produced the other, but that they were coproduced and interdependent phenomena.² A further general hypothesis is that the usual statement that science is universal because it is true can be turned on its head, in order to suggest that the ability of certain kinds of information (“matters of fact”) to be readily communicated across cultural and linguistic boundaries made it possible to imagine a universal kind of knowledge. This holds out the possibility (again) of showing that while abstractions about nature might be constructed, they are not merely relativistic points of view: there is something other than “culture” at stake, something that includes material life, from which science is made.³ In any case, the sorts of practices and values that supported both a particular kind of science and a particular kind of economy are worth further consideration.

Such views might be generalizable to other periods and places, but only if the terms *economy* and *science* are pluralized in order to press otherwise essentialist abstractions toward a set of diverse and interactive processes located in time and place, which in turn might invite further historical inquiry. In other words, the relationships between economic activity and scientific activity will change according to the circumstances that produce them both. The manner in which they are interconnected in early modern Europe may not apply to, say, the nineteenth-century United States of America, or twentieth-century East Asia, or other places and times. In considering once again the possible relationships between natural knowledge and material betterment, then, it is very apparent that economic history is as important as intellectual and cultural history for an understanding of STM.

THE SCIENCE AND DEVELOPMENT PARADIGM

Currently, the dominant generalist view about development remains associated with the presumption that the modern economic system originated in Britain and continues to be led by the countries that also went through an industrial revolution in the nineteenth century, although a number of other nations are recognized as gaining

¹ For the moment, I use these general terms to capture the spirit of the discussion; I will be more precise later on.

² *Coproduced* is an idiom associated with Sheila Jasanoff; Jasanoff, *States of Knowledge: The Coproduction of Science and the Social Order*, International Library of Sociology (London, 2004), 1–6.

³ For related thoughts, see, e.g., Bruno Latour, “Why Has Critique Run Out of Steam? From Matters of Fact to Matters of Concern,” *Crit. Inq.* 30 (2004): 225–48.

through the adoption of similar economic structures. As we will see, the basic premise is that “the West” came to dominate the globe because of certain kinds of rationality coupled with political liberty, which allowed innovators to reap the rewards of their efforts and so led to human betterment as measured by per capita income and life expectancy. I will refer to this version of development, which has material improvement as its end and science as a critical contributor, as the science and development paradigm (SDP).⁴ A second version of SDP (SDP₂) more explicitly associates development with moral improvement as well: good governments are instituted for the benefit of the governed, which means that material benefits and human rights are interdependent, being the two fundamental pillars of the hopeful aspects of humanity’s collective journey through history. In SDP₂, science also plays a critical role, contributing not only to material improvement but to an investigative and reality-checking discourse that encompasses the human sciences as well, demanding attention to the potential of human capital. SDP₂ more openly asserts that scientific modernity brings political goods as well as material wealth.

At the moment, the chief historical rival of SDP for a generalist vision is the theme of competition between civilizations, currently much discussed in terms of the “clashes” of civilizations, with science sometimes being invoked as one of the chief markers of Western civilization. Because of the moral arguments often attached to SDP₂, ideas about development and ideas about the virtues of Western civilization are sometimes intermingled, resulting in occasional confusion about which of these major paradigms is being discussed. But given that the simple version of SDP—about material improvement—is the most elementary of these three generalist views, and so is shared among them, we can simplify our review by considering its relation to the history of science and (for the moment) setting the others aside.

Versions of SDP have been with Europeans since before the age of Francis Bacon, and they have remained close to the center of political discussion throughout the world since the nineteenth century. To illustrate the purchase that SPD still has on those concerned about current economic development one may turn to Jeffrey Sachs. Because he is one of the most visible figures among those who have argued for reforms that will lead to material improvement for all people—having, for example, served as director of the UN Millennium Project—he can be cited for what might be called current wisdom. The historical remarks he makes in his 2005 book on the possibilities of ending world poverty are therefore meant not to be original but to establish a basis for consensus, and can therefore be considered to be widely shared. Sachs begins his historical discussion by quoting from a 1930 essay by John Maynard Keynes to the effect that all economies were stagnant until the Industrial Revolution in Britain in the mid-eighteenth century. Keynes was among those who thought that all economies bumped up against ceilings to growth (often because of Malthusian limits) until new forms of technology, first invented in Britain, unleashed a new kind of economy, to which a word like *development* can be properly applied. Or as Sachs

⁴ I am fully aware of the problems in using *science* as a general term, but will continue to do so as a vernacular shorthand—as in “the history of science”—for a collection of activities that included not only natural philosophy, mathematics, and mechanics, but laboratories, natural history, forms of museology, and many aspects of medicine and technology. See also the historical justification in Deborah E. Harkness, *The Jewel House: Elizabethan London and the Scientific Revolution* (New Haven, Conn., 2007), xv–xviii.

himself puts it, slightly more expansively, “The combination of new industrial technologies, coal power, and market forces created the Industrial Revolution. The Industrial Revolution, in turn, led to the most revolutionary economic events in human history since the start of agriculture ten thousand years earlier.” It gave rise to urbanization and social mobility, transforming gender roles and family structures, even creating the division of labor. Politically, the major consequence was that “the British Empire became the global political manifestation of the Industrial Revolution.”⁵ By implication, modern history is the process by which the rest of the world is being caught up in the developmental transformation of material betterment and personal improvement begun in Britain.

Striving for persuasive clarity, Sachs goes on to set out his causal assumptions simply. Why the origin in Britain rather than in China or other “centers of power” in Europe or Asia? Sachs gives six reasons, which include not only coal and geography, but social and political liberty along with, “critically,” the prior development of science.⁶ Expanding on this last point, Sachs writes that

after centuries in which Europe was mainly the importer of scientific ideas from Asia, European science made pivotal advances beginning in the Renaissance. . . . The decisive breakthrough came with Isaac Newton’s *Principia Mathematica* in 1687, one of the most important books ever written. By showing that physical phenomena could be described by mathematical laws, and by providing the tools of calculus to discover those laws, Newton set the stage for hundreds of years of scientific and technological discovery, and for the Industrial Revolution that would follow the scientific revolution.⁷

Sachs goes on to reemphasize the importance of science when he writes, a few pages later, “I believe that the single most important reason why prosperity spread, and why it continues to spread, is the transmission of technologies and the ideas underlying them.”⁸ The general message is therefore that while the modern economic system is the product of the British Industrial Revolution, it could not have occurred without the prior Scientific Revolution; technology depends upon science. The simple lessons learned from this history continue to hold out the promise of development for any people, anywhere, even where it has been absent. I will take this to be the general model for contemporary SDP.

While most historians of science have shied away from such claims, Margaret C. Jacob and Larry Stewart have argued a similar position to Sachs’s with vigor, underlining the importance of “Newtonianism” in further deepening the relationship between scientific concepts and economic innovation in the lead-up to the Industrial Revolution. “Newton’s science in the service of industry and empire” is how they put it in the subtitle of their coauthored book of 2004. There they write, succinctly, that “Newton’s followers” and “most of his explicators” focused on how he mathematically described “the mechanics of earthly bodies,” which provided “the foundations for the study of fluids in motion and at rest,” while also seeing his work as an example of the importance of “experimental evidence.” Newton therefore appealed to engineers, and to many entrepreneurs. Such people consequently made the *Principia*

⁵ Sachs, *The End of Poverty: Economic Possibilities for Our Time* (New York, 2005), 35, 36–7, 33; the quotation from Keynes is on 32.

⁶ *Ibid.*, 33–5.

⁷ *Ibid.*, 34–5.

⁸ *Ibid.*, 41.

“the cornerstone of Western economic development.”⁹ This comes close to saying, à la Sachs, that without the *Principia* there would have been no Industrial Revolution, which, for reasons developed further below, seems to me implausible.

On the other hand, in also writing about what they term the “culture of Newtonianism” Jacob and Stewart offer a more expansive account about how Newton’s *Principia* served as an inspiration for a wide range of people investigating the world and making things from it, rather than a set of particular mathematical problems and solutions per se. That is, it was not the particular conceptual details articulated in the *Principia* but the efforts of those who liked what it stood for that did most of the work in creating change. Similar arguments about how a special kind of scientific and technological “culture” lay behind the Industrial Revolution and subsequent world economic development have become common. In a work suggested for further reading by Sachs, for instance, David Landes adopts the phrase “invention of invention” to describe what he sees as the “pleasure in new and better” that characterized European technological innovation.¹⁰ Although his *Wealth and Poverty of Nations* places the origin of “development and modernity” in Europe in the later medieval period, and stresses the importance of institutional changes rather than political liberty as such—both points to which we will return below—he thinks that European expansion and empire, like the Industrial Revolution of Britain, flowed from the culture of invention.

Similarly, a recent account of the history of technology emphasizes the “culture of improvement” as the driving force for change and something unique to the West,¹¹ while an eminent member of the American historical profession, Joyce Appleby, has recently declared that England gave rise not only to the Industrial Revolution but to capitalism itself, with its “secret spring” being “innovation,” which in turn grew from a new cultural formation that followed the Scientific Revolution.¹² At least one economic historian has fully adopted the cultural argument in explaining that only when capitalistic values are widely shared does economic growth occur.¹³ Other grand syntheses connect the culture of innovation tightly to its institutional expressions, as in *The Most Powerful Idea in the World*, where William Rosen states that “human character (or at least behavior) was changed, and changed forever, by seventeenth-century Britain’s insistence that ideas were a kind of property,” allowing the democratization of the nature of invention through the patent system.¹⁴ In yet another powerful synthesis, Ian Morris points to the “accumulation of technology,” which

⁹ Jacob and Stewart, *Practical Matter: Newton’s Science in the Service of Industry and Empire, 1687–1851* (Cambridge, Mass., 2004), 15. See also Stewart, *The Rise of Public Science: Rhetoric, Technology, and Natural Philosophy in Newtonian Britain, 1660–1750* (Cambridge, 1992), and Jacob, *Scientific Culture and the Making of the Industrial West* (New York, 1997).

¹⁰ Landes, *The Wealth and Poverty of Nations: Why Some Are So Rich and Some So Poor* (New York, 1999). The quoted phrases are from the title of chap. 4 and p. 58.

¹¹ Robert D. Friedel, *A Culture of Improvement: Technology and the Western Millennium* (Cambridge, Mass., 2007).

¹² Appleby, *The Relentless Revolution: A History of Capitalism* (New York, 2010), on 155; also note her comment on 156 that the true innovators were not mere tinkerers but “genuine geniuses.” For her views of the Scientific Revolution, see 141–5.

¹³ Deirdre N. McCloskey, *Bourgeois Dignity: Why Economics Can’t Explain the Modern World* (Chicago, 2010).

¹⁴ Rosen, *The Most Powerful Idea in the World: A Story of Steam, Industry, and Invention* (New York, 2010), xxiii. For a counterargument to the central importance of patents, see Karel Davids, *The Rise and Decline of Dutch Technological Leadership: Technology, Economy and Culture in the Netherlands, 1350–1800*, 2 vols. (Leiden, 2008).

was in turn the result of an “Atlantic economy that could generate higher wages and new challenges, stimulating the whole package of scientific thought, mechanical tinkering, and cheap power.”¹⁵

But resorting to cultural values is not the only way of framing the argument. In another widely cited study of the relationship between science and economy, Joel Mokyr gives his attention not to “science” or even “knowledge” but to particular forms of them. In *The Gifts of Athena*, for instance, Mokyr argues that the Industrial Revolution was due to a “knowledge revolution.”¹⁶ While he gives credit to Jacob for inspiring some of his views, he at the same time criticizes her emphasis on Newtonian ideas as the origin of the kind of “understanding” that led to mechanization.¹⁷ He instead tries to move beyond the usual categories of science and technology to write of both as containing “useful knowledge,” which in turn made industrialization possible, while also arguing that useful knowledge could be divided into two kinds: “propositional” knowledge (or *episteme*, about what exists), and “prescriptive” knowledge (or *techne*, about how things work). One can find both propositional and prescriptive knowledge in both science and technology, making the common differentiation between the two pointless. For the moment, we need not go further into Mokyr’s definitions, only observe that while he argues for feedback between propositional and prescriptive knowledge, he believes the modern economy to be based mainly on knowledge that is about things rather than reasons, about the intelligence of “how” rather than “why.”¹⁸ He stresses that scientific knowledge did not have to be “true” in what are commonly called its “theoretical” claims; instead, the power of the new knowledge practices lay in their descriptive credibility and clarity about the phenomena, which arose from experimental practice, and in the developing custom of making such informational knowledge public. Like Sachs and Jacob, then, he thinks that the origins of the Industrial Revolution in Britain were determined by “the scientific revolution of the seventeenth century and the Enlightenment movement of the eighteenth century.”¹⁹ And he urges other economic historians to “re-examine the epistemic roots of the Industrial Revolution.”²⁰ But it is the power of what he calls prescriptive knowledge rather than either Newtonian science or a culture of innovation that is the chief focus of Mokyr’s attention.²¹

Something like prescriptive knowledge has of course been of importance to historians of STM for many decades, and that form of knowledge is currently also of much interest to other economic historians who seek to explain the European take-off toward self-sustained growth. For instance, Ian Inkster has long been studying the forms of knowledge and technique that were incorporated into the Industrial

¹⁵ Morris, *Why the West Rules—for Now: The Patterns of History, and What They Reveal about the Future* (New York, 2010), on 499–500 and 502.

¹⁶ Mokyr, *The Gifts of Athena: Historical Origins of the Knowledge Economy* (Princeton, N.J., 2002), 31, 56–76.

¹⁷ *Ibid.*, 30.

¹⁸ *Ibid.*, 24–5, 5, 10, 20.

¹⁹ *Ibid.*, 33.

²⁰ *Ibid.*, 29.

²¹ More recently, however, he has moved more toward culture as an explanation: “Economic change in all periods depends, more than most economists think, on what people believe.” Mokyr, *The Enlightened Economy: An Economic History of Britain, 1700–1850*, *New Economic History of Britain* (New Haven, Conn., 2009), 1.

Revolution and their forms of movement.²² To articulate the focus of his subject, he adopts the phrase “useful and reliable knowledge” from the economic historian Patrick O’Brien.²³ O’Brien in turn currently has a major comparative project underway funded by the European Research Council, titled “Useful and Reliable Knowledge in Global Histories of Material Progress in the East and the West from the Accession of the Ming Dynasty (1368) to the First Industrial Revolution (1756–1846).”²⁴ The goal of the researchers is to study the history of several Eurasian regions in order to compare the possibilities for the development of useful and reliable knowledge in Europe and elsewhere as a fundamental aspect of the European takeoff. In a different fashion, but with similar questions in the background, Wolfgang Kaiser, director of studies at l’École des hautes études en sciences sociales and professor of modern history at l’Université Paris I Panthéon-Sorbonne, has a working group studying knowledge and knowledge transfers as critical aspects of economic history.²⁵ A recent and explicitly anti-Eurocentric work titled *The Eurasian Miracle* by the historically well-informed anthropologist Jack Goody also gives these kinds of knowledge exchanges pride of place in its explanations of historical change.²⁶ Such examples could be multiplied many times over.

In short, there is a very widespread and important discussion underway that is seeking much greater precision about how particular kinds of investigations into material nature produced the modern economy. They seek to cut through both older formulations about the contributions of “science” and more recent ones about a “culture” of innovation, favoring terms such as “prescriptive knowledge” and “information.” Arguments within the history of STM, too, are pointing toward ways in which the so-called Scientific Revolution also placed a very high value on reliable information about material structures and processes. Something like the formation of an information economy might be said to have been at work. I know of no larger set of problems to which historians of STM can contribute.

THE LATE MEDIEVAL AND EARLY MODERN INSTITUTIONAL REVOLUTION

To further clarify the questions now being asked, let us begin with the recent “revolt” among many medieval and early modern historians who have argued that the beginnings of European economic exceptionalism came before the period of the Industrial Revolution. They are arguing that its origins lie in the sixteenth and seventeenth centuries, or even earlier, in the late medieval period, which happens to be precisely the period usually examined for the origins of the Scientific Revolution. The fact that the

²² E.g., Inkster, “Mental Capital: Transfers of Knowledge and Technique in Eighteenth Century Europe,” *J. Eur. Econ. Hist.* 19 (1990): 403–41; Inkster, “Cultural Engineering and the Industrialisation of Japan circa 1868–1912,” in *Reconceptualizing the Industrial Revolution*, ed. Jeff Horn, Leonard N. Rosenband, and Merritt Roe Smith (Cambridge, Mass., 2010), 291–308.

²³ Inkster, “Potentially Global: ‘Useful and Reliable Knowledge’ and Material Progress in Europe, 1474–1914,” *International History Review* 28 (2006): 237–86; see 260 n. 2 for his credit to O’Brien for using the phrase at a conference in Leiden in 2004.

²⁴ Described on the website of the Department of Economic History, London School of Economics and Politics, www2.lse.ac.uk/economicHistory/Research/URKEW/aboutUrkew.aspx (accessed 25 October 2011).

²⁵ Described on the Centre de Recherches Historiques website, crh.ehess.fr/document.php?id=440 (accessed 25 October 2011).

²⁶ Goody, *The Eurasian Miracle* (Cambridge, Mass., 2010).

rise of global seaborne commerce carried on European ships was contemporary with the rise of what we recognize as science was no coincidence, I believe, but rather a case of codependent phenomena.²⁷ Is it possible to go further and identify some of the structural changes that might have produced them both?

The importance of commerce to the development of early modern Europe is plain.²⁸ To be simpleminded about it, in the transition from feudalism to capitalism the taxable monetary wealth derived from urban commerce made new forms of gunpowder warfare possible and gradually undercut older methods of raising armies and navies based on personal loyalties, so that new forms of wealth and power gave rise to new kinds of polities that in turn encouraged commerce as their lifeblood. The late medieval city-states of northern Italy are well-known examples of the process, but many of the free cities of the Holy Roman Empire, the Hanseatic League of the Baltic and North Seas, the heavily urbanized areas of southeast England and the Low Countries, and the commercial cities of France and Iberia shared in a general process of acquiring political rights and privileges in return for monetary payments, making the voices of the merchants noticeable even at the most haughty aristocratic courts. How influential the values of the merchants were of course varied from place to place, but even where a prince's ideological orientation remained focused on controlling the beliefs and behaviors of his subjects, attention had to be given to the question of money and the arrangements necessary for its generation and acquisition.

Behind the development of such particular kinds of political economy lay important changes in behavior and belief. For, as historians of science are well aware, in any exchange between humans the question of trust arises.²⁹ It is often resolved by acquaintance with the other people involved, being especially strong among families and clans; where the parties are personally unacquainted, other markers such as ethnicity can establish the social bonds necessary for sufficient confidence to allow transactions.³⁰ In later medieval Europe, new formal methods came into being that allowed nonfamilial groups of merchant-traders to work together. These methods were partly based on new legal forms such as corporations, partly on the political negotiations that gave those corporations the credibility to enforce contracts. Such arrangements allowed a certain amount of confidence to flow from family to family, group to group, and city to city, lowering what the new institutional economics calls "transaction costs": the nonprice costs of conducting business, such as negotiation, the drawing up of contracts, inspections, and the resolution of disputes.³¹ And indeed,

²⁷ Harold J. Cook, *Matters of Exchange: Commerce, Medicine and Science in the Dutch Golden Age* (New Haven, Conn., 2007).

²⁸ A masterwork is Fernand Braudel, *Civilization and Capitalism, 15th–18th Century*, trans. Siân Reynolds, 3 vols. (New York, 1979).

²⁹ To be very brief, Bruno Latour and Steve Woolgar made the question of the "credibility" of scientific facts an issue, and Steven Shapin and Simon Schaffer identified a key part of that as being a matter of "trust"; Latour and Woolgar, *Laboratory Life: The Social Construction of Scientific Facts* (Beverly Hills, Calif., 1979), and Shapin and Schaffer, *Leviathan and the Air-Pump: Hobbes, Boyle, and the Experimental Life* (Princeton, N.J., 1986); Shapin, *A Social History of Truth: Civility and Science in Seventeenth-Century England* (Chicago, 1994). Shapin has also brought the analysis of trust to a study of the modern system of capital formation and science in *The Scientific Life: A Moral History of a Late Modern Vocation* (Chicago, 2008).

³⁰ I am here indebted especially to Janet T. Landa, *Trust, Ethnicity, and Identity: Beyond the New Institutional Economics of Ethnic Trading Networks, Contract Law, and Gift-Exchange* (Ann Arbor, Mich., 1994), and to conversations with David Harris Sacks.

³¹ A pioneering and still useful work in the field of the new institutional economics is Douglass C. North and Robert Paul Thomas, *The Rise of the Western World: A New Economic History* (Cambridge,

when one measure of transactions costs is mapped—the cost of money, which is an indicator of the level of confidence in the borrower to pay back what is owed—it appears that interest rates in Western Europe declined significantly during the late medieval period, in the fifteenth century reaching something like a modern rate, a low of 5 to 6 percent.³²

In other words, while neoclassical economics focused on the role of price as a coordinating mechanism in economic behavior, a new band of historians have investigated other issues of coordinating exchange, which might generally be described as the social relationships behind economic forms. Exploring such relationships has taken them into questions of noncooperative behaviors such as coerced exchange (stealing, defrauding, and breach of contract), as well as what enabled those involved in economic exchanges to overcome such barriers. Such economic historians have also departed from neoclassical views in arguing that methods of establishing the formal mechanisms of trust can sometimes take place alongside the mechanisms of established governance—indeed, some have gone on to argue that state formation was a result of the kinds of formal arrangements for negotiation put in place by the merchants.³³ (One might say that these historians are Lockean rather than Hobbesians.) In other words, it is not technology and the development of markets that came first but certain kinds of social and political relationships, which in turn gave rise to institutional structures (including “property rights”) that underpinned the “modern” economy. Perhaps what we recognize as modern science grew from the same processes.

To grasp a few of the details, it is key to explore further the views of an important group of historians who have been arguing that the Industrial Revolution was only one outcome—if a fundamental one—of an economic transformation being wrought in Europe from the late Middle Ages forward. One of the foremost among these historians, Jan Luiten van Zanden, has called the new view a “revolt of the early modernists,”³⁴ which might equally be called a revolt of the Northwest Europeanists. It was most visibly marked by the appearance in 1995 of a study of the early modern Dutch economy by Jan De Vries and Ad van der Woude that was translated two years later under a bold title: *The First Modern Economy*.³⁵ If the appearance of “the market” rather than “markets” is the best sign of capitalism, then the modern European economy did not emerge until later in the sixteenth century; but most parts of the Low Countries had authentic markets in goods, labor, land, and capital by the beginning of the sixteenth century, along with measurable economic growth (which was not necessarily a “success story,” however, since the consequent proletarianization

1973); see also North, *Institutions, Institutional Change, and Economic Performance* (Cambridge, 1990), and Joel Mokyr, “The Institutional Origins of the Industrial Revolution,” in *Institutions and Economic Performance*, ed. Elhanan Helpman (Cambridge, Mass., 2008), 64–119.

³² See esp. chap. 1 in J. L. van Zanden, *The Long Road to the Industrial Revolution: The European Economy in a Global Perspective, 1000–1800* (Leiden, 2009); for the figures on interest rates, 22–3.

³³ E.g., Landa, *Trust, Ethnicity, and Identity* (cit. n. 30), 49–65; Avner Greif, *Institutions and the Path to the Modern Economy: Lessons from Medieval Trade* (New York, 2006).

³⁴ Van Zanden, “The ‘Revolt of the Early Modernists’ and the ‘First Modern Economy’: An Assessment,” *Econ. Hist. Rev.* 55 (2002): 619–41.

³⁵ De Vries and Van der Woude, *Nederland, 1500–1815: De eerste ronde van moderne economische groei* (Amsterdam, 1995), translated as *The First Modern Economy: Success, Failure, and Perseverance of the Dutch Economy, 1500–1815* (Cambridge, 1997). The title took up an argument De Vries advanced as early as 1973: De Vries, “On the Modernity of the Dutch Republic,” *J. Econ. Hist.* 33 (1973): 191–202.

of labor was only slightly beneficial for the population as a whole, while social welfare overall declined).³⁶ Van Zanden's own recent analysis, titled *The Long Road to the Industrial Revolution*, does not quarrel with the phenomenon of an economic takeoff from about 1800 associated with the Industrial Revolution, but he demonstrates the rise of market institutions and real economic growth from the late medieval period, which provided the "long runway" that made the modern takeoff possible. From modeling real wages and productivity, moreover, he concludes that "the transition towards modern economic growth" occurred in both the Dutch and English economies not in the nineteenth century but "at some point between the 1590s and 1620s" (with Dutch productivity growth declining after 1670 and starting up again after 1820). The "Little Divergence" of these parts of northwest Europe was, he argues, in turn founded on unique processes of family formation that emerged in the fourteenth and fifteenth centuries (which made for fewer children but higher investment in human capital) and on consequent methods for making nonfamilial institutions credible and trustworthy.³⁷

Historians of other regions of Europe, most notably northern Italy, might wish to quarrel with some of the conclusions of the Northwesterners, but for the moment we can take away two propositions: new schools of economic and historical thought have been signaling that late medieval and early modern social and institutional changes were fundamental to the development of the modern economy, and the Low Countries were a region where this new economy was clearly emergent. One can also call the new economy capitalistic by at least the seventeenth century, when financial institutions existed that allowed investors to have confidence that they could make money from money without engaging in trade themselves. In 1621, the word *capitalist* was even used in Holland as a legal term (for those who owned more than 2,000 gilders' worth of movable property).³⁸ While some recent work shows that not all markets in Europe and the Middle East were convergent in terms of price—a sign of "the market" at work—by the seventeenth century Dutch markets were among the most integrated of all.³⁹ In exploring the possible connections between emergent capitalism and the Scientific Revolution, then, this is a period and place worth our attention.

In general terms, moreover, one can say that through processes of the Dutch Revolt the capitalists had become sovereign in the United Provinces. The practical sover-

³⁶ Martha C. Howell, *Commerce before Capitalism in Europe, 1300–1600* (New York, 2010); Bas van Bavel, "The Medieval Origins of Capitalism in the Netherlands," *Bijdragen en mededelingen betreffende de geschiedenis der Nederlanden—Low Countries Historical Review* 125 (2010): 45–79.

³⁷ Van Zanden, *Long Road* (cit. n. 32), quotations on 253–4; see also his summary on 264–5. For similar kinds of arguments, although differing in emphasis and detail, see Michael Mitterauer, *Why Europe? The Medieval Origins of Its Special Path*, trans. Gerald Chapple (Chicago, 2010), and Bas van Bavel, *Manors and Markets: Economy and Society in the Low Countries, 500–1600* (New York, 2010).

³⁸ Marjolein C. 't Hart, *The Making of a Bourgeois State: War, Politics and Finance during the Dutch Revolt* (Manchester, 1993), 122–3.

³⁹ Larry Neal, "The Integration and Efficiency of the London and Amsterdam Stock Markets in the Eighteenth Century," *J. Econ. Hist.* 47 (1987): 97–115; Jonathan I. Israel, "The Amsterdam Stock Exchange and the English Revolution," *Tijdschr. Gesch.* 103 (1990): 412–40; Süleyman Özmucur and Pamuk Şevket, "Did European Commodity Prices Converge during 1500–1800?" in *The New Comparative Economic History: Essays in Honor of Jeffrey G. Williamson*, ed. T. J. Hatton, Kevin H. O'Rourke, and Alan M. Taylor (Cambridge, Mass., 2007), 59–85.

eignty of urban merchant-magistrates—soon called the *regenten*, or regents—meeting in formal committees to seek consensus and pound out agreements, created a large enough network of personal acquaintance and credit to finance a defensive war.⁴⁰ The polity that emerged, internationally recognized as a sovereign state in the Treaty of Westphalia of 1648, was often referred to as the Dutch Republic. It was a true republic during the period from 1650 to 1672 when, in most of the provinces, no *stadholder*, or commander of the armed forces, also held high political office, but the details of governance—which even Dutch politicians themselves were sometimes at a loss to explain—need not delay us long. Simply put, the republic was a place where powerful merchants ruled. Revolt against Habsburg centralization in the Low Countries, which included resistance to the imposition of the Inquisition and new taxes, was framed not as a revolution advocating new political rights but as a defense of the liberties of the nobles, cities, and provinces of the region.⁴¹ After Philip II sent Spanish troops to restore his authority in the later 1560s, bitter warfare left the seven United Provinces of the north *de facto* independent and the Spanish Netherlands of the south, including Flanders and Brabant, under Habsburg dominion. For various reasons, Amsterdam profited from the decline of Antwerp, becoming the most powerful city in the most powerful province, Holland, but the republic contained many other important cities, such as Middleburg, Rotterdam, Dordrecht, Utrecht, Deventer, Delft, Leiden, Haarlem, Alkmaar, Enkhuizen, Leeuwarden, Groningen, and so on.

The result was a polity in which the regents had the upper hand in making their voices heard in provincial assemblies, while the provinces in turn retained most sovereign rights, giving way to collective “national” decision making only for the sake of warfare. In matters of law and taxation the provinces were virtually independent. Even after the restoration of the stadholder (William III) in 1672, and his purging of local governments to ensure that his supporters held power, it was regents who governed the cities and who in turn dominated the provinces. They were effectively collective sovereigns who ruled via often difficult negotiations with one another and, at times, with the stadholder. They even privatized much of their long-distance warfare by contracting it out to some of themselves via the East India Company (which was granted sovereign powers east of the Cape of Good Hope) and the West India Company. Unsurprisingly, the cultural values of the merchants also dominated the republic, so that the kinds of knowledge they valued most highly also took precedence.⁴²

The institutional processes that were producing something resembling a modern economy and polity were therefore also producing something like modern technoscience. The forms of knowledge that Dutch early modern merchants authored and valued have not attracted as much attention as those of the British during the

⁴⁰ For the fiscal mechanisms enabling this, see James D. Tracy, *The Founding of the Dutch Republic: War, Finance and Politics in Holland, 1572–1588* (Oxford, 2008); 't Hart, *Making of a Bourgeois State* (cit. n. 38).

⁴¹ For a masterful survey that shows the medieval roots of the Dutch Republic, see Marten Prak, *The Dutch Republic in the Seventeenth Century: The Golden Age*, trans. Diane Webb (Cambridge, 2008).

⁴² It is my impression that the cultural influence of the court of Orange had its greatest effect when the princes were working with the regents rather than against them, as in the period of Frederick Henry, but this deserves further investigation. For an example, see Marika Koblusek and Jori Zijlmans, eds., *Princely Display: The Court of Frederick Hendrik of Orange and Amalia Van Solms* (The Hague, 1997).

Industrial Revolution, no doubt because they are not as obviously related to technology as the much-memorialized experimental tinkering of steam engines and spinning jennys. But it was a period and place of enormous technical innovation. A recent and important study by Karel Davids has investigated changes in land use and water management, fishing and shipping, the movement of goods, energy production, institutional regulations (from guilds and markets to patents and municipal underwriting), manufacturing industries (building, clothing, brewing, shipbuilding, salt and soap boiling, metalworking—including the making of armaments and the minting of coins—textile and book printing, and the manufacture of gilt leather, ceramics, glass, tobacco pipes, and paper), and processing industries (oil pressing, barley hulling, hemp crushing, timber sawing, tanning, sugar refining, diamond cutting, tobacco processing, distilling, chemical manufacturing and pharmaceutical preparation, and, after 1770, the use of steam engines).⁴³ The patterns of change in each of these sectors were subject to different constraints of supply, demand, capital, organizational and manufacturing methods, and expertise. But Davids finds that from about 1580 to 1700 the overall rate and scope of technological innovation was pronounced in the Dutch Republic, although after 1700 changes became much more uneven according to sector, with technological leadership being retained in only a few areas (such as armaments and minting).

While economic factors such as demand, wage rates, and capital costs help to explain Dutch technological innovation, they cannot do it alone: the effects of nonmarket institutions were also very important (although not religion, since Davids finds that the positive developments came despite Calvinism rather than because of it). As many other recent studies do, Davids also concludes that the many microinnovations that improved technologies already in place, which were in turn often the result of the introduction of knowledge and skills by way of immigration, were more important than breakthrough discoveries. More generally, a relatively open society that encouraged the intermingling of discourses among a variety of social groups, and political decentralization, together with targeted encouragement for innovation from the regents, were critical. Borrowing from Mokyr's distinction between propositional and prescriptive forms of useful knowledge, Davids also finds that science made a difference once the methods of representing the latter (the how-it-is form of knowledge) began to be written down and supplemented with numbers, pictures, and models in ways that made this knowledge somewhat independent of the persons who created or employed it. The values of the regents were therefore fundamental to technological development. Their management of institutional incentives for innovation was probably the most important factor of all. Decline set in as they moved from being an entrepreneurial to a rentier class: instead of close involvement with the material of economic production and the exchange of goods, the development of financial instruments shifted the most powerful regents into dependence on legal abstractions such as investments in land, bonds, and shares, and so led them to take less interest in the details of the means of production, while at the same time their increasingly comfortable political hold on power increased their reliance on secrecy, protectionism, and patriotism, which interfered with the exchange of propositional and prescriptive knowledge.

⁴³ Davids, *Rise and Decline* (cit. n. 14).

MATTERS OF FACT AND COMMERCIAL ECONOMIES

To understand the development of the Scientific Revolution in the republic,⁴⁴ then, we need to understand more about the kind of knowledge of nature valued by the Dutch regents. The basis of their information economy required attentiveness to matters of fact, and so their science was framed by the same attentiveness to the objects of nature (i.e., they valued “objectivity” highly). In recent decades, especially following the work of Barbara Shapiro, many historians of early modern science have placed this concern for matters of fact at the center of their accounts.⁴⁵ Sir Francis Bacon was deeply involved in such reforms, and it is therefore no accident that those writing in English have often described this kind of science as “Baconian.”⁴⁶ But the valuing of facts was well established before Bacon’s time and in other places, and it did not require his endorsement.⁴⁷ Matters of fact may be either propositional or prescriptive (in Mokyr’s language) or constitute reliable information (in O’Brien’s terms). While some kinds of facts are constructed through the elaborate procedures of modern laboratories, there are others that refer to recognizable natural kinds, such as gold, that are not constructed in the same way. Even in the case of complex constructions (such as the identification and naming of trace compounds in the body), their material manifestations are not constructions in the same way that linguistic expressions about them might well be.⁴⁸ In the early modern period, at least, it was the matters of fact known from the senses and experience that gained increased attention as the basis for a new kind of philosophy.

For various reasons, the history of science long gave its chief attention to theories and concepts, and more recently to the linguistic expressions of constructed knowledge. But early modern matters of fact are different from concepts in many ways.

⁴⁴For recent overviews, see K. van Berkel, “The Dutch Republic: Laboratory of the Scientific Revolution,” *Bijdragen en mededelingen betreffende de geschiedenis der Nederlanden* 125 (2010): 81–105; Eric Jorink, “*Het boeck der natuere*”: *Nederlandse geleerden en de wonderen van Gods schepping, 1575–1715* (Leiden, 2007), recently translated as *Reading the Book of Nature in the Dutch Golden Age, 1575–1715*, trans. Peter Mason (Leiden, 2010).

⁴⁵Shapiro, *Probability and Certainty in Seventeenth-Century England: A Study of the Relationship between Natural Science, Religion, History, Law, and Literature* (Princeton, N.J., 1983); Shapiro, “Beyond Reasonable Doubt” and “Probable Cause”: *Historical Perspectives on the Anglo-American Law of Evidence* (Berkeley and Los Angeles, 1991); Shapiro, *A Culture of Fact: England, 1550–1720* (Ithaca, N.Y., 2000). See also Simon Schaffer, “Making Certain,” *Soc. Stud. Sci.* 14 (1984): 137–52; Lorraine Daston, “The Factual Sensibility,” *Isis* 79 (1988): 452–67; Peter Dear, “*Totius in Verba*: Rhetoric and Authority in the Early Royal Society,” *Isis* 76 (1985): 145–61; William Eamon, *Science and the Secrets of Nature: Books of Secrets in Medieval and Early Modern Culture* (Princeton, N.J., 1994); Pamela O. Long, *Openness, Secrecy, Authorship: Technical Arts and the Culture of Knowledge from Antiquity to the Renaissance* (Baltimore, 2001). My thoughts are especially indebted to David S. Lux, *Patronage and Royal Science in Seventeenth-Century France: The Académie de Physique in Caen* (Ithaca, N.Y., 1989).

⁴⁶E.g., Shapiro, “Law and Science in Seventeenth-Century England,” *Stanford Law Review* 21 (1968): 727–66; Shapiro, “Law Reform in Seventeenth-Century England,” *American Journal of Legal History* 19 (1975): 280–312; Shapiro, “Sir Francis Bacon and the Mid-Seventeenth-Century Movement for Law Reform,” *American Journal of Legal History* 24 (1980): 331–62.

⁴⁷E.g., Harold J. Cook, *The Decline of the Old Medical Regime in Stuart London* (Ithaca, N.Y., 1986); Paula Findlen, *Possessing Nature: Museums, Collecting and Scientific Culture in Early Modern Italy* (Berkeley and Los Angeles, 1994); Lorraine Daston and Katharine Park, *Wonders and the Order of Nature, 1150–1750* (New York, 1998); Harkness, *Jewel House* (cit. n. 4).

⁴⁸Ian Hacking, “The Participant Irrealist at Large in the Laboratory,” *Brit. J. Phil. Sci.* 39 (1988): 277–94, responding to Latour and Woolgar, *Laboratory Life* (cit. n. 29).

Concepts can be explained, for instance. If they are associated with a proof, it can be demonstrated. In either case, while argument may ensue, in principle agreement can be reached through a process of “reasoning.” Facts, however, are propositions about truth founded on what can be known through the senses and so are subject to the vagaries and certainties of sensory experience. Many modern European languages other than English have words to indicate this kind of knowledge, words like German and Dutch *kennen*, or French *connaître* and *connaissance*, all of which indicate knowing by acquaintance rather than by reasoning. Put another way, what one knows from the senses as filtered by taste and experience has to do with familiarity rather than universal propositions. Hence doubts about the validity of testimony via the potentially misleading senses were vigorously attacked by many other early modern figures, including René Descartes.⁴⁹

As has been much noticed, however, public acknowledgment and conveying of facts require the witnessing of intermediaries in the form of trusted persons and institutions. Individually reported facts are not only subject to doubt about the state of an observer’s senses, but often involve particular instances rather than repeatable events. It is significant, then, that as Shapiro pointed out, the English word derives from the legal term *factum*, meaning an event that was agreed to have happened. In other words, a fact is what a consensus of eyewitnesses agree took place. It is reminiscent of the point made by Martin Heidegger about the word *thing*: it, too, derives from legal language. As his translators comment, *das Ding* originally designated “the tribunal, or assembly of free men. The *thing* was a cause one negotiated or reconciled in the assembly of judges. Heidegger in a later work refers to this in setting forth the notion of *thing* as what *assembles* a world.”⁵⁰ Put another way, the facts of a matter are those elements of a consensus about an object or event that are agreed upon by the participants in a meeting before they move on to debate questions about what decisions to make in light of the facts. As Steven Shapin and Simon Schaffer argued eloquently, the problem for early modern science was therefore to establish the credibility of descriptions of objects or happenings, often by assembling witnesses for demonstrations and writing reports that allowed the reader to participate vicariously as a “virtual witness.”⁵¹

Similar processes were at work in the methods of keeping track of business affairs on paper. Miles Ogborn, for instance, has argued that the English East India Company was constituted by an assemblage of writing practices to which the parties had to conform. By showing how information and interests were embedded in routines of formal recording and communication, he was able to uncover some of the mechanisms of conveying trust from authorities in one place to their deputies far away, even when those faraway persons had many motivations to act against the best interests of

⁴⁹ See Michele de Montaigne’s famous “Apologie for Sebon,” in *The Complete Works of Montaigne*, trans. Donald M. Frame (Stanford, Calif., 1989), esp. 443–57, refuted in Descartes’s sixth meditation. See also the still-worthy Richard H. Popkin, *The History of Scepticism from Erasmus to Descartes* (New York, 1964).

⁵⁰ Heidegger, *What Is a Thing?* trans. W. B. Barton Jr. and Vera Deutsch (South Bend, Ind., 1967), 5; see also the translators’ n. 3, pp. 8–9.

⁵¹ Shapin and Schaffer, *Leviathan* (cit. n. 29). See also the employment of the concept by others, as in Michael Aaron Dennis, “Graphic Understanding: Instruments and Interpretation in Robert Hooke’s *Micrographia*,” *Sci. Context* 3 (1989): 309–64, and Rob Iliffe, “Material Doubts: Hooke, Artisan Culture and the Exchange of Information in 1670s London,” *Brit. J. Hist. Sci.* 28 (1995): 285–318.

those in London.⁵² The ability to establish agreement about goods and persons, and what happened and when, was the groundwork of the activities that allowed people to calculate probable risks and benefits and to plan for the future. The Dutch East and West India Companies were, if anything, even more bureaucratic than the English. In other words, the factual sensibility encouraged attentiveness to descriptions of material substances, which, like other goods in which merchants had interests, became trustworthy nuggets of information that could be moved easily from place to place despite local cultural barriers.

The centerpiece of the Dutch market was the Amsterdam *Beurs*, or “exchange,” where merchants could speculate on the differences in price between different qualities and quantities of goods at various places and on potential future value given a variety of circumstances, and even purchase shares in businesses. Such markets allowed strangers to buy and sell under publicly acknowledged conditions, so that financial affairs no longer needed to be transacted by clans or family firms or others who were personally bound to one another: trust could be diffused through more impersonal institutions. All things for sale (and we have noted that this now included land and labor as well as goods and even money itself) could then acquire a value measured in a common currency—could become commensurable—allowing a kind of lowest common denominator that existed as a figure written on paper to substitute for the material thing itself. This kind of abstract exchange was in turn based on the flow of information. No market information was completely transparent, and people and firms held back important information when they could and when it was to their advantage. But to make an exchange on the *Beurs*, some modicum of information about the facts at hand needed to be accepted by both parties. Hence the beginnings of newsheets and later newspapers, which conveyed information about the goods themselves, the price other people had been willing to pay for the same commodities at different times and places, the people involved in the transactions, the firms and markets from which they came, the availability and quality of transport and shipping, the state of war and peace, and so forth. The exchange was, then, first and foremost a meeting place for the exchange of information, which was in itself highly valued and which supported the flow of credit (from the Latin *credo*, “I believe”).⁵³

Neoclassical economists long ago emphasized the importance of information in any economy, although usually assuming that access to information is a transparent process. Questions of secrecy aside, it was from placing a high value on factual knowledge and the means by which its truths were assessed that commercial exchanges might happen; on such kinds of values the new science was founded, too.⁵⁴ More important, finding out the facts was a process to which people had become accustomed through their daily activities, a process in which they commonly invested some of their resources (as transaction costs), so that acting by the familiar rules of that game outside of business hours, so to speak, might bring delight as well as

⁵² Ogborn, *Indian Ink: Script and Print in the Making of the English East India Company* (Chicago, 2007); the book draws not only on the work of Shapin and Schaffer but on Adrian Johns, *The Nature of the Book: Print and Knowledge in the Making* (Chicago, 1998), among other works of the history of science.

⁵³ Cook, *Matters of Exchange* (cit. n. 27), 49–53.

⁵⁴ Long, *Openness, Secrecy, Authorship* (cit. n. 45); William R. Newman and Anthony Grafton, eds., *Secrets of Nature: Astrology and Alchemy in Early Modern Europe* (Cambridge, Mass., 2001); William Eamon, *The Professor of Secrets: Mystery, Medicine, and Alchemy in Renaissance Italy* (Washington, D.C., 2010).

material benefit.⁵⁵ Factual knowledge of nature did not have to be directly useful or financially profitable (although it might). But attentiveness to descriptive information about nature was part of a more general attention to those matters of fact that allowed a wide variety of transactions to take place.

Moreover, among the shared values in both commercial exchanges and scientific communication was clarity of speech, at the time called “plain speech.” As the Dutch physician Cornelis Bontekoe put it, “I am accustomed to pay more attention to the subject, and to the truth of what I say than to the fair choice of words and eloquence of style: all the more since I believe I am eloquent enough if I can make myself understood, since the only standard of speaking and writing is that of being understood.”⁵⁶ Similar statements can be found among early proponents of the Royal Society of London. In the work of historians of science of decades ago, plain speech was therefore seen as one of the chief characteristics of science, although it was often associated with “puritan” preaching.⁵⁷ But it may have even deeper roots in the kinds of exchange of accurate and precise information and promises necessary for business. Almost from the beginning of printing, publishers traded on the provision of information in order to supplement the manuscript newssheets on which merchants relied.⁵⁸

As an example of how the values common to both business and science were evidenced in one life, we can turn to a Dutch regent-savant, Nicolaes Witsen, born in 1641.⁵⁹ The son of an Amsterdam patrician and Muscovy merchant, Witsen rose to prominent positions in business and politics as well as becoming a well-known advocate for the new science and a patron of learning-as-information. As a young man he traveled with embassies to London and Moscow before embarking on a grand tour of France and Italy. He later gained election to the city council of Amsterdam—serving as burgomaster thirteen times—and to the governing board of the Dutch East India Company (the VOC), represented his city as an ambassador extraordinary in England after the Glorious Revolution, and hosted the visit of Tsar Peter to Amsterdam in 1697–8. He took a keen interest in land and sea routes, and maps, languages, and peoples, as well as new information about nature, collecting an impressive cabinet of *artificialia* and *naturalia* from throughout the Dutch East and West Indies. In 1671 he published a book on shipbuilding (*Scheepsbouw en Bestier*; revised and expanded as *Architectura Navalis* in 1690) and printed a map of what are now called Central and East Asia, which became the basis for a book on the subject (*Noord en Oost Tartarije*, 1692; expanded in an edition dated 1705 on the copperplate frontispiece but not published until many years after his death). Witsen also promoted expeditions to Namaqualand in southern Africa and to the maritime “southland” (western Australia, or Nieuw Holland); was a patron of many men of learning and the arts, including many informants about Asia; ventured into the republic of letters; became a fellow

⁵⁵ See also Anne Goldgar, *Tulipmania: Money, Honor, and Knowledge in the Dutch Golden Age* (Chicago, 2007).

⁵⁶ Bontekoe, *Tractaat van het excellenste kruid thee* [Treatise about the most excellent herb tea], vol. 14, *Opuscula Selecta Neerlandicorum de Arte Medica* (Amsterdam, 1937), 127.

⁵⁷ Richard F. Jones, *Ancients and Moderns: A Study of the Rise of the Scientific Movement in Seventeenth-Century England* (1936; repr., St. Louis, 1961).

⁵⁸ Andrew Pettegree, *The Book in the Renaissance* (New Haven, Conn., 2010), 130–50.

⁵⁹ I rely on Marion Peters, *De wijze koopman: Het wereldwijde onderzoek van Nicolaes Witsen (1641–1717), burgemeester en VOC-bewindhebber van Amsterdam* (Amsterdam, 2010), and Bruno Naarden, “Witsen’s Studies of Inner Asia,” in *The Dutch Trading Companies as Knowledge Networks*, ed. Siegfried Huigen, Jan L. de Jong, and Elmer Kolfin (Leiden, 2010), 211–39.

of the Royal Society of London; and much else. His personal library was sizable but not outstanding, being for his use rather than display and aimed at assembling information rather than model literature. Moreover, in his attempts to discover the truth of things in the midst of misinformation, rumor, and legend, he not only assessed his agents and compared accounts, but sought pencil sketches of people, places, and things, clearly placing a high value on picturability. Things with shape and solidity, which could be described carefully and acknowledged as real by the eyes, vouched for the nature of truth.⁶⁰

Or take another example, Witsen's cousin (and fellow burgomaster) Johannes Hudde. He is best known to historians of science as someone who contributed to the development of the mathematics of probability, but he was deeply involved in many kinds of political, mercantile, and scientific projects. The Huddes and Witsens of the world were necessarily highly numerate, and Hudde had a further excellent education in the mathematical school at Leiden, while in office he gave his attention to concerns such as raising funds for public institutions via lotteries, which in turn caused him to take up the problems of calculating probabilities.⁶¹ His mathematical explorations were in keeping with his experimental interests generally: for instance, he taught both Johannes Swammerdam and Antoni van Leeuwenhoek how to make the single-lens microscopes that made their own reputations, and he proved his personal abilities as a virtuoso in other ways, too.⁶² In other words, like Witsen, Hudde placed a very high value on discovering new and accurate information about the natural world, information that was available through the senses—sometimes with the aid of instruments—and equally encouraged the use of mathematics in support of both accuracy (as in Witsen's mapmaking) and generalization (as in Hudde's own calculations). One could multiply these examples by pointing to other urban patricians and improving landowners and princes throughout early modern Europe.⁶³ Their attentiveness to material detail fits well with what Shapiro terms a factual sensibility, Mokyr calls useful knowledge, and O'Brien characterizes as useful and reliable knowledge.

Of course, less wealthy and powerful people also took a major part in describing and analyzing the world of natural facts that the leaders of commerce valued so highly. Isaac Beeckman exemplifies many of these well-educated but middling sorts.⁶⁴ Best known as the person who introduced Descartes to the methods of mathematical physics, Beeckman was, among other things, a craftsman, businessman, physician, and schoolmaster. Intended by his father to be a minister, Beeckman had a fine education at a Latin school, also picking up practical mathematics from a teacher in Rotterdam, Jan van den Broecke, before continuing to read philosophy and mathematics during 1607–8 on the advice of Leiden professor Rudolph Snell.

⁶⁰ This may give further support to an older idea that associates the new science with the outlook of Petrus Ramus, although it does not reduce it to that; Walter J. Ong, *Ramus: Method, and the Decay of Dialogue; From the Art of Discourse to the Art of Reason* (1958; repr., Cambridge, Mass., 1983). See also Klaas van Berkel, *Isaac Beeckman (1588–1637) en de mechanisering van het wereldbeeld* (Amsterdam, 1983), revised and translated edition forthcoming.

⁶¹ Ian Hacking, *The Emergence of Probability: A Philosophical Study of Early Ideas about Probability, Induction and Statistical Inference* (Cambridge, 1975), 114–8.

⁶² Marian Fournier, "Jan Swammerdam en de 17e eeuwse microscopie," *Tijdschrift voor de Geschiedenis der Geneeskunde, Natuurwetenschappen, Wiskunde en Techniek* 4 (1981): 75–6; J. van Zuylen, "The Microscopes of Antoni Van Leeuwenhoek," *Journal of Microscopy* 121 (1981): 309–28; see 310.

⁶³ For an earlier example of the argument, see Pamela Smith, *The Business of Alchemy: Science and Culture in the Holy Roman Empire* (Princeton, N.J., 1994).

⁶⁴ For this account I rely on Van Berkel, *Isaac Beeckman* (cit. n. 60).

Returning from the university without a degree, he took up the candle-making trade of his father, then tried again for the ministry under the influence of the Pietist movement, while in business he developed an expertise in the piping of water for breweries, fountains, and other uses. He also began studying medicine and apparently became convinced of the truth of atomism after finding the arguments against it offered by Galen, Fernel, and others to be insufficient (he took an MD from Caen in 1618).

Two years later, in Breda, the city of his future bride, whom he was visiting, Beeckman met the young cavalier Descartes at the *rederijkerskamer* Het Vreuchdendal (one of the urban literary and debating societies common in the region). By then he had a new position as a schoolmaster in one of the most distinguished Latin schools in Utrecht, but he also acted as a technical consultant, advising on the dredging of the harbor of Dordrecht, for example. At the end of 1620 he moved to a position as rector of an illustrious school in Rotterdam, where he became a member of various social circles of regents, merchants, craftsmen, and tradesmen. He was frequently consulted on many industrial and infrastructural projects in the rapidly developing city and was among the eight founders of a *collegium mechanicum* there. He moved again in 1627, to the somewhat grander city of Dordrecht, as the rector of its distinguished Latin school, where he gave an inaugural oration on what he termed *fysisch-mathematische wijsbegeerte* (physico-mathematical philosophy) and where he built a tower full of instruments for the study of physical phenomena. He was connected to people who knew William Harvey, Giordano Bruno, and Galileo Galilei as well as to libertines and Rosicrucians, and hosted Pierre Gassendi and Marin Mersenne on their visits to the republic, although he quarreled bitterly with his former friend Descartes when he returned to the Netherlands in 1629. After returning to Zeeland in 1635, and before his death in 1637, he investigated methods for grinding lenses. He was a truly important figure for his ideas as well as for his investigative energies and technical abilities. But he also represents a group of very skilled and able students of natural phenomena who moved easily between the worlds of formal education, commerce, and governance, between medicine and natural philosophy, and between personal information networks and the distribution of information and ideas through impersonal books and devices. In cases like Beeckman's, it makes little sense to try to decide whether his abilities in craftsmanship and sales, engineering, politics, or learning, or even religion, led the way—they were of a piece, held together by the formal and informal institutions of the day.

A philosophical formulation of such values was given in 1632, on the occasion of the founding of an athenaeum in Amsterdam. The city's merchant princes had wanted a university, but were prevented by the states of Holland and Zeeland, who supported the supremacy of the university in Leiden, so they had to settle for an advanced school that could not award degrees. As the first professors in their new institution they appointed two of the most eminent philosophers in the country: Caspar Barlaeus and Gerhard Joannes Vossius. For his inauguration, Barlaeus delivered an address titled *Mercator Sapiens* ("The Wise Merchant")—afterward printed in both Latin and Dutch versions.⁶⁵ For his theme, he gave a modern twist to Martianus Cappella's late classical *Marriage of Mercury and Philology*, which would have been well known to

⁶⁵ For a recent study and translation into French, see Catherine Secretan, "*Le marchand philosophe*" de Caspar Barlaeus: *Un éloge du commerce dans Hollande du siècle d'or; Étude, texte et traduction du "Mercator Sapiens"* (Paris, 2002).

his distinguished audience. He turned the god Mercury into *Mercatura* (trade), and Philology into *Sapientia* (wisdom), and showed how their union in Amsterdam had created the most powerful and knowledgeable of polities.⁶⁶

Barlaeus could almost take it for granted that the merchants cared deeply about formal education, not only because they were establishing the athenaeum but because from the later Middle Ages they had promoted one of the most extensive systems of schooling in Europe.⁶⁷ Apprenticeship usually required initial literacy and numeracy, and further training in these skills was often stipulated by the guilds.⁶⁸ Cities in the Low Countries—as in the Breda of Beeckman and Descartes—also fostered *rederijkerskamers*, in which many adults could continue to pursue their enthusiasm for learning. Literacy in the republic was probably the highest in Europe, the rate around 1500 being approximately 30 to 40 percent of men and 20 to 30 percent of women, rising to about 85 and 64 percent, respectively, by 1800, and was even higher in the countryside than in the cities.⁶⁹ (Even rural workers might be involved in proto-industrial occupations, since imported grain from the Baltic freed much labor from the simple and heavy tasks of agricultural routine.) Many Dutch cities offered formal schooling in navigation, surveying, and other technical mathematical subjects, while private schoolmasters and tutors advertised their expert abilities to further educate pupils in Latin and other languages, mathematics, and other subjects.⁷⁰ Some families invested in advanced tutoring for their female children, too, with a few Dutch women gaining widespread reputations for their learning, such as Anna Maria Schurman, or Descartes's interlocutor, the princess Elizabeth.⁷¹

In Amsterdam, moreover, something like 7 percent of boys went on to universities, which was considered essential for any responsible position in business, law, politics, or religion.⁷² While Philip II had developed plans to establish a new university in Deventer, William the Silent and the provinces of Holland and Zeeland had founded a university in Leiden in 1575.⁷³ The province of Friesland followed that example by establishing a university in Franeker in 1585, and Groningen did the same in 1614. Many other cities also established athenaea or "illustrious schools," which gave local boys the equivalent of an introduction to university education: Harderwijk (in Gelderland) in 1600, Deventer in 1630, Utrecht in 1634, both Dordrecht and Den Bosch in 1636, Breda in 1646, Middelburg in 1650, Nijmegen in 1655, Rotterdam in

⁶⁶ For additional thoughts on Barlaeus's address, see Cook, *Matters of Exchange* (cit. n. 27), 68–73, and K. van Berkel, "Rediscovering Clusius: How Dutch Commerce Contributed to the Emergence of Modern Science," *Bijdragen en mededelingen betreffende de geschiedenis der Nederlanden* 123 (2008): 227–36.

⁶⁷ Engelina Petronella de Booy, *De Weldaet der scholen: Het plattelandsonderwijs in de provincie Utrecht van 1580 tot het begin der 19de eeuw*, Stichtse historische reeks 3 (Haarlem, 1977).

⁶⁸ Stephan R. Epstein and Maarten Roy Prak, eds., *Guilds, Innovation, and the European Economy, 1400–1800* (Cambridge, 2008).

⁶⁹ Van Zanden, *Long Road* (cit. n. 32), 190–5.

⁷⁰ A project on the culture of early modern Dutch mathematics is coming to a conclusion at the University of Twente, led by Fokko Jan Dijksterhuis and including Tim Nicolaije and Arjen Dijkstra.

⁷¹ Mirjam de Baar et al., eds., *Choosing the Better Part: Anna Maria Van Schurman (1607–1678)*, trans. Lynne Richards (Dordrecht, 1996).

⁷² Willem Frijhoff, "Het Amsterdamse Athenaeum in het academische landschap van de zeventiende eeuw," in *Athenaeum Illustre: Elf studies over de Amsterdamse Doorluchtige School, 1632–1877*, ed. E. O. G. Mulier Haitsma et al. (Amsterdam, 1997), 37–65; see 40–1.

⁷³ Frijhoff, "Deventer en zijn gemiste universiteit: Het Athenaeum in de sociaal-culturele geschiedenis van Overijssel," *Overijsselse historische bijdragen* 97 (1982): 45–79; M. W. Jurriaanse, *The Founding of Leyden University*, trans. J. Brotherhood (Leiden, 1965).

1681, Maastricht in 1683, and Zutphen in 1686. In Utrecht, the athenaeum was converted into a university proper in 1636 (i.e., it gained the legal right to grant degrees), followed by Harderwijk in 1648. Prince Maurits, who used the latest technology to excellent effect in his military campaigns, also insisted on setting up a formal engineering school at the university in Leiden under the leadership of an adviser and tutor of his, Simon Stevin: the curriculum was in Dutch, being called the *Nederduytsche Mathematique*, or “Dutch mathematics.”⁷⁴ While the governance structures of the advanced schools and universities varied, they usually contained representatives of the academic body together with a majority of members from the town council and provincial estates, who funded the schools partly from their own pockets via taxation. Even at this level of education the interests of the ruling merchants were dominant.

In his address to the Amsterdam regenten, then, Barlaeus could spend most of his words not explaining why merchants should be educated but countering the arguments of those who feared that engagement with worldly activity would undercut academic excellence. Thus, he explained why giving attention to the creation of wealth increased “ruminations of the mind,” too. Some of his arguments drew on the views of the famous jurist Hugo Grotius, French advocates of amour propre, and others who were showing why the pursuit of self-interest was natural and good.⁷⁵ But in looking around at the magnificent buildings of the expanding city, the canals and locks, docks and warehouses, and great ships, which brought bustling commerce in precious things from all the world over, Barlaeus not only praised the activities that created the city’s wealth and might but also demonstrated that its worldly interests were founded on virtue and learning. Both the merchant and the sage needed to cultivate honest conduct, and to value all things that helped them to discover what they sought after; moreover, a kind of love of worldly learning produced knowledge necessary both for trade and for learning. In going on to explain what he called “speculative philosophy” Barlaeus pointed not to abstract topics but to tangible subjects such as geography, natural history, astronomy, languages, and the study of other peoples’ dress, habits, and so forth.

In turning the attention of people to the “philosophical” implications of descriptive and factual subjects by revisiting ancient myths in light of this new world, Barlaeus was contributing to a Europe-wide discourse. His more famous English contemporary, Sir Francis Bacon, had of course been making similar claims as to how the conjunction of power and majesty depended on cultivating a knowledge of the world rather than of words; in the later sixteenth century, the French royal cosmographer Louis Le Roy had similarly shown not only that all great nations had united both power and wisdom, but that their cycle of rise and fall could be broken if the learned turned their attention to the preservation of the arts and sciences and all things necessary for life.⁷⁶ For Barlaeus’s contemporaries, there was even a new name for the kind of person who loved knowledge of the world virtuously: *liefhebber*. (At about

⁷⁴ Willem Otterspeer, *Groepsportret met dame: Het bolwerk van de vrijheid, de Leidse Universiteit, 1575–1672* (Amsterdam, 2000), 200–2.

⁷⁵ A good basic introduction to these themes remains Arthur O. Lovejoy, *Reflections on Human Nature* (Baltimore, 1961), 129–51.

⁷⁶ Le Roy, *Of the Interchangeable Course or Variety of Things in the Whole World, and the Concurrency of Armes and Learning thorough the First and Famousest Nations, from the Beginning of Civility, and Memory of Man, to This Present*, trans. R A (London, 1594); for one of the many suggestive works on Bacon, see Julie Robin Solomon, *Objectivity in the Making: Francis Bacon and the Politics of Inquiry* (Baltimore, 1998). See also Adrien Delmas, “Writing History in the Age of Discovery,

the same time, the English adopted the Italian *virtuoso*; the French would later use the word *amateur*, from *amare*, to indicate this kind of lover.)⁷⁷ Liefhebbers became particularly known for their collections of paintings, prints, and objects, both artificialia and naturalia.

It would certainly be possible at this point to start listing examples of the many other people in the Dutch Republic who would have shared the values placed on this kind of factual information as observed in Witsen, Hudde, and Beeckman and as articulated by Barlaeus. At almost the same moment that Barlaeus was speaking, Dr. Tulp commissioned from Rembrandt the famous painting of his anatomy lesson, a painting rich in symbolism about how it is possible to know the wonders of God's most magnificent creation, humanity, from the careful study of our physical bodies. It would not be long before people like Beeckman would be carefully considering William Harvey's new idea about the circulation of the blood, which was based on careful experimentation, or Descartes would be proposing a physiological account of human behavior in his work on the passions. Plans were also then being discussed to create a medical faculty in Utrecht, and an anatomy theater would soon be constructed in Amsterdam, where the apothecary Jan Swammerdam senior was only the best known of the many collectors of naturalia. All of them, despite their different backgrounds and various religious preferences, agreed on one thing: the first duty of anyone who wished to find out about natural things was to find out the matters of fact, in all their fine detail, before going on to speculate about their causes.

"EAST AND WEST" IN EARLY MODERN MEDICINE

Looked at from the home country, then, the northern Dutch world had become an entrepôt for scientific and technical information and ideas as much as an entrepôt for goods and finance. But at the same time, the Dutch had become powerful partly because they were not limited to activities in their home country: they had become sometimes-brutal merchants to the world, interacting not only with their European neighbors but with peoples of North America and Brazil; with the Caribbean, Angola and the Slave Coast of Africa, the South African Cape, the Malabar Coast of South Asia, Ceylon, Sumatra and Java, Taiwan, and Japan; and with other VOC cities and trading posts strung along the Indian Ocean from Basra and Mokka to what is today Thailand. In the home metropolis manuscripts and collections were accumulated, housed, and preserved, inventories were taken and sometimes published, and redistribution of the value-added information and objects was initiated. The cabinets of curiosities and gardens of men like Witsen were filling with specimens from the East and West Indies, and maps, engravings, travel writings, and books chock-full of information were pouring from the presses. Matters of fact from all over the world were uncovered and assessed, and at the same time that Dutch soldiers and sailors, and mercenaries, were to all intents and purposes destroying some indigenous peoples in order to retain a monopoly position in the spice trade, respect was offered to other people whose knowledge of the uses of nature was admired. Some of the indigenous

According to La Popelinière, 16th–17th Centuries," in Huigen et al., *Dutch Trading Companies* (cit. n. 59), 297–318.

⁷⁷ Jan de Jong et al., *Virtus: Virtuosititeit en kunstliefhebbers in de Nederlanden*, Nederlands kunsthistorisch jaarboek 2003, vol. 54 (Zwolle, 2004); Craig Ashley Hanson, *The English Virtuoso: Art, Medicine, and Antiquarianism in the Age of Empiricism* (Chicago, 2009).

peoples, such as the Chinese and Japanese, even seemed to possess a kind of scientific knowledge that equaled or bettered that of the Dutch, at least in some areas. The rise of science in the republic (as well as elsewhere) therefore demands some account of how it interacted with, and compared to, the information and concepts of other places.

A couple of examples might help to make the problem clear. The first is the physician Jacobus Bontius—son of the first professor of medicine at Leiden University—who took ship for the capital of the Dutch East Indies, Batavia (now Jakarta), in 1627. He survived for four years, during which time he endured a punishing schedule of administrative and medical duties and two sieges of the city by the Matamarese in which his own health suffered terribly; yet he also gathered together a great deal of information from local informants, from which he composed five major studies of the medicine and natural history of the region. He did so in the years shortly after the VOC virtually exterminated the population on some of the Banda Islands in order to insure its monopoly over the production and distribution of nutmeg. But Bontius himself grew to think so well of many of his local acquaintances that he considered them superior in knowledge and skill to any European medical practitioner. He then turned the strange and exotic customs he encountered into parcels of useful and accurate information, information that could be easily transported from Java to literal-minded readers elsewhere.

Bontius's efforts have been explored at length recently.⁷⁸ For the moment it is enough to note a few points. One is that he had the governors of the VOC in mind when he composed his works, although the manuscripts were sent to his brother (a lawyer in Leiden) and published many years after his death, when increased interest in the Dutch enterprises overseas became manifest. Second, despite the difficulties he encountered, he managed to collect a very large body of information. In doing so, he explained, he was an eyewitness to the truths of the Indies that none of his European medical forebears had experienced, yet in retrospect it is clear that he was heavily dependent on local informants for the details he gathered about the use of plants, animals, and minerals to treat diseases. While he does not explain his methods directly, from various hints it would appear that most of his informants were women, and some of them slaves. In interacting with them, it would appear that he came to admire them, frequently defending them against usages of his contemporaries that included calling them "barbarians." Third, when he wrote down his findings, he left out some topics. While he loudly praised the God-given medicinal effects of local plants and the uses made of them by local people, at the same time he dismissed out of hand the local meanings attached to the plants and practices. That is, his concern for descriptive information—matters of fact—gave him a blind spot when it came to what we would call the intellectual system of, or cultural assumptions behind, local medical practices. He says nothing about any learned medical traditions he might have encountered, nor does he reveal anything substantial about the practices that

⁷⁸ Harold J. Cook, "Global Economies and Local Knowledge in the East Indies: Jacobus Bontius Learns the Facts of Nature," in *Colonial Botany: Science, Commerce, and Politics in the Early Modern World*, ed. Londa Schiebinger and Claudia Swan (Philadelphia, 2005), 100–18, and *Matters of Exchange* (cit. n. 27), 191–209. For his works, see Jacobus Bontius, *De Medicina Indorum* (Leiden, 1642); William Piso, *De Indiae Utriusque Re Naturali et Medica Libri Quatuordecim* (Amsterdam, 1658); modern translations in *Opuscula Selecta Neerlandicorum de Arte Medica*, 19 vols. (Amsterdam, 1907–48), vol. 10 (1931).

were deeply embedded in much of local medical ritual, although he makes occasional dismissive remarks about “superstition” and “idolatry.” In other words, Bon-tius did not simply encounter and speak with various sorts of people; he was boiling things down to their lowest common denominator, information units that could be circulated in just about any context. He (re)produced knowledge, accumulated it, and handed it on in a form that made his information about nature commensurable with that produced in any other place.

Or take the example of another physician in the East Indies, Willem ten Rhijne.⁷⁹ He is well known as the first European university-educated physician to live in Japan, which he did for two years in the 1670s. He was there because the Japanese government had ordered the VOC to send such a person. Many well-placed Japanese scholar-physicians were then seeking to modify the principles of classical Chinese medicine into a Japanese approach and were intrigued by the possibility of using Western medical knowledge as part of their reforms. Many of the Japanese translators who worked with the Dutch were scholars in their own right, and because of the close link between classical learning and medicine, many were also physicians, or at least knowledgeable about medicine. By the later 1660s, someone close to the shogun wanted access to more than Dutch surgeons, which had led to the orders that caused the VOC to seek someone like Ten Rhijne.

To be brief, during the two years he spent on the tiny island of Deshima, in the harbor of Nagasaki—to which the Dutch were confined for the purposes of trade—Ten Rhijne was kept busy answering questions and even visiting patients and pharmacies. But in the process he also managed to turn the personal relationships with his Japanese acquaintances into opportunities to ask questions of them in turn. The difficulties of finding a vocabulary for the exchanges were clearly evident from some of Ten Rhijne’s complaints, for not all of the official translators understood him easily. But there had implicitly been much preparation on the part of the translators before they started to work, and indeed some of them became well versed in medicine. Most of the questions they asked concerned the composition of Western medicines, and their use, but some were of a more general nature, such as “Why do you touch only the left radial pulse?” and “How do you discriminate the yang-type and yin-type carbuncles?” He replied with explanations based on European physiology, such as that the circulation of the blood meant that there was no difference between the left and right pulses, and that the yang and yin referred to hot and cold, which were qualities from an older medical system that no longer had meaningful diagnostic significance. Other kinds of questions, such as those regarding the uses of certain kinds of botanicals, he could answer with less concern for conceptual incompatibilities. He also helped the translators learn more about the latest anatomical findings from Europe. In turn, Ten Rhijne learned from the Japanese.

In the late 1670s and early 1680s, living on the west coast of Sumatra, he had a chance to put many of his medical thoughts in order and wrote a letter to Henry Oldenburg, the secretary of the Royal Society of London, asking whether the society

⁷⁹ I have also written about him at greater length: Harold J. Cook, “Medical Communication in the First Global Age: Willem Ten Rhijne in Japan, 1674–1676,” *Disquisitions on the Past and Present* 11 (2004): 16–36, and *Matters of Exchange* (cit. n. 27), 339–77. See also Wolfgang Michel, “Willem Ten Rhijne und die japanische Medizin (I),” *Studien zur deutschen und französischen Literatur* 39 (1989): 75–125; Michel, “Willem Ten Rhijne und die japanische Medizin (II),” *Studien zur deutschen und französischen Literatur* 40 (1990): 57–103.

would be interested in seeing his work. One part of his manuscript contained the first detailed report by a European on the practice of acupuncture, as well as further information on moxibustion. The letter caused considerable discussion at a meeting of the Royal Society, which quickly agreed to publish it—it appeared in 1683, helping to create a brief flourishing of popularity for acupuncture in Europe.⁸⁰ But it is noticeable that Ten Rhijne's attempts to summarize Chinese medical concepts, as filtered through his Japanese acquaintances who had studied in China, were hopelessly garbled, so that even in our own day the proper names of Chinese authors to whom he referred remain unrecognizable.⁸¹

SCIENCE AND "OBJECTIVITY"

One could elaborate much further on these and other examples of early modern East-West medical exchanges.⁸² But the general point is that some matters were successfully exchanged while other matters were not. Information about medicines and practices—descriptions about tangible things available to the senses—moved as readily between places as other goods, while meanings and explanations, and some kinds of concepts, presented a great deal of linguistic and philosophical difficulty, leading to elision, speculation, and (sometimes creative) misunderstanding on each side. In other words, to invoke a distinction from decades ago between knowledge claims that refer to sensations and those that refer to words: "Observation sentences peel nicely; their meanings, stimulus meanings, emerge absolute and free of all residual verbal taint. Theoretical sentences such as 'Neutrinos lack mass,' or the law of entropy, or the constancy of the speed of light, are at the other extreme. For such sentences no hint of the stimulatory conditions of assent or dissent can be dreamed of that does not include verbal stimulation from within the language."⁸³ Some Europeans, Ten Rhijne among them, made considerable efforts to understand not only the medical practices of East Asians, but their terminology and even their medical views, just as some Japanese tried to understand aspects of European medical practices, anatomical findings, and basic principles; in the process, some fundamental concepts, such as *yin* and *yang*, resisted attempts at translation. But other aspects of their work moved easily, because they were more descriptive: more objective. This is to turn upside down the common claim that scientific ideas are universal, saying instead that those words and formulae that can be conveyed from place to place are by definition "scientific" (in the German sense of *wissenschaftlich*).

Such episodes did not lead to any major revolutions in medical practice on either side, but they make it clear that contemporary commerce enabled personal networks to convey a great deal of information about the natural world around the globe. The information was communicated in more than one direction (although like others who do not know Asian languages, my own knowledge is about how a host of locales con-

⁸⁰ Ten Rhijne, *Dissertatio de Arthritide* (London, 1683).

⁸¹ For example, see the struggles to interpret his views by Gwei-Djen Lu and Joseph Needham, *Celestial Lancets: A History and Rationale of Acupuncture and Moxa*, new ed., ed. Vivienne Lo (London, 2002), 271–6.

⁸² Harold J. Cook, "Conveying Chinese Medicine to Seventeenth-Century Europe," in *Science between Europe and Asia: Historical Studies on the Transmission, Adoption and Adaptation of Knowledge*, ed. Feza Günergun and Dhruv Raina (Heidelberg, 2011), 209–32.

⁸³ Willard Van Orman Quine, "Meaning and Translation," in *On Translation*, ed. Reuben Brower (Oxford, 1966), 148–72, quotation on 171.

tributed to the accumulation of information in European entrepôts). Ideas and information flowed from place to place in the minds or on the notebook pages of travelers often enough to make it possible to speak of wider intellectual “movements.” While recent work in the history and sociology of science has stressed how knowledge was produced in close-knit groups of local investigators, local knowledge became part of more general developments, giving rise to the Renaissance, the Scientific Revolution, the Enlightenment, and so on.⁸⁴ But something we often term “culture”—rooted in ways of life and language—made some aspects of early modern knowledge systems very difficult to move about.

The transmission of information and, sometimes, ideas from West to East and vice versa is therefore a particularly illustrative example of a more general problem: how did the knowledge claims of people in the commercial parts of the Dutch Republic interact with those in other regions? The interactions might be at far distances, or among regions or nations that bordered one another, or between a commercial capital and its rural hinterland—even between one person and another. But while there are exciting debates occurring about the economic exchanges between “the West and the rest,” we have a more rudimentary understanding of the exchanges of knowledge.

A particularly important and long-standing argument for our present purposes is the Needham thesis, which has set the stage for so many of the comparisons between Europe and China. Joseph Needham was both a practicing scientist and a historian of embryology who fell in love with a woman from China and spent time there during the Second World War while beginning to document the country’s history of science in order to show that it was responsible for many of the material innovations most important for humankind. The many volumes of the huge project for which he is responsible began to appear in 1954, and as of 2000 they had been published in twenty-one parts.⁸⁵ Although he changed some of his eclectic views over time as his research accumulated, his impressive studies immediately posed a challenge to standard accounts of the history of science. During the period of the European Middle Ages, the Chinese could be shown to have been more innovative and possessed of more technically superior methods than any other people on earth; but it was the Europeans rather than the Chinese who had the Scientific Revolution. Why? It is a question that has continued to set a framework for the history of science in China—and indeed, in many other non-European contexts, too⁸⁶—despite attempts by many of its practitioners to move beyond it.⁸⁷

⁸⁴ Also, Harold J. Cook and David S. Lux, “Closed Circles or Open Networks? Communicating at a Distance during the Scientific Revolution,” *Hist. Sci.* 36 (1998): 179–211.

⁸⁵ Needham, *Science and Civilisation in China*, 7 vols. (21 parts) (Cambridge, 1954). See also Colin A. Ronan, ed., *The Shorter “Science and Civilization in China”: An Abridgement of Joseph Needham’s Original Text*, 2 vols. (Cambridge, 1978–81). For an introduction to Needham’s biography and views, see H. Floris Cohen, *The Scientific Revolution: A Historiographical Inquiry* (Chicago, 1994), 418–29; Alain Arrault and Catherine Jami, eds., *Science and Technology in East Asia: The Legacy of Joseph Needham* (Turnhout, 2001); Jack Goody, *The Theft of History* (Cambridge, 2006), 125–53; and Simon Winchester, *The Man Who Loved China: The Fantastic Story of the Eccentric Scientist Who Unlocked the Mysteries of the Middle Kingdom* (New York, 2008).

⁸⁶ Dhruv Raina, “Cognitive Homologies in the Studies of Science in Indian Antiquity: A Historiographic Axis of the Indian Journal of History of Science,” in Arrault and Jami, *Science and Technology in East Asia* (cit. n. 85).

⁸⁷ E.g., see Mark Elvin, *The Retreat of the Elephants: An Environmental History of China* (New Haven, Conn., 2004); Benjamin A. Elman, *On Their Own Terms: Science in China, 1550–1900* (Cambridge, Mass., 2005); Francesca Bray, *Technology and Society in Ming China (1368–1644)*

It may be, however, that Needham's is a *question mal posée*. While on the one hand his question elevated science in China to world significance, on the other it also made the Scientific Revolution an even more singular instance of Europe's exceptionalism. At the moment, many of the historians of European science who have taken Needham's question to heart have used it mainly to explore the special qualities of Europeans. An example is Floris Cohen's impressive studies.⁸⁸ In a recent book on the Scientific Revolution written for a Dutch audience, when pondering the question, why Europe? Cohen ends up supplying an answer based on what he takes to be special qualities of European culture: "greater openness, more intensive curiosity, stronger energy, more powerful individualism and judgment—and a stronger seeking of everything in an active earthly existence."⁸⁹ In his more recent analysis for a more scholarly audience, he explains these differences as being due to "Europe's singular dynamism," which was in turn the result of "how European civilization aimed in action *and* in thought to intervene in the world and manipulate it for human ends."⁹⁰ He is certainly not alone in offering such explanations. Purported special cultural attributes are often proposed for European exceptionalism, or even superiority. To mention just two more examples: In a recent stimulating account on globalization in the early modern period, Geoffrey Gunn explains that "the 'divergence' was as much intellectual as it was material. Eventually, European science and technology triumphed" because of a unique attribute that he characterizes with the word *curiosity*, which he thinks the Europeans possessed in abundance but which was lacking elsewhere.⁹¹ In another recent work promising a global perspective on the history of science Toby Huff agrees. He finds evidence "of a wide and deep embedding of an infectious *ethos of scientific curiosity* across Europe that remained unmatched outside Europe during the seventeenth and eighteenth centuries."⁹²

If we do not think that Europeans exhibited characteristics such as a drive for domination or curiosity because of some inherent trait—and I certainly do not—then this sort of explanation must carry weight only when the authors who invoke it show what elements in Europeans' form of life caused them to be more curious than other people. Otherwise we fall into the vexed problem of comparing civilizations. One of the chief advocates for including civilizations additional to the Western in the post–World War II American curriculum, Marshall Hodgson, defined a civilization as "what is carried in the literature of a single language, or of a single group of culturally related languages." He broadened the definition further to include cultural formations committed to "major lettered traditions," which in turn made for continuity "in social and economic institutions generally. All cultural traditions [therefore] tend to be

(Washington, D.C., 2000); and Vivienne Lo's introduction to Lu and Needham, *Celestial Lancets* (cit. n. 81).

⁸⁸ See esp. Cohen, "Joseph Needham's Grand Question, and How to Make It Productive for Our Understanding of the Scientific Revolution," in Arrault and Jami, *Science and Technology in East Asia*, 21–31, and his earlier considerations in Cohen, *Scientific Revolution*, 418–29 (Both cit. n. 85).

⁸⁹ Cohen, *De Herschepping van de Wereld: Het ontstaan van de moderne natuurwetenschap verklaard* (Amsterdam, 2008), 267; similar sentiments are expressed on 149–50.

⁹⁰ Cohen, *How Modern Science Came Into the World: Four Civilizations, One 17th-Century Breakthrough* (Amsterdam, 2010), 138, emphasis in the original; see also 47, where Cohen highlights his debt to Landes's idea of "latent developmental potential" to explain the differences.

⁹¹ Gunn, *First Globalization: The Eurasian Exchange, 1500–1800* (Lanham, Md., 2003), quotation on 7–8, and see esp. 4 for his summary of his views about curiosity among Europeans.

⁹² Huff, *Intellectual Curiosity and the Scientific Revolution: A Global Perspective* (Cambridge, 2011), 299; emphasis mine.

closely interdependent.”⁹³ In other words, civilizations are defined by their core texts and the cultural values that are embodied in them and flow from them, which give rise to unities of outlook and behavior. A recent popular reformulation of this argument sees contemporary events in terms of the “clash of civilizations,” one influential statement of which, by Samuel Huntington, gives a six-part definition that amounts to saying that civilizations are ideological formations that underlie politics but are not political systems per se; he also adds that “religion is a central defining characteristic of civilizations.”⁹⁴ Ironically, perhaps, in light of the arguments above, he goes on to write that while “the causes for the rise of the West are multiple” they rely on technological means of coercion. “The West won the world not by the superiority of its ideas or values or religion (to which few members of the other civilizations were converted) but rather by its superiority in applying organized violence. Westerners often forget this fact; non-Westerners never do.”⁹⁵

But one of the most helpful aspects of recent versions of world and global history is that they are led by questions about economies, which challenge us to rethink national, cultural, ideological, and even civilizational units in order to examine levels of human organization that are closer to ordinary life. In the past two decades, several powerful arguments along such lines have offered a fundamental revision of previous assumptions about comparisons between European and other places. Immanuel Wallerstein and Fernand Braudel have both taken the view that European economic domination of the world’s trading system, which began with the upswing in urban commerce in the later medieval period and was consolidated under the Spanish and Portuguese overseas commercial empires of the sixteenth century (and the later successful interloping of the Dutch and English), created a commercial-financial engine of growth.⁹⁶ They were stimulated in part by earlier work on the commercial system of the Indian Ocean, which in the early modern period came to be dominated by the European trading companies, implicitly showing how much wealth was transferred from Asia to Europe.⁹⁷ Other historians, such as Jonathan Israel, attribute much economic growth in Europe (in his case, the Dutch Republic) to the wealth acquired from overseas commerce.⁹⁸ Asian goods were clearly highly sought after and brought tremendous wealth to the European merchants controlling the trade.⁹⁹

But a powerful counterblast has come from economic historians who are keenly

⁹³ Hodgson, *Rethinking World History: Essays on Europe, Islam, and World History*, ed. Edmund Burke III (Cambridge, 1993), on 82, 84.

⁹⁴ Huntington, *The Clash of Civilizations and the Remaking of the World* (New York, 1996); for the definition see 41–5; for the quotation, 47.

⁹⁵ Ibid., 51. Anthony Pagden gives more weight to the Scientific Revolution, though not because of useful “science” in the usual, technological, sense, but because it led to a better understanding of humankind in the Enlightenment (i.e., he incorporates SDP₂ in his account); Pagden, *Worlds at War: The 2,500-Year Struggle between East and West* (New York, 2008), esp. 252–61.

⁹⁶ Wallerstein, *The Modern World-System*, vol. 1, *Capitalist Agriculture and the Origins of the European World-Economy in the Sixteenth Century*, and vol. 2, *Mercantilism and the Consolidation of the European World-Economy, 1600–1750* (New York, 1974 and 1980); Braudel, *Civilization and Capitalism* (cit. n. 28).

⁹⁷ Kristof Glamann, *Dutch-Asiatic Trade, 1620–1740* (Copenhagen and The Hague, 1958); Niels Steensgaard, *The Asian Trade Revolution of the Seventeenth Century: The East India Companies and the Decline of the Caravan Trade* (Chicago, 1974).

⁹⁸ Israel, *Dutch Primacy in World Trade, 1585–1740* (Oxford, 1989).

⁹⁹ Jan De Vries, “Connecting Europe and Asia: A Quantitative Analysis of the Cape-Route Trade, 1497–1795,” in *Global Connections and Monetary History, 1470–1800*, ed. Dennis O. Flynn, Arturo Giráldez, and Richard von Glahn (Aldershot, 2003), 35–106.

interested in the Eurasian story from the viewpoint of East Asia. Three of them argue that throughout the early modern period the Chinese economy rather than the European one dominated global commerce. Andre Gunder Frank's *ReOrient*, for instance, takes the view that there was nothing in European commercial methods that the Chinese did not also have; in fact, the Europeans were latecomers to the Asia trade. According to Frank, then, the "Rise of the West" came only in the nineteenth century and has caused our historical and social models, based on the supremacy of Europe and mainly articulated in the period of European dominance, to be fundamentally mistaken. Most important in terms of the common SDP arguments, his summary of the reasons why Europe rather than China had an Industrial Revolution makes no case for political or intellectual advantages, only for a conjuncture of ecological/economic incentives and demographical/economic structures.¹⁰⁰ R. Bin Wong similarly argues that Chinese history cannot be interpreted according to the widely used formulations of Marx, Weber, and others, and that the importance of the early Industrial Revolution in Europe has been overrated.¹⁰¹ The third of this group, Kenneth Pomeranz, offers a somewhat more familiar view of the Industrial Revolution as separating parts of Europe from the path of labor-intensive growth previously shared with regions of China and the rest, making for a profound historical difference, however temporary in the long term. To do so, however, Pomeranz compares and contrasts the economic development of "core areas" in Europe and East Asia rather than nations, and without holding one to be the norm, finds that the Industrial Revolution emerged from new sources of capital made possible by the appropriation of New World resources through force and slavery, assisted by the peculiar institutions of armed long-distance trading companies. For Pomeranz, too, then, what has made for economic advantage has nothing to do with science or technology per se, let alone representative polities or special ideologies.¹⁰²

Since these works of the late 1990s, the question of why the Industrial Revolution occurred in Europe rather than China has been hotly debated, gaining the attention of scholars of the new comparative economic history, for instance.¹⁰³ Members of that group have made the coercive power of gunpowder and naval technology even more important in the shifting story of the world economy.¹⁰⁴ For our purposes, we need only observe that among the conclusions of such debates is that while areas of northwest Europe were becoming part of an integrated market, elsewhere there were many regional and local markets. Long-distance firms like the Dutch and English East India Companies therefore made a great deal of their profit from something like

¹⁰⁰ Frank, *ReOrient: Global Economy in the Asian Age* (Berkeley and Los Angeles, 1998); see esp. 312–4.

¹⁰¹ Wong, *China Transformed: Historical Change and the Limits of European Experience* (Ithaca, N.Y., 1997). See also the critique of mainline Western social science principles in Goody, *Theft of History* (cit. n. 85).

¹⁰² Pomeranz, *The Great Divergence: China, Europe, and the Making of the Modern World Economy* (Princeton, N.J., 2000); for a summary of his views, see 8–21.

¹⁰³ T. J. Hatton, Kevin H. O'Rourke, and Alan M. Taylor, eds., *The New Comparative Economic History: Essays in Honor of Jeffrey G. Williamson* (Cambridge, Mass., 2007), 1–8.

¹⁰⁴ Ronald Findlay and Kevin H. O'Rourke, *Power and Plenty: Trade, War, and the World Economy in the Second Millennium* (Princeton, N.J., 2007). Another emerging alternative is to emphasize the peculiarities of European urbanization, which forced industry behind city walls because of high levels of warfare; Jean-Laurent Rosenthal and R. Bin Wong, *Before and Beyond Divergence: The Politics of Economic Change in China and Europe* (Cambridge, Mass., 2011).

arbitrage, exploiting the price differences among the markets by moving goods from one place to another.¹⁰⁵

If the early modern world continued to exhibit several different forms of economy, were there perhaps also several forms of science? It would appear so if we pay attention to recent works in the history of Chinese science, for instance. Mark Elvin's investigations bring us back again to terms such as *useful and reliable knowledge*, suggesting that the critical difference between Europe and China was the lack of fact-finding in the latter, or what we might better say was a lack of suitable institutional arrangements to produce facts. Elvin takes the example of an early modern scholar writing an encyclopedic work that contains a section on dragons. Why does he not explain that dragons are legendary rather than real? "Xie has no procedure that will systematically tend to establish facts and to discredit falsehoods. Hence it is possible for him to show a relatively high level of logic in his arguments, but to make no useful progress, because often what he takes to be facts are not." He elaborates,

The fact was not known in premodern China. By a "fact" in this sense, I mean a publicly recorded and accessible statement about an observable aspect of the world, set in the context of a systematic evaluation of the evidence that yields an approximate probability of its being true, and subject to a continuing public scrutiny and re-evaluation, with the results and the evidence being publicly recorded and accessible. China came quite close; what was mainly lacking was the continuity of public scrutiny and the circulation of the results. In other words, the feedback process.¹⁰⁶

In yet other words, China did not have the institutional arrangements for assessing natural facts that had become so familiar in early modern Europe because of the extent and power of commercial arrangements.

CONCLUSIONS

If we wish to understand the values of European merchants thinking about the connections between distant places, we need to consider not only how they valued their material goods, but the high value they placed on factual descriptions of a variety of people, places, objects, and conditions at many places. Together, they probed for the similarities and differences to find common denominators. Their institutional solutions for reducing transaction costs depended on being able to exchange matters of fact among themselves, which in turn allowed them to exert long-distance control over their representatives, employees, and laborers while at the same time negotiating with colleagues, rivals, law courts, and the abstract reckoning of markets. In such circumstances, commercial materialism happily went hand-in-hand with the new science, which also offered careful descriptions of physical phenomena and explanations couched in terms of philosophical materialism. To people like the merchants and those around them who held similar values, focusing on inquiries and explanations that invoked nothing more than material facts might provide comfort as well as offer openings toward the productive management of such phenomena, and the familiarity of such matters could sometimes become joyful indulgence or fond admiration for unusual information or elegant explanations. But it was not everyone's

¹⁰⁵ See esp. the thoughts of De Vries, "Connecting Europe and Asia" (cit. n. 99), 94–7.

¹⁰⁶ Elvin, *Retreat of the Elephants* (cit. n. 87), 388.

cup of tea. Clerics often objected to the limitations and conclusions of such lines of inquiry—the Calvinist ones could be as obstreperous as the Catholic ones about Copernicanism, for instance—while they were probably of little interest to those of other frames of mind.¹⁰⁷ Elsewhere, such forms of knowledge could provoke both admiration for their exactness and frustration at their moral emptiness. In Japan, for instance, one neo-Confucian scholar admitted that the descriptive power of European astronomy was very great, but held that the attention given to the appearances of things was vulgar.¹⁰⁸ So were merchants in his eyes, no doubt.

We sometimes forget that Copernicus wrote on monetary policy, or that Robert Boyle held a place on the board of the English East India Company and held shares in the Hudson's Bay Company, or that Newton—the master of the mint who ferreted out and bound over for execution a large number of counterfeiters—lost his fortune in the South Sea bubble (although Sir Hans Sloane managed to get out in time).¹⁰⁹ Such scientists moved easily from commerce to science and back again, since both were founded on the factual sensibility. The shape of the concerns of, say, a director of the VOC such as Witsen would have been quite familiar to his fellow virtuosi in seventeenth-century London, and in Hamburg, Augsburg, Paris, Marseilles, and Venice; and it was probably familiar enough to those in Osaka, Canton, Cochin, Basra, and many other trading capitals. But it may be that those outside Europe did not have durable institutional arrangements for organizing their activities according to something like lawful regularities among people who were of different clans and ethnicities and so could not draw on as many allies when in need.¹¹⁰ Moreover, merchants had political authority—even sovereign power—almost nowhere else beyond a few parts of Europe, those in the rest of the world usually being as despised by their rulers as their counterparts had been by European kings of distant generations. That is the explanation once offered by Needham for the differences between Chinese and European science: despite having all the seeming prerequisites, China did not give rise to the Scientific Revolution because it was ruled by the mandarins, with merchants being placed considerably lower on the social scale. The rise of European commercial power and science at the same time was no accident. Both appeared on the back of new forms of social life that are described as formal and informal institutions and that made information exchange sovereign.¹¹¹

What I am suggesting is that science and the ways of life that are often termed economic share many sources, so that the relationships between them might illuminate

¹⁰⁷ Rienk Vermij, *The Calvinist Copernicans: The Reception of the New Astronomy in the Dutch Republic, 1575–1750* (Amsterdam, 2002).

¹⁰⁸ Shigeru Nakayama, *A History of Japanese Astronomy: Chinese Background and Western Impact* (Cambridge, Mass., 1969), 88–98.

¹⁰⁹ J. Taylor, "Notes and Documents: Copernicus on the Evils of Inflation and the Establishment of a Sound Currency," *J. Hist. Ideas* 16 (1955): 540–7; Timothy J. Reiss and Roger H. Hinderliter, "Money and Value in the Sixteenth Century: The Monete Cudende Ratio of Nicholas Copernicus," *J. Hist. Ideas* 40 (1979): 293–313; Sarah Irving, *Natural Science and the Origins of the British Empire* (London, 2008); Carl Wennerlind, *Casualties of Credit: The English Financial Revolution, 1620–1720* (Cambridge, Mass., 2011).

¹¹⁰ Timur Kuran, *The Long Divergence: How Islamic Law Held Back the Middle East* (Princeton, N.J., 2011).

¹¹¹ On the importance of information exchange to early modern politics, see Filippo De Vivo, *Information and Communication in Venice: Rethinking Early Modern Politics* (Oxford, 2007), and Jacob Soll, *The Information Master: Jean-Baptiste Colbert's Secret State Intelligence System* (Ann Arbor, Mich., 2009).

some of their commonalities in other circumstances as well. The means of production powered by coal may have shifted attention to concepts of energy, the telegraph and other forms of communication to theories of signaling, the German chemical dye industry to cell theory, and so on, all of which involve ways of understanding nature that could not have been imagined in the early modern period. Such a strategy may help us to penetrate the sometimes obscure formulations of the “culture” of science by allowing us to examine the material relationships entangled in it rather than treating it as a more encompassing form of intellectual history. Newton’s science may not have created the Industrial Revolution, but it was certainly a careful articulation of a massive amount of information about the physical universe compiled using the most precise methods available, as well as calculations and proposals about how the details all fit together. He therefore became deservedly famous among the businessmen and entrepreneurs, as well as the virtuosi, of his age. It may be that numerate and critical merchants could understand what he was proposing far better than their aristocratic contemporaries. And it may be that such a form of science, based on exchangeable units of reliable information, remains fundamental to our lives, like commerce, despite the fact that the methods of both have been enormously altered since his time. We need not think that Newton’s scientific or economic concerns are the same as ours, although there are familiar elements in them. But we should remind ourselves of the reason why development economists regularly associate modern science and modern economies: they are coproduced.

Calling for attention to the connections between economic history and intellectual history is no longer a revolutionary move. A new generation of work in the history of science is attentive to what one recent book title calls the “mindful hand”; this work can offer thoughtful assistance to the many who are concerned with SDP.¹¹² The recent study by Lissa Roberts on steam machines and entrepreneurs in the Dutch Republic, France, and Britain in the eighteenth century is an excellent example of how very different the picture of the Industrial Revolution looks if one moves away from the standard figures of the British story and considers knowledge and economy as interactive rather than distinct processes.¹¹³ For a somewhat earlier period, examples include the works of William Eamon, Pamela Long, and Deborah Harkness on practical knowledge and science; Paula Findlen, Lorraine Daston, and Katherine Park on collections; Pamela Smith on artisanal knowledge of nature; Karel Davids on technological development and the knowledge economy of the urban Dutch Republic; and Mario Biagioli on Galileo’s “instruments of credit,” as well as a continuing interest in the medical marketplace and collected volumes on natural history, commerce, and empire.¹¹⁴ Other work, like that of Ursula Klein, has emphasized the material culture

¹¹² Lissa Roberts, Simon Schaffer, and Peter Dear, eds., *The Mindful Hand: Inquiry and Invention from the Late Renaissance to Early Industrialisation* (Amsterdam, 2007).

¹¹³ Roberts, “Full Steam Ahead: Entrepreneurial Engineers as Go-betweens during the Late Eighteenth Century,” in *The Brokered World: Go-betweens and Global Intelligence, 1770–1820*, ed. Simon Schaffer et al. (Sagamore Beach, Mass., 2009), chap. 5.

¹¹⁴ Eamon, *Science and the Secrets of Nature*; Long, *Openness, Secrecy, Authorship* (Both cit. n. 45); Harkness, *Jewel House* (cit. n. 4); Findlen, *Possessing Nature*; Daston and Park, *Wonders* (Both cit. n. 47); Smith, *The Body of the Artisan: Art and Experience in the Scientific Revolution* (Chicago, 2004); Davids, *Rise and Decline* (cit. n. 14); Biagioli, *Galileo’s Instruments of Credit: Telescopes, Images, Secrecy* (Chicago, 2006); Schiebinger and Swan, *Colonial Botany* (cit. n. 78); Timothy Walker, “Acquisition and the Circulation of Medical Knowledge within the Early Modern Portuguese Colonial Empire,” in *Science in the Spanish and Portuguese Empires, 1500–1800*, ed. Daniela Bleichmar et al.

of scientific practice.¹¹⁵ Moreover, prompted in part by some of the literature on early modern global interconnectedness, and in part by Bruno Latour's imagining of networks of practice, the boundary crossers and intermediaries who made the exchange of knowledge among people of different languages and cultures possible and profitable are now receiving the kind of attention they deserve.¹¹⁶ Since the authors of such work often explore the experiences of Europeans abroad that challenge set narratives of colonialism and empire, they offer much evidence of the kind of interactions that produced knowledge, which should interest a new generation of global historians. Investigations such as these, at the intersections of the grand themes of the history of science and economy, have the potential to open up new vistas on historical contingency and structure, exploring how small and seemingly unrelated events can have larger consequences at far distances.

A world in swift motion and transformation, full of potential dangers as well as benefits, pictured against a steadying backdrop of facts that remained constant: by the sixteenth century, this was becoming an increasingly acceptable way to know the things constituting nature in the academies of Europe. It was worldly knowledge, gained from the bubbling up of countless encounters with the material world rather than a trickling down of appreciation for eternal verities. It was the knowledge gained in the first instance not by the professors, but by the people who moved about, working with things and other people, gaining confidence from their acquisition of experience and knowledge of precise details, and sharing at least some of it. It may not have been the big picture, but in the midst of change one might take comfort in the stability of small things, through which, sometimes, one might glimpse the larger interconnections of all things that are.

Maybe the moral threat of materialism to the established politico-religious order was real. Horrors like the events in the Banda Islands certainly were. But at the same time, seaborne commerce provided new means of exchange, exchange that necessarily brought people around the globe into conversation with one another, creating the framework for a kind of discourse about what everyone could agree was true, which we used to call objective science. In some cases, at least, those conversations encouraged not only finding utilitarian benefits for human life but respect for one another. Attention to material things gave no hint of personal salvation, but it fostered the building of information networks that stretched across the globe. For Grotius, Spinoza, and many other philosophers of the early modern period, developing forms of sociability were now the key to a kind of secular hope of betterment in both knowledge and material life. Perhaps, then, the values of the exchange economy were not simply a religion of the damned, but gave glimpses of new worlds as well.

(Stanford, Calif., 2009); Mark S. R. Jenner and Patrick Wallis, eds., *Medicine and the Market in England and Its Colonies, c. 1450–c. 1850* (Houndsmills, 2007).

¹¹⁵ E.g., Klein and Wolfgang Lefèvre, *Materials in Eighteenth-Century Science: A Historical Ontology* (Cambridge, Mass., 2007); Klein and E. C. Spary, eds., *Materials and Expertise in Early Modern Europe: Between Market and Laboratory* (Chicago, 2010).

¹¹⁶ E.g., Pamela H. Smith and Paula Findlen, eds., *Merchants and Marvels: Commerce, Science, and Art in Early Modern Europe* (New York, 2002); Kapil Raj, *Relocating Modern Science: Circulation and the Construction of Scientific Knowledge in South Asia and Europe, 17th–19th Centuries* (Delhi, 2006); Schaffer et al., *Brokered World* (cit. n. 113); Steven J. Harris, "Mapping Jesuit Science: The Role of Travel in the Geography of Knowledge," in *The Jesuits: Cultures, Sciences, and the Arts, 1540–1773*, ed. John W. O'Malley et al. (Toronto, 1999), 212–40; Latour, *Reassembling the Social: An Introduction to Actor-Network-Theory* (New York, 2005).