THE CAMBRIDGE HISTORY OF SCIENCE

VOLUME 3

Early Modern Science

Edited by

KATHARINE PARK

LORRAINE DASTON

CAMBRIDGE
UNIVERSITY PRESS

CAMBRIDGE UNIVERSITY PRESS
Cambridge, New York, Melbourne, Madrid, Cape Town, Singapore, São Paulo

Cambridge University Press
40 West 20th Street, New York, NY 10011-4211, USA

www.cambridge.org
Information on this title: www.cambridge.org/9780521572446

First published 2006

Printed in the United States of America

A catalog record for this publication is available from the British Library.

Library of Congress Cataloging in Publication Data

(Revised for volume 3)
The Cambridge history of science
p. cm.
Includes bibliographical references and indexes.
Contents: – v. 3. Early modern science / edited by Katharine Park and Lorraine Daston
v. 4. Eighteenth-century science / edited by Roy Porter
v. 5. The modern physical and mathematical sciences / edited by Mary Jo Nye
v. 7. The modern social sciences / edited by Theodore M. Porter and Dorothy Ross
ISBN 0-521-57244-4 (v. 3)
ISBN 0-521-57243-6 (v. 4)
ISBN 0-521-57199-5 (v. 5)
ISBN 0-521-59442-1 (v. 7)
1. Science – History. I. Lindberg, David C. II. Numbers, Ronald L.
QI25C32 2001
509 – dc21
200102531I

ISBN-13 978-0-521-57244-6 hardback
ISBN-10 0-521-57244-4 hardback

19

NATURAL HISTORY

Paula Findlen

In the midst of his great *Historia animalium* (History of Animals, 1551–8), the Swiss-German naturalist Conrad Gessner (1516–1565) offered the following reflection on the process of creating knowledge. "Reason and experience are the two pillars of scientific work," he affirmed. "Reason comes to us from God; experience depends on the will of man. Science is born from the collaboration of the two."[1] Gessner's experience gathering materials for a new history of nature in the mid-sixteenth century gave him direct insight into the problems of combining reason and experience. The more material he uncovered, the more difficult it was to organize the natural world into distinctly logical patterns. By placing great emphasis on experience, Gessner had amassed enough material to write four hefty volumes that far surpassed what anyone had known before about animals. But he confessed that experience alone was an undisciplined kind of knowledge. It was reason that allowed him to give some semblance of order to nature and to interpret the similarities and differences he saw among the natural things of the world.

Gessner's methodological lessons in the midst of his Renaissance zoology remind us that the natural sciences were an important arena in which new definitions of knowledge arose from an increased emphasis on experience. In the early modern period, natural history was an important, controversial, and much discussed kind of knowledge. Natural history was a truly encyclopedic science in which broad sectors of society participated, although not, at this point, as a unified group. Learned scholars delighted in the questions of terminology that allowed them to use their formidable linguistic erudition, developing a more precise vocabulary for the natural world that conformed to their experience of it. Philosophers immersed themselves in paradoxes of classification. Travelers provided fresh and plentiful observations that conveyed the vast expanse of nature to an eager audience at home. Physicians

[1] Conrad Gessner, *Historia animalium*, quoted in Lucien Braun, *Conrad Gessner* (Geneva: Editions Slatkine, 1990), p. 15. Braun does not indicate from which edition he takes this quotation.

and apothecaries transformed their professional acumen about the medicinal uses of plants into full-scale observation of nature. Civil servants in nascent European empires asked themselves how natural commodities might benefit the state. Princes and patricians delighted in the cultivation and display of curiosities in their gardens and homes. Artists worked closely with physicians and philosophers to determine how their skills might convey accurately the fruits of observation and classification, and used natural objects in their own compositions. It is little wonder that natural history became the "big" science of the late seventeenth and eighteenth centuries, when the proliferation of European overseas empires further enlarged its scope.[2] It was a vast collective enterprise with intellectual, political, and economic implications.

Until the early 1990s, historians of science placed little emphasis on developments in natural history as part of the transformation in knowledge that occurred during the sixteenth and seventeenth centuries, preferring to concentrate on physics and astronomy.[3] Natural history did not fit well with the model of science that had been developed in the study of these other subjects. It produced no singular moment of discovery, no dramatic transformation of mind that we might associate with one individual. It yielded no heady confrontation with religious authority in the manner of Copernican astronomy, nor did tales of gathering Alpine flora and Mediterranean fauna have the same illicit appeal as Andreas Vesalius's exaggerated accounts of nocturnal body snatching to supply cadavers for dissection.[4]

[2] For the exponential growth of natural history in the eighteenth century, the following works provide a good introduction: Tore Frängsmyr, ed., *Linnaeus: The Man and His Work* (Canton, Mass.: Science History Publications, 1994; orig. publ. 1983); Mary Pratt, *Imperial Eyes: Travel Writing and Transfiguration* (London: Routledge, 1992); Londa Schiebinger, *Nature's Body: Gender in the Making of Modern Science* (Boston: Beacon Press, 1993); Richard H. Grove, *Green Imperialism: Colonial Expansion, Tropical Island Edens and the Origins of Environmentalism, 1600–1860* (Cambridge: Cambridge University Press, 1995); and Nicholas Jardine, James A. Secord, and Emma C. Spary, eds., *Cultures of Natural History* (Cambridge: Cambridge University Press, 1996), pp. 127–245.

[3] Several early exceptions to this approach include Karen Reeds, "Renaissance Humanism and Botany," *Annals of Science*, 33 (1976), 519–42; Barbara Shapiro, "History and Natural History in Sixteenth- and Seventeenth-Century England," in Barbara Shapiro and Robert G. Frank, Jr., *English Scientific Virtuosi in the Sixteenth and Seventeenth Centuries* (Los Angeles: William Andrews Clark Memorial Library, 1979); and Joseph M. Levine, "Natural History and the Scientific Revolution," *Clio*, 13 (1983), 57–73. An overview can be found in Jardine, Secord, and Spary, eds., *Cultures of Natural History*. The status of natural history within accounts of the Scientific Revolution has been raised in Harold J. Cook, "The Cutting Edge of a Revolution? Medicine and Natural History Near the Shores of the North Sea," in *Renaissance and Revolution: Humanists, Scholars, Craftsmen and Natural Philosophers in Early Modern Europe*, ed. J. V. Field and Frank A. J. L. James (Cambridge: Cambridge University Press, 1993), pp. 45–61.

[4] Needless to say, historians of these other sciences have found this older approach also unsatisfactory in explaining the development of the fields of physics, mathematics, astronomy, and anatomy. The current significance of natural history in accounts of the Scientific Revolution reflects this widespread shift in historical interpretation, exemplified well in such general works as Steven Shapin, *The Scientific Revolution* (Chicago: University of Chicago Press, 1996). See, for example, Brian Ogilvie, "Observation and Experience in Early Modern Natural History," Ph.D. dissertation, University of Chicago, 1997; Alix Cooper, "Inventing the Indigenous: Local Knowledge and Natural History in Early Modern Germany," Ph.D. dissertation, Harvard University, Cambridge, Mass., 1998; and

Rather than concluding that natural history was a less important or less innovative kind of science, as earlier historians of science occasionally suggested, we might consider instead how the significance of natural history in the early modern period reflected a different intellectual model of the growth of scientific thought. Natural history described a kind of incremental (as opposed to revolutionary) knowledge that emerged directly out of ancient and medieval encyclopedism. It also encompassed some of the most fundamental developments in Renaissance medicine, most notably the growing emphasis on the evidence of the senses and a deep conviction that knowledge of the natural world provided a crucial foundation for understanding the human body because the body was a microcosm of all that the terrestrial world contained. Finally, natural history was the site in which scholars struggled most openly with the problem of new knowledge. Catalogues of new stars seemed insignificant in their size and scope in comparison with the flood of reports from all corners of the globe regarding the novelties one could find in terrestrial nature. "What a great abundance of the rarest things are found in the newly discovered lands," exclaimed the Italian naturalist Ulisse Aldrovandi (1522–1605) in 1573.[5] The combination of these different factors shaped natural history in the sixteenth and seventeenth centuries.

THE REVIVAL OF AN ANCIENT TRADITION

Natural history was an ancient form of scientific knowledge, most closely associated with the writings of the Roman encyclopedist Pliny the Elder (ca. 22–78). His loquacious and witty *Historia naturalis* offered an expansive definition of this subject. Pliny's natural history broadly described all entities found in nature, or derived from nature, that could be seen in the Roman world and read about in its books; art, artifacts, and peoples as well as animals, plants, and minerals were included in his project.[6] Thus, Pliny's definition of "nature" included everything natural as well as artificial, and the idea of "history" underscored the important role of description in understanding nature rather than any specific sense of the past.[7] Pliny imagined the unit of natural history to be something he called a *factum*, not by any means our

Antonio Barrera, "Science and the State: Nature and Empire in Sixteenth-Century Spain," Ph.D. dissertation, University of California, Davis, 1999.

[5] Ulisse Aldrovandi, *Discorso naturale*, in Sandra Tugnoli Pattaro, *Metodo e sistema delle scienze nel pensiero di Ulisse Aldrovandi* (Bologna: Cooperativa Libraria Universitaria Editrice Bologna, 1981), p. 205.

[6] Roger French and Frank Greenaway, eds., *Science in the Early Roman Empire: Pliny the Elder, His Sources and Influence* (London: Croom Helms, 1986); and Mary Beagon, *Roman Nature: The Thought of Pliny the Elder* (Oxford: Clarendon Press, 1992).

[7] In its original usage, *historia* connoted an ahistorical idea of description rather than a chronological ordering of events, which explains why disciplines such as geology and paleontology did not emerge until ideas about history changed beginning in the late seventeenth century.

modern sense of the fact but rather an early term for information gathered through a variety of techniques considered reliable by the standards of the time (which might include reliable hearsay, the words of authorities, and other forms of indirect evidence). He compiled twenty thousand of these singular pieces of information in his work, through personal observation, the reports of others, and the writings of one hundred authors.[8]

Pliny did not see himself as the creator of an entirely new enterprise. Rather, he compiled a comprehensive and well-organized guide to the overwhelming amount of information about the natural world that was already available in antiquity. The intellectual genealogy that Pliny offered for natural history traced its origins to the work of his Greek predecessors, most notably Aristotle (384–322 B.C.E.) and his disciple Theophrastus. Their treatises on animals and plants represented the earliest surviving efforts to describe and classify the natural world in any detail and to offer general principles regarding the anatomy, physiology, reproduction, and habits of living things.[9] In this respect, the Aristotelian approach to nature differed noticeably from that of Pliny. It helped to establish a causal rather than descriptive foundation for the study of nature, downplaying the wonders of nature that Pliny highlighted in favor of describing the structure and function of specimens that typified the general rule of nature. All of these ancient investigators attempted to form basic conclusions about the nature of nature itself.

Pliny's contemporary, the Greek physician Dioscorides (ca. 40–80), offered yet another model of what natural history could be. *De materia medica* (On Medical Material), one of the most successful and enduring herbals of antiquity, emphasized the importance of understanding the natural world in light of its medicinal efficacy.[10] Dioscorides' treatise described approximately 550 plants and provided succinct descriptions of the virtues of Mediterranean plants in curing various ailments. Implicitly, it suggested that any description of nature should always be in the service of medicine, making greater knowledge of nature a precondition to the improvement of health. In the next century, the prolific Roman physician Galen further underscored this

[8] Pliny, *Natural History*, preface 17–18, trans. H. Rackham, 10 vols. (Cambridge, Mass.: Harvard University Press, 1938–63), 1: 13. For a discussion of the fact, see Lorraine J. Daston, "Baconian Facts, Academic Civility, and the Prehistory of Objectivity," *Annals of Scholarship*, 8 (1991), 337–63.

[9] G. E. R. Lloyd, *Science, Folklore, and Ideology: Studies in the Life Sciences in Ancient Greece* (Cambridge: Cambridge University Press, 1983). For a general overview, see Roger French, *Ancient Natural History* (London: Routledge, 1994). The most important works in this category are Aristotle's *History of Animals, Generation of Animals*, and *Parts of Animals*, as well as Theophrastus's *Enquiry into Plants*.

[10] John Riddle, *Dioscorides on Pharmacy and Medicine* (Austin: University of Texas Press, 1985). For the later fortunes of the work of Dioscorides, see Riddle, "Dioscorides," in *Catalogus translationum et commentariorum: Mediaeval and Renaissance Latin Translations and Commentaries*, 8 vols. (Washington, D.C.: Catholic University Press, 1960–), vol. 4 (1980), ed. Paul O. Kristeller and F. Edward Cranz, pp. 1–143; and Jerry Stannard, "Dioscorides and Renaissance Materia Medica," in *Materia Medica in the XVIth Century*, ed. M. Florkin (Analecta Medico-Historica, 1) (Oxford: Pergamon, 1966), pp. 1–21.

idea by writing copiously about pharmacology.[11] The ancient tradition of writing about nature's medicinal uses continued through the Middle Ages, when Christian fascination with the symbolic properties of animals, and occasionally plants, gave rise to new genres of writing about nature such as the medieval bestiary.

Thus, early modern scholars who perused the works of the ancients had a multiplicity of approaches to nature to consider. Like Dioscorides, they could devote themselves entirely to the improvement of medicine, as the majority did in the late fifteenth and early sixteenth centuries. They could expand and critique the Aristotelian project to comprehend causally and classify the natural world, or they could take up Pliny's idea of understanding the world through its natural description.

First and foremost, however, aspiring naturalists had to contend with a world of books. Natural history easily made the transition from the written to the printed word with the appearance of the printing press in the mid-fifteenth century largely because of its strength in the manuscript culture of medieval and early Renaissance science.[12] The first printed edition of Pliny's *Natural History* appeared in 1469. By 1600, no less than fifty-five editions had rolled off the presses.[13] During that same period, Aristotle's zoological writings began to appear in the original Greek rather than through the Latin translations of medieval Arabic commentaries. Manuscript editions of Theophrastus's botanical writings, known only indirectly prior to the fifteenth century, arrived in the Rome of Pope Nicholas V. A great patron of learning, Nicholas V commissioned between the 1440s and 1470s not just one but two translations of a good Greek manuscript of Aristotle's three books on animals, desiring Latin editions that were "no less elegant and correct than that in which they are possessed among the Greeks."[14] A Latin translation of Theophrastus's *De plantis* (On Plants) and *De causis plantarum* (On the Causes of Plants), completed by 1454 for the same pope by Theodore Gaza,

[11] For a discussion of Galen's contributions to medicine and natural philosophy, see Owsei Temkin, *Galenism: The Rise and Decline of a Medical Philosophy* (Baltimore: Johns Hopkins University Press, 1973).

[12] On medieval natural history, see Jerry Stannard, "Natural History," in *Science in the Middle Ages*, ed. David C. Lindberg (Chicago: University of Chicago Press, 1976), pp. 429–66; and David C. Lindberg, "Natural History," in Lindberg, *The Beginnings of Western Science* (Chicago: University of Chicago Press, 1992), pp. 348–53.

[13] Albert Labarre, "Diffusion de l'*Historia naturalis* de Pline au temps de la Renaissance," in *Festschrift für Claus Nissen* (Wiesbaden: Guido Pressler, 1973), p. 451. See also Martin Davies, "Making Sense of Pliny in the Quattrocento," *Renaissance Studies*, 9 (1995), 240–57; and John Monfasani, "The First Call for Press Censorship: Nicolò Perotti, Giovanni Andrea Bussi, Antonio Moreto, and the Editing of Pliny's *Natural History*," *Renaissance Quarterly*, 41 (1988), 1–31.

[14] Nancy G. Siraisi, "Life Sciences and Medicine in the Renaissance World," in *Rome Reborn: The Vatican Library and Renaissance Culture*, ed. Anthony Grafton (Washington, D.C.: Library of Congress, 1993), p. 174. This quote comes from the preface of George Trebizond's 1449–50 Latin translation of Aristotle's *Historia animalium*, *De partibus animalium*, and *De generatione animalium*. The second translation was completed by Theodore Gaza in 1473 or 1474. On the fortunes of Aristotle in this period, see Charles Schmitt, *Aristotle in the Renaissance* (Cambridge, Mass.: Harvard University Press, 1983).

engendered even more excitement because the works of Theophrastus had not been read directly by anyone in Western Europe since late antiquity.[15] They, too, found their way quickly into print in the 1490s. A printed Greek edition of Dioscorides appeared in 1499, preceded by a Latin edition in 1478.[16]

The profusion of published natural histories had two immediate effects. It increased the accessibility of ancient accounts of nature in Western Europe, and it allowed scholars to compare these texts with one another. When Aristotle's translator George Trebizond invoked the criterion of a "correct" text around 1450, he suggested the growing awareness of the ways in which problems of translation made it difficult to know what the ancients had really said about nature; Greek words frequently had been mangled by Latin and Arabic translators and further misinterpreted as a result of the errors that inevitably occurred with repeated copying of the same texts over many centuries. The world of words, like nature itself, was infinite and subtle in its variations. The more early Renaissance scholars studied the writings of the ancients, the more frustrating the task of recuperating the original meaning seemed.

The ancients themselves, as much as their medieval and early Renaissance translators, proved to be a source of frustration. Take the case of Pliny, who based his *Natural History* on extensive readings of Greek and Roman authors. By the 1490s, discerning readers of Pliny had noted a disturbing fact about their favorite encyclopedist: His command of Greek sources was notoriously unreliable. Very little of what he said about plants, for instance, could be correlated with the remarks of Dioscorides. A debate ensued that seemed to have very little to do with the actual stuff of nature and everything to do with language. Were the mistakes Pliny's or did the fault lie with later copyists and editors? Did he know the difference, for example, between a strawberry bush and a variety of similarly leafy plants that did not yield such delectable fruit?

The first salvo was launched by the Italian physician Niccolò Leoniceno (1428–1524), who taught medicine in Ferrara, then a center for the kind of humanistic learning that was deeply engaged in debates about textual criticism and accurate philology. His *De Plinii et plurium aliorum medicorum in medicina erroribus* (On the Errors in Medicine of Pliny and Many Other Medical Practitioners, 1492) reported numerous errors in Pliny's twenty thousand facts, many of them a result of mistranslation from his Greek sources.[17]

[15] Charles Schmitt, "Theophrastus," in Kristeller and Cranz, eds., *Catalogus translationum et commentariorum*, vol. 2 (1971), pp. 239–322.

[16] The Venetian printer Aldus Manutius published a Greek edition of Theophrastus's works in 1497 in conjunction with his edition of all the known works of Aristotle that appeared between 1495 and 1498. The 1499 edition of the works of Dioscorides also came from the Aldine press, which suggests how important this one publisher was to the dissemination of ancient scientific texts in the first fifty years of printing.

[17] On the debates about Pliny, see Lynn Thorndike, "The Attack on Pliny," in Thorndike, *A History of Magic and Experimental Science*, 8 vols. (New York: Columbia University Press, 1923–58), 4: 593–

Had Pliny only known Greek, Leoniceno suggested, he would have known the strawberry.

Respondents to Leoniceno's attack on Pliny initially came from the local intellectual community in northern Italy, then the leading center for medical education and humanistic study. As the debate continued into the sixteenth century, it attracted the attention of Northern European scholars.[18] The diversity of occupations of those involved reflected the widespread appeal of natural history. Participants in this public debate in no way defined a professional community of naturalists. Pandolfo Collenuccio, who responded to Leoniceno's treatise with his *Pliniana defensio* (Plinian Defense, 1493), was a lawyer and humanist. Ermolao Barbaro (1454–1493), whose *Castigationes plinianae* (Plinian Castigations, 1492) claimed to have uncovered some five thousand errors in the *Natural History* – none of them Pliny's, he felt, but all the fault of bad copyists of early manuscripts and of misinformation in the Greek sources – belonged to one of the leading families of Venice and was an important humanist. Alessandro Benedetti taught medicine in Bologna. Despite their diversity of occupations, all of them felt qualified to comment upon the problems Leoniceno had raised about Pliny's veracity because no one group could claim a monopoly on the kinds of expertise needed to assess natural history.

The result of this debate was a growing public recognition that the ancient texts of natural history were far from perfect. A great deal of scholarly work needed to be done examining different editions of key authors to determine what they really had said. Barbaro, for instance, read Pliny's work in light of the writings of Theophrastus and Dioscorides. Comparing books, however, quickly became an imperfect exercise in knowledge. Collenuccio argued that it was not enough to "read authors, look at plant pictures, and peer into Greek vocabularies."[19] Observation offered the potential for greater certainty than words alone. On this important point, virtually all of the participants in the debate on Pliny agreed, even as they argued vociferously about everything else. Leoniceno had argued from the start for a natural history written "not

610; Arturo Castiglioni, "The School of Ferrara and the Controversy on Pliny," in *Science, Medicine, and History*, ed. E. Ashworth Underwood, vol. 1 (Oxford: Oxford University Press, 1953), pp. 269–79; Charles G. Nauert, "Humanists, Scientists, and Pliny: Changing Approaches to a Classical Author," *American Historical Review*, 84 (1979), 72–85; Giovanna Ferrari, "Gli errori di Plinio: Fonti classiche e medicina nel conflitto tra Alessandro Benedetti e Niccolò Leoniceno," in *Sapere e/è potere*, ed. A. Cristiani, 2 vols. (Bologna: Istitute per la Storia di Bologna 1990), 2: 173–204; and Ogilvie, "Observation and Experience," pp. 89–112. For a general account of the intellectual climate in which these debates occurred, see Vivian Nutton, "The Rise of Medical Humanism: Ferrara, 1464–1555," *Renaissance Studies*, 11 (1997), 2–19; and Daniela Mugnai Carrara, *La biblioteca di Niccolò Leoniceno* (Florence: Leo S. Olschki, 1991).

[18] Peter Dilg, "Die botanische Kommentarliteratur Italiens um 1500 und ihr Einfluss auf Deutschland," in *Der Kommentar in der Renaissance*, ed. August Buck and Otto Herding (Bonn: Harald Boldt, 1975), pp. 225–52.

[19] Pandolfo Collenuccio, *Pliniana defensio*. As quoted in Edward Lee Greene, *Landmarks of Botanical History*, ed. Frank N. Egerton, 2 vols. (Stanford, Calif.: Stanford University Press, 1983), 2: 551.

from words, but from things."[20] Neither he nor any of his critics trusted words alone by the end of their dissection of Pliny.

Natural history offers us an ironic lesson about the growth of empirical practice at the beginning of the sixteenth century. In many instances, scholars observed nature more closely because they had decided to read ancient works of science more comprehensively and carefully. Whether one examined animals and plants to prove the ancients right or to demonstrate their fallibility ultimately did not matter. Initially the goal was to correct Pliny's words through observation of nature rather than to observe per se. In contrast, by the end of the sixteenth century, commentators on Pliny could more accurately be described as naturalists. In 1572, the German naturalist Melchior Wieland based his criticisms of Pliny on years of travel in the Near East as well as on his work as the curator of the University of Padua's famous botanical garden.[21] Although he possessed the same skills in Greek that had produced Leoniceno's testy criticisms eighty years earlier, Wieland could no longer be accused by his critics of lacking knowledge of nature. He reflected the new image of natural history as an observational practice.

WORDS AND THINGS

It was one thing for a handful of humanist commentators to suggest that examining nature would resolve their questions about an ancient text. This provided a specific reason for a limited group of scholars to gain experience of nature but said little about the means by which observation was to be generally put into practice or what its other sources of inspiration might have been. During the 1530s and 1540s, observation began to play a systematic role in the study of the natural world. Practitioners of medicinal botany, the most established part of natural history because of its close association with medicine, were at the forefront of this transformation. They saw their work as a revival of an ancient science. The German herbalist Otto Brunfels wrote in his *Herbarum vivae eicones* (Living Images of Plants, 1530) that he hoped "to bring back to life a science almost extinct."[22] Similarly, the University of Ferrara's first professor of medical botany, Gaspare Gabrieli, commented in his inaugural lecture of 1543 that "herbal medicine is despised and neglected by everyone."[23] Both comments reflected the growing perception that new information and new techniques of conveying knowledge, most notably the use of

[20] Niccolò Leoniceno, *De Plinii et plurium aliorum medicorum in medicina erroribus* (Basel: Henricus Petrus, 1529), p. 215.

[21] Nauert, "Humanists," pp. 84–5; and Anthony Grafton, "Rhetoric, Philology and Egyptomania in the 1570s: J. J. Scaliger's Invective Against M. Guilandinus's *Papyrus*," *Journal of the Warburg and Courtauld Institutes*, 42 (1979), 167–94.

[22] Greene, *Landmarks of Botanical History*, 1: 244. Greene quotes from the 1532 edition.

[23] Gaspare Gabrieli, *Oratio habita Ferrariae in principio lectionum de simplicium medicamentorum facultatibus anno MDXLII per me Gasparem Gabrielum*. A modern version of this text is found in

printing to circulate words and images more widely, would recuperate botany, and by extension natural history, as a subject that learned men should study.

Given the number of words spilled over Pliny's errors, and the amount of energy spent creating splendid new editions of Aristotle and Theophrastus, the image of natural history as a neglected field of study seemed unsustainable by the mid-sixteenth century. Yet it was precisely the well-known problems with these texts that made it possible to present the revival of natural history as a matter of urgent necessity. Naturalists had the fruits of several decades of renewed observation of the natural world upon which to build. Although their knowledge of non-European (in fact, non-Mediterranean) nature was still sparse, new accounts of European nature that paid greater attention to Northern Europe, coupled with tantalizing glimpses of New World nature, provided just enough information for them to imagine how limited the ancient geography of nature actually was. If the ancients had described less than one-hundredth of the plants in the world, as one physician estimated in 1536, then naturalists had a great deal of new knowledge to contribute to society.[24]

The new influx of natural knowledge came from two distinct sources: changes in medical education, and the conquest and exploration of the Americas and the East Indies. In the first instance, a vocal sector of university-trained physicians argued strongly for a new kind of medical education in the universities that made medicinal botany a precondition of medical expertise. In the introduction to *De historia stirpium commentarii insignes* (Remarkable Commentaries on the History of Plants, 1542), one of the first botanical texts to make illustrations an important part of natural description, the German physician Leonhart Fuchs (1501–1566) lamented that few physicians knew plants well. "They appear to think that this kind of information does not belong to their profession," he observed.[25] As a professor of medicine at the newly created University of Tübingen, Fuchs was in a position to change medical pedagogy. He belonged to a generation that introduced the teaching of Dioscorides' *De materia medica* into the curriculum. By the late 1540s, one could hear lectures on this text not only in the most venerable medical faculties such as Montpellier, where the French physician Guillaume Rondelet began to teach Dioscorides in 1545, but also in new universities such as Wittenberg, which formally added Dioscorides to its curriculum in 1546.[26]

Felice Gioelli, "Gaspare Gabrieli: Primo lettore dei semplici nello studio di Ferrara (1543)," *Atti e memorie della Deputazione Provinciale Ferrarese di Storia Patria*, ser. 3, vol. 10 (1970), 31.

[24] The physician in question, Antonio Musa Brasavola, taught medicine and medicinal botany at Ferrara until 1541. His *Examen omnium simplicium medicamentorum* (1536) is an early example of an attempt to teach botany as a dialogue among observers studying nature in the field.

[25] Leonhart Fuchs, *De historia stirpium* [1542], "Epistola nuncupatoria," p. v. I have used the translation in Greene, *Landmarks of Botanical History*, 1: 276.

[26] Karen Reeds, *Botany in Medieval and Renaissance Universities* (New York: Garland, 1991), p. 57; and Karl H. Dannenfeldt, "Wittenberg Botanists During the Sixteenth Century," in *The Social History*

The Italian universities played a leading role in defining the new institutional culture of natural history, which was a direct result of their strength in medical education (see Grafton, Chapter 10, this volume). In 1533, the University of Padua established the first permanent chair in "medicinal simples," which primarily covered botanical knowledge.[27] One year later, the University of Bologna appointed Luca Ghini to a similar position, where he taught the writings of Theophrastus. By 1545, both Pisa and Padua had botanical gardens in which professors demonstrated plants to students when they were not taking students on botanical trips during the summer months.[28] For the rest of the sixteenth century, scholars interested in the study of nature felt obliged to travel and study in Italy not only because it contained many of the Mediterranean plants described by the ancients but also because its universities promoted a new kind of natural history that emphasized evidence of the senses.

Observation gradually assumed an important place in pedagogy, leading some naturalists to redefine natural history as "sensory natural history" in order to distinguish the textual tradition of nature from its early modern counterpart.[29] Professors who taught medicinal botany in this fashion, such as Fuchs and Ghini, received lucrative offers from other universities, which hoped to increase the prestige of their medical faculties through the addition of a famous natural history professor. The majority of these positions appeared in Italy. Important medical centers in Europe followed their example in the 1570s through 1660s as natural history became a more integrated part of the medical curriculum. Basel created a professorship in 1589; Montpellier formalized the place of medicinal botany in its curriculum in 1593. Newer

of the Reformation, ed. Lawrence P. Buck and Jonathan W. Zophy (Columbus: Ohio State University Press, 1972), p. 226. Wittenberg was also the site of an interesting but ultimately unsuccessful attempt to introduce Pliny into the curriculum in 1543; for these and other curricular reforms, see Sachiko Kusukawa, *The Transformation of Natural Philosophy: The Case of Philip Melanchthon* (Cambridge: Cambridge University Press, 1995).

[27] A temporary chair was established at the University of Rome in 1513 but did not last for more than a few years.

[28] For a more detailed account of these developments, see Charles Schmitt, "Science in the Italian Universities in the Sixteenth and Seventeenth Centuries," in *The Emergence of Science in Western Europe*, ed. Maurice Crosland (New York: Macmillan, 1975), pp. 35–56; Schmitt, "Philosophy and Science in Sixteenth Century Italian Universities," in Schmitt, *The Aristotelian Tradition and the Renaissance Universities* (London: Variorum, 1984), chap. 15, pp. 297–336; Paula Findlen, "The Formation of a Scientific Community: Natural History in Sixteenth-Century Italy," in *Natural Particulars: Nature and the Disciplines in Renaissance Europe*, ed. Anthony Grafton and Nancy Siraisi (Cambridge, Mass.: MIT Press, 1999), pp. 369–400; and Findlen, *Possessing Nature: Museums, Collecting, and Scientific Culture in Early Modern Italy* (Berkeley: University of California Press, 1994). The rise of the botanical garden is discussed in Margherita Azzi Visentini, *L'Orto botanico di Padova e il giardino del Rinascimento* (Milan: Edizioni il Polifilo, 1984); Alessandro Minelli, ed., *The Botanical Garden of Padua, 1545–1995* (Venice: Marsilio, 1995); and Fabio Garbari, Lucia Tongiorgi Tomasi, and Alessandro Tosi, *Giardino dei Semplici: L'Orto botanico di Pisa dal XVI al XIX secolo* (Pisa: Cassa di Risparmio, 1991).

[29] This phrase comes from the pen of Ulisse Aldrovandi, one of the most vocal advocates of the history of sensible, or sensory, things in the second half of the sixteenth century. Biblioteca Universitaria, Bologna, *Aldrovandi* MS. 21, vol. IV, c. 36.

universities such as Leiden (founded 1575) actively recruited distinguished naturalists, persuading a reluctant Carolus Clusius (1526–1609, also known as Charles de L'Écluse) to return home in 1594 to help develop its botanical garden after he had spent a good part of his career as a court naturalist to the Holy Roman Emperor Maximilian II in Vienna.[30] By the seventeenth century, most medical students enjoyed some basic training in botany and comparative anatomy prior to graduation.

The new emphasis on observation did not displace books. Upon the death of the French naturalist Guillaume Rondelet (1507–1566), his loyal students joked that no one "wore out Dioscorides with so much use."[31] Reading and discussing ancient texts continued to generate new ways of looking at things. The German naturalist Valerius Cordus (1515–1544) traveled to Italy in order to create new descriptions of the plants that Dioscorides had identified from living specimens.[32] Cordus participated in the invention of the field trip as a fundamental part of natural history – yet another innovation that owed a great deal to the desires of Renaissance naturalists to find new ways to use ancient texts. Within a few decades, the field trip became a source of authoritative knowledge in itself, though books still played an important role in its formulation. These books included pocket editions of standard botanies in which travelers might record their own field observations. "I have made many pilgrimages to various lands," declared Luigi Anguillara, one of the directors of the Paduan botanical garden, in 1561, informing his readers that he was no armchair naturalist.[33] Increasingly, the image of the naturalist emphasized his role as an active observer of the world. Obviously, the distinction between the naturalist who participated in an occasional summer excursion in the Alps, primarily collecting specimens at home, and one who spent years in distant lands was significant in terms of what experience of nature actually meant. Yet both activities were crucial in building a new encyclopedia of nature.

The field trip became one of the important markers of communal activity among Renaissance naturalists. Its pedagogical role in training medical students complemented its important function in defining natural history as a

[30] Reeds, *Botany*, pp. 83, 111. On Clusius, also known by his Flemish name, Charles de L'Écluse, see F. W. T. Hunger, *Charles de l'Escluse*, 2 vols. ('s-Gravenhage: Martinus Nijhoff, 1927).

[31] Joannes Posthius, *De obitu D. Guillelmi Rondeletii*, in Reeds, *Botany*, p. 66.

[32] Greene, *Landmarks of Botanical History*, 1: 375–6; and A. G. Morton, *History of Botanical Science* (London: Academic Press, 1981), p. 126. For a discussion of the early development of such practices and their relationship to Renaissance humanism, see Peter Dilg, "Studia humanitatis et res herbaria: Euricius Cordus als Humanist und Botaniker," *Rete*, 1 (1971), 71–85. This last essay discusses the work of Valerius's father, Euricius.

[33] Luigi Anguillara, *Semplici dell'Eccellente M. Luigi Anguillara, liquali in piu pareri a diversi nobili huomini scritti appaiono* (Venice: Vincenzo Valgrisi, 1561), p. 15. This approach to nature is discussed in Findlen, *Possessing Nature*, pp. 155–92; and in Brian Ogilvie, "Travel and Natural History in the Sixteenth Century," in Brian Ogilvie, Anke te Heesen, and Martin Gierl, *Sammeln in der Frühen Neuzeit* (Max-Planck-Institut für Wissenschaftsgeschichte, Preprint 50) (Berlin: Max-Planck-Institut für Wissenschaftsgeschichte, 1996), pp. 3–28.

science of collective observation and description. New books of nature were created from information painstakingly gathered firsthand and compared with old descriptions and eventually with old specimens. In time, the importance of the specimen complicated the role of the learned word because there were plenty of new words to be written as a result of looking at nature. Perhaps it did not matter that the French ichthyologist and ornithologist Pierre Belon couldn't read "two lines of Pliny," as his contemporaries alleged.[34] He had seen more of the world than most of them when he traveled in the Near East from 1546 until 1549, writing about his journey in a rich French vernacular that spoke directly to his contemporaries of his experiences. By the 1560s, naturalists spoke enviously of their colleagues who had had the opportunity to travel outside of Europe and thus obtain a direct knowledge of those parts of the natural world that most scholars experienced only in their studies, museums, and botanical gardens. "If I had had the luck to find a patron, or if my fortune had not been so restricted," wrote Gessner in his *Historia animalium*, "I would have traveled to the most distant lands, propelled by my strong passion to know."[35]

The thousands of unpublished pages of observational notes left behind by Renaissance naturalists suggest how important this activity was to their definition of science. Even when confined to travel within Europe, they found plenty to say about nature that was novel and illuminating. Valerius Cordus, for example, eulogized by the community of naturalists because of his untimely death while botanizing in Italy in 1544, bequeathed to posterity notes filled with precise descriptions of plants that set a new standard when they appeared posthumously in 1561 under the careful editing of Gessner. Cordus attempted to write a complete description of a plant that took into account not only surface details such as the appearance of leaves and flowers but also more subtle characteristics such as the nature and timing of fructification and the appearance of the seeds, roots, and loculi.[36] This was a level of specificity that no ancient natural history offered.

University professors who taught medicinal botany, and later natural history, formalized the role of observation by taking students on field trips in the summer months. The Flemish naturalist Clusius's careful study of the plants of Languedoc was a direct result of his education in Montpellier under Rondelet, who was so famous for his field trips that François

[34] Pierre Belon, *L'Histoire de la nature des oyseaux*, ed. Philippe Glardon (Geneva: Librairie Droz, 1997), p. xxiii. For an interesting discussion of Belon's world, see George Huppert, *The Style of Paris: Renaissance Origins of the French Enlightenment* (Bloomington: Indiana University Press, 1999).

[35] Conrad Gessner, *Historia animalium*, 1, in Braun, *Conrad Gessner*, p. 60. Karl H. Dannenfeldt's *Leonhard Rauwolf: Sixteenth-Century Physician, Botanist, and Traveler* (Cambridge, Mass.: Harvard University Press, 1968) is an excellent account of one of the few naturalists to travel extensively in the late sixteenth century.

[36] Morton, *History of Botanical Science*, p. 126.

Rabelais gently satirized him in his *Gargantua* (1534).[37] In 1595, the Swiss medical student Thomas Platter noted that the professor of anatomy and botany at Montpellier was officially required to take students on summer excursions.[38] By the end of the century, a great deal was known about the plants in the vicinities of the leading medical universities in Europe such as Bologna, Padua, Basel, and Montpellier. Similarly famous were Mount Pilatus, near Lucerne, and Mount Baldo, in the vicinity of Verona – the two mountains described by the Zurich physician Gesner and the Veronese apothecary Francesco Calzolari (1521–ca. 1600), both of whom routinely led groups to their summits, demonstrating plants as they went.[39] Each created a local laboratory for the investigation of the natural world.

The more naturalists observed nature in situ, the more they realized that limited contact with specimens did not yield enough knowledge to describe and compare medicinal herbs. They needed to take nature home. By the 1540s, the herbarium (a collection of dried plants) played an important role in natural history, its use advocated most forcefully by Luca Ghini, who had been among the first naturalists to initiate the field trip. Rondelet probably learned the technique of drying plants from Ghini during a trip to Italy in 1549 and then passed it on to many of his students. Felix Platter, for instance, described how he "collected plants, and arranged them properly on paper" as a medical student in Montpellier in 1554.[40] When Michel de Montaigne visited him in Basel in October 1580, he was amazed to see twenty-year-old specimens glued into nine volumes in Platter's study.[41]

The herbarium provided naturalists with a convenient tool with which to organize specimens, modifying ancient theories of classification with modern examples and testing general theories about the nature of plants against specific examples. It facilitated an important new project for natural history: to make new books of nature out of modern ingredients that supplemented and eventually replaced those of the ancients. Similarly, the new passion for

[37] F. David Hoeniger, "How Plants and Animals Were Studied in the Mid-Sixteenth Century," in *Science and the Arts in the Renaissance*, ed. John W. Shirley and F. David Hoeniger (Washington, D.C.: Folger Shakespeare Library, 1985), p. 139. On the influence of Rondelet's pedagogy on many northern naturalists, see Reeds, *Botany*, esp. pp. 55–72.

[38] Thomas Platter, *Journal of a Younger Brother: The Life of Thomas Platter as a Medical Student at Montpellier at the Close of the Sixteenth Century*, trans. Seán Jennett (London: Frederick Muller, 1963), p. 36.

[39] Conrad Gessner, "Descriptio Montis Fracti sive Montis Pilati, ut vulgo nominant, iuxta Lucernam in Helvetia," in Gesner, *De raris et admirandis herbis, quae sive quod noctu luceant, sive alias ob causas, Lunariae nominantur, Commentariolus* (Zurich: Andreas Gesner and Jakob Gesner, 1555); and Francesco Calzolari, *Il viaggio di Monte Baldo* (Venice: Vincenzo Valgrisi, 1566).

[40] Felix Platter, *Beloved Son Felix: The Journal of Felix Platter, a Medical Student in Montpellier in the Sixteenth Century*, trans. Seán Jennett (London: Frederick Muller, 1961), p. 88. See also Walther Rytz, "Das Herbarium Felix Platters: Ein Beitrag zur Geschichte der Botanik des XVI. Jahrhunderts," *Verhandlungen der Naturforschenden Gesellschaft in Basel*, 44 (1932–33), 1–222. This subject has received an interesting treatment in Ogilvie, "Observation and Experience," pp. 200–71.

[41] Michel de Montaigne, *Montaigne's Travels*, trans. Donald M. Frame (San Francisco: North Point Press, 1983), p. 14.

collecting natural objects, as seen particularly in the case of Ulisse Aldrovandi (1522–1605) in Bologna, whose museum was among the largest and most visited in Europe by the 1570s, created rich repositories of artifacts from which to write new zoologies and mineralogies.[42] Gradually, ancient description paled in comparison with the flood of words that poured from the pens of eager observers.

THINGS WITHOUT NAMES

One of the fundamental reasons for writing new natural histories related to the impact of the Americas, and long-distance travel in general, on thought about the natural world.[43] The larger the world became, in written description and in actual experience, the more limited Aristotle's, Dioscorides', and Pliny's image of nature seemed. What had the ancients really known? The Mediterranean surely, and parts of the Near East and North Africa. They knew little of Northern Europe and nothing of the Americas and Asia. As accounts of the Indies flooded Europe in the wake of Columbus's landing on San Salvador – which quite appropriately occurred in the same year that the debates on Pliny began – Renaissance naturalists found themselves awash in a sea of uncertain claims and unverified but intoxicating new facts about nature.

Initially, accounts of the New World emphasized its marvelous qualities. Columbus, who had read Pliny with some care, measured what he saw against his expectations of a natural world that, in true Plinian fashion, allegedly became more extraordinary and surprising the farther one traveled away from the center of the known world. He did not expect American nature to be ordinary, reporting in 1493 his surprise that he had seen no human monsters. Other aspects of American nature fulfilled his expectations, leaving him initially speechless at the sight of animals and plants that had no corollary in Europe. Of the trees of Hispaniola, Columbus wrote: "It grieves me extremely that I cannot identify them, for I am quite certain that they are all valuable and I am bringing samples of them and of the plants also."[44] When words were

[42] On Aldrovandi's collecting, see Giuseppe Olmi, *L'Inventario del mondo: Catalogazione della natura e luoghi del sapere nella prima età moderna* (Bologna: Il Mulino, 1992); and Findlen, *Possessing Nature*. For an interesting discussion of the evolution of a kind of natural history publication specific to the museum – the museum catalogue – see Alix Cooper, "The Museum and the Book: The *Metallotheca* and the History of an Encyclopaedic Natural History in Early Modern Italy," *Journal of the History of Collections*, 7 (1995), 1–23.

[43] Henry Lowood, "The New World and the European Catalog of Nature," in *America in European Consciousness*, ed. Karen Ordahl Kupperman (Chapel Hill: University of North Carolina Press, 1995), pp. 295–323.

[44] J. M. Cohen, ed. and trans., *The Four Voyages of Christopher Columbus* (London: The Cresset Library, 1969), pp. 69–70. These entries in Columbus's logbook are from 19 and 21 October 1492, respectively. The following works are especially useful in studying Columbus's encounter with nature: Antonello Gerbi, *Nature in the New World*, trans. Jeremy Moyle (Pittsburgh, Pa.: University of Pittsburgh

inadequate, things themselves became more important. They demonstrated their own existence, challenging those who saw them to capture their reality. In time, Columbus and those who followed him to the Indies found words to describe the unknown, familiarizing and eventually transforming many marvels into part of the ordinary fabric of nature.

Columbus's initial response to American nature contained elements of a procedure that became a common feature of early modern natural history. He did not see the point of describing all aspects of nature – only those that were relevant to his most immediate concerns. Collecting and describing nature became two of the most fundamental scientific activities associated with the New World.[45] Already in the 1490s, ships returned home laden with parrots, monkeys, iguanas, macaws, and other curiosities.[46] The arrival of these specimens imposed new pressures on traditional accounts of nature, making even more apparent the importance of observation as a source of information. Many aspects of American nature, from the exotic armadillo to the lowly potato, lacked a textual presence in the European natural history tradition. They demanded new space in the crowded pages of natural history writing, offering up the kind of information that a commentary on a writer such as Aristotle or Pliny could not comfortably accommodate. Very quickly, these aspects of American nature demanded their own histories.[47]

Such histories posed unique challenges because they lacked the standard ingredients of an authoritative description of a natural specimen, namely a long list of authorities whose words had solidified the meaning of an object over centuries. Take the case of corn, which was called "Turkish grain" (*turcicum frumentum*) by many naturalists when it first appeared in the pages of European natural histories in the 1540s; modern vernacular words for corn, such as *granturco* in Italian, still bear the traces of this misperception. Readers of New World reports were perfectly aware that it did not come from Turkey, but others exhibited an all too typical confusion between the old

Press, 1985), pp. 12–26; Mary B. Campbell, *The Witness and the Other World: Exotic European Travel Writing, 400–1600* (Ithaca, N.Y.: Cornell University Press, 1988), pp. 165–209; Stephen Greenblatt, *Marvelous Possessions: The Wonder of the New World* (Chicago: University of Chicago Press, 1991), pp. 52–85. For a general discussion of science and the metaphors of discovery, see Paula Findlen, "Il nuovo Columbo: Conoscenza e ignoto nell'Europa del Rinascimento," in *La rappresentazione letteraria dell'alterità nel Cinquecento*, ed. Lina Bolzoni and Sergio Zatti (Lucca: Pacini-Fazzi, 1997), pp. 219–44.

[45] The disintegration of the early model of discussing American nature in relation to European nature is described well in Richard White, "Discovering Nature in North America," *Journal of American History*, 79 (1992), 874–91; and Raquel Álvarez Peláez, *La conquista de la naturaleza americana* (Madrid: Consejo Superior de Investigaciones Científicas, 1993).

[46] Wilma George, "Sources and Background to Discoveries of New Animals in the Sixteenth and Seventeenth Centuries," *History of Science*, 18 (1980), 79–104.

[47] The consequences of this shift can be seen in William J. Ashworth, "Natural History and the Emblematic World View," in *Reappraisals of the Scientific Revolution*, ed. David C. Lindberg and Robert S. Westman (Cambridge: Cambridge University Press, 1990), pp. 303–32; and Ashworth, "The Persistent Beast: Recurring Images in Zoological Illustration," in *The Natural Sciences and the Arts* (Uppsala: S. Academiae Ubsaliensis, 1985), pp. 46–66.

Indies to the East and the new ones that had appeared in the West. By 1570, the Italian naturalist Pier Andrea Mattioli (1500–1577) pointed out this mistake, though other naturalists continued to disagree with him throughout the sixteenth century.[48] The problem was that too few naturalists had seen American maize to offer a reliable account of it. As long as corn was described as an extra-European product, its novelty – though not its exact provenance – was conveyed.

The age of conquest and discovery created a distinctive genre of natural history: the natural history of the Indies, both East and West. In an age of great curiosity about exotic nature, writing travel accounts and natural histories became a lucrative enterprise. Works such as the notary Gonzalo Fernández de Oviedo's *Historia general y natural de las Indias* (General and Natural History of the Indies, 1535–49), the physician Garcia da Orta's *Coloquios dos simples e drogas he cousas mediçinais da India* (Colloquies on Simples and Medicinal Drugs from India, 1563), and the Jesuit José Acosta's *Historia natural y moral de las Indias* (Natural and Moral History of the Indies, 1590) fed the European appetite for information about American and Asian nature. They anticipated a renewed fascination with locality as one of the conceptual parameters for studying nature, reviving the ancient Hippocratic interest in places as an important way of understanding nature. The "Indies" became one of the most strongly defined geographic entities in the study of nature.[49] It was an ideal site, yielding hundreds of novel flora and fauna on which naturalists could hone their newly developed observational skills.

Oviedo (1478–1557), who had first arrived in the Americas in 1514 as a gold mine inspector, proudly proclaimed his departure from the tradition of writing natural history as a commentary on the ancients when he declared: "My intention is not to relate the things . . . that have been written by other authors, but the notable things that come to my attention in these Indies of ours."[50] Many of his descriptions – of tobacco plants, rubber trees, and a myriad of other novelties – offered the first account of such things for European readers. Oviedo's *Historia general y natural de las Indias*, and many similar works that followed, went into multiple editions in many languages over the next century.

One of the crucial issues that Oviedo confronted concerned the credibility of knowledge. Much as the critics of Pliny had turned to observation as a means of correcting a text, Oviedo grappled with the obverse of this coin: how to use words to make things believable. Drawing inspiration from Pliny, who had briefly raised the problem of credible knowledge in his own fact-gathering, Oviedo used his skills as a notary to emphasize the importance

[48] Lowood, "New World," in Kupperman, ed., *America in European Consciousness*, p. 300.

[49] The reaction to the emphasis on exotic nature can be found in the development of self-conscious traditions of local natural history within Europe, especially in Germany and England; see Cooper, "Inventing the Indigenous".

[50] Gonzalo Fernández de Oviedo, *Historia*, 5.3, in Gerbi, *Nature in the New World*, p. 226.

of good witnesses.[51] Whenever possible, he observed nature firsthand. When describing things that he himself had not seen, he preferred to rely on multiple corroborative accounts of the same phenomenon rather than privileging the individual report. Such techniques did not yield reports of absolute certainty, and early modern naturalists expended a good deal of ink correcting each other's exaggerations and misidentifications. These techniques went a long way, however, toward persuading readers that Oviedo was not simply another purveyor of tall tales about the marvels of the East but rather an observer whose personal experience of the Americas and whose careful management of information made him a trustworthy source of knowledge.[52] He was a worthy precursor to Francis Bacon in the development of important ideas about the relationship between the quality of good testimony and the reliability of knowledge.

Very few naturalists made it to the Americas. Instead, they relied on examination of New World specimens in European collections and the reading of New World accounts to enlarge their portrait of nature. Gessner, for example, owned and annotated works such as André Thevet's *Les Singularitez de la France antarctique* (Singularities of Antarctic France, 1558), writing on its frontispiece: "I noted and drew [its] animals and plants."[53] He included corn in a 1542 plant catalogue and was growing tobacco and tomatoes in his garden by the 1550s. Gessner's cautious, probing attitude toward reports of a new nature led him to include only one American animal, the opossum, in the first volume of his *Historia animalium* (1551). By the time he completed this work in 1558, other examples of the bounty of the New World had found a place in his encyclopedia, though they by no means overwhelmed its Old World content.[54]

The next generation of naturalists engaged more passionately and systematically with American nature. Aldrovandi, for instance, fancied himself a new Columbus and repeatedly attempted to interest various rulers in financing a trip to the Indies.[55] Where he failed, others, working for monarchs with overseas empires, succeeded. In 1570, Philip II of Spain ordered his royal

[51] The role of witnessing in early modern science has been most famously discussed in Steven Shapin and Simon Schaffer, *Leviathan and the Air-Pump: Hobbes, Boyle and the Experimental Life* (Princeton, N.J.: Princeton University Press, 1985), with attention to the development of an experimental community in mid-seventeenth-century England. The case of Oviedo suggests how the problems of long-distance communication in early accounts of the Indies already raised the issues of credibility and certainty (see Harris, Chapter 16, this volume).

[52] For the marvels of the East, see Lorraine Daston and Katharine Park, *Wonders and the Order of Nature, 1150–1750* (New York: Zone Books, 1998), pp. 21–66.

[53] Urs B. Leu, "Konrad Gesner und die Neue Welt," *Gesnerus*, 49 (1992), 285. Subsequent information about Gessner's interest in the new world is derived from this article.

[54] George, "Sources," pp. 81–3, 87. She estimates that the New World accounted for 9% of the total content of Gessner's zoology.

[55] Mario Cermenati, "Ulisse Aldrovandi e l'America," *Annali di botanica*, 4 (1906), 3–56; Olmi, "'Magnus campus': I naturalisti italiani di fronte all'America nel secolo XVI," in Olmi, *L'Inventario del mondo*, pp. 211–52; and Findlen, "Il Nuovo Colombo."

physician Francisco Hernández (1517–1587) to sail for New Spain, charging him with the mission of writing its natural history. Hernández remained in New Spain for seven years, primarily exploring the flora and fauna of Mexico. During that period, he and his European assistants worked extensively with native artists and informants to create a catalogue of Mexican nature that would bring together the best of European and American knowledge. Hernández not only learned Nahuatl to discuss what he observed with local informants but also translated his work into Nahuatl so that, appearing simultaneously in Spanish and in the most prominent indigenous language, it would be useful to all of New Spain's inhabitants.[56] He returned to Spain in February 1577 with a ship full of seeds and roots, an extensive herbarium, and thirty-eight volumes of notes and illustrations. Unfortunately, Philip's interest in the natural history of New Spain had waned, so very little of Hernández's work saw its way into print. What did appear was financed primarily by a Roman scientific academy, the Accademia dei Lincei (1603–30), which understood the value of his work. The original manuscripts burned in a fire at the Escorial in 1671.[57] Despite the intrinsic value of Hernández's work, it was too dependent on royal patronage to proceed without the continued interest of the Spanish monarch. In his case, the ingredients that had made such an ambitious project possible were also the reasons why it was unable to come to fruition.

A similar fate befell the Raleigh expedition to Virginia. In 1584, the artist John White accompanied Sir Walter Raleigh, the English astronomer Thomas Harriot (1560–1621), and other colonists to Roanoke. Harriot described and White drew. Although they intended to publish a natural history of Virginia, the project floundered, much like the colony. Erratic interest on the part of the Crown, funding problems, and the difficulties of settling the colony all contributed to its demise. Eventually Harriot published *A Briefe and True Report of the New Found Land of Virginia* (1590), in which a few engravings based on White's drawings appeared. Others became the basis for drawings of insects in Thomas Penny's *Theatrum insectorum* (Theater of

[56] The full history of this fascinating expedition remains to be written, but there has been a resurgence of interest in Hernández and his world. See German Somolinos d'Ardois, *El Doctor Francisco Hernández: La primera expedicion cientifica en America* (Mexico City: Secretaría del Educación Pública, 1971); Jacqueline de Durand-Forest and E. J. de Durand, "À la découverte de l'histoire naturelle en Nouvelle Espagne," *Histoire, Economie et Société*, 7 (1988), 295–311; José M. López Piñero, "The Pomar Codex (ca. 1590): Plants and Animals of the Old World and from the Hernández Expedition to America," *Nuncius*, 7 (1992), 35–52; Simon Varey and Rafael Chabráu, "Medical Natural History in the Renaissance: The Strange Case of Francisco Hernández," *Huntington Library Quarterly*, 57 (1994), 125–51. For a broader account of the relations between Spain's empire and its vision of nature, see Barrera, *Science and the State*.

[57] An editorial and translation project published in 2000 will make parts of the Hernández corpus more widely available. See Simon Varey, ed., Rafael Chabrán, Cynthia Chamberlin, and Simon Varey, trans., *The Mexican Treasury: The Writings of Dr. Francisco Hernández* (Stanford, Calif.: Stanford University Press, 2000); and Simon Varey, Rafael Chabrán, and Dora B. Weiner, eds., *Searching for the Secrets of Nature: The Life and Works of Dr. Francisco Hernández* (Stanford, Calif.: Stanford University Press, 2000).

Insects), edited and published posthumously by Thomas Moffet in 1634.[58] White's animals found their way into other accounts of English expeditions to the New World. But no complete natural history ever appeared. By contrast, the natural history of Brazil was a successful collaboration that resulted in Georg Markgraf's *Historia naturalis Brasiliae* (Natural History of Brazil), edited by Willem Pies and published in 1648.[59]

The most systematic effort to integrate descriptions of non-European nature into natural history occurred at the hands of Clusius. In 1564, during a trip to Spain and Portugal to observe Iberian plants, Clusius found himself in a bookstore in Lisbon, looking at a copy of Orta's *Colloquies*. He purchased it and, recognizing that such important information would never reach a wide audience if it remained in Portuguese, he began to translate it into Latin, abridging it so that it might be more directly informative.[60] Successively, he performed the same operation on the writings of Nicolas Monardes and Cristobal Acosta.[61]

At the same time, Clusius carefully amassed a collection of New World flora and fauna that would have been the envy of any naturalist at the end of the sixteenth century. He profited from his time at the imperial court in Vienna and, more briefly, in Prague, where the Holy Roman Emperors Maximilian II and Rudolf II delighted in collecting American artifacts as talismans of their ability to command the length and breadth of the globe (see Vogel, Chapter 33, this volume). Once again, royal patronage of natural history played an important role in encouraging certain directions in the study and representation of nature. Rudolf II's sizable menagerie and considerable library on the New World helps to explain why a number of naturalists in Prague, far from trading centers such as Seville, Venice, and Amsterdam, where New World artifacts were in plentiful supply, seem to have had a great deal of knowledge about the Americas.[62] Upon returning to the Netherlands, Clusius tried to exploit the proximity of the Dutch East India Company by attempting to give its physicians and apothecaries instructions on what to collect in travel. He complained, however, that they did not

[58] Paul Hulton, *America 1585: The Complete Drawings of John White* (Chapel Hill: University of North Carolina Press, 1984).

[59] E. van den Boogaart, with H. R. Hoetink and P. J. P. Whitehead, eds., *Johan Maurits van Nassau-Siegen, 1604–1679: A Humanist Prince in Europe and Brazil* (The Hague: The Johan Maurits van Nassau Stichting, 1979); and P. J. P. Whitehead and M. Boeseman, *A Portrait of Dutch 17th Century Brazil: Animals, Plants and People by the Artists of Johan Maurits of Nassau* (Amsterdam: North Holland, 1989).

[60] Garcia da Orta, *Aromatum et simplicium aliquot medicamentorum apud Indos nascentium historia*, ed. and trans. Carolus Clusius (Antwerp: Plantinus, 1567). This episode is discussed in Grove, *Green Imperialism*, pp. 77–81; Hunger, *Charles de l'Escluse*, vol. 1; and Ogilvie, "Observation and Experience," pp. 372–8.

[61] Nicolas Monardes, *Simplicium medicamentorum ex Novo Orbe delatorum*, ed. and trans. Carolus Clusius (Antwerp: Plantinus, 1579); and Cristobal Acosta, *Aromatum & medicamentorum in orientali India nascentium liber*, ed. and trans. Carolus Clusius (Antwerp: Plantinus, 1582).

[62] Eliska Fucíková, *Rudolf II and Prague: The Court and the City* (New York: Thames and Hudson, 1997).

seem to appreciate sufficiently the value of his enterprise, though some animals and plants captured in trade did make their way into his collection.[63] Dutch collectors such as the physician Bernard Paludanus (1550–1633), whose museum was not as large as Aldrovandi's but surely richer in American and Asian artifacts, seem to have fared better, judging by the quantity of objects that came directly to his museum through the trade routes.

Clusius planted what marvels of the Indies he managed to obtain in the Leiden botanical garden, and consulted extensively with friends and fellow naturalists, reminding them in his letters to send gifts to augment his project. He also benefited from the more workaday knowledge of the men he employed as gardeners – whose knowledge of plants derived not from books and learned debates about nature but from their experience as practicing horticulturalists who tended the gardens of Europe as artisans rather than as scholars of nature.[64] Clusius's *Exoticorum libri decem* (Ten Books of Exotic Things, 1605) represented the summation of all that he had read, seen, and discussed about nature beyond Europe.[65] It was a supreme testimonial to the quest to find words for things that had not been seen before 1492.

SHARING INFORMATION

By the mid-sixteenth century, naturalists shared information regularly. The scientific letter became the most important tool of communication in the development of natural history (see Harris, Chapter 16, this volume).[66] Techniques of comparing and collecting specimens worked better when discussing plants rather than animals, because plants were easy to transport and preserve. Yet all information was potentially transportable as long as words and images sufficed. Letters traveled hundreds of miles, often folded around seeds or accompanying a precious piece of a friend's herbarium. Clusius, for example, obtained some of the first tulip bulbs ever seen in the Netherlands in 1569 by writing a friend in Vienna for a sample from the Habsburg ambassador to the Ottoman sultan, who had brought them back from Istanbul.[67] Such singular exchanges accumulated over the years to create entire botanical gardens, natural history collections, and ultimately publishable natural

[63] Ogilvie, "Observation and Experience," pp. 390–2.

[64] Claudia Swan, *The Clutius Botanical Watercolors: Plants and Flowers of the Renaissance* (New York: Abrams, 1998).

[65] The full title is: *Exoticorum libri decem: quibus animalium, plantarum, aromatum, aliorumque peregrinorum fructuum historiae describuntur*.

[66] On the subject of exchange, see Paula Findlen, "The Economy of Scientific Exchange in Early Modern Europe," in *Patronage and Institutions: Science, Technology, and Medicine at the European Courts, 1500–1750*, ed. Bruce Moran (Woodbridge: Boydell Press, 1990), pp. 5–24; Giuseppe Olmi, "'Molti amici in varii luoghi.' Studio della natura e rapporti epistolari nel secolo XVI," *Nuncius*, 6 (1991), 3–31; and Ogilvie, "Observation and Experience," pp. 166–70.

[67] Ernest Roze, *Charles de l'Escluse d'Arras, le propagateur de la pomme de terre au XVIe siècle* (Paris: J. Rothschild, 1899), p. 53.

histories. Most naturalists felt so indebted to their patrons and colleagues, given the enormous expense and effort required to produce an illustrated natural history, that they profusely thanked them when they reached the point of publication. Aldrovandi, perhaps, took this to an extreme when he signed the title page of all his books *Ulyssis Aldrovandi et amicorum* – Ulisse Aldrovandi and friends.[68] Because it had taken him most of a lifetime to publish even the first volume of his natural history, which appeared in print in 1599 when Aldrovandi had achieved the ripe old age of seventy-seven, he had many debts to acknowledge.

The regular exchange of words and things suggests how important collaboration was in the pursuit of natural history. It was also a means for younger members of the community to introduce themselves to prominent naturalists. As a medical student studying in Montpellier in 1563, Jean Bauhin the Younger (1541–1612) sent the revered Gessner some of his best dried herbs accompanied by his own descriptions, knowing that Gessner had returned to the study of botany after completing his magisterial *Historia animalium*, the most extensive zoology since the works of Aristotle and his great medieval commentator Albertus Magnus. Months later, Bauhin's herbarium languished with Gessner in Zurich, though Gessner attempted to console his young friend over the temporary loss of his specimens with the promise of naming a plant after him. Finally, in July 1565, Gessner wrote, "Now I have your dried herbs in hand and soon, with the help of God, I will end my study of them to return them to you, as you ask."[69] Surely only Gessner was surprised to discover that Bauhin ceased to be so generous with his senior colleague after this experience, a lesson that many young naturalists learned in dealing with their elders, who did not always repay their gifts with generosity.[70]

What did a naturalist such as Gessner do with the materials scholars sent him? "I have more notes in my head, perhaps, than on slips of paper," he confessed to Fuchs in 1556.[71] Yet those slips of paper were crucial to Gessner's system of recording information. Like many Renaissance scholars, he reorganized all the information he received – from books, letters, and observations – into a format that allowed him gradually to create descriptions

[68] See, for example, Ulisse Aldrovandi, *Ornithologiae, hoc est de avibus historiae libri* (Bologna: Franciscus de Franciscis Senensis, 1599–1603). On Aldrovandi, see Giuseppe Olmi, *Ulisse Aldrovandi: Scienza e natura nel secondo Cinquecento* (Trent: Libera Università degli Studi di Trento, 1976); Sandra Tugnoli Pattaro, *Metodo e sistema delle scienze nel pensiero di Ulisse Aldrovandi* (Bologna: Cooperativa Libraria Universitaria Editrice Bologna, 1981); and Findlen, *Possessing Nature*.

[69] Conrad Gessner, *Vingt lettres à Jean Bauhin fils (1563–65)*, trans. Augustin Sabot (Saint-Étienne: Publications de l'Université de Saint-Étienne, 1976), p. 88.

[70] On this general subject, see Findlen, "The Formation of a Scientific Community."

[71] John L. Heller and Frederick G. Meyer, "Conrad Gesner to Leonhart Fuchs, October 18, 1556," *Huntia*, 5 (1983), 61. I have modified the translation slightly. On Gesner, see Hans Wellisch, "Conrad Gesner: A Bio-Bibliography," *Journal of the Society for the Bibliography of Natural History*, 7 (1975), 151–247; Braun, *Conrad Gessner*; and Udo Friedrich, *Naturgeschichte zwischen artes liberales und frühneuzeitlicher Wissenschaft: Conrad Gesners "Historia animalium" und ihre volkssprachliche Rezeption* (Tübingen: Max Niemeyer, 1995).

of individual objects that were as complete as the information then available allowed. "I have already noted the names of each of those [plants] that you describe, and I have sorted them in my notebooks, so that when I am ready [to write] the history of each one, I examine your descriptions in detail," he told Bauhin.[72] He did the same thing with information on English nature provided by William Turner and John Caius.[73] The letter, in short, was a form of communication that facilitated the encyclopedic process of gathering and sorting information. It allowed a town physician such as Gessner, who rarely left Zurich after 1546 (except to ascend to the Alps to botanize), to command the world. It exemplified well the mixing of words and things in the study of nature.

The size, expense, and relative fragility of animals in comparison with plants meant that they circulated in more finite quantities than portable plants and inanimate stone. Although some letters occasionally accompanied crates of skins, bones, and stuffed bodies, they more often described animals with words and images. Both Gessner and Aldrovandi, the two sixteenth-century naturalists most enamored of the idea of writing an entire history of animals, published descriptions of many animals that they had not personally seen, though they provided more information on those they were able to dissect as well as read about. When Clusius wished to gain access to the first birds of paradise to arrive in Europe with their feet – for the first two-thirds of the sixteenth century, it was believed that they did not have feet because native hunters cut them off when preparing them for European traders[74] – he was annoyed to discover that all examples had gone to Prague at the request of Rudolf II.[75] Field mice, snakes, and similarly ordinary fauna were in plentiful supply, but more exotic animals often could be seen alive only in the menageries of princes or seen stuffed in the cabinets of curiosities owned by many scholars, nobles, and patricians. When Charles IX's toucan died after the lengthy voyage from Brazil to Paris, a typical fate for most New World animals, the king gave the body to his royal surgeon, Ambroise Paré, to embalm and display.[76] Even though it began to mold, Paré continued to

[72] Gessner, *Vingt lettres*, p. 81. For a more detailed discussion of the use of commonplace books in Renaissance science, see Ann Blair, "Humanist Methods in Natural Philosophy: The Commonplace Book," *Journal of the History of Ideas*, 53 (1992), 541–51.

[73] Vivian Nutton, "Conrad Gesner and the English Naturalists," *Medical History*, 29 (1985), 93–7.

[74] Wolfgang Harms, "On Natural History and Emblematics in the Sixteenth Century," in *The Natural Sciences and the Arts: Aspects of Interaction from the Renaissance to the Twentieth Century* (Acta Universitaria Upsaliensis, nova ser., 22) (Uppsala: Almquist and Wiksell, 1985), pp. 67–83.

[75] Ogilvie, "Observation and Experience," p. 383. On the role of nature in the court of Rudolf II, see Thomas DaCosta Kaufmann, *The Mastery of Nature: Aspects of Art, Science, and Humanism in the Renaissance* (Princeton, N.J.: Princeton University Press, 1993), pp. 100–28, 174–94; and Fucíková, *Rudolf II and Prague*.

[76] Ambroise Paré, *On Monsters and Marvels*, trans. Janis L. Pallister (Chicago: University of Chicago Press, 1982), p. 139. For more on the collecting culture of this period, see Kryzsztof Pomian, *Collectors and Curiosities: Paris and Venice, 1500–1800*, trans. Elizabeth Wiles-Portier (London: Polity, 1990); Joy Kenseth, ed., *The Age of the Marvelous* (Hanover, N.H.: Hood Museum of Art, 1992); Olmi, *L'inventario del mondo*; Findlen, *Possessing Nature*; Horst Bredekamp, *The Lure of Antiquity and*

show it to visitors because it was rare to have this kind of specimen, however imperfect.

The difficulties of acquiring and preserving animals made illustrations even more important to zoology than to botany. They were often the only source of visual information and frequently accompanied the letters naturalists and their patrons exchanged. The printed image was usually created from an artist's or a naturalist's drawing. In the wake of Otto Brunfels's advertisement in 1530 of his herbal as a repository of "living images" – representations drawn from the living object – the idea of the image as a means of conveying crucial information about nature took shape. Fuchs declared in 1542 that "nature was fashioned in such a way that everything may be grasped by us in a picture."[77] He argued strongly for the particularity of each image, criticizing previous illustrators for making images generic rather than particular. Coordinating a well-drawn image based on observation with the catalogue of names associated with a particular plant or animal became a powerful shorthand for the object itself. In the second half of the sixteenth century, illustrations grew in number and importance. Gessner's *Historia animalium* was an encyclopedia of images as much as words, a total of approximately 1,200 woodcuts that included illustrations published in earlier natural histories and cosmographies as well as images made specifically for Gessner's zoology. Aldrovandi had a team of artists and engravers create approximately 3,000 wood blocks from his archive of natural images.[78]

By the 1550s, most naturalists advertised their publications as being filled with "portraits drawn from nature."[79] They championed the image as a guarantor of words because agreement between the two constituted a double form of proof. "If the ancients had drawn and painted all the things that

the Cult of the Machine, trans. Allison Brown (Princeton, N.J.: Markus Weiner, 1995); Luca Basso Peressut, ed., *Stanze delle meraviglie: I musei della natura tra storia e progetto* (Bologna: Cooperativa Libraria Universitaria Editrice Bologna, 1997); and Daston and Park, *Wonders*, pp. 135–72.

77 Leonhart Fuchs, *De historia stirpium commentarii insignes* [1542], sig. B1r, in Sachiko Kusukawa, "Leonhart Fuchs on the Importance of Pictures," *Journal of the History of Ideas*, 58 (1997), 411. My additional comments on Fuchs are based on this article.

78 William J. Ashworth, "Emblematic Natural History in the Renaissance," in Jardine, Secord, and Spary, eds., *Cultures of Natural History*, pp. 18, 27–9; Braun, *Conrad Gessner*, p. 68; and Giuseppe Olmi, "La bottega artistica di Ulisse Aldrovandi," in *De piscibus: La bottega artistica di Ulisse Aldrovandi*, ed. Enzo Crea (Rome: Edizioni dell'Elefante, 1993), p. 19. On natural history illustration, see also Olmi, *L'Inventario del mondo*, pp. 21–117; *Immagine e natura: L'Immagine naturalistica nei codici e libri a stampa delle Biblioteche Estense e Universitaria, Secoli XV–XVII* (Modena: Mucchi, 1984); and Brian Ogilvie, "Image and Text in Natural History, 1500–1700," in *The Power of Images in Early Modern Science*, ed. Wolfgang Lefèvre, Jürgen Renn, and Urs Schöpflin (Basel: Birkhäuser, 2003), p. 141–66.

79 This phrase is from Pierre Belon's *L'Histoire de la nature des oyseaux, avec leurs descriptions, & naïfs portraicts retirez du naturel* (Paris: Guillaume Cauellat, 1555). Other examples include Guillaume Rondelet's *Liber de piscibus marinis in quibus verae piscium effigies expressae sunt* (Lyon: Matthew Bonhomme, 1554) and his *Universae aquatilium historiae pars altera cum veris ipsorum imaginibus* (Lyon: Matthew Bonhomme, 1555). Lucia Tongiorgi Tomasi also points to the frequency of such phrases as *vivae eicones*, *verae effigies*, and *vrais portraicts* in her "Ulisse Aldrovandi e l'immagine naturalistica," in Crea, ed., *De piscibus*, p. 38.

they described," wrote Aldrovandi, "one would not find so many doubts and endless errors among writers."[80] Such an optimistic statement masked a number of complications that Aldrovandi himself knew well from his extensive efforts to create a visual archive of nature. Although many images were the product of personal observation, any naturalist who aspired to write a universal history of nature had to rely on the reports of others in order to create an adequate supply of information. Ascertaining the reliability of such material was a difficult task, which is why Pliny advised his readers not to trust images at all. Illustrations, however helpful, did not necessarily record the veracity of nature, though they did a great deal to record its variety, because conveying knowledge from the eye to the hand produced its own kind of errors. A drawing, let alone a print made from a drawing, yielded no simple truth of nature (see Niekrasz and Swan, Chapter 31, this volume).

Knowing how difficult it was to pass final judgment on all the information that was out there, naturalists hoped that the communal project of natural history ultimately would yield a common truth. "[I]f every person offers his observations in the public good," wrote Gessner in 1556, "there is hope that at some time it will come about that from them a single, perfectly complete work will be produced by someone who will add the final touch."[81] By the time of Gessner's death in 1565, the project of writing a new natural history was well under way but far from complete. Several decades later, Francis Bacon (1561–1626) would return to the idea of natural history as a collective enterprise, writing copiously about the need to realize the kind of project that Gesner had imagined decades earlier.[82]

The constant flow of materials among European naturalists by the late sixteenth century underscores their passionate belief that Gessner's dream of completing the project of natural history was a goal to be taken seriously.[83] If scientific letters at the dawn of the seventeenth century began to betray a certain skepticism about the plausibility of this project, they nonetheless maintained the structures of gathering and sharing information that had been put into place in the service of an encyclopedic ideal (see Harris, Chapter 16, this volume). "Since so many famous men are exhausting themselves in this work, it is to be hoped that the study of the knowledge of plants cannot help

[80] Ulisse Aldrovandi, "Avvertimenti del Dottor Aldrovandi," in *Trattati d'arte del Cinquecento*, ed. Paola Barocchi, 3 vols. (Bari: Laterza, 1960–2), 2: 513.

[81] Heller and Meyer, "Conrad Gesner," p. 67.

[82] See Francis Bacon's *Sylva sylvarum* as an example of the early seventeenth-century efforts to reprise this project.

[83] The image of natural history as an encyclopedic project that could nonetheless be completed was shared by many Renaissance naturalists. When Gessner died in 1565, Aldrovandi essentially replaced him as the naturalist most committed to writing a universal history of nature in imitation of the ancients. Later naturalists such as Clusius and Bauhin confined themselves to more restricted projects, though we should also think of the late seventeenth-century naturalist John Ray and his eighteenth-century successor, Carolus Linnaeus, as worthy successors to Gessner and Aldrovandi in the goal of studying all nature.

but progress," wrote Clusius to one of his correspondents in 1566.[84] This prediction turned out to be an accurate assessment of the kind of science that natural history promoted – knowledge whose gradual accumulation eventually allowed naturalists to derive general principles from it. When Caspar Bauhin's *Pinax Theatri Botanici* (Index of a Botanical Theater), appeared in 1623, the most important attempt to create a unified language and structure for all known plants prior to the work of John Ray and Carolus Linnaeus, it described and classified over 6,000 species.[85] Very few of these discoveries – a tenfold increase from what had been known a century earlier – were Bauhin's. Like the animals in Gessner's and Aldrovandi's large Latin folios, they represented the collective knowledge of a scientific community.

THE EMERGENCE OF THE NATURALIST

But who belonged to that community? What, for that matter, defined it?[86] The identity of the naturalist emerged from many diverse ingredients. He – and, with the exception of women such as seventeenth-century German artist and entomologist Maria Sybilla Merian (1647–1717), there seem to have been few women before the eighteenth century who actively collected, described, and drew nature, except as part of a family project (see Cooper, Chapter 9, this volume), let alone published the results of their research under their own name[87] – was most likely a physician by training, but not necessarily a practitioner of the healing arts. Felix Platter, for instance, wrote of his classmate Clusius that he "never practiced medicine."[88] The same was also true of Aldrovandi, who infuriated some of Bologna's physicians and apothecaries by claiming that his knowledge of nature made him a

[84] Roze, *Charles de l'Escluse*, p. 40.

[85] André Cailleux, "Progression du nombre d'espèces des plantes décrites de 1500 à nos jours," *Revue d'Histoire des Sciences*, 6 (1953), 44. The development of taxonomy in natural history has received the most attention in the realm of botany. Its broadest treatment can be found in Scott Atran, *Cognitive Foundations of Natural History: An Anthropology of Science* (Cambridge: Cambridge University Press, 1990). This work is an explicit response to Michel Foucault's account of the rise of classification and argues against Foucault's interpretation of classification as a reaction to the Renaissance doctrine of signatures in his *The Order of Things: An Archaeology of the Human Sciences* (New York: Random House, 1970). On Bauhin's contributions, see Reeds, *Botany*; Reeds, "Renaissance Humanism"; and Brian Ogilvie, "Encyclopedism in Renaissance Botany: From *Historia* to *Pinax*," in *Pre-Modern Encyclopedic Texts: Proceedings of the Second COMERS Congress, Groningen, 1–4 July 1996* (Leiden: E. J. Brill, 1997), pp. 89–99.

[86] This question has been most specifically addressed in Findlen, "The Formation of a Scientific Community"; and Ogilvie, "Observation and Experience," pp. 131–70.

[87] Kurt Wettengl, ed., *Maria Sibylla Merian: Artist and Naturalist, 1647–1717* (Frankfurt am Main: Gert Hatje, 1998); and Natalie Zemon Davis, *Women on the Margins: Three Seventeenth-Century Lives* (Cambridge, Mass.: Belknap Press, 1995), pp. 140–202. Women also appear in other contexts as illustrators of natural histories. See Agnes Arber, "The Colouring of Sixteenth-Century Herbals," reprinted in her *Herbals*, pp. 317–18; and J. D. Woodley, "Anne Lister, Illustrator of Martin Lister's *Historiae conchyliorum*," *Annals of Natural History*, 21 (1994), 225–9.

[88] Platter, *Beloved Son Felix*, p. 74.

better judge of medicines than they, despite his having never seen a patient. Medical education, in short, provided the skills but did not necessarily define a vocation for many of Europe's leading naturalists.[89]

The growing popularity of natural history created a variety of opportunities for aspiring naturalists to make a living studying nature. A number, of course, already had established professional identities as physicians and apothecaries before they embarked on the study of nature.[90] Others were drawn to the study of medicine because of their interest in nature. The case of Gesner – who taught Greek and Latin grammar to Zurich schoolboys and then taught mathematics, natural philosophy, and ethics at a local academy before becoming a town physician in 1554 – exemplifies this other tendency.[91] Yet another group abandoned the study of medicine as a result of their encounter with a dynamic generation of university professors who encouraged their interests in zoology, botany, and mineralogy.

University-educated naturalists enjoyed a growing number of professional opportunities by the late sixteenth century. They were leading candidates for positions in medical faculties as professors of medicinal botany and as demonstrators in university botanical gardens. (The latter category included a number of naturalists who did not have university degrees.)[92] Many also received court appointments in such cities as Madrid, Florence, Mantua, Ferrara, Prague, and Vienna – wherever rulers prized the study of nature, collected exotic marvels, and promoted the improvement of medicine.[93] Prior to the appearance of the 1554 Latin edition of his commentary on Dioscorides' *De materia medica*, Pier Andrea Mattioli (1501–1577) was a town physician in northern Italy with no strong network of patrons. After its initial success, he became an imperial physician, with the resources of the Habsburgs at his disposal to make his work even more magnificent. Imperial artists and

[89] In other instances, teaching medicinal botany became a means to a professorship but was clearly secondary to the desire to practice medicine. The case of the anatomist Gabriele Falloppia, who chastised Aldrovandi for spending too much time on subjects that he considered beneath a physician's dignity, exemplifies this other pattern; see Findlen, *Possessing Nature*, p. 255. The Bauhin family, which produced several generations of physicians who studied nature, also offers examples of physicians who felt that their work as naturalists at times conflicted with their medical practice; see Reeds, *Botany*. Even Gesner, who spent most of his life writing and publishing natural histories, complained that his need to earn a living from his publications conflicted with his work as a physician; see Wellisch, "Conrad Gesner," p. 164.

[90] Very few apothecary-naturalists published works of natural history, though many contributed to the exchange of information. Ferrante Imperato in Naples and Francesco Calzolari in Verona were important exceptions in this regard.

[91] Wellisch, "Conrad Gesner," pp. 153–63.

[92] Azzi Visentini, *Orto*; Tongiorgi Tomasi and Tosi, *Giardino*, pp. 27–114, passim, and L. Tjon Sie Fat and E. de Jong, eds., *The Authentic Garden: A Symposium on Gardens* (Leiden: Clusius Foundation, 1991), pp. 3, 37–69, offer good case studies of the personnel employed in botanical gardens.

[93] The courtly world in which natural history thrived is outlined in Moran, *Patronage and Institutions*; Dario A. Franchini, Renzo Magonari, Giuseppe Olmi, Rodolfo Signorini, Attilio Zanca, and Chiara Tellini Perina, *La scienza a corte: Collezionismo eclettico natura e immagine a Mantova fra Rinascimento e Manierismo* (Rome: Bulzoni, 1979); Kaufmann, *Mastery of Nature*; and Fucíková, *Rudolf II and Prague*.

engravers in Vienna worked with Mattioli to enhance his commentary, which contained approximately 1,200 images by the time of his death.[94] The Holy Roman Emperor Maximilian II rewarded Mattioli lavishly, ennobling his entire family.

As we have already seen in a number of cases, however, some important naturalists had no medical training at all. Oviedo occupied a variety of different posts in the nascent Spanish empire. He was a literate civil servant who used his abilities to write and assess evidence to create the natural history of the Indies. His appointment as "Official Chronicler of the Indies" in 1532 represented a logical culmination of his efforts to distinguish himself from the many other bureaucrats employed in the Americas by becoming the Spanish empire's Pliny. In his instance, it was his proven ability to write history for the state that led Charles V and his councilors to create a formal position that defined the work he was already doing.

The study of law, like the profession of the notary, also proved to be fertile ground in which naturalists could flourish. Most famous is the case of Francis Bacon, whose legal training and courtroom experience markedly shaped his ideas about evidence.[95] But he was not alone in finding in law and natural history compatible ways to exercise the mind. In late sixteenth-century Naples, one of the greatest naturalists in a city filled with interesting scholars and philosophers was the lawyer and nobleman Fabio Colonna (1567–1650). By the 1590s, Colonna was a judge whose duties led him to travel widely in southern Italy. In between cases, he observed the plants and fossils of the region. His *Phytobasanos* (Touchstone of Plants, 1592) identified and carefully described living examples of twenty-six plants found in Dioscorides' *De materia medica*. It also included six plants of southern Italy that no one had described previously and introduced the term "petal" as a standard descriptor in botanical terminology.[96]

Colonna's later works described over two hundred plant species using the same principles of "legal testimony" that he had advertised in his *Phytobasanos*. He advocated a fairly radical empiricism that emphasized direct

[94] Findlen, "The Formation of a Scientific Community."

[95] On Bacon and natural history, the literature continues to grow. See especially Julian Martin, *Francis Bacon, the State, and the Reform of Natural Philosophy* (Cambridge: Cambridge University Press, 1992); Antonio Pérez-Ramos, *Francis Bacon's Ideal of Science and the Maker's Knowledge Tradition* (Oxford: Clarendon Press, 1988); and Findlen, "Francis Bacon and the Reform of Natural History in the Seventeenth Century," in *History and the Disciplines: The Reclassification of Knowledge in Early Modern Europe*, ed. Donald Kelley (Rochester, N.Y.: University of Rochester Press, 1997), pp. 239–60. On the legal and cultural environment of Bacon's ideas about evidence, see Daston, "Baconian Facts"; Barbara Shapiro, "The Concept 'Fact': Legal Origins and Cultural Diffusion," *Albion*, 26 (1994), 1–26; and Shapiro, *Beyond "Reasonable Doubt" and "Probable Cause": The Anglo-American Law of Evidence* (Berkeley: University of California Press, 1991).

[96] Colonna has not yet received the full study that he deserves. See Greene, *Landmarks of Botanical History*, 2: 835–46; Nicoletta Morello, *La nascita della paleontologia nel Seicento: Colonna, Stenone e Scilla* (Milan: Franco Angeli, 1979); and Martin J. Rudwick, *The Meaning of Fossils: Episodes in the History of Paleontology*, 2nd ed. (Chicago: University of Chicago Press, 1985), pp. 42–4.

evidence of the senses over other forms of knowledge. "The observable thing perfectly gives a method," he wrote in 1618.[97] By observing animals and animal-like fossils, Colonna came to believe that fossils were animal remains or impressions, organic in origin, in contrast with the prevailing explanation that they were mere images of animals made in stone by a playful nature.[98] Others came to similar conclusions in the 1660s and 1670s by different means, and by the eighteenth century this new theory prevailed. Yet it was a lawyer who first argued this view by offering sustained evidence, even drawing and engraving his own images in order to unify every stage of his presentation. In doing this, he emulated the activities of artisan-naturalists such as Leonardo da Vinci (1452–1519) and the sixteenth-century French ceramicist Bernard Palissy (ca. 1510–1590), both of whom advocated a similar view of fossils and drew what they saw.[99]

Behind the divergent educational training and professional itineraries of many naturalists lay some core intellectual principles that only gradually eroded. To a certain degree, the identity of the naturalist continued to be defined by his relationship to the writings of the ancients. Many Renaissance naturalists proudly bore the epithet of the "new Aristotle" or the "new Pliny." At the beginning of the first volume of his *Ornithologia* (1599), Aldrovandi had the engraver record the following words beneath his portrait: "This is not you, Aristotle, but an image of Ulysses: though the faces are dissimilar, nonetheless the genius is the same."[100] The past continued to be a productive metaphor for the present. Oviedo and Hernández identified deeply with Pliny, undoubtedly recognizing themselves as heirs to Pliny's project of describing the nature of an empire – to such a degree in the latter's case that he produced one of the greatest translations of and commentaries on Pliny in the late sixteenth century.[101]

As the medical model of natural history, dominated by medicinal botany, waned at the end of the sixteenth century, the encyclopedic premise of natural

[97] Fabio Colonna, *La sambuca lincea* (Naples: C. Vitale, 1618). This passage is quoted in Giuseppe Olmi, "La colonia lincea di Napoli," in *Galileo e Napoli*, ed. F. Lomonaco and M. Torrini (Naples: Guida, 1987), p. 54, which places Colonna's work in the context of the Accademia dei Lincei's colony in Naples.

[98] On this symbolic way of looking at nature, against which Colonna reacted, see Foucault, *Order of Things*, pp. 17–45; Ashworth, "Natural History"; and Findlen, "Jokes of Nature and Jokes of Knowledge: The Playfulness of Scientific Discourse in Early Modern Europe," *Renaissance Quarterly*, 43 (1990), 292–331.

[99] Stephen Jay Gould, *Leonardo's Mountain of Clams and the Diet of Worms* (New York: Harmony, 1998), pp. 17–44; and Bernard Palissy, *Admirable Discourses*, trans. Aurèle La Rocque (Urbana: University of Illinois Press, 1957).

[100] Ulisse Aldrovandi, *Ornithologiae* (Bologna: Franciscus de Franciscis Senensis, 1599), n.p. The Sienese physician Pier Andrea Mattioli, who wrote one of the most popular commentaries on Dioscorides in the sixteenth century, also expressed a similar relationship to his ancient author; see Findlen, "The Formation of a Scientific Community"; and Jerry Stannard, "P. A. Mattioli: Sixteenth Century Commentator on Dioscorides," *Bibliographic Contributions, University of Kansas Libraries*, 1 (1969), 59–81.

[101] Gerbi, *Nature in the New World*, pp. 386–7; and Varey and Chabráu, "Medical Natural History."

history took on greater importance. "I take a strong interest in all of nature's curiosities," Clusius proclaimed in 1566, even though he concentrated primarily on the study of plants.[102] Aldrovandi wrote emphatically that he studied nature, "not as a physician, according to that more common practice, but as a philosopher."[103] In such statements, he underscored his distinctive contribution to natural history, which entailed its elevation to the status of natural philosophy (an Aristotelian ideal with which Bacon partly agreed when he made natural history the foundation of all natural philosophy by the 1620s) and the expansion of natural history from exclusively medical subjects to a more comprehensive account of nature. He, after all, was the only professor of natural history to occupy a position that had been specifically redefined from *lectura de simplicibus* (readership in simples) in 1543 to *lectura philosophiae naturalis ordinaria de fossilibus, plantis et animalibus* (ordinary readership in the natural philosophy of fossils, plants, and animals) in 1559.[104] The shift in title reflected an active attempt to make natural history a discipline autonomous from medicine. "Yet in these matters I am less a doctor than a natural philosopher," wrote the great English naturalist John Ray a century later, echoing the heritage of Aldrovandi, Clusius, and Bauhin.[105] Natural history would continue to be closely associated with medicine through the eighteenth century. But increasingly its leading practitioners studied nature apart from medicine.

Specialization was not the hallmark of the sixteenth- and early seventeenth-century naturalist. Gesner and Aldrovandi, imitating ancient writers such as Aristotle and Pliny, established the image of the naturalist as someone who aspired to describe a universal nature. Although many naturalists disagreed on what the best starting point might be – animals or plants? fossils or insects? – and how to arrange and interpret the details, they did not question the encyclopedism of their subject. The popularity of such works as Francis Bacon's *Novum organum* (New Organon) and *Instauratio magna* (Great Instauration), both of which appeared in 1620 and were read by the scholarly community in the second half of the seventeenth century, served to further the image of the naturalist as a collector, experimenter, and system-builder who was concerned with general inquiry into nature. "[B]estow on the world a general history of nature," wrote one friend to John Ray (1627–1705) in 1684, capturing the vastness of the enterprise in this pithy phrase.[106]

[102] Roze, *Charles de l'Escluse*, p. 43. Clusius's identity as a naturalist is discussed extensively in Ogilvie, "Observation and Experience."

[103] Ulisse Aldrovandi, *Lettere a Costanzo Felici*, ed. Giorgio Nonni (Urbino: Quattro Venti, 1982), p. 79.

[104] Findlen, *Possessing Nature*, pp. 253–6.

[105] Charles E. Raven, *John Ray, Naturalist: His Life and Works*, 2nd ed. (Cambridge: Cambridge University Press, 1986; orig. publ. 1950), p. 157. Of course, such efforts did not sever the possible uses of natural history for medicine, and many early modern naturalists actively continued to cultivate such ties, contra Aldrovandi and Clusius. See Harold J. Cook, "Natural History and Seventeenth-Century Dutch and English Medicine," in *The Task of Healing: Medicine, Religion, and Gender in England and the Netherlands, 1450–1800* (Rotterdam: Erasmus, 1996), pp. 253–70.

[106] Raven, *John Ray, Naturalist*, p. 212.

By the late seventeenth century, as Ray's numerous publications joined the works of many other scholars in redefining the natural world with a greater level of precision and detail than Gesner could ever have imagined, the context of natural history had changed dramatically. Even as the idea of a universal history remained important, divisions emerged among naturalists with regard to the best means of achieving this goal. If the sixteenth century was characterized by its simultaneous fascination with old books and new objects, the seventeenth century can be described as an age in which natural history became more conscious of the place of history in studying nature, more open to the role of instruments and experimentation, and more reliant on European overseas empires to provide materials for study. When Ray published his *Historia plantarum* (History of Plants) in 1686, he felt no need to reiterate the entire history of botany that preceded him because, he observed, "the Bauhin brothers had done this thoroughly."[107] The historical consciousness to which Ray alluded shaped natural history in at least two distinct ways. First, it conjured up the image of natural history as a cumulative discipline in which successive generations tried valiantly to tame unruly masses of information by developing better classification schemes and methodologies to identify the crucial characteristics of animals, plants, and minerals, such as the nascent work to classify plants according to their reproductive characteristics rather than the shape of their leaves. By Ray's time, Caspar Bauhin's *Pinax* was the starting point for any subsequent work in botany because it provided such a masterful synthesis of all that was known about plants before 1623, cross-referencing names and characteristics.

Although he admired the utility of such classificatory works and participated in their perfection, Ray was already less sanguine about the naturalist's holy grail: the quest for a perfect method by which all nature could be reduced to a simple set of characteristics. In the seventeenth century, the fascination with universal and artificial languages closely connected natural history to various intellectual schemes to reduce knowledge to a set of simple unifying principles. In his own work, Ray advocated the utility of classification for beginning naturalists but felt that it ultimately had its limits in accounting for all of nature's variety.[108] He did not want naturalists to oversimplify nature in the search for the crucial characteristics of different species, addressing evident mistakes of classification, such as placing whales among the fishes – an error Ray caught as he began to transform such categories as "quadruped," which classified animals according to the nature and arrangement of their limbs, into Linnaeus's idea of a "mammal."[109] History, in its root sense, reminded naturalists that resolving problems of nomenclature did not count as understanding nature.

[107] Ibid., p. 219.

[108] See John Ray, *Methodus plantarum* (London: Henry Faithhorne and John Kersey, 1682); and M. M. Slaughter, *Universal and Artificial Languages in the Seventeenth Century* (Cambridge: Cambridge University Press, 1982).

[109] On this episode, see Schiebinger, *Nature's Body*, pp. 40–74.

The second aspect of the naturalist's engagement with history regarded a transformation in the understanding of "natural history" as a historical as well as descriptive enterprise. The general portrait of nature prior to 1660 described an invariate rather than dynamic nature. All species existed across time, if not space. Such ideas found validation not only in Aristotle but also in the Bible, neither of which suggested that nature had changed since the moment of Creation. By the 1660s, the problem of understanding fossil formation seemed on the verge of undermining this ancient principle. Naturalists in many different parts of Europe – from Robert Hooke in England to Nicolaus Steno, a Danish scholar transplanted to Italy – argued that fossils were remains of creatures that had once existed.[110] As knowledge of fossils expanded, it became apparent that not every fossil corresponded to a living animal or plant. The fossil record was a historical record that eventually would revise the scientific understanding of human history in relation to nature's history. Naturalists in this early generation of fossil hunters were indeed historians – to such a degree that they often wrote about the natural and human history of a location simultaneously.[111] They struggled valiantly to contain their findings within biblical time, developing elaborate arguments about the role of the Flood in shaping the fossil record. By the mid-eighteenth century, naturalists such as Georges Leclerc, Comte de Buffon, began to suggest that nature's history significantly predated the human record.

The 1660s also represent an important watershed in the development of new techniques with which to observe nature. New instruments and a nascent culture of experimentation profoundly transformed the meaning of observation. The microscope, an instrument known to members of the Accademia dei Lincei in Rome as a modified version of Galileo's telescope, first gained popular currency with the publication of Robert Hooke's *Micrographia* (1665), which closely associated the compound microscope with the early Royal Society. In the hands of patient observers such as Marcello Malpighi, Jan Swammerdam, and Antonie van Leeuwenhoek, both handheld and compound microscopes yielded a myriad of surprising and fundamentally disturbing facts about nature.[112] Hooke, for instance, invited his readers to contemplate the wonders of an insect eye, the complexity of a flea, the patterns in a segment of cork, and the similarities between fossils and their living analogues when magnified. More controversially, Leeuwenhoek's sperm seemed to validate the idea of preformation when he claimed to see perfectly formed creatures inside them – and produced equally strong counterarguments from

[110] See Rhoda Rappaport, *When Geologists Were Historians, 1665–1750* (Ithaca, N.Y.: Cornell University Press, 1997), which contains an excellent bibliography.

[111] A good example of this genre is Robert Plot's *Natural History of Oxford-shire* (Oxford: Printed at the Theatre, 1677).

[112] Catherine Wilson, *The Invisible World: Early Modern Philosophy and the Invention of the Microscope* (Princeton, N.J.: Princeton University Press, 1995); Edward Ruestow, *The Microscope in the Dutch Republic: The Shaping of Discovery* (Cambridge: Cambridge University Press, 1996); and Marion Fournier, *The Fabric of Life: Microscopy in the Seventeenth Century* (Baltimore: Johns Hopkins University Press, 1996).

those who believed that the egg contained everything, making the microscope at best an indecisive tool for solving some of nature's most pressing mysteries.[113] After the initial enthusiasm for the microscope subsided, it was unclear in its first century of existence whether it would become anything more than a pleasing toy that introduced natural history to a general audience.[114]

By contrast, the experimental studies of insects in the late seventeenth century offered an excellent example of the development of observation from simple description to repeated observation and testing of diverse natural phenomena. Works such as the Tuscan physician Francesco Redi's (1626–1687) celebrated *Esperienze intorno alla generazione degl'insetti* (Experiments on the Generation of Insects, 1668) and Jan Swammerdam's *Historia insectorum generalis* (General History of Insects, 1669) used naked-eye observation and simple magnifying glasses more than microscopy to argue against the ancient idea that insects generated spontaneously. Redi, for instance, created a series of controlled experiments to demonstrate that maggots formed only when rotting meat was uncovered and larvae deposited, and never spontaneously from the animal itself.[115] No doubt inspired by reports of the work of Redi and Swammerdam, Maria Sibylla Merian recalled that she had begun her study of caterpillars in 1670 at the tender age of thirteen. By 1679, her *Raupenbuch* (Book of Caterpillars) was complete – the first of several publications illustrating and describing insect metamorphoses. So committed was Merian to the study of living nature that she described a gift of dead insects in 1672 as being "useless" to her work.[116] No inert specimen could provide the kind of observation that she and her contemporaries needed to study the caterpillar's life cycle.

Merian's dedication to the study of living nature led her to spend two years in the Dutch colony of Surinam between 1699 and 1701 with her younger daughter, Dorothea Maria, so that she might see for herself the insects that travelers had brought to Amsterdam and described in their travel accounts. Her *Metamorphosis insectorum surinamensium* (Metamorphosis of the Insects of Surinam, 1705) offers an excellent example of the ways in which European colonization helped to shape the culture of natural history by pushing it more insistently outside the boundaries of Europe itself (see Vogel, Chapter 33, this volume). Although ridiculed by the Dutch colonists for her interest in anything beyond the sugar cane that was the mainstay of the local economy, Merian nonetheless found herself in possession of a rich repository of natural lore that came directly from the African and Indian slaves who worked in

[113] Clara Pinto Correia, *The Ovary of Eve: Egg and Sperm and Preformation* (Chicago: University of Chicago Press, 1997).

[114] The same thing might also be said of Robert Boyle's air pump, also a product of the 1660s. It became an important site in which to examine nature in an artificial state, bringing living creatures to the brink of death with every drop of air that an experimenter removed, and demonstrating the significance of air for life.

[115] For an example of this kind of work, see Francesco Redi, *Experiments on the Generation of Insects*, trans. Mab Bigelow (New York: Kraus Reprint, 1969).

[116] Wettengl, *Maria Sibylla Merian*, p. 21.

the colony. Like the Spanish physician Hernández in the preceding century, Merian quickly understood that increasing natural knowledge through communication with native informants and making this information available to a European audience was one of the important scientific outcomes of the early age of imperialism (see Schiebinger, Chapter 7, this volume).

By the end of the seventeenth century, communicating natural knowledge had evolved well beyond random travelers' reports to become a sophisticated economy of information that linked mercantile and scientific activities. Just as Merian benefited from the Dutch presence in the New World, English naturalists began to see their own nation's overseas activities as a source of invaluable information. In 1661, the Royal Society appointed a committee that drew up a list of important questions about remote places that they might ask of merchants, sailors, and travelers.[117] In the next few decades, individual naturalists such as the physician John Woodward produced pamphlets instructing travelers how to observe and collect a nature that he would never see in person. Woodward's *Brief Tract for Making Observations in All Parts of the World* (1696) exemplifies the more entrepreneurial culture of late seventeenth-century natural history, in which naturalists encouraged travelers to become observers by offering them a share in the profit of collecting exotic natural objects for their wealthy patrons. Nature had indeed become a global commodity.

From the 1660s through the 1690s, the Baconian image of natural history as a common enterprise that defined the entire scientific community seemed on the verge of success. The nascent French and British overseas empires created a political and economic framework that built upon the earlier activities of the Portuguese, Spanish, and Dutch in making natural history the science of empire (see Chapters 16 and 33, this volume).[118] They provided an infrastructure in which to gather information to a degree that was unimaginable in 1492. At the same time, institutional developments in the realm of science gave natural history greater prominence. Early scientific societies, from the Accademia dei Lincei (1603–30) in Rome to the Royal Society (founded 1660) in London and the Académie Royale des Sciences (founded 1666) in Paris, all proposed natural history as their communal project. In many instances, Bacon's writings as well as the labors of his predecessors inspired these groups.[119]

By the time a Swedish pastor's son, Carolus Linnaeus (1707–1778), began his study of medicine at the University of Uppsala in 1728, in a facility that

[117] Daniel Carey, "Compiling Nature's History: Travellers and Travel Narratives in the Early Royal Society," *Annals of Science*, 54 (1997), 274–5.

[118] The most important theoretical formulation of this process remains Pratt, *Imperial Eyes*, which focuses on the eighteenth century. See also Grove, *Green Imperialism*; and Barrera, "Science and the State."

[119] The best case study of natural history within a scientific society is Alice Stroup, *A Company of Scientists: Botany, Patronage, and Community at the Seventeenth-Century Parisian Royal Academy of Sciences* (Berkeley: University of California Press, 1990).

already boasted a thriving botanical garden, he was heir to a lengthy and well-defined tradition of studying nature that had been in place for almost two centuries.[120] He guided visitors through the garden, developing the initial ideas for his *Systema naturae* (System of Nature, 1735), which laid out the basic principles of binomial nomenclature as a means of classifying not only those things that were known but all future things to be known. Linnaeus traveled abroad, especially to the Netherlands, where he worked for several years in the garden of a Dutch banker, returning home to become the most prominent member of the Uppsala medical faculty and a favorite of the Swedish nobility, who botanized with him on the weekends. He sent his disciples all over the world to collect specimens for his natural histories and obsessively edited and reedited his most important works until they swelled beyond recognition – fat tomes laden with information and erudition that seemed only to replicate some of the problems of the earlier generations. Linnaeus, in other words, pursued natural history on a scale that his predecessors could only dream of, but, on the level of practice, it was still fundamentally early modern, even as he returned to the questions of classification that naturalists such as Ray found unsatisfactory.

Had natural history changed very much by then? It certainly had routinized the process of gathering information on a global scale that had been such a thorny problem in the early sixteenth century. It had begun to grapple with problems of nomenclature in direct relation to the descriptive characteristics of animals and plants – a good example of how analysis of nature ultimately could not be divorced from experience. Issues of terminology and description were only beginning to enjoy the kind of prominence they would have by the mid-eighteenth century, and there was still much to know and describe of the natural world, as Linnaeus knew well when he trained his best students to travel far and wide in search of the rare and unknown specimen.

Natural history offered no simple or universally sustainable account of how nature worked as a whole. Its success lay with practitioners who privileged experience of nature as the foundation of all other aspects of science, which is undoubtedly why a methodical thinker such as Descartes found the naturalists' fascination with the material world so distracting – it cluttered the mind with more than it could ever possibly hope to know and with no end in sight to what else there was to be known.

[120] Frängsmyr, *Linnaeus*; James Larson, *Reason and Experience: Representation and the Natural Order in Carl von Linné* (Berkeley: University of California Press, 1971); Wilfrid Blunt, *The Compleat Naturalist: A Life of Linnaeus* (London: Collins, 1971); Schiebinger, *Nature's Body*; and Lisbet Koerner, *Linnaeus: Nature and Nation* (Cambridge, Mass.: Harvard University Press, 1999).

The Department of History and Philosophy of Science (HPS), of the University of Cambridge is the largest department of History and Philosophy of Science in the United Kingdom. A majority of its submissions received maximum ratings of 4* and 3* in the 2014 REF (Research Excellence Framework). Located in the historic buildings of the Old Physical Chemistry Laboratories on Free School Lane, Cambridge, the Department teaches undergraduate courses towards the Cambridge Tripos and graduate courses including Alexander Jones, Liba Taub. This volume in the highly respected Cambridge History of Science series is devoted to the history of science, medicine and mathematics of the Old World in antiquity. Organized by topic and culture, its essays by distinguished scholars offer the most comprehensive and up-to-date history of ancient science currently available. Together, they reveal the diversity of goals, contexts, and accomplishments in the study of nature in Mesopotamia, Egypt, Greece, Rome, China, and India. Intended to provide a balanced and inclusive treatment of the ancient world, contributors c 'â€¦ the Cambridge History will no doubt be an indispensable reference for researchers, educators, and general readers interested in the field.' Source: Chemical Heritage. 'â€¦ an impressive testament to the depth and breadth of current study of the history of the physical sciences. It will become the definitive reference work for the field. â€¦ a wide range of methodologies â€¦ The sheer number of topics addressed is â€¦ staggering â€¦ excellent contributions on the relationship of the physical sciences to society and culture. â€¦