CHAPTER 2

The Colonial Iberian Roots of the Scientific Revolution

Some readers may be familiar with the frontispiece to Francis Bacon's *Instauratio magna* (1620), which shows a ship sailing through the pillars of Hercules (fig. 2.1), standing for the voyage of empirical and experimental discovery of nature's secrets on which Europeans embarked as soon as they put the authority of ancient texts behind them. The introductory engraving in Jan van der Straet's *Nova reperta* (ca. 1580), a collection of thirteen illustrations of key early modern "discoveries," also highlights the importance of new technologies such as the printing press, the clock, and the cannon (fig. 2.2).

Paradoxically, these two illustrations have come to be associated first with a "Protestant" and later with an "Enlightenment" narrative of modernity, which purposefully obscures the role of Catholic Iberia in the so-called Scientific Revolution. I say paradoxically because these two illustrations either drew on Iberian motifs of discovery or sought to capture Iberian contributions to knowledge.

Take Francis Bacon's motif of sailing through the pillars of Hercules to signify the triumph of the moderns over the ancients, for example, which was in fact a sixteenth-century Spanish export. As José Antonio Maravall persuasively argued some forty years ago, it was in the Iberian Peninsula, and particularly Spain, that intellectuals first developed a sense that the moderns had superseded the ancients. The discovery of hitherto unknown patterns of oceanic wind currents, the development of new vessels, and the mastery by sailors of new techniques to find their bearings in the open sea led in the fifteenth century to a growing realization that the cosmographies inherited from the ancients were wrong. By the early sixteenth century, Iberians had discovered that the Indian Ocean was not an inland sea, as Ptolemy maintained, and that there was a whole new world in the middle of the Atlantic. Numerous peoples who had clearly been unknown to the ancients were discovered in Africa and the Americas. The new empires that the Portuguese and Spaniards put together, which encompassed peoples and bureaucracies

FIG. 2.1. Frontispiece to Francis Bacon's *Instauratio magna* (London, 1620). New York Public Library.

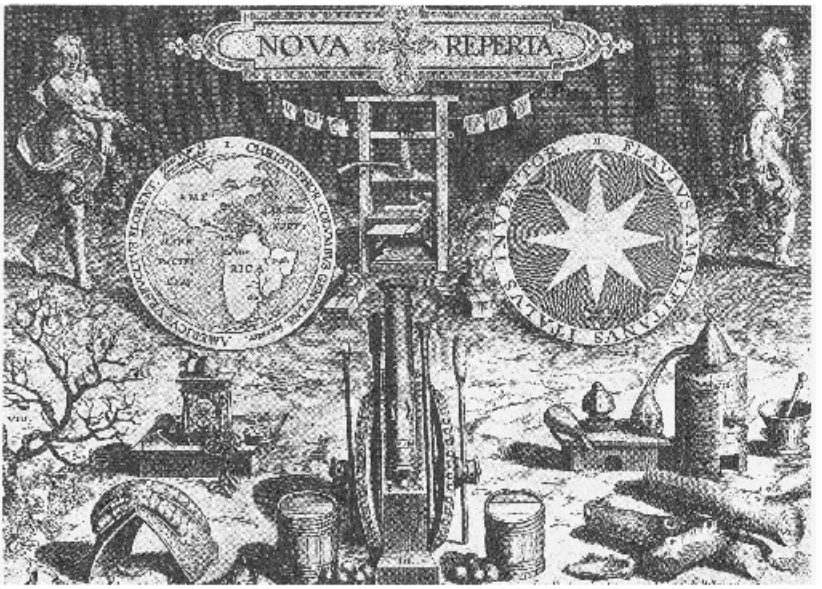

FIG. 2.2. Introductory image in Jan van der Straet's *Nova reperta*, engraved by Philippe Galle (ca. 1580). The Burndy Library, Dibner Institute for the History of Science and Technology, Cambridge, Massachusetts.

on four different continents, were wonders of political engineering and military prowess that dwarfed anything Rome had ever accomplished. No wonder that when looking for motifs to capture the deeds of his new Holy Roman Empire, Charles V (1500–1558) chose both the Golden Fleece to symbolize rightful providential rewards for chivalric valor and the pillars of Hercules to signal the superiority of his age over that of the ancients.[1]

Consciousness in the Iberian Peninsula of the preeminence of the moderns over the ancients had more than one manifestation. Iberian humanists were less easily dazzled than their Italian peers by Latin and Greek, and they purposefully set out to develop their own vernaculars.[2] The literatures on metallurgy, medicine, agriculture, surgery, meteorology, cosmography, cartography, navigation, and fortifications studied by Maravall are peppered with comments both on the ignorance of the ancients and on the technical superiority of the moderns. Intellectuals relished every opportunity to remind their readers about all the novelties that had completely eluded the ancients: new empirical breakthroughs in metallurgy (which allowed Spain

Fig. 2.3. Frontispiece to Andrés García de Céspedes's *Regimiento de navegación* (Madrid, 1606). Courtesy of the James Ford Bell Library, University of Minnesota.

to develop economies of scale in silver mining in the New World); new plants, diseases, and cures; new forms of military maneuver and fortification; and new agricultural techniques.[3] Luis de Camões (1524–80) and Alonso de Ercilla (1533–94) wrote epic poems recording the extraordinary voyages and adventures of real-life Iberian Argonauts and confidently believed that they were superseding Homer. Arguing that Vasco da Gama's deeds dwarfed those of Ulysses, Camões asserted, without inspiring astonishment: "Cesse tudo o que a Musa antiga canta. Que outro valor mais alto se alevanta" (May the ancient Muse be silenced. For greater heroes have now arisen).[4] David A. Lupher has shown that classical Rome became the standard against which Iberians measured their military prowess and scholarly feats in the New World. Conquistadors repeatedly found Julius Caesar and Augustus wanting: petty, insignificant conquerors in a small corner of the world. Poets ridiculed Aeneas as a little hero whose adventures and ordeals had been put to shame by the new Iberian Argonauts. And naturalists dismissed Pliny as a provincial cataloguer of curiosities.[5] It was in this environment critical of the achievements of the ancients that the royal cosmographer Andrés García de Céspedes (d. 1611) published his *Regimiento de navegación* in 1606 (fig. 2.3), the frontispiece to which resembles and foreshadows that later used by Francis Bacon in the *Instauratio magna*.[6]

It is very likely that Bacon (1561–1626) purposefully sought to imitate García de Céspedes, for throughout the sixteenth century, English authors followed the military and technical accomplishments of the Iberians with a mixture of interest and envy. The English acknowledged the technical superiority of the Portuguese and Spaniards when it came to navigation and avidly translated treatises published by Iberian royal cosmographers introducing local audiences to tables and calculations on how to locate latitude (and even longitude) in the open sea. The English sought to imitate the schools for pilots institutionalized in Seville and admired the role of Spanish mathematicians, metallurgists, cosmographers, astronomers, navigators, and hydrographers in the development of empire. As the jealous Richard Hakluyt (1552?–1616) put it in his *Principal Navigations of the English Nation* (1599; smaller first ed. 1589), the Spaniards were far ahead of the English in the colonization of the New World, not only because the former enjoyed "those bright lampes of learning (I mean the most ancient and best Philosophers, Historiographers and Geographers) to showe them light," but also because they possessed "the loadstarre of experience (to wit, those great exploits and voyages layed up in store and recorded) whereby to shape their course." Hakluyt presented the writings of such Spanish cosmographers as Alonso de

Chaves (d. 1587), Jerónimo de Chaves (1523–74), and Rodrigo Zamorano (b. ca. 1545) as exemplary.[7]

It is therefore not preposterous to think that Bacon might have had the Spanish empire in mind when he wrote his *New Atlantis*. The culmination of a lifetime engagement with devising new epistemologies, Bacon's *New Atlantis* describes a utopian island organized around the utilitarian, pragmatic, and experimental manipulation of natural resources. Stranded European sailors happen upon an unknown Pacific island on which the local nobility have instituted a crusading order, Solomon's House. After days of idle waiting on the island, the sailors finally get to meet a powerful member of the order, who introduces them to the secrets of the islanders, namely, the carefully planned, large-scale, mechanical exploitation and reproduction of all natural resources and phenomena. That the islanders and the great lord of the House speak Spanish and that the island is located off the coast of Peru are not the only inklings that Bacon may have had Spanish institutions of knowledge in mind. As Antonio Barrera has elegantly shown, in the sixteenth century, the Spaniards created an extensive culture of empirical, experimental, and utilitarian knowledge gathering that took its cues, not from the classics or the learned, but rather from merchants, enterprising settlers, and bureaucrats.[8]

Settlers and merchants were always on the lookout for new natural resources to sell, constantly hyping the economic windfalls that would accrue to those capable of exploiting the various new mineral, pharmaceutical, and agricultural resources found in the Indies. They also sought to introduce new mechanical devices, demanding patents and monopolies. The Crown responded eagerly but cautiously to all these claims by farming out the testing of the new products and devices to experts back home: physicians, pilots, cosmographers, apothecaries, and inventors. By the early sixteenth century, the scale of claims and counterclaims was such that new institutions had to be created, including the Casa de Contratación in Seville, a veritable "Chamber of Knowledge." Training ships' pilots and assembling credible maps was one of the functions of this new institution; another was apportioning credit among contradictory reports. The Crown also standardized questionnaires and launched large-scale campaigns of data gathering. Finally, the mechanical transformations of landscape undertaken by engineers in the pay of the Spanish empire in Potosí and the central valley of Mexico were as extraordinary as those dreamed up by the knights of Solomon's House, including the creation of artificial lakes and rivers to power mills to crush silver ore and the cutting of sluices through massive

FIG. 2.4. Frontispiece of *Ordenaçôes manuelinas* (Lisbon, 1521)

mountains to drain Mexico City (on this, see below). Just like Hakluyt, Bacon seems to have been well informed about the new Spanish institutions and practices.[9]

There is also another reason to suspect that Bacon had the Iberians in mind when he wrote the *New Atlantis*. Like the Portuguese and the Spaniards, Bacon linked knowledge to crusading. A quick glance at the sixteenth-century Iberian treatises of cosmography so admired by the English shows that the Iberians saw knowledge gathering as an expansion of crusading virtues. In his much acclaimed and widely influential *Arte de navegar* (1545), the royal cosmographer Pedro de Medina (1493?–1567?) asserted that ships' pilots were the new knights, whose horses were their vessels, and

FIG. 2.5. Frontispiece of Bernardo de Vargas Machuca's *Milicia y descripción de las Indias* (Madrid, 1599). Courtesy of the John Carter Brown Library, Brown University, Providence, R.I.

whose swords and shields were their compasses, charts, cross-staffs, and astrolabes.[10] Astrolabes and coats of arms appear in the *Ordenaçôes manuelinas* of 1521 (fig. 2.4) and other classics of the Portuguese expansion to Africa and Asia—in fact, the armillary sphere and the cross of Saint George are the chief elements of Portugal's coat of arms—and the frontispiece of Bernardo de Vargas Machuca's 1599 *Milicia y descripción de las Indias* (fig 2.5) displays the motto "A la Espada y el compás/Más, y más y más y más" (To the Sword and the compass/More, and more, and more, and more [imperial territorial expansion]). The institutions and values of Bacon's New Atlantis, with its crusading order of Solomon's House, in every respect resemble those created by Spain and Portugal to gather knowledge for utilitarian purposes.

But it is best not to speculate. Juan Pimentel has persuasively shown that Bacon did take key ideas of his *New Atlantis* from the 1606 memorial of Pedro Fernández Quirós's discovery of what he named "Terra Australis." Fernández Quirós (1562–1615) had begun his career in Peru, navigating the Pacific as a pilot for Alvaro de Mendaña, who after having "discovered" the Solomon Islands (1568–69) continued to search for Solomon's Ophir for years. After sailing from Peru in search of Ophir, Fernández Quirós happened upon an island in the Pacific that he took to be a continent. Perhaps thinking to honor the Austrian Habsburg dynastic roots of his reluctant patron Philip III, Fernández Quirós christened the new territory "La Australia del Espíritu Santo." Upon arrival there, he proclaimed the crusading order of the Holy Spirit and set about founding the city of New Jerusalem. Informed by the ideas of the Franciscan Joachim de Fiore, he associated this momentous discovery with the imminent arrival of the new millennium. More important, he envisioned the island as a future utopia where, unencumbered by the learning of the ancients, clear-eyed settlers would collect natural histories. The millenarian, crusading, and utopian empiricist dimensions of Bacon's project are all present in Fernández Quirós's writings. The memorial was translated into several languages, including Latin and English (1617), and Bacon most likely owned a copy.[11]

The *Nova reperta* of the Dutch engraver and painter Jan van der Straet (1523–1605), who latinized his name as Johannes Stradanus, indicates that awareness of the role of Iberians in a dawning modernity was not limited to jealous English imperial competitors.[12] Since his career unfolded in Italy and his patrons were Roman, Florentine, and Genoese clerics and merchants, Stradanus highlighted the contributions to the discovery of America and to the development of the compass of Christopher Columbus (1451–1606), Amerigo Vespucci (1451–1512), and "Flavius Amalfi" (most likely a fictional character, who appears in Italian histories of the compass in the mid sixteenth century) respectively, in the first engraving in his *Nova reperta* (see fig. 2.2). Yet Stradanus's catalogue of nine remarkable new discoveries includes at least three that any of his contemporaries would immediately have granted to the Iberians: namely, the sighting of new constellations in the Southern Hemisphere (the Southern Cross),[13] the introduction of new remedies (the bark of the guaiacum tree), and the discovery of new lands (America). There are also other elements in this picture that contemporaries would not have separated from the history of the Portuguese and Spanish expansions, such as the development of new cash crops and of new military technologies (e.g., the cannon).

Stradanus's *Nova reperta* and Bacon's *Instauratio magna* and *New Atlantis* demonstrate the importance of Iberia to any narrative of the Scientific Revolution. Yet this term has strangely become synonymous with developments in northwestern Europe and the North Atlantic region. When the first histories of the Scientific Revolution by A. Rupert Hall (1954), Marie Boas (1962), and Richard Westfall (1971) appeared in Britain and the United States, they found no room to accommodate Iberia at all. This absence, which is at the core of most metanarratives of the genesis of modernity, derives from the secretive policy of Spain's Habsburg regime, which, as Richard Kagan shows, had a culture of *arcana imperii*, a tendency to keep details of the empire (maps, natural history reports, etc.) unpublished. The secrets leaked, but the massive collected learning related to empire building was destined to circulate only in manuscript form.[14] Even the Bourbons, who set out to do away with many such Habsburg practices in the eighteenth century, failed to publish the countless studies of cartography and natural history they sponsored.

In addition to being marginalized by the practice of privileging scribal over print culture in order to keep knowledge secret, the science sponsored by the Spanish-Portuguese state was of a kind historians of science like Hall, Boas, and Westfall considered peripheral to the narrative of the Scientific Revolution. For these historians, astronomy, physics, and mathematics held the key to explaining the transformations of early modern understandings of nature. The mathematization and mechanization of the cosmos in the seventeenth century ultimately led to secularism, industrialization, and capitalism: the birth of the modern world. The sciences the Iberian powers sponsored, mostly cartography and natural history, were thought not to have been related to these economic, religious, and cultural changes. Yet there is today a growing realization that natural history and cartography were not entirely peripheral to the momentous epistemic transformations of modernity. Some historians of science have therefore turned to study the sciences sponsored by Iberian empires.[15] But interest in Spain and Portugal is still marginal. Why?

The reason lies, ultimately, in the narratives of modernity inaugurated first by Protestantism and later by the Enlightenment, both profoundly hostile to Catholic Iberia. Some one hundred and fifty years after Bacon borrowed the tropes and motifs to depict the arrival of modernity from García de Céspedes, Zacharie de Pazzi de Bonneville (ca. 1710–ca. 1780) has his "philosophe La Douceur" declare that "there is no nation more brutish [*abruti*], ignorant, savage, and barbarous than Spain."[16] In 1777,

Joseph La Porte (1713–79) concluded in his *Le voyageur françois* (1766–95), a massive compilation of travel narratives presented as letters from a fictional roving observer to a lady back home, that Spain was a land of superstitious folk, still practicing sciences inherited from the Moors, namely, "judicial astrology, Cabala, and other Arab inanities." Spaniards, he further argued, had boundless admiration for Aristotle, "whose senseless and tenebrous philosophy" they blindly followed.[17] Finally, in 1781, the abbé Raynal (1713–96) maintained in his *Histoire philosophique et politique des établissements et du commerce des Européens dans les deux Indes* that "never has a nation been as enslaved to its prejudices as Spain. In no other place has irrationality [*le déraison*] proven as dogmatic, as close, and as subtle."[18] Ever since the eighteenth century, Iberians have come to represent the antithesis of modernity.

The erosion of the Iberian empires in the face of increasing Dutch and English competition and the failure of Spain and Portugal to carry out reforms to consolidate the centralizing power of the state, as in France, led to the relative decline of the Iberians in the seventeenth century. Already during the Reformation and wars of Dutch independence, northwestern European printers had created an image of the Iberians as superstitious and rapacious plunderers. The decline of the Iberian empires not only hardened this perception; criticism now came wrapped in the language of progress, and the Iberians were cast as essentially non-Europeans: backward and ignorant.[19] By 1721, Montesquieu (1689–1755) could maintain in the pages of *Lettres persanes*, without being challenged, that Spaniards were only good at writing chivalric romances and dogmatic scholastic treatises.[20] Not surprisingly, none of the metanarratives of modernity and progress that came of age in the eighteenth century have found a place for the technological and philosophical contributions of the Iberians in the early modern period.

This tendency to neglect the contributions of the Spanish to natural philosophy in the sixteenth century can be observed in Frances López-Morillas's translation into English of José de Acosta's *Historia natural y moral de las Indias*, published by Duke University Press (2002). For all its merits, the new edition seems more preoccupied with Acosta the historian and anthropologist than with Acosta the natural philosopher.

"And my desire is that all I have written may serve to make known which of his treasures God Our Lord divided and deposited in those realms; may the peoples there be all the more aided and favored by the people of Spain, to whose charge divine and lofty Providence has entrusted them." With these words in the dedication to Philip II (1527–98), José de Acosta (1540–1600)

summed up the spirit of his *Historia*, for the celebrated Jesuit was interested both in explaining the conquest as a preordained providential event and in identifying signs of intelligent design in the many natural wonders of the American continent. Acosta was a man of omnivorous curiosity, with an uncanny ability to find divine order in contingency, chaos, and probability. But he was not simply a Christian philosopher. As the above quotation makes clear, he was also a pragmatist interested in how things work and how colonial peoples thought, so as to use and manipulate the former and to convert and govern the latter.

Acosta's views have been available to English-speaking audiences for centuries. Unlike the writings of scores of other sixteenth-century Spanish, Creole, mestizo, and Amerindian authors whose treatises on the natural wonders of the Indies and the past of local indigenous peoples commanded little attention until recently, Acosta's *History* was immediately translated into several European languages, including English. In the eighteenth-century Atlantic world, when all sources produced in the early Spanish empire came to be seen as untrustworthy and useless, only Acosta's treatise was deemed worth reading. Despite Acosta's reputation, however, since 1604, the average English-speaking reader interested in the Jesuit has had to plow through Edward Grimeston's translation. Grimeston's prose in *The natvrall and morall historie of the West Indies* may have served Elizabethan audiences well, but today it seems stodgy and distant. Fortunately, students can now turn to López-Morillas's crisp new rendition.

López-Morillas's translation has been edited by the Andeanist Jane E. Mangan and is accompanied by an introduction and commentary by the literary critic Walter D. Mignolo. Both Mangan's annotations and Mignolo's study help put Acosta in a larger cultural and ideological context, but their approach betrays a bias that is typical of most contemporary scholarship in the field.

In 1604, Grimeston and his Tudor and Stuart audiences considered Acosta to be not only a keen observer of things Amerindian but a great natural philosopher. Yet by the late seventeenth century, Acosta began to be read only for his contributions to anthropology and ethnography. Students and scholars today do not turn to Acosta for information about the nature of the stars and heavens in the Americas but to reconstruct the lives of Amerindian peoples and the nature of colonial power. What is left out, however, are the questions that most captivated Acosta: why tides and winds in the Southern and Northern hemispheres have different timings and directions; why the torrid zone of Peru enjoys a temperate climate year round, instead of scorch-

ing heat; why seasons of rain and drought follow exactly opposite patterns in Europe and Peru; why mercury attracts silver; and so on. Three out of five pages in Acosta's *Historia* are devoted to accounting for the seemingly puzzling behavior of the cosmos in the Indies. Acosta sets out to prove that nature in America, just as much as in Eurasia, is a docile servant of God, following predictable laws. For all their contributions, Mangan and Mignolo deal only tangentially with this essential facet of Acosta's world.

The disregard for Acosta as a natural philosopher and for Spanish science at large is also obvious in Lorraine Daston and Katherine Park's otherwise marvelous book *Wonders and the Order of Nature, 1150–1750*. Although they make passing and superficial references to Nicolás Monardes (ca. 1512–88) and one Ferrando de Oviedo (actually Gonzalo Fernández de Oviedo [1478–1557]), Daston and Park completely overlook the Spanish literature on the New World's wonders, including, for example, Juan de Cárdenas's path-breaking *Problemas y secretos maravillosos de las Indias*, published in Mexico in 1591, Baltazar Dorantes de Carranza's *Sumaria relación de las cosas de Nueva España* ([1604] 1902), the massive seventeenth-century natural history of marvels by the Jesuit Juan Eusebio Nieremberg, *Historia natvrae, maxime peregrinae* (1635), the capstone of this tradition, and Antonio de León Pinelo's *El paraíso en el Nuevo Mundo* ([1645–50] 1943).[21] Daston and Parker show absolutely no awareness that Spanish natural histories of the Indies like Acosta's were attempts at modifying dominant narratives of marvels. A firm believer that demons were particularly powerful in the Indies and largely responsible for the idolatry of the colonized natives, Acosta was nevertheless not willing to cede the realm of the natural and the marvelous in the New World to the devil.[22] His *Historia natural y moral* constantly seeks to frame puzzling natural phenomena and the seeming inversion of physical laws in the Indies with a discourse of providential design and lawful regularities. By so doing, Acosta sought to steer early modern European perceptions of nature in the New World away from the realm of the preternatural and thus the demonic.[23] This is all the more remarkable because Acosta was a firm believer in the imminence of the Apocalypse, a fact that goes completely unnoticed by Mangan and Mignolo. Acosta's *De temporibus novissimis libri quatuor*, originally published in Rome in 1590, sought to prove, among other things, that the multiplying instances of witchcraft, demonic possessions, prodigies, and the preternatural in early modern Europe were all signs of the devil having been unleashed on the eve of the Apocalypse, as suggested in the Bible.[24]

Examples of how the history of Renaissance Iberian natural philosophy

is usually overlooked abound. Given the dominant narrative of the North Atlantic origin of modernity sketched above, this is not at all surprising. It is surprising, however, that there is little room in the vibrant new field of the history of botany, natural history, and empire for considering how Portugal and Spain set long-term European patterns. Take, for example, Richard Drayton's account of the rise of the modern botanical garden in his *Nature's Government: Science, Imperial Britain, and the "Improvement" of the World* (2000). Drayton offers a dazzling, brilliant account of how botany and empire developed in tight, mutual interaction during England's eighteenth and nineteenth centuries. Although Drayton's focus is on the history of the Royal Botanic Gardens at Kew, he spends considerable time exploring the origins of the early modern botanical garden, which he traces to particular intellectual, religious, and political forces. Intellectually and religiously, the culture of the botanical garden was tied to humanist efforts to catalogue the world and recover Adam's long-lost grip on creation.[25] Politically, the garden first sought to glorify monarchs as new Solomons—learned kings deeply concerned with the secrets of nature so as to benefit the local commonwealth. Later, these monarchical philosophical pretensions gave way to a culture of ornamentation, in which all sorts of powerful patrons, not only rulers, set out to collect plants and tend gardens to dazzle, while consolidating power and prestige. In these various phases, Drayton reminds us, naturalists, monarchs, and humanists found the plants they needed overseas. But this very process of primitive accumulation of botanical knowledge changed ideas about the polity, religion, and the order of nature. Eventually, the botanical garden became an institution that helped generate colonialist ideologies, while promoting large, global agricultural economies of scale.

This genealogy of the botanical garden (from medicine to ornamentation to plantation agriculture) does not pay sufficient attention to developments in sixteenth-century Portugal and Spain, however, for early modern botany was as rooted in the entrepreneurial, utilitarian efforts of apothecaries in gardens and hospitals in Seville, Lisbon, Goa, and New Spain as in the humanist culture of the medical faculties of Padua, Leiden, and Montpellier. From the time of its revival as a science in the Renaissance, botany served the needs of transnational merchant capital. Take, for example, the case of Carolus Clusius (1526–1609), whom Drayton refers to as "the Copernicus who shattered the Hellenocentricsm of Renaissance botany."[26] The dean of early modern botany and the founder of the botanical gardens of Vienna and Leiden, Clusius spent his life chasing after exotica to expand the classical repertoire of European botanical knowledge, limited for centuries to the few

hundred plants catalogued in the works of Theophrastus and Dioscorides. As Drayton himself correctly points out, Clusius made available in Latin the works of Portuguese and Spanish doctors and apothecaries such as Nicolás Monardes, García d'Orta, and Cristobal Acosta (ca. 1515–ca. 1592). These, however, were all works single-mindedly focused on the potential commercial value of newly discovered plants, with little use for speculative philosophy.[27] Clusius inherited a keen eye for the utilitarian, commercial value of exotic commodities from these Portuguese and Spanish treatises, as well as from his travels through the various botanical gardens of Portugal and Spain.[28] Thus Clusius's additional notes to Orta's short treatise on Southeast Asian aromatic and pharmaceutical plants also included references to potentially profitable exotica collected by Francis Drake (1540?–96) in his recent circumnavigation of the globe.[29] Clusius's translation into Latin of Thomas Harriot's description of Virginia for Theodore de Bry (1528–98) is not a simple rendition. It includes long lists of goods used by the local inhabitants, as well as of botanical staples with potential commercial value.[30]

The utilitarian, pragmatic, commercial aspect of Iberian natural history found its culmination in the expedition and work of Francisco Hernández. Sent by Philip II to gather material for a natural history of herbals, Hernández spent seven years in Mexico (1571–77) experimenting in hospitals for natives established by the Spanish clergy and interviewing Nahua intellectuals versed in Latin. By the time of his return, he had assembled eleven volumes of illustrations of 3,000 different species of plants (as well as of minerals, animals, and local antiquities) and several other volumes of text. Phillip II felt the work to be too philosophical and asked his royal physician, the Neapolitan Nardo Antonio Recchi, to plow through Hernández's work to come up with a list of useful pharmaceutical plants. Philip died while Recchi was at work on this, however, and neither Recchi's anthology nor Hernández's massive natural history was ever made available by the Crown, which at the time was seeking to shut down all publications on the Indies in an effort to deny rival powers any additional knowledge of, and footholds in, the New World. Recchi's compilation had to wait some sixty years to appear, this time with various appendices and notes by several members of the Accademia dei Lincei.

The history of the Academy of the Lynx and of the publication of Recchi's manuscript is told by David Freedberg in *The Eye of the Lynx*, a most learned and lavishly illustrated book (2002). In Freedberg's narrative, this Roman academy, to which Galileo belonged, appears, again, as *the* harbinger of modernity. Mostly composed of German, Roman, and Neapolitan scholars,

led by Federico Cessi (1585–1630), the academy edited works that sought to find the hidden order of nature. With the aid of microscopes, telescopes, and the art of dissection, academicians like Galileo and Cessi observed not only the surface appearance of plants, fossils, insects, and stars but also their internal, intimate structure. In so doing, these *novatores* set out to undermine the authority of the ancients and radically altered the way knowledge was gathered and classified. As part of this new effort, the academicians were particularly interested in curiosities and exotica, and when they learned that Recchi's nephew, one Marco Antonio Petilio, had kept the doctor's manuscripts, they pounced on them. Over the course of some forty years, at different times, Johannes [Terrentius] Schreck (1576–1630), Johannes Faber (1570–1640), Fabio Colonna (1567–1650), Francesco Stelluti (1577–1653), and Federico Cessi continued to add notes and marginalia to the original manuscript, until it finally came to light in 1651 under the title of *Rerum medicarum Novae Hispaniae thesaurus*.

A quick glance at the frontispiece (fig. 2.6) demonstrates the utilitarian emphasis of the whole enterprise: scantily clad natives offer Philip IV (1605–65) (represented by his coat of arms) the botanical riches of Mexico, which (pace Drayton) are simultaneously medicinal, ornamental, and agricultural. Viewers are invited to step through the doorway and into one of the territories of the Spanish empire, which also include Castile, Leon, Granada, Portugal, Sicily, Naples, Aragon, Flanders, Jerusalem (!), Mexico, and Peru (see the coat of arms in the frontispiece in *Rerum*, originally designed in 1628, when Portugal was still part of the Spanish empire; the serpents and eagles below the Portuguese coat of arms would seem to represent Mexico and Peru). It is useful at this stage to remind the reader that Cessi and his Roman and Neapolitan allies were subjects of the loose Spanish monarchy.[31] The utilitarian, commercial emphasis of the work surfaces repeatedly in the text itself. The printer Giacomo Mastardi, for example, ends his preface to the reader, in which he outlines the complex, tortuous history of the manuscript and identifies the various contributors, by insisting that "not only the herbalist, the lover of natural history, the medical doctor, the philologist, the taxonomist [*Phytosophus*], and the collector of ornamental flowers for princes and noblewomen . . . but also the shopkeeper [*institor*], the quack [*pharmacopola*], the apothecary [*pharmacis mercator*], and the perfumer [*odorarius*], whether in search of health, pleasure, or money, will find a wealth of objects, images, and names to satisfy your mind, eyes, and desire."[32] Johannes Schreck (aka Johannes Terrentius), charged with adding glosses and commentary to Recchi's original manuscript, defends Recchi's

decision to follow Theophrastus and Dioscorides on pragmatic, commercial grounds. Thus in the section on Mexican trees, Terrentius argues that dividing plants into trees, bushes, and herbs is justifiable in the case of trees, because trees are the source of many riches, give us shelter from the attack of beasts, keep us from drowning in tempests, and allow us to ply the menacing seas to discover new lands and ultimately engage in commerce.[33]

For all his enormous contribution, Freedberg excludes Iberia from his history of the Accademia dei Lincei and particularly from the history of the publication of Recchi's manuscript. In Freedberg's narrative, Spain appears as an obstacle, and he presents Hernández as incompetent, barely capable of organizing the material he collected (247). Ricchi appears as a physician cowed into silence by the Spanish king, fearful of sharing the fruits of his labor with others (249). Although he acknowledges that it was a Spanish official in Rome, Alfonso de Las Torres, who finally put up the money to publish the work, Freedberg does not make much of this, nor of the fact that Rome and Naples were at the time cultural satellites of Spain.[34] Yet the very evidence Freedberg presents shows that Spain was a willing participant throughout the many years it took the Accademia dei Lincei to bring the book to light. Linceans like Johannes Heckius (1576–ca. 1618) (253) and Cassiano dal Pozzo (1588–1657) (262) had repeatedly had access to Hernández's manuscripts and illustrations at El Escorial. Moreover, when Cassiano visited Madrid in 1626, he obtained the Codex Badianus, an illustrated herbal written in Latin in 1552 by two Nahua intellectuals, Juan Badiano and Martín de la Cruz, as a present for the pope.[35] More important, Freedberg unwittingly shows that the academicians received help at every turn from learned Spanish or Creole clerics living in Rome, who again and again provided Linceans with animals, plants, documents, and much-needed interpretations (261, 265).[36] Freedberg's work demonstrates how difficult it has become for Anglo-American scholarship to bring Iberia back into narratives on the origins of modernity.

Spaniards, to be sure, have not taken kindly to this neglect. Spanish intellectuals compiled massive bio-bibliographies to demonstrate the remarkable intellectual successes of the Spaniards since the Romans. Patriotic compilations such as the *Bibliotheca Hispana vetus* (1696) and *Bibliotheca Hispana nova* (1672) of Nicolás Antonio (1617–84) multiplied in the eighteenth and nineteenth centuries, particularly those on sixteenth- and early seventeenth-century authors and texts. With the support of Dutch and German printers and scholars, a Valencian scholar, Gregorio Mayans y Siscar (1699–1781), catalogued the achievements of early modern Spanish arts and science,

FIG. 2.6. Frontispiece to Francisco Hernández's *Rerum medicarum Novae Hispaniae thesaurus* (Rome, 1651). Reproduced by permission of the Huntington Library.

inventing a new period in Spanish history, the *siglo de oro*, or "Golden Age."[37] These writings, unfortunately, led nowhere. They were consumed within Spain and deployed to bolster various patriotic agendas. The Spanish Golden Age today evokes the names of Diego Velásquez (1599–1660) and Lope de Vega (1562–1635). We associate early modern Spain with painters and poets, not metallurgists and astronomers.

José María López Piñero's *Ciencia y técnica en la sociedad española de los siglos XVI y XVII* (1979) has perhaps been the most significant and influential study of the history of early modern Spanish science and technology to appear in the last quarter of the twentieth century. It is a formidable effort, wide-ranging and ambitious in scope. The book is unevenly divided into four sections. The first is slim and devoted to issues of historiography and methodology. It surveys the literature that since Nicolás Antonio has sought to reconstruct the accomplishments of sixteenth-century science in Spain. Most of these studies, López Piñero maintains, were patriotically biased. Many were erudite but narrowly focused on one or two disciplines. López Piñero presents his book as the first comprehensive, unbiased study, entirely based on meticulous research from primary sources in all disciplines. Section two is a statistical and a historicist study of practitioners of science and technology in sixteenth-century Spain. It defines science according to early modern criteria and shies away from anachronistic categories. It identifies the institutions in which science was done in Spain and seeks to quantify this work according to such variables as the number of published texts per field and the regional origin of authors and publications. This section also contains studies of the social standing of the various practitioners according to trade, profession, and ethnicity (Christian, Jewish, converso, and Morisco).[38] Finally, by looking at patterns of self-imposed cultural isolation on the part of universities and the Crown, encouraged by the Inquisition, it offers suggestions as to why Spanish science and technology had begun its inexorable decline by the late sixteenth century. The third section, the bulk of the book, is a veritable encyclopedia, a painstaking discussion of hundreds of texts and authors according to disciplines: mathematics, cosmography, navigational science, geography, natural philosophy, engineering, metallurgy, natural history, anatomy, medicine, and surgery. Section four, much slimmer, jumps to the late seventeenth century to study innovators in places like Valencia, Madrid, and Seville who sowed the seeds of eighteenth-century scientific renewal by embracing the empirical-experimental practices and philosophical categories of the new mechanical philosophy. This section, also encyclopedic in scope, is organized around authors, not disciplines, namely, the *novatores* (innovators)

Juan Bautista Juanini (1636–91), Crisóstomo Martínez (ca. 1638–ca. 1694), Juan de Cabriada (1660–1730), Joan d'Alós, Jaime Salvador, Juan Caramuel Lobkowitz (1606–82), Vicente Mut (1614–87), José de Zaragoza (1627–78), Tomás Vicente Tosca (1651–1723), Juan Bautista Corachán (1661–1741), and Antonio Hugo de Omerique.

López Piñero's study of sixteenth-century Spanish silver-mining technologies typifies his approach. In an impressive command of both primary and secondary literature, López Piñero identifies a series of errors that have plagued the literature on the subject ever since the publication in 1786 of the first history of technologies of amalgamation by the Austrian mineralogist Ignaz von Born (1742–91), *Über das Anquicken der old- und silbehaltigen Erze, Rohsteine, Schwarzkupfer und Hüttenspeise* (Of the Amalgamation of Gold and Silver Ores [etc.]). Beginning with Born, it has been common to argue that the process of extracting silver from silver ore with mercury involved a single "discovery." There is some debate as to where that "discovery" took place; some have argued that it was a well-established ancient practice; others that it was originally tried by German miners, who took it with them first to Spain and later to the New World; and still others, particularly Spaniards and Spanish Americans, that it was invented in the New World (with some debate as to whether this was in Peru or Mexico). López Piñero shows that the process of amalgamation was not reproducible from place to place and that therefore it was a complex practice that had to be "discovered" time and again. Although mixing mercury and silver was a well-known alchemical procedure, extraction of silver *from silver ore* was a new technology first developed by Spaniards, not Germans. This technology, however, required persistent experimentation, because the amount of mercury needed varied according to the nature of the local ore. It was also an industrial process; it needed to be standardized and reproduced in economies of scale. Bartolomé de Medina (1492–1585) achieved the first successful trial in Pachuca, Mexico, in 1555. Yet his procedures and formulas (they included crushing the ore and mixing it with salt, copper/iron sulfides, and mercury) did not travel well. They did not work in Spain (1555–62) or Germany (1588), and between 1559 and 1568, they did not work in Peru either. It was only in the 1570s that the miner Pedro Fernández de Velasco, through controlled experiments with local ore, discovered successful new formulas and techniques, triggering a silver rush in the Andean highlands that in the space of a few years created the largest city in the Spanish empire, Potosí. López Piñero closes his brief study of amalgamation describing the new technologies introduced by Juan Capellín (1576) in Tasco, Mexico

(which shortened the time the amalgams "rested" in *patios* from twenty to four days); by Carlos Corzo (1587) in Potosí (which reduced the amount of mercury needed by introducing new iron sulfites into the original reaction with salt and crushed ore);[39] and by Alvaro Alonso Barba (ca. 1600) in Potosí (which improved the amount of silver recovered from the amalgam by heating the combination of sulfites, mercury, and crushed ore).

In fewer than six pages (259–65), López Piñero takes on well-established scholarly traditions and offers a comprehensive history of amalgamation in the New World.[40] Moreover, he offers tantalizing suggestions for future research. López Piñero insists that all experimentation and innovation in amalgamation took place in the New World, not Europe. There are remarkable similarities between this case on the imperial periphery and the metallurgical experimentation in the ironworks of seventeenth-century New England. William Newman has shown that figures like George Starkey (1627–65) took advantage of the very marginality of New England in the British empire to introduce rigorous experimental procedures (tied to accounting measures in proto-industrial firms) that transformed the content and practices of seventeenth-century alchemy at the European core.[41]

There are some aspects of López Piñero's book that the above example on metallurgy should make obvious. First, the book aspires to be an encyclopedia: López Piñero privileges sorting, weighing (credibility), counting, identifying, and cataloguing over grandiose speculation. Second, the book has no other overarching argument besides insisting on the vitality of Spanish science in the sixteenth century through the accumulation of encyclopedic examples. Finally, Spain is thought of in the wider Atlantic context. The New World occupies center stage.

For all its claims to objectivity and scholarly detachment, López Piñero's book, like the genre of bio-bibliographies exemplified by Nicolás Antonio, is organized around the study of authors and texts (particularly the third and fourth sections) and motivated by patriotism. Like that other Valencian Mayans y Siscar, López Piñero is enthralled by the idea of a sixteenth-century Spanish golden age of erudition and creativity in the sciences and technology. Like Mayans, he finds the hegemonic North Atlantic historiography on the Scientific Revolution by and large unaware of Iberian contributions to it.[42] Aware that his book could be construed as yet another in a long list of patriotic surveys, López Piñero devotes the first section to establishing differences with this literature. But there is much in López Piñero's study that resembles the genre he dismisses. Like the eighteenth-century monumental studies by Juan Francisco Masdeu (1744–1817), Francisco Xavier

Lampillas (1731–1810), and Juan Andrés (1740–1817) on ancient, medieval, and contemporary Spanish literature, done to correct claims of the negative influence of Spanish bad taste in Italian literatures from Martial to Lope de Vega, López Piñero offers his readers a veritable encyclopedia.[43]

The encyclopedic aspirations of López Piñero come through most clearly in his editorial efforts. The Instituto de Historia de la Ciencia y Documentación (Institute of the History of Science and Bibliographic Documentation, now named after López Piñero) at the University of Valencia, has over the past four decades published some sixty volumes in three different series: monographic studies, editions of primary sources, and that most traditional of Spanish genres, bio-bibliographies. In addition to organizing this massive editorial effort, López Piñero has also put together the invaluable two-volume *Diccionario histórico de la ciencia moderna en España* (Historical Dictionary of Early Modern Spanish Science) (1983), in collaboration with Thomas Glick, Víctor Navarro Brotóns, and Eugenio Portela Marco.

Typical of this effort to publish primary sources is Lopez Piñero's edition of the beautiful Codex Pomar (2000). Philip II was a generous patron of natural history. His palace at El Escorial had eleven rooms full of ovens and glassware, large alchemical laboratories devoted to distilling the quintessence of plants. The "philosophical tower" was the jewel of Philip's laboratory: a twenty-foot glass tower capable of producing two hundred pounds of liquid herbal extracts every twenty-four hours. To keep his alchemical laboratories running, Philip established botanical gardens in and near El Escorial. The king also kept pleasure gardens, where in lavish displays of engineering prowess, he manipulated water and earth like Hercules and Orpheus. Lest his commitment to natural history ever be doubted, Philip sent expeditions to the New World and kept birds and quadrupeds, including such exotica as a rhino (which commanded admiration, even though it was hornless and blind), in his palaces. Philip II had at his disposal plants and animals from every corner of the planet, for he ruled over the largest empire ever assembled, with colonies in Africa, India, China, Europe, and the New World. In his sumptuous edition of the Codex Pomar, López Piñero has, once again, made it possible for historians to glimpse the world of medical herbals and natural histories at the court of Philip II.

A collection of 218 hand-colored illustrations of plants (148) and animals (70) from Europe, the New World, and Asia, the Codex Pomar originally belonged to Philip II. Seeking to lure Jaume Honorat Pomar (ca. 1550–1606), one of the leading luminaries of the medical school of the university of

Valencia, to Madrid, Philip II gave Pomar the codex as a gift. After having taught anatomy (inspired by the humanism of Vesalius) for four years, and after having led the chair of herbals for fourteen, Pomar finally relented and left Valencia to serve Philip II in Madrid the very year the king died (1598).

In the introduction to this edition, López Piñero goes over material he has already covered in other publications: the tradition of alchemical-herbal medicine in Spain; the humanism of the Valencian medical school; and the contributions to natural history of Nicolás Monardes and Francisco Hernández (on which see further below). Surprisingly, there is precious little here on the codex itself. Although López Piñero, with the erudition that has always characterized his work, locates each of the animals and plants in the illustrated codex within ancient and contemporary (Dioscorides, Pliny, Covarrubias) and Linnaean modern taxonomies, readers are largely left on their own to interpret the 218 images. What do the images tell us about the culture of patronage, diplomacy, gardens, and menageries in late sixteenth-century Spain? There are, for example, six gorgeous images of tulips. Were these collections of tulips ever used as a diplomatic tool to deal with the Ottomans? A beautiful illustration of a rhino's horn parades before our eyes. Where did the rhino come from and how did it contribute to enhancing the prestige and ritual power of the king? The introduction also does not help us to understand how the codex fits into sixteenth-century European traditions of plant illustrations. Most of the plants in the codex are shown at different stages in their natural life cycles; some seem to represent pressed plants, not live specimens. Were these typical illustrating techniques?

Some twenty-three years after its publication, *Ciencia y técnica* remains highly influential within Spain. The methodology, insights, and encyclopedic sensibilities that López Piñero first deployed in his treatise surface now in almost every study on any subject in the field of early modern science and technology. Consider, for example, the superb *Técnica y poder en Castilla durante los siglos XVI y XVII* (1989) by Nicolás García Tapia, in which the author seeks to reconstruct a long-forgotten chapter in the history of sixteenth-century northern Castilian engineering of roads, bridges, canals, aqueducts, watermills, looms, ironworks, public buildings, and water pumps. Like López Piñero's, his approach is comprehensive and erudite. García Tapia ransacks the archives of Simancas, Valladolid, Burgos, Medina del Campo, Palencia, Salamanca, and Segovia for evidence. The results confirm many of López Piñero's findings, including that sixteenth-century Spain witnessed much innovation, only to experience a decline in the following century; that northern Castile was part of larger European networks,

exporting hydraulic engineers to the rest of the continent and relying on imports or industrial spying to develop other technologies; and that a number of striking technical innovations did not first take place in Italy or northwestern Europe. García Tapia locates several patents by northern Castilian inventors of steam engines, diving gear, submarines, and water turbines, for example. Finally, like López Piñero, García Tapia shies away from sweeping arguments or large interpretations; his goals are modest; he simply seeks to add one brick to the edifice of knowledge.

This attention to erudition also permeates the work of López Piñero's colleague Víctor Navarro Brotóns, who has for several decades contributed mightily to the editorial and encyclopedic efforts of the Institute of Bibliographic and Historical Studies on Science at the University of Valencia. A leading authority on the history of early modern Spanish astronomy and mathematics, Navarro Brotóns has studied the reception of Nicolaus Copernicus (1473–1543) in sixteenth-century Spain. Typical of his approach and sensibility are his publications on the "Copernicans" Diego de Zúñiga (1536–1600) and Jerónimo Muñoz (d. 1591).[44]

Zúñiga, a polymath biblical scholar and professor of Holy Scripture at the University of Osuna, is known among specialists on Copernicus for having embraced the physical reality of heliocentrism as early as 1584 in an interpretation of Job 9:6 ("God moves the Earth from its place and makes its columns tremble") entitled *Job commentaria*. In fact, Zúñiga was not alone: Copernicus's *De revolutionibus* (1543) made it onto the reading lists at the University of Salamanca as early as 1561. These facts throw a monkey wrench into the North Atlantic narratives of modernity. How could a closed, backward, post-Tridentine country like Spain be at the forefront of the Copernican revolution? Fortunately for the survival of these North Atlantic discourses, the Spanish Inquisition clamped down on Zúñiga's work in 1616, although it never banned *De revolutionibus*. Oddly, this story has served to reinforce the very North Atlantic narratives that Zúñiga's alleged intellectual precocity threatened. Along with Galileo's, Zúñiga's name is bandied about to exemplify the retrograde medieval impulses of a dogmatic Catholic Church.

Navarro Brotóns does not believe any of this. In his study, Zúñiga is depicted as a self-aggrandizing biblical scholar who, in order to impress patrons at court and Rome, used Copernicus to offer a dazzlingly novel exegesis of this passage of Job. Having been told that heliocentrism did not conform to contemporary perceptions of physical reality, however, he immediately set out to write one of the first essays in Europe denouncing

the theory as scientific nonsense, his *Philosophia prima pars* (1597). This in fact was part of larger pattern in Spain: Copernicus was well received among astronomers, who found his calculations useful. Spanish astronomy and cosmography, one would be right to infer, were particularly pragmatic, because they developed not only within universities but also at court and in special academies to train ships' pilots, in the context of relentless imperial expansion.[45] Whatever worked to calculate the motion of planets and stars was welcomed. But when Copernicus's theory became part of larger philosophical and biblical debates in the 1590s, all Spanish intellectuals, including Zúñiga, quickly opted to reject Copernicus and embrace "common sense": the Aristotelian notion of an Earth at rest.[46]

Navarro Brotóns does not really offer any all-encompassing interpretation of Spanish astronomy. Pragmatism prompted by the needs of imperial expansion might be a useful theory to account for why Copernicus's mathematical model was particularly welcomed in sixteenth-century Spain, yet Navarro Brotóns is not really looking for great explanatory models. He simply identifies the facts in painstaking detail, author by author, text by text. His *Matemáticas, cosmología y humanismo en la España del siglo XVI* (1998) is, in the same vein, a study of the life and works of another controversial Spanish scientific figure, the Valencian astronomer Jerónimo Muñoz. Like Zúñiga, Muñoz was a humanist, so good at languages, particularly Hebrew, that there was some suspicion he was a converso (i.e., a Jew feigning conversion to Christianity to escape the Inquisition). Be that as it may, Muñoz got his training in France, Flanders, and Italy and returned to teach astronomy and mathematics first in Valencia and later in Salamanca. All his life he was part of larger European corresponding networks (which included Tycho Brahe [1546–1601]). His *Libro del nuevo cometa* (1573) made the first forceful case for the recent origin of a star, the supernova of 1572, demonstrating its supralunar origin.[47] His observations led him to challenge Aristotle's thesis of the incorruptibility of the heavens. Like Zúñiga, Muñoz read and praised Copernicus for pragmatic purposes, but in his unpublished "Commentaria Plinii libri secundi" (1568), Muñoz sought to refute the physical plausibility of heliocentrism. Navarro Brotóns traces Muñoz's works in painstaking detail and, after collating two extant manuscripts of the "Commentaria," offers an annotated edition (and a Spanish translation) of it. Like López Piñero and García Tapia, Navarro Brotóns emphasizes getting the facts straight, not daring interpretations.[48]

Although many other studies of Renaissance science and technology by Spanish historians could be included in this review, there is enough here

to advance a handful of generalizations.[49] It is clear that López Piñero's *Ciencia y técnica* had a considerable impact in shaping a particular research agenda and epistemological style.[50] In most Spanish studies, a premium is put on erudition and on meticulous reconstruction of past events through painstaking sifting of texts and archival research. Authors shy away from grand interpretations. The sixteenth century is particularly well regarded, because most authors seek to present Spain as European, partaking of larger continental intellectual movements. By the same token, the seventeenth century is something of an embarrassment for most authors, for at this time Spain allegedly withdrew and went into a spiral of intellectual isolation and decline. It is not that Spanish historians of science ignore the seventeenth century. On the contrary, they are always looking for evidence of innovation and revival. Navarro Brotóns, for example, has sought to reconstruct some aspects of the history of physics and mathematics during Spain's age of "decline" by examining the history of the Colegio Imperial (Imperial College), a court institution led by the Jesuits, that most cosmopolitan of religious orders.[51] López-Piñero, as noted, also devoted one entire section of his *Ciencia y técnica* to the science of the seventeenth century. His interests, however, are narrowly limited to identifying those who brought Spain back onto the modern path by embracing the new mechanical philosophy. The issue is that by looking only for traces of modernity in the Spanish polity, these scholars ignore all other aspects of the practice of natural philosophy in early modern Spain. The allegorical and emblematic sciences of the baroque that flourished in the seventeenth century have been forgotten, for example, cast aside as a shameful chapter in Spanish history (on this tradition, see chapters 3 and 4 below).

There is a clear teleological thrust to the scholarship I am reviewing: the disciplines and practices explored are those that can be linked to the genealogy of European modernity. Let me be clear: Spanish scholars are perfectly aware that most modern disciplines looked rather different in the Renaissance; there were no chemists but alchemists, no physicists but astrologers, no biologists but collectors of cabinets of natural history and curiosities. But for all their historicist sensibilities, most Spanish historians of science seem overly concerned with identifying the pioneers of modernity. Moreover, for all their emphasis on placing Spain firmly within wider European traditions, they have little to say on Portugal. This is surprising, given the fact that Renaissance science in Spain was deeply influenced by fifteenth- and sixteenth-century Portuguese traditions in cosmography, astronomy, and navigation.[52] More important, from Philip II to Phillip IV,

the empire was as much Portuguese as it was Spanish. But despite their emphasis on exploring the intellectual genealogies of the modern nation, Spanish historians of Renaissance science and technology have long been interested in understanding developments in colonial Spanish America.

López Piñero, again, has been instrumental in cultivating this Atlantic sensibility. He and his Valencian colleagues have made great strides in understanding the process by which botanical and pharmaceutical knowledge collected by Spain in the New World spread to the rest of Europe.[53] Valencians have been particularly interested in reconstructing how the work of the naturalist Francisco Hernández moved around Europe. A typical humanist, steeped in classical learning, who befriended such luminaries as Benito Arias Montano (1527–98) and Francisco Valles (1524–92), Hernández went well beyond Philip II's request for exotic plants for the royal pharmacy and put together a mammoth natural history of New Spain that took seven years to complete (1571–77) and included descriptions of some 3,000 new species of plants (compared to some 350 inventoried by Theophrastus and 500 by Dioscorides).

Scholars had long assumed that Hernández's work reached other Europeans only through Juan Eusebio Nieremberg's *Historia naturae, maximae peregrine* (1635) and the Academy of the Lynx's *Rerum medicarum Novae Hispaniae thesaurus* (1651). But López Piñero and his Valencian colleagues have demonstrated that many copies of different sections of Hernández's manuscript had long been circulating in Mexico, Spain, Holland, and Britain. Pieces of Hernández's labor surfaced in works by Gregorio López (ca. 1583; published 1678), Juan Barrios (1607), Francisco Ximénez (1615), Johannes de Laet (1625, 1630, 1633), Georg Margraf (1648), Robert Lovell (1659), Henry Stubbe (1662), Hans Sloane (1707–25), James Newton (1752), and James Petiver (1715). We also know now that some of the original illustrations of Hernández's natural history survived in such manuscripts as the Codex Pomar.[54]

Two handsome volumes on Hernández published by Stanford University Press, *Searching for the Secrets of Nature* (2000; ed. Varey et al.) and *The Mexican Treasury* (2001; ed. Varey), go a long way toward making this new Spanish scholarship available to English-speaking audiences. *The Mexican Treasury* offers readers a thoughtful selection of some of Hernández's writings. It includes pieces drawn from his extant manuscripts, as well as selections from several of the authors who copied his writings in the course of the seventeenth and eighteenth centuries. Although the selection privileges Hernández's natural history, it also includes a translation of his correspon-

dence with Philip II and Arias Montano, his will, his "Christian Doctrine" (a pedagogical poem he wrote while in Mexico summarizing the tenets of Catholic theology), and excerpts from his treatise on Mexican antiquities. Although these selections clearly encourage contextual readings of his work, they do not go far enough. We know, for example, that Hernández translated and glossed Aristotle, Pliny the Elder, and Pseudo-Dionysius. He also wrote essays on Stoic philosophy. Samples of these writings should have been included as well.

The accompanying volume, *Searching for the Secrets of Nature*, seeks to put Hernández in his appropriate historical context. There are a few essays in this collection that are particularly insightful. Peter O'Malley Pierson presents Philip II not as an obscurantist monarch but as a patron of natural philosophers whose generosity was always limited by a bankrupt treasury. Rafael Chabrán locates Hernández in the philological and experimental traditions of Spanish humanism that thrived at the universities of Alcalá de Henares and Valencia. Hernández found in Nahuatl etymologies and taxonomies an alternative to the botanical classifications of Dioscorides. He also sought to confirm the medical virtues of plants through clinical trials. Guenter B. Risse offers an enlightening study of sixteenth-century Mexican hospitals, where local shamans introduced Hernández to Nahuatl botanical knowledge, and where Hernández did his clinical research. Essays by López Piñero and Pardo Tomás and by Rafael Chabrán and Simon Varey painstakingly reconstruct the history of the dissemination of Hernández's manuscripts in Mexico, Spain, Britain, and the Netherlands. Jaime Vilchis highlights the importance of understanding Hernández's Neoplatonic and Stoic writings to comprehend why he went to Mexico in the first place. Hernández still remains a poorly understood figure. Yet these two books have contributed to lifting the fog enveloping his life and work. The contribution in *Searching for the Secrets of Nature* that truly breaks new ground is that by María José López Terrada, who studies the incorporation of new plants of the Indies into the repertoire of Golden Age painting. López Terrada demonstrates the awareness of Spanish painters of the botanical novelties introduced to the Iberian Peninsula by the writings of Nicolás Monardes and Hernández; more important, his article points to the impact that New World flowers and plants had on the early modern garden.

The history of Spanish gardens cannot be overlooked in a review of the literature on early modern Spanish science. The Renaissance garden expressed the values and aspirations of natural philosophers. Like the medieval gardens of courts and cloisters, early modern gardens sought to re-create paradise.

Fountains in Catholic cloisters stood for the blood of Christ, the giver of life; the enclosing walls symbolized the virginity of Mary and the spiritual purity of the Church; flowers represented virtues, and weeds, vices.[55] Humanism added pagan and utilitarian dimensions to the mix. In the fifteenth and sixteenth centuries, the medieval garden, a locus of contemplation and amorous courtship, was transformed into a space that promoted mastery and dominion over territory.[56] It also became a place to store and reproduce encyclopedic knowledge (particularly in the botanical garden);[57] to reproduce the geometrical Neoplatonic structure of the cosmos;[58] and to build patriotic replicas of local landscapes.[59] Visitors, like epic heroes, stepped into mazes and labyrinths on voyages of philosophical discovery.[60] Marble sculptures, topiary work, grottos, and loggias helped these voyagers find their cues along the way. The study of Renaissance and mannerist Italian, French, English, and Netherlandish gardens as microcosms of early modern knowledge is a well-established field. Yet, typically, scholars have paid little attention to developments in Spain.

Carmen Añón Feliú has long been seeking to correct this oversight.[61] *Jardín y naturaleza en el reinado de Felipe II* (Garden and Nature in the Reign of Philip II), a book she edited in 1998 along with José Luis Sancho, demonstrates, in case there was any doubt, that sixteenth-century Spain was part of the much larger culture of the European Renaissance, and that many gardens, old (Arabic) and new, flourished under the leadership of Philip II: in the Reales Alcázares of Seville, the Alhambra, the Royal Garden of Valencia, the Casa de Campo, El Pardo, Aranjuez, Vaciamadrid, Valsaín, Escorial, La Fresnada, El Quexigal, and the *dehesas* of Campillo and Monasterio. Like their English, Italian, and French peers, Spanish scholars imagined and created philosophical gardens and embarked on the construction of allegorical and emblematic landscapes. More important from the perspective of this review, natural philosophers used the garden to encapsulate the new encyclopedic knowledge arriving from the Indies. Gardens were part of the larger set of institutions and practices put in place to master the botanical resources of the Indies.

This newfound interest in the role of botany in the history of early modern Spanish science and culture is part of a larger discursive pattern in Spanish scholarship. In *La conquista de la naturaleza Americana* (1993), Raquel Alvarez Peláez explores many of the same authors and developments that captured the attention of López Piñero and his Valencian colleagues throughout the 1990s. Like them, Alvarez Peláez seeks to understand the Spanish contributions to early modern European botanical and medical

knowledge, but she brings in new sources to the discussion, namely, the hundreds of documents from the Spanish American colonies sent to answer the "geographical" questionnaires ordered by Philip II in 1577 and 1584. These so-called *relaciones geográficas* have long attracted the attention of historians and ethnohistorians, for they contain useful information on the social, cultural, and economic history of dozens of regions in the Americas. Cities, towns, and pueblos across the continent scrambled to reply to the queries by submitting maps, narrative histories, and detailed descriptions of local natural resources. Alvarez Peláez studies some fourteen volumes' worth of replies from Mexico alone for evidence of contemporary understanding and mastery of natural history. The conclusions she reaches are not particularly surprising: Spanish authorities all over the continent duly replied to the metropolitan queries by imposing European categories on local resources, while thoroughly relying on local informants and knowledge.

Also not surprising is what moved Alvarez Peláez to write this lengthy study. Throughout, she seeks to prove that the charges leveled against Spain by Antonello Gerbi in his celebrated study *La natura delle Indie nove: da Christoforo Colombo a Gonzalo Fernández de Oviedo* (1975) are wrong, for Gerbi had argued that, compared to the Italians in the sixteenth century, Spanish naturalists in the Americas clearly lacked descriptive and analytical powers. According to Gerbi, Fernández de Oviedo was the exception, largely because he had been trained in Italy. Alvarez Peláez rejects this characterization.[62] Like her peers in the seventeenth and eighteenth centuries, Alvarez Peláez takes up her pen to battle foreign innuendos. Claims to objective detachment notwithstanding, patriotism remains a powerful motivating factor in modern Spanish scholarship.

Patriotism can engender creative and stimulating work. Alvarez Peláez's book, however, is not particularly illuminating. She uses the rich documentary cache of the *relaciones geográficas* to reconstruct some Mesoamerican indigenous medical and botanical categories, but without much anthropological imagination. For a more inspiring example of what can be done, the reader should peruse Barbara Mundy's *The Mapping of New Spain* (1996). Using the same sources, Mundy offers a dazzling study of the rise of hybrid conceptions of space and mapmaking in sixteenth-century Mexico.

Like Alvarez Peláez's book, José Sala Catalá's posthumous treatise *Ciencia y técnica en la metropolización de America* (1994) is a study of the history of Spanish science in colonial settings. Like Alvarez Peláez, Sala Catalá also has a patriotic agenda, namely, to demonstrate the scale, complexity, and sophistication of the Spanish sixteenth- and seventeenth-century

technologies that went into the building of the new cities of Mexico and Lima. The draining of the central valley of Mexico alone, Sala Catalá concludes, constituted "the most important piece of civil engineering of the Renaissance." Mexico, the author forcefully maintains, became "the most extraordinary laboratory of hydraulic experimentation [*experiencias*] in the world."[63] Readers who discount these assertions as mere patriotic nonsense do so at their own peril. Persuasively and ingeniously, Sala Catalá reconstructs the multitude of complex technologies involved in the Spanish urban settlement of America.[64] His long and beautifully illustrated account of the feats of hydraulic engineering required to drain the central valley of Mexico by cutting sluices through the massive mountains surrounding the valley is particularly illuminating. It shows among many other things the multinational character of the empire, for Flemish technicians first directed these works.

The chronic Spanish reliance on foreign technicians is a theme that runs through the British scholar David C. Goodman's *Power and Penury: Government, Technology and Science in Philip II's Spain* (1988).[65] This book is as comprehensive and synthetic as López Piñero's *Ciencia y técnica* and García Tapia's *Técnica y poder*. In fact, Goodman covers remarkably similar ground. *Power and Penury* describes in encyclopedic fashion developments in science and technology ranging from alchemy to cosmography, shipbuilding to artillery, metallurgy to navigation, and surgery and medicine to botany. Goodman discovers for himself something Spaniards had been saying for centuries: that Spain was intellectually part of Europe. Philip II was not a superstitious, ignorant tyrant but a monarch remarkably open to innovation in new experimental fields. His palace at El Escorial contained a large alchemical laboratory to produce medicinal waters by distillation, as well as the much-hoped-for transformation of base metals into gold and silver. Like other monarchs of his age, Philip believed in astrology and the occult, but he remained far more skeptical than many of his European colleagues. Although he sought to control and regulate the training of ships' pilots, gunners, physicians, and surgeons, and although the shadow of the state lurked behind most of the great technological and scientific developments of the age, there was great room in Spain for private initiative and entrepreneurship. Spaniards were no more adverse to science and technology than other European peoples. What ultimately kept many away from technical professions were low wages, not any innate aristocratic aversion to menial occupations. For all his goodwill, Philip II was always plagued by chronic fiscal deficits, unable to sustain long-term initiatives and support foreign technicians.

That all these points needed to be made by Goodman in 1988 is a testament to the power of the traditional narratives of the Scientific Revolution that located the roots of modernity in astronomy and physics, not natural history. The marginalization of the epistemic traditions first introduced by the early modern Iberian empires to the genealogies of modernity is also a testament to the power of the printing press. The early modern Spanish Crown held knowledge to be a state secret (*arcana imperii*), and it therefore circulated through manuscripts. It has taken historians many years, if not centuries, to unearth the evidence needed to upset the well-established narratives of the Black Legend of Spanish backwardness. These prejudices are still with us, blinding historians every day. New accounts of the Scientific Revolution by Steven Shapin (1996) and Peter Dear (2001) manage to exclude the Iberian empires as completely as Marie Boas and A. Rupert Hall once did. It is extraordinary that decades after the publication of José Antonio Maravall's *Antiguos y modernos* (Ancient and Moderns) and López Piñero's *Ciencia y técnica*, North Atlantic historians of early modern science and technology still can so easily elect not to study this literature. Fortunately, as demographic patterns in the United States change, the self-satisfying North Atlantic narratives of the origins of modernity are in for a rude awakening. It is just a matter of time before books in English on the Scientific Revolution begin adorning their dust jackets with the frontispiece of García de Céspedes's *Regimiento de navegación*, rather than that of Bacon's *Instauratio magna*.