# Iberian Science in the Renaissance: Ignored How Much Longer?

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*The contributions of Portuguese and Spanish sixteenth century science and technology in fields such as metallurgy, medicine, agriculture, surgery, meteorology, cosmography, cartography, navigation, military technology, and urban engineering, by and large, have been excluded in most accounts of the Scientific Revolution. I review several recent studies in English on sixteenth and seventeenth century natural history and natural philosophy to demonstrate how difficult it has become for Anglo-American scholarship to bring Iberia back into narratives on the origins of "modernity." The roots of this exclusion, to be sure, hark back to the Protestant Reformation and the Enlightenment. The oversight is unfortunate for it has blinded scholars to the fact that the Iberians first created a culture of empirical, experimental, and utilitarian knowledge-gathering of massive proportions that did not get its cues from the classics or the learned, but from merchants, enterprising settlers, and bureaucrats. The Portuguese and the Spanish confidently saw themselves as the first "moderns," superseding the ancients. The English were the first to recognize this fact and they sought to imitate the new institutions of knowledge-gathering created by the Iberians. I demonstrate, for example, the Iberian origins of many of Francis Bacon's epistemological insights and metaphors. Spanish and Portuguese scholars have long been making this point. I therefore introduce English-speaking audiences to some of the most recent scholarship by Spanish scholars on sixteenth century Iberian science and technology.*

Readers of this journal know well the frontispiece to Francis Bacon's *Instauratio Magna* (1620). The image shows a ship sailing through the columns of Hercules; it stands for the voyage of empirical and experimental discovery of nature's secrets on which Europeans embarked as soon as they left behind the authority of ancient texts [Fig 1].

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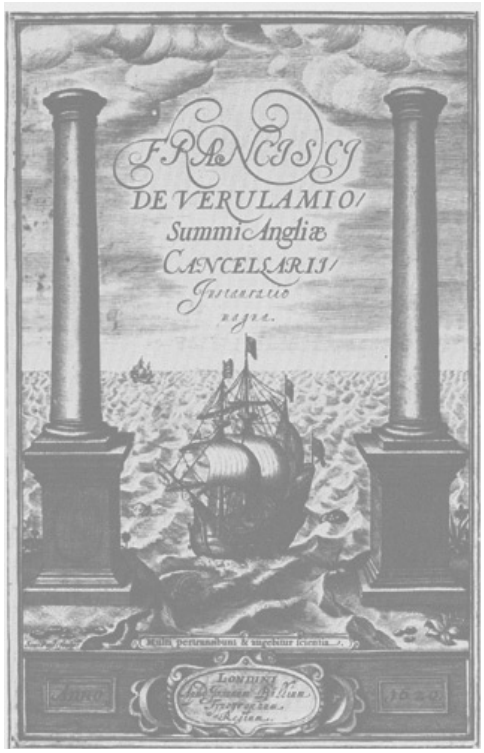


**Figure 1:** Frontispiece. Francis Bacon. *Instauratio Magna* (London, 1620)

Readers are also familiar with Jan van der Straet's introductory engraving to his *Nova Reperta* (ca. 1580), a collection of thirteen illustrations on key early-modern "discoveries." The engraving highlights the importance of new technologies such as the printing press, the clock, and the cannon [Fig 2].

Paradoxically, these two illustrations have come to be associated first with a "Protestant" and later with an "Enlightenment" narrative of modernity, which purposefully excludes 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, for example, Francis Bacon's motif of sailing through the columns of Hercules to signify the triumph of the moderns over the ancients. This motif was in fact a sixteenth century Spanish export. As José Antonio Maravall ([1966] 1986) persuasively argued nearly forty years ago, it


**Figure 2:** Philippe Galle (after Jan van der Straet) *Nova Reperta* (ca. 1580)

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 discovered that the Indian Ocean was not an inland sea as Ptolemy had long maintained and that an entire "new" world stood in the middle of the Atlantic. The discovery of a whole range of peoples from West and Central Africa to the Americas that had remained unknown to the ancients also became apparent. The new empires that the Portuguese and Spaniards put together, which encompassed peoples and bureaucracies on four different continents, were wonders of political engineering and military prowess that dwarfed anything Rome ever accomplished. No wonder that Charles V, when looking for motifs to capture the deeds of his new Holy Roman Empire, chose both the Golden Fleece to symbolize rightful providential rewards to chivalric valor and the columns of Hercules to signal the superiority of his age over that of the ancients.[1]

1. Charles V adopted the columnar "plus ultra" device in the 1510s to signal a break with medieval readings of Hercules that emphasized cautious (military) prudence ("non

Consciousness of pre-eminence of the moderns over the ancients had more than one manifestation in the Iberian Peninsula. Unlike their Italian peers, local humanists were not easily dazzled by the virtues of Latin and other classical languages and consciously set out to develop their own vernaculars. 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 escaped the purview of the ancients: new empirical breakthroughs in metallurgy (that allowed Spain to develop economies of scale in silver mining in the New World); new plants, diseases and cures; new forms of arranging armies and building fortifications; and new agricultural techniques (Maravall 1986, pp. 431–53, 483–549). Luis de Camões (1524–1580) and Alonso de Ercilla (1533–1594) wrote epic poems recording the extraordinary voyages and adventures of actual Argonauts, and confidently thought they were superseding Homer. While arguing that Vasco de Gama's deeds dwarfed Ulysses's, Camões asserted without raising a single eyebrow: "May the ancient Muse be silenced, for greater heroes have now surfaced" (*Cesse tudo o que a Musa antiga canta, Que outro valor mais alto se alevanta*) (Camões 1997, p. 20).[2] It was in this environment critical of the achievements of the ancients that the Royal Cosmographer Andrés García de Céspedes published in 1606 his *Regimiento de Navegación.* The frontispiece of this treatise is identical to that later used by Bacon in the *Instauratio Magna* (Fig 3).[3]

It is very likely that Bacon 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

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plus ultra"). The columns and the motto originally meant to signify Charles V's willingness to launch a crusade through North Africa by crossing Gibraltar. By the mid sixteenth century, however, the motto took on the meaning of daring trans-Atlantic imperial expansion. On this topic, see Rosenthal (1971 and 1973). Marie Tanner (1993) has argued that the Golden Fleece was part of classical and medieval discourses to legitimate emperors that first began with Virgil's *Aeneid* and *Fourth Eclogue* (to honor Augustus). The motif was Christianized under Constantine, Clovis, and Charlemagne. In medieval epics the Fleece came to stand for the recovery of Jerusalem from Islam.

2. Alonso de Ercilla y Zúñiga's *La Araucana* came out in three parts in 1577, 1578, and 1589 respectively. David Quint has written a remarkable study (1993) that locates Camoes's and Ercilla's poems within the classical epic tradition of Virgil's *Aeneid* and Lucan's *Pharsalia.* Quint, however, overlooks the self-confident modernity of the sixteenth century Iberians as a critical configuring factor of their poetry.

3. To my knowledge, Juan Pimentel has been the first to call attention to the similarities (and differences) between these two frontispieces (2000).


**Figure 3:** Frontispiece, Andrés García de Céspedes, *Regimiento de Navegación* (Madrid, 1606)

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 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 a jealous Richard Hakluyt put it in his *Principal Navigations of the English Nation* (1599), the Spaniards were far ahead of the English in the colonization of the New

World largely because the former enjoyed "those bright lampes of learning (I mean the most ancient and best Philosophers, Historiographers and Geographers) to showe them light" as well as "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 (1523–1574), and Rodrigo Zamorano (b. ca,. 1545) as exemplary (Hakluyt 1599, 1:*3r-v and 4v).[4]

It is therefore not preposterous to think that Bacon might have the Spanish empire in mind when he wrote his *New Atlantis* (1624, published posthumously in 1627). A 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 island on which the local nobility has instituted a chivalric order, the House of Solomon. 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, massive, mechanical exploitation and reproduction of all natural resources and phenomena (Bacon 1627). 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 might have had Spanish imperial institutions of knowledge in mind when he wrote the book. As Antonio Barrera has elegantly shown (Barrera 1999, 2002), the Spaniards created throughout the sixteenth century a culture of empirical, experimental, and utilitarian knowledge-gathering of massive proportions that did not get its cues from the classics or the learned but from merchants, enterprising settlers, and bureaucrats.

Settlers and merchants were always on the lookout for new natural resources to sell, constantly hyping the economic windfall that would accrue to those capable of exploiting the various new mineral, pharmaceutical, and agricultural resources found in the Indies. They also sought to

4. Hakluyt most likely was referring to Alonso de Chaves's "Quatri partitu en cosmogarphia practica, y por otro nombre, Espejo de navegantes" (unpublished Ms written in the 1530s but that circulated widely); Jerónimo de Chaves's translation of Johannes Sacro Bosco's *Sphera mundis, Tractado de la sphera* (Seville, 1545); one of the multiple editions of Chaves's *Chronographia* (1548, 1561, 1566, 1572, 1581, 1584); and Rodrigo Zamorano's *Compendio del Arte de Navegar* (Seville, 1581), *Cronología y repertorio de la razón de los tiempos* (Seville, 1594), and *Los seis libros de geometría de Euclides* (Salamanca, 1576). Surprisingly Hakluyt does not mention Pedro de Medina's *Arte de Navegar* (Valladolid, 1545) and *Regimiento de Navegación* (Seville, 1563) that were translated and reprinted several times in England.

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 pilots and assembling credible maps was one function of this new institution; another was to apportion credit to contradictory reports. The crown also standardized questionnaires and launched massive campaigns of data gathering. Finally, the mechanical transformation of landscape undertook by engineers in the pay of the Spanish empire in Potosi and the central Valley of Mexico were as extraordinary as those dreamed up by the knight of the House of Solomon, including the creation of artificial lakes and rivers to power mills to crush silver ores and the cutting of sluices through massive mountains to drain the city of Mexico (on this, see below). Just like Hakluyt, Bacon seemed to have been well informed of the new Spanish institutions and practices.[5]

There is however 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 chivalry. A quick glance at the sixteenth century Iberian treatises of cosmography admired so much by the English shows that the Iberians saw knowledge gathering as an expansion of chivalric virtues. The royal cosmographer Pedro de Medina, in the pages of his much acclaimed and widely influential *Arte de navegar* (1545), insisted that pilots were new knights whose sword and shield were the compass, the chart, the cross-staff and the astrolabe just as their horses were ships (Goodman 1988, pp. 72–3). This trope lay behind the appear-

5. In face of all the criticism of the cruelty of the Spanish conquest by the English, especially in the Elizabethan period, it would appear counterintuitive to claim that Bacon could have considered the Spanish colonies a model. But precisely at the time that Bacon was writing his *New Atlantis,* the Virginia Company held up the Spanish colonies as an example to follow in every single respect. Having faced the loss of one third of the settlers of Virginia to a rebellion of Tidewater indigenous peoples, the official spokesman of the company, Edward Waterhouse, argued that the massacre occurred only because the English had failed to follow in the footsteps of Spain. The English, he argued, needed to learn from the likes of Cortes and Pizarro to do things right. The natives of Virginia had to be conquered and enslaved and their leaders manipulated to fight with one another to be weakened. Moreover Waterhouse praised the Spanish colonies of what "industry, patience and constancy" can accomplish. Arguing against the grain of what are now centuries of accumulated wisdom about Spanish colonialism, Waterhouse claimed that to succeed in the New World the English had to learn from the Spaniards to stop looking for treasure and turn to the production of agricultural staples and export commodities (Waterhouse 1622: 30, 32–33).

ance of astrolabes and coats of arms in such classics of the Portuguese expansion to Africa and Asia as the *Ordenaçôes manuelinas* (1521) (in fact the armillary sphere and the cross of Saint George are the chief elements of Portugal's coat of arms) (Fig 4) and the appearance of the motto "*a la espada y el compás, más, más y más*" ("to the sword and the compass, more, more and more [imperial territorial expansion]") adorning the frontispiece of Bernardo de Vargas Machuca's *Milicia y descripción de las Indias* (Madrid, 1599) (Fig 5). Bacon's New Atlantis with its chivalric order of the House of Solomon resembles in every respect the institutions and values created by the Iberian powers (Spain and Portugal alike) to gather knowledge for utilitarian purposes.

Jan van der Straet's *Nova Reperta* indicates that awareness of the role of Iberians in a dawning modernity was not limited to jealous English imperial competitors. The Dutch Jan van der Straet was in fact an engraver and painter whose career developed in Italy and who went by the Latinate name of Johannes Stradanus (Baroni Vannucci 1997). Since his patrons were Roman, Florentine, and Genoese clerics and merchants, Stradanus highlighted in the opening engraving of his *Nova Reperta* the contributions to the discovery of America and to the development of the compass of Christopher Columbus, Americus Vespucci, and Flavius Amalfiti, respectively (Fig 2). Yet Stradanus's catalogue of nine remarkable new discoveries includes at least three that any of his contemporaries would have immediately granted to the Iberians: namely, the sighting of new constellations in the southern hemisphere (the Southern Cross),[6] the introduction of new remedies (the bark of the guaiacum tree), and the discovery of new lands (America). There are others in this picture that contemporaries could not have separated from a history of the Portuguese and Spanish expansions, such as the development of new cash crops (silk) and of new military technologies (the cannon).

Stradanus's *Nova Reperta* and Bacon's *Instarautio Magna* and *New Atlantis* demonstrate the importance of Iberia to any narrative of the so-called "Scientific Revolution." Yet this term has strangely become synonymous with understanding developments in nonwestern Europe and the North Atlantic. When the first histories of the "Scientific Revolution" by A. Rupert Hall (1954), Marie Boas (1962), and Richard Westfall (1971) began to appear in Britain and the USA beginning in the 1950s, they found no room to accommodate Iberia at all. Such forgetfulness is at the core of most "Western" meta-narratives of the genesis of modernity since the eighteenth century. The roots of such provincialism, to be sure, lie deep in Protestant and, later, Enlightenment ideologies. Some one

6. On the "discovery" of the New World as the discovery of new stars and constellations, see (Cañizares-Esguerra 1999).


**Figure 4:** Frontispiece, *Ordenações manuelinas* (Lisbon, 1521)

hundred and fifty years after Bacon borrowed from García de Céspedes the tropes and motifs to depict the arrival of modernity, Zacharie de Pazzi de Bonneville, also known as *philosophe La Douceur,* concluded in 1771 that "there is no nation more brutish [*abruti*], ignorant, savage, and barbarous than Spain"(Pazzi Bonneville 1771, p. 61). In 1777 Joseph La Porte concluded in his *Le voyageur françois* (1766 –1795) 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 (La Porte 1968–1795, 16:94). Finally, in 1781 the Abbé Raynal maintained in his *Histoire philosophique des deux Indes* that, "never has a nation been as enslaved to its prejudices as


**Figure 5:** Bernardo de Vargas Machuca's *Milicia y descripción de las Indias* (Madrid 1599)

Spain. In no other place irrationality {*le déraison*} has proven as dogmatic, as close, and as subtle"(Tietz 1991, p. 100). 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. "Decline" not only hardened perceptions; criticism now came wrapped in the idioms of progress and the Iberians were cast as essentially non-Europeans: backward and ignorant (Hillgarth 2000; Juderías 1943; García Carcel 1981; Maltby 1971; Schmidt 2001). By 1721 Montesquieu could maintain in the pages of *Lettres Persanes,* without being challenged, that Spaniards were only good at writing chivalric romance and dogmatic scholastic treatises (Montesquieu 1971,

p. 115). Not surprisingly, all meta-narratives of modernity and progress that came of age in the eighteenth century have found no place for the technological and philosophical contributions of the Iberians in the early modern period.

This tendency to neglect the contributions of the Spanish sixteenth century to natural philosophy can be observed in the recent new translation into English of José de Acosta's *Natural and Moral History of the Indies* published by Duke University Press (J. Acosta [1590] 2002). For all its merit, 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, José de Acosta summed up the spirit of his *Historia Natural y Moral de las Indias,* for the celebrated Jesuit was interested in both explaining the conquest as a preordained Providential event and 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 Acosta was not simply a Christian philosopher. As the citation above 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.

The views of Acosta 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* might have served Elizabethan audiences well, but today it sounds stodgy and distant. Fortunately students can now turn to Frances López-Morillas' crisp new rendition.

This new translation forms part of a much larger editorial effort that also includes an annotated edition by Jane E. Mangan, an Andeanist, and a study by Walter D. Mignolo, a literary critic. Both the annotations and

the study help put Acosta in a larger cultural and ideological context. But Mangan and Mignolo's approach to Acosta betrays a bias that is typical of most contemporary scholarship.

In 1604 Grimeston and his Tudor and Stuart audiences considered Acosta to be a great natural philosopher, not only a keen observer of things Amerindian. 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 answers on the nature of the stars and heavens in Americas but to reconstruct the lives of Amerindians 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 instead of scorching heat enjoys temperate climate year round; 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 the otherwise marvelous book by Lorraine Daston and Katherine Park, *Wonders and the Order of Nature 1150–1750.* After passing and superficial references to Nicolás Monardes and one Ferrando de Oviedo (actually Fernández de Oviedo) (pp. 146–9), Daston and Park completely overlook the Spanish literature on New World's wonders, including, say, Juan de Cárdenas's path breaking *Problemas y Secretos Maravillosos de las Indias,* published in Mexico in 1591, and the massive seventeenth century natural history of marvels by the Jesuit Juan Eusebio Nieremberg, *Historia natvrae, maxime peregrinae* (1635), the capstone of this tradition (see also Nieremberg 1643 and 1645). 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, largely responsible for the idolatrous religious practices of the colonized natives (MacCormack 1991; Cervantes 1994, pp. 24–31), Acosta was nevertheless not willing to cede the realm of the natural and the marvelous in the New World to the devil. His *Natural History* constantly seeks to frame seeming inversion of physical laws in the Indies, puzzling natural phenomena, within a discourse of providential design and lawful regularities. By so doing, Acosta sought to steer early-modern

European perceptions of the New World's Nature away from the realm of the preternatural and thus the demonic (Clark 1997, esp. part II). This is all the more remarkable because Acosta was a firm believer in the forthcoming arrival of the apocalypse, a fact that goes completely unnoticed by Mangan and Mignolo. One of Acosta's works (*De temporibus novissimis libri quatuor,* originally published in Rome in 1590) sought to prove, among other things, that the multiplication of witchcraft, demonic possessions, prodigies, and the preternatural in early-modern Europe were all signs of the devil unleashed on the eve of the apocalypse as suggested in the Bible (J. Acosta 1592).

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 in the vibrant new field of the history of botany, natural history, and empire there is little room for considering how Portugal and Spain set long-term European patterns. Take for example the recent account on the rise of the modern botanical garden, *Nature's Government,* by Richard Drayton (Drayton 2000). Drayton offers a dazzling, brilliant story 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 (on this topic see also Prest 1981). 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 overseas the plants they needed. 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), however, does not pay sufficient attention to developments in sixteenth century Portugal and Spain, for early-modern botany was as rooted in the humanist culture of the medical facul-

ties of Padua, Leyden, and Montepellier as in the entrepreneurial, utilitarian efforts of apothecaries in gardens and hospitals in Seville, Lisbon, Goa, and New Spain. From its inception botany served the need of transnational merchant capital. Take for example the case of Carolus Clusius, whom Drayton refers as "the Copernicus who shattered the Hellenocentricsm of Renaissance botany" (p. 13). The dean of early modern botany and the founder of the gardens of Vienna and Leyden, 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 Orta, and Cristobal Acosta. These, however, were all works single-mindedly focused on the potential commercial value of new- found botanical staples, with little use for speculative philosophy (Monardes 1565–1569; Orta 1563; C. Acosta 1578). Clusius inherited from these Portuguese and Spanish treatises, and from his travels through the various botanical gardens of Portugal and Spain, a keen eye for the utilitarian, commercial value of exotic commodities (Clusius 1567, 1574, 1576).[7] Thus Clusius' additional notes to Orta's short treatise on South East Asian aromatic and pharmaceutical plants also included references to potentially profitable exotica collected by Francis Drake in his recent circumnavigation (Clusius 1582). Clusius's translation into Latin of Thomas Harriot's description of Virginia for Theodore de Bry is not a simple rendition. It includes long lists of goods used by the local inhabitants as well as botanical staples with potential commercial value (Clusius 1591).

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 a natural history of herbals, Hernandez spent seven years in Mexico (1571–1577) experimenting in hospitals for natives established by the Spanish clergy, and interviewing Nahua intellectuals versed in Latin. Upon his return, he had assembled 11 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, how-

7. In Clusius's *Rariorum aliquot stirpium per Hispanias* (Clusius 1576) he repeatedly cites botanical gardens he visited or friends from whose botanical gardens he obtained samples. The network was vast, including contacts with gardens in Belgium, France, Austria, Italy, and England. Among the botanical gardens in Portugal and Spain he visited are the following: the monastery of "Divae Virginis" in the outskirts of Valencia (pp. 16, 444); Ferdinand Cotinho's, a Portuguese gentleman (pp. 131, 280); Johannes Plaza's, a "most learned" physician in Valencia (pp. 254, 289, 444, 479); the royal palace in Lisbon (p. 299); and Pedro Alemán's (p. 444).

ever, felt the work 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. As Recchi complied, Philip II passed away. Neither Recchi's anthology nor Hernández's massive natural history were ever made available by the crown, which at the time was seeking to shut down all publications on the Indies in an effort not to allow rival powers to gain 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 *Academia dei Lincei.*

The history of the Academy of the Lynx and of the publication of Recchi's manuscript has recently being told by David Freedberg in *The Eye of the Lynx,* a most learned and lavishly illustrated book (Freedberg 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, 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. By 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 Rechhi's nephew, one Marco Antonio Petilio, had kept the doctor's manuscripts, they pounced at the opportunity. Over the course of some forty years Johannes Schreck, Johannes Faber, Fabio Colonna, Francesco Stelluti, and Federico Cessi, at different times, 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* (Hernández 1651)

A quick glance at the frontispiece (Fig. 6) demonstrates the utilitarian emphasis of the whole enterprise: scantily clad natives offer Philip IV (represented through his coat of arms) the botanical riches of Mexico. These riches (pace Drayton) are medicinal, ornamental, and agricultural, all at once. Viewers, in the meantime, are invited to cross through the doorway and step 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 coat of arms in a frontispiece originally designed in 1628, when Portugal was still part of the Spanish empire. The serpents and eagles below the Portuguese coat of arms 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

**Figure 6:** Frontispiece. Hernandez's *Rerum Medicarum Novae Hispaniae Thesaurus* (Rome, 1651)

Spanish monarchy (Dandelet 2001). 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, twisted 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 perfumist (*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."[8] Johannes Schreck (a.k.a.

8. "Si Herbariae, si naturali Historiae addictus: si Medicus, si Philologus, si denique Phytosophus: si Florilegus Principium, aut Heroinorum blandiris deliciis: vel si novis e

Johannes Terrentius), charged with adding glosses and commentary to Recchi's original manuscript, defends on pragmatic, commercial grounds Recchi's decision to follow Theophrastus and Dioscorides. 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 while we discover new lands and ultimately engage in commerce.[9]

For all his enormous contribution, Freedberg excludes Iberia from his history of the Academy and particularly from the history of the publication of Recchi's manuscript. In Freedberg's narrative Spain appears as an obstacle. Thus Freedberg presents Hernández as incompetent, barely capable of organizing the material he collected (p. 247). Ricchi appears as a physician cowered into silence by the Spanish king, fearful of sharing with others the fruits of his labors (p. 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 it, nor does he make much of the fact that Rome and Naples were at the time cultural satellites of Spain (Dandelet 2001). Yet the very evidence Freedberg presents shows that Spain was a willing participant throughout the many years it took the Academy to bring the book to light. Linceans like Johannes Heckius (p. 253) and Cassiano dal Pozzo (p. 262) repeatedly had access to Hernández's manuscripts and illustrations at El Escorial. Moreover, when Cassiano visited Madrid in 1626 he obtained as a present for the pope the *Codex Badianus,* an illustrated herbal written in Latin in 1552 by two Nahua intellectuals, Juan Badiano and Martín de la Cruz (De La Cruz and Badiano 1940).[10] More important, Freedberg unwittingly shows that the academicians received help at every turn from

fructibus, aut Pharmacis Mercator, Institor, Pharmacopola, Odorarius, sanitatem, oblectamenta quaeris, aut lucrum, novas hic certe habes Rerurm, Imaginum, Vocabulorum Myriades, quae & oculos, & mentem, &desiderium omni ex parte explere possint." (Hernandez 1651, Iacobus Mascardus Typographus Lectoris, n.p.).

9. "Ne dicam quicquam de ingentibus illis arborum trabibus, quibus domicilia nobis paramus, quo tutiores a ferarum incursionibus, & tempestatum inundationibus persistamus, & naves aedificamus, quibus nos nostraq. committentes audacissimi hominess turbulentissimo, & minacissimo oceano fidimus ignotas Terras, ignotaq hominum commercia exquirimus. (Hernandez 1651, Liber Tertius. Arbores describit, p. 44).

10. Freedberg misidentifies De la Cruz as Juan. He also presents Badiano as a humble "Indian" given to self-deprecating remarks, compounding the image of exploited Indians and haughty Spaniards. Clearly Freedberg is unaware of the rhetorical and cultural conventions of classical Nahuatl (pp. 263–64). The Codex, originally entitled *Libellus de medicinalibus Indorum herbis,* resembles in many ways than one the images and text in Hernández's original manuscript, clearly showing that Hernández's was a collective work in which Nahua intellectuals played a central role.

learned Spanish or Creole clerics living in Rome who repeatedly provided Linceans with animals, plants, documents, and much needed interpretations (pp. 261, 265).[11] 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 whose origin goes back to the Protestant Reformation and the Enlightenment. Ever since the publication of Nicolas Antonio's *Bibliotheca hispana vetus* and *Bibliotheca hispana nova* in 1696, Spanish intellectuals compiled massive bio-bibliographies to demonstrate the remarkable intellectual success of the Spaniards since the Romans. These patriotic compilations multiplied in the eighteenth and nineteenth centuries, particularly those on six-

11. The commentaries by Johannes Faber on some of Hernandez's illustrations of animals, one of the longest sections of the *Rerum Medicarum Novae Hispaniae Thesaurus,* appended under the title *Aliorum Novae Hispaniae Animalium Nardi Antonii Recchi Imagines et nomina. Ioannis Fabri lyncei Bambergensis Philosophi, Medici, publici Professoris Romani, & Summo pontifici ab herbariis studiis Expositione* (Hernandez 1651, pp. 457–840), relies utterly on information Faber obtained in Rome and Naples from several Spanish and Spanish American intellectuals. Among those Faber relies on the most is: Gregorio de Bolivar, a Spanish Franciscan who spent twenty five years in the most faraway places in Peru and Mexico as well as additional years in the East Indies, very learned in three indigenous languages. Throughout Faber copies verbatim page after page of Bolivar's unpublished treatise on the natural history of the New World: "Et ecce, dum sic haeremus, commodum ipsum salutatum advenit Reverendus admodum pater F. Gregorius de Bolivar Hispanus Placentinus, Ordinis S. Francisci de observantia dicti, qui annos XXV integros in America vixit, Regnum utrumque Peruavum & Mexicanum, plurimasque adhuc incognitas aliis, nec descriptas novi orbis provincias peragravit, verbo & exemplo infideli illi populi (cuius tres diversas linguas optime callet) Christi Evangelium annunciando, & ad veram ac Catholicicam fidem illum inducendo: cuius reii gratia ad Molucanas quoque Insulas & Orientem ipsum penetravit" (p. 506); Bernardino de Cordoba, a grandee addicted to the study of nature who assembled a collection of exotic things and animals from the Indies in Naples: "Accessi statim hic Neapoli D. Bernardinum de Corduba, virum, ut antiqua Nobilitate clarum, ita Musis amoenioribus, & naturalium studiis rerum addictissimum, qui ob id plurimas tam bestias exoticas, quam res Indicas alias adseruat" (p. 550); Pedro de Aloaysa, a Dominican born in Lima representing the American interests of his order in Rome and who in long, friendly conversations educated Faber on all things American: "Est autem vir hic doctissimus, Ordinis S. Dominici sodalis, in America & quidem in principalissima Peruani regni civitate Limana natus, qui adfectum etiam librum habet de Americanis sui ordinis negotiis, praelo propediem committen dam. Huius amicissima confabulatione, cum saepe hic Romae de Americanis rebus colloqueremur, mirabiliter fui recreatus" (p. 695); and Bartolomé dela Ygarza, a Spanish Dominican, who lived in America for seven years whose knowledge of American animals and plants he transmitted to Faber most willingly "Huius, uti & plurium aliorum animalium, atque plantarum Americanarum . . . descriptions mihi lubens communicavit Reverendus admodum P. Fr. Bartholomaeus dela Ygarza Hispannus, ex Ordine S. Dominici, qui septennis in Americam delatus" (p. 743).

teenth- and early seventeenth century authors and texts. It was a Valencian scholar, Gregorio Mayans y Siscar, who in the eighteenth century first catalogued the achievements of early-modern Spanish arts and science. With the help of German and Dutch printers, Mayans y Siscar invented a new period in Spanish history, namely the "Golden Age" (Mestre 1990, pp. 53–81; Lopez 1979). These efforts, unfortunately, led nowhere. They were consumed within Spain and deployed to bolster various patriotic agendas. The Spanish Golden Age today elicits images of Velásquez and Lope de Vega among the public. We associate early-modern Spain with painters and poets, not metallurgists and astronomers.

Efforts to weave Iberia back into narratives of the rise of modern science and technology have continued. As in the past, unfortunately, these efforts are mostly overlooked. In the following pages I review some of these recent efforts.

*Ciencia y técnica en la sociedad española de los siglos XVI y XVII* (1979) by José María López Piñero is perhaps the most significant and influential book in the history of early-modern Spanish science and technology to appear in the last quarter of the twentieth century. It is indeed 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 these practices took place and seeks to quantify these practices 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*) (on this see also Goodman 1992 and Romano 1992). Finally by looking at patterns of self-imposed cultural isolation on the part of universities and the crown, encouraged by dogmatic Inquisitorial practices, 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 those circles of 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, Crisóstomo Martínez, Juan de Cabriada, Joan d'Alós, Jaime Salvador, Juan Caramuel, Vicente Mut, José de Zaragoza, Tomás Vicente Tosca, Juan Bautista Corachán, and 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 mineralogists Ignaz von Born, *Über das Anquicken der Gold- und silbehaltigen Erze, Rohsteine, Schwarzkupfer und Hüttenspeise* (New Process of Amalgamation of Gold and Silver Ores, and other Metallic Mixtures). Beginning with Born it has been common to argue that the process of extracting silver from silver ores 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 first 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 first invented in the New World (with some debate as to whether in 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 ores* 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 ores. It was also an industrial process, it needed to be standardized and reproduced into economies of scale. Bartolomé de Medina achieved in 1555 the first successful trial in Pachuca, Mexico. Yet his procedures and formulas (they included crushing the ores and mixing them with salt, copper/iron sulfides, and mercury) did not travel well. They did not work in Spain (1555–1562) and 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 ores, discovered successful new formulas and techniques, trig-

gering a silver rush in the Andean highlands that in 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, México (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 ores);[12] and by Alvaro Alonso Barba (ca 1600) in Potosí (which improved the amount of silver recovered from the amalgam by introducing heat to the original combination of sulfites, mercury, and crushed ores).

In less than six pages (López Piñero 1979, pp. 259–265), López Piñero takes on well-established scholarly traditions and offers a comprehensive history of amalgamation in the New World.[13] 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 the metropolis. There are remarkable similarities between this case in the imperial periphery and the metallurgical experimentation in the iron-works of seventeenth century New England. William Newman has shown that the figures like George Starkey 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 (Newman 1994 and 2002).

There are some aspects of López Piñero's book that the above example on metallurgy should have made 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 overarching argument: interpretations abound but they are nestled within subsections and are pointed and limited. Finally, Spain is thought of in a wider Atlantic context. In his book, the New World occupies center stage.

But for all its claims to objectivity and scholarly detachment, the book, like the genre of bio-bibliographies initiated by Nicolas 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 a sixteenth century Spanish golden age of erudition and creativity in the sciences and technology. Like

12. The procedure, however, was banned because the crown captured a sizeable amount of the wealth produced in the mines by its monopoly of mercury.

13. There are, to be sure, more detailed studies of the history of amalgamation and other technological improvements in the silver mines of colonial Spanish America; see for example, Menes-Llaguno [1989]; Bargalló [1955]; Muro [1964]; and Bakewell [1977].

Mayans, he finds the hegemonic north Atlantic historiography on the Scientific Revolution oblivious, by and large, to Iberian contributions (López Piñero 1979, pp. 34–37). 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 (Masdeu 1783–1805), Francisco Xavier Lampillas (Lampillas 1782–1789), and Juan Andrés (Andrés 1784–1806) on ancient, medieval, and contemporary Spanish literatures, carried out to correct claims of the negative influence of Spanish bad taste in Italian literatures from Martial to Lope de Vega, López Piñero offers his reader a veritable encyclopedia.

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 published over the last four decades 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, in collaboration with Thomas Glick, Víctor Navarro Brotóns, and Eugenio Portela Marco, the invaluable two-volume *Diccionario histórico de la ciencia moderna en España* (Historical Dictionary of Early Modern Spanish Science) (1983).

Typical of this effort to publish primary sources is Lopez Piñero's edition of the beautiful *Codex Pomar* (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 watery herbal extracts every twenty-four hours. To keep his alchemical laboratories running, Philip had botanical gardens built 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 in his palaces birds and quadrupeds, including such exotica as a rhino (who albeit hornless and blind still commanded admiration). 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, once again, has made it possible for historians to have a

glimpse of 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 originally belonged to Philip II. Seeking to lure Jaume Honorat Pomar, 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 (Pomar 2000), Lopez 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; the contributions to natural history of the Nicolás Monardes and Francisco Hernández (more on this below). Surprisingly, there is precious little here on the codex itself. Although Lopez Piñero, with the erudition that has always characterized his work, locates each of the animals and plants in the illustrated codex within 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 enhance the prestige and ritual power of the king? The introduction also does not help us to understand how the Codex fits within sixteenth century European traditions of plant illustrations. Most plants in the Codex are shown at different stages in their natural cycle; 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 most 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 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 it García Tapia seeks to reconstruct a long forgotten chapter in the history of sixteenth century north-Castilian engineering of roads, bridges, canals, aqueducts, watermills, looms, iron-works, 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 striking technical innovations did not first take place in Italy or northwestern Europe. García Tapia, for example, locates several patents by northern-Castilian inventors of steam engines, diving gear, submarines, and water turbines. Finally, like López Piñero, García Tapia shies away from sweeping arguments or large interpretations; his goals are modest, and he simply seeks to add one brick to the edifice of knowledge.

This attention to erudition and epistemological positivism also permeates the work of Víctor Navarro Brotóns. A colleague of López Piñero, he 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 Copernicus in sixteenth century Spain. Typical of his approach and sensibility are his publications on the "Copernicans" Diego de Zúñiga (1536–1600) (Navarro Brotóns 1995) and Jerónimo Muñoz (Navarro Brotóns and Rodríguez Galdeano 1998)

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 a verse of the Book of Job (Job 9:6: "God moves the Earth from its place and makes its columns tremble") by the title of *Job commentaria.* In fact Zuñiga was not alone: Copernicus' *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 Zuñiga'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, Zuñiga 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 surfaces 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. As soon as he was made aware, however, that

heliocentrism did not conform to evidence from physical reality, he set out to write one of the first essays in Europe denouncing the theory as scientific non-sense, 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 pilots, in a context of relentless imperial expansion (Lamb 1995).[14] 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 (Navarro Brotóns, 1995).

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' mathematical model was particularly welcomed in sixteenth century Spain, yet Navarro Brotóns is not really looking for 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* is, in the same vein, a study of the life and works of another controversial Spanish scientific figure, the Valencian astronomer Jerónimo Muñoz (Navarro Brotóns 1998). Like Zúñiga, Muñoz was a humanist, so skillful at languages, particularly Hebrew, that there was some suspicion he was *converso.* 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). 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. His observations led him to challenge Aristotle's thesis of the incorruptibility of the heavens. Like Zúniga, 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* Navarro Brotóns also offers an

14. Building on Lamb's scholarship, Alison Sandman has recently offered a provocative interpretation of the reason why academies to train learned pilots found courtly support in sixteenth century Spain. A seamanship obsessed with locating latitudes and longitudes in maps was largely the result of competing Portuguese and Spanish imperial claims over Asian and American territories (Sandman 2002).

annotated edition (and a Spanish translation) of Muñoz's manuscript. Like López Piñero and García Tapia, Navarro Brotóns emphasizes getting the facts straight, not daring interpretations (Navarro Brótons and Enrique Rodríguez Galdeano 1998).

Although many other studies on Renaissance science and technology by Spanish historians could be included in this review, there is enough here to advance a handful of generalizations.[15] It is clear that López Piñero's *Ciencia y técnica* had a considerable impact in shaping a particular research agenda and epistemological style.[16] In most Spanish studies there is a premium 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 becomes 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 this 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 (Navarro Brotóns 1996). 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, for example, have been forgotten, cast aside as a shameful chapter in Spanish history.

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 as-

15. For a survey of recent scholarship, see the proceedings of the international congress on science and technology under Philip II (Martínez Ruiz 1999).

16. In 1996, a Spanish leading journal on the history of science and technology, *Arbor,* devoted the issue April-May (# 604–605, vol. CLII) solely to assessing the impact of López Piñero's *Ciencia y técnica.*

trologers, 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 (on these traditions, see Albuquerque [1991]; Seed [1995], pp. 107–116; Corteseão [1935]). More important, from Philip II to Phillip IV, the empire was as much Portuguese as it was Spanish. But despite their narrow 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 through which botanical and pharmaceutical knowledge collected by Spain in the New World spread to the rest of Europe (López Piñero and Calero 1992; Pardo Tomás and López Terrada 1993; Fresquet Febrer 1993; López Piñero and López Terrada 1997). Valencians have been particularly interested in reconstructing how the work of the naturalists Francisco Hernández moved around Europe. Hernández was a sixteenth century physician steeped in classical learning, who was sent by Philip II to the New World to study new exotic plants for the royal pharmacy. A typical humanist who befriended such luminaries as Benito Arias Montano and Francisco Valles, Hernández went well beyond Philip II's request and put together a mammoth natural history of New Spain that took seven years to complete (1570–77) and that 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), for in 1671, Hernández's eleven volumes of botanical illustrations burned in a great fire at the library of El Escorial. 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/ publ. 1678), Juan Barrios (1607), Francisco Ximénez (1615), Johannes de Laet (1625, 1630, 1633), Georg Margraf (1648) Robert Lovell (1659), Henry Stubbe (1662), Hans Sloane (1707–1725), 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 (Pomar 2000; López Piñero and Pardo Tomás 1994 a and 1994 b; Bustamante 1992, 1997, 1998).

The two handsome volumes on Hernández published in 2000 by Stanford University Press, *Searching for the Secrets of Nature* and *The Mexican Treasury,* 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 in the course of the seventeenth and eighteenth centuries copied his writings. Although the selection privileges Hernandez's natural history, it also includes a translation of his correspondence 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-Dionysus. 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 Hernandez carried out his clinical research. Essays by Lopez Piñeros and Pardo Tomás and by Rafael Chabrán and Simon Varey painstakingly reconstruct the history of the dissemination of Hernandez's manuscripts in Mexico, Spain, Britain, and the Netherlands. Jaime Vilchis highlights the importance of understanding the Neoplatonic and Stoic writings of Hernández 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 lift the fog enveloping his life and work. But the contribution in the collection 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 by Spanish painters of the botanical novelties introduced to the peninsula by the writings of Nicolás Monardes and Hernández; more importantly 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 was modeled after the values and aspirations of natural philosophers. Like the medieval garden of courts and cloisters, the early-modern garden also sought to recreate Paradise. In Catholic quarters, fountains in cloisters still 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; and flowers represented virtues and weeds vices (MacDougall 1986). But the humanist culture also 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 dominium over territorial space (Mukerji 1997; Coffin 1979). It also became a place to store and reproduce encyclopedic knowledge (particularly in the botanical garden) (Prest 1981); to reproduce the geometric, Neoplatonic structure of the cosmos (Strong 1979; Comito 1978); and to build patriotic replicas of local landscapes (Lazzaro 1990, esp. chs 7 and 9; Coffin 1960). Visitors, like epic heroes, stepped into mazes and labyrinths in voyages of philosophical discovery (Darnall and Weil 1984; Strong 1979; Comito 1978). Marble sculptures, topiary work, grottos, and loggias helped these voyagers find their cues along the way. The study of the Renaissance and Mannerist Italian, French, English and Netherlandish gardens as microcosms of early modern knowledge is a well-established field. Yet, not surprisingly, scholars have paid little attention to developments in Spain.

Carmen Añón Feliú has long been seeking to correct this oversight (Añon Feliú 1987, 1991a, and 1991b). *Jardín y naturaleza en el reinado de Felipe II* (Garden and Nature under Philip II), a book she edited in 1998 along with José Luis Sancho, represents her latest effort. *Jardín y naturaleza* 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, 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 importantly from the perspective of this review, natural philosophers used the garden to store 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* 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 (Alvarez Peláez 1993). Like them, Alvarez Peláez seeks to understand the Spanish contributions to early-modern European botanical and medical knowledge. Alvarez Peláez, however, 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. The 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 offering maps, narrative histories, and detailed descriptions of local natural resources. Alvarez Peláez studies some fourteen volumes's 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* (Milan, 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, to be sure, rejects this characterization (Alvarez Peláez 1993, pp. 152–3). Like her peers in the seventeenth and eighteenth centuries, Alvarez Peláez takes to her pen to battle foreign innuendo. 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. The author, for example, uses the rich documentary cache of *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.* Using the same sources, Mundy offers a dazzling study of the rise of hybrid conceptions of space and map-making in sixteenth century Mexico (Mundy 1996).

José Sala Catalá's *Ciencia y técnica en la Metropolización de America* is like Alvarez Peláez's a study about the history of Spanish science in colonial settings. Like Alvarez Peláez, Sala Catalá has also 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" (Sala Catalá 1994, p. 16). Readers who discount these assertions as mere patriotic nonsense do so at their own peril. Persuasively and ingeniously, Sala Catalá reconstructs in this posthumous treatise the multitude of complex technologies involved in the Spanish urban settlement of America.[17] 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 Spanish chronic reliance on foreign technicians is a theme that runs throughout David C. Goodman's *Power and Penury. Government, Technology and Science in Philip II's Spain.*[18] Unlike other titles reviewed in this second half of the essay, this is the only one not written by a Spaniard. It needs to be included, however, because it 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, a British

17. For a marvelous study of colonial Spanish American urbanism, see Kagan (2000).

18. For an interpretation of the early-modern Spanish empire as a vast, global, multinational and multiethnic array of actors awkwardly (yet efficiently) brought together by the crown, see Kamen (2003).

scholar, discovers in 1988 what Spaniards had for centuries been saying, namely, that Spain was intellectually part of Europe. Philip II we are told 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, he believed in astrology and the occult, but remained far more skeptical than many of his European colleagues. Although Philip II sought to control and regulate the training of 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 in Spain great room for private initiative and entrepreneurship. Spaniards were not any 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 besieged by chronic fiscal deficits, unable to sustain long-term initiatives and support foreign technicians.

That all these points needed to be made in 1988 is a testimony to how remarkably enduring narratives of the Spanish Black Legend have proven to be. They are still with us, blinding historians every day. New narratives of the so-called Scientific Revolution by Stevin Shapin (1996) and Peter Dear (2001) remain every bit as parochial and provincial as those once written by Marie Boas and A. Rupert Hall. It is extraordinary that decades after the publication of Maravall's *Ancient and moderns* and López Piñero's *Ciencia y técnica,* north-Atlantic historians of early modern science and technology still can so easily afford not to study this literature. Fortunately, as demographic patterns in the USA 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 donning dust jackets with the frontispiece in García de Céspedes's *Regimiento de Navegación* instead of Bacon's *Great Instauration.*

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