Two regions which may have considerable functional significance during protein synthesis are described in detail. One involves the joining of the TψC and D loops, which may undergo conformational change in the ribosome during protein synthesis. The other region is the anticodon, which seems conformationally poised, ready to interact with a single-stranded polynucleotide messenger RNA. Analysis of this end of the molecule suggests ways in which the anticodon may interact with the message, although as yet not enough is known to understand how two tRNA molecules interact with adjoining codons on the message. The next goal in this research effort is clearly that of trying to relate the detailed structural conformation of tRNA molecules to their important biological functions in the transmission of genetic information during protein synthesis.

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Early History of Science in Spanish America

Marcel Roche

There is widespread belief that science and technology have been minimal activities in the culture of Latin America. This belief, popular among Latin Americans themselves, finds expression in the words of a North American expert on the region: "To refute the charge that Latin American science has little historical importance, some historians exhume numbers of minor figures whose names are known only to God and to local historians" (*1*). On the other hand, some feel that the history of Latin American science is extensive and that "when fully known should alter the world's view of scientific developments in Spanish and Portuguese America" (*2*). Both views are somewhat extreme, and they make it evident that more studies about Latin American science are needed (*3, 4*).

In this article I attempt only a brief overall view of the main features of science—and technology—in early Spanish America, before the end of the wars of independence in the 1820's, to the exclusion of indigenous lore and of science done locally by non-Spaniards (such as Humboldt or Darwin) with no social or cultural ties with the countries of the region.

General Characteristics

Early Spanish American science has shown two peaks: the first in the 16th century, when the quality of knowledge generated in the region—especially in Mexico—was of a high level, and widely influential in Europe (*5*). The other period of some interest for Spanish American science was the second half of the 18th century, particularly under the reign of Carlos III of Spain (1759 to 1788), when the great expeditions were undertaken, ideas began to circulate, and some local development took place, especially in Mexico and Colombia.

At first sight, science in the region appears to be discontinuous, inasmuch as the main characters seem to have no masters and no followers; but this impression probably would not bear close scrutiny, since science never rises from a vacuum. Further studies may indeed

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throw new light on the social background of the development of new knowledge in Spanish America. Thus, it was recently shown (*6*) that Carlos Sigüenza y Góngora, one of the main characters of Mexican 17th-century science, was preceded and taught by Fray Diego Rodríguez, who wrote widely on astronomical subjects, made the most accurate calculations of the longitude of Mexico before the 19th century, and was well aware of Copernicus and of the meaning of his work.

Other examples of continuity in Spanish American science are the Observatory of Bogotá, which was founded by Mutis (*7*) in 1803 and has operated without interruption to this day, and the amalgamation process, which was perfected through several centuries, of which I will say more later.

A source of continuity in Spanish American science was the founding, throughout the colonial period, of many universities (*8*) and the setting up of numerous printing presses. This was in keeping, at least in the early days, with university policy in Spain, where in the 16th century the proportion of university students was "higher than that for England and probably the highest in Europe at that time. In fact, such proportions were not exceeded in modern nations until the late nineteenth century and in many countries until a few decades ago" (*9*). Actually, the active Spanish colonial policy regarding universities is in striking contrast with that of many colonial powers, in particular that of Portugal. The Spaniards founded no less than 30 universities in the Spanish American region during the colonial period (Santo Domingo, 1535; Mexico and Lima, 1551; Colegio del Rosario in Colombia, 1580; Córdoba in Argentina, 1613; and so forth) (*8*). On the other hand, in Brazil the first university, at Rio de Janeiro, was founded only in 1920, followed by Minas Gerais in 1927 and São Paulo in 1934, even though there were, before that, professional schools of law, medicine, mining, and so on. Similarly, printing presses appeared in Mexico in 1539, in Lima in 1584, in Puebla in 1640, in Guatemala in 1660, and so on (*10*). In Brazil the first press was set up in 1747, with the authorization of Gomez Freire de Andrade, and it was almost at once forbidden by the Court and dismantled (*11*); it was not until 1808, the date of the arrival of the royal family of Portugal, that there was a legal printing press in Brazil (*12*). The difference between the two regimes, Spanish and Portuguese, with respect to university, printing, and scientific activities, was probably due to a much more centralizing policy in the latter. The elite in Brazil had to study in Coimbra, while Spanish Americans could find locally what they needed in the way of higher studies, generally law or theology.

Spanish American science in the colonial period was highly practical in its motivations, and this can best be exemplified by the setting up of the amalgamation process in the 16th century, the botanical expeditions, the anthropological studies of Bernardino de Sahagún, the adaptation of many species of plants and animals brought from Europe, the founding of the Royal College of Mining in Mexico in the 18th century, and the vaccine expedition in the early 19th century.

Amalgamation

The setting up of amalgamation as an industrial process, under the pressure of economic necessity, stands out as a unique event in the annals of Spanish American technology, up to the present time. It is said to have been started in Zacatecas, Mexico, by Bartolomé de Medina, who was originally from Seville (*13, 14*). Medina came from Spain in 1553 and, after 2 years of trials and errors, set up his new process in 1555. Amalgamation allowed the extraction of silver from its ores by use of mercury and made possible the profitable exploitation of ores of much lower grade than could be used with the old process of smelting; it was largely due to amalgamation that Spain was able to inundate Europe with silver.

The principle of the process, probably based on differential solution of silver in mercury, was clearly given by José de Acosta (*15, 16*): "Though there be a league and simpathie betwixt golde and quickesilver, yet whereas the mercurie findes no golde, it ioynes with silver, though not in the like manner as with golde; but in the end, it doth cleanse and purge it from the earth, copper and lead, amongst the which the silver growes, without any neede of fire to melt it: yet must they use fire to separate it from the silver."

The process itself, as it was transmitted orally from generation to generation of metallurgists, consisted essentially of the following steps. The ore was first ground to a fine powder (*harina*); it was then gathered in small mounds (*montones*) in open or roofed patios (for this reason the process was known as *beneficio de patio*). After wetting, ordinary salt was added (*ensalmorado*), and later a mixture of copper sulfate and iron oxides (*curtido*). Mercury was then mixed in (*incorporo*) and the mixture was thrashed by foot (*repaso*); the resulting product was suspended in water and the amalgam of silver and mercury separated from the rest of the mixture (*lavado* and *separación de la pella*). Silver and mercury were then separated by distillation (*desasogado*). It is interesting to see that the process evolved its own Spanish terminology, as a result of the inventiveness of the Spanish American technicians. One does not find in later years many such examples, perhaps none (*17*). Amalgamation, which was later introduced to Perú, in 1571 or 1572, was the object of improvements in the region throughout the 16th, 17th, and 18th centuries, including the famous process of the metallurgist Alonso Barba (1590) in Perú.

Although he had a manifest interest in the Indians' language and culture, Sahagún's anthropological and cultural studies of the Aztecs were supported chiefly because of an interest on the part of the Spanish crown to better control the Indians and to evangelize them (*18*).

The Period of Expeditions

The Spaniards effected considerable transfer of agronomical technology from Europe to the Americas. They innovated little in the cultivation of local crops (*19*), but brought from Europe a large number of plants and animals, the list of which can be seen in Bernabé Cobo's (*20, 21*) writings in the 17th century, and which included, among many other plants, wheat, barley, rice, all kinds of legumes and fruits, sugarcane, and probably bananas. Horses, cows, sheep, donkeys, mules, chickens, and goats were also carried to the Americas and adapted there. In many cases adaptation was easy, as we can surmise from Cobo's writing where, when discussing the wide extension reached by European species, he states that they grow often "without the industry and benefit of man" (*21*, p. 375). Nonetheless, to adapt European products to the widely varied conditions of the Americas, considerable empirical observation must have been necessary at the time (*19, 22*).

The outstanding science in the Spanish colonial possessions was botany, and it too was developed chiefly for practical reasons: to find medicinal and industrial products. The first Spanish and indeed the first scientific expedition to the Americas was that of Francisco Hernández (*23, 24*) to Mexico. His mission was a highly practical one; his orders were: "You shall inform yourself wherever you may go of all the physicians, surgeons, botanists, and indians and other persons knowledgeable in these activities and who may appear to you to understand and know something, and obtain from them report of all the herbs, trees and medicinal plants present in the province where they may be" (*24*, p. 146). Hernández went about his business in an empirical, in many ways modern way. As he stated, "in these our books of History of Plants, there is nothing that we have not seen with our own eyes and tried by taste or smell or by our own experience" (*24*, p. 231).

Acosta's book (*16*) also contained many descriptions of plants, but these were not, as was the case with Hernández, first-hand accounts. On the other hand, Nicolás Monardes (*25*) received in Seville many plants that came from the Americas and introduced them to Europe.

During the 17th century there was a lull in botanical work, but in the 18th century a number of expeditions were sent to the Americas by Carlos III. Expeditions were characteristically colonial undertakings, with men and ships sent from the mother country to study the flora and the fauna in the colonies and bring back those plants and animals that were of potential benefit to Spain and Europe. The sums spent by Spain on botanical research were considerable. "No European Government has sacrificed more considerable sums to advance the knowledge of plants than the Spanish Government" (*26*). Lanning (*27*) states that the Crown "spent nearly half a million pesos on botanical stations and expeditions throughout the Empire—at a time when four thousand pesos was the adequate annual budget for an important university."

Although there is a grain of truth in the notion that botany was extensively cultivated because it was then an innocuous form of activity from the religious point of view, this is to a large extent a distortion. The main motivation behind the botanical expeditions was the potential beneficial utilization of plants in medicine and industry (*28*).

But, in at least two cases, expeditions resulted in the development of scientific institutions and scientists in the colonial possessions. The "expedition" of Mutis (*29*) to New Granada differed from most in that Mutis had already migrated on his own to Bogotá, in 1760, before the expedition was started. Mutis had many local disciples, among whom the most important was the Colombian José de Caldas (*30, 31*). The expedition of Martín Sessé (1788 to 1796), which covered most of present-day Mexico, was joined by the talented Mexican Mariano Mociño. This expedition led to a number of local developments, among which the most important was probably the setting up of the Jardin de Plantas in Mexico, by Vicente Cervantes.

Other botanical expeditions of the 18th century were those of Hipólito Ruiz (1764 to 1815), who visited Perú and Chile from 1778 to 1788 and was first to describe the virtues of the Peruvian bark, which contains quinine; of Féliz de Azara (1742 to 1821) who spent 20 years in Argentina, Paraguay, and Brazil, studying mammals and birds; of Alejandro Malaspina, who visited Montevideo, Argentina, Patagonia, Bolivia, the Falkland islands, Chile, Perú, and Mexico from 1789 on; and of the Swede Peter Loeffling, a disciple of Linné, who traveled in an expedition of the Spanish Crown to Venezuela in 1754 (*32*).

The Colegio Real de Minería in Mexico was founded in 1792, under the directorship of the Spaniard Fausto de Elhuyar (*33*), the codiscoverer of tungsten. The Colegio was a highly practical undertaking, dedicated to teaching and to the solution of the problems of Mexican mines, but a measure of research was also performed there. Andrés Manuel del Rio (*34*), professor of mineralogy at the Colegio, described, in 1801, a hitherto unknown red substance, which he called *eritronio* and which was rediscovered in 1830 by the Swede N. G. Sefstrom and called vanadium by him.

The expedition of Francisco Javier de Balmis is a good example of the sometimes rapid application of science by the Spanish Crown. In 1803, only 5 years after the publication by Jenner of the vaccine discovery, Balmis set out from La Coruña. He maintained the vaccine alive by inoculating foundling children who were carried aboard the ship. His expedition visited Puerto Rico, Venezuela, Colombia, Ecuador, Peru, Bolivia, Mexico, and later the Philippines, Macao, Canton, and St. Helena, introducing the vaccine in all those places and vaccinating several hundreds of thousands of persons (*35*).

Theoretical Contributions

There were exceptions, of course, to the practical character of Spanish American science, the earliest one being that of Hernández. Although given a specific pragmatic mandate, he acted very much as a pure scientist when he stated, "It is not our purpose only to give an account of the medicines, but rather to gather the flora and compose the history of the natural things of the New World" (*24*, p. 146).

The various astronomers who worked in Spanish America, especially in Mexico in the 17th and 18th centuries, dealt largely with such problems as devising calendars and measuring longitudes, but some of them went beyond this practical view. A particularly interesting scientist in this respect was Carlos de Sigüenza y Góngora (*36–38*), who gave an account of the comets and showed a modern, rational outlook. He protested against the excessive use of authority by his rival Father Kino: "As there is nothing, no matter how anomalous or contemptible, that does not have the support of some author" (*37*, p. 55). He stated furthermore: "He who has understanding and discourse will never be governed by authorities, if such authorities lack congruence" (*37*, p. 40). In astronomy and like sciences, Ptolemy himself "cannot set forth dogmas . . . since in these sciences authority is worth nothing, but rather proofs and demonstrations" (*37*, p. 123).

Acosta (*15, 16*) tried at several points to theorize and to put the new knowledge brought forth by the discovery of America in the context of Aristotelian and medieval science. He was particularly successful in his hypothesis of the settlement of America by human populations, which, according to him, came about partly by sea ["Why might not this be? Must we beleeve that we alone, and in this our age, have onely the Arte and knowledge to saile through the Ocean" (*16*, vol. 1, p. 16)] but chiefly by land, possibly through a northern junction between Asia and America. Human dwellers came to America "travelling by land, which might be done without consideration in changing little and little their lands and habitations. Some peopling the lands they found, and others seeking for newe, in time they came to inhabite and people the Indies, with so many nations, people, and tongues as we see" (*16*, vol. 1, p. 20).

Caldas (*30*), in New Granada, besides his practical contributions to the knowledge of plants, developed an original formula relating the boiling point of water to elevation and was one of the original contributors to the field of hypsometry. It is very proper, of course, that this science should have been developed in a mountainous region like Colombia.

In Ecuador, we find an interesting anticipation of the germ theory, set forth in the remarkably lucid prose of Eugenio

Espejo (*39*), in which he argued that disease, far from being a scourge sent by God to punish man, was of natural origin. He wrote: "The generation of contagious diseases requires particular principles which characterize them. . . . These particles, which create contagion, are bodies distinct from the elemental elastic fluid which we call air. . . . The cause of all epidemic diseases lies in these animalcules. . . . If microscopic observations could be refined, even further than the level reached by Malpighi, Réaumur, Buffon and Needham, perhaps we should find in the incubation, development, situation, figure, movement and duration of these subtle corpuscles, the rule that could serve to explain the whole nature, degrees, properties and symptoms of all the epidemic fevers and in particular smallpox" (*40*).

These are then the only small contributions to theory which I can find in early Spanish American science. It may be that this practical feature is peculiar to colonial science, but it may be related also to the characteristics of science in Spain, which, as has been pointed out by several Spanish authors, was highly practical and lacking in theory. According to Santiago Ramón y Cajal, scientific research in Spain has been "poor and discontinuous, showing backwardness in comparison with the rest of Europe and most specially, deplorable theoretical penury" (*41*). The great critic Menéndez y Pelayo makes a similar remark, in his famous book where he otherwise purports to defend the worth of Spanish science: "In this country of idealists, of mystics, of wandering knights, what has always flowered with more vigour is not pure science . . . but rather its practical and, so to speak, utilitarian applications. What our science has lacked most in modern times is scientific disinterest" (*42*). And the mathematician Rey Pastor states that the Spaniards were "poor in pure science, and indigent in Mathematics, this being the purest of all sciences" (*43*).

Conclusion

Many Spanish American scientists worked with a feeling that, because of the limited facilities at their command, and because of their peripheral location, with few books, little apparatus, and few contacts with other scientists, it was more difficult for them to do science than for Europeans. They also felt keenly the disdain with which their science purportedly was being treated in the central countries. These feelings are given vent in different areas and in different times. Thus, Sigüenza remarked ironically, when Father Kino overlooked his observations: "In certain parts of Europe, in particular the Northern ones . . . they think that not only the Indians, original dwellers of these our countries, but also those of us who happen to have been born in them of Spanish fathers, either walk on two legs by divine dispensation or that, even with the help of English microscopes, reason can hardly be discovered in us" (*37*, p. 85). Father Kino had dismissed his writings "because they had not been done in Germany, or because the observers had not studied in the University of Ingolstadt." And Sigüenza goes on to state proudly: "But from the context of my writings he will practically recognize that there are mathematicians outside Germany, even though they be buried in the reed grass of the Mexican lake" (*37*, p. 119).

In the 18th century, in Mexico, Joaquín Velásquez de León complained that "The humility, fear and difficulty which the Spanish Mexicans regularly have in producing their ideas is great, and much greater is the preoccupation of the Europeans with our barbarism. Why should they seek data from men whom they still visualize with bows and feather plumage as they depict us on their maps?" (*44*).

Again in the 18th century, but this time in Guatemala, José Felipe Flores (*45*) on his way to Europe through Philadelphia, realized suddenly that many of the ideas he had had in Guatemala had already arisen elsewhere and were being put to use. In a letter to his friend Goicoechea, he gave another example of the Spanish American "peripheral complex" when he wrote: "If instead of having lived in the rump of the world I had been elsewhere, I would have carried out more than one exploit" (*46*).

Somewhat later, this time in New Granada (Colombia), Caldas, in a fit of depression, exclaimed: "What doubts, what a sad fate that of an American! After much work, if he comes to find something new, the most he can say is: it is not in my books. Can any country in the world become wise without an accelerated communication with cultivated Europe? What darkness surrounds us!" (*31*, p. 16).

It may be interesting to draw some conclusions from what has been said for today's Latin American science. Colonial science in Spanish America was not negligible, and the Spaniards—in contrast probably to the Portuguese—especially in the 16th and the 18th centuries, made a determined effort to study local products, and, in one case at least—that of amalgamation—produced an important technology with an impact on the economy. But science appears to have been limited to the richer colonies, in particular Mexico during the three centuries of colonial rule, and Colombia in the 18th century. Science was, with very few exceptions, of a highly practical nature, apparently discontinuous, and probably not much in demand by local society. Although there were eminent scientists (Hernández, Sahagún, Mutis, Caldas, Elhúyar, Sigüenza, and so on) there were none of notable international stature, particularly in the theoretical fields, which were poorly represented. There was no theoretical work comparable to that, say, of Benjamin Franklin on electrostatics.

Considering the poor showing to this day of Latin American science on a worldwide scale, it is difficult to escape the idea that the cultivation of solid theoretical science is an indispensable factor in the continuity and quality of science in the region, through its role in the teaching and amplification of ideas, and through its effects on technology. Such cultivation is beginning to take place today, and this may be an early sign that Latin Americans are coming out from their isolation, taking steps to reduce their dependence on foreign ideas and know-how and to eliminate the "peripheral complex" which has plagued them to this day.

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16. J. de Acosta, *Historia Natural y Moral de las Indias, en que se tratan las cosas notables del cielo, y elementos, metales, plantas, y animales dellas, y los ritos y ceremonias, leyes y Gouierno, y guerras de los Indios* (Lelio Marini, Barcelona, ed. 2, 1591); J. O'Brien, Ed., *ibid.* (Fondo de Cultura Económica, Mexico City, 1940). Quotations in this article are from O'Brien's edition, from which I also obtained the biographical data on Acosta.
17. Indeed, R. Blanco-Fombona, a Venezuelan writer well versed in the character of Spain, where he resided in exile for many years, and sympathetic to that country, has stated: "Contemporary science does not speak Spanish" [in *El Conquistador Español del Siglo XVI* (Edima, Madrid, 1956), p. 70].
18. Bernardino de Sahagún (1500–1590), born in Villa de Sahagún, Province of León, Spain, came to the Americas in 1529, where he taught and did research in the famous Colegio de Tlatelolco, Mexico. Through interviews and direct experience, he was able to gather extensive material on the Aztec civilization, which he published, in both Spanish and Nahuatl, in 1585. Although he was not entirely free from European prejudices, Sahagún had a benevolent and loving attitude toward the Indians. See B. de Sahagún, *Historia General de las Cosas de Nuevo Mundo* (Pedro Robredo, Mexico City, 1938). See also E. de Gortari (*4*).
19. V. M. Patiño, *Historia de la Actividad Agropecuaria en América Equinoccial* (Imprenta Departamental, Cali, Colombia, 1965), pp. 216 and 298.
20. Bernabé Cobo (1580–1657), a Jesuit priest and a naturalist, born in Lopera, near Jaén, Spain, traveled to the Americas at the age of 16 and remained in Lima, Peru, for the rest of his life, except for a long stay in Mexico from 1629 to 1642. In his *Historia del Nuevo Mundo* (*21*) he described elegantly local varieties of plants and animals and gave a historical and botanical account of varieties brought to the Americas by the Spaniards.
21. B. Cobo, *Historia del Nuevo Mundo*, in *Obras Completas del P. Bernabé Cobo* (Artes Gráficas, Madrid, 1956).
22. See also, besides Patiño (*19*), R. Cappa, *Estudios Críticos acerca de la Dominación Española en América*, Part III, *Industria Agrícola-Pecuaria Llevada a América por los Españoles* (Asilo de Huérfanos, Madrid, 1915); J. García Mercadal, *Lo que España Llevó a América* (Taurus, Madrid, 1959).
23. Francisco Hernández (1518–1587), a physician and *médico de cámara* to the Court of Spain, was sent to Mexico by Philip II in 1570. He remained there for 7 years, traveling widely through the countryside, studying the flora of the region and trying out, on patients in Mexico City, the medicinal properties of plants. His findings were later published in Rome, under the sponsorship of the Academia dei Lincei (*24*).
24. F. Hernandez, *Rerum Medicum Novae Hispaniae Thesaurus seu Plantarum Animalium Mexicanorum* (Vitalis Mascardi, Rome, 1651); G. Somolino d'Arbois, Ed., *Francisco Hernández, Obras Completas* (Universidad Nacional, Mexico City, 1970). Quotations in this article are from Somolino d'Arbois' edition, from which I also obtained biographical data.
25. Nicolás Monardes (about 1493–1588) lived in Seville, Spain, the point of arrival of ships from the Americas. He received many plants from the colonies, described them, and communicated to Europe their characteristics and their medicinal properties. His famous book *Primera y Segunda y Tercera Partes de la Historia Medicinal de las Cosas que se traen de Nuestras Indias Occidentales que Sirven en Medicina* was published in Seville (Alonso Escriuano, 1574). The book was enormously successful and soon there were Italian (1574), Latin (1574, 1579, 1582, 1589, 1593, and 1605), English (1577, 1580, and 1596), and French (1619) editions. The English editions, translated by John Frampton, bore the title *Joyfull Newes out of the Newe Founde World*. See F. Guerra, *Nicolás Monardes, Su Vida y Obra* (Compañía Fundidora de Fierro y Acero de Monterrey, Mexico, 1961).
26. Alexander von Humboldt, *Essai Politique sur le Royaume de la Nouvelle Espagne* (Schoell, Paris, 1811), book II, p. 15.
27. J. T. Lanning, *The Eighteenth-Century Enlightenment in the University of San Carlos de Guatemala* (Cornell Univ. Press, Ithaca, N.Y., 1956), introduction XX.
28. I have derived my information about expeditions chiefly from: C. E. Chardon, *Los Naturalistas en la América Latina* (Caribe, Ciudad Trujillo, Santo Domingo, 1949), pp. 81–115; J. C. Arias Divito, *Las Expediciones Científicas Españolas* (Cultura Hispánica, Madrid, 1968).
29. José Celestino Mutis (1732–1808) was born in Cádiz, Spain, and resided in Bogotá, present-day Colombia, from 1760 on. He described the nocturnal variations of the barometer and discovered, in 1772, in the neighborhood of Bogotá, the *quina* (cinchona) plants. Under a grant from Carlos III, he made an exhaustive study of the flora in Mariquita, near the Magdalena River.
30. José de Caldas (1771–1816), born in Popayán in the southern part of present-day Colombia, studied the variations of the boiling point of water with height, made many botanical studies, and was the first director of the Bogotá Observatory. Appointed chairman of mathematics in the Colegio del Rosario, he gave an inaugural speech which was outstanding for its brevity, contrasting markedly with lengthy addresses commonly given on such occasions. The address, in full, was: "Gentlemen: the angle at the centre is twice the angle at the periphery." From 1810, Caldas fought in the wars of independence, was appointed captain of engineering cosmographers, and put in charge of the manufacture of guns, cannons, and powder. In 1816, he was caught by the Spanish army and shot. See de Pombo (*31*) and A. D. Bateman, *Rev. Acad. Colomb. Cienc. Exactas Fis. Nat. Suppl.* (1958), pp. 47–93.
31. L. de Pombo, *ibid.*, pp. 9–49.
32. See S. Ryden, *Pedro Loeffling en Venezuela (1754–1756)* (Insula, Madrid, 1957).
33. Elhúyar was born in Logroño, northern Spain, in 1757. He studied natural sciences in Paris and later chemistry in Germany, Sweden, Norway, and England. At the age of 20, with his brother Juan José, he discovered tungsten at the Seminario Patriótico de Vergara. In 1786, he was appointed to the Mining Tribunal of New Spain and later founded the Real Colegio de Minería. See Bargalló (*13*); Howe (*14*); J. J. Izquierdo, *La Primera Casa de las Ciencias en México* (Ediciones Ciencia, Mexico City, 1958).
34. Del Rio was born in Madrid in 1764. He studied at Alcalá de Henares and later in Paris and Germany. In 1794 he was called to Mexico by de Elhúyar.
35. G. Diaz de Yraola, *La Vuelta al Mundo de la Expedición de la Vacuna* (Consejo Superior de Investigaciones Científicas, Escuela de Estudios Hispanoamericanos de Sevilla, Seville, 1948). See also S. F. Cook, in *History of Latin American Civilization. Sources and Interpretations*, L. Hanke, Ed. (Methuen, London, 1967), pp. 441–451. For the story of the expedition in Venezuela, see R. Archila, *La Expedición de Balmis en Venezuela* (Tipografía Vargas, Caracas, 1969).
36. Carlos Sigüenza y Góngora (1645–1700) was a Mexican savant who held the chair of astrology and mathematics at the University of Mexico and was chief cosmographer and regius mathematician. Sigüenza's chief interests were poetry, astronomy, history, and geography. In his best known work (*37*) he gave an entirely naturalistic and rational account of comets, as part of a controversy with the Jesuit Father Kino. See Leonard (*38*); E. Trabulse, *Ciencia y Religión en el siglo XVII* (Colegio de México, Mexico City, 1974), pp. 24–32; E. Navarro, Ed., *Nicolás Copérnico: Sobre las Revoluciones de los Orbes Celestes* (Sepsetentas, Mexico City, 1974), pp. 15–34. I am also indebted to Trabulse for his personal communications about Sigüenza.
37. C. Sigüenza y Góngora, *Libra Astroñomica y Filosófica* (1690, reprinted by the Universidad Nacional Autónoma de México, Mexico City, 1959).
38. I. A. Leonard, *Don Carlos de Sigüenza y Góngora, a Mexican Savant of the Seventeenth Century* (Univ. of California Press, Berkeley, 1929).
39. Eugenio Espejo (1747–1795) was a physician of mixed blood and of humble origins. He wrote a "Treatise on smallpox" around 1787.
40. J. M. Vargas, *Biografía de Eugenio Espejo* (Editorial Santo Domingo, Quito, 1968), pp. 52–53.
41. S. Ramón y Cajal, *Reglas y Consejos sobre Investigación Científica*, in *Obras Literarias* (Aguilar, Madrid, 1961), p. 624.
42. M. Menéndez Pelayo, *La Ciencia Española* (Aldus S.A. de Artes Gráficas, Santander, Spain, 1953), vol. 2, p. 434.
43. R. Pastor, *La Ciencia y la Técnica en el Descubrimiento de América* (Espasa-Calpe, Buenos Aires, 1945), p. 120.
44. The English translation is by Leonard (*38*, p. 313).
45. José Felipe Flores (1751–1824), born in Ciudad de Chiapas, Guatemala, studied medicine in the Universidad de Santiago and was active in the teaching of anatomy, constructing wax models which could be taken apart to show the various layers. In 1796, although successful at home, he obtained a permit and a stipend to travel to Europe, from which he never returned, becoming thus one of the earliest examples of "brain drain" from the region. In Europe, he worked on a method to conserve food by means of ethyl alcohol, on perfecting telescopes, and on the correction of chromatic aberrations. See J. Aznar López, *El Dr. Don José de Flores, una Vida al Servicio de la Ciencia* (Editorial Universitaria, Guatemala, 1960).
46. Quoted by Carlos Martínez Durán, *Las Ciencias Médicas en Guatemala, Origen y Evolución* (Editorial Universitaria, Guatemala, ed. 3, 1964), p. 305.