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Training Researchers in Ibero-America: Early Brazilian Chemists as Case Study

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Introduction

What do we speak about when we speak of 'Latin' America? This is a rather fuzzy concept, formulated following the independence of the former American colonies of European powers—mainly Spain, Portugal, Britain, and France—during the nineteenth century, and created a division within the Americas into North and South, Anglo and Latin, respectively. 'Latin', thus, in a wider meaning, referred to French-, Portuguese-, and Spanish-speaking America. This identity has been asserted particularly by the French and adopted by the Creole elites to define themselves.[1] The idea of an 'Ibero'-America is no less misleading, as a large part of this region fell under the dominion of Spain, while Portugal colonized Brazil after these two nations split their American possessions in 1494. The colonial policies implemented by these two European powers differed substantially, and the case of higher education is a particularly representative example.

The Spanish colonizers began establishing universities all across their American possessions soon after their arrival in the continent in 1492.[2] By contrast, the first Brazilian university opened its doors more than 400 years later, in 1920. The traditional explanation offered for the Spanish university policy derives from the notion of empire as a confederation of kingdoms, held by the Habsburgs, in contrast to the centralism later

[1] Walter D. Mignolo, *The Idea of Latin America* (Malden, MA, 2005), xv; see ch. 2 in particular.

[2] Carlos Tünnermann Bernheim, *La universidad latinoamericana ante los retos del siglo XXI* (México DF, 2003), 55; José J. Brunner, *Educación superior en América Latina: cambios y desafíos* (Mexico, 1990), 4. From Tünnermann Bernheim, see also *Historia de la universidad en América Latina: de la época colonial a la Reforma de Córdoba* (San José, Costa Rica, 1991).

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favored by the Bourbons. This view made Spain a notable exception among the fifteenth- and sixteenth-century colonial powers.[3] Each component of this political entity therefore had to have a university of its own. Royal or pontifical universities, or a mixture of both, began to be created in 1538 (Santo Domingo, Hispaniola). By 1812, their number had reached thirty-two, even though some were only on paper.[4] The majority of these universities, including the two most successful, those in Lima (Peru) and Mexico, followed the Salamanca pattern, according to which universities were intended to serve the state, and the academic unit was the professorial chair. Teaching was delivered in Latin and complied with the traditional style of *lectio* (reading aloud of canonical texts) and *disputatio* (presentation of objections and arguments).[5] Despite several attempts at reform, teaching remained bookish until the end of the eighteenth century.

After the Spanish colonies achieved independence, starting in the early 1800s, professional training became a privileged focus of interest for the new countries.[6] The traditional integrated university was replaced by an aggregate of professional schools meant to prepare personnel for public administration and to meet social needs, like health care and engineering.[7] As such, the universities remained a stronghold of the local elites until the early decades of the twentieth century.[8] For instance, in Chile an innovative project was devised based on the idea that the university ought to be the core of the entire educational system, whose benefits would thus naturally extend to society at large.[9] European science was to be incorporated following its adaptation to the Chilean nature and population, and to

[3] Tünnermann Bernheim, *Universidad latinoamericana*, 55. To remind briefly, the Habsburgs ruled over Spain from 1516 to 1700. While several other reasons were put forward, they do not truly account for this considerable difference, for example: to tend to the educational needs of the clergymen who accompanied conquerors; a desire to heighten the level of studies at the colonies; and education of the children of the Spanish and American-born elite to establish cultural links to the Empire and prepare personnel for colonial administration. See also Elsi Jiménez, 'Historia de la universidad en América Latina', *Revista de la Educación Superior*, 36/141 (2007), 169–78.

[4] Ibid, 59. By the time of the independence from Spain, only 25 remained; see Brunner, *Educación superior*, 17.

[5] Ibid, 57. [6] Ibid.

[7] Ibid, 66. Under such spirit, several new universities were founded, including University of Buenos Aires, Argentina (1821), University of Chile (1842), University of Uruguay (1860), National University of Asunción, Paraguay (1889) and National University of Mexico (1910). For a new historiographical movement emerging at the end of the 1990s asserting the existence of non-marginal, non-subordinated, non-precarious scientific practice in Latin America in the nineteenth century, see the special issue edited by Antonio Lafuente and Leoncio López-Ocón in the journal *Asclépio*, 50/2 (1998).

[8] In 1918, a movement for reshaping the university emerged, fueled by the fledgling middle classes, first in Córdoba (Argentina) and soon extending to the remainder of Hispanic America; see Tünnermann Bernheim, *Universidad latinoamericana*, 69.

[9] Brunner, *Educación superior*, 8.

accomplish this purpose, teaching was distributed across five schools: philosophy and humanities, mathematical and physical sciences, medicine, law and political sciences, and theology. Nevertheless, in practice it became a 'university of lawyers': 75% of the graduates from 1844 to 1879 came from the School of Law. This, indeed, was a typical phenomenon of the universities in Spanish-speaking America as a whole.[10]

The teaching of science and engineering in these countries underwent considerable development only from the 1950s onward, partly as a result of the need of the local industries to expand and replace imports from abroad. However, the entrepreneurs' expectations were to reproduce the technical specifications of the imported goods as exactly as possible.[11] As a result, teaching did not lose its emphasis on professional training. With the single exception of the exact and natural sciences in Argentina—whose government, inspired by the German academic ethos, had made research a priority—not until the period between 1960 and 1975 did the modern university take hold in Ibero-America, including new careers in the humanities and education, and in the social, exact, and natural sciences.[12]

Contrary to a commonly held view, in the present essay we shall argue that, although it is true that the modern research university only began to take root in Ibero-America from the mid-1950s onward (therefore, after the period considered in this collection), chemical studies actually developed earlier. Admittedly, the close association with attempts at boosting the local economies impeded fundamental research until the establishment of new approaches to higher education and the creation of research support agencies in the twentieth century. However, our conclusion is that the relative late arrival of universities (in comparison with Hispanic America) did not significantly slow the growth of chemical studies in Brazil.

Birth of Nations and Chemical Research in Spanish-speaking America

One of the consequences of the era of independence from Spain during the early decades of the nineteenth century was a fragmentation of vast

[10] Ibid, 9; the reason being that following the establishment of the republican system, a degree in law was the main channel for socialization and access to the political elite, in addition to ensuring the training required for a career in the government.

[11] Jorge Vivas, 'Formación universitaria en ciencias e ingeniería y el sistema científico-tecnológico en América Latina', in Jorge Graciarena et al. (eds.) *Universidad y desarrollo en América Latina y el Caribe*, (Caracas, 1984), 89–142. Until about 1950, the vast majority of universities taught law and medicine only; see Brunner, *Educación superior*, 18.

[12] Ibid, 103, 107–8.

colonial domains into a number of new countries.[13] Several categories of reasons contributed to the emergence of these new nations around several poles of attraction.[14] Long debated in the historiography, reasons range from regional rivalry and internal conflict to what many characterize as 'sovereignty dispersion'.[15] In any case, there is wide agreement that despite the countless newly drawn boundaries, much of the older colonial structures survived all across Hispanic America,[16] including the teaching and learning institutions (despite several attempts at modernization). Thus, when chemistry began to acquire its modern contours and to earn a central role elsewhere, little of this movement reached these young countries. Attempts at developing an appropriate research infrastructure, which was particularly relevant for new chemical studies, were few and usually ill fated,[17] as the following examples help illustrate.

To begin, Peru, one of the most powerful regions in the colonial era, had to overcome several obstacles before its independence could consolidate. In fact, many such hindrances persisted, and even gained new strength following emancipation.[18] These included not only border issues and conflict with its new neighbors, but also internal problems. For instance, the natural barriers represented by the high Andean mountains

[13] The most striking exception is Cuba, which proclaimed its independence only in 1899, to be immediately occupied by the United States.

[14] To remind briefly, the vast territory of Hispanic America had a complex geopolitical history. First divided into two large viceroyalties – New Spain in the north (capital: Mexico) and Peru in the south (capital: Lima)—at the end of the colonial period the latter lost a part of its territory, resulting in further two large viceroyalties, New Granada (capital: Santa Fe, present day Bogota) and Rio de la Plata (capital: Buenos Aires) and the General Captaincy of Chile (capital: Santiago). For more detail, especially after independence from Spain, see, e.g., Rafe Blaufarb, 'The Western Question: The Geopolitics of Latin American Independence', *American Historical Review*, 112 (2007), 742–63.

[15] For a more thorough and up-to-date review on so-called 'sovereignty dispersion', see Wolfgang Knöbl, 'La contingencia de la independencia y de la revolución: perspectivas teóricas y comparadas sobre América Latina', *América Latina Hoy*, 57 (2011), 15–49.

[16] A classic sociopolitical analysis is provided by John Lynch, *The Spanish American Revolutions, 1808-1826* (London, 1973). For a historiographical review reaching the present time, see Juan B. Amores, 'Nuevos enfoques y métodos en la historiografía sobre las independencias: el debate continua', *Historia y Sociedad*, 20 (2011), 13–31.

[17] On the new room for chemistry and laboratory processes in the eighteenth and nineteenth centuries, see, e.g., Ernst Homburg, 'The Rise of Analytical Chemistry and its Consequences for the Development of the German Chemical Profession (1780–1860)', *Ambix*, 46/1 (1999), 1–32; and Ursula Klein, 'The Laboratory Challenge: Some Revisions of the Standard View of Early Modern Experimentation', *Isis*, 99/4 (2008), 769–82.

[18] It is worth observing once again that along the last century of the colonial period the viceroyalty of Peru lost a large part of its territory, and with it a considerable fraction of its resources and the access to the Atlantic Ocean, in addition to being subjected to stronger control by Spain, followed by a long and difficult process of independence and border issues with its new neighbors. For more detail on the historical changes underwent by Peru, see e.g. Raul P. Barrenechea, *Historia de los límites del Perú* (Lima, 1926).

and a dense rainforest hindered the development of communication and transportation systems within the country, and the Peruvian government was left with poor access to its own territory during a large part of the nineteenth century. This and other weak points made the mapping, exploration, study, and exploitation of natural resources substantially difficult, with the corresponding impact on the creation of teaching and research institutions.[19]

Nevertheless, chemical innovations, including Lavoisier's new chemistry, awakened much interest among the Peruvian scholars starting in the late 1700s, i.e. still during the colonial period. This is evidenced by the local publication of the *Méthode de nomenclature chimique* soon after its original French edition. Countless brochures, articles, reports, and even books and dictionaries devoted to the principles of the new chemistry began to appear soon after independence from Spain in 1821.[20] In addition, whenever financial conditions were favorable, the government sought to promote national and foreign expeditions. With very few exceptions, these travelers behaved more as explorers than as scientists, possibly as an outcome of a rather pragmatic view seemingly adopted by the local oligarchy since the end of the colonial period. The first mining and civil engineering school was founded in the last quarter of the nineteenth century. Though its graduates proactively engaged in constructing roads and exploring mineral resources, the few fine works on Peruvian natural history and archeology did not awaken the same degree of interest. Indeed, many of these works were published too late and/or incompletely, while their diffusion and continuity demanded specialized laboratories and equipment that were then unavailable in Peru.[21] Therefore, chemical studies remained restricted to engineering, medical, and pharmacy schools, which focused on professional training and provided few resources, room, or staff for research. In addition, most such schools were located in Lima, the capital, where all attempts to reform the traditional university curriculum—much respected in colonial times—suffered serious setbacks or were short-lived.[22]

In Peru, chairs in chemistry gained enough momentum to form a school of chemistry in the university during the 1940s. Around the same

[19] For more detail on the troubles Peru had to overcome, see Carlos Contreras and Marcos Cueto, 'Caminos, ciencia y Estado en el Perú, 1850-1930', *História, Ciências, Saúde—Manguinhos* 15/3 (2008), 635–55.

[20] On these and other publications related with the new chemistry, see Juan D. Guevara, *Historia de la quimica en el Perú* (Lima, 1993), 71–113, 164–174.

[21] Contreras and Cueto, 'Caminos, ciencia', 642–4.

[22] On the creation (and setbacks) of higher education schools in independent Peru and the establishment of chemistry as ancillary chair, see Guevara, *Historia de la química*, 212–50; on the concentration of higher education schools in Lima and some attempts at reform, see Ibid, 649–50.

time, the Chemical Society of Peru and the Superior Institute of Chemistry at San Marcos National University were also created. Official support for research was first secured following a major reform in the 1960s.[23]

The situation was similar, although with some peculiarities, in other young Andean countries. For instance, in Chile—a very wealthy area under the rule of the viceroyalty of Peru for a large part of its colonial history—chemistry succeeded in achieving autonomy from medicine by the middle of the twentieth century, though still joined to pharmacy.[24] Another relevant example is that of the viceroyalty of New Granada, the birthplace of one of the earliest and strongest independence movements in Hispanic America, and from which Colombia and Venezuela emerged. Like Chile, these territories were rich in natural and agricultural resources. But they had unexplored areas, too, and poor communication systems. Its situation resembled that of Peru, again complicated by instability and internal conflict for a large part of the nineteenth century.[25] Within this context, sciences such as chemistry remained taught as auxiliary to medicine and engineering, while scarce resources were afforded to specialized studies or laboratories fit for research.

In Colombia, chemistry severed its ties to medicine only in the 1930s. For this development—set off by the creation of the National Chemical Laboratory—governmental support was crucial. Various isolated chemical chairs were united in one single school at the National University, which produced the first graduates in the 1940s. However, it seems that in its beginning this school had very simple laboratories intended for teaching purposes only, since the government's interest was exclusively in training chemists for the emerging Colombian industry. As a result, advanced research took off only in the second half of the century.[26] In Venezuela, the first superior schools of chemistry were created in the 1940s, once again to train professionals to meet government and industry needs, e.g. petroleum development. The same reasons account for the foundation of the first

[23] Guevara, *Historia de la química*, 270–95, 304–47.

[24] Eduardo Guzmán Riberos, *Historia de una profesión: Colegio Químico Farmacéutico y Bioquímico de Chile A.G. 60 años, 1942–2002* (Santiago, Chille, 2003), 59–60.

[25] Although these independence movements were among the earliest in the Americas, consolidation was particularly delayed and bloody; in addition, emancipation was followed by periods of serious instability. For more detail, see, e.g., Clement Thibaud, 'En búsqueda de un punto fijo para la república: el cesarismo liberal (Venezuela-Colombia, 1810–1830)', *Revista de Indias*, 62/225 (2002), 463–92. On expeditions during the period of independence, see e.g., Álvaro Villegas Vélez, 'Paisajes, experiencias e historias en las dos primeras expediciones de la Comisión Corográfica', *Historia y Sociedad*, 20 (2011), 91–112.

[26] Rogino Martínez-Chavanz, German Cubillos and Flor M. Poveda, *Historia social de la ciencia en Colombia*, vi: Fisica y quimica (Bogotá, 1993), 189–90; Diana Obregón, 'Trade and the Natural Sciences in the United State of Colombia', in P. Petitjean, C. Jami and A. M. Moulin (eds.), *Science and Empire* (Dordrecht, 1992), 147–52.

School of Pharmacy and Chemistry at Central University of Venezuela about this time. Also, in this case institutions devoted to specialized research began to appear in the second half of the century.[27]

The picture painted up to this point is completed by a group of young Hispanic American countries born out of the viceroyalties of New Spain and Rio de la Plata. Many such countries were small and achieved their independence later compared to the larger ones. They therefore had to overcome additional hindrances and took longer to establish scientific programs and create research institutions.[28] It is worth noting that these countries were the result of the aforementioned 'sovereignty dispersion'. They spared no efforts to avoid being absorbed into the two larger poles of attraction. We allude here to Argentina and Mexico, which in a succession of internal wars and agreements following independence saw a number of new and small countries appear on their former borders. In any case, these two larger countries were precisely the ones in the best condition to maintain or create scientific institutions, as we discuss next.

Chemical Research in Argentina and Mexico

Any approach to the development of science in Hispanic America needs to consider the violent political upheavals that took place in this region following its independence from Spain. Periods of civil war alternated with dictatorships and attempts at 'national reorganization', which usually comprised well-defined, albeit seldom successful, social, economic, and cultural reform programs.

This phenomenon is, for instance, illustrated by two early attempts at establishing teaching laboratories for chemistry in Argentina. Once the wars of independence were over, a period of relative stability settled in. The government consisted of a liberal, enlightened, and European-minded elite, one of whose first actions was to create the University of Buenos Aires (1821) to bring the city closer to the large and modern European

[27] Ivan de la Vega, José L. Paz, Jorge Mostany, Domingos Vargas and Jaime Requena, 'Sociología de la ciencia: la investigación química en Venezuela. Retrospectiva y perspectivas', *Espacio Abierto* 21/1 (2012), 119–44, on 120–2; Reinaldo Rojas, 'Historia de la universidad en Venezuela', *Historia de la Educación Latinoamericana*, 7 (2005), 75–100.

[28] In some cases, like the one of Uruguay, new schools including facilities for chemical studies were established. However, as the standard pattern goes, research only gained momentum late in the twentieth century; see Bernardo Borkenztain, Amilcar Davyt, Fernando Ferreira and Patrick Moyna, 'Giovanni Battista Marini Bettolo: su incidencia en el desarrollo de la química en Uruguay', *História, Ciências, Saúde—Manguinhos*, 12/2 (2005), 535–46, on 537–38.

urban centers.[29] This university was organized on the basis of departments. One of them was the Department of Preparatory Studies, in which natural sciences, including chemistry, were taught.[30] Although a state-of-the-art teaching laboratory of chemistry was established, following the model developed by the French chemist Louis J. Thénard (1777–1857), it never fulfilled its goals, and in fact did not survive long.[31] The entire university system entered a period of decline under the dictatorship of Juan Manuel de Rosas (1829–32, 1835–52).

Consistent with the pattern in Spanish-speaking America, this dictatorship was followed by a process of national reorganization. In this process, by the 1860s the economic system of Argentina had undergone a major transformation. It was integrated into international markets as an agricultural and livestock producer, and imported manufactured goods. This resulted in dramatic social and demographic changes. Within this context, particular relevance was attributed to chemistry for its close relationship to industry, production, and health.[32] Several institutions were created for public health, food production, trade, and agriculture in the 1880s, including government-run chemical bureaus and laboratories.

The new dean of University of Buenos Aires, appointed in 1861, was strongly persuaded that science afforded the path to train the professionals needed for the economic and industrial development of the country, as well as to develop and spread the values of a democratic republican society. A new Department of Exact Sciences was thus created (1865) with the explicit purpose of establishing the teaching of science and training engineers.[33] Within this context, a young Spaniard with a doctorate in physical and mathematical sciences and a career in pharmacy, Manuel Puiggari (1827–1899), was appointed to the chair of chemistry.[34] Puiggari established a teaching laboratory on the model of that of Justus von Liebig

[29] Gabriel Matharan, 'Los inicios de la enseñanza experimental de la química: el caso del Laboratorio de Química de la Universidad de Buenos Aires (1823–1865)', *Saber y Tiempo* 1/1 (2015), 96–117, on 99–101.

[30] Up to that moment, chemistry was only taught as a part of the training of doctors and pharmacists; see Daniel Coria, 'La química en Argentina: un esbozo de 200 años de historia', *Invenio*, 19/37 (2016), 7–10.

[31] Matharan, 'Inicios de la enseñanza', 102–6; Gabriel Matharan, 'La emergencia y la dinámica de la investigación química en la Argentina (1896–1942)', in *13º Seminário Nacional de História da Ciência e da Tecnologia. Anais*. São Paulo, September 3–6, 2012, on 3. Available at:
http://www.13snhct.sbhc.org.br/resources/anais/10/1345002400_ARQUIVO_GabrielMatharanTrabajo.pdf

[32] Matharan, 'Emergencia y dinámica', 6.

[33] Along the 1880s, the government established laboratories for chemical studies and research, such as the municipal chemistry bureau of National Institute of Hygiene, and laboratories at the National Sanitation Service; see Ibid, 6.

[34] Matharan, 'Inicios de la enseñanza', 107–11.

(1803–1873), i.e. where students were expected to learn by performing 'chemical manipulations'.[35] Yet, chemistry remained tied to medicine and pharmacy through a link that only began to dissolve at the end of the 1890s, when the first university career in chemistry, a doctoral course, was established at the University of Buenos Aires School of Exact, Physical, and Natural Sciences (1896).[36] As we shall see, this association of chemistry with pharmacy was also present in Mexico.

The focus of this doctoral course in Argentina was not chemistry as such, but its possible applications. It aimed at training professionals for the technico-bureaucratic needs of the government. Thus, the practical side of the course was conducted at the aforementioned government-run laboratories, which eventually hired the graduates of this doctoral course. Interest increased gradually, as the number of graduates grew from 3 (1897–1902) to 217 (1932–1941).[37] Starting around 1910, two trends began to take shape and remain to this day: teaching that was centered on the training of professionals for industry, and the education of university professors, investigators, and laboratory experts.[38] Research began to gain momentum when chemists, congregated in the Argentinian Chemical Society (created in 1912 and renamed the Argentinian Chemical Association in 1920) succeeded in persuading the government, universities, and the industry of their relevance. The establishment of the earliest research institutes and incipient professionalization of research became available.[39] The creation of these institutes led to the emergence of research as a profession and to the development of research groups. Yet, positions of full-time professors and professional investigators were established only at the turn of the 1950s, with the creation/re-foundation of institutions such as the National Scientific and Technical Research Council (CONICET) and the modernization of the universities.[40]

Mexico has had a long tradition of chemical research starting from the colonial period. It first focused on mining and metallurgy, then also on the native flora and fauna. Nevertheless, specifically chemical laboratories

[35] Ibid, 107–11.

[36] To be sure, Puiggari strongly associated with pharmacists and the teaching of pharmacy and his tenure was characterized by efforts to detach this profession from the control and supervision of doctors; see Coria, 'La química en Argentina', 8.

[37] Matharan, 'Emergencia y dinámica', 7; 'Constitución de la química', 68.

[38] Coria, 'Química en Argentina', 8; Matharan, 'Constitución de la química', 70.

[39] Matharan, 'Constitución de la química', 70. The earliest research-only institutions were Institute of Chemical Research, National University of La Plata (1926); Institute of Microchemical Research, National University of the Littoral (1936); and Institute of Scientific and Technological Research, National University of the Littoral (1929); see Matharan, 'Emergencia y dinámica', 11–12.

[40] Matharan, 'Constitución de la química', 71.

began to appear only at the turn of the twentieth century.[41] An example was the Departments of Analytical and Industrial Chemistry of the National Medical Institute (opened in 1904). These laboratories, designed for manufacturing industrial chemicals and pharmaceuticals from native plants and products, also served to train pharmacists. Some of their trainees later became professors at the School of Chemistry at the National University of Mexico.[42]

Following a long period of civil war, industrialization and economic reactivation ensued in the early decades of the twentieth century. The new constitutional governments were persuaded that professional education, particularly within the university setting, ought to be fully aligned to the problems affecting the population and to boost the Mexican economy. This development-centered approach gave a strong impulse to careers in applied science and industry. This was the context for the creation of the National School of Chemical Industries in 1916, the first formal school for chemical teaching in the country.[43] This school, incorporated the following year into the National University as the School of Chemical Sciences, sought to train chemical technicians, industrial investigators, chemical engineers, and chemists, and particularly to prepare youths for the

[41] Royal Mining Body of New Spain (1792) and Royal Mining Seminary; 19th century: chemical laboratories at National School of Medicine and National School of Agriculture, mainly devoted to teaching; chemical laboratory at the Customs Administration, targeting control of the quality of food, beverages and other products; chemical laboratory at the Superior Health Council, for analysis of food, beverages and medicines, among others. See Andoni Garritz Ruiz, 'Breve historia de la educación química en México', *Boletín de la Sociedade Química Mexicana*, 1/2 (2007), 3–24; Liliana Schifter and Patricia Aceves, 'The Development of Industrial Chemistry at the National Medical Institute (1904–1915), The Study of Mexican Medicinal Plants' in Ana M. Alfonso-Goldfarb et al. (eds.), *Crossing Oceans: Exchange of Products, Instruments and Procedures in the History of Chemistry and Related Sciences* (Campinas, 2015), 285–98.

[42] Schifter and Aceves, 'Development of Industrial Chemistry', 288, 295–6. There are instances of chemists who sought more specialized training in Europe, as e.g., V. Ortigosa, who spent some time at von Liebig's laboratory in Giessen in 1842; however, upon returning to Mexico, he met a total lack of infrastructure to continue his work of research; see Garritz Ruiz, 'Breve historia', 9.

[43] Until this moment, the few academically trained chemists had their professional education in European universities; see Felipe L. Olivares, 'Pioneros de la investigación científica de la UNAM', *Educación Química*, 17/3 (2006), 335–42. On this subject, see Rogelio Godímez Resendiz and Patricia Aceves Pastrana, 'Los primeros químicos y el surgimiento de la industria farmacéutica en México (1900–1940)' in A.M. Alfonso-Goldfarb et al. (eds.), *Simão Mathias—Cem Anos: Química e História da Química no Início do Século XXI* (São Paulo, 2010), 88–106; and Patricia Aceves and Sandra Martínez, 'Los farmacéuticos y los químicos mexicanos en la búsqueda de su identidad en los inicios del siglo XX', in J.A. Chamizo (ed.), *Historia y filosofía de la química: aportes para la enseñaza* (México DF, 2010), 114–41, on 125 et seq. Between 1865 and 1870, the Literary Institute (later Scientific and Literary Institute) included a chair of organic and inorganic chemistry; see Garritz Ruiz, 'Breve historia', 10.

exploration and exploitation of Mexico's natural resources.[44] However, due to budget restraints, this school never enjoyed the infrastructure required for experimental training, which instead was available in industrial laboratories.[45] Though grants for the best students to pursue their studies in Europe, Germany in particular, were available, upon these students' return to the country they had to contend with the lack of research infrastructure.[46] Nevertheless, the school's graduates became the professional manpower in schools, laboratories, and the incipient chemical-pharmaceutical industry.[47]

Starting in 1934, the National University of Mexico underwent a thorough reform, leading, among other results, to the creation of a doctoral course in the sciences. The explicit goal of the course was to train researchers in subjects of practical and industrial interests for the economic development of the country. This new orientation resulted in the creation of two learning programs, one for professional training and the other devoted to formal graduate education (the Graduate School). The Chemistry Department at the School of Philosophy and Literature was incorporated into the Program of Advanced Studies, which was entitled to grant doctoral degrees.[48]

The teaching profile at the chemical school began to change following the appointment of Fernando Orozco (1899–1978) as its director in 1935. Having graduated in industrial chemistry at the School of Chemical Sciences and then earning a doctorate in chemistry in Germany, he sought to boost chemical research upon his return to Mexico. For that purpose he first transformed the older workshops into proper laboratories for scientific education, updated the teaching curriculum, and established the Chemistry Institute—with help from the Rockefeller Institute and the Bank of Mexico—as a locus for fundamental research and the training of researchers.[49] Although material resources were scarce, the Institute activities flourished through partnerships with industry.[50] As part of the new program, the best students of the School of Chemical Sciences were

[44] Godímez Rezendiz and Aceves Pastrana, 'Primeros químicos', 90–1. Following the inclusion of pharmacists, in 1919 the institution was renamed School of Chemistry and Pharmacy.

[45] Ibid, 91; Aceves and Martínez, 'Farmacéuticos', 130.

[46] Garritz Ruiz, 'Breve historia', 12–13.

[47] Godímez Rezendiz and Aceves Pastrana, 'Primeros químicos', 91.

[48] Olivares, 'Pioneros', 336. To remind briefly, in the nineteenth century, especially in Germany, the traditional faculty of arts became the faculty of philosophy, which included teaching of sciences; for more detail see, e.g., Charles E. McClelland, *State, Society and University in Germany, 1700–1914* (Cambridge, 1980); and Kathryn M. Olesko (ed.), *Science in Germany: The Intersection of Institutional and Intellectual Ideas*, *Osiris*, 5/1 (1989).

[49] Ibid, 337. [50] Ibid, 340.

invited to perform their dissertation research at the Institute. A system of grants to study abroad was established, whereby several candidates spent periods in England, the United States, or France.[51] Starting in 1941, the Graduate School offered a doctoral program in chemistry, which was coordinated by the Chemistry Institute, and the young doctors were consequently invited to join the group of researchers at the Chemistry Institute.[52] Professionalization of research was sanctioned when the position of full-time investigator was established in 1954.[53]

To summarize, in Argentina and Mexico, as well as in other countries in Hispanic America, the fact that universities were created early as part of the Spanish colonization policy does not seem to have contributed to the development of research traditions or communities for chemistry. Following independence, the traditionally integrated university was fragmented into professional schools intended to boost the economic development of the young countries, and were accessible mainly to the elite. Chemistry, first taught as an auxiliary discipline to mining, engineering, or medical students, gradually came to be seen as particularly useful for agriculture and local industries, though it hardly lost its close ties to pharmacy, e.g. through the manufacture of drugs, until it became an independent field of research at the turn of the twentieth century.

A Country Without Universities: No Institutional Locus for Chemistry in Brazil?

Brazil, the largest country in Ibero-America, had a substantially different geopolitical history. To begin with, the Portuguese Crown's policies for exploration, exploitation, and education included a stubborn refusal to establish formal universities for more than 400 years, from the early period of colonization, through those of royal and imperial rule and republican governments, to the age of Positivism in the last decades of the 1800s.

The Portuguese policy for Brazil was dramatically different from that applied by Spain in its American colonies, particularly in regard to actions likely to promote the development of its 'new' territory. Indeed, only elementary education was allowed in the Portuguese colony until the beginning of the nineteenth century, especially following the expulsion of the Jesuits in 1759. As part of the organized efforts to strengthen the colony's dependence, creating higher education institutions was strictly prohibited. Anyone desiring advanced learning had to seek it in Europe,

[51] Ibid, 339. [52] Ibid. [53] Ibid, 340.

Portugal in particular.[54] Even books were scarce: those that succeeded in reaching Brazil were subjected to heavy censorship, and printing presses were banned. Initiatives to explore native resources were all but irrelevant until the end of the eighteenth century. In addition, the results could be informed to the Portuguese government alone, which kept these discoveries secluded as state secrets.

This sorry state of affairs, in comparison with other American countries, began to change when the Portuguese Crown moved to Rio de Janeiro in 1808, facing the imminent invasion of Portugal by Napoleon. Brazil thereby became the administrative seat of the kingdom, and the Portuguese sought to replicate some of their traditional institutions there. For instance, on his way to Rio de Janeiro, Prince Regent João (future King D. João VI) stopped in Salvador, Bahia, where he decided to establish a school of surgery.[55] The conditions in the colony long precluded the creation of a true medical school, therefore, the earliest initiatives for medical teaching in Rio de Janeiro consisted of a simple anatomy chair in 1808, followed by the few others needed to train elementary qualified health care providers, especially surgeons.[56] Teaching in engineering began soon after, in 1810, and was somewhat more organized in terms of guidelines.[57] Together with these first schools, a publishing house opened to print governmental documents along with some books, usually translations, needed by the students of these new schools.

In 1822, the colony proclaimed its independence from Portugal, and consequently became the Empire of Brazil, headed by Emperor D. Pedro I, a son of King D. João VI. Some changes in education ensued, such as improved organization of the medical and engineering courses, and the creation in 1827 of two courses on 'juridical and social sciences', one in São

[54] Ana M. Alfonso-Goldfarb, Márcia H.M. Ferraz and Maria H.R. Beltran, 'Substitutos do "Novo" Mundo para as Antigas Plantas Raras: Um Estudo de Caso dos Bálsamos', *Química Nova*, 33/7 (2010), 1620–26; Daniel Guerrini, Renato de Oliveira and Luciano Fedozzi, 'A Formação da Universidade de Pesquisa no Brasil', in *Seminário Internacional de Educação Superior 2014, Anais Eletrônicos*, available at: http://uniso.br/publicacoes/anais_eletronicos/2014/5_es_memoria/01.pdf, cited 24 July 2017; Maria de L. de A. Fávero, 'As Universidades no Brasil: Das Origens à Reforma Universitária de 1948', *Educar*, 28 (2006), 17–36, on 20. The only institutions for higher education in Brazil were Jesuit colleges; see Arnaldo Barreto and Carlos A.L. Filgueiras, 'Origens da Universidade Brasileira', *Química Nova*, 30/7 (2007), 1780–90.

[55] Ruling from February 18th, 1808, *Collecção das Leis do Brasil, 1808*, part 2 (Rio de Janeiro, 1891), 2.

[56] Márcia H.M. Ferraz, *As Ciências em Portugal e no Brasil (1772–1822), O Texto Conflituoso da Química* (São Paulo, 1997), 191–92.

[57] Ferraz, *Ciências em Portugal*, 209; Decree from July 6th, 1810, *Collecção das Leis do Brasil, 1810*, part 1 (Rio de Janeiro, 1891), 118.

Paulo and the other in Olinda.[58] Further modifications were introduced in the nineteenth century, including the splitting of the engineering course into the Military School and the Central School, which was renamed the Polytechnic School in 1874, as the result of a considerable reform.[59] This Polytechnic School, the medical school, and a few other schools created along the last quarter of the nineteenth century, along with private laboratories, engaged in studies on minerals and other native resources.

Of particular interest for our purpose here are a 'Chair of Chemistry' established in 1817 in Bahia (though it is not known whether it ever functioned as designed),[60] and a 'Practical Chemical Laboratory' created in Rio de Janeiro in 1812 to perform chemical analyses,[61] with emphasis on substances for use in the crafts and trade.[62] The Practical Chemical Laboratory lasted about seven years and is believed to have also developed processes for native products.[63] In addition to these official facilities, a private chemical laboratory was established by Antônio Araújo de Azevedo (1754–1817). This laboratory functioned from 1808 to 1819, when it was incorporated by the state and closed soon afterwards. In addition to analyses of natural products, this laboratory also served to prepare medicines for the army and to teach chemistry lessons, mainly to medical students.[64]

[58] Law from August 11th, 1827, *Collecção das leis do Brasil, 1827* (Rio de Janeiro, 1878), i. 5.

[59] Ana M. Alfonso-Goldfarb and Marcia H.M. Ferraz, 'Mining School of Ouro Preto: An Attempt to Establish Metallurgy in Brazil', *Quipu,* 12/1 (1999), 25–37, on 29.

[60] Ferraz, *Ciências em Portugal*, 195; Ana M. Alfonso-Goldfarb and Marcia H.M. Ferraz, 'Reflexões sobre uma História Adiada: Trabalhos e Estudos Químicos e Pré-Químicos Brasileiros', *Quipu* 5 (1988), 3–12. According to some sources, this chair was inaugurated in 1833, see Kedima F. Oliveira Matos, 'A Química na Bahia: da Faculdade de Medicina à Faculdade de Filosofia, Ciências e Letras (1889–1950)' (Master's thesis, Pontifical Catholic University of São Paulo, 2006), 9.

[61] Ferraz, *Ciências em Portugal*, 212 et seq.; Simon Schwartzmann, 'Introdução', in Simon Schwartzmann (ed.), *Universidades e Instituições Científicas no Brasil* (Brasilia, 1982), 7–16, on 9; Heinrich Rheinboldt, 'A Química no Brasil', in Fernando de Azevedo (ed.), *As Ciências no Brasil* (São Paulo, 1955), ii. 9–92, on 22–6.

[62] Rheinboldt, 'Química no Brasil', 22–5. However, the laboratory activities were soon channeled toward work without any scientific value whatsoever, namely, selling of medicines.

[63] Activities included analysis of brasilwood and sulfur mineral waters, as well as preparation of opium from poppy; see dos Nadja P. Santos, 'Laboratório Químico-Prático do Rio de Janeiro: A Primeira Tentativa de Difusão da Química no Brasil (1812–1819)', *Quimica Nova*, 27/2 (2004), 342–8, esp. on 346.

[64] Ferraz, *Ciências em Portugal*, 197–9; Santos, 'Laboratório Químico-Prático', 347; Nadja P. dos Santos, 'Os Primeiros Laboratórios Químicos do Rio de Janeiro' in *XI Encontro Regional de História, ANPUH-RJ, 2004*. Rio de Janeiro: UERJ/ANPUH/Arquivo Público do Rio de Janeiro, 49–50 (full text available at: http://www.memoriasdaquimica.ccs.ufrj.br/txt/npds.pdf).

More relevant and long lasting was the chemistry laboratory established at the National Museum in 1824, devoted to chemical analyses of natural resources such as minerals, coal, and pau-brasil (*Paubrasilia echinata* Lam., brazilwood). Initially run by chemists who had had training in France,[65] the appointment of the German naturalist and pharmacist Theodor Peckolt (1822–1912) in 1874 raised expectations. However, whereas Peckolt did restructure and renovate the laboratory, his tenure was too short to have lasting impact. More interested in the Brazilian medicinal plants, he established a laboratory in his own chemist's shop, where he conducted studies on about 6,000 species, many of which were published in Brazil and abroad or presented in national and universal exhibitions. Peckolt thus contributed to the development of phytochemistry, one of the most relevant fields of chemical research in Brazil. However, he did not devote any attention to the training of future researchers.[66]

Here we have the first sign of a pattern that, as we shall see, would repeat time and again: foreign chemists were hired to teach and/or establish laboratories, they performed their research and/or trained students, but their tenure was too short, or their institutions were closed after their death or as the result of political upheavals. This was the case, for instance, of Claude H. Gorceix (1852–1919), who was brought from France by Emperor D. Pedro II to establish and direct the first mining school for the studies of minerals. The conditions seemed ideal: Brazil is rich in minerals, and Minas Gerais, the province where the school was located, remains to this day one of the richest in minerals, which at that time demanded urgent studies. For this purpose, Gorceix formulated a program that included specialized training for engineers and scientific studies of Brazilian minerals in laboratories furnished with modern equipment. Such goals were accomplished. But soon they had to be modified, because the students did not have the preparation necessary to follow the teaching, and the few who managed to graduate had to compete with specialists brought to the country by foreign mining companies.[67] In order not to lose all the time and money invested in this school, a course on civil engineering was established, while Gorceix was compelled to continue his research with a single assistant.[68]

[65] Rheinboldt, 'Química no Brasil', 26–32.

[66] Nadja P. dos Santos, Angelo C. Pinto and Ricardo B. de Alencastro, 'Theodoro Peckolt: Naturalista e Farmacêutico do Brasil Imperial', *Quimica Nova*, 21/5 (1998), 660–70; Simão Mathias, 'Cem Anos de Química no Brasil', *Revista de História*, 63 (1975), 5–69, on 6–7.

[67] Alfonso-Goldfarb and Ferraz, 'Mining School', 37–8.

[68] Ibid, 37–8; Mathias, 'Cem Anos', 15.

A similar story occurred in Rio de Janeiro, the Empire's capital. As was mentioned above, in 1874 the Polytechnic School was created as an offshoot of the older Royal Military Academy. The curriculum demanded that students first attend a common preparatory course, including chemistry, before entering the professional schools. However, appropriate teachers were lacking.[69] In 1884 Wilhelm Michler (1846–1887), a professor at the Polytechnic School of Zurich, was appointed to the chemistry chair. He established a well-equipped research laboratory—first with his own resources, reimbursed only much later and with considerable difficulty. In this laboratory, with room for 30 students, he conducted original chemical studies of Brazilian plants. Although he trained some Brazilian disciples, the laboratory did not survive after his death.[70]

In a few cases, specialists brought from abroad succeeded in making a difference in chemical research and education. One example is the Imperial Agronomic Station of Campinas, founded in 1887 in the interior of the province of São Paulo for the study of tropical crops in the area, one that was very fertile and home to large plantations. The appointed director was the Austrian chemist Franz W. Dafert (1863–1933), who had earned his doctoral degree from the University of Giessen.[71] Soon Dafert established laboratories and stoves, and collected all the equipment needed for research to bear expected fruit. Research was to be conducted in the German style. He gathered a highly qualified staff rather quickly, including Brazilian and foreign experts. All were engaged in original research based on the local conditions, not always with an eye on immediate practical applications. During the ten years of Dafert's tenure, research at the Station attained a stunningly high level. However, despite several practical problems that he solved related to pests and epidemics, Dafert's work was a target of continued criticism by those who expected immediate results.[72] After his departure in 1897, the new director enacted a research policy centered on profitable applications to agriculture. Dafert's guidelines were reestablished

[69] Rheinboldt, 'Química no Brasil', 54 et seq.

[70] Mathias, 'Cem Anos', 12–4; Nadja P. dos Santos, Angelo C. Pinto and Ricardo B. de Alencastro, 'Wilhelm Michler, uma Aventura Científica nos Trópicos', *Quimica Nova*, 23/2 (2000), 418–26, esp. on 422–4.

[71] Tamás J.M.K. Szmrecsányi, 'Origens da Liderança Científica e Tecnológica Paulista no Século XX', *Revista Gestão & Conexões*, 2/2 (2013), 181–206, on 189; Pedro Ramos and Fabrício J. Piacente, 'O Instituto Agronômico de Campinas: Sua Criação, Importância e um Pouco de sua História', *Revista Brasileira de Inovação*, 15/2 (2016), 365–92. The Agriculture Ministry Report for 1888 mentions the emphasis on the chemical work conducted by Dafert at the Station; see Brazil, *Relatorio apresentado à Assembleia Geral, pelo Ministro e Secretario Interino dos Negocios da Agricultura, Commercio e Obras Públicas* (Rio de Janeiro, 1889), 73.

[72] São Paulo state, *Relatório Anual do Instituto Agronômico do Estado de São Paulo em Campinas* (1892), [. . .] pelo Director Dr. F. W. Dafert (São Paulo, 1893).

in 1924, when Teodureto de Camargo, a Brazilian, was appointed director. Original studies were again conducted in large scale. According to some scholars, the success of the Station was largely due to the fact that in its earliest years Brazil had become a republic, and the institution was transferred to the state government.[73]

One of the characteristics of the First Brazilian Republic, proclaimed in 1889, was its decentralizing nature. The individual states had the authority to establish teaching and research institutions considerably independent of the federal government.[74] Most of these new institutions were created with the explicit purpose of solving immediate problems related to agriculture—control of pests, workers' health, and the ubiquitous epidemics that periodically broke out across the country.[75] Most of these research institutes had no links whatsoever to higher education institutions, while some of them established courses for training researchers. For example, the Manguinhos Institute in Rio de Janeiro trained a full generation of investigators who later furnished staff to the main research institutions in other states.[76]

In any case, a spurt of industrialization, triggered by World War I, led the Brazilian government and scholars to adopt an overtly favorable position for scientific development, especially for its practical application and, significantly, with a focus on chemistry. An article written in 1917 by José de Freitas Machado, a professor at the Superior School of Agriculture and Veterinary Medicine of Rio de Janeiro, achieved wide circulation. Entitled 'Let's Make Chemists', it demanded the creation of schools and centers for chemical studies following the Parisian model.[77] It was thus no coincidence that the following year the Chemical Institute of Rio de

[73] Mathias, 'Cem Anos', 15; Szmrecsányi, 'Origens da Liderança', 188–9; Ramos and Piacente, 'Instituto Agronômico', 36–71; Rosely A. de Vargas, 'A Produção Científica Brasileira em Ciências Agrárias Indexada na Web of Science: Características e Redes de Colaboração (2000–2011)' (Master's thesis, Federal University of Rio Grande do Sul, 2014), 32.

[74] Helena Sampaio, 'Evolução do Ensino Superior Brasileiro, 1808–1990', *Documento de Trabalho*, 8/91 (São Paulo, 1991), 7.

[75] Bacteriological Institute (1892) for manufacture of vaccines and medicines and performance of microbiological tests; Butantan Institute (1889) following an outbreak of plague, as a laboratory for production of sera and vaccines; Vaccinogenic Institute (1892); Biological Institute (1928); Forest Institute (1896); Experimental Station of Campinas (later Agronomic Institute of Campinas, 1887). In Rio de Janeiro, Serotherapy Institute of Manguinhos was created in 1899 as a center for combat of environmental diseases to later on become the prestigious Oswaldo Cruz Institute, present-day Oswaldo Cruz Foundation; Guerrini et al., 'Formação da universidade', 6; Sampaio, 'Evolução do Ensino', 7–8.

[76] Schwartzman, 'Introdução', 10.

[77] Mathias, 'Cem Anos', 17; Nadja P. dos Santos, Angelo C. Pinto and Ricardo B. de Alencastro, 'Façamos Químicos: A "Certidão de Nascimento" dos Cursos de Química de Nível Superior no Brasil', *Quimica Nova*, 29/3 (2006), 621–6.

Janeiro was founded. Its chair for more than twenty years was Mário Saraiva, a physician from Bahia who was considered to be an expert in chemical research. The Institute specialized in Brazilian natural products. Transferred in 1934 to the National Department of Plant Production, it became the Institute of Agricultural Chemistry, enjoying national and international fame. More than 200 papers on natural products and agricultural production ensued, almost all of them published in highly reputable journals.[78]

In addition, starting in 1919, several independent courses on industrial chemistry were appended to previously existing technical schools. Many of these courses eventually became the present-day programs in chemical engineering, which gradually introduced research programs in the 1920s and 1930s.[79] For instance, a 'Course of Industrial Chemistry' was established in 1926 at the Polytechnic School of São Paulo (founded in 1918) side by side with a five-year university-level 'Chemical Engineering Course' that resulted from the merging of the courses for 'chemists' and 'industrial engineers'. Both the courses of industrial chemistry and of chemical engineering were meant to feed trained manpower to the chemical industry that was undergoing overt expansion.[80]

Decentralization favored the establishment of institutions not only in São Paulo, but also all across the country. Following the implementation of these new establishments, foreign chemists were then hired to establish laboratories and training courses, but all of them were ephemeral. This is, for instance, the case with the School of Industrial Chemistry of Pará, in which the former chemist assayer at Université de Nancy, Paul Le Cointe (1870–1956) performed studies on Amazonian flora together with other French colleagues from 1921 until the school's closure in 1930.[81] Chemistry courses were launched in 1921 at the School of Engineering of Porto Alegre, Rio Grande do Sul, taught by German professors, before closing in 1930.[82] Likewise, chemistry courses were available at the School of Engineering of Belo Horizonte, Minas Gerais, taught by German

[78] Mathias, 'Cem Anos', 17; unfortunately, the central government closed this prestigious and highly productive institution in 1962, with no explanation whatsoever and despite the protests of the entire Brazilian scientific community.

[79] Mathias, 'Cem Anos', 18–19.

[80] Rheinboldt, 'Química no Brasil', 68.

[81] Mathias, 'Cem Anos', 18 et seq. This was a four-year course, comprising a minimum of 20 hours/week of practical work in laboratories or seminars, and that delivered a 'chemist diploma' following the conclusion of a dissertation; Rheinboldt, 'Química no Brasil', 3–4.

[82] Rheinboldt, 'Química no Brasil', 71.

professors from 1921 to 1931.[83] Altogether these courses trained about 300 graduates, half of whom entered the profession.[84]

New University Space for Chemical Research

While several higher education institutions in Brazil had been given the name of 'university', one of the first that truly deserved it was the University of Rio de Janeiro (URJ), established by a presidential decree in 1920. It resulted from the union of three professional schools—polytechnic, medicine and law—though without any connecting links between them.[85] In any case, this development promoted serious discussions in the 1920s on the role of universities, especially within the Brazilian Academy of Sciences and the Brazilian Academy of Education, which strongly advocated the value of 'pure science' that had no immediate useful application.[86] This trend developed against an older Positivistic tradition particular to Brazil, according to which professional and technical training was to be preferred over the university style of education, considered to be exclusively accessible to the elite.[87]

This wave of optimism notwithstanding, the decade closed in 1930 with a political coup that enthroned Getúlio Vargas (1882–1954) as president. Vargas enacted radically centralizing and interventionist policies with direct impact on education. A Statute of the Brazilian Universities was passed in 1933, including a reform of URJ, which against the expectations of the intellectual elite remained a professional school without any room

[83] Ibid, 72. This pattern would have a remarkable long life: in 1941 the German chemist Fritz Feigl (1891–1971) was hired to run a—very modest—chemical laboratory in Rio de Janeiro, where he performed considerable work with Brazilian colleagues. However, the laboratory, which was never incorporated into any higher education institution, was closed when he died. Since Feigl never had a chance to create a school of researchers, he was not able to establish facilities for high-level chemical research. The same was the fate of Hans Zocher (1893–1969) who arrived in Rio de Janeiro in 1946; see the anonymous 'À Memória do Professor Hans Zocher', *Anais da Associação Brasileira de Química*, 30/3&4 (1979), 7–10.

[84] Rheinboldt, 'Química no Brasil', 74.

[85] Fávero, 'Universidades no Brasil', 22. In 1927, a second university was created in Minas Gerais, also out of the merging of professional schools (engineering, medicine, dentistry and pharmacy).

[86] Ibid, 3; Antonio Paim, 'Por uma Universidade no Rio de Janeiro', in Simon Schwartzman (ed.), *Universidades e Instituições Científicas no Brasil* (Brasilia, 1982), 17–96, on 29–30; Eunice R. Durham, 'As Universidades Públicas e a Pesquisa no Brasil', *Documento de Trabalho*, 9/98 (São Paulo: Núcleo de Pesquisas sobre Ensino Superior/USP, 1998); Simon Schwartzman, *Um Espaço para a Ciência: A Formação da Comunidade Científica no Brasil*. 2nd ed. (Brasilia, 2001), v. 5–6; Sampaio, 'Evolução do Ensino', 8.

[87] Ana M. Alfonso-Goldfarb and Márcia H.M. Ferraz, 'Raízes Históricas da Difícil Equação da Institucionalização da Ciência no Brasil', *São Paulo em Perspectiva*, 16/3 (2002), 3–14, on 9.

for scientific research.[88] Yet the decree also preserved room for state universities, granting them full freedom from federal supervision, which in the last instance afforded the path through which research could be finally institutionalized.[89] Naturally, this could not occur in Rio de Janeiro, the capital and seat of the central government. The radical shift took place in São Paulo.[90]

The state of São Paulo had rebelled against Vargas in 1932 with the ambition of reestablishing a constitutional government, only to be quickly defeated. The appointed federal intervenor had close ties to the liberal and intellectual Paulista elite, who strongly supported the creation of a research university more akin to the European standards of higher education.[91] As a result, the University of São Paulo (USP) was created through a state decree in 1934.[92] From its very inception, the basic design of USP was substantially different from any other university projects in Brazil. Although the preexisting professional schools were integrated into the new institution,[93] the core of the new institution was the School of Philosophy, Science and Literature (Faculdade de Filosofia, Ciências e Letras—FFCL), the equivalent of the German philosophical faculty, originally intended to be of mandatory attendance for all students before their admission into the professional schools.[94] The university statutes introduced an academic

[88] Talamira T.R. Brito and Ana M. de O. Cunha, 'Revisitando a História da Universidade no Brasil: Política de Criação, Autonomia e Docência', *Aprender*, 7/2 (2009), 43–63, on 51–2; Fávero, 'Universidades no Brasil', 24; Paim, 'Por uma Universidade', 18, 57; Schwartzman, 'Introdução', 10; Sampaio, 'Evolução do Ensino', 10–11.

[89] Paim, 'Por uma Universidade', 57.

[90] Schwartzman, 'Introdução', 10. To be true, also a new university conceived of as a locus for free activity and non-utilitarian culture was established in Rio de Janeiro (University of the Federal District) however, it was closed after just four years; Fávero, 'Universidades no Brasil', 25–6.

[91] Paim, 'Por uma Universidade', 69. Application of the model varied according to the professors called to develop new scientific areas, to wit, the French model mainly in the humanities, the German in chemistry, and the Italian in physics and mathematics.

[92] Diogo da S. Roiz, 'Entre Memórias e Histórias da Universidade de São Paulo: Histórias em Construção', *HISTEDBR*, 21 (2006), 52–64, on 53. Creation of USP resulted from a convergence of reasons, including: the will of the federal government to appease powerful São Paulo after crushing the 1932 revolt; symbol of power for the state of São Paulo; and attempt of the Paulista elite to return to the political foreground, however, no longer through military, but through intellectual power; see Alexandre M. de M.P. Ferreira, 'A Criação da FFCL da USP: Um Estudo sobre o Início da Formação de Pesquisadores e Professores de Matemática e Física em São Paulo' (PhD dissertation, Pontifical Catholic University of São Paulo, 2009), 60 et seq.; Sampaio, 'Evolução do Ensino', 11–12; Schwartzmann, *Espaço para a Ciência*, v. 21–2.

[93] Schools of law, polytechnic, agronomy, medicine, and veterinary medicine; also the Institute of Education was incorporated into USP; see Brito and Cunha, 'Revisitando', 53.

[94] Which desire, however, never came to fruition; see Paschoal Senise, *Origem do Instituto de Química da Universidade de São Paulo: Reminiscências e Comentários* (São Paulo, 2006), 14; Brito and Cunha, 'Revisitando', 53; Ferreira, 'Criação da FFCL', 77 et seq; Roiz, 'Entre

doctoral program for the very first time in the history of Brazil. The doctoral degree could be granted after students completed a previous licentiate degree requiring three years of studies, two additional years of internship in seminars and laboratories, and the defense of a dissertation resulting from original research or substantial cultural work.[95] To fulfill these goals, USP had to have research laboratories, experimentation fields, equipment for biological, biogeographical, geological, and mineralogical research, general and specialized libraries, an office for national and international exchange, a university press, meeting halls, movie and records collections, a radio station, and an outreach office.[96] Per the statutes, the position of full-time professor was established, and all the professors were required to perform, promote, and supervise research projects, as well as organize and participate in courses and conferences.[97]

The underlying objectives of this plan were to create research schools, train researchers, and prepare professors with close contacts within the international scientific community.[98] The founders of USP believed that these goals could only be accomplished by hiring European professors from abroad for FFCL, the university's base for research. These professors were recruited from France, Germany, and Italy.[99] As concerns chemistry, our focus of interest here, the Department of Chemistry, FFCL/USP, was the first institution explicitly established to educate scientifically trained chemists who would lay the groundwork for a genuine center of research and innovation.[100] Throughout its thirty-five years of existence (1935–1970) before becoming the Institute of Chemistry, as we discuss below, the Chemistry Department staff trained around forty doctoral students and published well over 300 articles reporting on original research, almost all of them in international journals.[101]

The first chair of the Chemistry Department was the German chemist Heinrich Rheinboldt (1891–1955). Rheinboldt studied general chemistry and geology at the Technische Hoschschule of Karlsruhe and the University of Strassburg (Strasbourg), and earned a doctoral degree in 1918 under the

Memórias', 52, 54; Schwartzman, *Espaço para a Ciência*, v. 22; Sampaio, 'Evolução do Ensino', 13. Actually, the idea of the School of Philosophy had been considered in the 1933 reform, but was not actualized in the Carioca universities; see Schwartzmann, *Espaço para a Ciência*, 5, 24; Sampaio, 'Evolução do Ensino', 11–12.

[95] State decree 6283/34, art. 10 and 12. The Law School had established a doctoral program in 1931; the one alluded here was the first doctoral program in sciences in Brazil.

[96] Ibid, 28. [97] Ibid, 39.

[98] Fávero, 'Universidades do Brasil', 27–8; Roiz, 'Entre Memórias', 4.

[99] Brito and Cunha, 'Revisitando', 54; Ferreira, 'Criação da FFCL', 77 et seq; Schwartzman, *Espaço para a Ciência*, 5, 22.

[100] Rheinboldt, 'Química no Brasil', 79. [101] Mathias, 'Cem Anos', 29.

supervision of Paul Pfeiffer, a student of Nobelist Alfred Werner.[102] After a period serving as a teaching and research assistant at chemistry institutes in Strasbourg and Karlsruhe, Rheinboldt moved with Pfeiffer to Bonn in 1922, where he obtained his habilitation in 1924, was made extraordinary professor in 1928, and two years later was charged with teaching analytical and inorganic chemistry. By 1934 he had supervised thirty-five doctoral dissertations.[103] Distressed by the rise of the Nazis, he accepted the position in Brazil, where he arrived in July 1934.[104] Upon Rheinboldt's request, USP hired from Europe Heinrich Hauptmann (1905–1960) as his assistant. After leaving the University of Göttingen to escape Nazi persecution, Hauptmann had been appointed professor at the École de Chemie in Geneva, and arrived in Brazil in February 1935.[105]

The reasons for the earliest students to enroll in the new chemistry course at USP were diverse and curious. Since his youth, Simão Mathias (1908–1991), the first student ever to earn a doctoral degree in science from USP (1942), dreamed of devoting himself to fundamental research in science—mathematics in particular.[106] Since there were no conditions for such endeavors in Brazil, he contented himself with what he believed

[102] Alfred Werner (1866–1915) established the grounds of modern coordination chemistry, earning the Nobel Prize in Chemistry in 1913. His most successful student and then assistant was Pfeiffer (1875–1951) known for the 'Pfeiffer effect', namely, the fact that optically active compounds influence the optical rotation of a racemic mixture of another compound.

[103] Biographical sketch in Fernando de Azevedo (ed.), *As Ciências no Brasil* (São Paulo, 1955), ii. 10. In addition, Rheinboldt was foreign editor of *Journal of Chemical Education* and *Chymia*; see also Ralph E. Oesper, 'Heinrich Rheinboldt', *Journal of Chemical Education*, 27 (1950), 296; and Simão Mathias, 'O Departamento de Química da Faculdade de Filosofia, Ciências e Letras: Primeiros Anos', *Química Nova*, 7/4 (1984), 191–7, on 191–2. A considerable part of the data in this section was taken from interviews given by the actors themselves, within a project conducted at Center Simão Mathias of Studies on History of Science (CESIMA), based on the concepts and methods of oral history; on this see Ana M. Alfonso-Goldfarb, Márcia H.M. Ferraz, Maria H.R. Beltran and Andrea P. dos Santos, ed., *Simão Mathias—Cem Anos: Química e História da Química no Início do Século XXI* (São Paulo, 2010); Andrea dos S.O. Kamensky, 'Construction of Documents and Memories of the Brazilian Chemical Community: Intellectual Influences, Beliefs and Achievements', in Ana M. Alfonso-Goldfarb et al (eds.), *Crossing Oceans*, 229–48; and Ana M. Alfonso-Goldfarb, Márcia H.M. Ferraz and Silvia Waisse, 'The Role of Oral History in the History of 20th Century Chemistry', in Isabel Malaquias and Peter J. T. Morris (eds.), *Perspectives on Chemical Biography in the 21st Century* (Newcastle upon Tyne, 2019), 61–9.

[104] Ernesto Giesbrecht, 'Ernesto Giesbrecht: O Desenvolvimento do Ensino de Química (interview)', *Estudos Avançados*, 8/22 (1994), 115–22, on 116.

[105] Senise, *Origem do Instituto*, 20; Mathias, 'Cem Anos', 21–6; Mathias, 'Departamento de Química', 195–6.

[106] A touching report of the ceremony in which Mathias was awarded USP first doctoral degree, rousing the applause of the full auditorium, was then made by freshman Antônio Candido, who later on became one of main Brazilian literary critics; see Antonio Candido, Aziz Ab Saber, Carlos G. Mota, Helena Hirata, José E. Mindlin, Maria L. Queiroz, Paulo S. Pinheiro and Pedro Moraes, 'O Ímã que Anima Amigos', in J.L. Goldfarb and

was closest, namely engineering, and then—for unclear reasons—also dentistry. He had already developed a sound career as a dentist when he first learned about the creation of USP. Not without sacrifice, he decided to bet everything to see his dream come true. He became one of the members of the very first class of the USP chemistry course. This decision was much criticized, but time eventually proved it was the best choice he could have made.[107] Another case was Paschoal Senise (1917–2011), then seventeen, who was troubled by professional indecision: while in truth he desired to enter medical school, he feared its rigorous entrance examination.[108] As he told the story, one day he read in a newspaper about the recent creation of USP and FFCL, as well as about the arrival of famous European professors. While he did not have a clear idea of what the job description of a chemist actually was,[109] he finally decided to apply, because 'sound chemical grounds would help me prepare for medical school'.[110] Many others enrolled in the chemistry course based on misguided ideas: some believed the Department was a center of advanced studies, and therefore soon dropped out upon learning it was a full-time undergraduate course with a heavy load of lectures and required credits in experimental work. The course opened in 1935 with forty seats for students, but only about a dozen stayed. Most of them were university professors,

L.F. Colombini (eds.), *O Ímã que Tudo Anima: Homenagem a Simão Mathias*, (São Paulo, 1989), 69–74, on 69–70.

[107] As discussed below, Mathias developed a sound and successful career in chemistry, playing a key role in the future transformations of this field in Brazil and other developments undergone by USP and the university system in the country. Mathias, Emeritus Professor, USP, was the first president of the Brazilian Chemical Association and of the Brazilian Society of History of Science, in addition to secretary of the Brazilian Society for Advancement of Science. For more detail on Mathias' life and work, see the various chapters in *O Ímã que Tudo Anima: Homenagem a Simão Mathias* (see the previous note), esp. the ones written by chemists, Alberto L.R. Barros, Crodowaldo Pavan, Eduardo Peixoto, Ernesto Giesbrecht, José A. Vanin, Luiz C. de Menezes, Paschoal Senise and Renato Cecchini, 'O Ímã que Anima Cientistas e Químicos', 19–68, personal friends, and Candido et al., 69–74.

[108] Senise developed instrumental methods for chemical analysis and played a key role in the development of graduate education in Brazil. He chaired Institute of Chemistry, USP, from 1970 to 1974 and from 1978 to 1982. In 1987 he was appointed Emeritus Professor at USP. Further detail of his career is given later in this article.

[109] Until the opening of the chemistry course, FFCL/USP, chemistry was taught at secondary schools by self-taught pharmacists, physicians, and engineers. As mentioned above, at the higher education level chemistry was taught exclusively as an applied, industrial science; the first chair of chemistry as fundamental science in Brazil was the one at FFCL/USP; Giesbrecht, 'Ernesto Giesbrecht', 116; Senise, *Origem do Instituto*, 16; Mathias, 'Cem Anos', 20–1.

[110] Paschoal Senise, 'Entrevista com Prof. Paschoal Senise (interview)', in A. M. Alfonso-Goldfarb et al. (eds.), *Simão Mathias—Cem Anos: Química e História da Química no Início do Século XXI* (São Paulo, 2010), 140–69, on 140.

joined by four students who were the first to finally graduate: Mathias, Senise, Luciano Barzaghi, and a woman, Jandira França.[111]

The learning style chosen by Rheinboldt was the traditional one for German universities.[112] While there is extensive scholarship on the rise of the so-called 'German model',[113] one might characterize it following Alan Rocke as including a neohumanist, idealist philosophy with its creed of pure science, an empiricist/objectivist laboratory/seminar pedagogy, an appeal to practice, group research tied to advanced education, and the research mandate.[114] Indeed, all the experimental classes were taught in the laboratory, and theoretical subjects were systematically illustrated with experimental demonstrations.[115] From the very beginning of their training, the students received samples for analysis in increasing order of complexity. The results were discussed in weekly colloquia, intended for the students to draw correlations among observed facts.[116] This experience prepared them for original research, albeit with a narrower scope.

Soundly grounded on the principles of self-cultivation and broad-based education, Rheinboldt expected to foster the development of a laboratory culture among his students.[117] His motto was 'to do everything with one's own hands', and consistent with this creed, the students were even required to prepare and clean all the equipment they used. Hauptmann monitored

[111] Senise, *Origem do Instituto*, 20; Mathias, 'Departamento de Química', 192; University of São Paulo, *Anuário da Faculdade de Filosofia, Ciências e Letras da Universidade de São Paulo (1934–1935)* (São Paulo, 1937), 29; Barros et al., 'Ímã que Anima', 39.

[112] Giesbrecht, 'Ernesto Giesbrecht', 116; Mathias, 'Cem Anos', 21.

[113] To mention just a few examples: McClelland, *State, Society and University*; Olesko (ed.), *Science in Germany*; Silvia Waisse, *The Science of Living Matter and the Autonomy of Life: Vitalism, Antivitalism and Neovitalism in the German Long Nineteenth Century* (Saarbrücken, 2010).

[114] See chapter 3 in this volume, 'The Rise of Academic Laboratory Science: Chemistry and the 'German Model' in the Nineteenth Century'. Rocke further observes that the 'German model' was variously interpreted and modified as per national context; therefore, here we contribute to the understanding of this process of import in the Brazilian case.

[115] Giesbrecht, 'Ernesto Giesbrecht', 116; Mathias, 'Cem Anos', 21–2; Senise, *Origem do Instituto*, 25–7; Senise, 'Entrevista', 145.

[116] Senise, *Origem do Instituto,* 27.

[117] This ethos is reflected in a biographical anecdote. Ricardo Ferreira developed an interest in chemistry while attending secondary school. However, in Recife, Pernambuco, Northeastern Brazil, chemistry was merely taught as a side course in the Agronomics School. Upon the advice of a professor, he travelled to São Paulo and enrolled in the chemistry course, FFCL/USP, but found it 'excessively practical'… to the point he was failed twice and finally dropped out; see Ricardo Ferreira, 'Entrevista', in A.M. Alfonso-Goldfarb et al. (eds.), In *Simão Mathias—Cem Anos: Química e História da Química no Início do Século XXI* (São Paulo, 2010), 170–9, on 173. Ricardo de Carvalho Ferreira (1928–2013) eventually became a theoretical chemist; in addition to having been invited to teach at prestigious universities abroad, he became Emeritus Professor, Federal University of Pernambuco, president of the Brazilian Chemical Society, and honor president of the Brazilian Society for the Advancement of Science.

the students' assignments following guidelines specifically formulated by Rheinboldt for this purpose. The overall goal of this program was not to produce skilled assayers, but to train the students in the practice of observation, a skill indispensable to succeed in 'understanding the phenomena and learn[ing] how to think in a chemical manner'.[118] Though without fixed schedules, the program followed Liebig's 'all-day practicum' model.[119] Though assignments were individual, and though the students were evaluated individually by completed tasks, they spent much time together at the laboratory. This promoted comradeship among them and their teachers, which awakened an early sense of professional identity. Indeed, many of these students decided to develop professional careers as chemical researchers, and appreciated the experimental approach as a learning method.[120] This entirely agreed with the laboratory culture that permeated and gave its original and unitary character to the entire FFCL, since the rationale underlying its creation was to privilege creativity through an emphasis on research leading to innovative learning techniques.

Initially, the Chemistry Department was relegated to an annex in the School of Medicine, built with the financial help of the Rockefeller Foundation.[121] Soon the space proved to be insufficient, while the medical students complained against the 'invasion of the philosophers'.[122] As a result, in 1939 the Chemistry Department moved to a different campus together with the other schools of natural sciences. In addition to the opportunity to attend classes in other schools—those of physics, mathematics, and natural history—this move to a new campus favored socializing among students and professors, which gave rise to what became a legendary 'Glette spirit', after the name of the street where the campus was located.[123]

The original undergraduate curriculum extended over three years, at the end of which graduates earned a licentiate degree. Subjects included general and inorganic chemistry (taught in alternating annual courses), physical chemistry and biochemistry (also annually taught in alternation), analytical chemistry, mathematics, physics, and mineralogy. History of

[118] Senise, *Origem do Instituto*, 25–7. [119] See Chapter 3 in this volume.

[120] Ibid, 65–6; Senise, 'Entrevista', 141, 146; Giesbrecht, 'Ernesto Giesbrecht', 117, 120.

[121] There are countless studies on the activities of the Rockefeller Foundation in Brazil; for the case of University of São Paulo, see, e.g., Maria G.S.M.C. Marinho, *Norte-americanos no Brasil: Uma História da Fundação Rockefeller na Universidade de São Paulo* (1932–1954) (Campinas, 2011).

[122] This was no rhetorical figure: in one of their protests, the medical students actually set to fire the construction site of the chemical annex; Mathias, 'Departamento de Química', 193–4.

[123] Senise, 'Origem do Instituto', 24, 31–3, 39; Senise, 'Entrevista', 144–5, 147; Mathias, 'Departamento de Química', 194–5; Giesbrecht, 'Ernesto Giesbrecht', 120.

chemistry was taught in each individual subject.[124] Rheinboldt was aware that a three-year undergraduate course was evidently insufficient to meet the expectations of the students who hoped to develop a career as 'scientific chemists.' Upon the spontaneous request of Mathias, Senise, Barzaghi, and França, a fourth year was added, devoted to chemistry of higher order compounds (present-day coordination chemistry), biochemistry, and additional laboratory work. The four-year course was officially sanctioned through a decree by the federal government from 1946, which also introduced preparative chemistry and industrial chemistry. Instrumental analysis was added in 1952.[125]

For further advancement, all the earliest graduates entered the doctoral program, which, as was mentioned above, required two additional years of courses and seminars and the defense of a dissertation based on original research.[126] A fundamental aspect of the organization of USP was the full autonomy granted to the department chairs. As a relevant example, Rheinboldt chose to apply the German standards of education to the chemistry doctorate, which correspondingly granted the degree of Doctor of Science (Dr. sc.).[127] In contrast, the French and Italian models were preferred for the humanities and for physics, respectively.[128] This situation began to change only after World War II, when North American patterns of graduate education were gradually implemented.

After earning their degrees, the new doctors were advised by Rheinboldt and Hauptmann to spend time as postdoctoral fellows abroad.[129] Indeed, international networking was a crucial component of Rheinboldt's program. In 1949, Hauptmann went to the University of California Berkeley and Harvard. In the 1950s all the doctors travelled abroad,

[124] Brazil, *Decreto nº 39, de 3 de Setembro de 1934*. Available at: http://www2.camara.leg.br/legin/fed/decret/1930–1939/decreto-39-3-setembro-1934-515616-norma-pe.html; Senise, *Origem do Instituto*, 23. Following a reform of the university system established by the federal government in 1939, the curriculum was redefined as follows: 1st year—Complements of Mathematics, General and Experimental Physics, General and Inorganic Chemistry, Qualitative Analytical Chemistry; 2nd year—Physical Chemistry, Organic Chemistry, Quantitative Analytical Chemistry; 3rd year—Superior Chemistry, Biological Chemistry and Mineralogy; Senise, *Origem do Instituto*, 43.

[125] Senise, *Origem do Instituto*, 27–8; 44–5; Mathias, 'Departamento de Química', 193; University of São Paulo, *Anuário da Faculdade de Filosofia, Ciências e Letras da Universidade de São Paulo (1936)* (São Paulo, 1937), on 239.

[126] Senise, *Origem do Instituto*, 36–7.

[127] As emphatically stressed by Simão Mathias in an interview he gave in 1977, see 'Entrevista (1977)', interview given to Simon Schwartzmann, Ricardo G.F. Pinto and Nadja C.X. Souza (Rio de Janeiro, 1985), 31. Transcripts available at Historical Archives, Center of Logic, Epistemology and History of Science, State University of Campinas (UNICAMP).

[128] Mathias, 'Entrevista', 34–5.

[129] Mathias, 'Cem Anos', 26.

especially to the United States, mainly funded by the Rockefeller Foundation.[130] A pattern subsequently developed: following their return to Brazil, these scientists were appointed to university positions, where they continued their research with the help of students, thus contributing to the training of the following generations of chemists.

The material conditions necessary to launch a formal research program were met after the move to the Glette campus. For this purpose, the earliest doctors were appointed as assistants—Matthias and Senise to Rheinboldt, and França to Hauptmann. Barzaghi was hired by the Institute of Technological Research (IPT), USP.[131] The latter appointment shows the high degree of recognition chemistry had already achieved as a fundamental science. While most professors at the Polytechnic School viewed the FFCL with misgivings, the IPT director clearly understood the significance of fundamental research, and sought to develop closer contacts with Rheinboldt and Hauptmann by requesting a researcher trained by them to work at IPT.[132]

At the Glette campus, the Chemistry Department was allocated a three-floor building, which included a lecture hall of sixty seats, three teaching laboratories, research laboratories, a library, and a chemical museum. The facilities were expanded in 1944/45 through the addition of one further teaching laboratory, two new research laboratories, a workshop to manufacture glassware, and a laboratory for microanalysis. The teaching style remained the same, i.e. laboratory-based, but now with the active participation of the new doctors as assistants.[133]

The position of assistant was crucial for the new teaching style implemented at USP, and at FFCL in particular. Per the university statutes, the organizational unit was the autonomous and privileged professorial chair, a tenured position that ended with its occupant's death or retirement. As a consequence, there was little upward mobility. The assistant was a formal position circumscribed by rigid set of rules. There could be up to three assistants per chair, with a hierarchical order—first, second, and

[130] Senise, *Origem do Instituto*, 51–2. Also, other North-American institutions funded not only training seasons, but also the purchase of laboratory equipment; see Barros et al., 'Ímã que Anima', 40. As mentioned above, the so-called 'North American model' of higher education became influential in Brazil after World War II, yet USP had initiated contacts with the Rockefeller Foundation quite earlier, especially for the development of exact and biological sciences, see Marinho, *Norteamericanos no Brasil*.

[131] Giesbrecht, 'Ernesto Giesbrecht', 117; Senise, 'Entrevista', 148; Senise, *Origem do Instituto*, 37.

[132] Senise, *Origem do Instituto*, 150.

[133] Ibid, 38; Mathias, 'Departamento de Química', 194–5; University of São Paulo, *Anuário da Faculdade de Filosofia, Ciências e Letras da Universidade de São Paulo (1939–1949)*, (São Paulo, 1953), ii, 62.

third assistant. All of them were chosen by the chair professor. Later, two additional teaching assistants were granted to each chair. As in the case of the head professors, new appointments could only be made when a position became vacant. The assistantship was at first a part-time position. Following the creation of CNPq (National Research Council, present-day National Council of Scientific and Technological Development) in 1951, the assistants' income was complemented by grants to make up for a full-time salary.[134]

Material and financial resources posed chronic problems all along the first fifteen years of existence of the Chemistry Department, until the creations of CNPq and other funding agencies, such as the Brazilian Federal Agency for Support and Evaluation of Graduate Education (CAPES) and the 'FAPs' (research support foundations of individual states, FAPESP in the case of São Paulo). In the 1940s and part of the 1950s, the only resources—besides the ones coming from the USP—were sporadic donations and the Rockefeller Foundation grants for postdoctoral visits abroad and purchases of laboratory equipment.[135]

To paint a more concrete picture of the training of the early Brazilian chemists and the actual unfolding of the new learning style for science in Brazil, we next briefly describe two illustrative cases, those of Mathias (introduced above), and Giuseppe Cilento (1923–1994). Each of these two scientists established new fields of chemical research in Brazil, physical chemistry and photo-biochemistry, respectively.[136] Mathias was not only a member of the very first class of chemists trained at USP, but was also the first student ever to earn a doctorate in science in Brazil. He travelled abroad for further specialization, and was hired as a chair professor, besides having played a fundamental role in the institutionalization of chemistry in Brazil.[137] Cilento was part of the following generation, though still trained in the 1940s. Just as Mathias, he had crucial participation in the institutionalization of chemistry, particularly in relation to the creation of the Chemistry Institute at the State University of Campinas (UNICAMP) in the 1960s.[138]

[134] Senise, *Origen do Instituto*, 46.

[135] Ibid, 50–1.

[136] Mathias, 'Entrevista (1977)', 23–4.

[137] Originally, the number of chairs was two (General and Inorganic Chemistry/ Analytical Chemistry, and Organic and Biological Chemistry), for which Rheinboldt and Hauptmann were appointed. A third chair (Physical Chemistry and Superior Chemistry) was created in 1945, for which Mathias was appointed; see Senise, *Origem do Instituto*, 44; Mathias, 'Entrevista' (1977), 29–30.

[138] Cilento's personal papers were carefully collected and conserved by his students, who donated them to CESIMA, our research center. This was the basis for a broad-scoped research project, also including oral history research and involving postdoctoral and doctoral students; see note #103 supra, and Andreia M. de Medeiros, 'As Contribuições de

An early concern of Rheinboldt was that neither he nor Hauptmann had a sound training in physical chemistry. Yet this was precisely the field Mathias preferred, given his early interest in mathematics. Aware of this proclivity, Rheinboldt suggested a physical-chemical subject for Mathias' dissertation, which he completed in 1942 with the title 'On Bivalent Mercaptans and Sulfide Dimercaptans'.[139] A short while earlier, the Rockefeller Foundation had sent a representative to Brazil to identify still unestablished fields with high potential for development. This was the context in which Mathias was selected for a postdoctoral fellowship at the prestigious department of physical chemistry at the University of Wisconsin, from 1942 to 1944.[140]

For many decades, from 1919 to 1952, the chair of the Chemistry Department at the University of Wisconsin–Madison was J. Howard Matthews (1880–1970). A physical chemist, Matthews had received his early training from Louis A. Kahlenberg (1870–1941), a former student of Wilhelm Ostwald (1853–1932) at Leipzig, who is considered one of the founders of modern physical chemistry. Matthews specialized in the correlations between electrical conductivity and chemical activity. In addition, he established the physical chemical laboratory course, which became standard throughout the United States, and together with Farrington Daniels and John Warren Williams wrote *Experimental Physical Chemistry* (first published in 1929, thereafter in seven more editions up to 1970), the bestseller among chemical laboratory textbooks up to the 1970s.[141] Mathias had strong interactions with these and other

Giuseppe Cilento para o Desenvolvimento da Fotobioquímica na Ausência de Luz' (PhD dissertation, Pontifical Catholic University of São Paulo, 2017), 139; Simão Mathias and Heinrich Rheinboldt, 'Sobre Mercaptanas Bivalentes e Sulfetodimercaptanas' (PhD dissertation, University of São Paulo, 1942).

[139] Mathias and Rheinboldt, 'Mercaptanas Bivalentes'.

[140] Senise, *Origem do Instituto*, 37, 41–2; Mathias, 'Entrevista (1977)', 6–7, 33; Mathias, 'Entrevista (1982)'.

[141] For more detail of chemistry at Wisconsin and the role of Matthews, see Aaron J. Ihde, *Chemistry, as Viewed from Bascom's Hill: A History of the Chemical Department at the University of Wisconsin in Madison* (Madison, 1990). For the leading role of North American chemists in physical chemistry, see John W. Servos, 'History of Chemistry', *Osiris*, 1/1 (1985), 132–46, on 139. In chemistry, and science as a whole, the modern American research university was a product of the import and modification of the German model starting at the end of the nineteenth century; see Rocke's chapter in this volume; and Alan Rocke, 'Origins and Spread of the "Giessen Model" in University Science', *Ambix*, 50/1 (2003), 90–115. On the rise of the American research university, see e.g. Roger L. Geiger, *To Advance Knowledge: The Growth of American Research Universities, 1900–1940* (Oxford, 1986); for the role of chemists, see e.g., Owen Hannaway, 'The German Model of Chemical Education in America: Ira Remsen at Johns Hopkins (1876–1913)', *Ambix*, 23/3 (1976), 145–64; Bruce V. Lewenstein, '"To Improve Our Knowledge in Nature and Arts": A History of Chemical Education in the United States', *Journal of Chemical Education*, 66/1 (1989),

investigators, and also visited several research centers across the United States, which afforded him, for instance, the occasion to establish contact with Linus Pauling. As a result, at the end of this period Mathias had a very clear idea of the path that would lead him to sound research in physical chemistry, as well as its relationship with other fields of science.[142]

After his return to Brazil, Matthias devoted himself to teaching and research on physical chemistry, following the style learned in Wisconsin, to eventually earn a tenured position in 1946. For this purpose, he constructed a laboratory with his own hands that included a mechanical workshop, the very first of such for physical chemistry in Brazil, and trained a glassware technician.[143] Mathias specialized in the determination of the dipole moment, which at that time could only be achieved through direct measurement, as there was no ready-made, commercially available equipment for this purpose.[144] To continue his work, Mathias had to build by himself a condenser with parallel or coaxial metallic plates, which were immersed into the material to be tested, and the condenser's capacity was then measured. The results were used to calculate the values of the dielectric constant and the dipole moment of the tested material.[145]

Mathias' international experience did not end in Wisconsin. Later he also visited Kazimierz Fajans at the University of Michigan, funded by the Guggenheim Foundation, which also funded a trip to France. Upon his return to Brazil, he conducted work together with his students and succeeded in finding experimental proof for quanticle theory values that Fajans had obtained through exclusively theoretical estimations.[146] Soon Mathias became the leading authority in physical chemistry in Brazil, and

37–44; and D. S. Tarbell, Ann T. Tarbell and R. M. Joyce, 'The Students of Ira Remsen and Roger Adams', *Isis*, 71/4 (1980), 620–6.

142 Mathias, 'Entrevista (1997)', 11; Mathias, 'Entrevista (1982)', interview given to Bernardo Kucisnki, *Canal Ciência* November/December 1982, available at: http://www.canalciencia.ibict.br/notaveis/livros/simao_mathias_60.html.

143 Mathias, 'Entrevista (1982)'; Mathias, 'Cem Anos', 26; Mathias, 'Entrevista (1977)', 11–12; Barros et al., 'Ímã que Anima', 44–5, 62–3.

144 Mathias had developed interest in a theoretical-experimental topic that called much attention at that time, to wit, the relationship between the volume of atoms and ions and the volume of electrons; see Mathias, 'Entrevista (1977)', 53.

145 Barros et al., 'Ímã que Anima', 45, 61; Mathias, 'Entrevista (1977)', 11–13, where he tells that his enthusiasm was such, that he succeeded in raising the funds needed for the construction of the physical chemistry laboratory, which called much attention at that time.

146 Senise, 'Entrevista', 154; Mathias, 'Entrevista (1977)', 50–3. Fajans (1887–1975) a specialist in radioactivity, having worked at Ernest Rutherford's laboratory in Manchester, coined word 'quanticle' to denote one or more quantized electrons with respect of one of more nuclei within the context of studies on oxidation; see Peter Day, *Nature Not Mocked: Places, People and Science* (London, 2005), 136.

was called to advise on the establishment of new research centers for chemistry. In recognition of his achievements, the Brazilian Society of Chemistry gave his name to its highest award, the Simão Mathias Medal.[147]

Our second example is Cilento, who entered the chemical course in 1941, graduated in 1943, and earned his doctoral degree in 1946 with a dissertation on 'Isosterism, Isology and Isomorphism'. For his dissertation he worked on azo compounds, a subject suggested by Rheinboldt, his supervisor.[148] Like Mathias, Cilento had neither the required equipment, nor the resource for a new analytical method devised by Rheinboldt himself while still in Germany.

The next stage in Cilento's career was probably determined by a lack of available positions, though extant records do not establish this. As was mentioned above, assistantships were limited. Cilento had to wait until 1951, when Jandira França resigned from her assistantship. Then Cilento accepted an invitation by the Andrea and Virgínia Matarazzo Foundation to conduct research on chemical carcinogenesis at the School of Medicine of USP, in collaboration with the National Research Council of Canada. He never gave up his original interest in azo compounds, which constituted the subject of his senior lecturer dissertation, 'Structural Spectral Behavior of Azo-Carcinogens' (1955). Briefly, Cilento's studies concerned the possible isomorphic substitution between two compounds with identical constitution. This was precisely the focus of the studies conducted by Frank Westheimer (1912–2007) first at the University of Chicago, then at Harvard, with special emphasis on the effects of isotopic substitution on the reactivity of organic molecules and eventually on the mechanisms of ATP formation in cell respiration.[149] Cilento took advantage of a postdoctoral grant provided by the Rockefeller Foundation to spend one year with Westheimer at Harvard, which triggered his academic shift to biological chemistry, a field that he developed in Brazil.[150] Mathias considered Cilento one of the best chemists he had ever met, an impression later

[147] More detail on the Simão Mathias Medal is provided at http://www.sbq.org.br/portal2/simaomathias/medalhasm.htm. On the predominant role of physical chemistry and the part of Mathias in the development of chemical science in Brazil, see Goldfarb and Colombini, (eds.), *Ímã que Tudo Anima*.

[148] All the information on Cilento was taken from Medeiros, 'Contribuições de Cilento'.

[149] Jeremy Pearce, 'Frank Westheimer, 95, Who Developed Model Valuable in Biochemistry, Dies', *New York Times*, 21/4/2007, http://www.nytimes.com/2007/04/21/obituaries/21westheimer.html; Addison Ault, 'Frank Westheimer's Early Demonstration of Enzymatic Specificity', *Journal of Chemical Education*, 85/9 (2008), 1246.

[150] Indeed, his research in Harvard on the enzyme aspects of ATP formation led him to investigate the nature of electron transfer, which eventually resulted in the development of photobiochemistry without light.

confirmed in international circles through the establishment of the Cilento Award by the Inter-American Photochemical Society.[151]

In 1970, the various courses on fundamental chemistry and biochemistry were reunited in the Institute of Chemistry, USP,[152] which became the most advanced center for chemical teaching and research in Brazil.[153] Ever since replacing Rheinboldt as department chair, Hauptmann was virtually obsessed with the idea of reuniting all these courses in a single building at USP Cidade Universitária.[154] For this purpose, he sought consensus among the professors at the various schools. A preliminary project for a common building was approved in 1960—which the architects named 'the Chemistries Suite'. But Hauptmann died soon afterward. Mathias was appointed department chair and led the project to its successful conclusion.[155]

At the same time, the ethos of the Chemistry Department had already been progressively conveyed to other parts of the country through some of its earliest graduates. These chemists spread across the state of São Paulo and Brazil, mainly as professors and consultants. This is, for instance, the case for Waldemar Saffioti, who graduated in 1942, entered the doctoral program under Rheinboldt's supervision, and earned his doctoral degree in 1948. After some time as a high school teacher and textbook author, in 1960 he was appointed to a chair in physical chemistry and superior chemistry that later became the chemistry course of the School of Philosophy, Sciences and Literature of Araraquara, São Paulo.[156] Saffioti and Cilento are just two of the links in a chain of researchers that extend to other institutions. The chemists thus trained became responsible for a large part of the research performed in São Paulo and Brazil.

Final Remarks

Our main focus in the present chapter is the training of the earliest generation of professional chemical researchers in Brazil, as a case study of the

[151] Mathias, 'Entrevista (1977)', 23–4. For further detail on the Cilento Award, see: http://www.i-aps.org/awards.asp#G._Cilento_Award.

[152] For instance, there were chairs of organic chemistry at FFCL, the Pharmacy School, and the Polytechnic School.

[153] Maria C.L. Santos, *USP, Universidade de São Paulo: Alma Mater Paulista, 63 Anos*, 2nd ed. (São Paulo, 1998), 162–3.

[154] Literally, 'University City'; it is the largest campus of University of São Paulo.

[155] Senise, 'Entrevista', 156–7.

[156] C. Antonio, Antonio C. Massabni, Cristo B. Melios and Douglas W. Franco, 'In Memorian', *Química Nova*, 22/ 4 (1999), 630–1. A Chemistry Department was established by this time, which was raised to the level of institute in 1977; see Antonio C. Massabni, José R. Ernandes and Cristo B. Melios, 'Quatro Décadas de Química na UNESP/Araraquara', *Química Nova*, 26/3 (2003), 439–44.

institutionalization of science and the scientific professions in the country. This we approached against a wider background, by considering the countries that had been former Spanish colonies, and famously had a university-learning tradition for over 400 years. While information in this regard is available in the literature, it is rather scattered, and our first task was to compile it. The resulting picture was unexpected: a long tradition of university education did not seem to facilitate the introduction and spread of the research ethos in these countries, at least not in the case of chemistry.

Based on our previous studies on Ibero-America, we have argued that, indeed, research in the strict sense and consequently the training of researchers could not take off until modern research universities were created. That this was a late affair in the former Portuguese America permeates practically all the specialized studies on higher education and the institutionalization of science in Brazil, and much scholarship was produced to account for the possible reasons.

However, when seen from a broader time perspective, research on chemistry arguably began soon after the move of the Portuguese court to Brazil in the first decade of the nineteenth century. The period from 1808 to 1934—the year of the foundation of USP, its FFCL, and the Department of Chemistry—was characterized by countless attempts at establishing research facilities and communities, not all of them doomed to failure, as is shown by the cases of the Agronomic Institute of Campinas and the Manguinhos Institute (present-day Oswaldo Cruz Foundation, FIOCRUZ). In addition, before the creation of USP, several courses on industrial chemistry at technical institutes were merged to become the present-day chemical engineering programs. Nevertheless, these institutions and programs were implemented for highly practical purposes: to boost development and solve immediate social and economic problems. A more thorough reassessment of the role of science and technology was necessary to professionalize research, following the trends developing in Europe since the beginning of the nineteenth century. This was achieved with the foundation of USP and the spread of the research and innovation ethos. In the case of chemistry, this process evolved under the influence of the German style of university training as implemented by Rheinboldt in São Paulo. Rheinboldt's program was heavily grounded on the laboratory, the development of skills and scientific reasoning, creativity, initiative, teamwork, and internationalization. With these tools, a chain of professional chemical researchers and educators soon developed to foster the creation of the first institutions for chemical research, and to find themselves places in the expanding global network of experts.

Perhaps this at least partially explains why chemistry as a fundamental science did not derive in Brazil from its applied sister disciplines, but was

established directly in accordance to the research ethos underlying the founding of USP in the model of the German, French, and Italian universities. By contrast, in Mexico and Argentina chemistry was tied to its practical applications, particularly to pharmacy, until it became an autonomous field of research at the turn of the twentieth century.[157] As was mentioned, though an attempt at establishing a German-style research university in Argentina was made in 1821, it never actually took off, and quickly entered a phase of decline that lasted until the end of the century.

Starting in 1968, through a federal law passed by a new military government and under strong North American influence,[158] the graduate education system was enthroned in Brazil as the privileged locus for professional research. It remains so to this day. But this is a story to be told on another occasion.

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[157] Matharan, 'Constitución de la química'.

[158] Brazil, *Law no. 5540, from November 28th, 1968,* available at: http://www2.camara.leg.br/legin/fed/lei/1960-1969/lei-5540-28-novembro-1968-359201-publicacaooriginal-1-pl.html; see also, Maria F. de Paula, 'A Formação Universitária no Brasil: Concepções e Influências', *Avaliação*, 14/1 (2009), 71–84, on 76–7; Alexandre T.N. Lira, 'Reflexões sobre a Legislação da Educação durante a Ditadura Militar (1964-1985)', *Histórica* 36 (2009), article 1. Available at: http://www.historica.arquivoestado.sp.gov.br/materias/anteriores/edicao36/materia01/