CHAPTER 43

Science in Latin America

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National scientific communities have emerged in Latin America during the twentieth century, under a cloud of tension between the need to join the international scientific community and the desire to achieve an independent voice, i.e., autonomy in the definition of their role and interests. The state of science in the region is highly inconsistent. In some countries there are government-supported laboratories and research teams which command international recognition. In others, the essential infrastructures of education and training are lacking. Often funding is meager and insufficient to maintain even the minimum scientific capability. There are not enough researchers to respond to government programs. Scientists are discouraged by the lack of incentive and poor conditions of work. At the same time, there is widespread criticism that much scientific work is trivial, and the ideology of 'applied science' with which pressure is often exerted on the scientific community, often masks and consolidates mediocre research capacity.

At a time when scientific knowledge means industrial opportunity, most Latin American countries have yet to develop a consensus about the role of science. Should governments support basic science? Should they compete with the research agendas in the United States and Europe? What kind of science, if any, should be funded? Or should budgets be spent on the development of badly needed technologies?

Caught between changing policies and inconsistent budgets, between the desire for economic development and international recognition, science in Latin America is as marginal as ever. In this chapter I try to convey something of the compromises, challenges and restrictions that accompanied the scientific endeavor in this particular region of the world in the twentieth century.

ORDER AND PROGRESS: POSITIVISM BETWEEN TWO CENTURIES

Towards the end of the nineteenth century, many countries initiated a process of economic and political modernization. Education, science, European immigration and foreign capital were the main tools. Exports were expanded and power showed with the civil oligarchies that had emerged in the previous half century. European positivism, with its strong belief in progress, offered politicians and intellectuals a conceptual scheme that combined knowledge of history, science and society. It reinforced the importance of order and stability, by contrast with the civil strife endemic since independence in the early part of the century. To such an order political liberties were sacrificed as unnecessary and perturbing. The unrelenting dynamism of the Northern neighbor and European powers gave a feeling of urgency to the social changes required. In the words of Mexican Justo Sierra (1880):

> We need to become stronger, otherwise, incoherence will increase, the organism will not be integrated, and this society will abort. We would remain defenceless and would be the weakest in the struggle for life Darwin speaks about. While we destroy ourselves, at our side lives a marvellous collective animal, for whose huge intestine there is not enough nutriment, armed to devour us. Confronted with this Colossus we are exposed to be a proof of Darwin's theory, and in the struggle for existence all the odds are against us.[1]

European philosophers like Comte, Stuart Mill, and Spencer had a great influence in Latin America in the late nineteenth century. The ideas of the British positivists would inspire liberal groups, while in Brazil, orhodox Comtians tried to carry through all the ideas of their teacher, including religious positivism, and declared Rio de Janeiro, that had founded the first and only Church in Iberoamerica, the orthodox center of universal positivism.[2] Many republicans, in their turn, supported the early, scientific Comte, particularly in educational reform and scientific ideology. In his major treatises, *Course of Positive Philosophy* (1830–1842) and *System of Positive Polity* (1851–1854) as well as in a number of lesser works, Comte developed his positive philosophy and his sociological theories, and set forth his plan for an ideal society, inspiring the minds longing for order and science in Latin America.

At this time, the number of qualified scientists was minimal and there was an almost complete lack of anything resembling a research position. In the universities, science was subordinated to liberal arts. It was taught merely to discipline the mind and most courses did not go beyond a most elementary level. Students learnt maths and physics, not to become scientists and engineers, but as part of a good education. With a few exceptions, science was taught, not by experiment in the laboratory, but by reading, recitation and repetition. In a continent where education was controlled by the Church, it is not surprising that most teachers were priests with a greater commitment to hierarchical obedience than to free enquiry.

Although positivism promoted a social appreciation of science as a source of progress and practical knowledge, it remained largely rhetorical, only becoming embodied in a true research effort in exceptional cases. Florentino Ameghino and Eduardo Holmberg in Argentina, Luis Razetti in Venezuela, Justo Sierra and

Alfonso Herrera in Mexico are some of the scientists influenced by positivism. In specific disciplines there were original developments in the production of texts, as in the explanation of infinitesimal calculus attempted by Diaz Covarrubias, Gargollo and Ramirez in Mexico; the geological and paleonthological works by Ameghino and Burmeister and the astronomical contributions by Gould in Argentina; and the texts by von Ihering and Goeldi in the natural sciences in Brazil.

Comparison, classification, and generalization became the goals of natural scientists who, funded by museums and other European, American and local institutions, made collections of flora, fauna and human diversity. After having fed the European public and private collections with exotica for many years, a number of Latin American museums of natural history had by the end of the century managed to build remarkable collections, both for their quantity and quality, with many irreplaceable and unique holdings. The La Plata Museum fossils were praised in the 1890s by the British Museum curator, for example, as "extraordinary and of world-wide interest."[3] Quite independently, numerous expeditions to the interior were funded by national and international interests to evaluate natural resources. The possibilities of commercial success supported a growing literature on the flora and fauna of the region.

A real demand for science emerged in the first years of the century as the need for graduates of law, medicine, and engineering increased. Scores of students with scientific ambitions left to study abroad, particularly in France, Germany and the United States. Brazilian microbiologist Oswaldo Cruz, who studied at the Pasteur Institute in Paris, and subsequently built up the Manguinhos Institute in Rio de Janeiro, was typical of the new generation. The original staff of this institute which rapidly acquired international recognition was entirely Brazilian, including future leaders of Brazilian medical science such as Carlos Chagas, Henrique de Rocha Lima and Artur Neiva.

During the first half of the twentieth century, the Southern Cone countries had an advantage over the rest (with the sole exception of Costa Rica in Central America) in having a literate population. Argentina, Uruguay, and to a lesser extent Chile, instituted programs of primary and secondary education for the entire population. Inherited positivist values of secularism, good citizenship, republicanism and scientific veracity were reflected in the school curriculum.

The Foundations of Experimental Science: 1918–1940

Progress remained an illusion as long as stability and order did no more than maintain the *status quo*. The enthusiasm for positivism waned and the allure of an advanced scientific Europe was undermined by the atavistic destructiveness of the First World War.

The inter-war period witnessed a deep transformation of Latin American societies marked by workers' strikes and student revolts. A new stage of political organization of the workers saw the emergence in most countries of communist and socialist parties. A revitalization of Catholic thought was also visible in the reassertion of religious education. Several national armies became professional.

The advancement and prosperity of a new middle class opened a new market for authors, stimulating the expansion of a publishing industry. This growth in the publishing field was a crucial factor in the professionalization and autonomy of intellectual work in Argentina, Brazil and Mexico. Although there were already scientific journals published in these countries before 1899, the first decades of the twentieth century saw a marked growth of periodical publications by learned institutions and scientific societies.

In 1918 Buenos Aires was the second largest Atlantic city after New York. Except for import and distribution trade centers like Holland and Belgium, no other country in the world imported as many goods per capita. The old Argentine universities were ripe for change as demonstrated by the Córdoba Reform Program of 1918, to which most of the Latin American university communities adhered. With the help of a group of German physicists and astronomers the *Universidad Nacional de La Plata* became one of the best centers of Latin American science.

In Mexico, after the first post-revolutionary decade, the Mexican state was restructured unifying the country ideologically within a nationalist model. The *Universidad Nacional* was established on a different base from that of the former Royal Pontifical University. Most of the new research institutes were created within the national university. Although several disciplinary institutes antedated it, the Science Faculty was founded in 1939.

In Brazil, the Sociedade Brasileira de Ciencias, founded in 1916 and transformed into the Brazilian Academy of Sciences in 1922, had as its main aim the development of basic sciences. In the same vein, some engineers, mathematicians, astronomers and natural and physical science teachers in Rio de Janeiro claimed the creation of a Higher Faculty of Sciences devoted exclusively to the education of scientists, without any commitment to technical or professional training. The argument was that in new countries like Brazil, utilitarism and pragmatism, associated with the positivistic tradition in the local context, degenerated and were transformed into a fanaticism of material progress.

The noticeable development of a discipline in a particular country today is often the result of efforts started much earlier, as in the case of geology and geophysics in Peru. Although linked from an early date to government interests in mining, it experienced a qualitative change in 1922 when the Carnegie Institution from Washington installed a Magnetic Observatory in Huancayo, thus beginning the local systematic register of geophysical information. Although the original concern was to know the origin of the Earth's magnetic field, the range of interest gradually broadened to other geophysical parameters, and the Observatory won world renown because of the quality of the data from its unique geographical location.

Agricultural research in most countries had an early start, aiming at enhancing the economic competitiveness of their staples, although the levels attained differed remarkably. The Argentine Rural Society, founded by a group of cattle-breeders in 1866, had already created an Agricultural Institute with experiment fields by 1870 and inaugurated the first agricultural-cattle-breeding exhibition in 1875. In Uruguay a Rural Association came into being in 1871 to bolster the modernization of the agricultural sector. The Campinas Agronomical Institute in Brazil was founded in 1887 in order to study tropical plants, particularly coffee, corn and tobacco. Applied institutes such as these, in most cases led by European or North American researchers, were the roots of the agricultural scientific traditions that would develop later, when National Institutes of Agricultural Technology, in which agricultural basic science was also pursued, were created in several Latin American countries.[4]

Small countries sometimes had a single institution influencing national scientific life, as was the case of the *Universidad de la República* in Uruguay where the introduction of the notion of academic research was due mainly to Clemente Estable, who left a deep imprint in the local evolution of biology. In the late 1920s he was the focal point for the founding core of the current *Instituto de Investigaciones Biológicas Clemente Estable*, devoted to basic research. By contrast, the authoritarian regime of Juan Vicente Gómez (1908–1927) in Venezuela, kept the country in a *sui generis* process of deep repression at the political level, penetration of monopolistic capital in the oil sector, and unification and centralization of the national territory. The small amount of scientific-technical activity carried out was directly linked to concerns of a practical nature, lagging behind other Latin American countries. The universities faced problems with the regime and remained open only sporadically.

In this period the foundations of experimental science were laid in several countries, with a marked influence of foreign professionals and the institutional cooperation of advanced countries.France created the "*Groupement des Universités et Grandes Ecoles de France pour les Relations avec l'Amérique Latine*" in 1907. While not completely indifferent to the 'scientific needs' of Latin America, it had closer contacts with diplomacy than with the universities, and with the humanities and the social sciences rather than the exact and experimental sciences. Without completely abandoning scientific exchanges, the *Groupement* gradually ceased to be a 'scientific-cultural' project to become a 'diplomatic-cultural' one. Two of its activities stood out during the 1920s: the creation of French cultural institutes in Latin America and the journal *Revue d'Amérique Latine*. The *Universidade de São Paulo*, founded in 1934, and especially its Faculty of Sciences and Letters, was probably the most important Latin American knowledge institution in whose creation and early life the French were strongly involved.

The United States, in their turn, were keen to consolidate an empire that extended from Puerto Rico through a large part of Central America to the Philipines. The State Department was supported in its Pan American policies by the largest firms, foundations and educational institutions. Between 1913 and 1940, the Latin

American activities of the Rockefeller Foundation concentrated on public health and the control of epidemics.[5] It also supported physiological research, particularly in Argentina, as a result of the high quality scientific work undertaken there, such as the 1947 Nobel Prize awarded to Bernardo Houssay, director of the *Instituto de Fisiología* of the University of Buenos Aires, for his research on the glandular basis of sugar metabolism.[6] Beginning around 1940 and coinciding with the interruption of scientific relationships between the United States and Europe produced by the Second World War, the Rockefeller Foundation expanded its interest in Latin America: It emphasized scientific education and the support of individual scientists in other physical and natural sciences and in basic and applied agricultural research, contributing, with its Mexican Program, to the Green Revolution.[7]

Germany had made substantial incursions into Latin America at the beginning of the century, particularly Argentina. With the active support of the Imperial Ministry of Foreign Affairs, German science and culture were implanted in Argentina in direct competition with North American interests. The development of physics at La Plata University was entrusted to Emil Bose, one of the first students of Walther Nernst's Physical Chemistry Institute in Göttingen. Bose's premature death in 1911 did not end La Plata's project,[3] that was pursued between 1913 and 1926 by Richard Gans, an assistant to Nobel Prize winner Ferdinand Braun who had already made a brilliant career in Tübingen and Strasbourg. Although a lack of interested students made it difficult to establish a local research base and the school produced many more engineers than physicists or astronomers Gans supervised the first six physics theses at an Argentine university. His most distinguished Argentine pupil, Enrique Gaviola, was awarded a doctoral degree in Berlin in 1926, studying with top figures such as James Franck, Max Born, Max von Laue, Max Planck and Einstein. Afterwards he spent some time in Johns Hopkins University and the Carnegie Institution. His work won recognition in Europe and North America but on his return to Argentina in 1931 he met with difficulties in adjusting to the petty politics of local academic circles. Later he had unsurmountable political disagreements with president Peron and the military over the national atomic endeavor,[9] and his valuable scientific know-how was thus not fully assimilated by the country of his birth.

In the early decades of the century, Spain reinforced its links with Hispanic America. The *Institución Cultural Española*, created in 1914 at the initiative of the Spanish colony in Argentina, aimed to make Spanish science and literature known in Argentina by means of a chair in the University of Buenos Aires to be occupied by Spanish researchers, and the development of other intellectual exchanges. The *Institución* was placed under the scientific auspices of the *Junta para Ampliación de Estudios e Investigaciones Científicas* in Madrid, presided over by neurohistologist Santiago Ramón y Cajal, who had won the 1906 Nobel Prize for medicine and was the scientist with the greatest prestige in Spain at the time. Well-known Spanish intellectuals benefited from invitations from the Spanish Cultural Institution to travel to America.

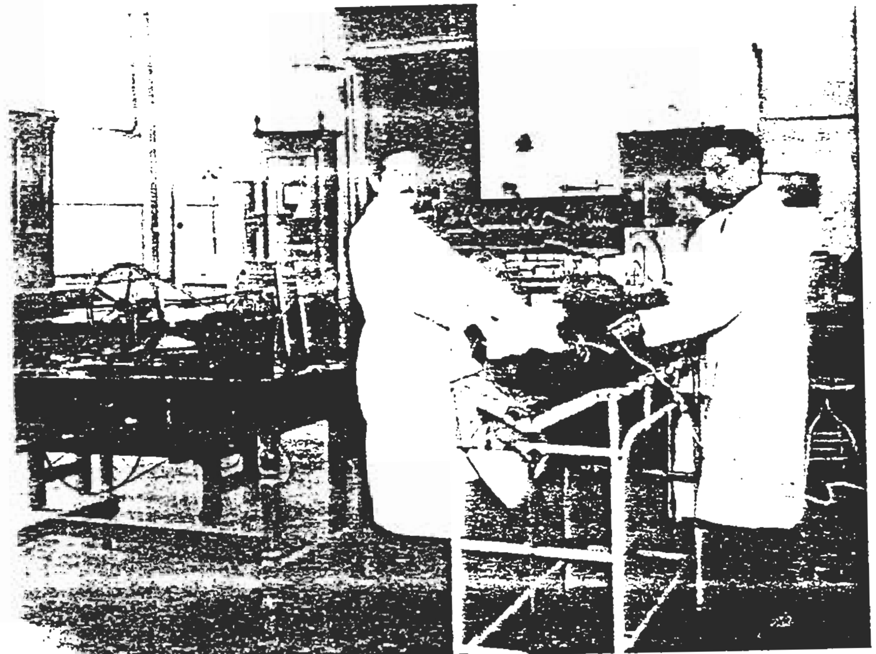

FIGURE 43.1: BERNARDO A. HOUSSAY AND COLLABORATOR DURING EXPERIMENTAL WORK AT THE INSTITUTE OF PHYSIOLOGY, BUENOS AIRES, AROUND 1936.

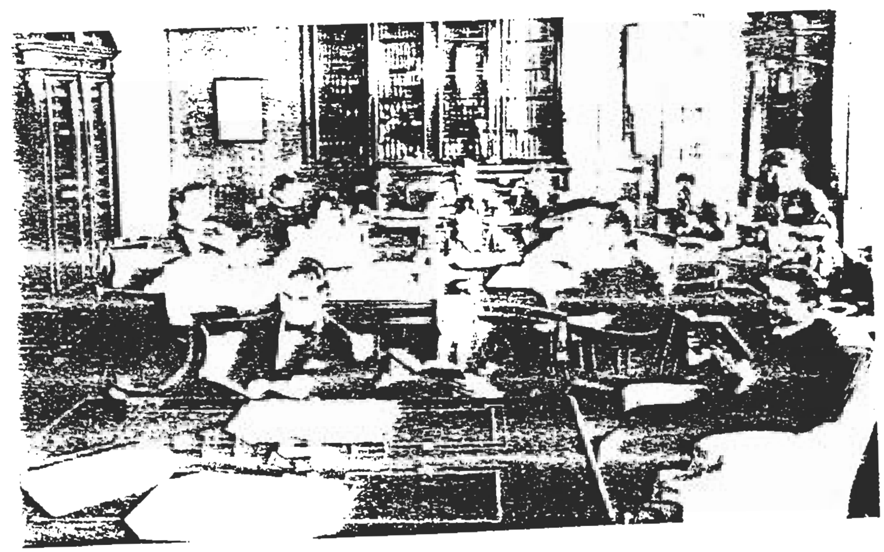

FIGURE 43.2: MORE READING-ROOM SPACE FOR STUDENTS AT THE FACULTY OF MEDICINE, BUENOS AIRES, IN THE 1920S.

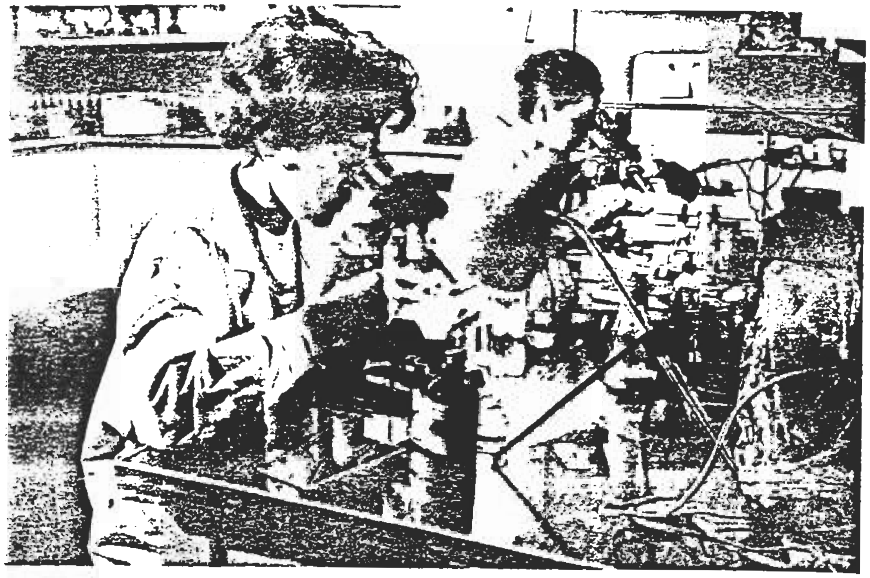

FIGURE 43.3: STUDIES OF EXPERIMENTAL EVOLUTION. UNIVERSITY OF CHILE, 1960.

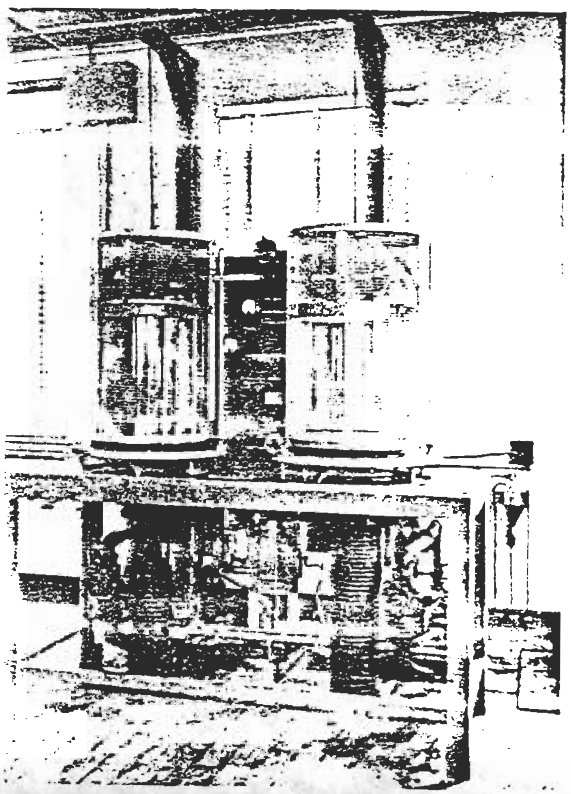

FIGURE 43.4: VACUUM CREATING UNIT, USP, PHYSICS.

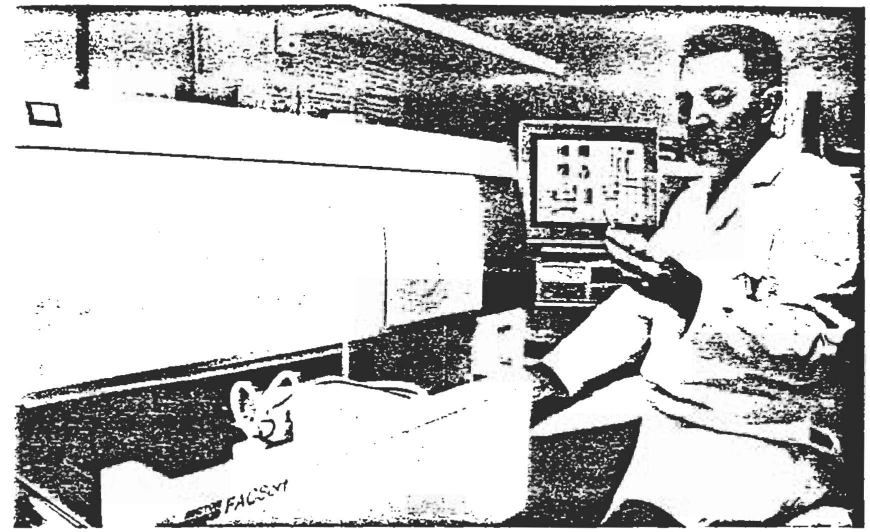

FIGURE 43.5: J.A. O'DALY, RESEARCHER ON *LEISHMOMIESIS* AT HIS IMMUNOBIOLOGY LAB., IUIC, VENEZUELA.

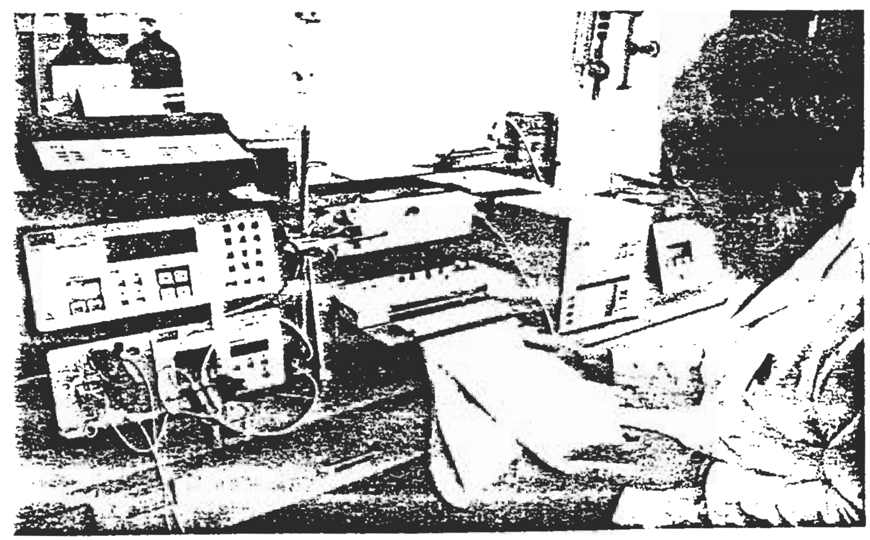

FIGURE 43.6: NEUROLOGY LABORATORY, IUIC, VENEZUELA.

But more important than these official initiatives was the mass collective contribution of the thousands of refugees from the Spanish Civil War who settled in Latin America. Many Spanish scientists and intellectuals, joining other mainly Jewish refugees from Nazism, played a crucial role as catalysts of an institutional transformation whose first phase was completed in the 1950s when substantial numbers of young Latin American scientists, trained mainly in the United States, began to be active in the region.

Italy also contributed considerable quantities of teachers to higher education and research laboratories, sometimes as part of the strong immigrant contingent that moved to the Americas, or as members of official cooperation programs. Great Britain had a smaller though significant role, fundamentally through the British Council and its fellowship program for Latin American students who received training in the famous British universities, as in the cases of Argentine Luis Leloir and Brazilian Mauricio Rocha Silva in biochemistry and pharmacology respectively.

The Development Decades, 1940–1960

During the 1930s and 1940s, scientific leaders claimed government support for basic research, usually on a shared basis with international cooperation, as a means of building scientific communities. World War II inaugurated a period of growth in industrial activity, of rapid expansion of the population in large urban centers and of improvement in the general level of education, in a political context that alternated between the predominance of populism and authoritarism. The notion that science and the universities would play a central role in socioeconomic development was part of the 'developmentalist' ideology emerging from the United Nations Economic Commission for Latin America (ECLA) established in 1949. The works of economist Raúl Prebisch and his associates argued the need to adapt and combine international technological knowledge, to define priorities from the point of view of economic planning and to organize research programs in response to those priorities.[10]

In practice, however, the substitution of imports was favored without systematic concern for technological learning. Most technology transferred to Latin America was embodied in equipment and procedures. The choice, negotiation, acquisition and assimilation of disembodied technology was widely ignored; the same happened with domestic R&D development. Objectively, local investment in technological development became too costly. This explains the late growth of the capital goods sector, the delayed start of graduate education, the marginal structure of experimental R&D and the still very low enterprise participation in the financial support of these activities. All these factors shaped a non competitive industry that continues to exist today.[11]

Despite the fact that the general pattern of industrialization adopted did not foster the growth of dynamic R&D systems, university and governmental research did achieve *momentum* in some fields, particularly since the 1950s. Universities were

the centerpiece of the model adopted for national science policies, indeed the only institutions to which it seemed to apply. The purpose was to grow a 'scientific-technical' infrastructure assuming, often in an implicit manner, that when achieving a 'critical mass' in scientific research, an automatic reinforcement of local technology would evolve to exploit raw materials and other resources, thereby increasing production and productivity. The elements of a public policy for science and technology, which came to fruition in the 1960s, were conceived in the 1950s and its most conspicuous spokesmen were leading figures of the scientific community. Physiologist Bernardo Houssay expressed his commitment to science as follows:

> I have devoted my life to three main aims: 1) to cultivate science to know her and make her progress; 2) to train pupils and help those who devoted themselves to science; 3) to work for the development of science in my own country. For me this third obligation is more rigid than the other two. I have been lucky to devote myself to science as I wished and to have received resources for what I did. Science is not a simple mercantile activity and in order to pursue it money is not enough. Discoveries are not made by equipments, buildings or money; they are made by able and idealist men, intensely and devoutly dedicated to science, with enough resources to advance and not stagnate or fall back. On several occasions I have exposed the causes of the slow scientific development of Latin America: 1) lack of scientific tradition; 2) ignorance of the role and importance of science; 3) vanity and other moral defects; 4) technical defects; 5) intellectual defects; 6) character and personality failures.[12]

The Brazilian scientific community began to expand on a par with the nation's industrialization. The new University of São Paulo (1934) was predicated on the assumption that the development of a research capability would help restructure the existing system of higher education. The foreign teachers it hired were crucial in training pupils and establishing research traditions, allowing the University to achieve a scientific density unequalled in the country. Two Europeans opened up fruitful research traditions in theoretical physics. In São Paulo, Gleb Wataghin developed two research lines between 1934 and 1942: one in theoretical physics, with his most distinguished pupil Mario Schenberg, and the other in the experimental side, on cosmic rays, with Marcelo Damy. With all major scientific groups in England and the United States involved in the war effort, Wataghin and his group were for a while considered the only scientists working on cosmic rays in the world.[13] In Rio de Janeiro, Bernhard Gross became interested in the interaction of radiation with matter, publishing the first systematic work on electrets in 1957 in the *Journal of Chemical Physics* and in *Physical Review*. Although his research was basic, a few years later a German and an American researcher, using the same method and theory he had described, made the first practical electretic microphones.[14]

As a symptom of the expansion of scientific activity, the *Sociedade Brasileira para* *o Progresso da Ciencia* (SBPC) was founded in 1948. The following year the private *Centro Brasileiro de Pesquisas Físicas* was established in Rio de Janeiro, bringing together several high-quality scientists such as Cesare Lattes, José Leite Lopes, Jaime Tiomno, and Roberto Salmerón. In 1951 the *Conselho Nacional de Pesquisas* (CNPq) was created to support science. In both institutions, Admiral Alvaro Alberto, a military man with a strategic view of science and technology, struggled to have a national commission on atomic energy organized within the research council. But in 1954 President Getúlio Vargas committed suicide and Alberto was dismissed from his post as President of CNPq. Having decided to link the Brazilian economy to the international economic system, in 1967–68 Brazil's military rulers attached nuclear institutions to the power industry establishment, excluding local scientists from the decision-making process, killing the domestic program of nuclear development already under way, and buying an American light-water reactor.[15]

Despite the fact that Brazil was endowed with an advanced industrial infrastructure and a more sophisticated physics program than available in Argentina, nuclear policy there became an arena for domestic and international political pressure, failing to become insulated from broad political, economic, and social issues, as was the Argentine nuclear program. In the latter country, by contrast, there was a central institution with the political autonomy and leadership necessary to sell an independent nuclear plan to the ruling elites and ensure its execution. Through careful policies of technology purchase, staff training, R&D backing, the establishment of physics labs and of the nuclear engineering profession, the Argentine *Comisión Nacional de Energía Atómica* generated a critical mass of scientists and a technological infrastructure that enabled this agency to have an excellent track record.[16] Each success generated further political support for the project, which continued well into the 1980s.

The National Institute of Amazonian Research, and the Institute of Pure and Applied Mathematics in Brazil were also established in this period. A small number of elite teaching and research institutions came into being, and served as model and inspiration for the broader reforms that would be attempted in the following phase at the level of the national system of higher education. The first one was the *Instituto Tecnológico de Aeronáutica* (ITA), supported by the Ministry for Aeronautics in close collaboration with the Massachusetts Institute of Technology (MIT), which carried out research and the training of military staff in R&D. ITA's experience was important in the renewal of the university curriculum in that it emphasized the need for a scientific base with an important experimental component aimed at technological applications. Another important institution was the Medical School of Ribeirão Preto, conceived as a model of modern biomedical research. The contribution of the Rockefeller Foundation, was decisive in the early development of the School. Another emblematic institution was the University of Brasilia, an ambitious, imaginative project imbued with developmentalist ideals, which rapidly fell victim to military repression in 1964. Although it continued to be

reputed as a good federal university, it never recovered its original mystique and prestige.

Scientific research in Mexico has been closely linked to the Science Faculty at the National Autonomous University of Mexico (UNAM), and to a series of measures geared to legitimate the role of the full time researcher within the University throughout the 1940s. In 1940 the Laboratory of Medical and Biological Studies was founded to accommodate a group of Spanish refugees who were students and followers of Ramón y Cajal. In 1956 it became the Institute of Biomedical Research.[17] When UNAM's University Campus began to be constructed in 1950, the first building was the Science Faculty, followed soon after by the Science Tower, where for the first time in the university specific space was allotted to research Institutes in an organizational pattern that has since separated undergraduate teaching from graduate teaching and research. Some individual researchers began to be hired on a full time basis although research budgets continued to be too small. In 1949 Manuel Sandoval Vallarta returned from the US, where he was a teacher at MIT, keen to develop physics locally. Spain's leading physicist, Blas Cabrera, and Spanish astronomer Pedro Carrasco were also influential in this task. Outside the university structure, Arturo Rosenblueth, a Mexican physiologist who had collaborated with Walter Cannon in Harvard, returned in 1944 to head the physiology laboratory of the new Cardiology Institute, that received strong financial support from the Rockefeller Foundation. In 1960 he became the founding director of the Center for Research and Advanced Studies (CINVESTAV) of the National Polytechnic Institute.

In Venezuela, in the wake of dictator Gómez'death in December 1935, a frantic process of modernization of the State apparatus ensued. The Central University started to build some research capability, basically relying on the contribution of foreign scientists. In the medical faculty alone, the arrival of people of the scientific stature of physiologist Augusto Pi Sunyer, the most distinguished scientific Spanish exile, the Swiss anatomo-pathologist Rudolf Jaffé, the former Hamburg University tropical pathologist Martin Meyer, the Spanish physiologist Rossend Carrasco i Formiguera and others, resulted in the establishment of research in several disciplines and a new mystique with respect to the practice of science. A student of Pi Sunyer, Francisco de Venanzi, would be a devoted heir to this tradition in later years, promoting the growth and social recognition of research in the country.

The Science Policy Era, 1960–1980

Economic and social planning agencies began to operate in the region and science had its share of them. Early reports complained about their shortcomings, such as lack of institutional coordination, incoherence between short, medium and long term plans; scarcity of adequately trained staff, projects and statistics. Sometimes, planning and policy-making emerged as an imposed mechanism for getting funds from international agencies. The dominant modernization ideology was expected to lead to higher levels of autonomy, self confidence and social justice. The post-war period witnessed the ascent of self-reliant, optimistic social movements, aimed at building more equitable societies. The development of local capabilities in science, technology, industry, management, and work-force, introduced significant changes and the emergence of new sets of individuals, better trained and with a better understanding of the art of negotiation. Groups of scientists, engineers, public officials and the armed forces, who tried to put into practice projects such as that of atomic energy in Argentina, electronics in Brazil or oil in Venezuela and Mexico, managed to make an impact on the international competitive game with their unexpected achievements.

But changes were insufficient and a pattern of economic development prevailed based on growth without social equity. Industrialization was geared to the domestic market and biased towards the conspicuous consumption of luxury goods at levels significantly higher than in other countries of comparable income levels. There was a lack of leadership in domestic private firms in the most dynamic industrial sectors (automobiles, chemistry, capital goods), combined with a weak development of small and medium sized industrial firms. The private sector had little participation in R&D even in the most advanced countries of the region, and this was coupled with distorted and underdeveloped entrepreneurial capacities. Growth rates have been unsatisfactory, showing deep regional and sector imbalances, marked income concentration, growing foreign control and substantial increases in the national debts.

In the 1960s, parallel to the abandonment of the post-war euphoria with science in the industrial countries, public criticism of science emerged in Latin America with regard to a double challenge: redirecting the aims of the scientific endeavor, and its ability to provide solutions to local and regional problems. An influential voice was that of Oscar Varsavsky, Argentine mathematician and physicist, who became impatient with the so called 'scientificist' researcher

> who has become adapted to this scientific market, that renounces to worry about the social meaning of his activity, dissociating it from political problems, and devotes himself entirely to his 'career', accepting the norms and values of the large international centres, embodied in an academic scale . . . The mission of the scientific rebel <by contrast>, is to study in all seriousness and using all the arms of science, the problems of social change, in all their stages and theoretical and practical aspects. This is to make *politicized science*.[18]

As a result of the growing number of unresolved problems authoritarian regimes emerged in Brazil, 1964; Peru, 1968; Ecuador, 1969; Bolivia and Uruguay, 1970; Chile, 1973; and Argentina, 1974. When authoritarian governments in the Southern Cone tried to suppress the social sciences, the large North American Foundations came to their rescue, contributing to the emergence of private research centers. The Ford Foundation was particularly generous. In Argentina, it helped Gino Germani's Institute of Sociology in the University of Buenos Aires. In Brazil, support for the social sciences, which was already significant at the beginning of the 1960s before a politically conservative military government took power in 1964, practically quadrupled in the wake of the deep reorganization of higher education in 1968. Chile was host to the most important Ford Foundation social science program in the region in the early 1970s.

In several countries, scientific and technological research moved out of the universities. The new groups that benefited from growing R&D resources tended to be young and politically indifferent, or at least had few personal links with the recent past. Working in isolated and protected places, with salaries unrelated to the university budget and without having to teach undergraduates, they often came to think of themselves as long-term reformers waiting for the political storm to wane so they could set the foundations of their country's future scientific and technological self-reliance.

In universities, the North American model of centralized institutes and departmental organization was adopted, but mass education came to be the crucial problem of universities, whose budgets were chronically insufficient to attend to the growing demand. Several traditional universities, which historically hosted research groups, suffered a progressive deterioration and lost their attractiveness as privileged *loci* for research. The small research communities had to compete with an increasing number of university teachers who did not do research but who nonetheless had access to the full-time regime and the stability of employment that had historically been reserved for researchers.[19] Scientists and engineers tried, when they could, to organize their work outside of the universities or around isolated graduate programs. However, the high mortality rate and the diversity of aims and objectives of the courses, as well as noticeable quality differences, insured that the old mechanism of sending students on scholarships to the developed countries continued to be operational whenever funds and opportunities were available. The National Science and Technology Councils began to fund the research that could not be supported by academic institutions and tried timidly to define priorities and guide scientific activity.

Since the end of the 1960s Brazil embarked on the broadest government attempt to direct the scientific endeavor as a function of economic development. Resources for scientific and technological research came from government sectors responsible for economic planning and long term investments. The government improved its ability to carry out policies through the Funding Agency for Studies and Projects (FINEP) under the Ministry of Planning, CNPq, CAPES (the agency within the Ministry of Education providing fellowships for graduate studies) and the São Paulo Foundation for Research Support (FAPESP). Large-scale centers for R&D also emerged during this period, such as the Coordination for Graduate Programs in Engineering of the Federal University in Rio de Janeiro (COPPE) and the University of Campinas, geared to technological research and graduate education in engineering and science. Although after 1980 the sector entered a period of great instability and uncertainty, Brazil managed to build a system which currently has some 35.5 thousand scientists and engineers active in R&D, and about one thousand graduate programs in most fields of knowledge. Several thousand students are on fellowships paid by the Brazilian government in North America and Europe with about 1.5 million students enrolled in undergraduate university programs, 30 thousand in masters and 10 thousand in doctoral programs.

Venezuela's modernization, initiated in previous decades, assumed a fast pace in the 1960s and 1970s, supported by the dramatic expansion of the oil income. Although there had been a small crop of science institutions since 1936, and even though the Venezuelan Association for the Advancement of Science (AsoVAC) came into being in 1950 at the initiative of a small group of scientists in the country, it was necessary to wait until the fall of the dictatorial regime of Pérez Jiménez in 1958 for science to begin to institutionalize on a more continuous basis. Education received a great boost at all levels. A new university law was approved that emphasized research as one of the basic functions of the universities. The Science Faculty at the Central University of Venezuela was founded in 1958 with the aim of training scientists. It was followed in 1959 by the Venezuelan Institute of Scientific Research (IVIC), a center of excellence with the exclusive purpose of doing world-class research and teaching, and in 1967 by the National Council of Scientific and Technological Research (CONICIT) for the promotion and funding of scientific research. With the nationalization of the oil industry in 1976, there was a need for an oil research institute. Thus, together with the creation of PDVSA (*Petróleos de Venezuela, S.A.*), the Venezuelan Institute of Oil Technology (INTEVEP) came into being as an R&D Center, but with the status of an operating oil company integrated to the PDVSA holding. The importance of this late development for a country that depends on oil exports for 70 percent of its foreign exchange is obvious. Scientific, technological and managerial capabilities grew considerably, as exemplified by INTEVEP's development of ORIMULSION®, thereby introducing a new fuel into the world energy market; a rare event, particularly when it has the potential to impact in a significant way such an important fuel consumer as the power industry.

The current phase of turbulence and macroeconomic unbalance in the transition towards more open and disregulated economies under new domestic conditions in the Latin American countries and a changed international economy, has not found them well prepared to face the challenges ahead. Particularly since the 1980s the Latin American industrial sector has presented relatively high margins of idle capacity in several branches and shown an increased technical obsolescence. In the public sector, the combined effects of restricted sources of investment, concentration on short-term problems with the consequent neglect of strategic thinking and drastic salary reductions weakened the support given to critical areas like R&D and also became manifest in the crisis of educational systems at all levels. What is at stake today is the entire productive and social system.

The possibilities of change and modernization in the universities on a global scale seem remote. But some public universities busy themselves with scientific research and the education of future researchers. Given the diminished levels of State patronage, many scientists who decide to remain in the academic context seek funding for basic research beyond the traditional governmental support. Others prefer to approach customers who might appreciate them for their ability to educate, innovate and give expert advice, rather than for their publications and scientific recognition, whilst profiting from their prior prestige as academic researchers. A new alliance between university science and utility begins to develop. The rhetoric of industrially useful science, however, faces two difficulties. On the one hand, the opportunities for an industrial science and for a highly qualified work-force are not many. The very low yield in industrial innovation is not explained by the existence of a 'useless' science but rather by the very low amount that industries invest in R&D. On the other hand, a pernicious gap widens between what is supposedly 'useful' or at least 'saleable' and what is purely cognitive.

The main R&D customers of the universities have been the large public enterprises. This situation did not come about as a result of political or ideological decision making; it was a consequence of the fact that in countries like Argentina, Brazil and Mexico State companies have represented the most important and advanced segment of the productive sector. However, in view of the ongoing privatization process of a significant number of these public enterprises this may not continue to be significant.

Conclusion

This century has seen remarkable changes in Latin American science, although it continues to occupy a marginal position in both national society and international landscape. The scientific enterprise at the international level has grown and changed dramatically during this century and continues to move with a dynamism that reduces the space of maneuver available to Latin American societies, putting at risk not only the markets for raw materials and industrial exports which they had slowly and painfully built up on the basis of low wage production but also the institutions, industrial firms and social learning processes that accompanied modernization in the last half a century.

The world economy appears clearly favorable to the most industrialized countries. Latin American science today needs to dramatically redefine the social contract with its host societies in order to help them face the new conditions, confront the threats of science-based technological development in many sectors of economic life and, at the same time, devise creative responses aimed at exploiting new opportunities. The risk of not doing it, is to be relegated to a subordinate position as appendixes of researchers from North America and Europe who head south in search of unique resources, cheap scientific talents and new topics for research.

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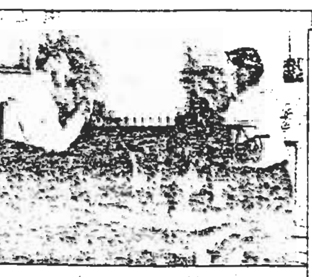

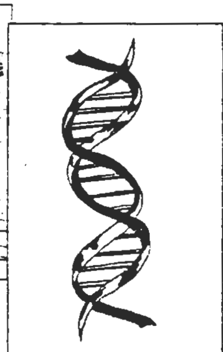

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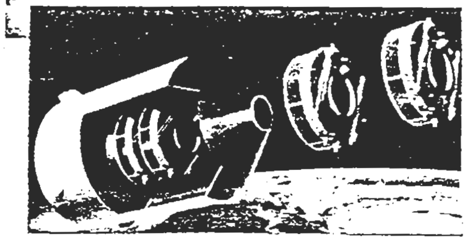

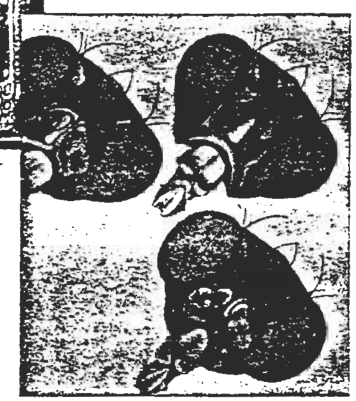

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