Title
Introduction and Institutionalization of Genetics in Mexico Ana Barahona, Susana Pinar and Francisco J. Ayala

Journal
Journal of the History of Biology, 38(2)

ISSN
0022-5010

Authors
Barahona, Ana
Pinar, Susana
Ayala, Francisco J

Publication Date
2005-06-01

DOI
10.1007/s10739-004-3798-0

Journal of the History of Biology (2005) 38: 273–299
DOI 10.1007/s10739-004-3798-6

Introduction and Institutionalization of Genetics in Mexico
Ana Barahona, Susana Pinar and Francisco J. Ayala

ANA BARAHONA
Departamento de Biología Evolutiva
Facultad de Ciencias, UNAM
Zapata 6-9, Col. Miguel Hidalgo
Tlalpan 14410, México, D.F.
México
E-mail: abe@hp.fciencias.unam.mx

SUSANA PINAR
Instituto de Historia, CSIC
c/Duque de Medinaceli
28014-Madrid
España
E-mail: pinarova@yahoo.com

FRANCISCO J. AYALA
Department of Ecology and Evolutionary Biology
University of California, Irvine
321 Steinhaus Hall
Irvine, CA 92697-2525
USA
E-mail: ayala@uci.edu

Abstract. We explore the distinctive characteristics of Mexico's society, politics and history that impacted the establishment of genetics in Mexico, as a new disciplinary field that began in the early 20th century and was consolidated and institutionalized in the second half. We identify about three stages in the institutionalization of genetics in Mexico. The first stage can be characterized by Edmundo Taboada, who was the leader of a research program initiated during the Cárdenas government (1934–1940), which was primarily directed towards improving the condition of small Mexican farmers. Taboada is the first Mexican post-graduate investigator in phytotechnology and phytopathology, trained at Cornell University and the University of Minnesota, in 1932 and 1933, respectively. He was the first investigator to teach plant genetics at the National School of Agriculture and wrote the first textbook of general genetics, *Genetics Notes,* in 1938. Taboada's most important single genetics contribution was the production of "stabilized" corn varieties. The extensive exile of Spanish intellectuals to Mexico, after the end of Spain's Civil War (1936–1939), had a major influence in Mexican science and characterizes the second stage. The three main personalities contributing to Mexican genetics are Federico Bonet de Marco and Bibiano Fernández Osorio Tafall, at the National School of Biological Sciences, and José Luis de la Loma y Oteyza, at the Chapingo Agriculture School. The main contribution of the Spanish exiles to the introduction of genetics in Mexico concerned teaching. They introduced in several universities genetics as a distinctive discipline within the biology curriculum and wrote genetics text books and manuals. The third stage is identified with Alfonso León de Garay, who founded the Genetics and Radiobiology Program in 1960 within the National Commission of Nuclear Energy, which had been founded in 1956. The Genetics and Radiobiology Program rapidly became a disciplinary program, for it embraced research, teaching, and training of academics and technicians. The Mexican Genetics Society, created by de Garay in 1966, and the development of strains and cultures for genetics research were important activities. One of de Garay's key requirements was the compulsory training of the Program's scientists for at least one or two years in the best universities of the United States and Europe. De Garay's role in the development of Mexican genetics was fundamental. His broad vision encompassed the practice of genetics in all its manifestations.

Keywords: Alfonso León de Garay, Bibiano Osorio Tafall, Edmundo Taboada, genetics and agriculture, genetics and health, institutionalization of genetics in Mexico, José Luis de la Loma y Oteyza

Introduction

The studies of the history of science in Latin America only started in the final decades of the 20th century, developed within the frame of European science and its influence. Many historians, especially those focused on colonial science, referred to and often sought to implement the model proposed by George Basalla in 1967.[1] This pattern framed, during the 70s and the 80s, the development of historical studies seeking to account for the development of science in countries such as Argentina, Australia, Brazil and Mexico.[2]

More recently, studies on the sociology of science, philosophy of science, and scientific literature have stressed and validated a local and comparative focus for doing history of science. These studies have lead to identifying key elements in the diffusion process and developing more accurate ideas about its complexity.[3]

There is, nevertheless a need for historical studies that acknowledge the complex interactions generated after the contact between imported scientific novelties and local cultural traditions, which can yield different results in different countries. The introduction of scientific disciplines in different Latin American countries has differently impacted the power and social status of scientists, and their interaction with the political structures of their country.[4] Emphasis on the local organizations and

[1] Basalla, 1967.

[2] For example, Sagasti and Guerrero, 1974; Stepan, 1981; Inkster, 1985; Chambers, 1987; MacLeod, 1987; Stafford, 1988, and Lafuente and Sala Catalá, 1989.

[3] Latour, 1987; Home and Kohlstedt, 1991; McClellan, 1992; Petitjean, 1992; Palladino and Worboys, 1993; Vessuri, 1994.

[4] Home and Kohlstedt, 1991; McClellan, 1992, Petitjean, 1992; Palladino and Worboys, 1993.

scientific institutions requires focusing on the scientific and technical elites. These elites, at different times and in different countries, have identified problems and their solutions, and provided the scientific community with a set of beliefs, objectives, and ideals.

Scientific institutions are characterized not only by their theoretical organization and components, but also develop as places where scientific values, skills, and practices are coordinated and fleshed out.[5] According to Pierre Bourdieu,[6] disciplines are institutionalized formations, where schemes of action and valuation are set up for teaching knowledge and skills; disciplines are the infrastructure of sciences and they are located in university departments, scientific and professional societies, textbooks and handbooks. So, for Bourdieu, disciplines are not only related to theoretical constructs, but also refer to institutions, professions and individuals. Timothy Lenoir further suggests that disciplines function as structures of political power that mediate between the production of knowledge and its social practice, that is, between scientific action and political economy.[7] The content of disciplines cannot be treated apart from its institutionalized forms; the content and production of scientific knowledge are entangled with social and political realities that will determine the establishment of agreements and practices which, in turn, will warrant the stabilization of a discipline's domain. For Lenoir, the disciplines play a fundamental role in the organization and stabilization of a domain that encompasses the negotiation of social conventions, criteria of what is and what is not scientific, experimental practices, standards of truth and of evaluation. That is, disciplines involve shared theoretical and instrumental values and, very importantly, are the place where monetary resources are allocated.[8]

We will distinguish between a discipline's research programs and disciplinary programs, because although both function within ''the scientific field, they are oriented differently with respect to objectives.''[9] Disciplinary programs are institutionally oriented; they are concerned with establishing social roles, facilitating the interaction with other disciplines, assuring the transmission of conceptual tools and scientific techniques to other groups, and training persons in a given curriculum. Research programs, on the other hand, are oriented towards a set of problems that may exist without having been institutionalized and that

[5] Vessuri, 1994.
[6] Bourdieu, 1977.
[7] Lenoir, 1997.
[8] Lenoir, 1997.
[9] Lenoir, 1997, p. 55.

may be successful even if they do not become the disciplinary basis of a science.

We shall attempt to analyze the conditions for scientific research and the social relationships that allowed the establishment of genetics in Mexico, as a new disciplinary field that began in the early 20th century and was fully consolidated and institutionalized in the second half. In order to analyze the distinction between research and disciplinary programs, we shall attempt a historical reconstruction of the institutions, the interests, the bodies of norms, and the practices that drove the acceptance of conceptual forms by formulating paradigms accepted by the international community. We will examine the effects that small local communities had during the early stages of consolidation of genetics in Mexico and the idiosyncrasies of the application, diffusion and acceptance of genetics by the agricultural, academic, and professional communities. It is worthwhile to examine the dynamics of disciplinary formation, consolidation, and institutionalization of science.

Agriculture and Genetics in Mexico

The armed battles associated with the Mexican Revolution (1910–1917) and the political conflicts of the following years (1920–1930) considerably damaged the Mexican economy, particularly in the area of agriculture. The government and its institutions had coordinated the scientific research on agriculture since the administration of President Porfirio Díaz (1884–1911), but the post revolutionary governments sought to promote it considerably more.[10]

Díaz's dictatorship favored higher education and scientific research in accordance with the French model, together with the positivist tradition, introduced to Mexico by Gabino Barreda during the regime of president Benito Juárez (1858–1861; 1865–1867; 1871–1872). Francisco I. Madero's call for universal suffrage and the prohibition of reelection gave rise to an armed uprising (November 10, 1910) that marks the start of the Mexican Revolution. After Díaz's resignation, Madero assumed the presidency on November 6, 1911, but he was assassinated in February 1913 by Mexican Army General Victoriano Huerta, who remained in power until 1914, as the war against the usurping government continued. After taking the capital city in 1915, Venustiano Carranza, one of the revolutionary leaders, headed a new government. Carranza promulgated a new political constitution in 1917, but was assassinated in 1920. Political instability prevailed through the 1920s, because the

[10] Webster, 1992; Ledesma and Barahona, 2003.

right wing forces continued the struggle and formed governments alternating with those of the Revolution until the late 1920s.

During the administration of Porfirio Díaz, legal frameworks and agricultural tools were developed; agricultural research was stimulated by the creation of the first experimental stations, professional level agricultural education, and the modernization of the National Agricultural College (*Escuela Nacional de Agricultura*). After the revolution, new curricula and titles were created, such as "agronomic engineer," "veterinarian," and "technician in agricultural mechanics and agronomy."[11] By the 1920s, there were already programs for improvement of cotton cultivars; the study, introduction, and improvement of new and cultivated agricultural varieties; and the cataloging of hybrids and their possible uses.

Since 1929, during the administration of Emilio Portes Gil (1928–1932), the Department of Agriculture and Promotion (*Secretaría de Agricultura y Fomento*) developed a plan to improve land redistribution and reorganize the production of the raw materials that the country needed.[12] Both activities were ideals that emanated from the Mexican Revolution. The "ejido" – a form of communal land-holding and social organization – was revived (its historical roots date from prehispanic and colonial times) under the slogan: "the land belongs to him who cultivates it;" it could not be taxed or mortgaged because it was a *family goods* transmitted only in a hereditary manner.

In 1932, during president Abelardo L. Rodríguez's government (1932–1934), the National Agronomic Commission (*Comisión Nacional Agraria*) was created within the Department of Agriculture and Promotion, with the following objectives: guaranteeing that the national plant and animal products would satisfy, totally and foremost, the needs of the whole population; establishing the regulatory norms needed by public agencies, within the principles of an economy directed towards a social organization of agriculture based on the *ejido*; promoting cooperation between all factors involved in food production; reducing the number of middlemen between the producer and the consumer, thus lowering the price of agricultural products; and arranging plant and animal production so as to achieve a more just redistribution of commodities. There was a great effort towards improving the teaching of technical agriculture, through the creation of the "agricultural engineer" major at the ENA, which had a totally practical approach.

During the 1930s and 1940s, two political tendencies that influenced research in plant genetics can be distinguished in Mexico's power circles,

11 Reyes, 1981, p. 127.
12 Portes Gil, 1929.

with roots dating back to the *Porfiriato* (the presidency of Porfirio Díaz). On one side were those who, as heirs of the Mexican Revolution, believed that farmer agriculture based on a tradition of communal land-holding had priority over the creation of a successful agriculture and, on the other side, were those who thought that Mexican agriculture could only improve by becoming a large-scale private enterprise, far from socialist agrarianism.[13]

During the administration of General Lázaro Cárdenas del Río (1934–1940), research was started to increase large scale food production, whereas during the *Porfiriato* a primary objective had been the exportation of grains. A main objective of General Cárdenas – a convinced agrarian and follower of Emiliano Zapata's ideals – was to transform the organization of agriculture and to grant credit and technical support to farmers. The first agronomists trained in the new agricultural techniques shared the "Cardenist" philosophy and focused on solving problems affecting the average farmer.

The scenario of a farmer policy based on the *ejido* changed drastically with the government of General Manuel Ávila Camacho (1940–1946); the capitalist tendency reappeared, supported by the private sector, favoring levels of production that would surpass the family needs of the *ejido*-based farmer, so as to meet the food needs of the greatly expanding cities and, above all, the needs of the developing industries.[14]

Different agronomic groups were integrated in the so-called Mexican Agricultural Program (*Programa Agrícola Mexicano,* MAP) of the Office of Special Studies (*Oficina de Estudios Especiales,* OSS), which was directed by North American researchers thanks to the cooperation between the Mexican government and the Rockefeller Foundation (RF) of the United States. This program had, as one of its fundamental objectives, the introduction of technologies distinctive of the Green Revolution, which were implemented in Mexico and afterwards exported to other countries in Latin America.[15]

[13] Hewitt de Alcántara, 1985.

[14] Hewitt de Alcántara, 1985, pp. 21–32.

[15] Barahona and Gaona, 2001; Gaona and Barahona, 2001. For the Green Revolution discussion in Mexico, see Frankel, 1963; Griffin, 1971; Reyes, 1981. The first activity of the Rockefeller Foundation (RF) in Mexico was in the 1923 campaign against yellow fever. After a major reorganization in 1928, the RF continued its emphasis on public health and medicine, but began to pay more attention to scientific education. Between 1940 and 1949, the RF launched a major agricultural program in Mexico with two main goals, to improve food-crop production (corn and wheat) and to train Mexicans in agricultural techniques. See Cueto, 1994. For the role played by the RF in the rise of biology, see Kay, 1993.

The engineer Edmundo Taboada Ramírez (1906–1976) was the leader of the research enterprise initiated during Cárdenas' government. He was the first Mexican researcher trained in phytotechnology and phytopathology, at Cornell University and the University of Minnesota, respectively in 1932 and 1933,[16] and would be the first to teach plant genetics at the ENA at Chapingo. At Cornell University, he worked on maize and wheat genetics and seed improvement under the direction of the well-known geneticist Rollins Adam Emerson. In 1933, he received an invitation from Herbert Kendall Hayes from the University of Minnesota to work with the *chahuixtle* fungus, a plague of maize, under the direction of the geneticist Elvin Stakman.[17]

After his return to Mexico in 1934, Taboada was named chief of the Experimental Agricultural Station of Yaqui, Sonora (*Estación Agrícola Experimental del Yaqui*), where he started his first genetic investigations, selecting among different varieties of sesame seed those best adapted to specific environmental conditions. In 1936, he became professor in the National Agricultural College, where he taught courses on general genetics and plant genetics and pursued agricultural experimentation and research.

Taboada wrote the first Mexican textbook of general genetics, *Apuntes de Genética* (*Genetics Notes*). This book encompasses the history of genetics, Mendelism, the chromosome theory of inheritance, cytogenetics, mutation, gene interaction, and population genetics. There are many references to Charles Darwin and natural selection, explaining how selection works on natural populations and the evolutionary process. Taboada describes with admiration the work of Thomas Hunt Morgan, the leader of the *Drosophila* research group at Columbia University and CalTech, and the work of Emerson, who was the leader of the Maize Genetics Group at Cornell University. For Taboada, the works of Darwin, Morgan, and Emerson were the cornerstone of biology. His textbook treated the various topics in a simple manner, as befits a textbook, with emphasis on the basic genetic principles. Taboada's *Apuntes de Genética* became very important for teaching genetics and also for the popularization of genetics in Mexico.[18]

In 1940, during the government of Ávila Camacho, in addition to the Office of Special Studies, the Office of Experimental Stations (*Oficina de Campos Experimentales, OES,*) was created within the Undersecretary of Agriculture (*Dirección General de Agricultura*), which belonged to the Department of Agriculture and Promotion. Taboada was appointed director. In the first 6 years of the Office of Experimental Studies, corn

[16] Instituto Nacional de Investigaciones Agrícolas, 1985.
[17] For a general discussion on Taboada's work, see Barahona et al., 2003.
[18] Taboada, 1938; Barahona et al., 2003.

selection for commercial production was carried out, seed production was increased, the first "mestizo" (hybrid) strains of corn were developed, different varieties of wheat were collected, and yield and resistance tests were conducted against the chahuixtle fungus.

As we have said, the Rockefeller Foundation began its first programs of technical assistance in 1943, when President Ávila Camacho signed a document that created the Mexican Agricultural Program,[19] with Jacob George Harrar as its first director.[20] Research objectives were the control of wheat rust, the improvement of corn-breeding production, studies related to the management of soils, and livestock diseases.[21]

In 1947 the Institute of Agricultural Research (*Instituto de Investigaciones Agrícolas,* IAR,) was created. Taboada would become its director from 1947 to 1960. One of its main objectives was the implementation of experimental stations in different parts of the country in order to increase the production of wheat, corn, cocoa, rice, sesame seed, and beans. For Taboada, the goal of Mexican geneticists was to genetically improve varieties and successfully adapt them for planting in the different agricultural regions of the country. One of the biggest successes of the Institute was to get a variety of corn with high productivity similar to that of hybrid corn, but which would retain its high productivity from one harvest to the next, without the need of producing new hybrid seed for each planting season. This variety of corn was called "stabilized" corn and was consistent with the goals pursued by Taboada: "There are several types of high yield corn seeds. The highest yields are obtained with the so called "hybrid" corn, but their exceptional productivity only lasts the first cycle. In subsequent cycles, the productivity decreases so rapidly that sometimes its yield is inferior to that obtained with ordinary seeds, forcing the farmer to acquire new seeds each year […] Improved stabilized varieties with open pollination are other type of high yield maize […] Thanks to their characteristics, the open pollination varieties are better for our poorest farmers and are nearly as productive as the hybrid types."[22]

To obtain the stabilized corn varieties, Taboada first obtained lines with the fewest agronomic deficiencies and that exhibited good crossing results. He would first cross any two given lines and select those particular combinations that exhibited high yield, obtaining eventually several combinations of lines that would be genetically stable, i.e., with

[19] Jennings, 1988.
[20] Harrar, 1950.
[21] Cotter, 1994.
[22] Secretaría de Agricultura y Ganadería, 1952. All translations from Spanish are ours.

productivity that remained high from one planting season to the next. These were distributed in the 1950s among Mexican farmers, especially in areas of small traditional farms.[23] Some of these varieties are still sowed today.

In regard to maize improvement, the approach of the Mexican OSS and the RF was contrary to Taboada's. The former institutions dedicated most resources to the production of high yield hybrid seed that could only be purchased by farmers who had substantial financial resources. This seed performed best with fertilizers and its efficiency depended upon being planted in irrigated areas. The OSS' approach had prevailed during the 1950s in the Department of Agriculture. In 1948, 80% of corn cultivars had been planted with open pollination varieties, but by 1956 the production program of the Department dedicated 96% of its capacity to hybrid seed production, which benefited the commercial production of corn and irrigated agriculture.[24]

An important mission of the OSS was the education and training of agronomists, who where commissioned by the Department of Agriculture to undertake research in the field and in the laboratory for one year; afterwards, the trainees were sent abroad, especially to the United States, for another year. This Office accepted foreign students, as well, to be trained in Mexico.[25]

The OSS contributed importantly to other research programs, such as the Institute of Research on Rice in the Philippines, the International Institute of Tropical Agriculture in Nigeria, The International Center of Tropical Agriculture in Colombia, and the International Center for the Improvement of Maize and Wheat (*Centro Internacional del Mejoramiento del Maíz y Trigo*) in Mexico.

Towards the end of the decade of the 1980s, it became apparent that there was no reason to keep two institutions dedicated to plant improvement. The OSS was being increasingly directed by Mexican specialists, who had been trained with the aid of the RF, while the latter's interests were focused on the exportation of the Green Revolution's new technology to other South American countries, especially Colombia, so that it increasingly left the running of the Office in Mexican hands. In 1961, the IAR merged with the OSS, forming the National Institute of Agricultural Research (*Instituto Nacional de Investigaciones Agrícolas*). This institution took control of all the experimental fields, equipment, and personnel.

[23] Taboada, 1960.

[24] Centro de Investigaciones Agrarias, 1970, p. 205.

[25] For discussion about the influence of the MAP on Mexican agriculture, see Cotter, 1994; Fitzgerald, 1994.

Taboada's stabilized corn varieties were the most important achievement of Mexican agriculture. This work may be considered a "research program," focused on solving farmers' problems and improving maize genetics research in Mexico. The stabilized corn varieties benefited farmers but did not contribute significantly to economic change in large-scale agriculture. Economically, the introduction of hybrid seed was more important. It led to the capitalization of the farms and the creation of a flourishing business, namely, the production and sale of seed. Taboada's textbook (1938) and his extensive teaching activities at the Colegio Nacional de Agricultura represent the initiation of the necessary infrastructure to support the institutionalization of genetics as a discipline. His early efforts would later mature with the development of new university curricula and with the arrival of the exiled Spanish professors (see below), yielding eventually a full scholastic program in support of the discipline of genetics.

Spanish Geneticists and their Exile in Mexico

The first group of exiles from the Spanish Civil War (1936–1939) arrived in Mexico in 1937; around 500 orphaned children, later known as the "Morelia children." Mexican President Lázaro Cárdenas del Río (1934–1940) decided also to accept the visit of highly renowned intellectuals, with the invitation to spend two or three years in a Mexican university. This decision materialized with the arrival of a second group of refugees in 1938, Spanish intellectuals, who established in Mexico Spain's Cultural Center (*Casa de España*), which in 1940 changed its name to College of Mexico (*Colegio de México*). The objective of this institution was to function as a research center, where Spanish exiles could work, but also as a meeting and exchange place for intellectuals and scientists of both countries.

After the end of the war in 1939, there was a massive arrival of Spanish refugees in Mexico. The acceptance of remunerated workers was forbidden by the *Ley General de Poblaciones del 16 de febrero de 1934* (General Law of Population of February 16, 1934), so that the only ones accepted were specialists in industrial, commercial, export, and agricultural sectors. Among those accepted for residence were professors from the group of exiled intellectuals mentioned above, who had been invited by universities or government agencies, originally for temporary (2–3 years) stays.[26]

[26] Maldonado, 1982, p. 52.

The Spanish immigrants became in Mexico if not the most numerous from any country, ‘‘certainly the ones with the highest intellectual standing.’’[27] Among the Spanish refugees, there were 501 elementary school teachers, 462 college professors, 208 lecturers and a total of 109 writers. This influx of trained specialists – who in Mexico did not encounter a language or cultural barrier, and who received facilities to validate their academic titles and skills – coincided with a period of expansion in the sciences fomented by Lázaro Cárdenas’ government. This expansion generated profound changes, which together with the nationalization of oil and agricultural reform, mark the beginning of a major industrial development and commercial expansion in Mexico. The Spanish exiles brought high scientific and technical skills that greatly contributed to the creation of new industries and the further development of the existing ones. Politically, the majority of the Spanish professionals, who came to Mexico were liberal, opposed to Franco’s Fascism. Only a minority of them were members of the communist or other extreme left parties.

With respect to science, the Spanish exiles collaborated and became integrated with Mexican scientists, directing laboratories, boosting growing disciplines, and contributing to the formation of new generations of Mexican researchers. The exiled Spanish scientists continued in Mexico the renewing role that the Council for the Advancement of Scientific Research and Study (*Junta para Ampliación de Estudios e Investigaciones Científicas*), created in 1907, had had in Spain. It must be noted that this was an exile of persons, not of ‘‘philosophical’’ schools, or research groups, so that the individuals had to adapt to the conditions and circumstances of the receiving centers. The Spanish exiles where eager to develop their profession in Mexican society, although this profession wasn’t always the same as they previously had in Spain. Some exiles became mostly active in politics, especially in activities seeking to legitimize the establishment of a Spanish Republic in exile and to pursue the fall of Franco’s Fascist government. Both trajectories are observed in the personalities involved in research on genetics in Spain. Among the geneticists arriving in Mexico, some contributed to the expansion of their discipline in the receiving country, while others shifted their interest to different biological disciplines. A number of them became primarily active politically.

Thus, a distinctive expansion of biological research in Mexico started in 1939, including the creation of the School of Sciences of the National University of Mexico (*Facultad de Ciencias of the Universidad Nacional*

[27] Cordero Olivero, 1997, pp. 46–47.

Autónoma de México) in 1939 and, later, the National School of Biological Sciences of the National Polytechnic Institute (*Escuela Nacional de Ciencias Biológicas of the Instituto Politécnico Nacional*). This last institution had earlier outlined its fundamental objectives: the preparation of specialized technicians, the training of professors, and the performance of research. In 1941, the former botany, zoology, and hybridology majors would become part of a new undergraduate program, the biology major.[28]

We cannot mention all the Spanish scientists who contributed to Mexican science, but we will point out some of those who contributed – to a greater or lesser extent – to the development of Mexican genetics. Three, who deserve special mention are Federico Bonet de Marco and Bibiano Fernández Osorio Tafall, at the National School of Biological Sciences and José Luis de la Loma y Oteyza, at the Chapingo Agricultural School. We also mention Félix Gordón Ordás, who had fought for the reform of biology and the introduction of genetics in Spain. Politically engaged, he participated in the negotiations between Spain and Mexico that specified the terms of the Spanish exile. He had earlier abandoned research for politics, becoming ambassador of Spain successively to Guatemala, Panama, and Cuba. Later on, he acted as the leader of the Republican Government in exile, between 1951 and 1960.[29]

Federico Bonet de Marco was born in 1906.[30] He was a natural science student in Madrid, where he obtained the equivalent of a B.S. in 1927. He simultaneously studied medicine, and concluded his medical studies in 1930, the same year when he obtained his doctorate in natural science. He studied genetics during the 1923–1924 school year under the tutoring of Antonio de Zulueta, who was one of the main personalities in the history of Spanish genetics in the period preceding the Civil War.[31] Bonet was named auxiliary curator of the National Museum of Natural Sciences (*Museo Nacional de Ciencias Naturales*) in Madrid, and he substituted for de Zulueta at the Museum as well as in the teaching of genetics course during Zulueta's 1933 stay at CalTech in Morgan's laboratory.

Because of his active role in the Spanish civil war, including repeated combat duty, Bonet went into exile, arriving in Mexico in July, 1939. He was immediately incorporated as a faculty member at the National

[28] Ledesma and Barahona, 2003.
[29] Pinar, 2000.
[30] For information about Bonet's papers, see the references in Halffter, 1970, which encompass mainly his Mexican period. For information about his entomologic work at the Museum of Natural History in Madrid, see Martín Albaladejo, 1994.
[31] Pinar, 1999a, 1999b, 2002a, 2002b; Candela, 2003.

School of Biological Sciences. Biology studies were directed towards the education of biology and entomology specialists, who would later work as teachers or research professionals. During his career, Bonet busied himself with the revision of the syllabus for the biological sciences major, and collaborated in the creation of the Zoology Department, of which he later took charge. In 1942, Bonet established a Zoology Laboratory and directed it from 1945 to 1962. The laboratory changed its name to Ecology and Paleontology in 1950, and later changed it again to Zoology, in order to include other disciplines. Bonet was the professor in charge of teaching the course on Variation and Evolution, which was part of the biology and entomology curriculum. His scientific publications were mostly on taxonomy, but he was nevertheless recognized as a great geneticist. Towards the later years of his life, he was named head of the biology department in the graduate section, and coordinator of the biology and medicine division in the National Polytechnic Institute. He died in 1980.[32]

Bibiano Fernández Osorio Tafall was born in 1903.[33] He studied natural science in Madrid from 1919 to 1925. He broadened his studies at the Museum in Madrid, where he took Antonio de Zulueta's genetics course in the year 1921–1922. After his return to Galicia (in northwestern Spain) he obtained the equivalent of a B.S. in economics at the University of Santiago de Compostela (1925–1929), which proved to be useful during his exile. He taught agriculture in Pontevedra, Spain since 1927, and was there named director of an education center in 1931. Since 1927, Osorio Tafall actively participated in the Galicia Biological Mission (*Misión Biológica de Galicia*), an important center of Spanish genetics at the time,[34] seeking particularly the improvement of corn and potato. For this purpose, he expanded his knowledge of genetics in the *Biologische Anslat* of Berlin between 1930 and 1931, and attended several meetings and brief courses in France and England.

After having been exiled for months in France and the United States, Osorio Tafall arrived in Mexico in 1940 and obtained citizenship the next year. He initially practiced as a bio-ecology professor in the hydrobiology laboratory of the National School of Biological Sciences. During this first period, Osorio Tafall taught, with Demetrio Sokoloff (a Russian immigrant), biometrics and genetics to biology and entomology students, and human biology to medical students with Fernando Priego. Osorio Tafall published a series of five articles entitled ''Adquisiciones recientes sobre virus'' (''Recent Advances about Virus'') in the Mexican

[32] Giral, 1994, p. 46.
[33] Alvarez, 1992; León-Portilla, 1978.
[34] Candela, 2003; Pinar, 2002b.

journal *Ciencia*, and published "Genética y mejoramiento humano" ("Genetics and Human Enhancement") in the *Anales de la Escuela de Biología*.[35] These articles were outside his main research interests. He participated actively in *Ciencia*, submitting numerous articles related to marine biology. He was part of the editorial board of that journal, and reviewed books on genetics. During his late years, Osorio Tafall alternated the direction of the Economy and Social Studies of the Third World Center with the direction of the International Problems Seminar at the College of Mexico.

In spite of the great number of Spanish scientists exiled to Mexico, only nine of them were agronomy engineers, among them José Luis de la Loma y Oteyza, who explained it by saying that "in Spain, the agronomy major is pursued mainly by the children of landowners, that is, people from the political right. Some, like myself, chose this profession out of vocation, without a particular economic interest."[36] De la Loma y Oteyza was born in Madrid in March 1901.[37] He entered the Agronomy Engineers Special School in Madrid in 1915, and graduated in 1922. He was member of a family of agronomy engineers, some of whom eventually migrated to Mexico and occupied different positions as mathematics and agronomy professors in Chapingo and other institutions.[38]

De la Loma left Spain for France, but arrived in Mexico still in 1939; he obtained citizenship in 1941. Immediately after his arrival in Mexico, he became a faculty member at the Chapingo National Agricultural School, directed at that time by Waldo Soberón. The first courses he taught were calculus and a genetics course that was just created. Thereafter, he taught general and applied genetics; he later took charge of the agricultural experimentation curriculum. Just like Taboada, de la Loma wrote several textbooks to support his courses: *Apuntes de Genética Vegetal Aplicada* (Notes on Applied Plant Genetics) in 1942, and *Apuntes de Experimentación Agrícola* (Notes on Agricultural Experimentation) in 1943.

Once he became part of the Agricultural school council, de la Loma introduced the teaching of genetics in all majors. The genetics course taught during the third year was complemented with a second general genetics course. The content of the genetics courses was broadened beyond basic genetics, with topics such as quantitative characters, cytoplasmic inheritance, etc. He revised the applied genetics syllabus, so

35 Osorio Tafall, 1941, 1943, 1944, 1945a, 1945b, 1945c.
36 Maya Nava, 1982, p. 127.
37 Jiménez, 1984; Loma, 1972.
38 About genetics in Spanish agronomy see Pinar, 2001, 2002b.

that it included two courses: one on phytotechnology methods, and another on applied plant genetics. One more course on special genetics – where plants like corn, wheat and beans were studied – was added at the request of de la Loma. The contribution of de la Loma to the introduction of genetics in Mexico was mostly at the teaching level.

The contribution of the Spanish exiles to Mexican natural sciences was important, but the role they played in the process of institutionalization of genetics in Mexico was primarily at the educational level. They improved the teaching of genetics, changed and added the genetics major to the biology syllabus, but they did not form research groups in genetics, or found genetics laboratories. The final steps towards the crystallization of genetics in Mexico would occur later, with the development of a full disciplinary program embracing both, teaching and research.

The Institutionalization of Genetics in Mexico

World War II inaugurated in many parts of the world a period of industrial growth, rapid expansion of the population in large urban cities, and improvement in the general level of education. Science and educational centers, such as the Universities, came to play a central role in socio-economic development, particularly in countries such as Mexico. Scientific research in Mexico had been closely linked to a series of measures throughout the 1940s that legitimatized the role of the full time researcher within universities and educational centers, including those, where most biological research was taking place, such as the National University of Mexico, the National School of Biological Sciences, the National Polytechnic Institute, and the Autonomous University of Puebla (Universidad Autónoma de Puebla).

In the 1950s, biological research in Mexico was mainly descriptive, encyclopedic, and utilitarian, including botanical and zoological taxonomy and physiology, morphology, and histology, linked to such national problems as parasitic diseases and the use of the national natural resources. Evolutionary aspects, including the genetic principles were being taught (only as part of general biology or technical courses), but were relegated to a secondary role.[39] Genetics had been introduced in agriculture as a heterogeneous collection of plant breeding and teaching practices, and in educational programs at the National School during the first half of the 20th century, but it was not until the second half of the century that genetics was institutionalized and oriented to medical and public health problems.

[39] For further discussion of biology in Mexico, see Ledesma and Barahona, 2003.

Alfonso León de Garay founded the Genetics and Radiobiology Program in 1960. It was part of the National Commission of Nuclear Energy (*Comisión Nacional de Energía Nuclear*), which had been founded in 1956. The Genetics and Radiobiology Program rapidly became a disciplinary program for it embraced research, teaching and training of academics as well as technicians. The creation of a scientific association, the Mexican Genetics Society, and the elaboration of specialized material for genetics research and teaching were part of de Garay's agenda. One key component was the compulsory training of the people in the program for at least one or two years in the best universities of Europe and the United States. De Garay's role in the development of Mexican genetics was fundamental. His broad vision encompassed the practice of genetics in all its manifestations. The program he created was the basis for the institutionalization of genetics in Mexico; therefrom emerged, in the fashion of a center of dispersion, many genetics laboratories in the country; the people who were educated within this program colonized new niches.

Alfonso León de Garay was born on January 31st of 1920, in the city of Puebla de Los Angeles, in Mexico, and died in Mexico City in October 2002. He was member of a wealthy family, whose origins went back to the viceroyalty of the 18th century. De Garay studied medicine at the Autonomous University of Puebla, but because of the many armed conflicts at the time, "the situation was very tense, and I had to leave; that is why I couldn't finish." His family moved to Mexico City. He completed his medical studies in 1947, and practiced as a neurologist for many years.[40] In 1957, he wrote to Lionel S. Penrose – who had been J.B.S. Haldane's student, and who was then director of the Galton Laboratory at University College, London – with the hope of doing graduate studies in population genetics with him. Penrose accepted him, but under the condition that de Garay would obtain a scholarship. Thanks to an agreement between the International Atomic Energy Organization of the United Nations (IAEO) and some European universities, de Garay obtained a grant and went to London.[41] Penrose assigned him to the anthropometry side of the laboratory, which was then divided in two sections, anthropometry on one side, and zoology and botany on the other.[42]

During the years that de Garay lived in England, he met distinguished personalities, such as John Maynard Smith – whose good friend

[40] Many years after that, in 1979, he obtained the degree of Doctor in Biology from the School of Sciences of UNAM.
[41] de Garay, 2001.
[42] De Garay, 1998.

he considered himself to be, as well as other scientists, such as Hans Kalmus, and Krishna Dronamraju – Haldane's student and biographer, and whom he later invited to Mexico. "Since I was Haldane's and Fisher's student, I was introduced to the population genetics elite of those times."[43] The relationships he established in Europe were extremely influential in the consolidation of the Genetics and Radiobiology Program he founded upon his return to Mexico, in 1960. His return to Mexico was precipitated because the National Commission of Nuclear Energy insisted on the immediate set-up of a radiobiology laboratory, due to international pressures that Mexico should develop its own research in genetics and radiobiology.

Foundation of the Genetics and Radiobiology Program

The Radiobiology Laboratory started its planning phase in 1957, after an interview of de Garay with the commissioners of the National Commission of Nuclear Energy in Vienna, Austria, José M. Ortiz Tirado, Nabor Carrillo Flores, and Manuel Sandoval Vallarta. The Program was established in order to "contribute to the conservation of health, physical and mental improvement, and sickness prevention, through the investigation of the factors which intervene – favorably or unfavorably – in the biological inheritance of the population."[44] There was at the time great interest throughout the world in the biological effects of atomic radiation. For example, the U.S. Atomic Energy Commission (which later evolved into ERDA, Energy Research and Development Administration, and still later into the Department of Energy) sponsored considerable research on the biological and genetic effects of high energy radiation. Eventually, the demonstration that atomic radiation generated deleterious genetic mutations at high rate would lead to a test ban treaty against nuclear explosions in the atmosphere.

The Radiobiology Laboratory consisted at first of a small staff composed of six researchers, including de Garay as director, Rodolfo Félix Estrada, chief of the *Drosophila* section, and María Cristina Cortina Durán, María Teresa Zenzes Eisembach, Víctor Manuel Salceda Sacanelles, and Claudina Berlanga Siller, who obtained their B.A. degrees in biology in 1960, and a technician, a secretary, and a service assistant.

[43] De Garay took the population genetics courses taught by Haldane and Fisher. In a personal interview, he said that these were the hardest courses he had ever taken while staying in London. De Garay, 2001.

[44] de Garay, 1960, p. 3.

The facilities were located in an apartment building divided in two parts. One part was the laboratory for genetic research with ionizing radiations; the other was dedicated to the tissue cultures and research on the fruit fly *Drosophila*, plus a darkroom and an office for the secretary. The laboratory consisted of six sections: tissue culture (where cytology and genetic analysis were practiced), photography (microphotography and autoradiography), biochemistry (biochemistry and radiochemistry), education (preparation of educational materials and training of personnel), *Drosophila* labs (conventional experimentation and computing of mutations, including irradiated stocks), and statistics and social work (population genetics and family studies).

In the 1960s research developed in several directions, new projects were planned, and it became a goal that genetic research at the National Commission of Nuclear Energy would become competitive on a worldwide scale. In 1965 and 1966, the Program incorporated the Aquatic Invertebrate Radiobiology section and the Molecular Genetics Laboratory. The idea was to work, respectively, on protective compounds against radiation effects in the flatworm *Planaria*, and to investigate the genetic mechanisms operating in microorganisms, as well as the radiation effects and consequences of radioprotective substances at the molecular level. In one decade, the Program's research projects had expanded from the six initial sections into nine laboratories subdivided in sections, and would participate in activities, such as the 19th Olympic Games in Mexico. The Olympic Organizing Committee provided the necessary space and equipment to conduct the Genetics and Anthropology protocols in Olympic athletes. This investigation covered to 1265 participants of the 1968 Olympics in Mexico. The results were published in 1974 in *Estudios Genéticos y Antropológicos de los Atletas Olímpicos (Genetic and Anthropological Studies of Olympic Athletes*).[45]

De Garay wanted his research team to learn the most up-to-date experimental techniques, and he encouraged the investigators of the Program to make at least short visits to universities abroad, always supported by the IAEO. Between 1960 and 1970, more than 25 people were trained in some of the world's best institutions, including Rockefeller University – where Theodosius Dobzhansky was located – the Universities of California at Berkeley, Chicago, Connecticut, Minnesota, Missouri, Texas, Tulane and Wisconsin in the United States; Cambridge University, University College, London and the University of Newcastle-Upon-Tine in England; and the *Hôpital des Enfant Malades* in Paris.

[45] de Garay and Levine, 1974.

A component of de Garay's agenda was to invite well-known international personalities to visit and participate in the different components of the program. Invited scientists included Hans Kalmus, already mentioned, of the Galton Laboratory, in 1963; Paul S. Moorhead, of the Winstar Institute, and David A. Hungerford, of the Institute of Cancer Research, both from Philadelphia in the United States; A. Lima de Faria, from the Institute of Genetics of Lund in Sweden during 1963–1964. Later, de Garay invited, in 1965, Louis Levine, from the City College in New York, who promoted the policy that young Mexican geneticists going for research training and development should stay abroad 3–5 years in order to get a Ph.D., instead of de Garay's current policy to stay one or two years for learning experimental techniques. Levine persuaded de Garay to start three new research programs: molecular genetics, developmental genetics, and behavior genetics.[46] From then on, Levine came to Mexico once a year, and established a close and long lasting friendship with Garay.

Although Theodosius Dobzhansky had visited Mexico in 1935, 1936 and 1938,[47] it was not until the Program started research in population genetics that his and his research group's collaboration with Mexican scientists began. First, de Garay convinced the young geneticist Víctor Salceda to go to New York to work with Professor Dobzhansky. The IEAO provided Salceda with a scholarship to go to New York, and in November 1965, he was incorporated to Dobzhansky's laboratory to do research on the genetic load of irradiated *Drosophila melanogaster* flies. When Salceda went back to Mexico in 1967, he tried to initiate, under Dobzhansky's advice, collections of *D. pseudoobscura* in natural populations, in order to study the geographical distribution of the chromosomal inversions that characterize this species. Because of Dobzhansky's illness (see below) and because de Garay's group was involved in the organization of the Olympic Games held in Mexico in 1968, this project never took off at the time.

De Garay met Francisco J. Ayala in 1966 in Chicago, during the III International Congress of Human Genetics (September 6–10, 1966). A correspondence began between the two, no later than September 12, 1966, which would persist at frequent intervals until 1976. De Garay invited Ayala to lecture in Mexico, an invitation that Ayala was "finally able to accept" for June 1968. De Garay had also invited Dobzhansky at various times to lecture in Mexico, an invitation that Dobzhansky

[46] de Garay, 1965, p.33.

[47] Dobzhansky and Sokoloff, 1938; Dobzhansky and Socolov, 1939; Barahona et al., 2000.

accepted for June or July 1968, when he intended to travel (with Ayala and to be joined in Mexico by Salceda and others) for collecting *Drosophila pseudoobscura* in several Mexican localities. Ayala's lecture, sponsored by the Mexican Genetics Society, took place in June 1968 (and he would lecture in Mexico again in 1974 and 1976 at the invitation of de Garay), but Dobzhansky canceled his trip. The reason for the cancellation (although this reason was not given to de Garay) was that on 1 June 1968, during a routine checkup, Dobzhansky was diagnosed as suffering from a relatively mild form of leukemia. Consequently, Dobzhansky canceled most or all of his planned travels so that he could concentrate on writing the intended fourth edition of *Genetics and the Origin of Species*, which eventually appeared under a different title, *Genetics of the Evolutionary Process*, 1970. In March 1974, Dobzhansky delivered a keynote address during the II Annual Meeting of the Mexican Genetics Society (II Reunión Nacional de la Sociedad Mexicana de Genética) in Mazatlán, a lecture that was separately printed and distributed in Mexico. (On March 11, 1976, shortly after Dobzhansky's death, de Garay wrote to Ayala: "… I have reprints of the Professor's [Dobzhansky] lecture and will send you 50 if you want them …").[48]

De Garay met Dobzhansky in person in 1973, during the celebration of the XIII International Congress of Genetics in Berkeley, California. De Garay (still unaware, like nearly everybody else at the time, of Dobzhansky's illness) agreed with Dobzhansky about the importance of establishing an academic relationship between the Mexican program and Dobzhansky's laboratory, through a project on the "Population Genetics of Mexican *Drosophila*", which would eventually begin one year later, in 1974, with funding from the National Science Foundation and the Mexican National Council for Science and Technology (*Consejo Nacional de Ciencia y Tecnología*). The development of this project was fundamental for the establishment and consolidation of population genetics in the Genetics and Radiobiology Program.[49] During nearly 30 years of research on the geographical distribution of the chromosomal inversions in *D. pseudoobscura*, close to 20 articles emerging from this project were published in international journals, and several papers were presented in various scientific meetings.[50]

[48] Correspondence files, 1966–1976, of Francisco J. Ayala, Department of Ecology and Evolutionary Biology, University of California, Irvine.

[49] The Mexican participants in the Project were Rodolfo Félix, Judith Guzmán, María Esther de la Rosa, and Víctor Salceda. U.S. participants were Louis Levine and Jeffrey R. Powell.

[50] Some of these papers are De la Rosa et al., 1975, 1989; Anderson et al., 1979; Olvera et al., 1979, 1985; Levine et al., 1980, 1989, 1995; Gaso et al., 1988.

The educational efforts of the Genetics and Radiobiology Program during its first 10 years were very important for the institutionalization of genetics in Mexico. Professors from the Program taught several courses in important Mexican institutions. Some of the courses taught at the School of Sciences at UNAM were: Advanced Genetics (de Garay), General Genetics (R. Félix), Hydrobiology, General Ecology and Animal Ecology (all three by A. Laguarda), Radiobiology (de Garay), Genetics of Development (R. Félix), and Genetics of Human Populations and Evolution (de Garay). Other courses were given at the Medical School and the School of Chemical Sciences, also at UNAM, the Autonomous University of Puebla, the *Iberoamericana* University, the National Commission of Nuclear Energy, the National Institute of Neurology, the National School of Agriculture, the National School of Anthropology and History, the Surgery Society of the Juárez Hospital, and health dependencies of the government.

Professor de Garay founded the Mexican Genetics Society in 1966, coinciding with the commemoration of the 100th anniversary of Mendel's publication of his epoch-making discoveries. The Society started with only a dozen members; today it has nearly 500. De Garay was the Society's President for several years, until 1979. The goals of the Society were to promote genetic research, teaching and popularization of genetics, communication and knowledge exchange among individual scientists and with national and foreign societies.

The Genetics and Radiobiology Program changed considerably in the ensuing years. The most important change happened in 1973, when it was incorporated to the National Institute for Nuclear Research in Salazar, in the state of Mexico, and had to be reduced to its current size that comprises only four laboratories: Plant Genetics, Microbial Genetics, the Drosophila lab, and Human Genetics. In 20 years of research, from 1960 to 1980 the Program published close to 140 papers in national and international journals.

At least 26 genetics laboratories founded by members of the Genetics and Radiobiology Program or their disciples are located in universities such as the National University of Mexico and the Autonomous Metropolitan University (*Universidad Autónoma Metropolitana*) in Mexico City, Baja California, Coahuila, Hidalgo, Chiapas, Oaxaca, Puebla, Querétaro, Tabasco, Tlaxcala, Veracruz, and Yucatán, and other states.

The success of this disciplinary program amounts to the institutionalization of genetics in Mexico, with the Garay as the disciplinary architect.

Conclusions

The institutionalization of genetics as a ‘‘discipline’’ became fulfilled in Mexico only in the 1960s, in the sense we have defined, which would include the teaching of the subject throughout universities and institutions of higher learning, the formation of research programs and institutions, and the applications of genetics to agriculture and human health. Two preliminary stages led to that fulfillment. The first stage can symbolically be identified with Edmundo Taboada, encompassing much of the first half of the 20th century. Government and other programs preceding Taboada, as well as his own activities, were primarily directed towards the improvement of agricultural practices and agricultural production. Education and training were overwhelmingly directed towards the preparation of agricultural technicians and effective farmers.

The second stage emerges with the arrival in Mexico of large number of Spanish intellectuals, including geneticists and other scientists, after the end of the Spanish Civil War in 1939. In the present context, the greatest impact of the Spanish exiles was on education, in the recognition of genetics as a scientific discipline that should be taught as an important component of the biology curriculum, and in the publication of genetics textbooks and manuals. The Spanish exiles became professors at several important universities, where the teaching of genetics had been previously handicapped not only by the lack of recognition of genetics as an important subject, but also by the scarcity of well trained geneticists. Throughout the 1940s and 1950s, genetics became a required subject within the biology curriculum and was identified as a distinctive major in some of the best universities. But no research groups were formed, nor genetics laboratories established.

The iconic event associated with the institutionalization of genetics as a discipline in Mexico was the creation in 1960 of the Genetics and Radiobiology Program under the leadership of de Garay. The establishment of the Mexican Genetics Society in 1966, also by de Garay, may also be considered as a second iconic event in the institutionalization of genetics in Mexico. De Garay’s activities were multipronged. He established research programs such as the various components of the Genetics and Radiobiology Program and its successor institutions; he acquired research and maintained materials, such as *Drosophila* mutant strains and cultures of various microorganisms; he formed teams of capable geneticists and engineered the training of additional scientists as well as technicians; he encouraged and facilitated the travel of Mexican geneticists abroad and their additional training; he invited foreign scientists to Mexico for lecturing and for developing joint research activities with Mexican scientists; he became instrumental in the creation of genetics research programs; and he successfully nourished the introduction in the universities of courses specifically dedicated to various genetics subdisciplines, such as quantitative genetics, radiation genetics, and human genetics. He and other members of his research team were often the professors in charge. As the Genetics and Radiobiology Program expanded, the territory of genetics was staked, resources and responsibilities were assigned, chairs and academies were founded, textbooks were published, and formal education in genetics was strongly encouraged. Disciplinary programs amount to strategies for the organization of scientific fields because they allow recruiting and training, as well as the building of alliances between different disciplinary fields.

References

Abellán, J.L. 1976. *El Exilio Español de 1939*, 6 vols. Madrid: Taurus.

Álvarez, S. 1992. *Osorio Tafall. Su Personalidad, su Aportación a la Historia*. A Coruña: Ed. Do Castro, Sada.

Anderson, Wyatt W., Levine, L., Olvera, O., Powell, J.R., Rosa, M.E. de la, Salceda, V.M., Gaso, M.I. and Guzmán, J. 1979. Evidence for Selection by Male Mating Success in Natural Populations of *D. pseudoobscura*. *Proceedings of the National Academy of Sciences USA* 76: 1519–1523.

Barahona, Ana and Gaona, A.L. 2001. "The History of Science and the Introduction of Plant Genetics in México." *History and Philosophy of the Life Sciences* 23: 157–168.

Barahona, Ana, Pinar, S. and Ayala, F.J. 2003. *La Genética en México: Institucionalización de una Disciplina*. México: UNAM.

Basalla, George, 1967. "The Spread of Western Science." Science 156: 611–622.

Candela, M. (ed.). 2003. *Los Orígenes de la Genética en España*. Madrid: Sociedad Estatal de Conmemoraciones Culturales.

Bourdieu, Pierre. 1977. *Outline of a Theory of Practice*. Cambridge: Cambridge University Press.

Centro de Investigaciones Agrarias. 1970. *Estructura Agraria y Desarrollo en México*. México.

Chambers, D.W. 1987. "Period and Process in Colonial and National Science." N. Reingold and M. Rotherberg (eds.), *Scientific Colonialism: A Cross Cultural Comparison*. Washington: Smithsonian Institution Press, pp. 297–321.

Cordero, Olivero I. 1997. *Los Transterrados y España. Un Exilio Sin Fin*, Huelva: Universidad, Servicio de Publicaciones.

Cotter, Joseph. 1994. "The Rockefeller Foundation's Mexican Agricultural Project: A Cross-Cultural Encounter, 1943–1949." Cueto, Marcos (ed.), 1994. *Missionaries of Science. The Rockefeller Foundation & Latin America*. Indiana University Press, pp. 97–125.

Cueto, Marcos. 1994. "Visions of Science and Development: The Rockefeller Foundation's Latin America Surveys of the 1920s." Cueto, Marcos (ed.), 1994. *Mission-*

aries of Science. The Rockefeller Foundation & Latin America. Indiana University Press, pp. 1–22.

De Garay, Alfonso León. 1960. *Programa de Genética y Radiobiología. Informe de Labores 1960*. México: Comisión Nacional de Energía Nuclear, Archivo de Información, Biblioteca del ININ.

—— 1965. *Programa de Genética y Radiobiología. Informe de Labores 1965*. México: Comisión Nacional de Energía Nuclear, Archivo de Información, Biblioteca del ININ.

—— 1998. Interview with Ana Barahona (in Spanish), Tecamachalco, Estado de México.

—— 2001. Interview with Ana Barahona (in Spanish), Tecamachalco, Estado de México.

De Garay, Alfonso León and Levine, L. (eds.). 1974. *Genetic and Anthropological Studies of Olympic Athletes*. New York: Academic Press.

De la Rosa, M.E., Guzmán, J., Levine, L., Olvera, O. and Rockwell, R.F. 1989. "Studies on Sibling *Drosophila* Species from Laguna Verde, Veracruz, México. I Species Frequencies, Viability, Desecation, Resistance and Vagility." *Journal of Heredity* 80: 44–47.

Dobzhansky, Theodosius. 1937. *Genetics and the Origin of Species*. New York: Columbia University Press (2nd and 3rd eds 1951 and 1961).

—— 1970. *Genetics of the Evolutionary Process*. New York: Columbia University Press.

Dobzhansky, Theodosius and Sokoloff, D. 1938. "Estructura y Variación de los Cromosomas en *Drosophila azteca* Sturtevant & Dobzhansky." *Anales de la Escuela Nacional de Ciencia Biológicas* 22(1): 37–62.

Dobzhansky, Theodosius and Socolov, D. 1939. "Structure and Variation of the Chromosomes in *Drosophila azteca*." *Journal of Heredity* 30: 3–19.

Fitzgerald, Deborah. 1994. "Exporting American Agriculture: the Rockefeller Foundation in Mexico, 1943–1953." Cueto, Marcos (ed.), 1994. *Missionaries of Science. The Rockefeller Foundation & Latin America*. Indiana University Press, pp. 72–96.

Frankel, S.H. 1963. "Some Conceptual Aspects of Technical Change." Maynaud, Jean (ed.), *Social Change and Economic Development*. Leiden: Noordhoff.

Gaona, Ana Lilia and Barahona, A. 2001. "La Introducción de la Genética en México: La Genética Aplicada al Mejoramiento Vegetal." *Asclepio* 53(2): 23–40.

Gaso, I., González, F., Guzmán, J., Levine, L., Olvera, O., Rockwell, R.F. and de la Rosa, M.E. 1988. "Chromosomal and Behavioral Studies of Mexican Drosophila. VI Effects of Density on Larval Digging and Population in *Drosophila pseudoobscura*." *The Southwestern Naturalist* 33(4): 445–449.

Giral, Francisco. 1994. *Ciencia Española en el Exilio (1939–1989). El Exilio de los Científicos Españoles*. Barcelona: Anthropos-CIERE.

Griffin, K. 1971. *The Green Revolution and Some Issues of Economic Policy*. Geneva: Instituto de Investigación de la Naciones Unidas para el Desarrollo Social.

Halffter, Gonzalo. 1970. "Biografía Federico Bonet de Marco." *Anales de la Escuela Nacional de Ciencias Biológicas de México*, 17(1–4): XV–XXII.

Harrar, J.G. 1950. *The Mexican Agricultural Program: A Review of the First Six Years of Activity Under the Joint Auspices of the Mexican Government and the Rockefeller Foundation. Rockefeller Foundation*, New York: Leo Hart Co.

Hewitt de Alcántara C. 1985. *La Modernización de la Agricultura Mexicana, 1940–1970*. México: Siglo XXI Editores, pp. 21–32.

Home, R.W. and Kohlstedt, S.G. (eds.). 1991. *International Science and National Scientific Identity: Australia between Britain and America*. Dordrecht: Kluwer Academic Publishers.

Inkster, I. 1985. "Scientific Enterprise and the Colonial Model: Observations on Australian Experience in Historical Context." *Social Studies of Science* 15: 677–704.

Instituto Nacional de Investigaciones Agrícolas, INIA. 1985. *Special publication of the Secretaría de Agricultura y Recursos Hidráulicos*. México.

Jennings, B.H. 1988. *Foundations of International Agricultural Research: Science and Politics in Mexican Agriculture*. Boulder: Westview Press.

Jiménez, L. 1984. "Doctor José Luis de la Loma y de Oteyza." In: *Las Ciencias Agrícolas y sus Protagonistas*. Colegio de Postgraduados, México: Chapingo, pp. 172–173.

Kay, Lily E. 1993. *The Molecular Vision of Life. CalTech, the Rockefeller Foundation, and the Rise of the New Biology*. Oxford: Oxford University Press.

Latour, Bruno. 1987. *Science in Action*. Milton Keynes: Open University Press.

Lafuente, A. and Sala Catalá, J. 1989. "Ciencia Colonial y Roles Profesionales en la América Española del Siglo XVIII." *Quipu* 6: 387–403.

Ledesma, Ismael and Barahona, A. 2003. "The Institutionalization of Biology in Mexico in the early 20th Century. The Conflict Between Alfonso Luis Herrera (1868–1942) and Isaac Ochoterena (1885–1950)." *Journal of the History of Biology* 36(2): 285–307.

Lenoir, Timothy. 1977. *Instituting Science. The Cultural Production of Scientific Disciplines*. California: Stanford University Press.

León-Portilla, A.H. 1978. "Bibiano F. Osorio Tafall." *In España desde México. Vida y Testimonio de Transterrados*. México: UNAM, pp. 297–312.

Levine, Louis, Asmussen M., Olvera, O., Powell, J.R., Rosa, M.E. de la, Salceda, V.M., Gaso, M.I., Guzmán, J. and Anderson, W.W. 1980. "Population Genetics of Mexican *Drosophila*. V.A High Rate of Multiple Insemination in Natural Population of *Drosophila pseudoobscura*." *American Naturalist* 116: 493–503.

Levine, L., Olvera, O., Rockwell, R.F., Rosa, M.E. de la and Guzmán, J. 1989. "Nuclear Power Plants and Natural Populations of Mexican *Drosophila*." *Genome* 31: 256–264.

Levine, Louis, Olvera O., Powell, J.R., Rockwell, R.F., Rosa, M.E. de la, Salceda, V.M., Anderson, W.W. and Guzmán, J. 1995. "Studies on Mexican Populations of *Drosophila pseudoobscura*." Levine, Louis (ed.), *Genetics of Natural Populations. The Continuing Importance of Theodosius Dobzhansky*. Columbia: Columbia University Press, p. 120.

Loma, José Luis de la. 1972. *Pinceladas de una Obra*. México: Ediciones Moncloa, pp. 7–27.

MacLeod, R. 1987. "On Visiting the Moving Metropolis: Reflections on the Architecture of Imperial Science." N. Reingold and M. Rotherberg (eds.), *Scientific Colonialism: A Cross Cultural Comparison*. Washington: Smithsonian Institution Press, pp. 217–249.

Maldonado, V.A. 1982. "Vías Políticas y Diplomáticas del Exilio." In AAVV, *El Exilio Español en México, 1939–1982*. México: Salvat, Fondo de Cultura Económica, pp. 25–53.

Martín Albaladejo, C. 1994. *Bibliografía Entomológica de Autores Españoles (1758–1990)*. Museo Nacional de Ciencias Naturales, Madrid: CSIC, pp. 137–139.

Maya Nava, A. 1982. "Actividades Productivas e Innovaciones Técnicas." In: AAVV, *El Exilio Español en México, 1939–1982*. México: Salvat, Fondo de Cultura Económica, pp. 125–155.

McClellan, James E. 1992. *Colonialism and Science: Saint Dominguez in the Old Regime*. Baltimore: Johns Hopkins University press.

Olvera, Olga, Rockwell R.F., Rosa, M.E. de la, Salceda, V.M., Gaso, M.I., Guzmán, J., Anderson, W.W. and Levine, L. 1979. Population Genetics of Mexican *Drosophila* VI. Cytogenetic Aspects of the Inversion Polymorphism in *D. pseudoobscura*. *Evolution* 33: 381–395.

Olvera, Olga, Rockwell R.F., de la Rosa, M.E., Gaso, M.I., González, F., Guzmán, J. and Levine, L. 1985. "Chromosomal and Behavioral Studies of Mexican *Drosophila* III. Inversion Polymorphism of *D. pseudoobscura*." *Journal of Heredity* 76: 258–262.

Osorio Tafall, Bibiano F. 1941. "Genética y Mejoramiento Humano." *Anales de la Escuela Nacional de Ciencias Biológicas* 3: 15.

—— 1943. "La Ciencia Moderna. Adquisiciones Recientes sobre Virus." *Ciencia* 4(2–3): 49–62.

—— 1944. "La Ciencia Moderna. Adquisiciones Recientes sobre Virus." *Ciencia* 5(6–8): 145–158.

—— 1945a. "La Ciencia Moderna. Adquisiciones Recientes sobre Virus." *Ciencia* 6(2): 42–58.

—— 1945b. "La Ciencia Moderna. Adquisiciones Recientes sobre Virus." *Ciencia* 6(7–8): 243–252.

——1945c. "La Ciencia Moderna. Adquisiciones Recientes sobre Virus." *Ciencia* 6(10–12): 337–352.

Palladino, Paolo and Worboys, M. 1993. "Science and Imperialism." *Isis* 84: 91–102.

Petitjean, Patrick. 1992. "Sciences et Empires: un Thème Promotteur, des Enjeux Cruciaux." C. Petitjean, Patrick, Jami and A.M. Moulin (eds.), *Science and Empires: Historical Studies about Scientific Development and European Expansion*. Boston Studies in the Philosophy of Science, 136. Dordrecht: Kluwer Academic Publishers, pp. 3–12.

Pinar, Susana. 1999a. "La Introducción de la Genética en España durante el Primer Tercio del Siglo XX." *Llull* 22(44): 453–473.

—— 1999b. "José Fernández Nonídez, Introductor de la Teoría Mendeliano-Cromosómica en España." *Asclepio* 51(1): 27–54.

—— 2000. "Sobre Genética y Plantas. La Evolución de los Métodos de Mejora de Plantas en la España anterior a la Guerra Civil." *Cronos* 3(2): 313–348.

—— 2001. "La Genética Española en el Exilio y su Repercusión en la Ciencia Mexicana." A. Sánchez Andrés and S. Figueroa Zamudio (eds.), *De Madrid a México. El Exilio Científico y su Impacto sobre el Pensamiento, la Ciencia y el Sistema Educativo Mexicano*. Madrid-Morelia: CAM-Universidad Michoacana de San Nicolás de Hidalgo, pp. 127–159.

—— 2002a. "La Vertiente Histológica de José Fernández Nonídez. Introductor de la Teoría Mendeliano-Cromosómica en España." *Asclepio* 54(2): 3–18.

—— 2002b. "The Emergence of Modern Genetics in Spain and the Effects of the Spanish Civil War (1936–1939) on its Development." *Journal of the History of Biology* 35(1): 111–148.

Portes Gil, Emilio. 1929. *Informe del C. Presidente de la República al H. Congreso de la Unión en la parte relativa al ramo de Agricultura y Fomento*. México: Ed. Cultura.

Reyes, Pedro. 1981. *Historia de la Agricultura: Información y Síntesis*. México: A.G.T.

Sagasti, F. and Guerrero, M. 1974. *El Desarrollo Científico y Tecnológico en América Latina*. Buenos Aires: Instituto para la Integración de América Latina.

Secretaría de Agricultura y Ganadería. 1952. *Informe de Labores,* 1951–1952. México.

Stepan, N. 1981. *Beginnings of Brazilian Science: Oswaldo Cruz, Medical Research and Policy,* 1890–1920. New York: Science History Publications.

Stafford, R. 1988. "The Long Arm of London: Sir Roderick Murchinson and Imperial Science in Australia." R.W. Home, (ed.), *Australian Science in the Making*. Cambridge: Cambridge University Press, pp. 69–101.

Taboada, Edmundo. 1938. *Apuntes de Genética*. México: ENA.

—— 1960. *Líneas Homocigotas I*. México: Instituto de Investigaciones Agrícolas. Secretaría de Agricultura y Ganadería. Biblioteca Central.

Vessuri, Hebe. 1994. "The Institutionalization Process." J.J. Salomon, F.R. Sagasti and C. Sachs-Jeantet (eds.), *The Uncertain Quest. Science, Technology and Development*. New York: United Nations University Press, pp. 168–200.

Webster, G. von. 1992. "La agricultura en el porfiriato: 1876–1911." *In Primer Simposio de Ciencias Agronómicas*. México: Colegio de Posgraduados en Ciencias Agrícolas de Chapingo, pp. 135–137.