Manuela Serra and the Cajal school: part laboratory technician, part neuroscientist

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ABSTRACT

Introduction. This study analyses the figure of Manuela Serra, who collaborated with the Nobel laureate Santiago Ramón y Cajal, as he himself noted in a list of collaborators and disciples in 1922, shortly before retiring.

Methods. We consulted the Legado Cajal (Instituto Cajal, Consejo Superior de Investigaciones Científicas [CSIC]), the archive of the Junta de Ampliación de Estudios (CSIC), and the historical archive of the Universidad Central (Universidad Complutense de Madrid), and conducted interviews with the descendants of Manuela Serra and her sister Carmen Serra.

Results. Manuela Serra began working as a "preparadora" (laboratory technician) in the Laboratorio de Investigaciones Biológicas (today, Instituto Cajal) in 1919, and soon stood out for her "sharp intelligence." In 1921, she published her only research article, which analysed gliofibrils in the spinal cord of frogs, illustrating mitosis in a mature astrocyte and the presence of microglia for the first time in amphibians. The study featured seven elegant illustrations by the author. During her time at the laboratory, Cajal acknowledged the quality of Serra's scientific work on many occasions, as did the Junta de Ampliación de Estudios. Serra married in 1927 and ceased to conduct research.

Discussion. This study is intended to complement a previous work (Giné et al., 2019) on the women researchers among Cajal's students, a subject not previously addressed in detail.

KEYWORDS

Neurohistological school, Spanish Neurological School, Cajal school, glia, women neuroscientists, Santiago Ramón y Cajal

Introduction

While the Nobel laureate Santiago Ramón y Cajal (1852-1934) specifically included the names Laura Forster and Manuela Serra in the list of collaborators and disciples he compiled when he was awarded the Echegaray Medal of the Real Academia de Ciencias Exactas, Físicas y Naturales in 1922, the value of these women and their scientific research was not acknowledged until very recently, when we completed our first study of women researchers in the Spanish Neurological School (Cajal school) between 1911 and 1945, who either worked directly with Cajal or with one of his direct disciples.[1] The study had a significant impact in national media outlets covering scientific research; for example, the newspaper *El País* printed an article on its back page addressing the findings.[2] Following this publication, we were

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Figure 1. Manuela Serra's early life and presence at Cajal's Laboratorio de Investigaciones Biológicas. A) A note announcing the death of Manuela Serra's father José Serra y López de Sagredo. B) A portrait of Manuela Serra during the years she worked at the Instituto Cajal. C) A still from the only known film of Santiago Ramón y Cajal (centre, with microscope). Back row: Francisco Tello (first on the left), Fernando de Castro (third left), and Carmen and Manuela Serra (far right of the image, with Manuela just in front of her sister, almost beside Cajal). The recording was made at the Instituto Cajal in the mid-1920s.

contacted by relatives of Manuela Serra and her sister Carmen, who provided us with a series of unpublished biographical and documentary details, which constitute a fundamental part of the present study. While the scientific contributions of these women researchers did not reach the level of those of other pioneering women neuroscientists in Europe,[1] they do demonstrate women's contribution to the saga of scientific discoveries of Cajal and his most distinguished direct disciples, which paved the way for modern neuroscience. They also complement data from numerous studies about women in scientific institutions in Spain in the first half of the 20th century that overlooked (where they did not directly ignore) Laura Forster, Manuela Serra, María Soledad Ruiz-Capillas, and María Luisa Herreros.[3,4]

Methods

This study was fully conducted in Spain between summer 2018 (when the study originally published by Giné et al.[1] was started) and spring 2020 (when we completed the historical research into Manuela Serra Savater, the subject of the present article). Information was consulted at the Legado Cajal (Instituto Cajal, Consejo Superior de Investigaciones Científicas [CSIC]), the archive of the Junta de Ampliación de Estudios (JAE) (CSIC), and the historical archive of the Universidad Central (Universidad Complutense de Madrid). We also conducted interviews with the descendants of Manuela Serra and her sister Carmen Serra, also a technician at the Laboratorio de Investigaciones Biológicas/Instituto Cajal. The relatives interviewed were José Antonio Serra, José García Serra, Eduardo García Serra, and Maruchi Marín Serra.

Results

To understand the careers of Manuela and Carmen Serra at the Laboratorio de Investigaciones Biológicas (officially renamed the Instituto Cajal in 1920), directed by Santiago Ramón y Cajal from the time it was founded in 1902, we must look back to their parents. Their father José Serra y López de Sagredo (1863-1918), a clerk at the public prosecutor's office of the Supreme Court of Justice, and their mother Guadalupe Savater (1873-1960) had six children (four girls and two boys): Manuela (the second-born, 1900-1988), Carmen (the fourth-born, 1908-1990), Patrocinio, María, José, and Eduardo. Their father's premature death (Figure 1A) due to stomach cancer left Guadalupe Savater caring for five young children; the eldest teenage daughter had tuberculosis and the youngest child was little more than a year old. At the time, the Serra-Savater family lived at number 26, Calle del Prado, Madrid; this is a key factor in the story, as the Nobel laureate Cajal lived at number 22 on the same street. Due to the family's difficult economic situation, Manuela, a high school graduate who according to

family sources was "very bright, capable, and active," was recruited by Cajal as a "preparadora" (laboratory technician) around 1919 (Figure 1B and C).

Manuela Serra published her first and only research article shortly thereafter, in 1921. In the study,[5] she trialled a method recently described by Cajal for staining neuroglial cells in the spinal cord of frogs. The method was initially developed by Max Bielschowsky, and *El Maestro* had introduced a new step, using formol ammonium bromide solution.[6-8]

There can be no doubt that Cajal suggested that she perform this study to complement a preliminary work conducted nearly 30 years earlier by Claudio Sala i Pons,[9] whose conclusions are extensively cited in Cajal's magnum opus.[10] Serra described the intracellular fibrils of the ependymal cells and astrocytes in the frog spinal cord, and reported the presence of "mesoglial" cells, now universally known as microglial cells (at the time, the term mesoglia [referring to the embryonic origin of these cells and used by Serra in her article] was used interchangeably with microglia [referring to their morphology] and "Hortega cells" [named after Pío del Río Hortega, who discovered them]), in the white matter and, in all likelihood, also in the grey matter.[5] This was one of the first studies from the Spanish Neurological School that unequivocally supported the existence of these cells, described by the great Spanish neuroscientist del Río Hortega in a series of four articles in which he untangled the composition of what Cajal called the "third element" of the nervous system[11-14] (for a recent review of the subject and the first English-language translation of these articles, see Sierra et al.[15]). Serra illustrated her article with a total of seven figures, some of which featured multiple panels (Figures 2 and 3). From today's perspective, the detailed description of enlarged astroglial processes under the pia mater and the perivascular "sucker" feet (perivascular end-feet) previously described in different neural structures by Cajal, Achúcarro, and de Castro are of particular interest (Figure 3A).[10,16,17] Serra also illustrated the cell division of an astrocyte (Figure 3B), a rare and highly interesting event in the adult nervous parenchyma: this was one of the first descriptions of a neuroglial cell undergoing mitosis despite being fully mature and possessing gliofibrils. The phenomenon had been described during embryonic development and in the central nervous system (CNS) of adult birds and mammals by Cajal, Achúcarro, del Río Hortega, and de Castro, as is eloquently discussed

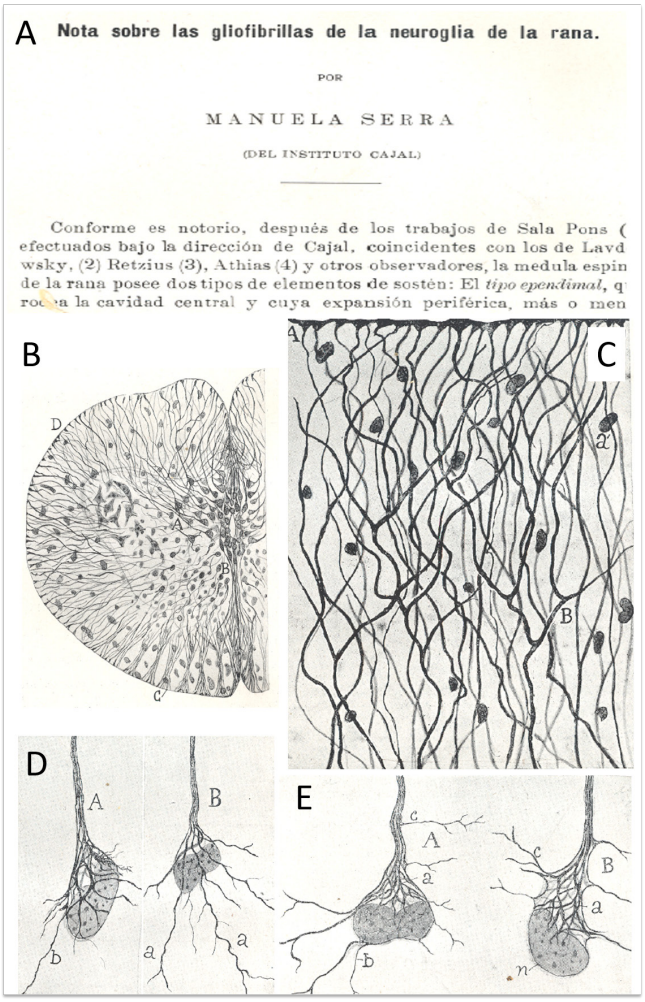

Figure 2. The heading of the original research article published by Manuela Serra.[5] A) The heading of the article, which was published in *Trabajos del Laboratorio de Investigaciones Biológicas*, signed by Manuela Serra as the sole author. B) A drawing showing a transverse hemisection of the spinal cord of an adult frog (figure 1 in Serra's article), showing, among other elements, neuroepithelial cells with robust gliofibrils, which have begun migrating from the germinal zone (*A*), and the subpial feet of astrocytes (*D*). C) Detail of radial glial cells passing through the white matter (originally published as figure 2), showing subpial feet (*A*), bifurcation of glial processes (*B*), and nuclei of cells in the white matter (*a´*: oligodendrocytes or oligodendrocyte precursor cells, in today's terminology). D and E) Detail of the migrating neuroepithelial cells described in A), originally published as figures 3 and 4.

in Serra's article.[5] Specifically, she described this mitotic division as:

> A corpuscule in the process of mitosis (parent cell star phase), whose soma, more or less round in shape, exhibits numerous gliofibrils on its cortical segment; these are distributed in a swirl, describing S shapes, figure-eights, and other complex curves.[5]

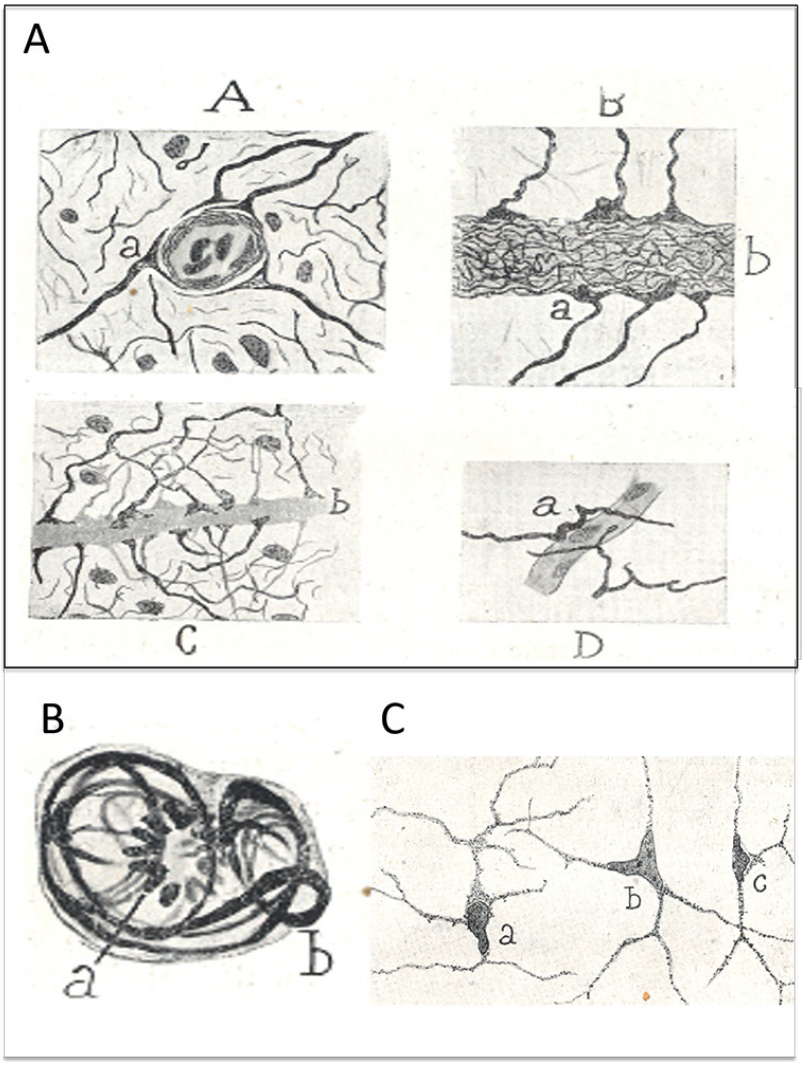

Figure 3. Images from the scientific article published by Manuela Serra.[5] A) Various dispositions of perivascular astrocytes (originally published as figure 5): surrounding a vessel (*A*), at either end of a longitudinal section of a vessel, with a fine plexus of interconnections (*B*), sucker feet surrounding a thin vessel (*C*), and the perivascular endfeet described by Achúcarro (*D*). B) An astrocyte undergoing mitotic cell division (originally published as figure 6). C) Microglial cells (described as mesoglia in the original, and published as figure 7 in Serra's article).

It should be noted that the ability of mature astrocytes to undergo mitosis, and the contribution of this phenomenon to neurogenesis in the adult CNS, were not confirmed until the early 21st century. This phenomenon has significant implications both in normal physiology and for brain plasticity and repair. Arturo Álvarez-Buylla, a Mexican neuroscientist based in the United States and the son of a Spanish neuroscientist working at the same time as Serra, with links to the Spanish Neurological School, made a crucial contribution to this discovery[18,19] (for a review of this subject, see Kriegstein and Álvarez-Buylla[20]). All of Serra's original illustrations show remarkable skill, consistent with the fundamental drawings by Cajal and almost all his direct disciples. In fact, there is increasing recognition of the scientific and artistic relevance of the drawings by Santiago Ramón y Cajal, Pío del Río Hortega, Fernando de Castro, Rafael Lorente de Nó, Domingo Sánchez, and Pedro Ramón y

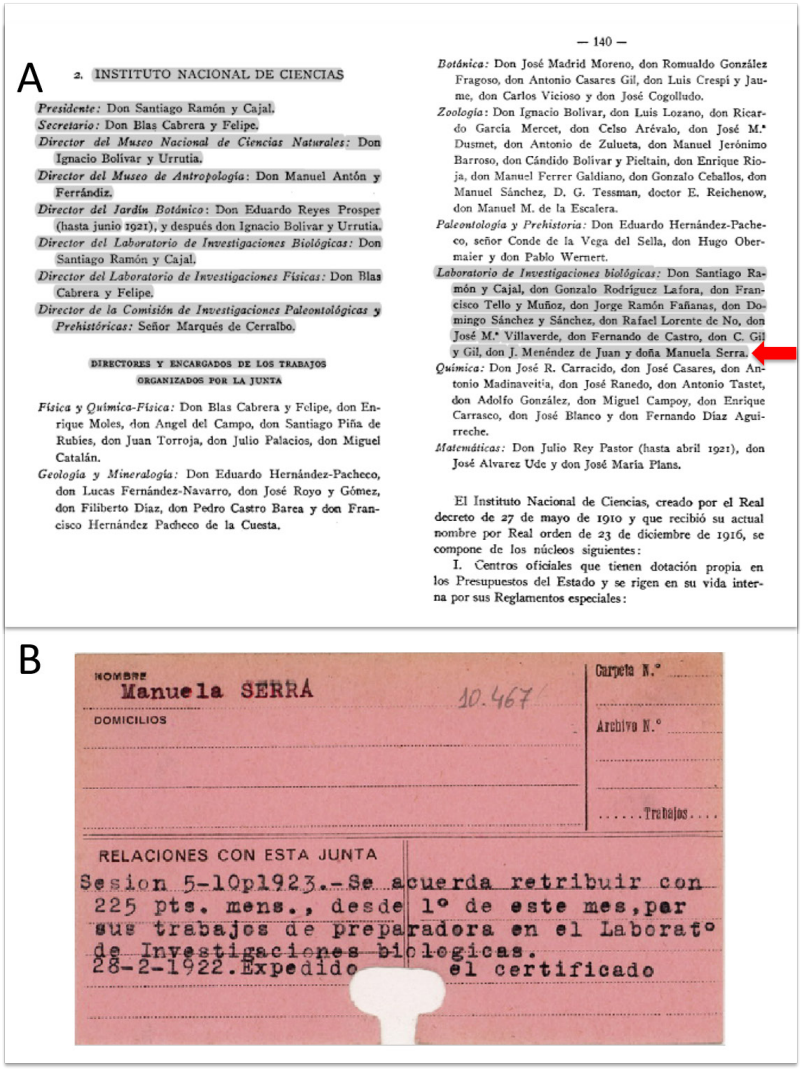

Figure 4. Mentions of Manuela Serra in various documents from the JAE. A) A list of the highest-level officials of the Instituto Nacional de Ciencias, including the Laboratorio de Investigaciones Biológicas (Santiago Ramón y Cajal was president of the former and director of the latter; JAE, 1922) and a list of the directors or lead researchers of projects commissioned by the JAE at the Laboratorio de Investigaciones Biológicas (highlighted in gray). In addition to the director and his best-known students, Manuela Serra appears last on the list (red arrow). B) A ticket from the archive of the JAE recording the decision to supplement Serra's salary in the light of her research work (JAE, 1925; Giné et al.[1]).

Cajal, and they were included in UNESCO's Memory of the World Register in 2017.[21-23] Serra dedicated the last lines of her article to an acknowledgement of "our master Cajal for his guidance in the interpretation of the histological slides and for taking the trouble to assist us with the bibliography," as well as "the advice of Mr Lorente de Nó, assistant at the Laboratorio de Investigaciones Biológicas."[5] In fact, Rafael Lorente de Nó, a highly distinguished member of the Spanish Neurological School,[24] began working alongside Cajal on research into spinal cord regeneration in tadpoles at approximately the same time that Manuela Serra began studying adult frogs.[25] It seems more than reasonable to imagine that the studies of the young Lorente de Nó and Serra should be closely related to the work of Cajal's first female disciple, Laura Forster, a British woman of Australian origin: during her time in Madrid, she focused on the post-traumatic regeneration of the spinal

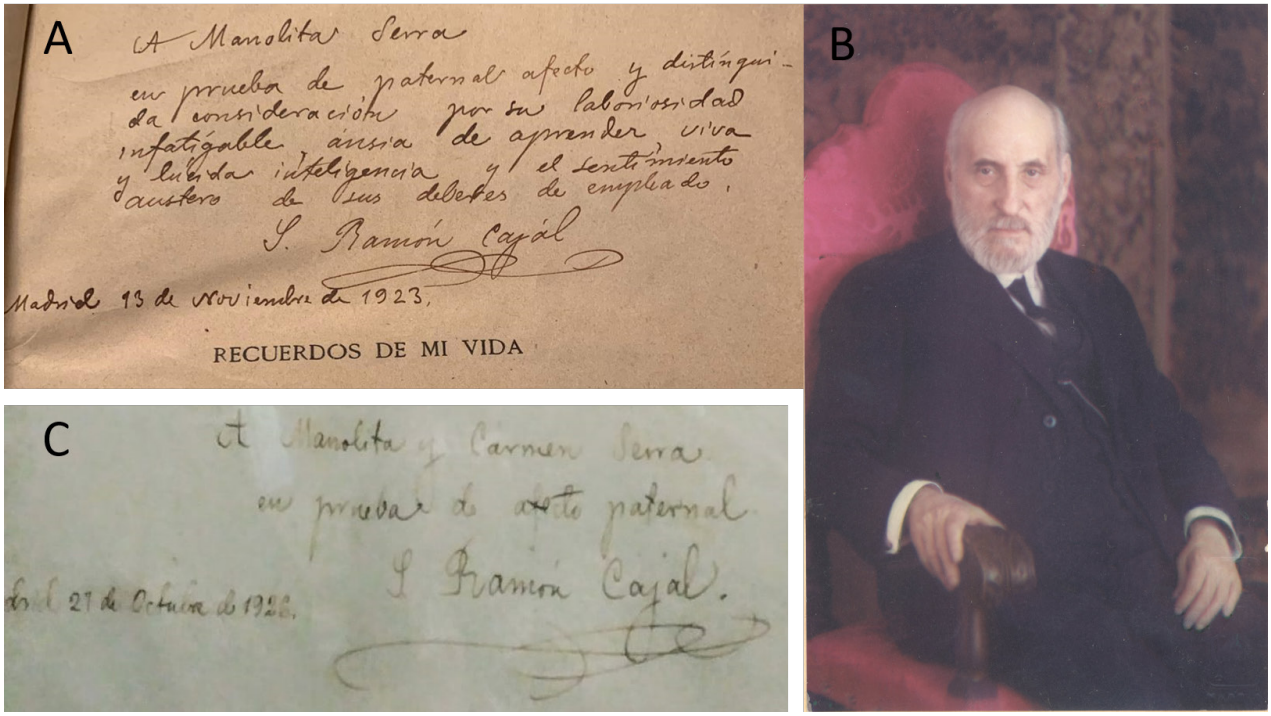

Figure 5. Dedications demonstrating Santiago Ramón y Cajal's high regard for Manuela Serra. A) A handwritten dedication in a copy of *Recollections of my life*[27]: "To Manolita Serra, for whom I have a paternal affection and great respect for her tireless hard work; eagerness to learn; her sharp, lucid intelligence; and her austere dedication to her duties as an employee. Madrid, 13 November 1923." B) A colour self-portrait of Ramón y Cajal and close-up of the dedication to the Serra sisters. C) "To Manolita and Carmen Serra, for whom I feel a paternal affection," signed in Madrid on 21 October 1926.

rd of birds.[26] It should also be noted that Serra signed the study in January 1922, despite it being published in the last volume of the laboratory's journal from 1921, the same year that Cajal's memoirs mention Serra as a direct disciple.[27] This explicit acknowledgement was already included in the report of the JAE for 1920 and 1921 (Figure 4A), which mentioned Manuela Serra as one the working directors of the Instituto Cajal; her name was given the same consideration as those of the most distinguished members of the Spanish Neurological School and *El Maestro* himself.[28] Serra received an economic reward for her contribution in 1921, with a pay increase from the JAE (on 5 October, she was receiving 225 pesetas per month for her work as a laboratory technician); to date, this has only been documented with a ticket recording the decision (Figure 4B).[1,29]

Around the same time, Cajal visited Serra's family home, offering to sponsor her to study at the School of Medicine, where he would fund her training (interview with the descendants of Manuela Serra, Madrid, October 2019), as he considered Serra to be highly intelligent and a capable worker based on his daily dealings with her in the laboratory. However, Serra's mother Guadalupe was against the idea, so Manuela ultimately did not gain a university education (see below). The same family sources report that whenever they heard Cajal described as an earnest, strict man, both Manuela and Carmen Serra (who also worked as a laboratory technician at the Instituto Cajal, starting several years after her sister) would comment that *El Maestro* was always genial and warm with them, and that he was friendly in general with all laboratory staff, not only with the researchers. Clear evidence of Cajal's affection for and closeness with the Serra sisters, and especially Manuela, is the dedication in a copy of Cajal's 1923 book *Recollections*

of my life to "Manolita" Serra (Manuela's nickname at the laboratory), "for whom I have a paternal affection and great respect for her tireless hard work; eagerness to learn; her sharp, lucid intelligence; and her austere dedication to her duties as an employee" (Figure 5A), as well as the colour self-portrait he gave her, with a note written in October 1926 (Figures 5B and C). All of these facts demonstrate that Cajal was not a man to make class distinctions between people with and without university education.

Therefore, Manuela Serra began her career as a budding researcher at the Instituto Cajal in the early 1920s, later becoming an experienced technician before eventually leaving her work when she married the travelling salesman José García Lara in 1927. The exact dates that her sister Carmen joined the Instituto Cajal and ceased her scientific activity are not known (she probably would have started in the mid-1920s); however, numerous images, publications, and press articles at the Legado Cajal place her at the Institute at that time; furthermore, references in the correspondence of members of the Spanish Neurological School seem to show that she was still working there in 1930.[1,30,31] Cajal died in October 1934, after the Institute had been moved to its second location at Cerrillo de San Blas (beside the Astronomical Observatory near the Retiro park), many years later than intended; this relocation and the loss of Cajal gave rise to numerous power disputes at the new centre.[24,31-33]

With the outbreak of the Spanish Civil War in July 1936, the Serra sisters and the rest of the family took refuge at the Chilean embassy, located in the same building as their home, which was owned by the Marquise of Perinat (Figure 6A and B). Among the embassies and envoys receiving the most refugees in Madrid in those days of war and revolution, the Chilean embassy may have taken in the most (approximately 4000 people), eventually extending its protection to several buildings across the city of Madrid.[34] Besides the Serra sisters, the Chilean embassy is known to have protected numerous conservative writers, including Rafael Sánchez Mazas, Joaquín Calvo Sotelo, and Víctor de la Serna, as well as the publisher Javier Morata Pedreño. Morata was well known in Spain for his publishing house Editorial Morata, which had published the work *Conditioned reflexes* by the Russian Nobel laureate in Physiology or Medicine Ivan Pavlov, as well as texts by Malinowsky, María Zambrano, and Gregorio Marañón. After the war and his return from his exile in Mexico, he would publish numerous works by the neuropsychiatrist Gonzalo Rodríguez Lafora (1886-1971), another of the most distinguished students of Cajal, and Nicolás Achúcarro, one of the most productive members of the Spanish Neurological School.[24,33,35] Carmen Serra

Figure 6. The Serra family home; the Chilean embassy during the Spanish Civil War. A) A recent photograph of number 26, Calle Prado, Madrid, the home of the Serra family and the site of the Chilean Embassy during the Spanish Civil War. B) A plaque installed at the building by the Madrid city government as part of its "Memoria de Madrid" programme, commemorating the fact that the Chilean ambassadors granted asylum to numerous refugees during the conflict. C) A photograph from the marriage of Carmen Serra (centre) and Carlos Marín (standing to her right), the only wedding held at the Chilean embassy in Madrid during the Spanish Civil War. The ceremony was organised and led by the ambassador, Núñez Morgado (wearing bow tie and glasses, standing to the left of the bride). Manuela and Carmen Serra's mother Guadalupe is shown at the far right. D) A photograph taken at the Chilean embassy in Madrid during the Spanish Civil War. The writer and co-founder of the Spanish fascist organisation Falange Española, Rafael Sánchez Mazas (centre, holding papers), is shown reading to the other refugees (including the writer Samuel Ros, to his left, leaning on the shoulder of Sánchez Mazas), as he did every night, from the novel he was writing at the time, *Rosa Krüger*. E) The 1984 edition of the novel.

married the industrial engineer Carlos Marín Ocón, also sheltered inside the Chilean embassy, on 14 March 1937, with the ambassador Núñez Morgado leading the service (Figure 6C). Theirs was the first and only wedding held at the embassy, and was faithfully reported by Sánchez-Mazas,[36] who wrote the novel *Rosa Krüger* to entertain the refugees, reading to them every night (Figure 6D and E). Sánchez-Mazas' misadventures during the Spanish Civil War, including his time as a refugee at the embassy in Madrid, were described years ago, and were made into the successful film *The Soldiers of Salamis*.[37] Finally, in an exchange of refugees and prisoners between the Republican and Nationalist sides of the war,[34] the Serra family were able to move to Seville in 1938, where they stayed throughout the rest of the conflict. After the war, they returned to Madrid, where they remained until their respective deaths in 1988 (Manuela) and 1990 (Carmen).

Discussion

The first evidence of the existence of women researchers among the direct disciples of Cajal is demonstrated by papers by Laura Forster from 1911, when some of the Spanish Neurological School's most genuine and brilliant members (Pío del Río Hortega, Fernando de Castro, Rafael Lorenté de Nó) had not yet joined.[1,27] While these women neuroscientists were few, and their contributions did not reach as high a level as those of other women researchers in Europe at the time (the most famous examples of pioneering women neuroscientists are addressed in Giné et al.[1]), they merit consideration in studies on the Spanish neurohistological school. In any case, they are no less important than figures from other areas of Spanish science, who have received some degree of research interest[3,4]; this is very striking, given the extensive literature on Cajal and his professional setting, and particularly in the light of the fact that he himself mentions them in his memoirs,[27] which serve as the basis for all subsequent literature on Cajal. It is certainly surprising that the Instituto Cajal's well-known librarian, Enriqueta ("Ketty") Lewy Rodríguez does not even mention in her well-known autobiographical work (signed as Enriqueta L. Rodríguez) the presence, and let alone the scientific contributions, of Cajal's women disciples, particularly given that she was close to the classic Spanish feminist circles, and presented herself as a feminist (this curious detail is discussed at length in Giné et al.[1]).[38]

In this context, Manuela Serra becomes a particularly interesting figure. A Spanish woman, a well-known laboratory technician at the Laboratorio de Investigaciones Biológicas, her only scientific publication was produced early in her career[5] and earned her the explicit recognition of Cajal and the JAE: in addition to the pay rise she was granted in February 1922, Serra was listed among the directors of the Instituto Cajal in 1921.[27-29] However, after her family ruled out the possibility of her studying medicine under the auspices of Cajal, Manuela Serra returned to her auxiliary work until she married and left the laboratory, as was customary at the time.

Returning to her scientific work, her research can be said to fall within a line complementing that developed by Cajal in the spinal cord of humans and vertebrates, which led Laura Forster, Manuela Serra, and Rafael Lorente de Nó to study the spinal cord of birds and amphibians, both during adult development and in response to traumatic damage.[5,25,26] It is interesting that Cajal should encourage all three researchers to follow the same complementary line of research for their initial training within his group of disciples. The study by Manuela Serra trials a variant of Bielschowsky's method, shortly after it was described by Cajal,[6] and includes one of the first descriptions of microglial cells in the Spanish Neurological School after the pioneering description of microglia by Pío del Río Hortega.[11-14,39] It is striking that Manuela Serra's study should be published during the time in which Cajal and del Río Hortega moderately and temporarily distanced themselves from one another; we believe this to show that this unfortunate distancing was more personal than scientific.[39-41] Furthermore, Serra's study further demonstrates the ability of mature astrocytes to undergo cell division, which had previously been shown by Cajal and other members of the Spanish neurological school, but was not widely accepted among neuroscientists until 80 years later, becoming a key element in our current understanding of neurogenesis in the adult CNS.[42,43]

Therefore, we can draw two important conclusions from the case of Manuela Serra: *1)* it disproves many assertions about the figure of Cajal, demonstrating his support for women in the world of research, even overcoming the almost insurmountable barrier of university education; and *2)* it is almost unique in European neuroscience, probably representing the first time that a technician or assistant at a laboratory was the sole author of an original research article.

Conflicts of interest and funding

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