Unveiling Science through Art. Technical Study and Conservation-Restoration Process of the Ramón y Cajal Teaching Canvas Ensemble

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Introduction

This chapter presents the technical study and the conservation-restoration process of the collection of teaching paintings created by Santiago Ramón y Cajal and Ramón Padró y Pedret, preserved at the Complutense University of Madrid, works of extraordinary historical, scientific, and heritage value. Conceived with an eminently didactic purpose within the context of late nineteenth-century university medical education, these pieces constitute an exceptional testimony to the convergence of art, science, and pedagogy.

The significance of this collection transcends its material dimension, as it represents a milestone in the visualization of knowledge. Its recovery has made it possible to restore not only its physical integrity but also its original scientific reading, which is essential for the rigorous interpretation of Ramón y Cajal's contributions to the field of neuroscience.

Thus, the technical study and conservation-restoration process have revealed significant findings that provide new insights into the execution methodology of these instructional paintings and the successive interventions they have undergone over time. Moreover, these discoveries contribute to expanding the understanding of the collection and enhancing its appreciation as part of the university's historical heritage.

Formal Elements of the Painting Ensemble

From a chromatic perspective, this group of paintings employs a color palette similar to that already used by Ramón y Cajal in numerous didactic illustrations produced in previous years, such as those included in the *Atlas of Anatomy* of the Faculty of Medicine of the University of Zaragoza ([5]). This collection —of which forty-nine color plates executed by Ramón y Cajal between 1877 and 1883 are preserved— shows notables affinities with the paintings held at the Complutense University, both in terms of format proportions (height-to-width ratio) and in the use of the characteristic bluish-grey background. This chromatic background functions as a unifying element and a distinctive feature throughout all the works, and its choice, far from being merely decorative or incidental, constitutes a deliberate visual resource intended to emphasize and contrast the depicted elements, generally rendered in warm and primary tones. In this sense, one may refer to a certain «chromatic asceticism», derived from the deliberate restriction of the palette, which is limited to scarcely three or four colors per composition.

([5]) Moralejo Álvarez, María Remedios. 2012. «El Atlas Anatómico de la Facultad de Medicina de la Universidad de Zaragoza. La recuperación de una pieza importante del patrimonio histórico universitario». *Pecia Complutense* 9, n.16: 89-95.

Each painting bears, in its lower and lateral margins, the seal of the *Centro Poligráfico* (Polygraphic Center) of the *Universidad Central*. It is pertinent at this point to contextualize the presence of this seal, as it identifies these works as part of the teaching materials produced by this institution. The *Centro Poligráfico de la Universidad Central* was established by Royal Decree on February 25, 1894, and was affiliated with the Dean's Office of the Faculty of Medicine of Madrid. It was located within the premises of the Anthropological Museum, founded by Pedro González de Velasco ([6]). Its main purpose was the reproduction and dissemination of didactic material—particularly anatomical and histological charts and diagrams—with the aim of improving instruction in Spanish medical faculties.

From its early years, this center distinguished itself by reproducing the drawings of Santiago Ramón y Cajal, thus demonstrating the early recognition of his scientific imagery as a pedagogical instrument. The institution's scope of action was national, since the copies produced were distributed to the medical faculties of the eight public universities (Madrid, Barcelona, Valencia, Seville, Granada, Santiago de Compostela, Valladolid, and Zaragoza), thereby ensuring a unified standard of instruction throughout Spain. Moreover, the structure of the center relied on a specialized technical team headed by a *technographer*, responsible for painting, sculpture, and scientific photography, whose efficiency was officially acknowledged by the *Gaceta de Madrid* (1905), which highlighted the «excellent results» achieved and its influence as a model for other faculties, such as that of Sciences ([7]). As documented in the original records preserved in the Archive of the Complutense University of Madrid, Ramón Padró y Pedret himself held the position of artist and head of the *Centro Poligráfico* from September 7, 1896, until his dismissal by the university rector on April 10, 1915, just a few days before his death.

Of the total number of didactic paintings produced through the *Centro Poligráfico*, few have been preserved within university collections. Among these, the most extensive known set of canvases is that safeguarded by the Complutense University of Madrid, which retains ten paintings in total. In addition to the paintings under study, signed jointly by Ramón y Cajal and Padró y Pedret, the collection includes two more signed solely by Padró y Pedret and two canvases executed by Zapata after drawings by Dr. Fleming.

([6]) Ministerio de Instrucción Pública y Bellas Artes (1894, 25 de febrero). Real orden creando un Centro Poligráfico en el local del Museo Antropológico, fundado por el Doctor Velasco. *Gaceta de Madrid*, Núm. 90, p. 909.

([7]) *Gaceta de Madrid* (1905, 18 de agosto). Núm. 230, año CCXLIV, tomo III, p. 637. Madrid: Imprenta del Ministerio de la Gobernación. [https://www.boe.es/gazeta/dias/1905/08/18/pdfs/GMD-1905-230.pdf]

Technical Characteristics and Condition Prior to the Intervention

Each of the six canvases was executed in oil on a textile support and mounted on a wooden stretcher, measuring 155 by 105 cm; five of the works have a vertical format, while one is horizontal. The following section describes key aspects of their original structure, as well as their condition prior to the intervention. The preliminary diagnostic assessment revealed a series of alterations common to all six canvases, along with certain specific features present in individual works.

This rigorous pre-intervention diagnosis made it possible to plan a restoration consistent with the fundamental principles of minimal intervention, respect for material and historical authenticity, and maximum reversibility of treatments. The technical characterization and damage assessment were essential in guiding the subsequent phases of the conservation-restoration process.

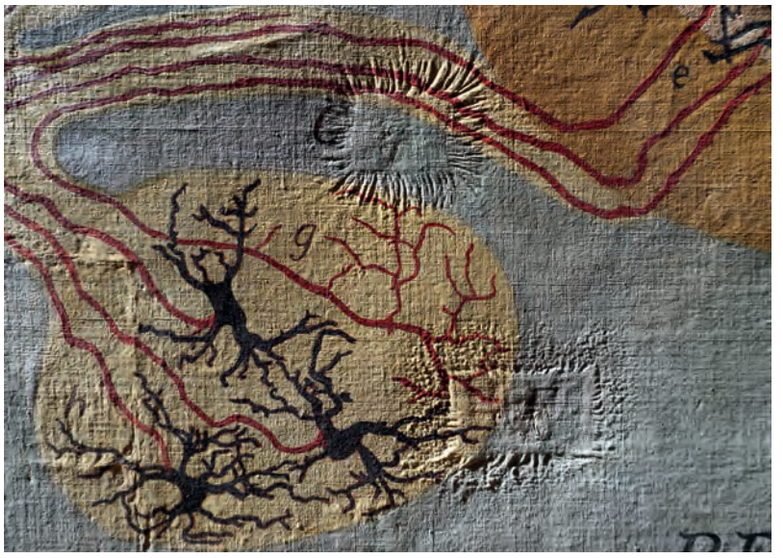
A. Textile Support and Stretchers

All six paintings were executed on a linen canvas support with a high-density plain weave, composed of fine threads that ensure proper adhesion of the paint layer. In most cases, the presence of old linings was confirmed, carried out with fabrics that exhibit certain differences in texture or density compared to the original support. In some works, the lining was applied in the form of individual patches, generating localized tensions that negatively affected the overall planarity of the canvas. Furthermore, numerous patches were found to be inadequately positioned, both in terms of application technique and the materials used.

The canvases are stretched over Spanish-type pinewood stretchers, assembled with mortise-and-tenon joints and equipped with expandable wedges. Each stretcher includes a central horizontal crossbar to ensure structural stability. In general, these are original stretchers that have been preserved over time, with minor later interventions some of them inappropriate. Handwritten graphite inscriptions were observed, corresponding to the numbering of the series (from 1 to 6), along with subsequent markings indicating the inventory numbers of the Complutense University of Madrid.

In all cases, the canvases exhibited severe structural deformations, caused both by uneven tension and by the presence of poorly applied patches. These alterations, visible as undulations and bulging, affected the correct presentation of the works and compromised the integrity of the paint layer. In several cases, seams or adhesive joints showed high rigidity, creating stress points that had resulted in longitudinal or transverse tears. Moisture stains and solid residues adhered to the reverse of the canvases were also documented.

At the structural level, the stretchers remained stable, although they showed clear signs of aging: stains, abrasions, holes from former hanging systems, and localized insect damage. The central crossbar fulfilled its stabilizing function, although in some cases its attachment required readjustment. The frames, in turn, exhibited surface dirt and oxidation of nails or metallic staples. In all cases, the hanging systems required replacement with alternatives compatible with current preventive conservation standards.



Deformations caused by patches from previous interventions on one of the canvases (CUC0005764). ECRA

B. Ground Layer and Paint Layer

The canvases display a white, industrial-type ground layer upon which a thin application of oil paint was laid. The pictorial execution is characterized by linear precision —consistent with the instructional purpose of the works— with flatly colored backgrounds and schematic, scientifically styled figures, featuring more pronounced impasto in certain highlighted areas, such as dendritic arborizations or neuronal somas.

The paint layer of all the works exhibited craquelure, both in stabilized and active phases. In areas with thicker paint application or near the joins with patches, the craquelure had progressed into localized losses of the paint film. Likewise, the presence of overpaint from previous inadequate interventions was confirmed. These overpaints, often applied in discordant tones, partially obscured the original painting and compromised the overall legibility of the works.

Ultraviolet fluorescence photograph showing the overpaint covering certain areas of the paint layer in the work *Scheme of the Structure of the Mammalian Retina* (CUC0005773). ECRA

In some paintings, such as the canvas titled *Connections of the Spinal Cord: Motor, Sensory and Autonomic* (CUC0005764), significant alteration of the paint layer was observed due to undocumented previous interventions, including the overpainting of the background in a grey tone that partially covered original inscriptions. In other cases, such as *Scheme of the Central Apparatus of Olfaction* (CUC0005772), inscriptions were found to have been altered or replaced, raising questions regarding their authenticity and scientific interpretation that had to be addressed during the intervention process.

C. Coating Layers

All the paintings presented protective varnish layers in an advanced state of oxidation, with yellowish or greenish hues that affected the chromatic reading of the compositions. In several canvases, non-original overlapping varnish layers were also detected, some of which had been applied unevenly, showing localized accumulations.

On top of these coatings, a veil of atmospheric pollution, nicotine, or greasy dirt had accumulated, significantly altering the chromatic perception of the paintings.

D. Auxiliary Elements

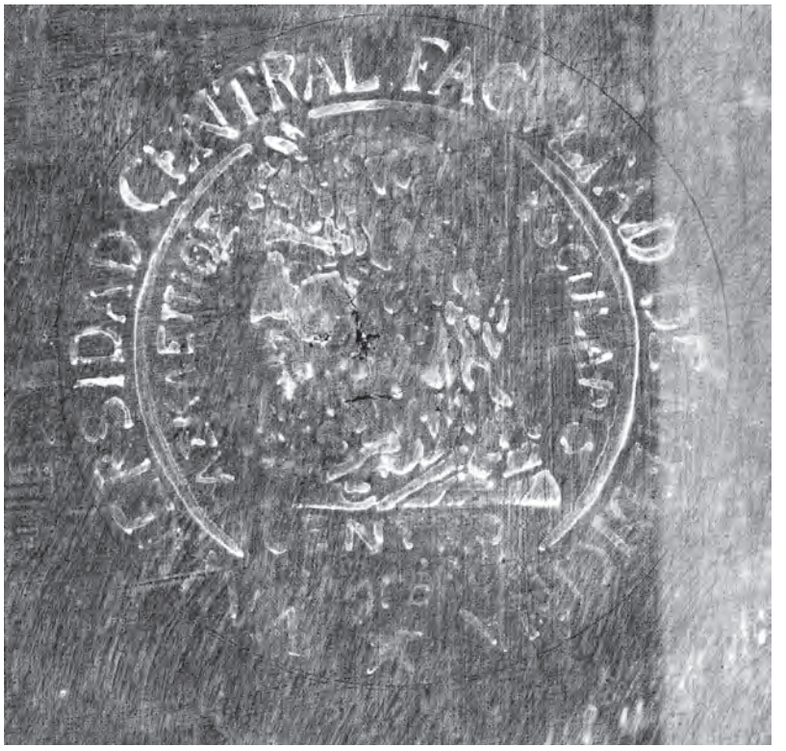
The mounting systems of the paintings included nails and metal wires that were not compatible with current preventive conservation standards. In some cases, the frames exhibited inadequate fittings, accumulated dirt, and moisture stains. The reverse of the canvases also showed traces of old adhesives and deposited dust.

Technical Study and Findings during the Conservation Process

The study conducted using various analytical techniques —including digital microscopy, X-radiography, infrared reflectography, and ultraviolet radiation— provided highly relevant data regarding the pictorial procedure employed by Padró y Pedret, as well as information concerning later interventions.

The radiographic study of the paintings ([8]) revealed the characteristic marks resulting from their extensive didactic use, along with accidental damage derived from their exibition in non-museum environments. The images show complex compositions with numerous losses and tears in the original support, which were treated through the application of patches mostly in an inadequate manner and, likely, by non-specialized personnel.

In the radiographic images of each painting, the seals of the *Centro Poligráfico* display closed contours typical of the use of a stencil for their transfer from one canvas to another. This process was probably carried out over the ground and/or the painted background by applying fluid-consistency oil, which produced accumulations along the outer edges of the contours; subsequently, while still wet, the lines appear to have been reinforced with a fine brush, as indicated by the topography of the brushstrokes. Furthermore, some radiographs of the seal areas show fine black lines that can be attributed to the absence of preparatory or pictorial material. This evidence supports the likely hypothesis that the stencil may have been positioned over the paintings by means of a corresponding marking or incision lightly traced onto the ground layer.



Radiographic detail of one of the paintings showing the incised lines used to position the stencil for transferring the seal of the Centro Poligráfico. Silvia G. Fernández-Villa

([8]) The authors would like to thank the team at IPunto Non-Destructive Testing and, in particular, Dr. Laura Alba, Dr. María Concepción García Cabarcos, and Óscar Solé for their invaluable assistance with the radiographic study.

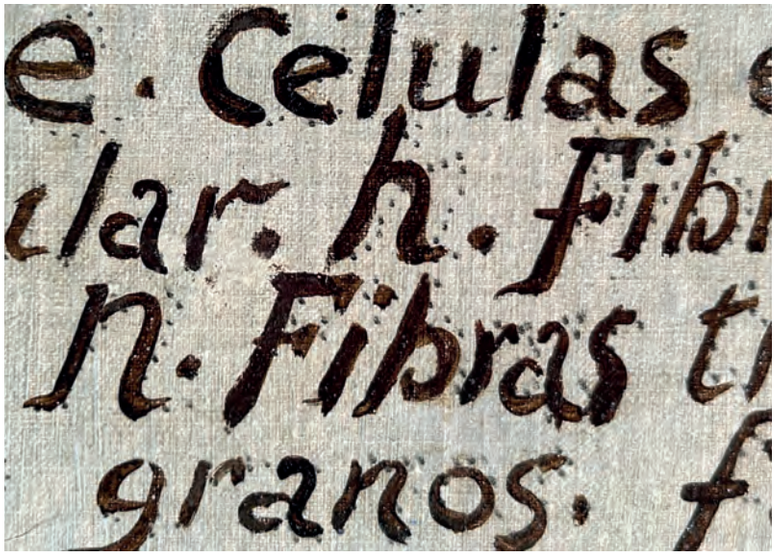


Image obtained through digital microscopy showing the pouncing used to transfer the descriptive inscriptions of the work *Cerebellar Cortex* (CUC0005763). Silvia G. Fernández-Villa

The contributions of infrared reflectography to the study of the pictorial technique are also highly significant. It is worth recalling that the method employed had to accommodate the production of several copies to be distributed among the eight faculties of Medicine; therefore, the use of a procedure that facilitated serial production would have been of great interest. Accordingly, the infrared reflectography study enabled the detection of pouncing marks through which Padró y Pedret transferred the main outlines of the composition, as well as the texts and explanatory legends. This methodology thus made it possible to generate virtually identical copies of each illustration, a fact corroborated by the comparative study of the works held by the Complutense University of Madrid and those preserved in other Spanish universities. The use of digital microscopy likewise contributed to the analysis of these pouncing patterns, which are also visible in areas where the final outline of the lettering has shifted.

Another significant contribution of the reflectography study was the detection of hidden elements beneath later overpaint layers. Such is the case of the work *Various Constituent Elements of the Cortical Grey Matter* (CUC0005762), in which a superimposition of different terms was found. In one of the inscriptions, the word «aferente» (afferent) had been placed over the original term «terminal», a fact revealed through the infrared reflectography examination ([9]). This finding raised questions regarding the authenticity and scientific interpretation of the inscription, which were resolved during the intervention process with the guidance of Dr. Elena Giné and the team from the Departmental Section of Cell Biology and Histology of the Complutense University of Madrid.

([9]) The authors wish to thank Dr. Sonia Santos Gómez for her collaboration in the infrared reflectography study of the work *Various Constituent Elements of the Cortical Grey Matter* (CUC0005762).

Furthermore, the restoration process itself led to certain discoveries that were not perceptible through the analytical techniques employed. One of the most significant was the finding of a lowercase «a» in the canvas titled *Cerebellar Cortex* (CUC0005763). Before cleaning, to the left of the letter «a», there appeared a short arrow pointing to the soma of a Purkinje cell, when in fact it should have indicated the axon of a granular cell (red line). However, after cleaning the pictorial surface, a second letter «a» was revealed beneath an overpaint layer, correctly pointing to the axon of the granular cell. Thanks to the removal of the overpaint and the contribution of the team from the Departmental Section of Cell Biology and Histology, it was possible to restore Ramón y Cajal's original intent, achieving an accurate reading in both scientific and historical terms.

Technical examination of one of the works by Ramón y Cajal and Padró y Pedret using infrared reflectography. Silvia G. Fernández-Villa

Before and after (left and right, respectively) the cleaning process of the painting *Cerebellar Cortex* (CUC0005763), which revealed new elements hidden beneath an overpaint layer. Silvia G. Fernández-Villa

Restoration Criteria

The intervention criteria applied during the restoration of the paintings by Ramón y Cajal and Padró y Pedret are based on the provisions established by Law 16/1985 of June 25 on Spanish Historical Heritage, the ECCO Code of Ethics ([10]), as well as on various international recommendations, agreements, and charters.

At the national level, the main reference for intervention guidelines is the *COREMANS Project: Criteria for the Treatment of Easel Paintings* ([11]). In accordance with the principles and directives set out in these standards and documents, the most relevant aspects to be considered in the actions undertaken can be summarized as follows:

- Preliminary studies. Every intervention must be preceded by a thorough preliminary study, supported by scientific and technical examinations providing objective data. Such studies must be carried out by an interdisciplinary team encompassing the different fields of knowledge involved in conservation and restoration.
- Documentation. The intervention process must be rigorously documented through written and photographic records before, during, and after the conservation treatment. All information generated must be compiled in a final report to ensure full traceability of the procedures undertaken.
- Minimal intervention. The smallest possible number of treatments should be applied, limited to those strictly necessary to ensure the stability of the work, thereby avoiding unnecessary risks and preserving its material integrity and authenticity to the greatest extent possible.
- Priority of conservation over restoration. Actions should focus primarily on preserving existing elements and preventing further deterioration, reserving restoration treatments for cases in which they are strictly necessary.
- Stabilization and consolidation. Priority must be given to stabilizing and consolidating the original elements of the work, avoiding their replacement and ensuring their long-term preservation.
- Use of stable and reversible or re-treatable materials. All materials and products used must be of proven quality—stable, durable, and guaranteeing reversibility and/or re-treatability—so that future interventions will not compromise the integrity of the work.
- Professional qualification. The execution of conservation and restoration treatments must be carried out exclusively by professionals holding an official degree in the field, thereby ensuring the technical and ethical competence of the process.

([10]) Confederación Europea de Organizaciones de Conservadores-Restauradores (ECCO). (2002). *Directrices profesionales de ECCO (II): Código ético*.

([11]) Salas Almela, C., y Porras-Isla Fernández, M. (Coords.). (2018). *Proyecto COREMANS: criterios de intervención en pintura de caballete.* Ministerio de Cultura y Deporte.

Regarding specific considerations for the group of paintings treated, the following intervention criteria were also applied:

- The restoration treatment was aimed at achieving a visually homogeneous and balanced result across the six paintings comprising the ensemble, ensuring both aesthetic and material coherence.
- Every effort was made to preserve the original materials, as well as previous interventions that remained stable and did not cause physical or aesthetic alterations to the works. The existing linings were retained, as they adequately fulfilled their structural function, and their removal would have involved an excessively invasive procedure carrying significant risks for the works.
- The decision was likewise made to keep the original stretchers, despite their lack of bevels on the inner edges, since they provided uniform tension across the canvases, thus avoiding the need for remounting. Furthermore, some of these stretchers contained elements of high documentary value, such as handwritten graphite inscriptions on the reverse, which were considered important to preserve.
- In cases where previous interventions had caused deformations or posed a risk to conservation (for example, distortions produced by patches applied during earlier treatments), these were removed. The resulting deformations were then corrected, and the tears were re-treated using appropriate suturing techniques.

Conservation-Restoration Treatments

The process began with the removal of the frames, followed by the mechanical cleaning of the reverse of the canvases and stretchers using soft-bristle brushes and a controlled suction system, carefully eliminating the accumulated deposits between the canvas and the stretcher. Subsequently, localized protection was applied to areas of the paint layer that showed a risk of detachment, using 18 g/m^2 Ino Shi Japanese paper adhered with a protein-based adhesive, under controlled pressure and temperature until complete fixation was achieved.

In order to remove the old patches that were causing structural distortions, a window-opening approach was adopted on the lining fabric. This strategy allowed the treatment to be carried out without fully removing the lining or dismounting the works, thereby minimizing the risks of intervention and maintaining proper tension in the canvases. Given the poor adhesion of the lining fabric, the openings were made dry using mechanical means, in the same manner as the extraction of the patches or reinforcements. In cases where the adhesions were more resistant, a rigid gel sheet was previously applied to soften the adhesives.

Once the patches were removed, the tears resulting from earlier interventions were exposed, allowing for the cleaning of the reverses. The next objective was to eliminate or reduce the pronounced

deformations caused by the old patches. These areas were treated through humidification, water vapor, and controlled pressure, which progressively corrected the distortions.

After the stabilization and correction of the canvas deformations, the cleaning of the paint layer across the entire set of works was undertaken. The chemical cleaning process was carried out in three phases:

Phase 1. General cleaning of pollution and surface dirt. After measuring the pH and conductivity of the pictorial surface using agarose discs, the cleaning solution was adjusted to match the work's specific values by preparing a buffered aqueous solution with pH 6 and conductivity of 2000 µS.

Phase 2. Removal of oxidized varnishes. Sequential solubility tests were carried out with solvents of increasing polarity until the most suitable mixture for the controlled removal of the film-forming layer was determined. The selected mixture was applied only after verifying its safety and the absence of adverse effects on the original paint film.

Phase 3. Selective removal of overpaint. A critical and carefully assessed elimination of overpaint layers was undertaken, evaluating on a case-by-case basis the appropriateness of their removal, since some of these modifications could correspond to corrections derived from advances in scientific knowledge, new discoveries, or adjustments made to Cajal's original delineations.

Cleaning process (phase 1) for the removal of pollution and surface dirt using a buffered aqueous solution. ECRA

Cleaning process (phase 2) for the removal of oxidized varnishes. ECRA

Finally, the process continued with the filling and levelling of losses, followed by the retouching of the losses, using materials of the highest quality and stability. The conservation-restoration treatment concluded with the application of a spray varnish and localized adjustment of surface gloss. These actions successfully achieved the structural stabilization of the canvases, the recovery of the correct visual and scientific reading of the works—previously altered by successive non-specialized interventions—and the enhancement of the documentary, scientific, and artistic significance of this valuable ensemble.

Retouching of losses on the painting *Scheme of the Central Apparatus of Olfaction* (CUC0005772). ECRA

Before (left) and after (right) the restoration of the painting *Cross Section of the Cochlea* (CUC0005776). Historical and Artistic Heritage Collection, Complutense University of Madrid.