OPEN ACCESS

University of Dundee

University of Dundee

Art, Intuition, and Identity in Ramón y Cajal

Hunter, Dawn; DeFelipe, Javier; Mehta, Arpan R; Conway, Bevil R.

Published in:
Neuroscientist

DOI:
10.1177/10738584241234049

Publication date:
2024

Licence:
CC BY-NC

Document Version
Publisher's PDF, also known as Version of record

Link to publication in Discovery Research Portal

Citation for published version (APA):
Hunter, D., DeFelipe, J., Mehta, A. R., & Conway, B. R. (2024). Art, Intuition, and Identity in Ramón y Cajal. *Neuroscientist*, 1-16. Advance online publication. https://doi.org/10.1177/10738584241234049

General rights
Copyright and moral rights for the publications made accessible in Discovery Research Portal are retained by the authors and/or other copyright owners and it is a condition of accessing publications that users recognise and abide by the legal requirements associated with these rights.

Take down policy
If you believe that this document breaches copyright please contact us providing details, and we will remove access to the work immediately and investigate your claim.

Download date: 11. May. 2024

Check for updates

The Neuroscientist
1–16
© The Author(s) 2024

Article reuse guidelines:
sagepub.com/journals-permissions
DOI: 10.1177/10738584241234049
journals.sagepub.com/home/nro


Art, Intuition, and Identity in Ramón y Cajal

Dawn Hunter[1], Javier DeFelipe[2,3], Arpan R. Mehta[4,5,6,7], and Bevil R. Conway[8]

Abstract

In the history of neuroscience, Cajal stands tall. Many figures in the late 19th and early 20th centuries made major contributions to neuroscience—Sherrington, Ferrier, Jackson, Holmes, Adrian, and Békésy, to name a few. But in the public mind, Cajal is unique. His application of the Golgi method, with an array of histologic stains, unlocked a wealth of new knowledge on the structure and function of the brain. Here we argue that Cajal's success should not only be attributed to the importance of his scientific contributions but also to the artistic visual language that he created and to his pioneering self-branding, which exploited methods of the artist, including classical drawing and the new invention of photography. We argue that Cajal created his distinctive visual language and self-branding strategy by interweaving an ostensibly objective research product with an intimately subjective narrative about the brain and himself. His approach is evident in the use of photography, notably self-portraits, which furthered broad engagement initially inspired by his scientific drawings. Through his visual language, Cajal made an impact in art and culture far beyond the bounds of science, which has sustained his scientific legacy.

Keywords

neuroscience, histology, Cajal, neuroscience history, arts and sciences, interdisciplinary, scientific conceptualization process, histology, drawing in science, art history, Spanish painting history

Foundations

Santiago Ramón y Cajal's understanding of the microscopic organization of the brain was borne of an intuitive, prescientific framework that only later translated into quantifiable discoveries. This was the opinion of the French philosopher Henri Bergson, a staunch supporter of vitalism, who saw this philosophy embodied in Cajal's drawings of neurons (Marañón 1950). Cajal (1852-1934) did not subscribe to vitalism. But he often resorted to poetic descriptions to breathe life into otherwise dead tissue samples. In *Recollections of My Life* (1989, p. 363) he wrote,

> Like the entomologist in pursuit of brightly coloured butterflies, my attention hunted, in the flower garden of the gray matter, cells with delicate and elegant forms, the mysterious butterflies of the soul, the beating of whose wings may some day—who knows?—clarify the secret of mental life.

Narrative was the genesis of Cajal's visual language. He used metaphors such as "butterflies of the soul" to describe the most common neuron in the cerebral cortex, the pyramidal cell, and "protoplasmic kisses" for synapses. The descriptions endow the science with poetry and liken the work to an epic love story. The poetry is evident not just in his descriptions but also in the images that he created. The illustrations in Cajal's publication *La rétine des vertébrés* evoke fantastical landscapes through the horizon and fugue lines

[1]School of Visual Art and Design, University of South Carolina, Columbia, SC, USA
[2]Instituto Cajal-CSIC, Madrid, Spain
[3]Laboratorio Cajal de Circuitos Corticales, Centro de Tecnología Biomédica (UMP), Madrid, Spain
[4]National Hospital for Neurology and Neurosurgery, London, UK
[5]Oxford University Hospitals NHS Foundation Trust, Oxford, UK
[6]Centre for Clinical Brain Sciences, University of Edinburgh, Edinburgh, UK
[7]MRC Protein Phosphorylation & Ubiquitylation Unit, School of Life Sciences, University of Dundee, Dundee, UK
[8]Laboratory of Sensorimotor Research, National Eye Institute and National Institutes of Mental Health, National Institutes of Health, Bethesda, MD, USA

Corresponding Author:
Dawn Hunter, School of Visual Art and Design, University of South Carolina, 1615 Senate St, Columbia, SC 29208-0001, USA.
Email: dmhunter@email.sc.edu

(DeFelipe 2010). The creative and intellectual rigor in Cajal manifests the interdisciplinary nature of scientific research. Cajal navigated the intersection of theory and observation, using intuition to reach beyond the limits of empirical science. Cajal's intuition is evident in his proposal that the richness of neuronal connections could explain intelligence. In his 1894 Croonian Lecture "La fine structure des centres nerveux" (SR Cajal 1988, p. 467), Cajal says,

> As opposed to the reticular theory, the theory that cellular processes could develop free arborizations seems not only the most likely, but also the most encouraging. A continuous pre-established net—like a lattice of telegraphic wires in which no new stations or new lines can be created—somehow rigid, immutable, incapable of being modified, goes against the concept that all we hold of the organ of thought, which within certain limits, is malleable and capable of being perfected by means of well-directed mental gymnastic. If we did not fear to abuse a comparison, we would uphold our conception by saying that the cerebral cortex is similar to a garden filled with innumerable trees, the pyramidal cells, which can multiply their branches thanks to intelligent cultivation, send their roots deeper and producing more exquisite flowers and fruits every day.

Cajal's choice of specimens and the histologic techniques that he used to treat them unveiled previously unseen forms in neuroanatomy. His research processes, grounded in his training as an artist, culminated in a visual narrative that ultimately substantiated many of his theories. But during his lifetime, most of Cajal's theories were unconfirmed; they evolved from hypotheses to facts only with the introduction of new technologies. For instance, the advent of the electron microscope confirmed Cajal's neuron theory with the direct observation of the gap between pre- and postsynaptic elements. Cajal had guessed that this gap existed and often wrote as if this were established by his work, but scientific validation came only after Cajal's death (DeFelipe 2010). Cajal's theory was accepted before that scientific validation. We argue that this acceptance can be partly attributed to Cajal's powerful visual language.

A visual language is a system of communication that uses graphical elements besides words. For example, Impressionism and hieroglyphics are visual languages. Visual and verbal languages both communicate information, but they remain distinctive modes of expression. Although it is not always appreciated by contemporary scientists, scientific figures can go beyond data representation to construct a visual language, where the images convey information that data and words may not capture. For Cajal and many 19th-century scientists, the purpose of scientific figures was not to provide "raw" data for critical assessment but rather as rhetorical devices to transmit ideas. Cajal extended this practice by refining the aesthetics of his images; he saw his images as art. The visual appeal of Cajal's images stemmed from both the anatomical form and its functional aspects.

By extending our gaze beyond Cajal the scientist to appreciate his humanistic persona, we highlight the role of his visual language—his art—in shaping science. Cajal constructed his visual language by combining observational drawing, histology staining methods, photographs, and microscopic observations. Cajal's extensive body of work can therefore be viewed as a synthesis of art and science, where art upholds and communicates science and where science serves as muse. Consider Cajal's image of the transverse section of a mammalian cerebellar convolution in his autobiography *Recuerdos de mi vida* (1917, chapter 18; Figure 1). The image presents a semidiagramatic idea about how the cerebellum is composed of delineated cellular components: it is not a directly observed fact but an assemblage constructed to form a holistic understanding of neural architecture (DeFelipe 2018).

Cajal gave voice to an artistic interpretation of his work in an interview from 1900. The interview was recorded by Cajal's granddaughter, M.ª Ángeles Ramón y Cajal-Junquera (DeFelipe 2018). Cajal said,

> Undoubtedly, only artists devote themselves to science. . . . I realized that if I wanted to make a name for myself as a painter, my hands needed to become precision instruments. I owe what I am today to my boyhood artistic hobbies, which my father opposed fiercely. To date, I must have done over 12,000 drawings. To the layman, they look like strange drawings, with details that measure thousandths of a millimetre, but they reveal the mysterious worlds of the architecture of the brain. . . . Look [*Cajal said to the journalist, showing one of his drawings*] here I am pursuing a goal of great interest to painters: appreciating line and color in the brain.

Cajal's experience as an artist is not merely a facet of his identity; it is the bedrock of his process of scientific inquiry. His art background informed his ability to observe and decipher neuroanatomic details, and it provided him with a skill set to make images that are persuasive because they are aesthetically engaging. It is through their aesthetic value, as well as their pivotal place in scientific history, that Cajal's images have sustained relevance for audiences far beyond neuroscience and anatomy (Hunter 2017, 2018; Mehta and others 2020). Indeed, exhibitions of his drawings, such as *The Beautiful Brain* (Newman and others 2017), attract critical reviews from the art world (Smith 2018); these reviews are often agnostic to the scientific facts at stake. The images achieve artistic success on par with the drawings of Leonardo da Vinci, without requiring an understanding of the scientific content (Saltz 2018).

Figure 1. Santiago Ramón y Cajal, *Semi-schematic Cross Section of the Cerebellum of a Mammal*, India ink and graphite on paper, 1894, 6.5 × 5.5 in. Image courtesy of the Cajal Institute, Cajal Legacy, Spanish National Research Council, Madrid, Spain.

Cajal as Artist

The "first condition of the microscopist drawer [*sic*] is to know how to see and to interpret what he sees",wrote Cajal in his *Manual de Histologia Normal y de Tecnica Micrografica* (1889, p. 39, translated by Erna Fiorentini; Fiorentini 2011).

The Golgi-stained tissue sections that Cajal looked at to inform his drawings often contain neurons cut in mid-structure. Cajal reconstructed the neurons in many of his drawings, so the drawings were not objective observations of single tissue sections but representations of concepts constructed by patching together elements from many slides. The drawings fill gaps in visual observation with educated suppositions guided by classical drawing principles. The lines in his drawings serve as anatomic illustration and as expressive elements, varying in thickness to convey the form and spatial relationships of neural elements. Cajal used various cues to depth, such as perspective, contrast, and occlusion, to create a three-dimensional impression of his ideas regarding the microscopic structure of the brain. His technique reflects Renaissance practices such as sfumato and chiaroscuro learned from his art teacher León Abadías y Santolaria (1836-1894).

Cajal had wanted to become an artist, but his father resisted and paid for art classes only after an apprenticeship as a shoemaker. Abadías (1882), as the founder of an arts program in Huesca that taught Renaissance perspective drawing techniques, satisfied the high standards of Cajal's father. The roots of Cajal's visual language can be traced through Abadías to the Renaissance master Albrecht Dürer (1471-1528) by way of Federico de Madrazo y Kuntz (1815-1894), an important figure in the Spanish neoclassical artistic milieu and a paragon Romanticism. Madrazo apprenticed with Jean-Auguste-Dominique Ingres (1780-1867) and participated in the Nazarene movement. The Nazarenes venerated Dürer (Grewe 2015), which is evident in Madrazo's self-portraits and landscapes. Madrazo was scion to a family with a prominent artistic heritage (Muller 1999). His father, José de Madrazo y Agudo, was a royal court painter and later director at the Museo del Prado. José had unparalleled access to works by Dürer that were owned by the Spanish Royal Family, and Dürer's art became a conspicuous part of the Prado's permanent exhibit in the 1800s. Abadías, Cajal's art teacher, was taught by Madrazo.

The Renaissance innovation of linear perspective in illusionistic painting brought a new sense of reality to art, aligning layers of visible and invisible planes toward a single vanishing point to simulate three-dimensional depth. As and art student, Cajal spent his evenings replicating printed reproductions of great artists' masterworks from Abadías's Renaissance and Baroque collections. In his autobiography, Cajal mentions copying Raphael's Renaissance portfolio (SR Cajal 1917, p. 129).

In creating masterworks, whether a painting or a scientific illustration, a selection and assemblage of elements are required. Cajal excelled. The parallel between Cajal's methodology and the practices of Renaissance painters such as Dürer and Raphael is instructive. Akin to these Renaissance masters, who began with a sample observational sketch or cartoon of their idea in a sketchbook or sheet of paper, Cajal initiated his work with a observational fragment—in Cajal's case, a histologic slide. This inception, a process analogous to the artist's *pouncing*, utilized an arsenal of colorful histology stains to reveal unseen microcosms. As the art historian Erna Fiorentin describes, "in the case of histological preparations, the process of observation must begin with an 'extortion of visibility' from the raw material, namely with staining procedures that uncover the structures that lay hidden in the object" (Fiorentini 2013, p. 369).

Renaissance artists would establish a painting's tonal values with a monochromatic underpainting. Similarly, Cajal employed selective staining to distinguish components of nervous tissue, setting the timbre of his biological imagery in the creation of each slide. Cajal described his process:

> It is well known that the gray matter is formed by something like a very dense felt of excessively fine threads; and for following these filaments thin sections or completely stained preparations are worthless. What is required for this purpose is very intense reactions which, nevertheless, permit the use of very thick almost macroscopic sections (the processes from nerve cells are sometimes many millimeters or even centimeters long), the transparency of which, in spite of their unusual thickness, is made possible by the exclusive colouration of some few cells or fibres which stand out in the midst of extensive masses of cells that are uncoloured. Only thus does the undertaking to follow a nervous conductor from its origin to its termination become possible. (SR Cajal 1989, p. 310)

In the Renaissance painter's studio, layers of semitransparent oil paint mixed with powdered glass were used to create planes of spatial depth in the shallow surface—Raphael's paintings are a prime example (Cooper and others 2023). The conception of images as constructions built in layers, whose visual impact derives from subjective engagement, had a substantial impact on thinkers in art and science. Johann Wolfgang von Goethe (1749-1832), who was admired by Cajal (LR Cajal 1986), trained as a painter in Italy and brought back to Germany a lifelong desire to understand color and aesthetic experience. Both Cajal and Goethe wanted to become visual artists. Both also craved scientific success, yet only Cajal achieved it. Perhaps the key difference between these two men was that Goethe, by his own reckoning, lacked artistic talent (Goethe and others 1850, p. 180). Goethe conducted many experiments, filling triangular glass containers with semitransparent media and layering colored glass plates against windowpanes to manipulate the contrast of landscapes while filtering out extraneous details. Goethe's color treatise describes the effect of placing yellow glass over a picture and how artificial light deepens, darkens, and neutralizes images (Goethe 1840). Goethe's idea that visual experience arises through the mediation of light by layers of atmosphere is manifest in Cajal's practice, in which his images arise through a layering of transparent filters (slides) that are themselves made visible because they are interposed between the light of the microscope and its objective lens.

Like Raphael and Goethe, Cajal sought to achieve a sense of depth through interacting layers—but by using stacked histologic slides rather than glazes of transparent paint or prisms. Cajal's approach is a precursor to the visual communication technique later used by Walt Disney: the multiplane camera (Holliday and Pallant 2021), which allowed animation to transcend two-dimensionality by having foreground and background depicted on different glass plates that could be moved at different speeds. Cajal captured this sense of depth in his drawings, using the knowledge of perspective that he obtained by

copying the Renaissance masters. Perspective became the foundation of his visual language: those graphic marks that manifest an intuitive grasp of microscopic spatial relationships.

Microscopic Narratives

"The histologist . . . has two important adversaries the smallness and the colorless", wrote Cajal in *Recuerdos de mi vida* (1917, p. 337, translated here by DeFelipe).

The microscope and the camera reveal information that cannot be accessed by the human eye. Indeed, both techniques reshaped science, altering the accessibility and interpretation of biological imagery. Cajal was a prominent microscopist; he was also an early adopter of photography. His splicing and merging of photographic images, presaging the rise of negative collage in the 1920s, brought forth an enthralling new perspective on the brain that undoubtedly shaped his ideas about the microcircuitry. But photography did not displace perceptual experience. Instead, Cajal used photography to augment his perceptual and interpretative capacities. He harmonized the three distinct vantage points—the microscope's optics, the camera's lens, and the human eye/brain—eschewing pure mechanical interpretations in favor of an integrated, an ultimately subjective, analysis to bring scale and color to his ideas about the microscopic circuits in the brain.

Cajal likely would not have attained eminence without Camillo Golgi's (1843-1926) staining method. Golgi's technique was the dream of earlier neuroanatomists (DeFelipe, 2018). Cajal vividly describes the moment that he discovered the power of the Golgi method (SR Cajal 1909, p. 29; translated here by Javier DeFelipe 2009):

> In summary, a method was necessary to selectively stain an element, or at most a small number of elements, that would appear to be isolated among the remaining invisible elements. Could the dream of such a technique truly become reality, in which the microscope becomes a scalpel and histology a fine [tool for] anatomical dissection? A piece of nervous tissue was left hardening for several days in Müller's pure liquid [potassium dichromate] or in a mixture of this [fixative] with osmic acid. Whether it was the distraction of the histologist or the curiosity of the scientist, the tissue was then immersed in a bath of silver nitrate. The appearance of gleaming needles with shimmering gold reflections soon attracted the attention. The tissue was cut, and the sections were dehydrated, cleared, and then examined [with the microscope]. What an unexpected spectacle! On the perfectly translucent yellow background sparse black filaments appeared that were smooth and thin or thorny and thick, as well as black triangular, stellate or fusiform bodies! One would have thought that they were designs in Chinese ink on transparent Japanese paper. The eye was disconcerted, accustomed as it was to the inextricable network [observed] in the sections stained with carmine and hematoxylin where the indecision of the mind has to be reinforced by its capacity to criticize and interpret. Here everything was simple, clear and unconfused. It was no longer necessary to interpret [microscopically] the findings to verify that the cell has multiple branches covered with "frost," embracing an amazingly large space with their undulations. A slender fiber that originated from the cell elongated over enormous distances and suddenly opened out in a spray of innumerable sprouting fibers. A corpuscle confined to the surface of a ventricle where it sends out a shaft, which is branched at the surface of the [brain], and other cells [appeared] like comatulids or phalangidas. The amazed eye could not be torn away from this contemplation. The technique that had been dreamed of is a reality! The metallic impregnation has unexpectedly achieved this fine dissection. This is the Golgi method! . . . whose clear and decisive images enable us to cast off the famous net of Gerlach, the [dendritic] arms of Valentin and Wagner, as well as many other fanciful hypotheses.

Cajal used Golgi's method to illuminate and delineate structures that were previously invisible, revealing a panorama in a *colorless* domain. Cajal's genius was to see in the Golgi-stained sections a demystification of the brain's apparent complexity. He attempted to use photography to document the histologic preparations but found the technique wanting. It could not effectively illustrate his understanding of the neural structures, an understanding that he accrued through many hours of direct observation of the slides. Drawing was his solution, leveraging the unencumbered connection between his brain and his hand. Drawing allowed him to put forward a comprehensible view of brain function that is not unlike the process of image generation that he employed: elements (neurons) connected in layers.

Cajal's research and interpretative process demanded the convergence of direct light, materiality, chemical reaction, and sensory response. Much of his work used tissue from embryos and young animals because the Golgi method rendered better results with immature tissue (SR Cajal 1933, 1991). The now-recognized less complicated neuronal structures of immature tissue, as compared with tissue from adults, allowed Cajal to see neurons with a simplification necessary for him to conceive of the neuron doctrine (de Castro and others 2007, Merchán and others 2016).

The Golgi black reaction produces thick entangled forests of black threads juxtaposed on a yellow-gold background, the result of the method that impregnates neurons with black silver salts. What Cajal shows in his drawings, however, are not entangled forests but distinct neurons, fruits of perception, with varying line values conveying cellular connections. His drawings do not

incorporate the microscope's entire view, and the selection is key to the success of the drawings. Like Renaissance preparatory drawings that feature a single curtain drape or figure's hand, Cajal's drawings consist of forms extracted from a larger context (SR Cajal 1999). The drawings are created with common artistic tools, such as India ink, watercolors, pencils, and pens, used singly or combined. While Cajal often sought to reconstitute in his drawings the colors produced by the staining method, as in the colors that he used in *Histologie* (SR Cajal 1909), he was not constrained by the color of the stains and would change them to achieve a marked color contrast (Figure 2). Through the act of drawing, Cajal was encouraged to capture not just what he saw but what he thought he should be seeing. "Eventually, this combining imaging process showed not the actual structure, but the conclusions he drew from the multiplicity of the structure's forms and from their mutual relations" (Fiorentini 2011). Cajal thus came to embody Goethe's conception of genius, which "does not imitate nature, but rather itself creates, like nature" (Goethe, as quoted in Safranski 2017, p. 44).

Cajal's finished drawings of the microscopic organization of any given brain structure are the culmination of many preparatory drawings, often made from different slides and specimens (SR Cajal 1917). Cajal synthetically represented the complexities of specific nervous system regions through composite drawings (DeFelipe 2018), as seen in the illustration depicting the cellular components and connections of the hippocampus (Figure 3). His approach was dictated by technical constraints. Tissue sections needed to be relatively thin so that light could pass through them to make them visible with a light microscope. But sectioning truncated the neural processes. Cajal had to mentally stitch cell bodies and their axons and dendrites back together, and that process of stitching depended on visualization (picturing in the mind's eye). Cajal's method alarmed skeptics but brought about significant scientific insight, for it allowed him to push beyond the technical limitations. Cajal's work therefore depended on interpretative skill and artistic training. In this way, Cajal's subjective judgment led to objective knowledge (Fiorentini 2013, p. 377). Cajal would use his intuition to not only reconstruct the three dimensions of the tissue samples caught at a single moment in time but also bring them to dynamic life.

In his drawings, Cajal used arrows to depict what he interpreted as the dynamic action within neural circuits, transforming his visual language in the temporal domain. With the arrows, a still image became a kind of movie, an apt pointer to the distinction between anatomy and physiology. Physiology is anatomy in action—and physiology is needed to understand how the brain works. Cajal's use of arrows is a hypothesis that extended the neuron doctrine to show the flow of information between neurons. His hypothesis was encouraged by his theory of dynamic polarization, itself suggested by the polarized anatomy of neurons in which dendrites are distinguishable from axons. Lorente de Nó (1934) would later describe the direction of impulse transmission in CA3 of the hippocampus, affirming Cajal's hypothesis. This "functional anatomy" inspired discoveries in the somatomotor system by Vernon Mountcastle (Mountcastle 1957) and the visual system by David Hubel and Torsten Wiesel (1977), becoming the foundation of systems neuroscience with ideas that resonate today (Conway 2018). But once again, scientific validation came after Cajal's theory of information flow was taken for fact, and, once again, the premature acceptance of the theory was secured by Cajal's visual language.

Cajal's arrows established a visual syntax, thrusting his work from illustration to a dynamic ideographic visual language of function. Cajal was not the first or the only scientist to employ arrows in scientific illustrations (Schott 2000)—his peers, including Sigmund Freud (1856-1939), also used arrows. But Cajal's arrows are distinctive graphic elements that took on a deeper meaning because they were used in the context of drawings that were taken to be accurate representations of neural circuitry. Combined with the characteristic black lines tracing out the neural circuits, themselves a trace of Cajal's hand gestures, the playful arrows forged a powerful and aesthetically appealing narrative about brain function that facilitated the communication of his scientific theories and earned his drawings distinction among art critics.

Imprints of Self

As his scientific work expanded, Cajal recognized the impossibility of continuing to develop his fine art painting practice. He found a surrogate in photography. In the introduction to *Fotografía de los colores*, Cajal (1912, p. IV) compares life to theater and describes the fulfillment of his dream to capture landscape and human form. He writes, "Have you ever thought about what a photo album means? When contemplating the effigy of non-existent beings, don't you think that, at the voice of an incantation, the dead leave their graves to tell us their sad or happy story? And often the ghost evoked does not appear dressed in the venerable gray hair of old age but adorned with the finery of youth."

Cajal used photography, especially self-portraits, consciously to advertise himself and his work and to shape his legacy. Spanish advertising first appeared in newspapers on April 6, 1825, with influences of Romanticism and Art Nouveau. By the 19th century, advertisements in

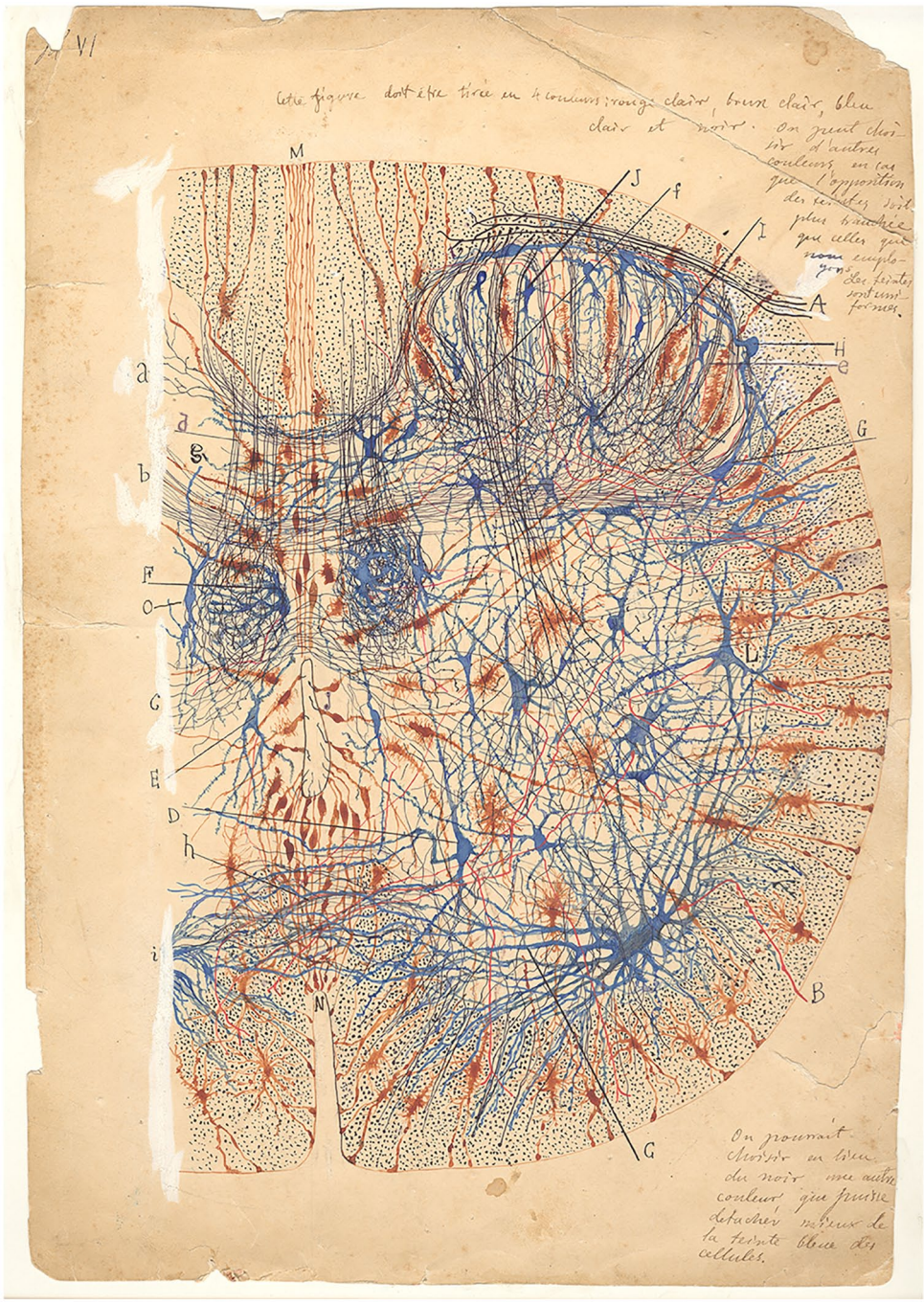

Figure 2. Santiago Ramón y Cajal, drawing of the spinal cord of a newborn dog, in contrasting colors, ink, and graphite on paper, 1894, 12 × 15 in. The drawing uses colors that differ from those of the stains in the original histologic specimens. This drawing was reproduced (SR Cajal 1895) with the following color codes: neuroglia in brown, nerve cells in blue, fibers that cross the gray substance in red, and the collaterals and fibers of the white substance in black. Ependymal cells are also colored in brown. Image courtesy of the Archivo científico Fernando de Castro.

newspapers, posters, trade cards, and packaging made icons out of images of people (McDonough and others 2003). Cajal's photographs fit right in.

Cajal curated self-portraits for press releases (Figures 4 and 5). Recognizing the potential of a lens to amplify aspects of reality—proportions, light, scale, and color—he

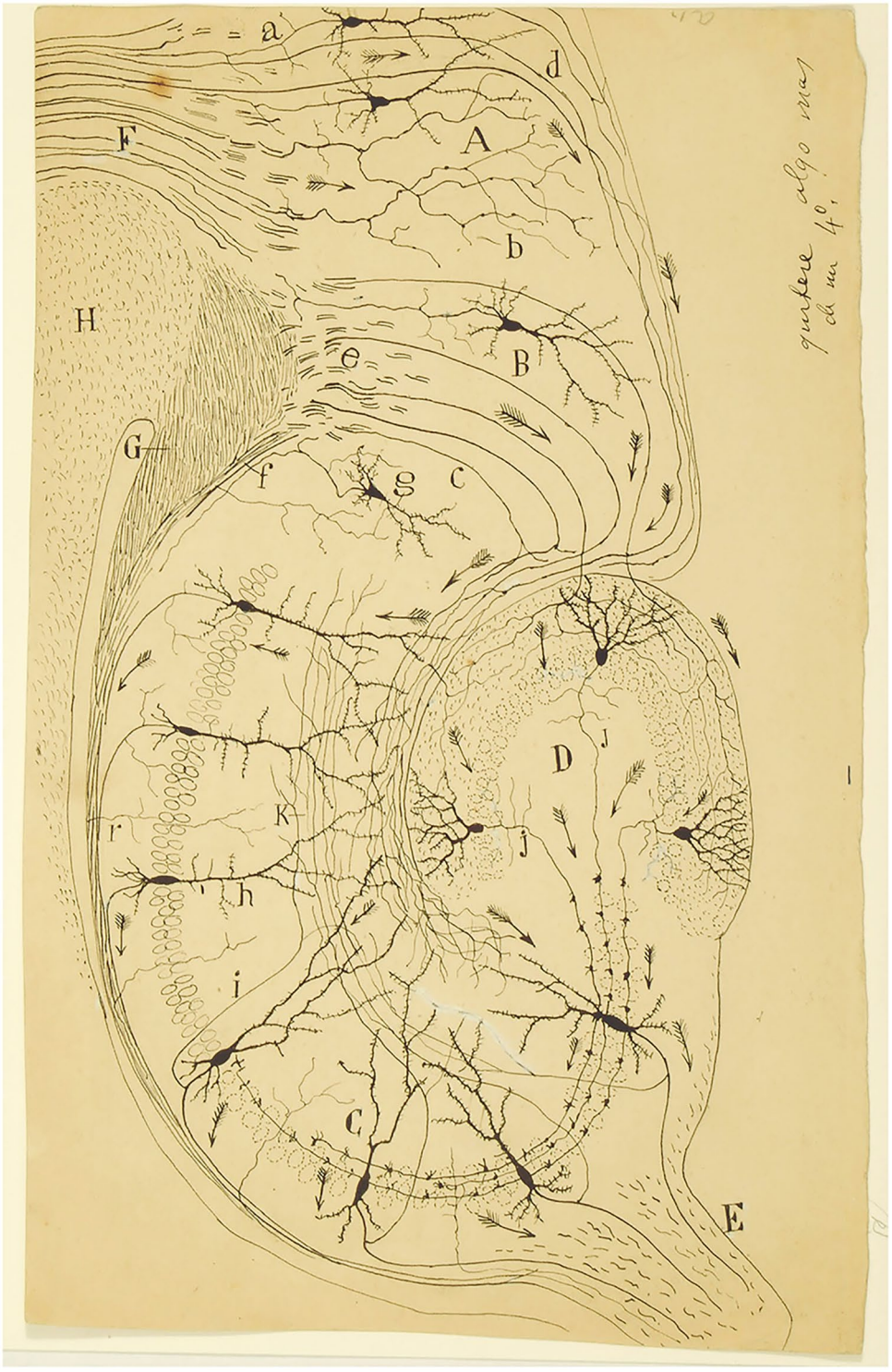

Figure 3. Santiago Ramón y Cajal, schematic drawing of the structure and connections of the hippocampus, India ink and graphite on paper, 1901, 6 × 9.5 in. Image courtesy of the Cajal Institute, Cajal Legacy, Spanish National Research Council, Madrid, Spain.

Figure 4. Santiago Ramón y Cajal, a self-portrait taken in 1900 that he printed and gave to his disciple Fernando de Castro on his wedding day. Image courtesy of the Archivo científico Fernando de Castro.

capitalized on the medium's ability to present multiple truths. In his youth, Cajal experimented with different personas, such as an archer or bodybuilder. As Cajal's reputation as a scientist advanced, his self-representation morphed into subdued studies in the laboratory. He poses himself, if not to conform to his viewer's mental image of a thoughtful scientist, then to create that mental image. Cajal economized by making his own photographic plates, allowing for extensive use and frequent modifications during his work. Within a single shoot, Cajal would try out a variety of postures, outfits, and hairstyles. Cajal was experimenting, exploring ideas of his own identity (Figure 6).

Cajal's self-portraits reflect the lasting impact of his art training. Specific decisions about lighting and composition suggest that Cajal was referencing Dürer. In Cajal's life, Dürer's media presence in Spain soared, with mentions jumping 800% between 1852 and 1934. Cajal took note. While narrative storytelling in his scientific work diminished over time, allegorical elements in his photographs, reminiscent of Dürer, flourished. Some of Cajal's self-portraits resemble Dürer's *Meisterstiche* trilogy: "Knight, Death, and the Devil," "Melencolia I," and "St. Jerome in his Study" (Figure 7). The trilogy—symbolizing earthly temptation and false valor, creative stagnation, and liberation of the diligent worker—resonated for Cajal at crucial junctures in his personal and professional life. For example, in 1880 Cajal depicts himself in submission under the dominion of a skeletal overlord, a reference to "Knight, Death and the Devil" that may have been pertinent as he became director of the Anatomical Museum, Universidad de Zaragoza. By connecting his image with images by Dürer, who was known for an almost occult power of visual observation, Cajal is creating the Myth of Cajal, draftsman of the brain.

Cajal created other portraits referencing "Melencolia I" (Figure 8). In one, he shows himself in a laboratory set up in his family's kitchen, donning work clothes and a sweat cap. The cap is a reference to the laurel leaf crown of Melancholy, the main figure in Dürer's print. But the reference to Dürer extends beyond the cap. Cajal's pose and the arrangement of worktable elements allude to the symbolism of "Melencolia I."

For the Renaissance masters, Melancholia was a symbol of creative genius. Through the allusion to Dürer, Cajal assumes this badge. In another photograph, Cajal depicts his wife Silveria (Figure 9). Cajal had young children at the time, and his wife was likely pregnant again. Like Cajal, Silveria is shown in work clothes; she is seated in the dining room with her elbow resting on a pile of Cajal's research books. Cajal said his research would not have been possible without his wife, declaring her half of his life's work. Again, the pose and composition allude to the sentiment of "Melencolia I," an allusion furthered by the presence of children in Cajal's life and the Dürer print. Perhaps the portrait of his wife was meant to be viewed with his self-portrait. This suggestion is encouraged by Cajal (1912, p. VI), who contemplated the narratives created through collections of photographs. When the portraits of Silveria and Cajal are side by side, the light on the floors of each photo point toward each other, a symbol of their marriage.

Again, in 1892, Cajal draws inspiration from Dürer. The occasion is Cajal's elevation to professor of normal histology and pathological anatomy in Madrid—and the Dürer is "St. Jerome in his Study" (Figure 10). Cajal's self-portraits of this time echo the imagery, composition, and lighting of Dürer's work, substituting St. Jerome's Bible with a microscope, intertwining the sacred and science. St. Jerome translated God's word; Cajal translated the brain. The "St. Jerome" self-portraits would become Cajal's iconic self-portraits, the idealized Cajal, cementing Cajal as Myth. He appears handsome, wise, the image of a prophet. The representation is in striking contrast with his appearance in real life. He had broken his nose several times. He was average looking, with an asymmetrical face, as captured in

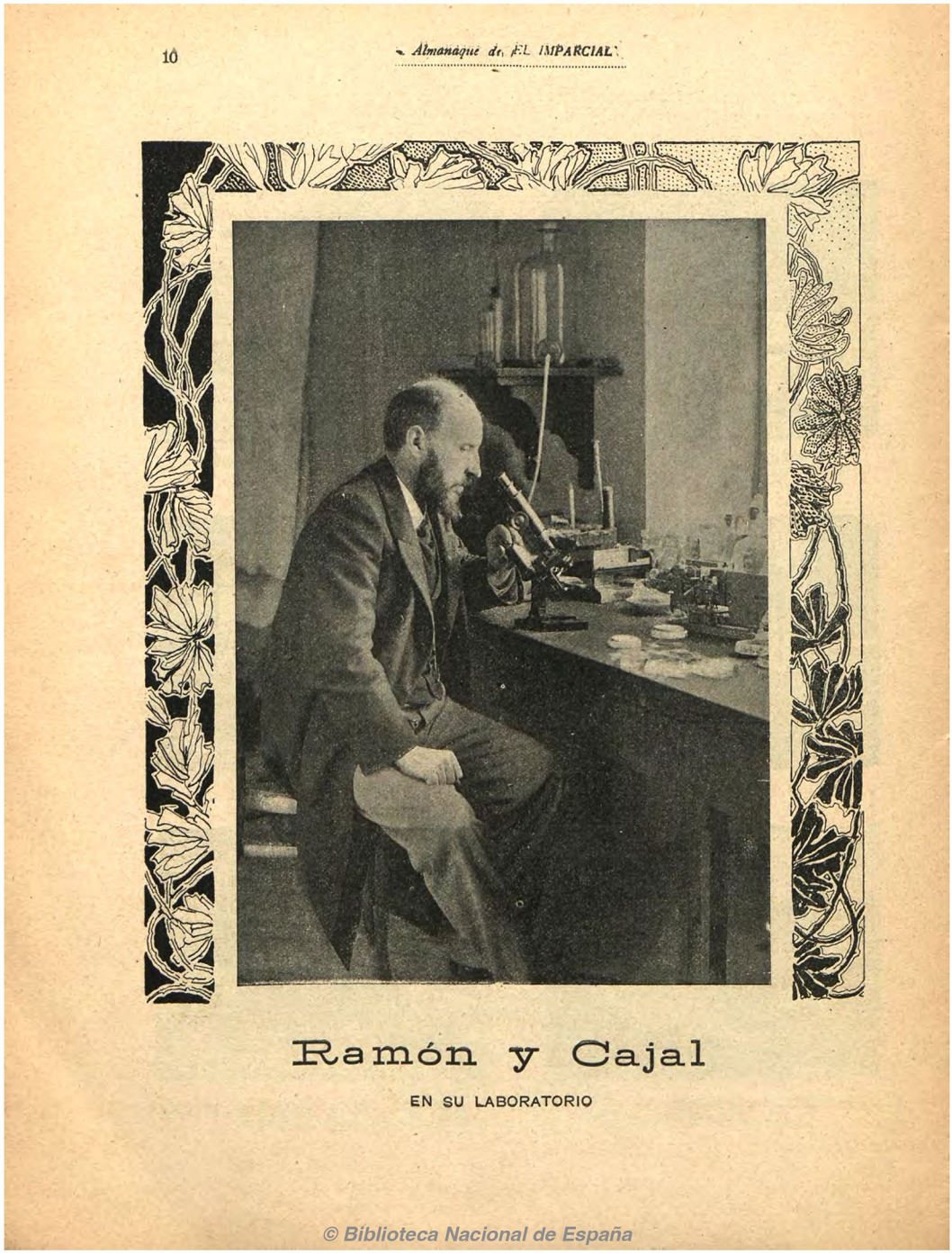

Figure 5. Self-portrait of Santiago Ramón y Cajal featured in *Almanque de EL IMPARCIAL 1901*. Rubio y Gali, Federico, 1901, "El Inventor y El Escritor," *Almanque de EL IMPARCIAL 1901*, Impresor, ROMERO, Madrid, 10-12. Image courtesy of and from the collections of the National Library of Spain.

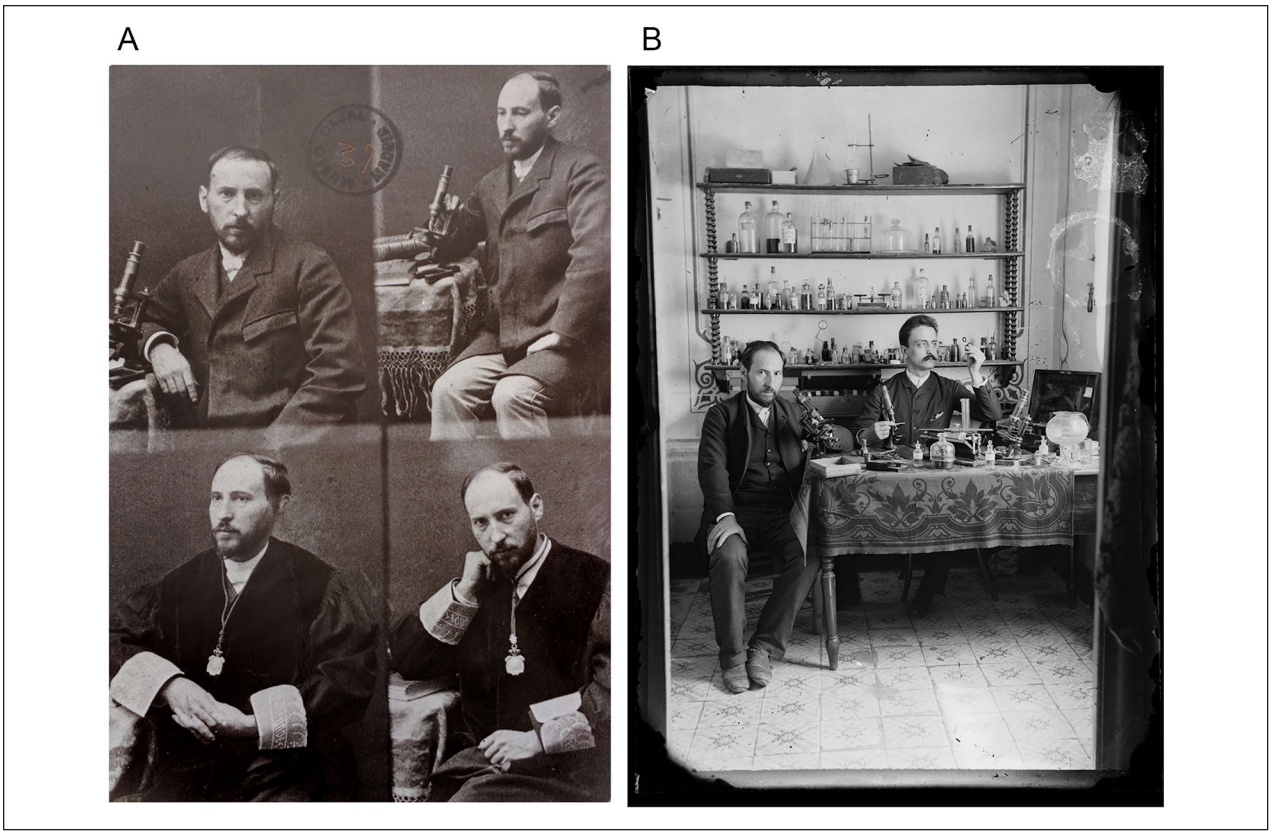

Figure 6. (A) Santiago Ramón y Cajal, undated multiple self-portrait photos printed by Cajal. (B) Santiago Ramón y Cajal, gelatin-bromide self-portrait by Cajal with his collaborator Juan Bartual Moret in this Valencia laboratory (1885).

his death mask. Cajal sent self-portraits in the "St. Jerome" composition to newspapers for the rest of his life. The portraits were emulated by others and continue to be published. Cajal imprinted himself in Spanish culture.

Cajal and Color

Cajal's son, Luis Ramón, said during a speech at the Cajal Club on the 50th anniversary of Cajal's death that Goethe's artistic and poetic philosophies were a lasting influence on his father's intellectual journey (LR Cajal 1996). Goethe was obsessed with color. Color was his most substantial and sustained scientific interest, and his treatise on color is the largest work in his entire oeuvre.

In his autobiography (SR Cajal 1989), Cajal discusses color. Given Cajal's admiration for Goethe, we suspect that Cajal was influenced by Goethe's ideas on the topic. Cajal conceives of nature's colors as emerging from grays, which aligns with Goethe's reanimation of the Aristotelean idea that color forms through the interaction of black and white, light and dark. Goethe writes, "In the division of physical colours, where semi-transparent mediums were considered, we saw colours antecedently to white and black. In the present case we assume a white and black already produced to be fixed; and the question is how color can be excited in them?" (1840, p. 206). These sentiments reverberate in Cajal's description of landscape painting (SR Cajal 1989, p. 92). Cajal writes, "I saw clearly the fundamental quality, but I was ignorant of the difficult use of gray and did not know that nature seldom presents an absolutely pure colour. It is well known that in the chromatic effect of a landscape, as in auditory sensation, there are only varied harmonies; with the color there are always mingled white and black in varying proportions, somewhat as silence and noise are mingled in auditory perception." Cajal's last sentence recalls Goethe's discourse on *Genuine Tone* (1840, p. 342), in which Goethe compares a painting's tone with a tonality in sound.

The dawn of color photography coincided with a profound period of introspection in Cajal's life while he was writing *Recuerdos de mi vida.* The autochrome process used color to rejuvenate his landscapes (Figure 11A) and self-portraits (Figure 11B). Autochrome plates were crafted by coating a glass surface with a sticky varnish and dusting it with a mixture of finely tinted, semitransparent starch

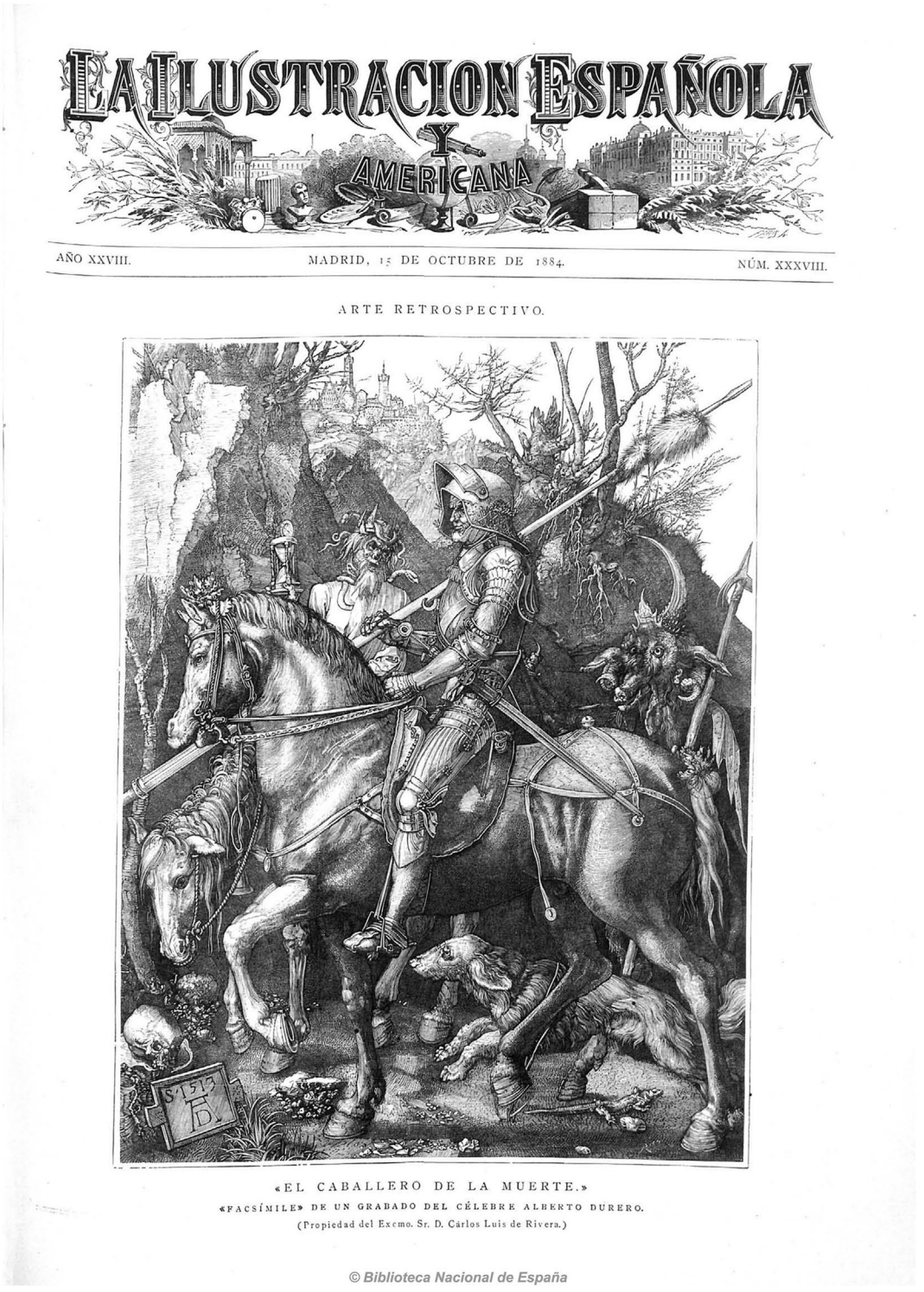

Figure 7. Albrecht Dürer's *Meisterstiche* "Knight, Death, and the Devil," featured on the cover of *La Illustration Espanola y Americana*, number 38, October 15, 1884, Madrid. Image courtesy of and from the collections of the National Library of Spain.

Figure 8. (A) Santiago Ramón y Cajal, gelatin-bromide self-portrait in his Valencia laboratory. This image is dated 1885. Image courtesy of the Cajal Institute, Cajal Legacy, Spanish National Research Council, Madrid, Spain. (B) Albrecht Dürer, *Melencolia I*, 1514, engraving, accession 43.106.1, courtesy of the Harris Brisbane Dick Fund, 1943, and the Metropolitan Museum of Art, New York, NY, United States.

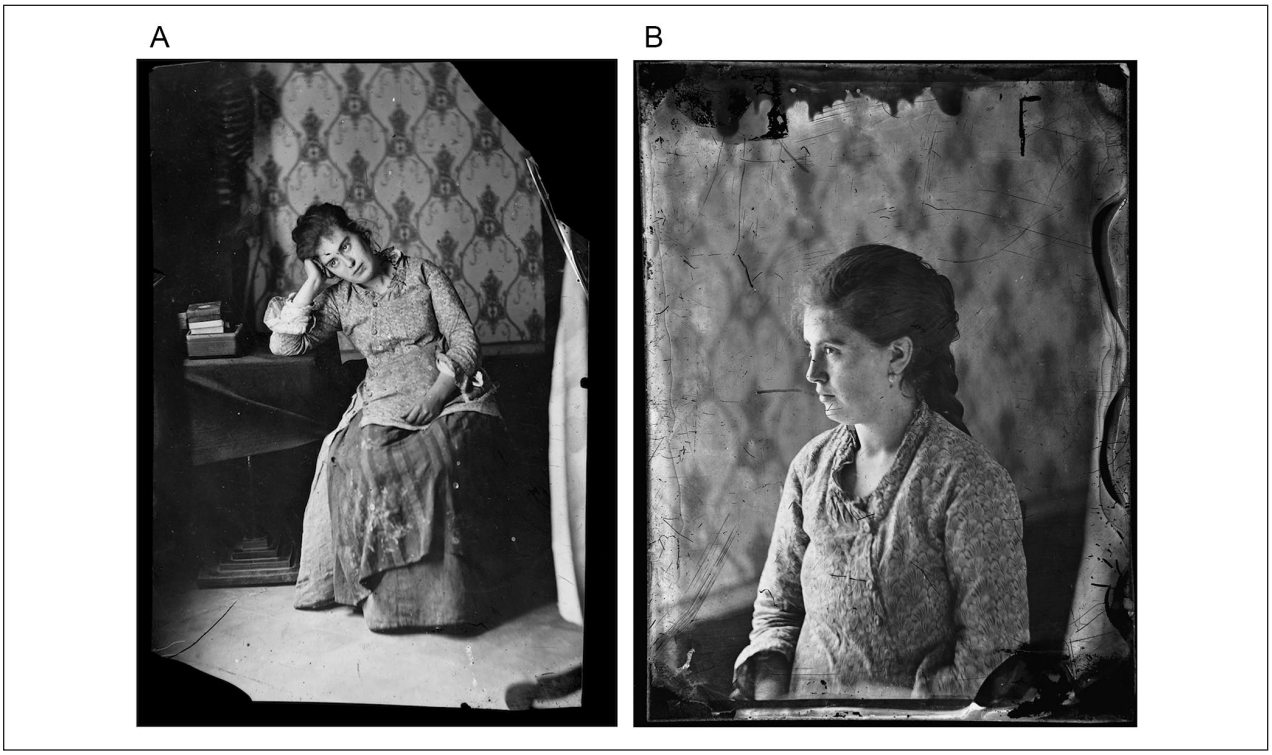

Figure 9. (A) Portrait of Silveria, Cajal's wife, by Santiago Ramón y Cajal, undated, printed with collodion or gelatin-bromide photographic methods, and estimated from 1879 to 1886 based on her attire, lighting, and overall presentation. (B) Undated collodion or gelatin-bromide portrait of Silveria by Cajal, likely from the same period, where she appears to be pregnant. Both images are provided courtesy of the Cajal Institute, Cajal Legacy, Spanish National Research Council, Madrid, Spain.

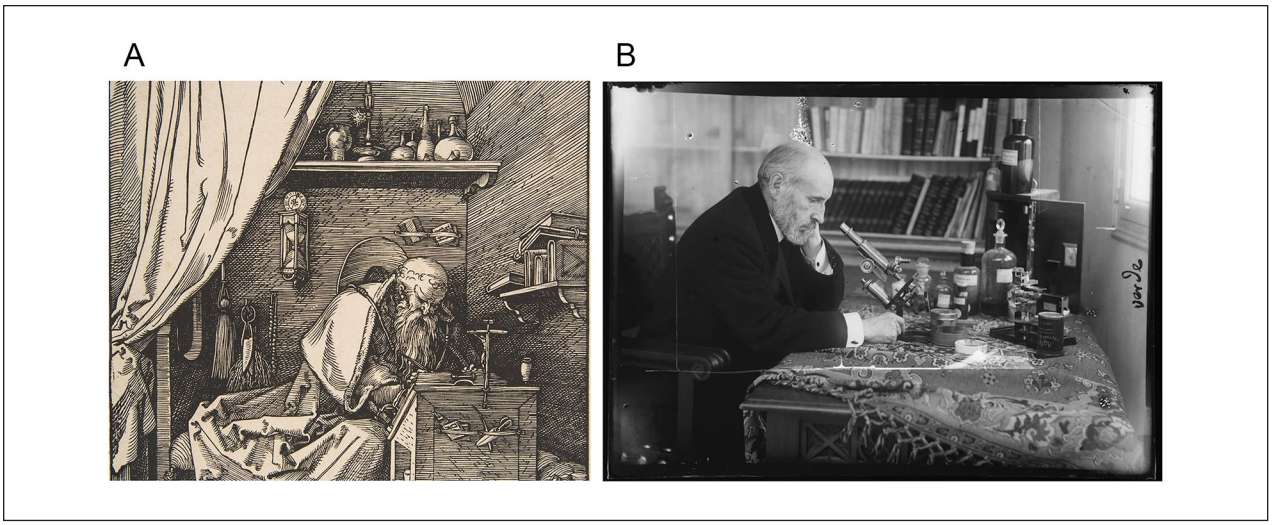

Figure 10. (A) Albrecht Dürer, *Saint Jerome in His Study*, woodcut (1514). Image courtesy of the Fletcher Fund 1919, Metropolitan Museum of Art, New York, NY, USA. (B) Santiago Ramón y Cajal, autochrome self-portrait. Cajal poses as *Saint Jerome in His Study*, 1908. Image courtesy of the Cajal Institute, Cajal Legacy, Spanish National Research Council, Madrid, Spain.

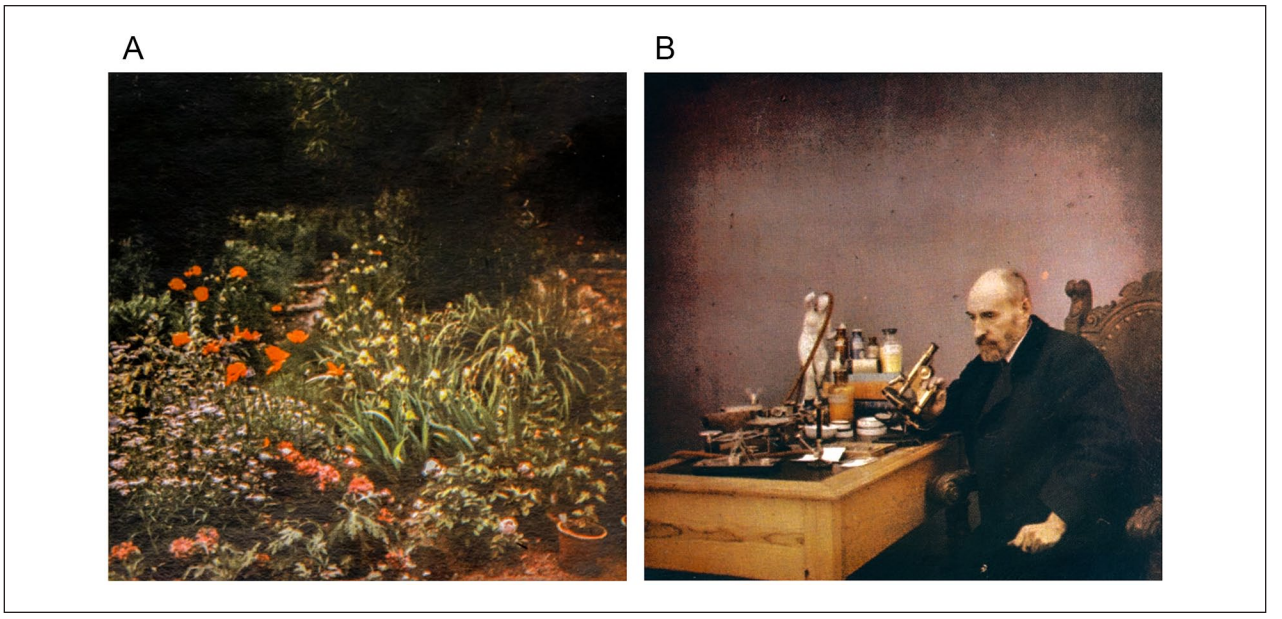

Figure 11. (A) Santiago Ramón y cajal, a Color photograph of the Rincon Garden at Cajal's rest house on Almansa Street, Madrid. This 1908 autochrome reflects Goethe's insights into the enduring nature of chemically produced colors, which Cajal described as having lasting intensity and transferability. When observed with anaglyph glasses, the garden's flora has a metallic sheen suggestive of gold and silver. Anaglyph photography was invented in 1891 and was quickly embraced by Cajal. Viewed through anaglyph glasses, the image appears to have motion, capturing a spatial depth that transcends the flatness of the image, a possibility not unfamiliar to Cajal, who had been pioneering three-dimensional photographic techniques well before this work. (B) Santiago Ramón y Cajal, an autochrome self-portrait in which Cajal poses as *Saint Jerome in His Study*, 1908. Both images are courtesy of the Archivo científico Fernando de Castro.

particles in red-orange, violet, and green, interspersed with black carbon, a process once again reminiscent of the Renaissance technique of glazing. The photosensitive layer used was silver bromide or silver iodide. During exposure, light passed through these colored particles, acting as tiny color filters before reaching the emulsion. The plates

underwent a reversal development process, transforming the initial negative into a final positive image. The result is a uniquely developed autochrome plate with a painterly aesthetic; the visible fine grains function like pointillism, creating optical mixing from the three colors used for the grains (Conway 2016; Rosenblum 1997). Cajal's early adoption of such photographic techniques suggests that he was attuned to the dynamic interplay of light and color, possibly anticipating the layered metallic quality of the garden's colors when the photograph is viewed through anaglyph glasses (Cajal had been printing anaglyphs from stereographs two decades earlier). Cajal's late color photographs show that the Romanticism learned from his art teacher endured.

Conclusion

Cajal was a common subject in the Spanish press. There were four mentions of his Moscow Prize in 1901-1902 and 17 mentions of his Helmholtz Prize in 1905-1906 (Biblioteca Nacional de España). But it was the Nobel Prize in Physiology or Medicine that captured the most press attention, with 110 mentions in 1906-1907, securing his identity as an icon of the award. To commemorate the award, Cajal created an autochrome that interweaves iconography from "Melencolia I" and "St. Jerome in His Study" (Figure 11B). Cajal was about to take on his final major work, *Degeneration and Regeneration of the Nervous System*. The self-portrait encapsulates the transitional moment. He remains surrounded by the tools of his trade. But now he is looking off to the side of the microscope's objective, as if searching for meaning beyond the microscope, toward the legacy that he hoped to have created. And there, on the table in the center of the photograph, is the white maquette of Venus, the Renaissance symbol of rebirth and transformation. She is surrounded by bottles of chemicals, arranged to capture Goethe's color harmonies. Red and orange, colors that penetrate the organs. Blue and yellow, "containing the ingredients for the ultimate state" (Goethe 1840, p. 322).

Cajal created and mastered an artistic visual language that enabled his scientific research. Meanwhile, his work fulfilled his desire for artistic expression and created an indelible image of himself as the Father of Neuroscience. If someone enters a room and says "Cajal," those who know who he is visualize his drawings of neurons, his profile image, and the Nobel Prize. His visual language continues to resonate in the art world, and his ideas conveyed with that language remain a foundation for neuroscience, preserving and perpetuating his legacy.

Acknowledgments

We would like to credit the Archivo Fernando de Castro (Census Guide of Archives of Spain and Latin America ES.28079.AFC; Madrid, Spain) for the images presented in Figures 2, 4, and 11A and 11B. This archive was recognized by UNESCO in 2017 and added to the Memory of the World International Register as a part of the human heritage, under the collection titled "Archives of Santiago Ramón y Cajal and the Spanish Neurohistological School" (collection 2016-312016).

Author Contributions

The idea to draft an essay about Cajal at the crossroads of science and art arose in a conversation between DH and ARM in 2021, and they formed a collaborative working group. DH did all the research and wrote the first draft. JF provided expertise on Cajal and his scientific methods, translations of the original Spanish texts, and reproductions of Cajal's drawings. ARM provided encouragement throughout the project. DH and BRC formulated the arguments, contributed original ideas, and rewrote the manuscript. All authors provided feedback on the text, contributed to editing, and approved the final draft.

Declaration of Conflicting Interests

The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Funding

The authors disclosed receipt of the following financial support for the research, authorship, and/or publication of this article: Support was provided by the Creative and Performing Arts Grant, Office of the Provost, University of South Carolina, Columbia, SC, USA; the Fulbright España Senior Research Award, Fulbright Foundation, Washington, DC (to D.H.); and the Intramural Research Program of the National Eye Institute (to B.R.C.).

ORCID iDs

Dawn Hunter https://orcid.org/0000-0003-0446-3515

Arpan R. Mehta https://orcid.org/0000-0002-5715-5025

References

Abadías y Santolaria L. 1882. *Importancia del Dibujo*. Cordoba: Establecimiento Tipografico, La Actividad, Liceo: 41.

Biblioteca Nacional de España. Hemeroteca Digital. https://hemerotecadigital.bne.es/hd/en/advanced. Accessed January 14, 2024.

Cajal LR. 1996. Cajal, as seen by his son. *Proceedings of the Cajal Club* 4:73–79.

Cajal SR. 1895 . L´anatomie fine de la moelle epinière. In: Babes V, von August Hirschwald V, eds. *Atlas der Pathologischen Histologie des Nervensystems. IV*. Lieferung, Berlín.

Cajal SR. 1889. *Manual de Histologia Normal y de Tecnica Micrografica*. Valencia: Aguilar.

Cajal SR. 1909. *Histologie du syste`me nerveux de l'homme et des vertebras*. L. Azoulay, trans. Paris: Maloine.

Cajal SR. 1912. *La fotografía de los colores. Fundamentos científicos y reglas prácticas*. Madrid: Moya.

Cajal SR. 1917. *Recuerdos de mi vida*. Vol. 2. Madrid: Moya.

Cajal SR. 1933. ¿Neuronismo o reticularismo? Las pruebas objetivas de la unidad anatómica de las células nerviosas. Arch Neurobiol 13:217–91, 579–646.

Cajal SR. 1988. 1894, the Croonian Lecture: La fine structure des centres nerveux. Proc Royal Soc London 55. DeFelipe J, Jones EG, trans. *Cajal on the Cerebral Cortex*. New York: Oxford University Press: 444–68.

Cajal SR. 1989. *Recollections of My Life*. Vol 8. In *Memoirs of the American Philosophical Society*. Craigie EH, Cano J, trans. Cambridge, MA: MIT Press.

Cajal SR. 1991. *Cajal's Degeneration and Regeneration of the Nervous System*. DeFelipe J, Jones EG, trans. New York: Oxford University Press.

Cajal SR. 1999. *Advice for a Young Investigator*. Swanson N, Swanson LW, trans. Cambridge: MIT Press.

Conway BR. 2016. Seeing: processing. In *Experience: Culture, Cognition, and the Common Sense*. Cambridge: MIT Press: 87–110.

Conway BR. 2018. The organization and operation of inferior temporal cortex. Annu Rev Vis Sci 4:381–402. doi:10.1146/annurev-vision-091517-034202

Cooper L, Pierre A, Ravaud E, Mélinge Y, Majérus O, Caurant D, and others. 2023. Influence of the addition of crushed glass on the physical and chemical properties of lead white oil paint. Journal of Cultural Heritage 61:238–46.

De Castro F, López-Mascaraque L, De Carlos JA. 2007. Cajal: lessons on brain development. *Brain Res Rev* 55:481–9.

DeFelipe J. 2009. *Cajal's place in the history of neuroscience*. In: Squire LR, ed. Encyclopedia of Neuroscience Academic Press; pp. 497–507.

DeFelipe J. 2010. *Cajal's Butterflies of the Soul: Science and Art*. New York: Oxford University Press.

DeFelipe J. 2018. *Cajal's Neuronal Forest: Science and Art*. New York: Oxford University Press.

Fiorentini E. 2011. Inducing visibilities: an attempt at Santiago Ramón y Cajal's aesthetic epistemology. *Stud Hist Philos Biol Biomed Sci* 42:391–94. doi:10.1016/j.shpsc.2011.07.008

Fiorentini E. 2013. Induction of visibility: reflections on histological slides, drawing visual hypotheses and aesthetic-epistemic actions. Hist Philos Life Sci 35:369–84.

Goethe JWV. 1840. *Goethe's Theory of Colours*. Eastlake CL, trans. J. Murray.

Goethe, JWV, Eckermann JP, Soret FJ. 1850. *Conversations of Goethe with Eckermann and Soret*. London: Smith, Elder.

Grewe C. 2015. *The Nazarenes: Romantic Avant-Garde and the Art of the Concept*. University Park: Penn State University Press.

Holliday C, Pallant C. 2021. The depth deception: landscape, technology and the manipulation of Disney's multi-plane camera in *Snow White and the Seven Dwarfs* (1937). In *Snow White and the Seven Dwarfs*. New York: Bloomsbury Academic, Bloomsbury Publishing: 61–77.

Hubel DH, Wiesel TN. 1977. Ferrier lecture: functional architecture of macaque monkey visual cortex. Proc R Soc Lond B Biol Sci 198(1130):1–59. doi:10.1098/rspb.1977.0085

Hunter D. 2018. Communing and giggling with Cajal. In *Circulating Now*. Bethesda: National Library of Medicine. https://circulatingnow.nlm.nih.gov/2018/10/02/communing-and-giggling-with-cajal-by-dawn-hunter/

Hunter D. 2017. Drawn to, drawn from experience. In *Circulating Now*. Bethesda: National Library of Medicine. https://circulatingnow.nlm.nih.gov/2017/11/14/drawn-to-drawn-from-experience/

Lorente de Nó R. 1934. Studies on the structure of the cerebral cortex: II. Continuation of the study of the Ammonic system. J Psychol Neurol 46:113–77.

Marañón G. 1950. *Cajal, su tiempo y el nuestro*. 2nd ed. Santander: Zuñiga.

McDonough J, Egolf K, Reid JV, eds. 2003. *The Advertising Age Encyclopedia of Advertising*. New York: Fitzroy Dearborn.

Merchán M, DeFelipe de Castro F. 2016. *Cajal and de Castro's Neurohistological Methods*. New York: Oxford University Press.

Mehta AR, Abbott CM, Chandran S, Haley JE. 2020. The Cajal Embroidery Project: celebrating neuroscience. *Lancet Neurol* 19:979.

Mountcastle VB. 1957. Modality and topographic properties of single neurons of cat's somatic sensory cortex. J Neurophysiol 20(4):408–434. doi: 10.1152/jn.1957.20.4.408

Muller PE. 1999. Works on paper by Federico de Madrazo y Kuntz in the Hispanic Society of America. Master Drawings 37:429–42. http://www.jstor.org/stable/1554464

Newman EA, Araque A, Dubinsky JM, Swanson LW, King L. 2017. *The Beautiful Brain: The Drawings of Santiago Ramón Y Cajal*. New York: Abrams Books.

Rosenblum N. 1997. *A World History of Photography*. 3rd ed. New York: Abbeville Press.

Safranski R. 2017. *Goethe Life as a Work of Art*. Dollenmayer D, trans. New York: Liveright Publishing Corporation.

Saltz J. 2018. The Nobel Laureate in medicine belongs next to Michelangelo as a dratsman. *Vulture*. https://www.vulture.com/2018/03/the-doctor-whose-drawings-rival-michelangelos.html

Schott GD. 2000. Illustrating cerebral function: the iconography of arrows. *Philos Trans R Soc Lond B Biol Sci* 355:1789–99. doi:10.1098/rstb.2000.0735

Smith R. 2018. A deep dive into the brain, hand-drawn by the father of neuroscience. *New York Times*. ISSN: 0362-4331.