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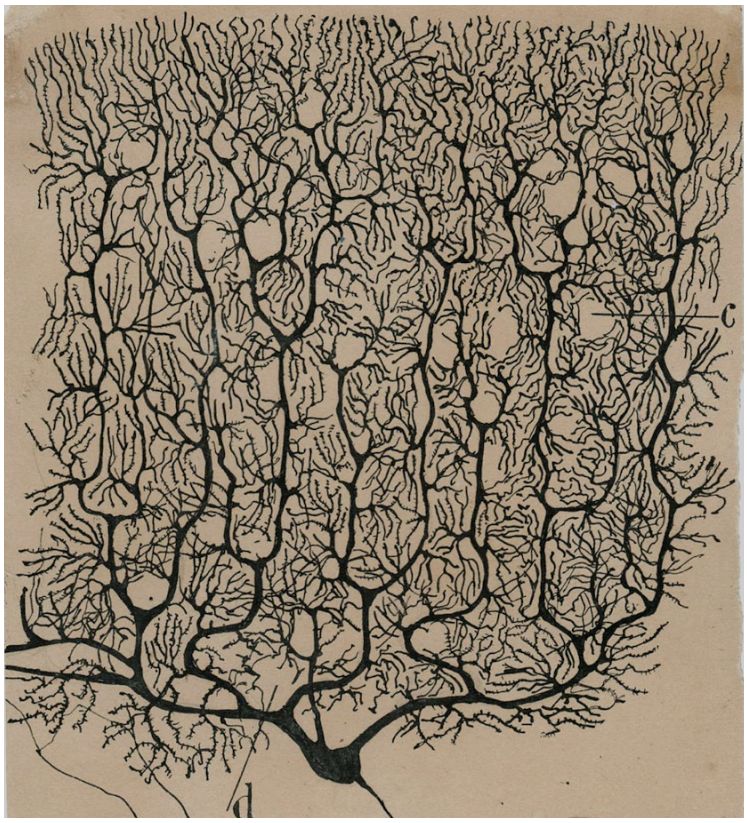
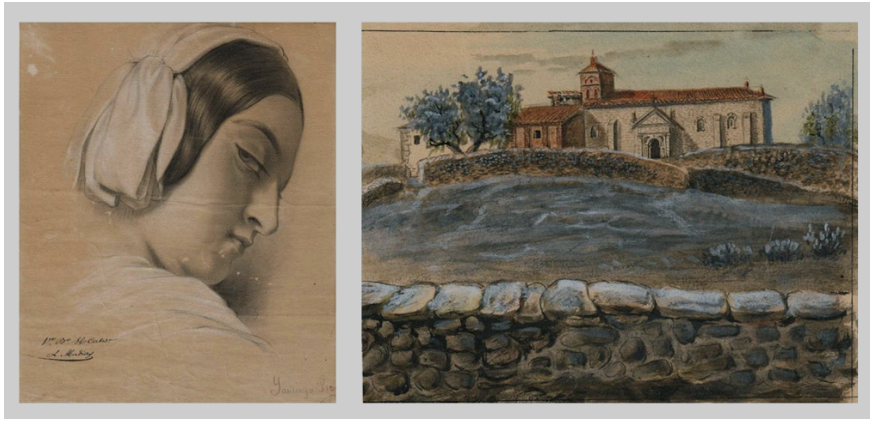
Drawing the Path to Discovery: Santiago Ramón y Cajal and His Genius



Find the base of the tree. Trace the meandering branches, choosing a random path at each junction, and explore the wondrously elaborate, labyrinthine creation of Santiago Ramón y Cajal. To those unfamiliar with the work of Cajal, his drawings are aesthetic exercises in geometric abstraction, but depicted is actually a neuron from an infant's cerebral cortex.

Though Cajal was not an artist professionally, he had such aspirations in his childhood. Cajal recalls his "irresistible mania for scribbling", a hobby through which he "[translated his] dreams onto paper, with [his] pencil as a magic wand". At the behest of his father, who was a doctor, Cajal resigned his aspirations to be a painter and pursued medical studies instead. Unexpectedly, his illustrious career as a neuroscientist would satisfy his "irresistible mania" for drawing.



Portrait of a girl (left) and landscape of a chapel (right) drawn by Santiago Ramón y Cajal in his teen years

Cajal's story is not complete without that of his Italian colleague, Camillo Golgi. Golgi also had a physician father and studied medicine, but—unlike his Spanish counterpart who loved to spend "all the hours of freedom…wandering about the outskirts of the town exploring glorious ravines, floodplains, springs, rocks, and hills"—Golgi shared neither Cajal's enthusiasm for the arts nor his free, spontaneous demeanor. Golgi was reserved and methodical. Cajal, at eleven years-old, demolished his neighbor's yard gate with a homemade cannon; Golgi's records for a semester of school in 1854 (when he was ten years-old) indicate that he had "'outstanding' moral conduct", "'serious and consistent' dedication" and "no absence from class".

After studying medicine at the University of Pavia and practicing as a physician and researcher at several different institutions, Golgi was compelled due to financial considerations to join Pio Luogo degli Incurabili, a hospital for the incurable. In a rudimentary laboratory of his own making, he continued the research he had done previously as a histologist. Golgi was fueled by his insatiable curiosity of the nervous system and was equipped with an obsessive diligence; the outcome of his experimentation with different dyes, preservatives, and procedures was the fruitful conception of la reazione nera, or the black reaction, in 1873. The black reaction was unlike any other staining method because it selectively stained a small, random portion of cells, allowing for the visualization of the central nervous system, an otherwise indecipherably dense and cluttered tangle.

Only a few years earlier and across a stretch of the Mediterranean Sea, Ramón y Cajal discovered the wonders of histology at the medical school of the University of Zaragoza. He likened the experience of viewing a carmine-injected lymph sac under a microscope to "a veil…suddenly lifting from my soul". He then became thoroughly absorbed in histological research, like Golgi was. Cajal eagerly familiarized himself with the black reaction after its dissemination from Golgi's makeshift laboratory. He recapitulates his first encounter with the method:

> everything is absolutely clear, without any possibility of confusion. There is nothing more to interpret: one need only observe and note these cells, with their different, ramified extensions, like plants in the morning frost, covering an astonishingly large space in wavy lines; these smooth and uniform extensions which, springing from the cell, cover great distances, before suddenly splitting up into a bunch of innumerable fibers…The delighted and astonished gaze cannot tear itself away from this fantastic sight.

Despite their shared passion for histology and appreciation of the black reaction, Golgi and Cajal interpreted their slides differently. Golgi was a proponent of the once predominant reticular theory; Ramón y Cajal formulated the neuron doctrine. The reticular theory postulated that the nervous system is composed of a single continuous network, whereas the neuron doctrine postulated that the nervous system is composed of discrete units or cells of signal transmission.

How could these brilliant minds come to utterly antithetical conclusions when viewing the same type of tissue?

Composing a precise image of nervous tissue is not as simple as reproducing what you see through the eyepiece of a microscope. Even with the black reaction, visualizations could be incredibly complex. Slides prepared for microscope-viewing are prepared by cutting tissue into thin slices, so neurons travelling vertically through the slides would not be shown in their entire length. A histologist had to consider planes at different depths, decipher blurriness, and parse through artifacts to compose a singular drawing. This is where Cajal excelled. Common practice was to take photographs of pertinent slides and manipulate the photographs until a satisfactory alignment emerged, but Cajal drew his images from memory, allowing his visual sensibility to render rational judgements on neuronal anatomical structure. Drawing and the mental processes involved allowed his thoughts to develop. The injection of an aesthetic element to his drawings revealed the elusive knowledge that could be extracted from histology of neurons. Therefore, soon after Cajal presented his work to his colleagues at an international conference in Berlin, the neuron doctrine overtook the reticular theory as the presiding school of thought.

But Camillo Golgi refused to embrace the neuron doctrine as the more comprehensive theory of neuroscience. Ideological bickering ensued between Golgi, Cajal, and their respective followers, which swelled into climax at the Nobel ceremony of 1906 where Golgi and Cajal jointly received the Nobel Prize in Physiology or Medicine. What the Nobel committee had presumably intended as a peacekeeping compromise further inflamed the feud between the winners. In their customary addresses at the ceremony, Golgi—betraying the restrained demeanor of his earlier years—recited his misgivings with the neuron doctrine, and Cajal intensely defended his ideas. Today, Golgi's obstructive obstinacy obscures his significant contributions to physiology and anatomy, whereas Cajal is celebrated as the father of neuroscience.

Cajal's once-in-a-century brilliance is an epistemological lesson in scientific advancement. According to Thomas Kuhn's model of scientific discovery, a typical scientist participates in a prevailing worldview that precludes the ability to make novel inferences from empirical information. Only the occasional visionary can overturn the established principles that determine how science is conducted, which Kuhn collectively calls a paradigm. Camillo Golgi, operating under the paradigm of his time, peered through the microscope and saw validation of the reticular theory. Santiago Ramón y Cajal saw distinct cells separated by infinitesimal gaps so miniscule that their existence could only be assuredly observed in 1955 through electron microscopy.

Cajal's artistic disposition offered him a remarkable ability that crowns him as a Kuhnian visionary: the ability to understand the nervous system in unrivaled complexity through superior visual perception. Learning was inextricably tied to the artistic process of drawing. In Cajal's

words, “A graphic representation of the object observed guarantees the exactness of the observation itself”. Then, from his mental reconstruction, Cajal made inferences about the nervous system, and those inferences are what comprise the revolutionary neuron doctrine. Golgi, on the other hand, was reluctant to participate in inference-making and admitted to a self-diagnosed “hypothesisphobia”. His objections with the neuron doctrine, as seen in papers and his Nobel lectures, are mostly disputes on validity and standards of proof. He accused his detractors of “exercising imagination” rather than “doing anatomy”.

Thomas Kuhn divides scientific work into two kinds: “normal science” and “revolutionary science”. Within the confines of a paradigm, “normal” scientists elucidate mysteries, engineer solutions, and predict outcomes. However, any paradigm has its limits and is squeezed until it has run dry of its scientific value. Progress demands a paradigm shift. “Revolutionary science” is—rather than “doing anatomy”—“exercising imagination”. Rather than Camillo Golgi, it is Santiago Ramón y Cajal. Rather than the pragmatic mind of a logician, it is the wandering mind of an artist that draws the path to discovery.

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