Talking to Ourselves:
Blueprints of the Mind

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Senior Division
Individual Exhibit
Exhibit: 496
Process Paper: 475

Process Paper

When given the theme of communication I originally thought of the human mind. But when I started researching, I came to realize that the body does almost all of our communication both mentally and physically. This led me to think of great thinkers who changed the way people view science. Inspired, I found Santiago Ramón y Cajal and his numerous accolades in the field of neurobiology. What struck me was how he incorporated illustration into his research. I discovered that his illustrations of neurons located throughout the body are prized possessions of the scientific community. I could clearly see this myself. As an artist, the detail he painstakingly went through to document the nervous system inspired me to tell his story as the father of neuroscience.

Before conducting any research, I briefly viewed secondary sources about his relevance. Unfortunately, many concepts he detailed were extremely complicated to understand at first. But by using Khan Academy and the help of college students taking biology courses, I was able to learn about the fundamentals of action potentials, types of neurons, and neurotransmitters. Learning these fundamental concepts helped me look into the explanations given by secondary sources and truly understand what Ramón y Cajal contributed.

This then became the essence of my thesis. I wanted to capture *how* and *why* he shifted our understanding of the nervous system. To do so, I researched the time period and context of his findings to show he literally offered a revolutionary new perspective. Specifically, he proved that the nervous system was a network of neurons and not a single organ. This is significant because he helped us see that there were complexities in how our body communicates with itself on a cytological level and with electricity. Furthermore, he made these discoveries in a time where a diametrically opposed theory influenced the current work of biologists. To better

understand his achievements, I read detailed primary sources. These helped me recognize how important his ideas were perceived by not only his contemporaries but also the scientific community as a whole. It was so revolutionary that he was even awarded a Nobel Prize.

With my topic and research completed, I aimed to follow a theme in celebration of the beautiful drawings he did of neurons. I drew the board paying homage to the mesmerizing feeling his drawings induce. By capturing this with his groundbreaking research, I could stimulate the reader to further reflect and view his contributions. In line with the theme of communication, Ramón y Cajal evolved our understanding of how the body communicates. Without his contributions, the popular understanding of the central and peripheral nervous system as control centers and information transmitters would not have come into fruition. Truly, I am passionate for his developments to be appreciated by an audience outside of the sciences as it is both breathtaking and revolutionary.

Annotated Bibliography

Primary Sources

Santiago, R. Y. (2004). *Advice for a young investigator*. Cambridge, MA: MIT.

A translation of Santiago's original book, it is extremely credible as the publisher is MIT. The book is not very significant in terms of scientific information. Instead, it is a collection of Santiago's wisdom from his years of studying the neuron. After reading, it is clear that he was patriotic and an advocate of originality and determination. In terms of impact, I feel that it is a great tool to see things from his perspective, but not so much in understanding the advancements he made.

Santiago, R. Y. (1924). *Reprints from Revista trimestral de histologia normal y patologica, 1888-1889*. Madrid: Jiménez y Molina.

A translation and reprint of Santiago's original work. This book contains many concepts that are beyond the scope of my understanding from secondary sources. The detail in his illustration and writing is obvious. But, from what I could gather, much of the information follows the idea that the neuron is not a single entity. His improvements to the Golgi staining method provide credence to his illustrations. Also, he proposes many theories commonly seen in modern biology such as depolarization and synapses. Clearly, he was ahead of his time and the proof is overwhelmingly in favor of the Neuron Doctrine theory.

Golgi, C. (1906, December 11). The neuron doctrine - theory and facts. Retrieved March 05, 2021, from https://www.nobelprize.org/uploads/2018/06/golgi-lecture.pdf

This lecture given by Camillo Golgi is one given after Santiago Cajo and he won the nobel prize for the neuron doctrine. The speech is slightly humorous because Golgi underplays the popularity of the neuron theory, since he received the nobel prize for a

theory he does not support. Littered throughout are distinct descriptions of how his staining method was improved upon and the major contributions of Santiago. It is both ridiculing and praising not only the neuron theory but also other ideas posed by Santiago like depolarization and the conduction pathway between neurons. This speech echoes much of the information told in secondary sources. Namely, that Golgi was an opponent to the theory even as he received the highest honor for its creation and that Santiago's ideas directly challenged the substance of the reticular theory.

Ink, S. (2018, August 23). The beautiful brain: The drawings of santiago ramón y cajal. Retrieved March 05, 2021, from https://greyartgallery.nyu.edu/exhibition/beautiful-brainthe-drawings-santiago-ramon-y-cajal/sec/images/

These gallery photos show me the detail Santiago put into his work in detailing the nervous system. It is important to note that he chose to draw over photography. These images will definitely be used for my display, but they will also be what I thematically use for the design of my board.

Secondary Sources

Khan, S. (n.d.). Overview of neuron structure and function (article). Retrieved March 05, 2021, from https://www.khanacademy.org/science/biology/human-biology/neuron-nervous-system/a/overview-of-neuron-structure-and-function

Finishing this crash course provided by Khan Academy helped me get a better understanding of the fundamentals of action potentials, the parts of a neuron, and how

hormones cause action potentials to trigger. From reading other secondary sources, I will not only use this information to get a better understanding of how Santiago influenced what we currently know but to also have a deeper understanding of the contributions he made.

The Nobel Prize in Physiology or medicine 1906. (n.d.). Retrieved March 05, 2021, from https://www.nobelprize.org/prizes/medicine/1906/cajal/biographical/

A summary of Santiago and Golgi's achievements towards neurobiology. It seems that Golgi's staining method and his supporting research is the reason he also received the Nobel Prize in 1906. This made him the first out of two spaniards to receive a nobel prize in the sciences. During the middle ages, Spain was a strong leader in the development of medicine and science. Before receiving the award, Spain's recognition towards these fields had been declining for a long period of time. Furthermore, despite being against the theory, Golgi received the award with Santiago. As the website notes, his most important contribution was definitely seeing the neuron as the fundamental unit in the nervous system. This is told in a theory called the Neuron Doctrine.

Santiago Ramón y Cajal. (n.d.). Retrieved March 05, 2021, from https://www.newworldencyclopedia.org/entry/Santiago_Ram%C3%B3n_y_Cajal

This article gave insight into Satiago's life and contributions. Again, I see that he improved Golgi's methods and disproved Reticular Theory. The article also notes some specifics on how he impacted future generations. Specifically, he impacted them by showing that the nervous system can act like a highway for information. This can tie into my thesis about how he helped scientists see the nervous system differently. The article provides a deeper understanding of what the Neuron Doctrine is.

Nemri, A. (n.d.). Santiago Ramón y Cajal. Retrieved March 05, 2021, from http://www.scholarpedia.org/article/Santiago_Ram%C3%B3n_y_Cajal

This article goes into much more detail about specific advancements made by Santiago. It puts into perspective his ideas by comparing them to reticular theory, while referencing relevant original works. The important work of note is his first publishing about the topic "*Revista trimestral de histologia normal y patologica."* Nothing this, it seems appropriate to review the writing and ask for help understanding its finer details. Additionally, many of the theories he derived from his observations are also noted in this article. In most articles, the idea of electrical activity being seen in his early iterations of his theory of depolarizations are told upfront by this article. Clearly, electrical activity as a concept is so important that it complemented his explanations of how the nervous system works as a network of neurons.

Rozo, J., & Rodríguez-Moreno, A. (2015, May 15). Santiago Ramón y CAJAL and ivan petrovic Pavlov: Their parallel scientific Lives, schools and Nobel prizes. Retrieved March 05, 2021, from https://www.frontiersin.org/articles/10.3389/fnana.2015.00073/full

While the article's main focus is not on Santiago, it puts much of his contributions into perspective. The way he shifted the way scientists look at the nervous system can be considered an extremely relevant contribution to how I should develop my argument. It also details the context with which his discoveries were made. Building off the cell theory is very critical in seeing why his topic was relevant to scientists of his time period. Clearly, his discoveries had two main impacts: proving cell theory and disproving reticular theory.

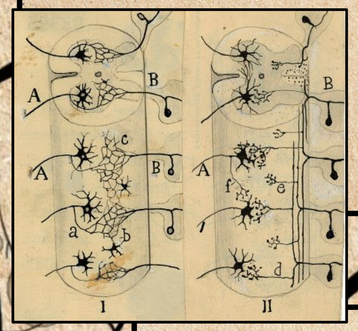
TALKING TO OURSELVES

BLUEPRINTS OF THE MIND

By: Mykha Lizette Floresca

THE RISE OF THE CELL THEORY

In the 19th century, advancements in the field of optics led Theodor Schwann, Matthias Schleiden, and Rudolf Virchow to hypothesize the cell theory. The theory describes how all living things arise from cells. All organ systems, at the time, were proven to follow its principles with the exception of the nervous system. The uniformity of its histological images made it appear as a single mass rather than individual cells.

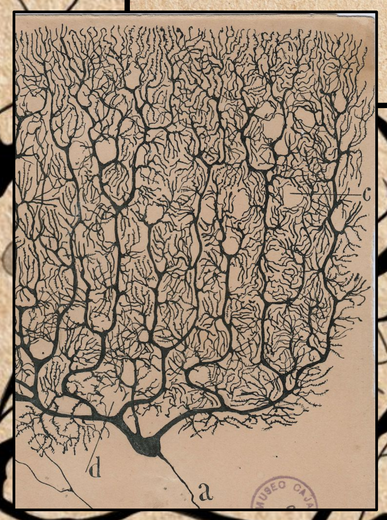


Left is reticular theory; right is the neuron doctrine.

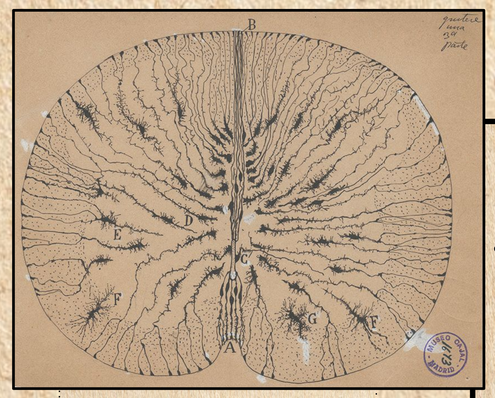
figure 9 in Recuerdos de mi Vida. Copyright by Herederos de Santiago Ramón y Cajal.

DISMANTLING THE RETICULAR THEORY

Camillo Golgi was opposed to the nervous system as a system of neurons. In 1873, he created a staining technique with the potential to view the entire nerve cell. A fellow reticularist, Ramón y Cajal borrowed Golgi's staining technique and improved its reliability to eventually see that his preconceptions were wrong. From 1888 to 1894, he made a series of discoveries that challenged the widely accepted reticular theory in his publishing "*Revista trimestral de Histologia norma y pataologica in the Revista*." Eventually, he formed the Neuron Doctrine, a theory that details the neuron as the unit of the nervous system, which offered the last piece of evidence needed to prove the cell theory.



detail from Ramón y Cajal's drawing of a Purkinje neuron from the human cerebellum ,1899. Ink and pencil on paper. Cajal Institute, Madrid.



Glial cells of the mouse spinal cord, 1899, ink and pencil on paper. Lent by the Instituto Cajal.

THESIS

Santiago Ramón y Cajal's illustrations and research on the brain proved to his contemporary Spanish scientists that the brain is not a single, continuous organ. By improving upon tissue staining and theorizing the concept of polarization, he would give rise to the field of neuroscience and give direction for future neuroscientists to study the nervous system as a sea of vast communicating neurons.

THE BIRTH OF NEUROSCIENCE

Ramón y Cajal birthed the concept of the nervous system as a network of individual, yet interacting neurons. Communication within the body had complexities in the processing of information. The idea of diverse cells and electricity influencing the speed of transmission was captured in both his writing and illustrations. Simply put, he opened scientists to think of the nervous system like a computer, a complex processing unit with a diversity of parts that are driven by electricity.

SHORT TERM IMPACT

Although Spain was a leader in the development of medicine and science in the Middle Ages, its prominence had long been in decline. Through Ramón y Cajal, Spain's scientific reputation was again on the rise as in 1906 he was the first of only two Spaniards awarded Nobel Prizes in the sciences.

Santiago Ramón y Cajal, Calyces of Held in the nucleus of the trapezoid body, 1934. Ink and pencil on paper, 5 3/5 x 3 3/5 in. Cajal Institute (CSIC), Madrid

HISTORICAL SIGNIFICANCE

For future scientists, Ramón y Cajal's contributions are felt through his detailed drawings of neurons throughout the body. By introducing the idea of the nervous system as a network, he helped others realize its importance in transporting and processing information. Later discoveries of the nervous system expanded upon his emphasis on the communicative abilities of the neuron by showing its interactions with itself and other body systems. As such, he gave humanity the fundamentals to understand how the body communicates with everything.