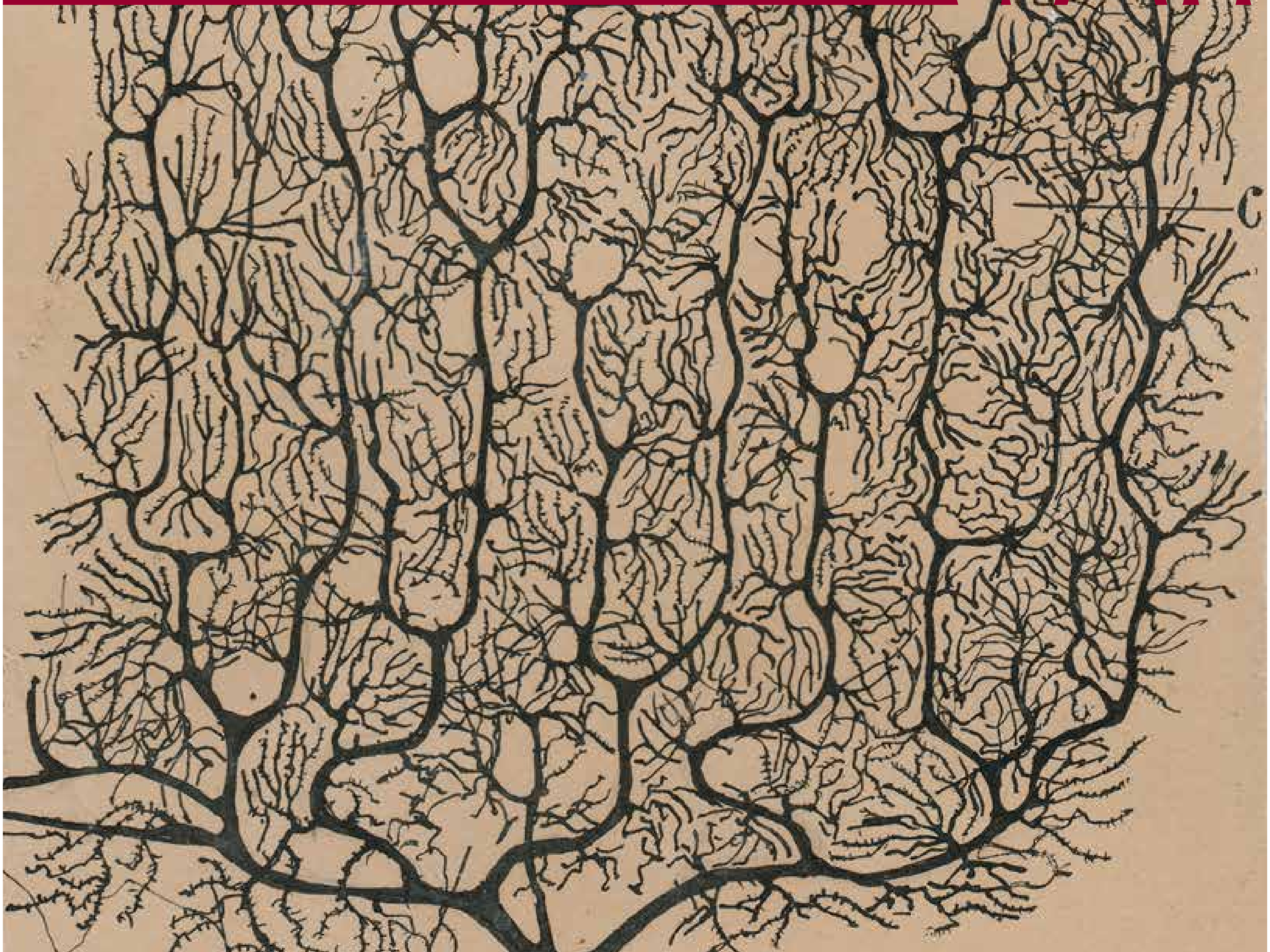


Santiago Ramón y Cajal, (Spanish, 1852 – 1934), a purkinje neuron from the human cerebellum, 1899, ink and pencil on paper. Courtesy of the Instituto Cajal (CSIC).

The Beautiful Brain: The Drawings of Santiago Ramón y Cajal

Weisman Art Museum Classroom Activities

The Beautiful Brain: The Drawings of Santiago Ramón y Cajal

Weisman Art Museum
Drawing As A Way Of Thinking: Classroom Activities

Developed by Jamee Yung, Weisman Art Museum Director of Education

Do You See What I See?
Math, science, visual arts
Create an Op Art image

Teacher's Guide
This guide, a framework for facilitating activities that suit your individual educational goals, supports a visit to the exhibition or students' responses to the art in the classroom. The activities explore the many intersections of the visual arts with scientific disciplines. These interdisciplinary activities focus on middle-school level, but they can be adapted for elementary and high school.

Introduction

Thank you for your interest in *The Beautiful Brain: The Drawings of Santiago Ramón y Cajal* at the Weisman Art Museum. We hope you find these materials to be a valuable addition to your curriculum and museum visit. Our goal is to develop resources that promote discussion of the history and the ideas behind the artwork. Through these conversations we aim to increase excitement for learning and further inquiry about art and culture. We encourage teachers to use these resources as a starting point for their own dialogue.

Activities

Santiago Ramón y Cajal was a neuroscientist with a background in art. It's not so easy at first glance to tell whether Cajal's drawings are abstract representations of plant roots or scientific studies of brain cells. Cajal's eye seems to be attuned to an artistic aesthetic and has the ability to make sense of a complicated topic. Each activity explores a variety of intersections between the visual arts and scientific disciplines. We created each activity with education strategies in mind so you can connect with the standards you are addressing in your classroom. These strategies include literacy, language arts, science, visual arts, and math standards. The activities were designed for middle school but can easily be adapted for elementary and high school.

The PERCEIVE questions direct the essential underlying process of careful observation or perception. This process guides students into an artwork and helps them begin to form meaning. By practicing the habit of increased perception (slowing down to look before judging), students find evidence to build their interpretations and opinions. They gain an awareness of, and confidence in their own thinking. Students learn to distinguish observations (the facts, the evidence, what they see) from interpretations (reasoned conclusions supported by evidence, why they say that about what they see). These PERCEIVE questions will facilitate discussions about the artwork. The PERCEIVE questions, images, neuron slide images, and background information for each image, are located in the resource section following the activities.

We hope you find our resources for *The Beautiful Brain: The Drawings of Santiago Ramón y Cajal* helpful and fun. We welcome your comments, questions, and feedback on these classroom materials.

All images courtesy of Instituto Cajal (CSIC).

Background Information

Santiago Ramón y Cajal's drawings of the brain are as aesthetically astonishing as they are scientifically important. *The Beautiful Brain: The Drawings of Santiago Ramón y Cajal* is the first museum exhibition to present and contextualize these amazing historical objects.

Scientists the world over know Cajal as the father of modern neuroscience, the study of the structure and function of the brain. Cajal made many seminal contributions to neuroscience. One of his most important discoveries was the idea that the brain is made up of individual cells called neurons. The most commonly held idea among scientists of Cajal's time was that the brain was a continuous, interconnected network. All research on the brain and brain related diseases, such as Parkinson's and Alzheimer's, are based on Cajal's concept of the structure of the brain.

Neuroscientists consider Cajal as important to their discipline as Einstein is to physics. During his lifetime (1852 to 1934) Cajal produced more than three thousand drawings of the brain. Cajal's detailed studies of the brain are as relevant today as they were a century ago. They have never been equaled in their clarity and their ability to express fundamental concepts about the brain. He was awarded the Nobel Prize in 1906 for his work on brain structure.

Cajal did not set out to be a scientist. In fact, he wanted to be an artist, but this was not considered an appropriate ambition in rural Spain where he grew up. When he was about fifteen his father did allow him to enroll in the Academy of Arts. The school's director said he was the most brilliant pupil ever.

But, is what Cajal produced art? It would not have been classified as such in the art world of his day. How should we look at it today? Cajal's drawings were intended to convey specific information but they are also informed by his training as an artist. He had choices in his drawings and he made aesthetic decisions. He arranged forms on his paper and highlighted some parts for emphasis.

Cajal said, in his Advice for a Young Investigator (1916),"Drawing . . . enhances discipline and attention, for it forces us to observe the totality of the phenomenon and see details overlooked in ordinary observation." While Cajal's drawings are visualizations of scientific arguments, we believe they are also works of art, shaped by his artistic training, his close observation of nature, and his expression of aesthetic values.

The Drawings of Santiago Ramón y Cajal

The Cajal Institute in Madrid, Spain, lent the eighty original drawings for the exhibition. The Cajal Institute is a research organization of the Spanish government and home to the thousands of drawings Cajal made to document and illustrate his neuroscience research.

Cajal's training as an artist is evident in the clarity of his drawings—the lines are confident and fine. He sometimes made a pencil drawing and then went over the pencil in black ink. He did not erase the pencil lines so they are often visible. He used cross-hatching, small dots, ink washes, and occasionally watercolor, to emphasize certain kinds of cells or to distinguish parts of an individual cell.

The evidence of their use for scientific study remains. You can still see the corrections Cajal made in white. They would not have been visible when a drawing was published. Many of the drawings are on paper cut into irregular shapes because Cajal cut them out of larger sheets of paper when he published them. The dark stains left on the drawings are from tape.

The drawings at the Cajal Institute have been treated as archival documents rather than works of art until recently. That is why you can see a circular stamp with the words "Museo Cajal Madrid" right in the middle of many of the drawings. The handwritten number inside is called the "Manzano number" after the librarian, Pedro Manzano, who made an inventory of the Cajal archive in the 1940s.

A curatorial team of University of Minnesota neuroscientists and an art historian from its Weisman Art Museum selected these eighty drawings from among the thousands Cajal made, based on both their scientific importance and aesthetic value.

Cells of the Brain

One of Cajal's greatest contributions to our understanding of the brain was his championing of the Neuron Doctrine, which held that the brain is composed of discrete cells (neurons) rather than a continuous network. Early in Cajal's career, the Reticular Theory, the idea that the brain is a continuous, unbroken network, held prominence. Cajal, using his keen observational skills and newly developed staining techniques that allowed him to see brain cells in great detail through his microscope lens, realized that the continuous network that others had seen was actually made up of discrete cells that were separated by gaps, called synapses. With the advent of the electron microscope in the 1950s, which magnified images to a much greater extent than the light microscopes used by Cajal, the Neuron Doctrine was conclusively confirmed.

There are hundreds of different kinds of neurons in the adult human brain. Neurons possess a tree-like structure that sprouts from the cell body, the dendritic tree. These trees receive inputs from other neurons where electrical impulses travel across synapses. Neurons also possess a long, threadlike appendage called the axon. The dendrites carry electrical signals to the cell body of the neuron while the axon transmits the signals away, to other neurons or to muscles or glands.

Cajal and his contemporaries recognized that, in addition to neurons, the brain was composed of a second kind of cell, called glial cells. They were able to distinguish between neurons and glial cells because they differed greatly in shape. Glial cells do not have dendrites or axons.

The drawings in this exhibit illustrate the neurons and glial cells that Cajal observed through his microscope and characterized in great detail. Cajal often labeled the different parts of his drawings because he intended to use them as illustrations in published articles or books. Cells in this section of the exhibit include the pyramidal neuron, which Cajal referred to as "the noble and enigmatic cell of thought"; the Purkinje neuron with its large, elaborately branched dendritic tree; and the astrocyte, a star-shaped glial cell. Cajal thought that neurons were the generators of human thought and action and speculated that glial cells also played an important role in brain function. Modern research has confirmed Cajal's speculations.

DO YOU SEE WHAT I SEE?

Learning objective: Students will view works from the genre called "Op Art" and discuss what an optical illusion is to create an "Op Art" piece of their own.

Education Strategies: By using color theory and various concepts and principles of art to create art that affects the viewer in a specific way, students will be required to:

- Expand vocabulary
- Use basic geometric language to describe shapes
- Determine detail and focus support
- Apply spatial and logical reasoning to recognize, describe, and analyze
- Understand connections among various art forms and other disciplines

Vocabulary

Repetition: One object or shape repeated; pattern is a combination of elements or shapes repeated in a recurring and regular arrangement; rhythm--is a combination of elements repeated, but with variations.

Movement: The path the viewer's eye takes through the artwork, often to a focal area. The suggestion of motion through the use of various elements.

Radial Design: Circular design radiating from a center.

Op Art: Short for optical art, is a style of visual art that uses optical illusions. Op art works are abstract, with many better known pieces created in black and white. Typically, they give the viewer the impression of movement, hidden images, flashing and vibrating patterns, or of swelling or warping.

Optical Illusion: Something that deceives the eye by appearing to be other than it is. An experience of seeming to see something that does not exist or that is other than it appears.

Vertical Lines: A vertical line is one the goes straight up and down, parallel to the y-axis of the coordinate plane.

Contrast: The arrangement of opposite elements (light vs. dark colors, rough vs. smooth textures, large vs. small shapes, etc.) in a piece so as to create visual interest, excitement and drama.

Complimentary Colors: Colors directly opposite each other in the color spectrum, such as red and green or blue and orange, that when combined in the right proportions, produce white light.

Geometric shapes: Shapes that follow rules about how many sides and what types of angles they have, including circles, squares, rectangles, triangles, and ellipses.

Materials

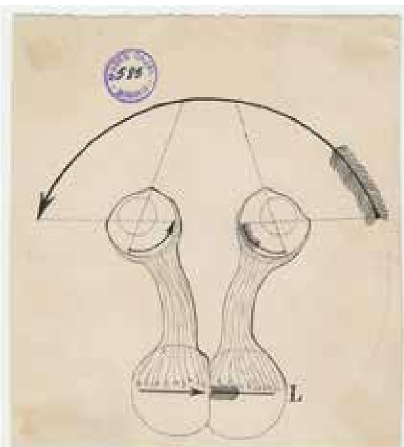
1. White drawing or marker paper
2. Black Sharpie markers
3. Rulers/compasses
4. Colored pencils or colored markers (optional)
5. Pencils and erasers
6. Variety of shapes to trace

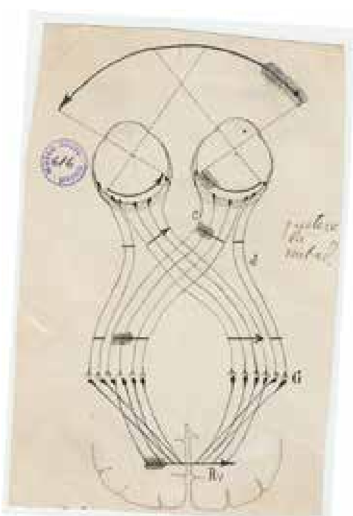
Images

Digitally project images or print copies of: *[Located in the resource section of this packet]*
Santiago Ramón y Cajal (Spanish, 1852 – 1934), diagram indicating how information from the eyes might be transmitted to the brain, 1898.
Santiago Ramón y Cajal (Spanish, 1852 – 1934), diagram indicating how information from the eyes might be transmitted to the brain, 1898.
Julian Stanczak (American, born in Poland, 1928), *Forming in Four Reds*, 1993-1994, acrylic on canvas.

CLASSROOM ACTIVITY

Introduce optical illusions:
The brain itself cannot perceive the external world. For that, it relies on our specialized sense organs, including the eye, the inner ear, and the nose. The retina, a paper-thin structure at the back of the eye, is the light-sensitive tissue responsible for vision. The retina is an integral part of the central nervous system and is composed of the same types of cells as the brain—neurons and glial cells.





Cajal was fascinated by the retina. Many of Cajal's most important conceptual breakthroughs were aided by his studies of the retina. One of Cajal's key contributions to neuroscience was his deduction of the direction of information flow within the brain.

Look at Cajal's diagrams indicating how information from the eyes might be transmitted to the brain.

Cajal's observations on the flow of information in retinal neurons are beautifully summarized in his drawing shown here. Arrows in the drawing indicate that information flows from the light-sensitive cells (photoreceptors) at the top of the retina (e and f) to the dendrites and cell bodies of intermediate cells (a and b) and then to the dendrites, cell bodies (c and d), and axons of cells at the bottom of the retina. Information then travels down the axons of these cells to the brain (B).

It was well known in Cajal's time that much of the information from the right eye traveled to the left side of the brain and vice versa. Cajal puzzled over why this was true in all animals. He imagined our two eyes looking at an arrow, as illustrated in the left-hand drawing. He reasoned that if information from the two eyes did not cross as it traveled to the brain, then a unified representation of the visual world could not be created in the brain (arrow L). On the other hand, if information from the eyes did cross, as illustrated in the right-hand drawing, a unified representation would result (arrow Rv).

Discuss with students the different ways that art can "play tricks with your eyes." Before starting the "Op Art" project, look at the fun science activities below to show them how seeing isn't always believing. You can also talk to students about shape and movement to teach them more about repetition, color contrast and complementary colors. Show students these examples of optical illusions.

http://www.optics4kids.org/home/content/illusions/
http://brainden.com/optical-illusions.htm

Look at these artworks:
Now look at the work, *Forming in Four Reds*, by Julian Stanczak

1. PERCEIVE
Work through the PERCEIVE card to investigate the artwork carefully.
What do you notice? What details do you see?
What does it remind you of? Does it make you think of something you've seen, heard, experienced before?
What feelings do you notice? What is the mood?
What questions would you like to ask the artist? What does it make you wonder about?
What do you think the artwork might be about? How do you think it was made?

2. CONSIDER
Can the image be seen another way?
What is creating this effect?
What is making this movement?
What do you notice about the colors?
Do you see any shapes?
Where have you seen optical illusions in your everyday life?

Introduce the artist. In this painting Stanczak focused on the movement and rhythm of vertical lines. The term "op art" was first used to describe Stanczak's 1964 exhibition in New York, spurring a movement of "optical art" that makes use of visual illusions. Stanczak's talent for layering patterns and interacting contrasting colors is shown here, creating a dizzying effect of vibrating shapes.

3. CREATE
Explain to the class that each student will create their own "op art" image. Show students the basics of starting an optical illusion. When you change the shape or change the pattern, an illusion will result.

Step 1: Choose a pattern for your background. You could do stripes, a checkerboard, zig zag, etc. It is your choice, but the background should cover the entire paper. Map this out in pencil first.
Step 2: Choose two or more shapes to layer over the top of your background.
Step 3: Label, using pencil, an X or small line, every other section in both your background and shapes. The pattern inside the shape must switch from the background pattern. For example, if your background is alternating black and white checkerboard, switch to alternating white and black inside the shape. The areas with a mark will get colored in black. The areas without will stay white. It's important to label because this will prevent any mistakes when you start in permanent marker.
Step 4: Using a black permanent marker, carefully color in all of the sections you marked in pencil. If there are mistakes along the way, whiteout works great.

Educator's note: If students want to make more complicated designs, they can work with complimentary colors instead of black and white.

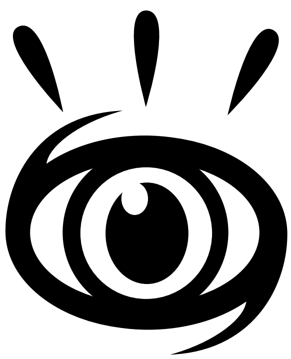
4. REFLECT
Students share their art with the class. The goal of this is to trick the eye. Hold your paper back for a neighbor. Does it fool their eye or make them dizzy? Did you change the pattern each time you created a new shape?

RESOURCES

PERCEIVE Card

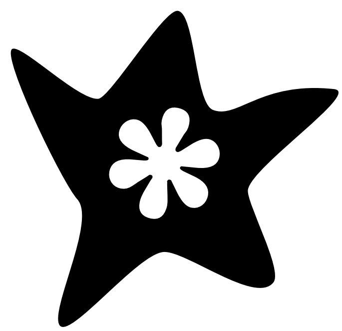
perceive

Before you read anything about the image, use your powers of observation to look slowly and closely.



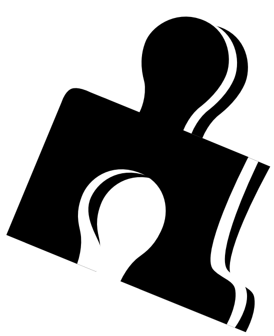
What do you notice?
Imagine using all of your senses.

What do you recognize?



What feeling do you get from the image?

Is there a mood?



What does this image remind you of?

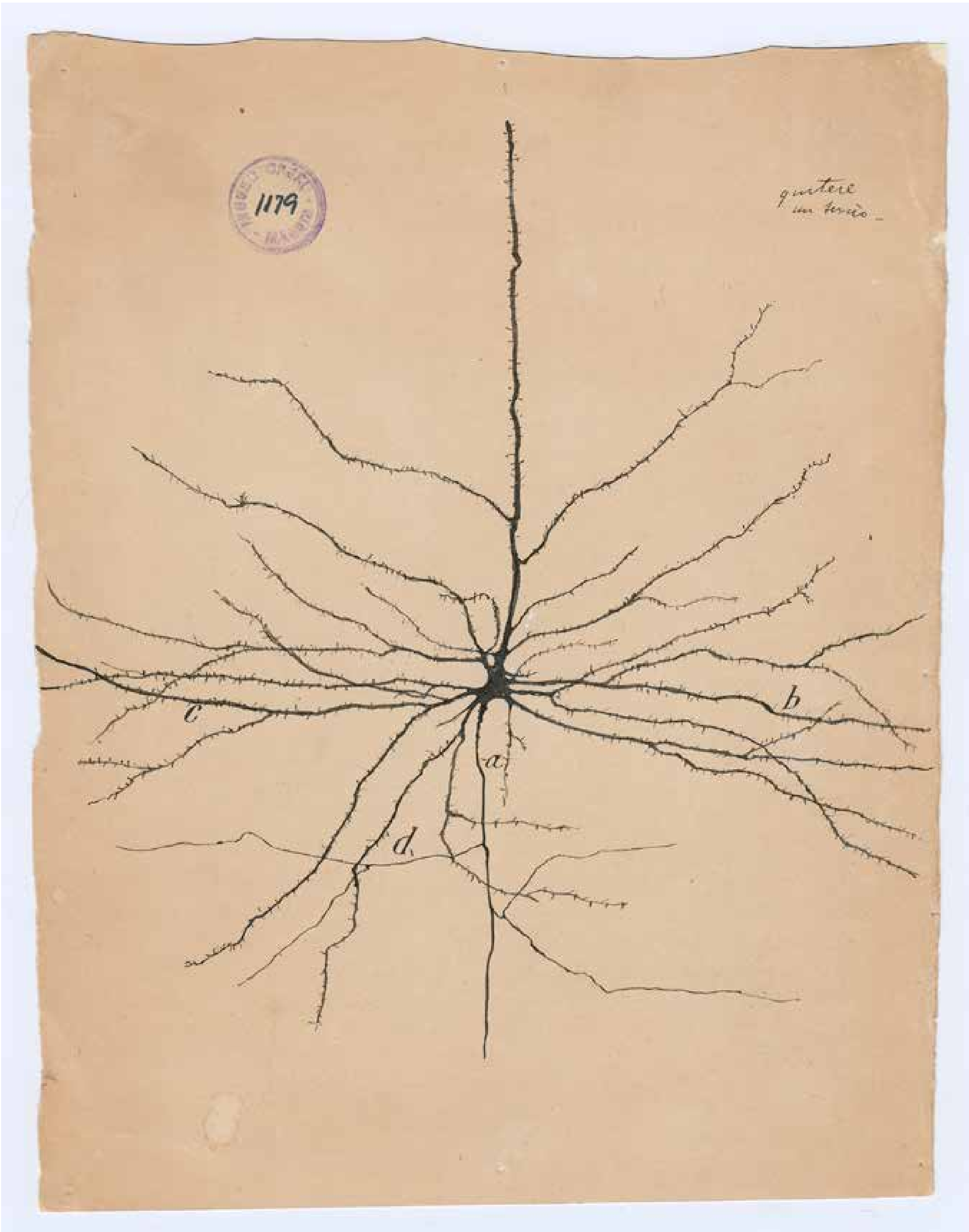
What is going on?

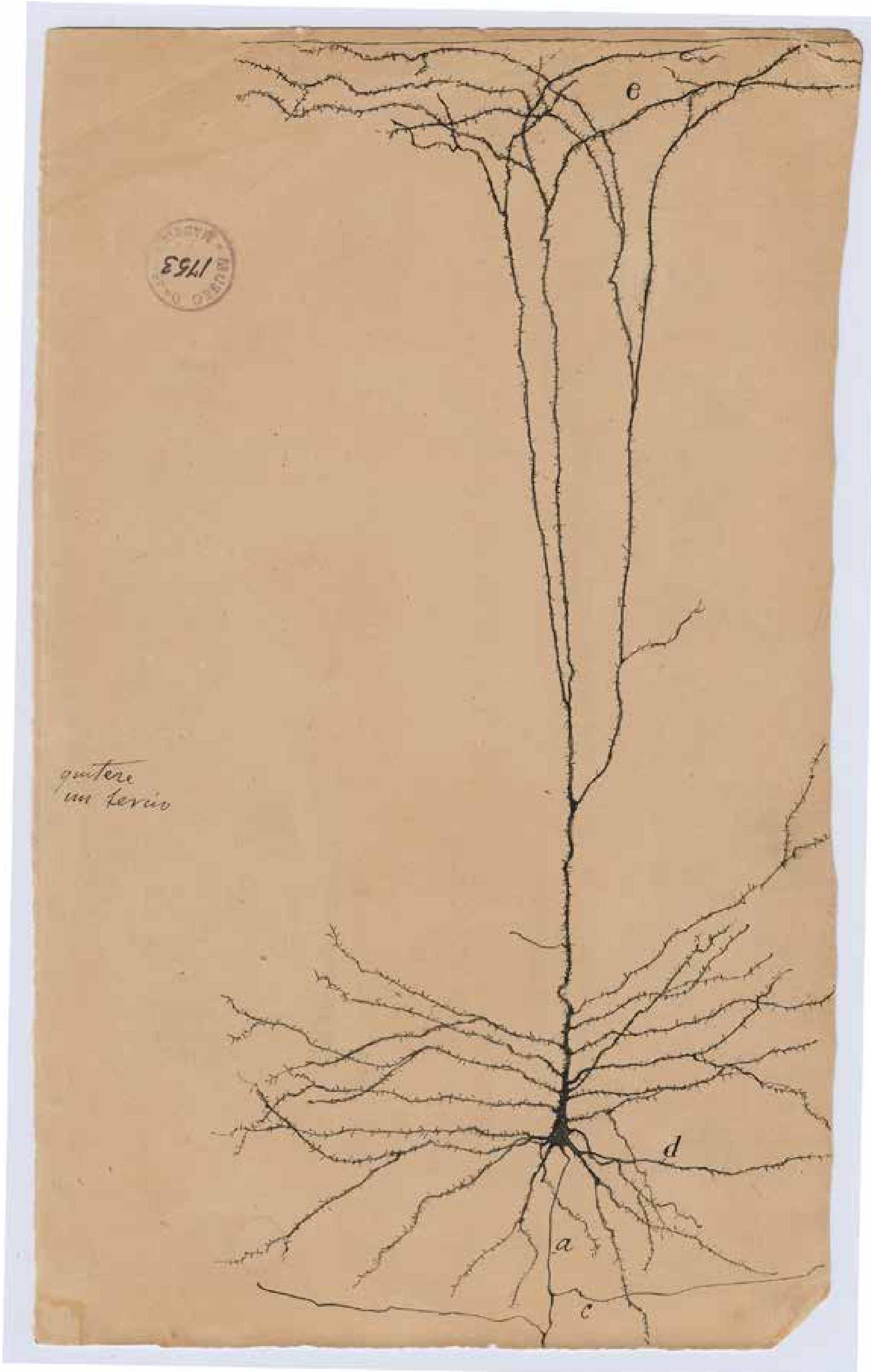
What other meanings could there be?

What does the image make you wonder about?

What more do you want to know?

IMAGES:

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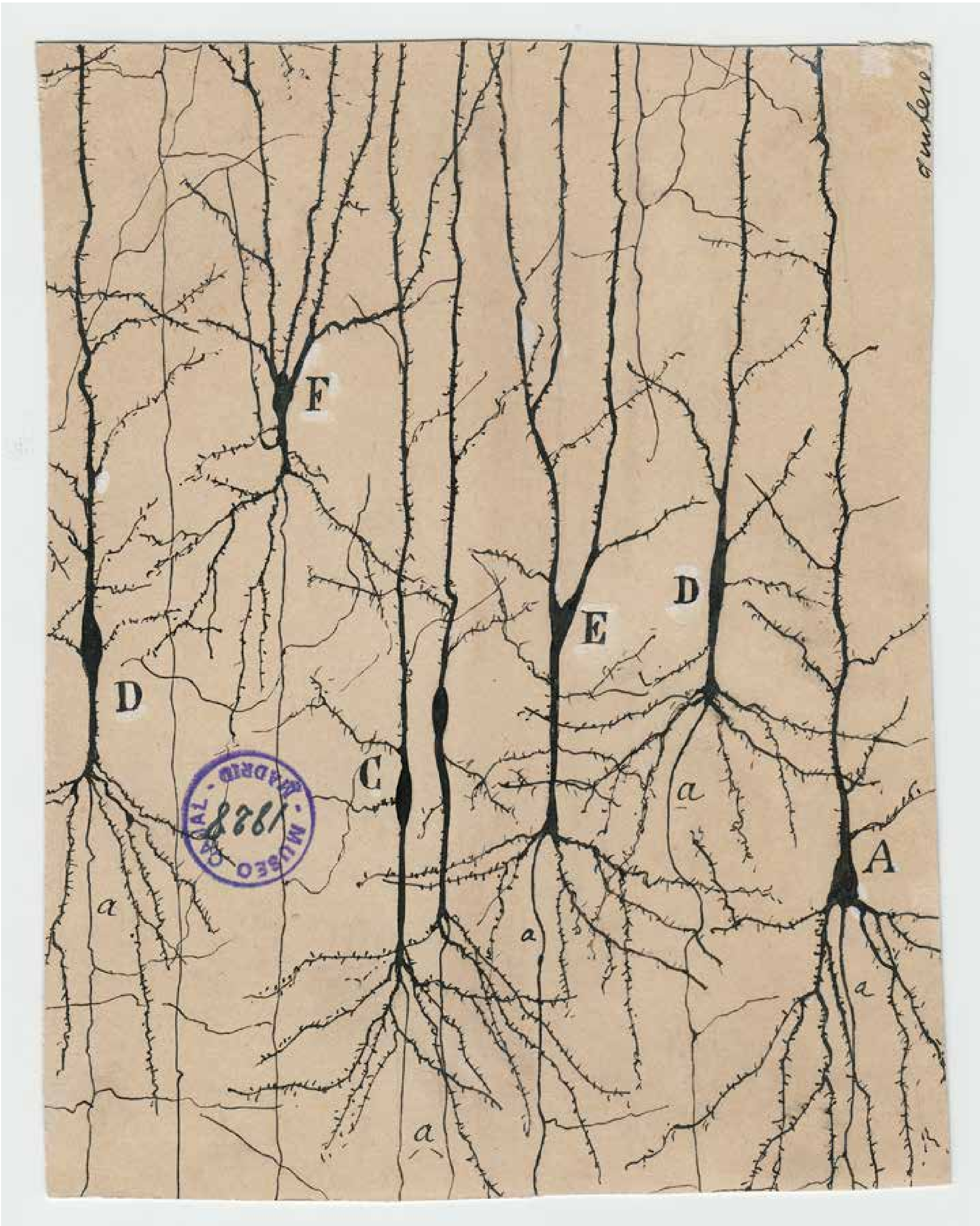
F
E
D
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A
a
MUSEO CAJAL
MADRID
1928

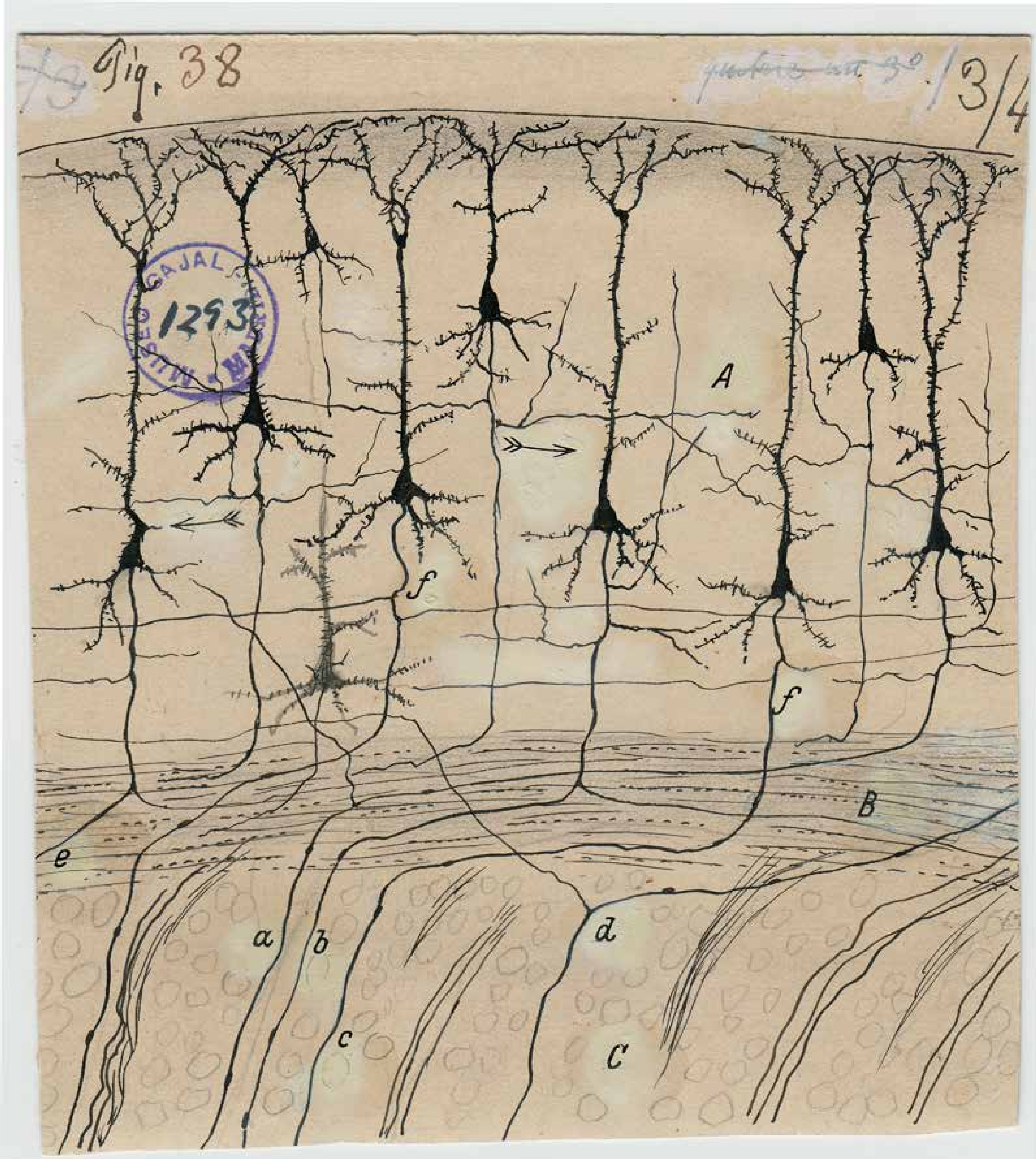

Fig. 38
3/4
CAJAL
1293
A
B
C
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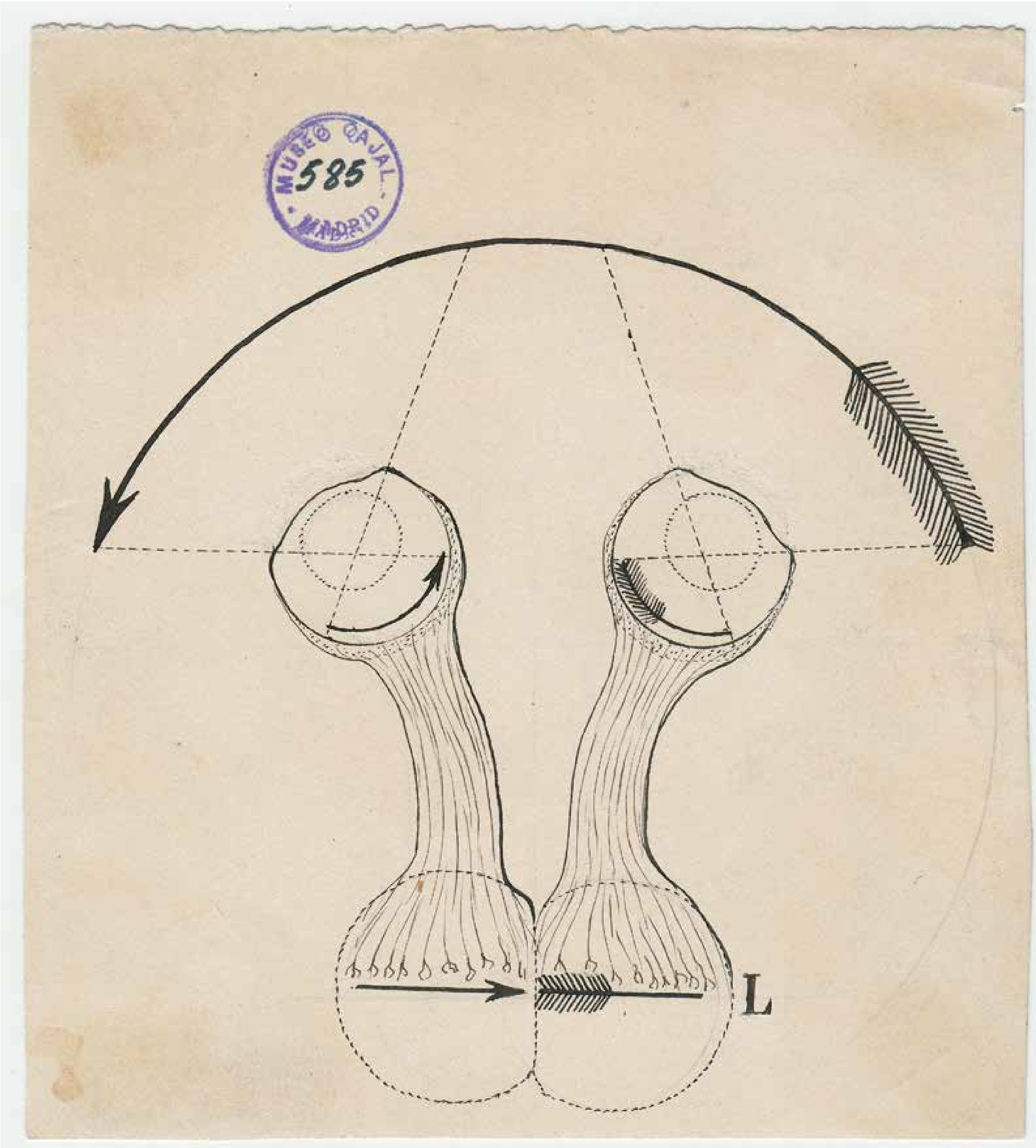
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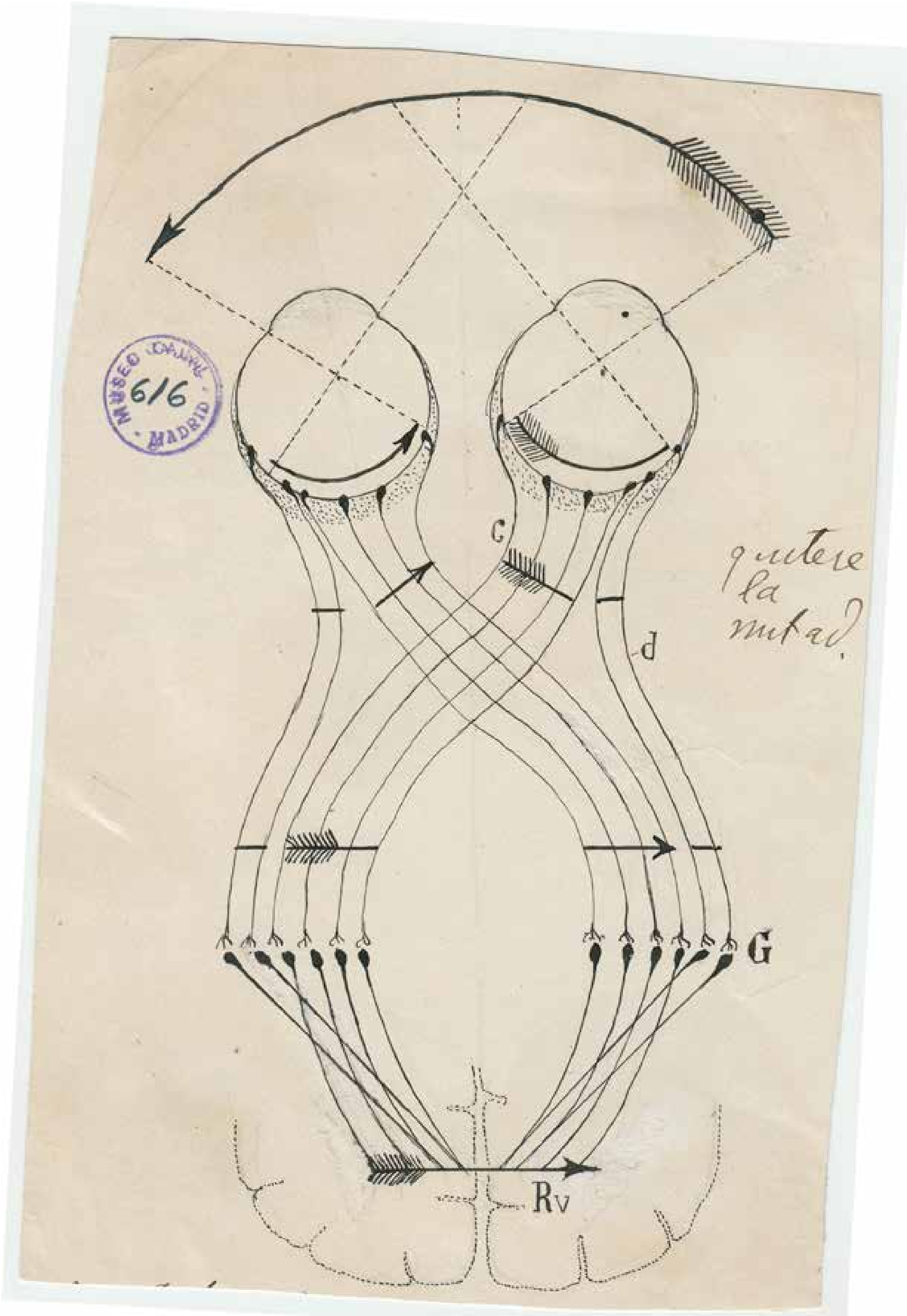
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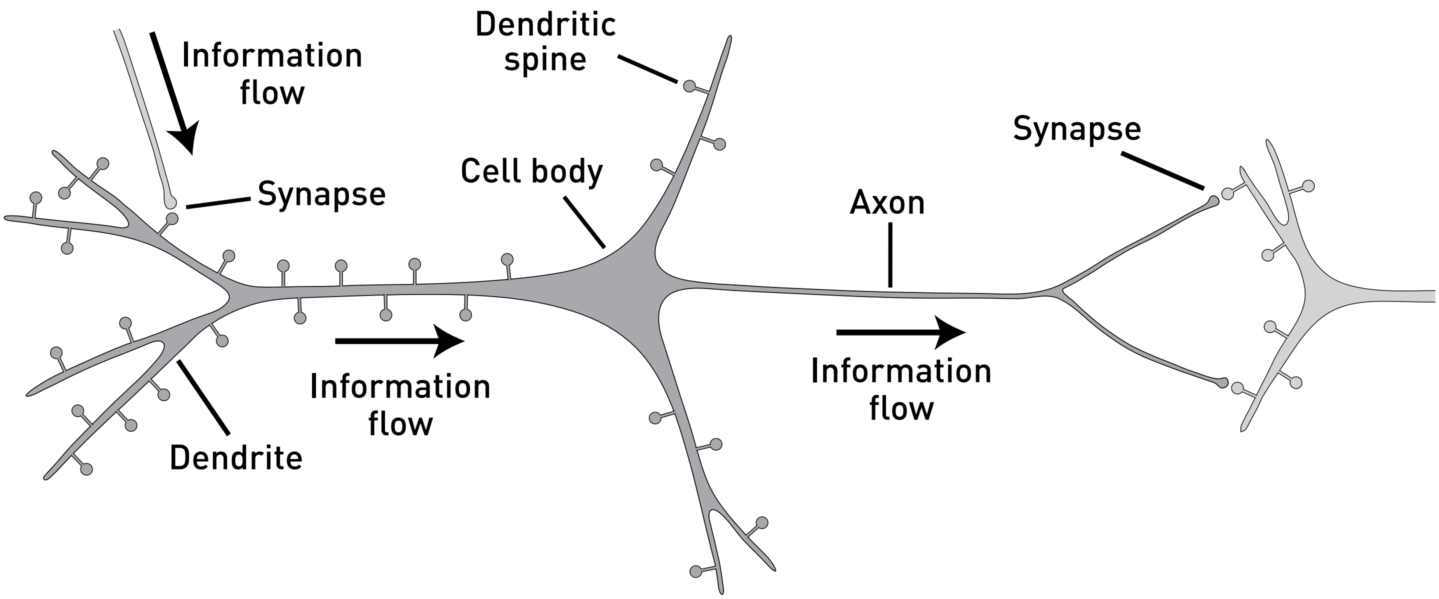
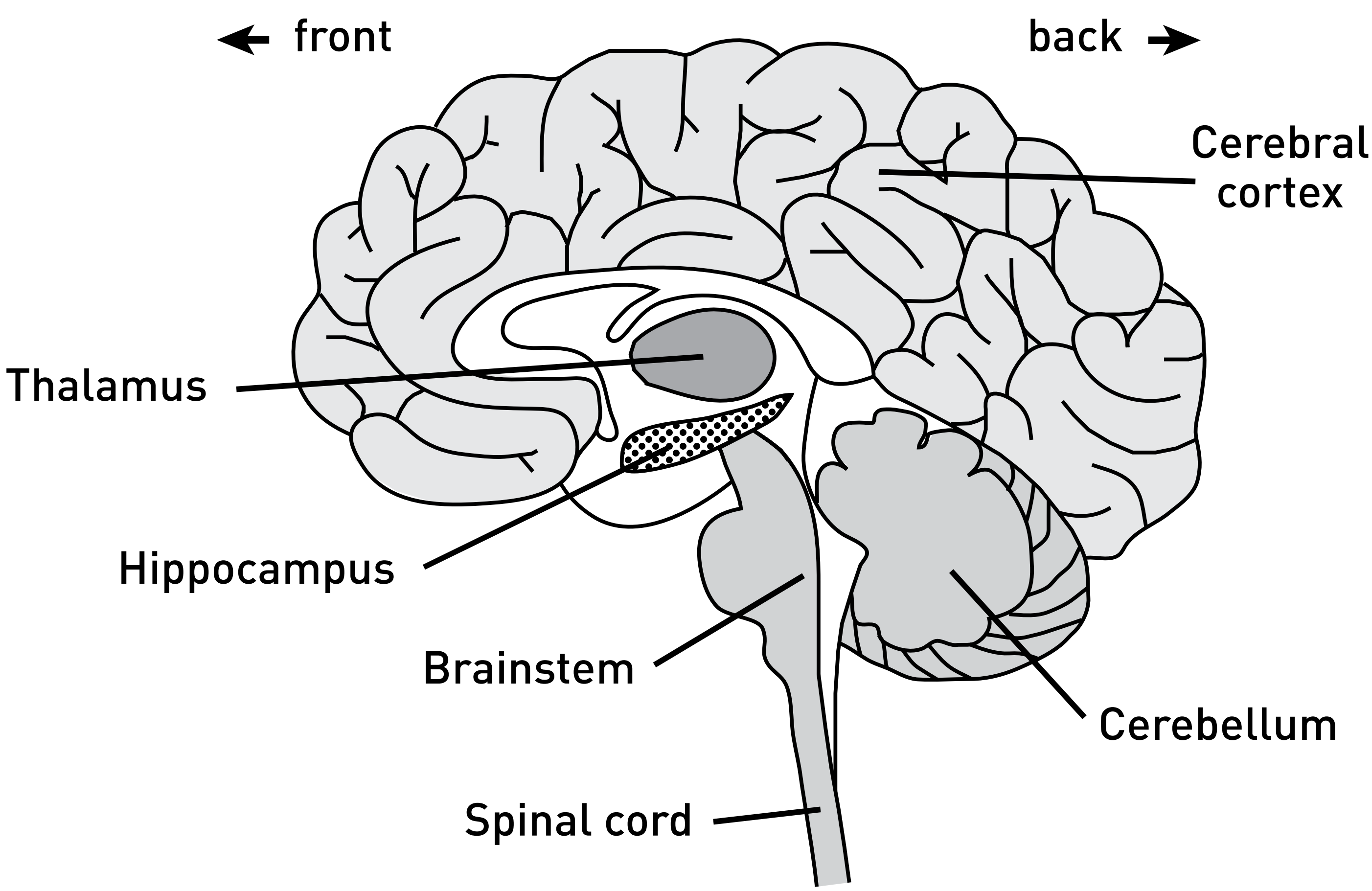

Information
flow
Dendritic
spine
Synapse
Cell body
Axon
Synapse
Information
flow
Dendrite
Information
flow


front
back
Cerebral
cortex
Thalamus
Hippocampus
Brainstem
Cerebellum
Spinal cord

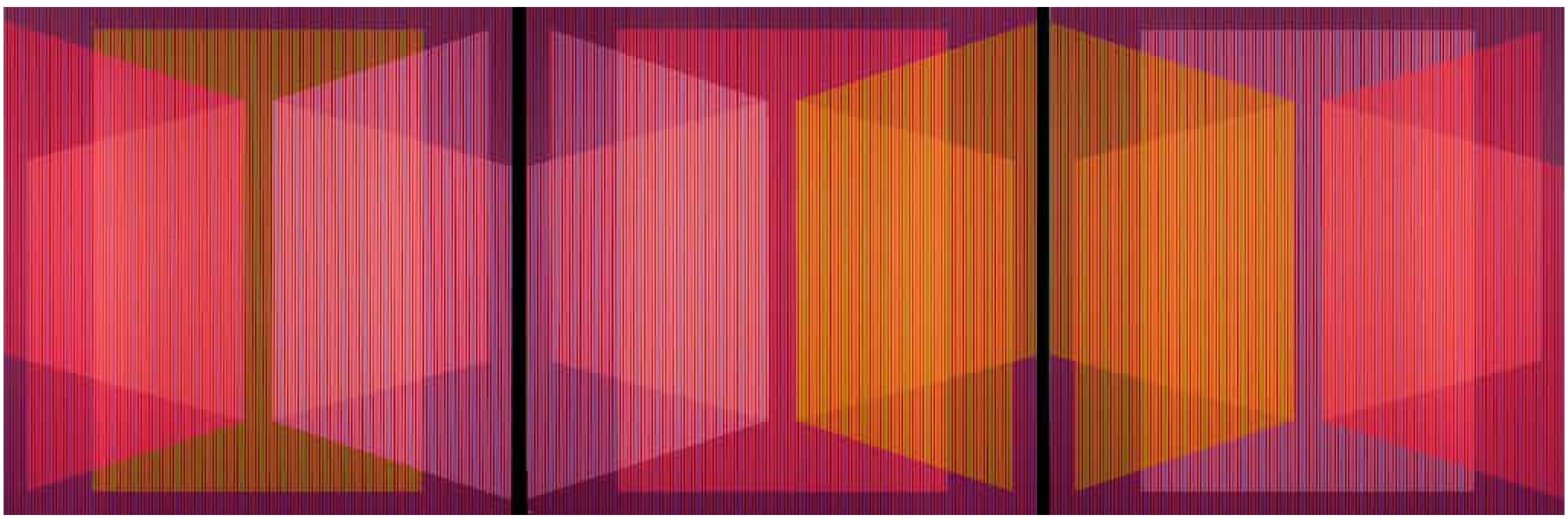


IMAGE INFORMATION

Santiago Ramón y Cajal (Spanish, 1852 – 1934)
the pyramidal neuron of the cerebral cortex
1904
ink and pencil on paper

Pyramidal neurons, which are critical to the function of the cerebral cortex, were characterized in great detail by Cajal. The cerebral cortex receives and processes information from our sense organs, commands motor activity, and is responsible for higher brain functions. The pyramidal neuron derives its name from its pyramid-shaped cell body, the large structure at the center of the cell. Because of their large size, pyramidal neurons are among the few neurons in the brain that can be seen with the naked eye, without the benefit of a microscope. A single pyramidal neuron is illustrated in this iconic image. This drawing illustrates Cajal's fine lines and confident drawing style. Even the tiniest spines on the dendrites are drawn with precision.

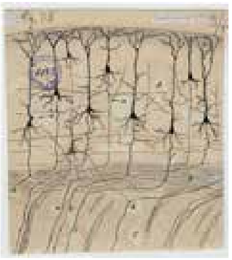
Santiago Ramón y Cajal (Spanish, 1852 – 1934)
a giant pyramidal neuron of the human cerebral cortex
1899
ink and pencil on paper

The pyramidal neuron illustrated here is a giant one. Its cell body lies deep below the surface of the cerebral cortex. Branching upward from its cell body is one set of very long dendrites over a millimeter (about a twenty-fifth of an inch) in length that extend all the way to the surface of the brain (e). Other dendrites (d) surround the cell body. Output signals from the neuron travel from the cell body into the axon (a), which splits into several branches (c). The longest branch of the giant pyramidal axon can travel all the way into the spinal cord.

Santiago Ramón y Cajal (Spanish, 1852 – 1934)
pyramidal neurons of the cerebral cortex
1900
ink and pencil on paper

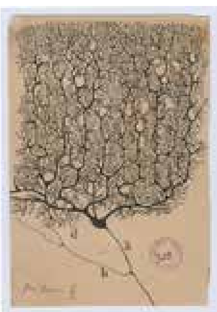
Cajal mused, "The cerebral cortex is similar to a garden filled with innumerable trees, the pyramidal cells, which can multiply their branches thanks to intelligent cultivation, send their roots deeper, and produce more exquisite flowers and fruits every day." This drawing, indeed, resembles a line of trees in a botanical drawing that shows their trunks, branches, and roots.

The profusely branching dendritic trees of pyramidal neurons receive information from many other brain areas. Pyramidal neurons in one region of the cortex control the voluntary movements of our bodies, while those in other areas are involved in cognitive functions such as reasoning and judgment as well as self-awareness.



Santiago Ramón y Cajal (Spanish, 1852 – 1934)
pyramidal neurons of the cerebral cortex and their axon pathways
1935
ink and pencil on paper

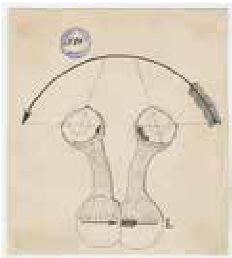
The signals from pyramidal neurons in the cerebral cortex travel to many other parts of the brain and spinal cord. In this drawing of a forest of pyramidal neurons, Cajal shows the pathways followed by the cells' axons, their output appendages. The axons extend downward from the neurons' cell bodies and branch into several daughter axons. Some of these axon branches stay within the cerebral cortex, sending information to other neurons in adjacent areas (indicated by arrows in layer A). Other axon branches travel deeper below the brain surface (a, b, c, and d in layer C), sending information to distant parts of the brain.



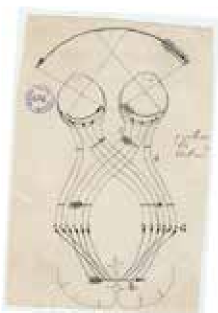
Santiago Ramón y Cajal (Spanish, 1852 – 1934)
a purkinje neuron from the human cerebellum
1899
ink and pencil on paper

Cajal mused in his autobiography, "In our parks are there any trees more elegant and luxurious than the Purkinje cell from the cerebellum . . . ?" In a different context, this drawing could be an abstract representation of a large tree.

Cajal studied and drew Purkinje neurons in great detail. These neurons are located in the cerebellum, a structure at the back of the brain that lies underneath the cerebral cortex and facilitates fine control of our movements. Purkinje neurons have an incredibly elaborate dendritic tree structure, making them among the most recognizable neurons in the brain. Their dendritic trees spread out in two dimensions, like a handheld fan.

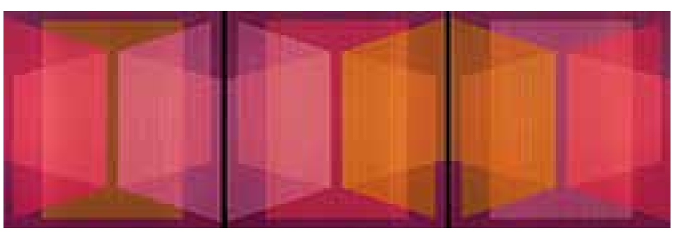


Santiago Ramón y Cajal (Spanish, 1852 – 1934)
diagram indicating how information from the eyes might be transmitted to the brain
1898
ink and pencil on paper



Santiago Ramón y Cajal (Spanish, 1852 – 1934)
diagram indicating how information from the eyes might be transmitted to the brain
1898
ink and pencil on paper

It was well known in Cajal's time that much of the information from the right eye traveled to the left side of the brain and vice versa. Cajal puzzled over why this was true in all animals. He imagined our two eyes looking at an arrow, as illustrated in the left-hand drawing. He reasoned that if information from the two eyes did not cross as it traveled to the brain, then a unified representation of the visual world could not be created in the brain (arrow L). On the other hand, if information from the eyes did cross, as illustrated in the right-hand drawing, a unified representation would result (arrow Rv).



Julian Stanczak (American, born Poland, 1928)
Forming in Four Reds, 1993–1994
acrylic on canvas
Gift of Neil K. Rector

In this painting Stanczak focused on the movement and rhythm of vertical lines. The term Op Art was first used to describe Stanczak's 1964 exhibition in New York, spurring a movement of "optical art" that makes use of visual illusions. Stanczak's talent for layering patterns and interacting contrasting colors is shown here, creating a dizzying effect of vibrating shapes.

Originally commissioned by Case Western Reserve University in Cleveland, Ohio, where the artist presently resides, this painting exhibits Stanczak's focus on movement and rhythm of vertical lines during the 1990's. He is widely known as a painter of geometric abstraction, and he studied under Josef Albers at the Yale University School of Art and Architecture where he received his Master of Fine Arts degree in 1956.
http://www.julianstanczak.net/