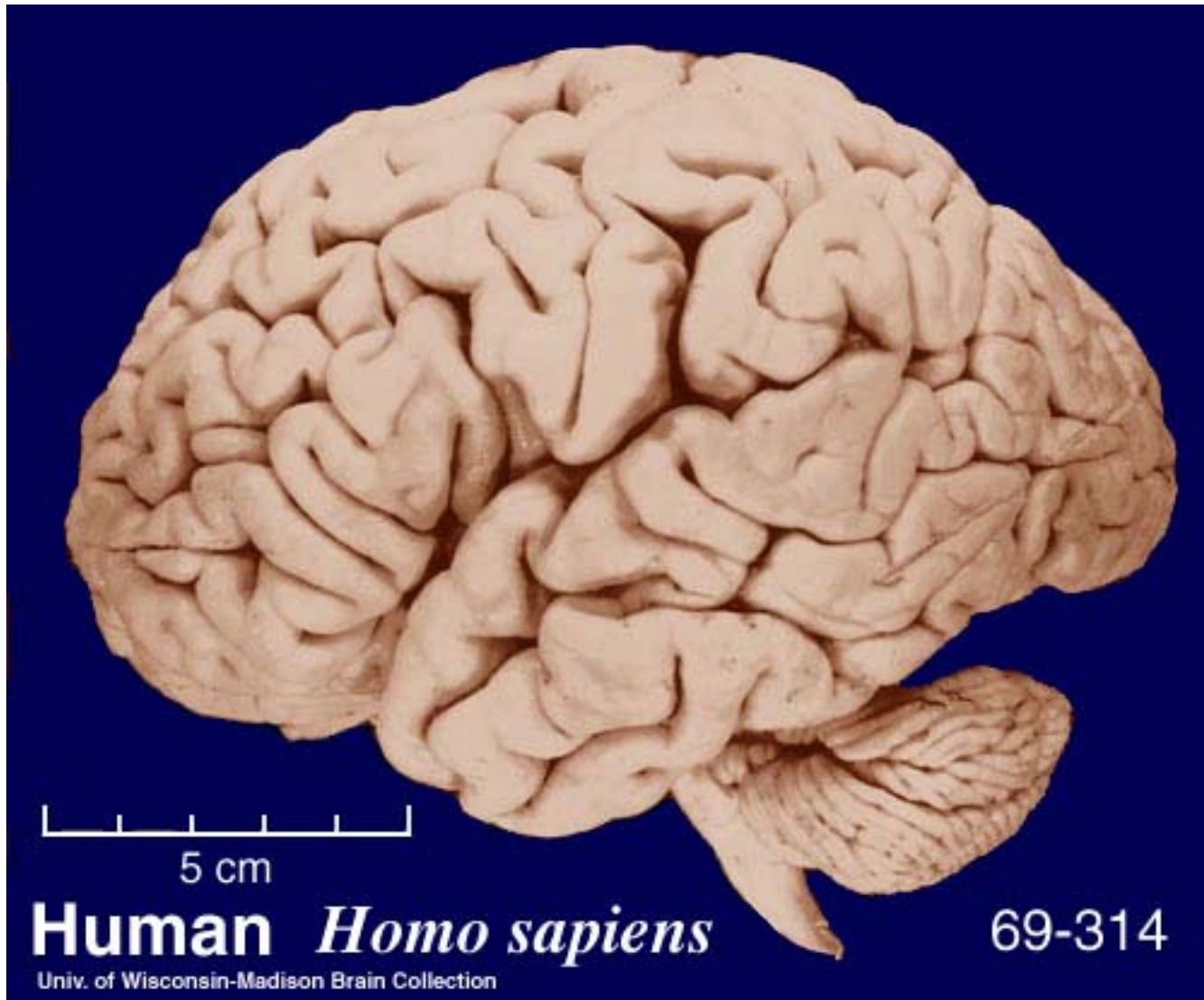
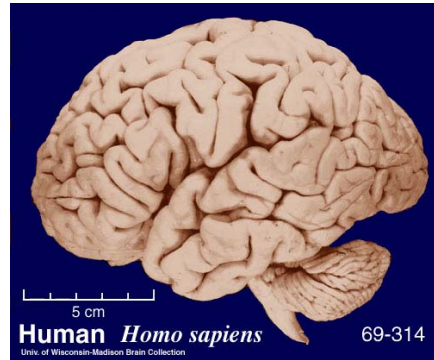


9.00 The Brain



Professor John Gabrieli

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Human Brain

neurons

gross anatomy

Localization of mental functions in human brain

phrenology

Phineas Gage, moral behavior, orbitofrontal cortex

Broca, Tan, and left lateralization of language

Hemispheric Specialization - parallel processing

appearance (right) vs. function (left)

global (right) vs. local (left)

BRAIN & MIND

Plato

rational soul in brain - part of the mind
nearest to the heavens

Aristotle

warm and active heart houses the mind
cool and inert brain cools the blood

Galen

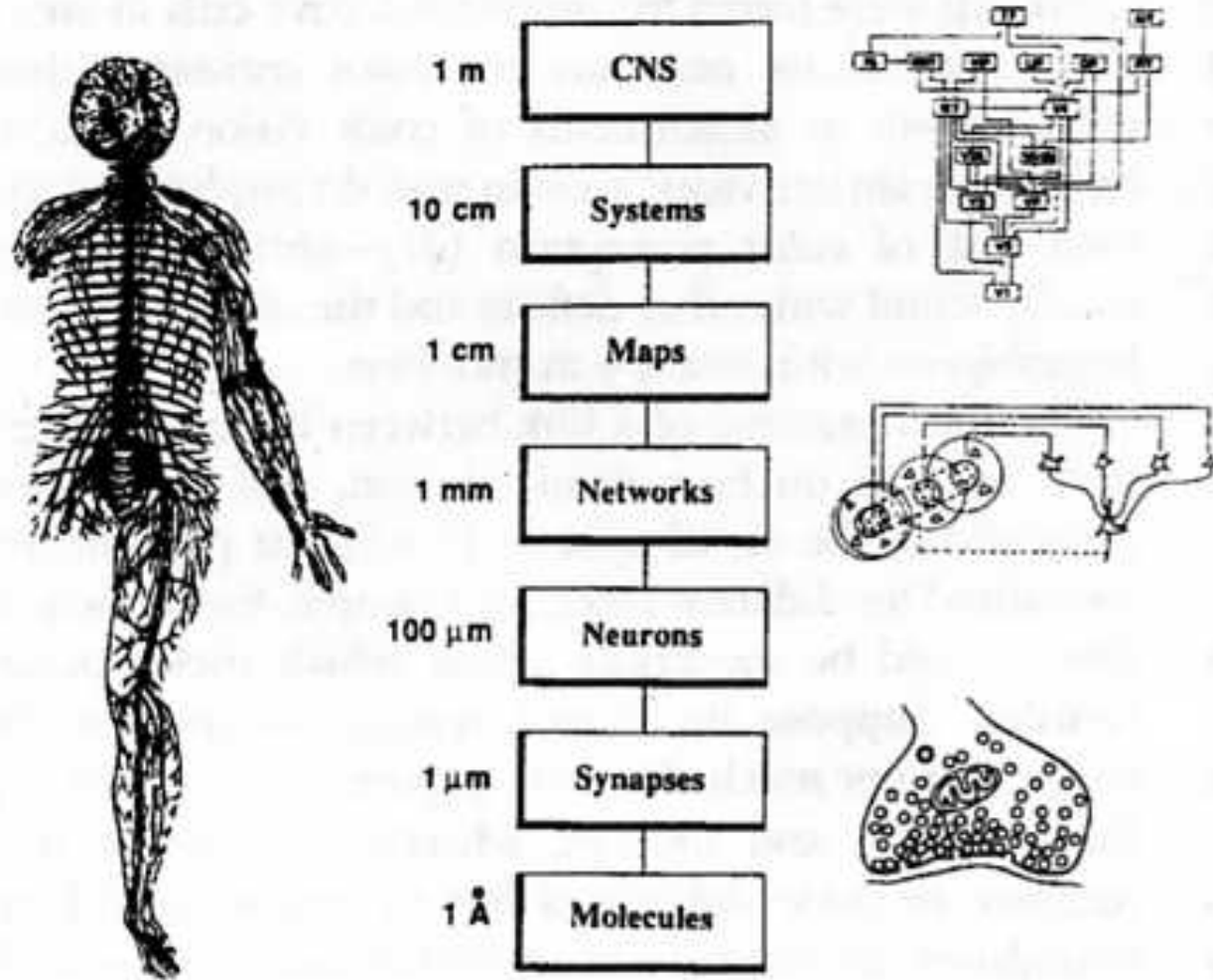
brain - mind in fluid filled ventricles

Descartes

pineal body - not composed of two
symmetric halves, near ventricles

Levels of Analysis

Molecules/Synapses/Neurons/Networks/ Maps/Systems/CNS



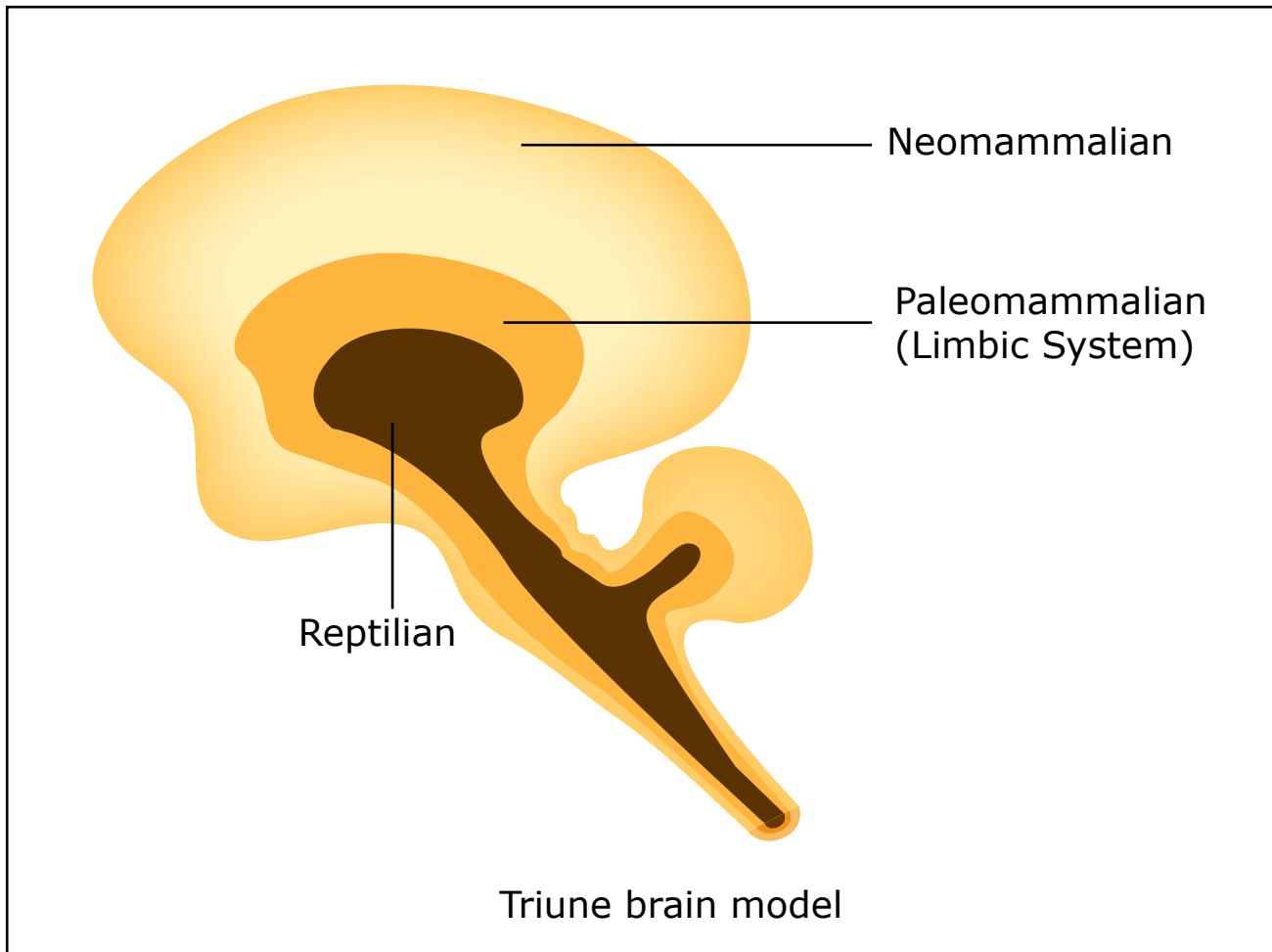


Image by MIT OpenCourseWare.

THE BRAIN

Neuronal Computational Elements

1. glia & neurons

2. neuron

- • soma = cell body = grey matter
- • axon = output = white matter
- • dendrite = input
- • synapses & neurotransmitters
- • collection of cell bodies = nucleus
- • collection of axons = tract

THE BRAIN (cont'd)

- 3. CNS has about 1,000,000,000,000 neurons & 1,000,000,000,000,000 synapses; 62,000 miles of myelinated axons; 100,000 miles of dendrites**
- 4. up to 15,000 connections per cell**
 - average neuron may have about 1,000 synapses**
 - average axon may synapse on about 1,000 neurons**
- 5. each of the 100 billion neurons may have the processing capacity of a medium-sized computer - computes about 1000 multiplications and additions every 10 msec**
- 6. time for information to go from one neuron to another about 10 msec - slower than millions of operations per second by fast computers - but billions of such neuronal computers yields massively parallel processing in the brain**

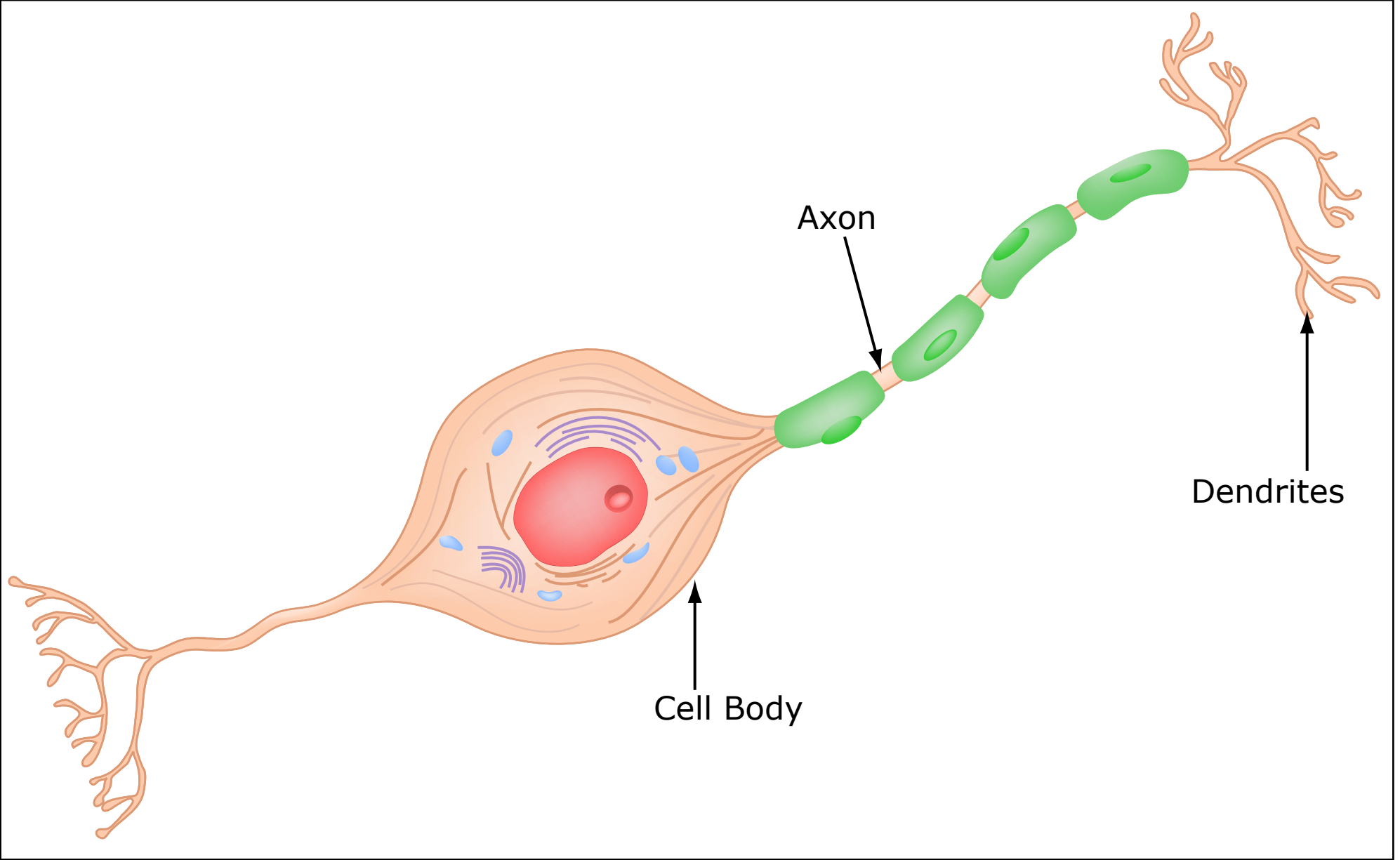


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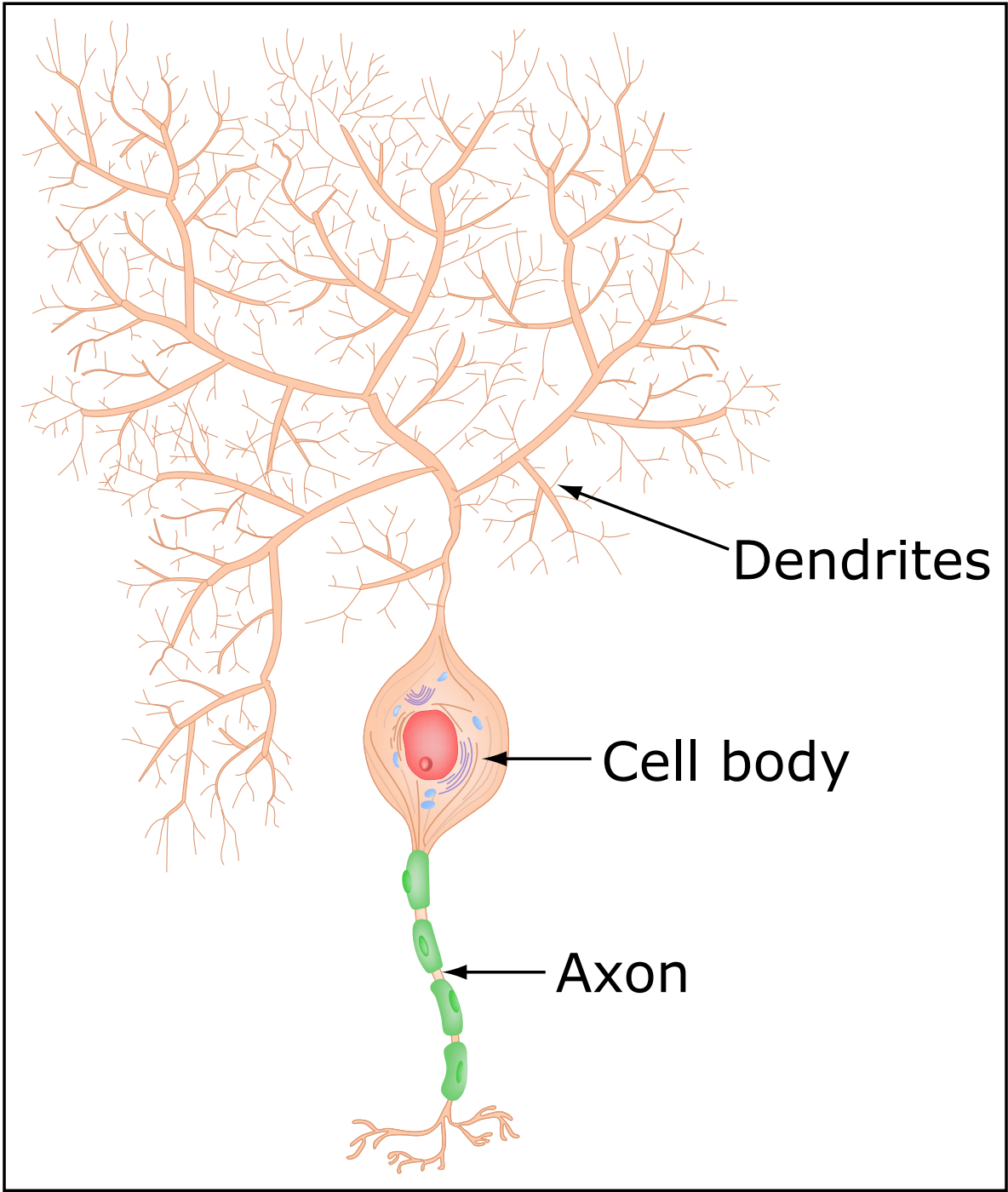
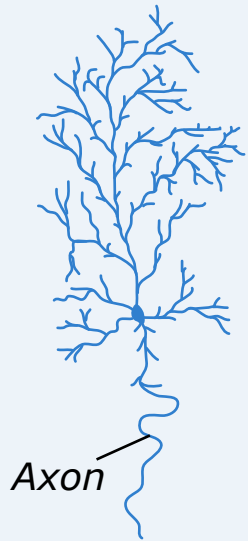
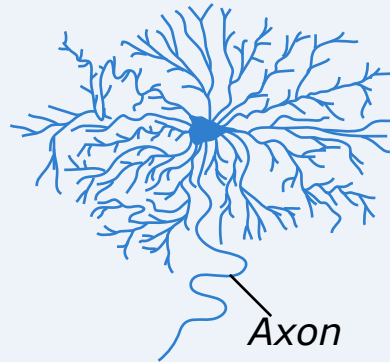
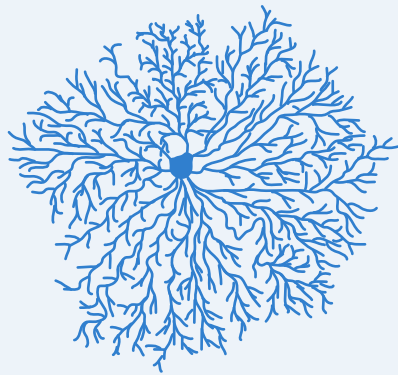


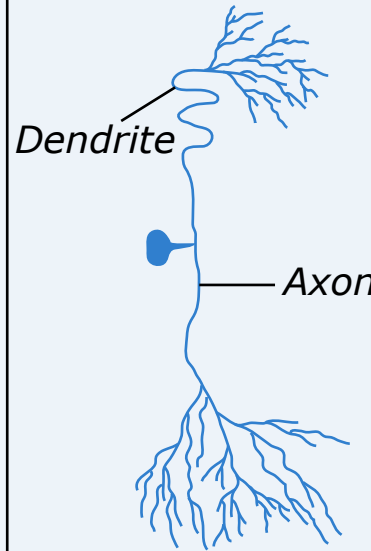
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Axon

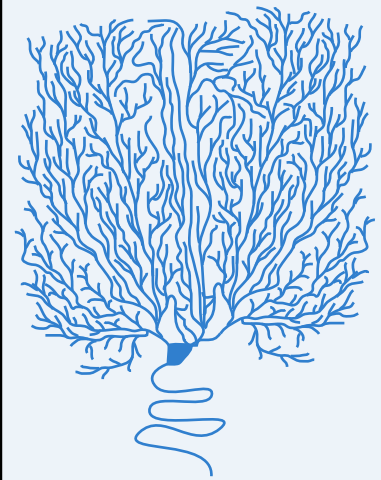


Axon



Dendrite

Axon



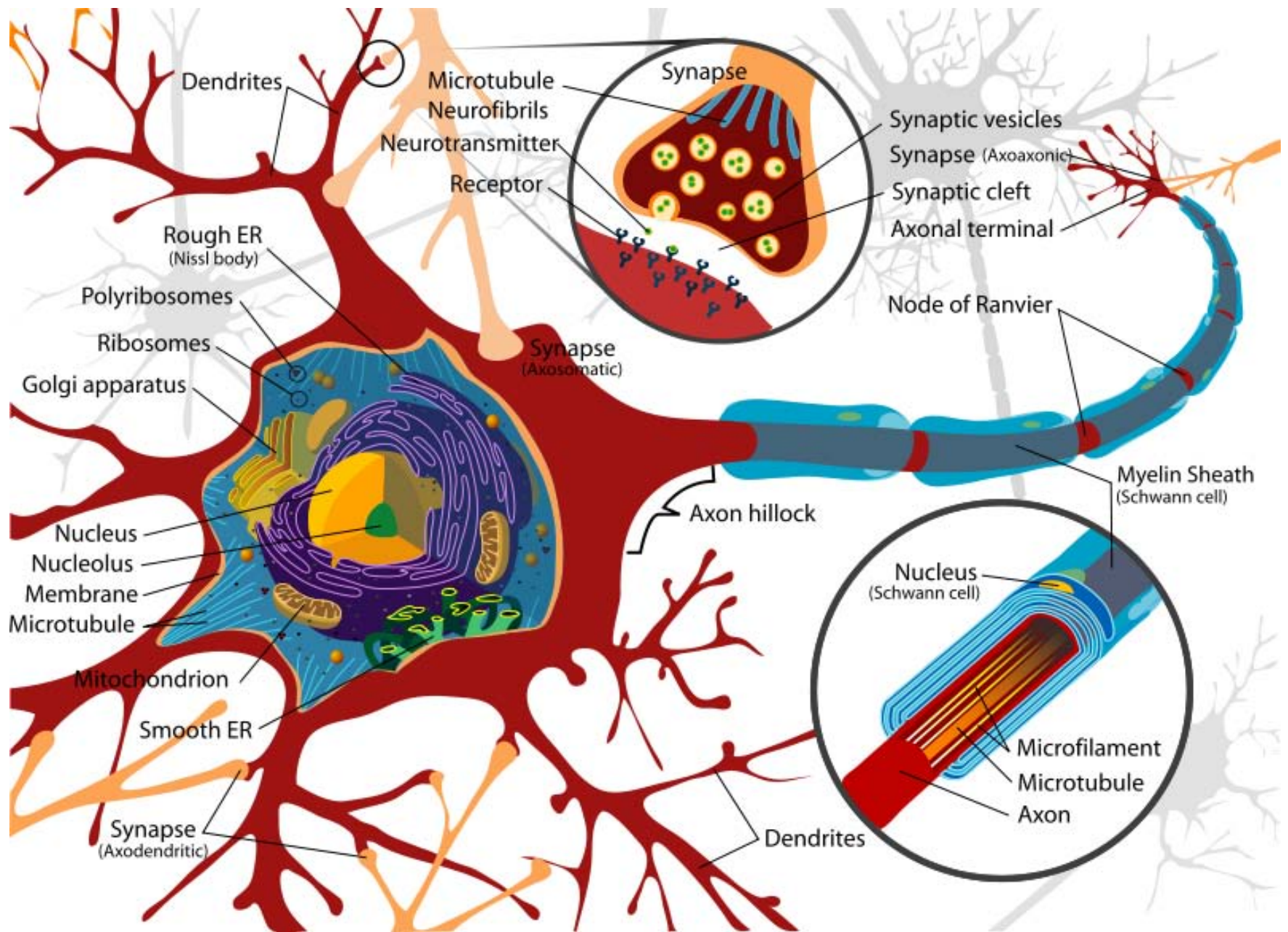
**Pyramidal Cell
(Cortex)**

**Association cell
(Thalamus)**

**Motor Neuron
(Spinal Cord)**

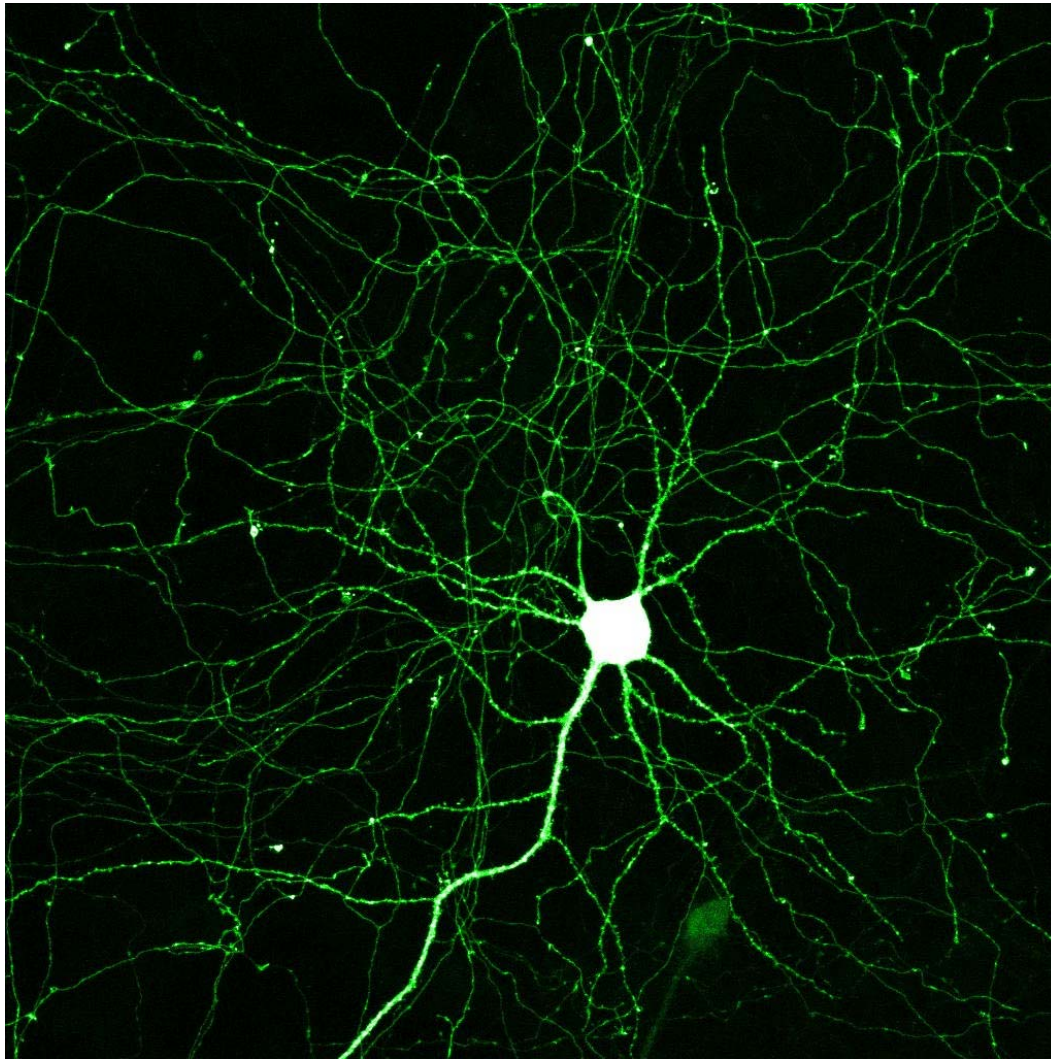
**Somatosensory Cell
(Skin)**

**Purkinje Cell
(Cerebellum)**



Public domain image.

Neuron



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Synapse

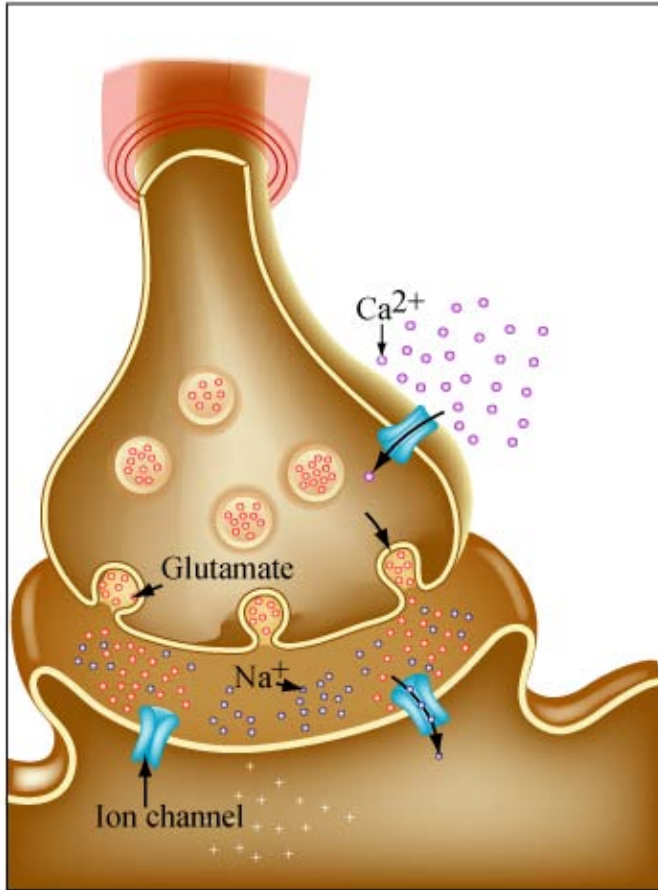
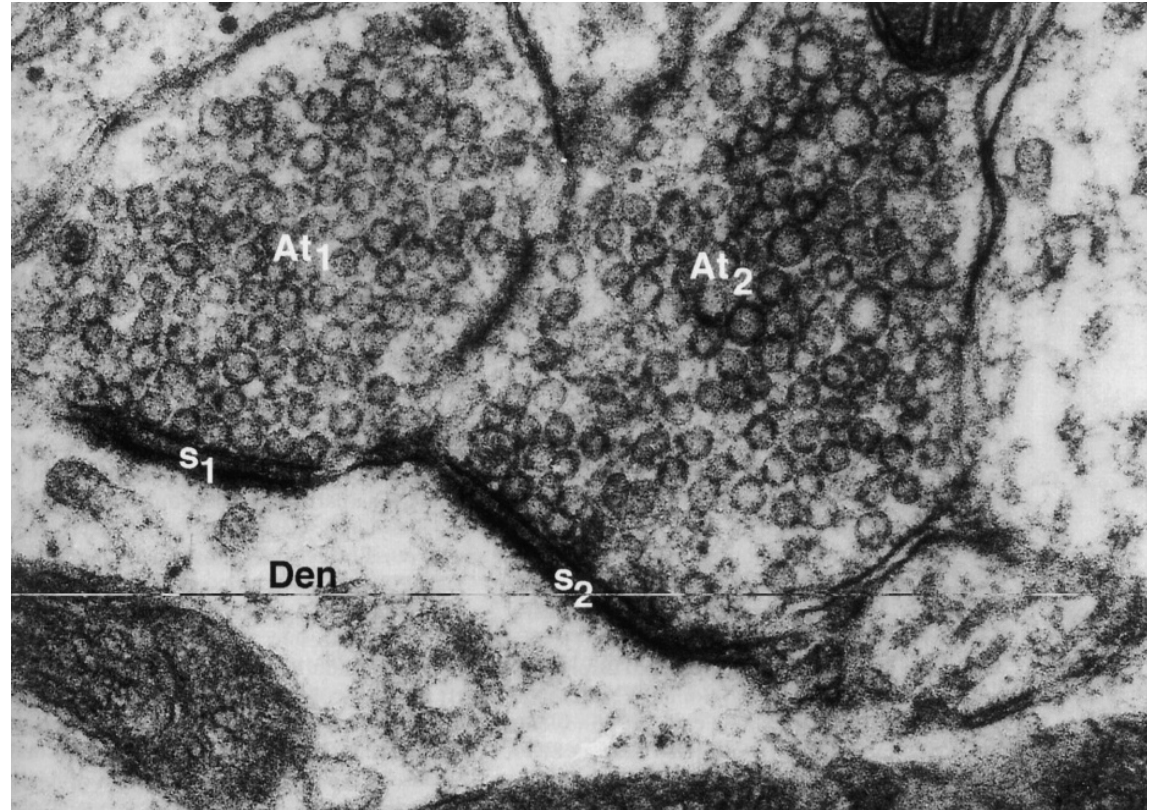
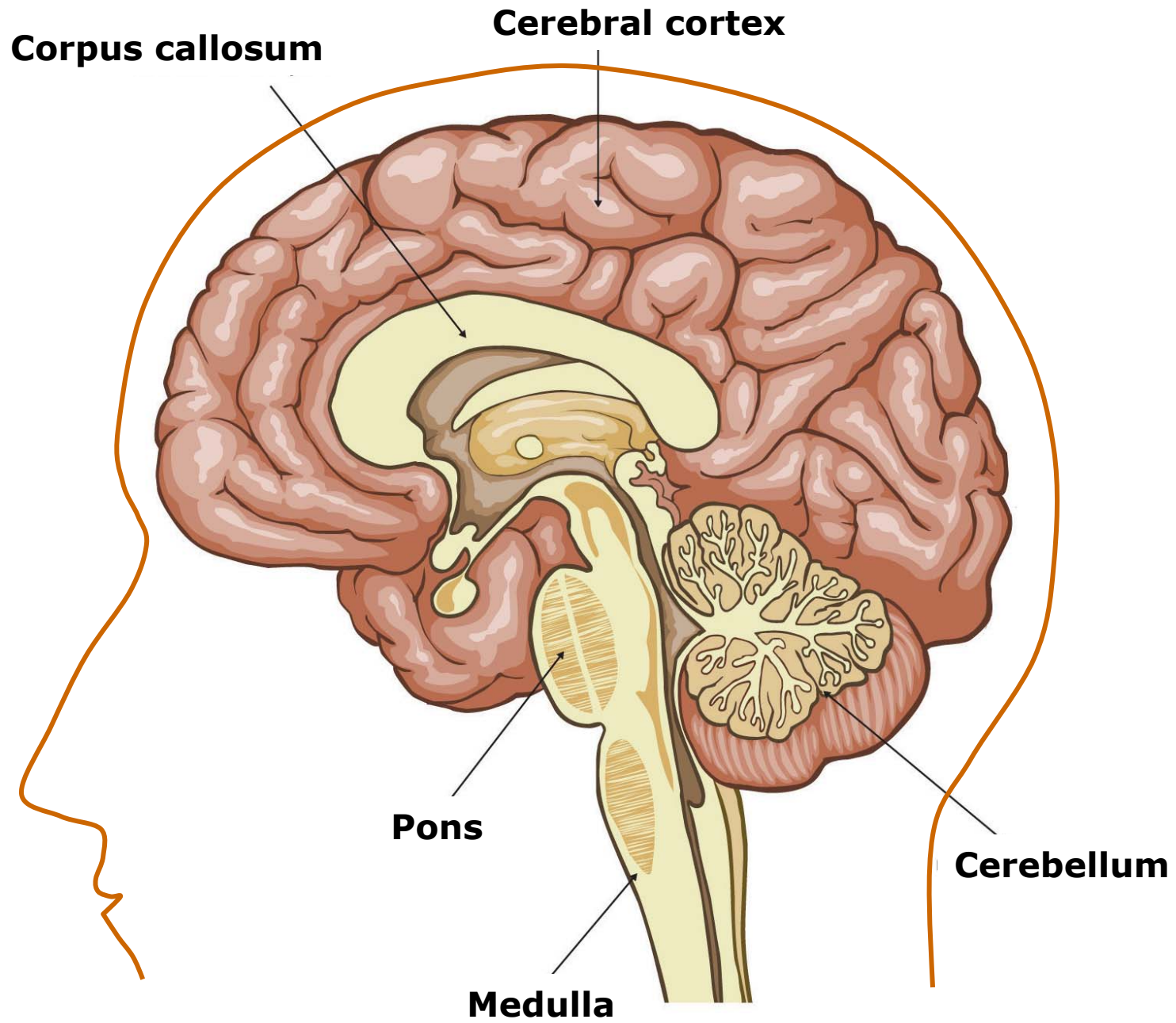


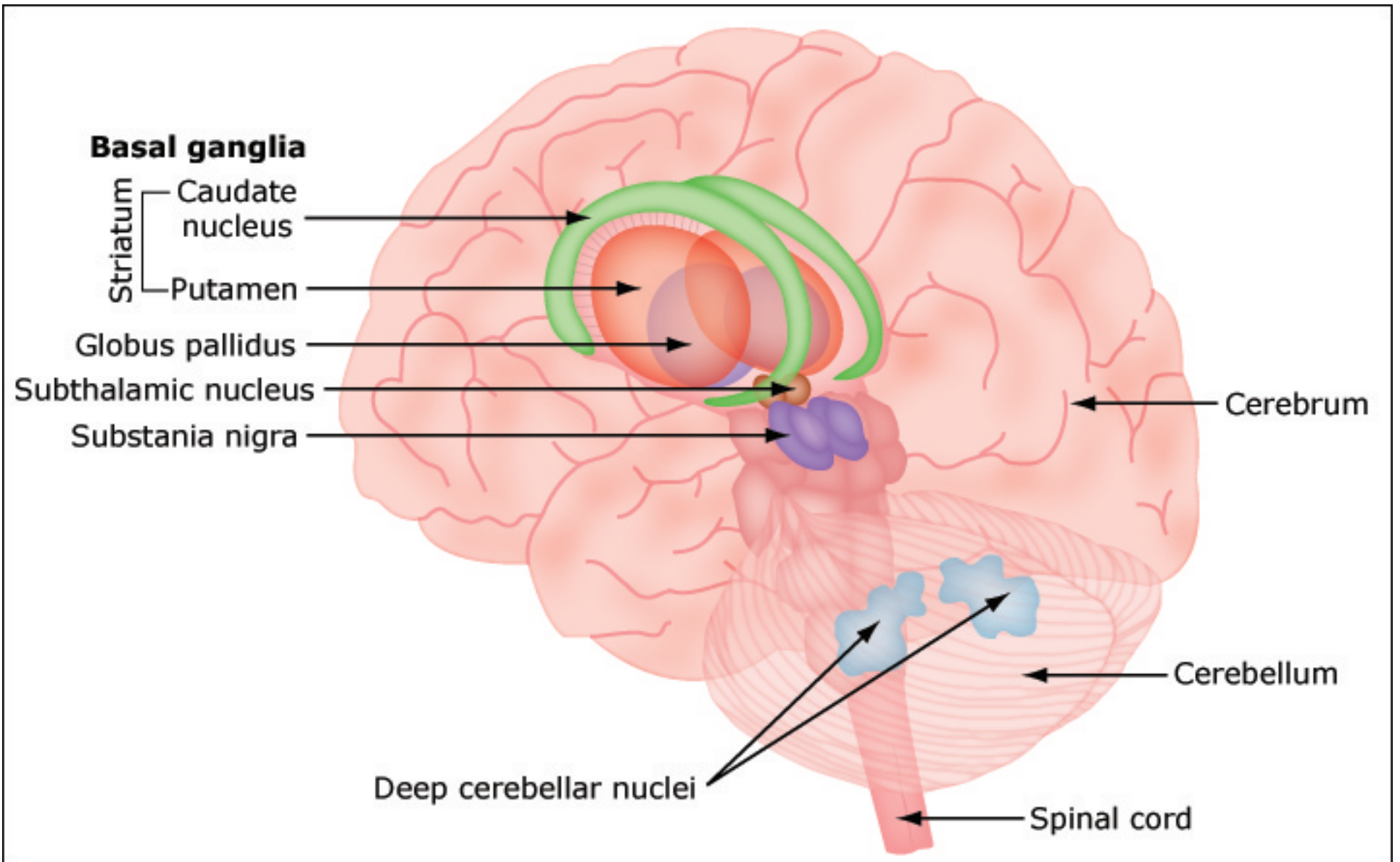
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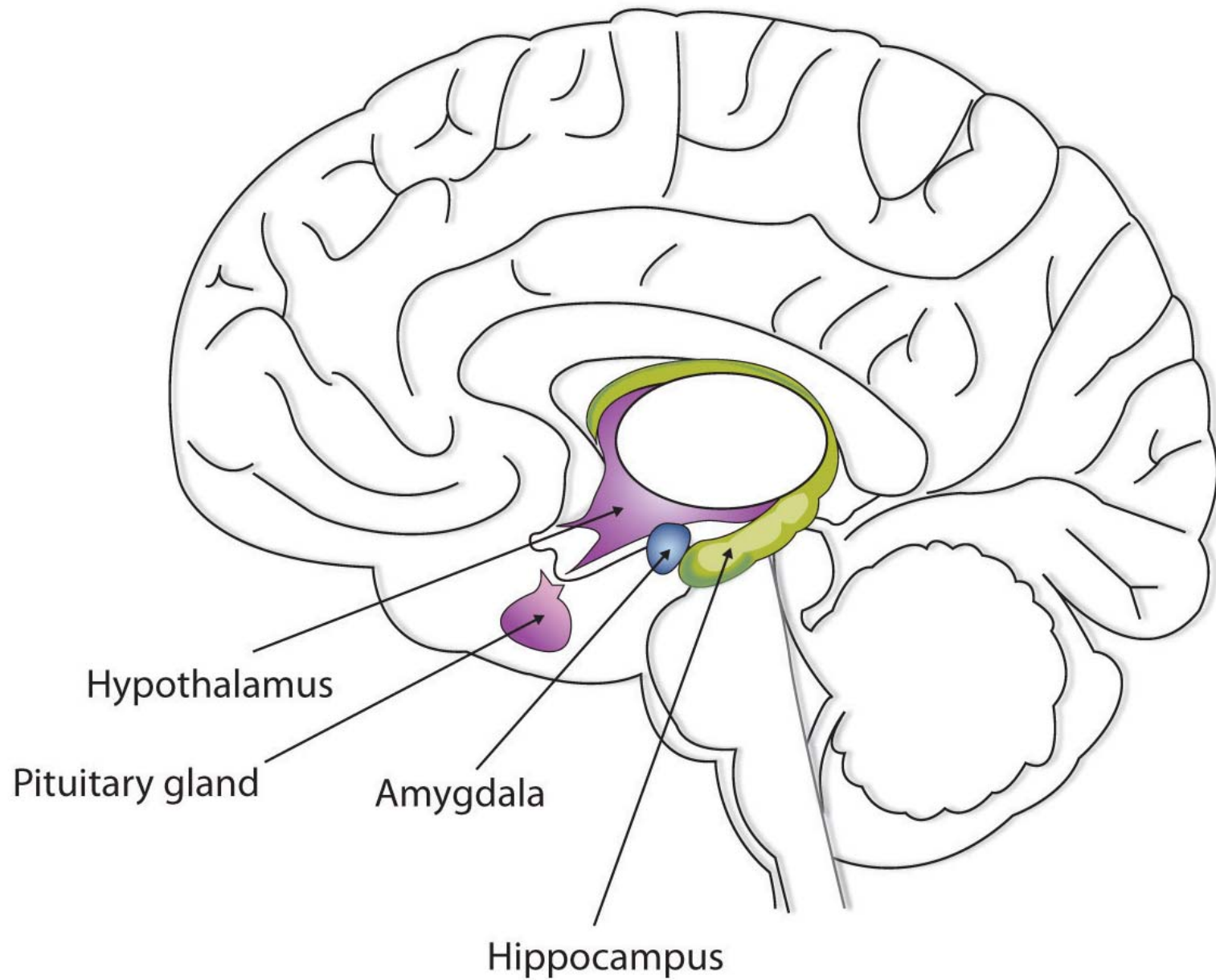


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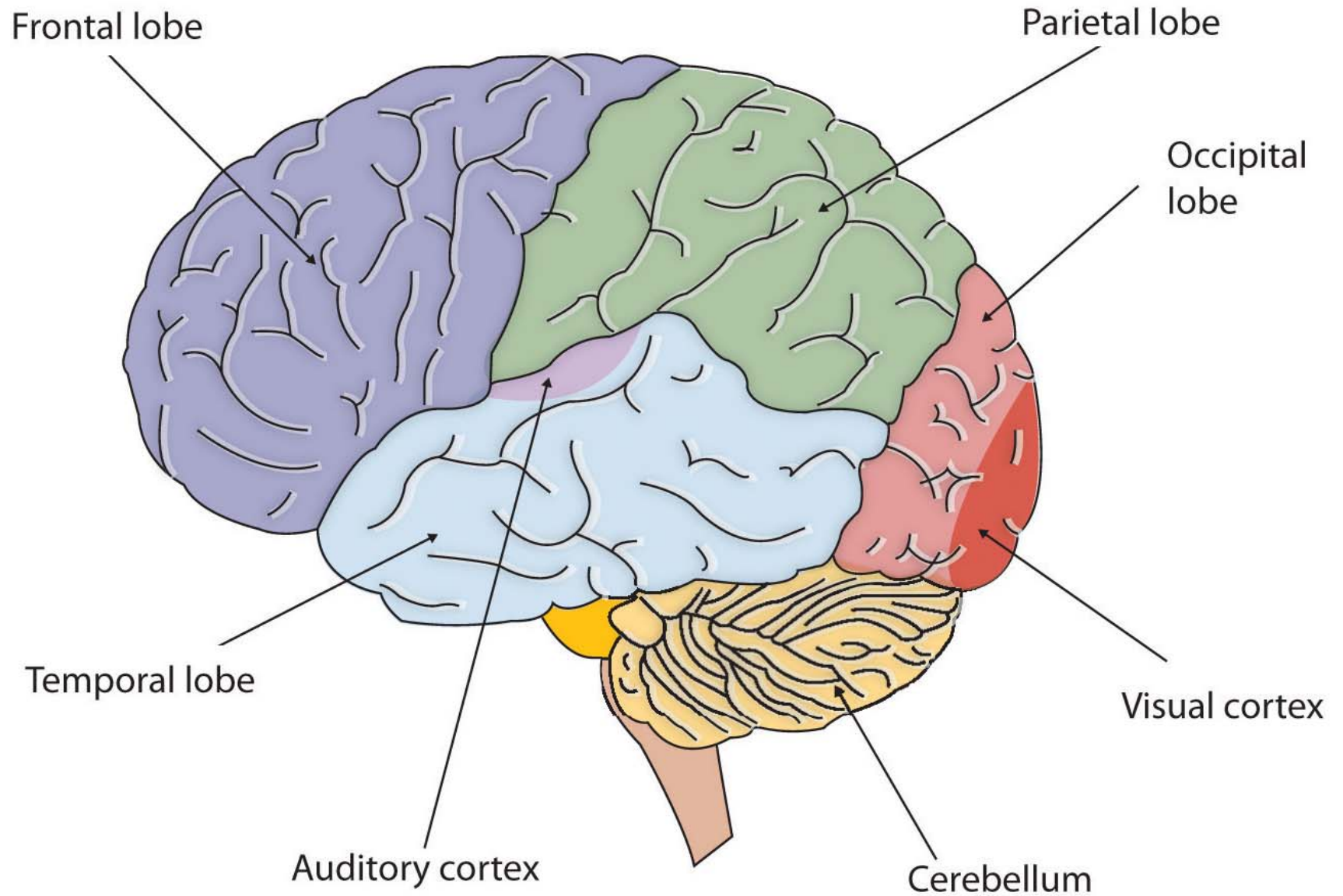


Adapted from Stangor, C. *Introduction to Psychology*. Flatworld Knowledge, 2010. Courtesy of Flatworld Knowledge.



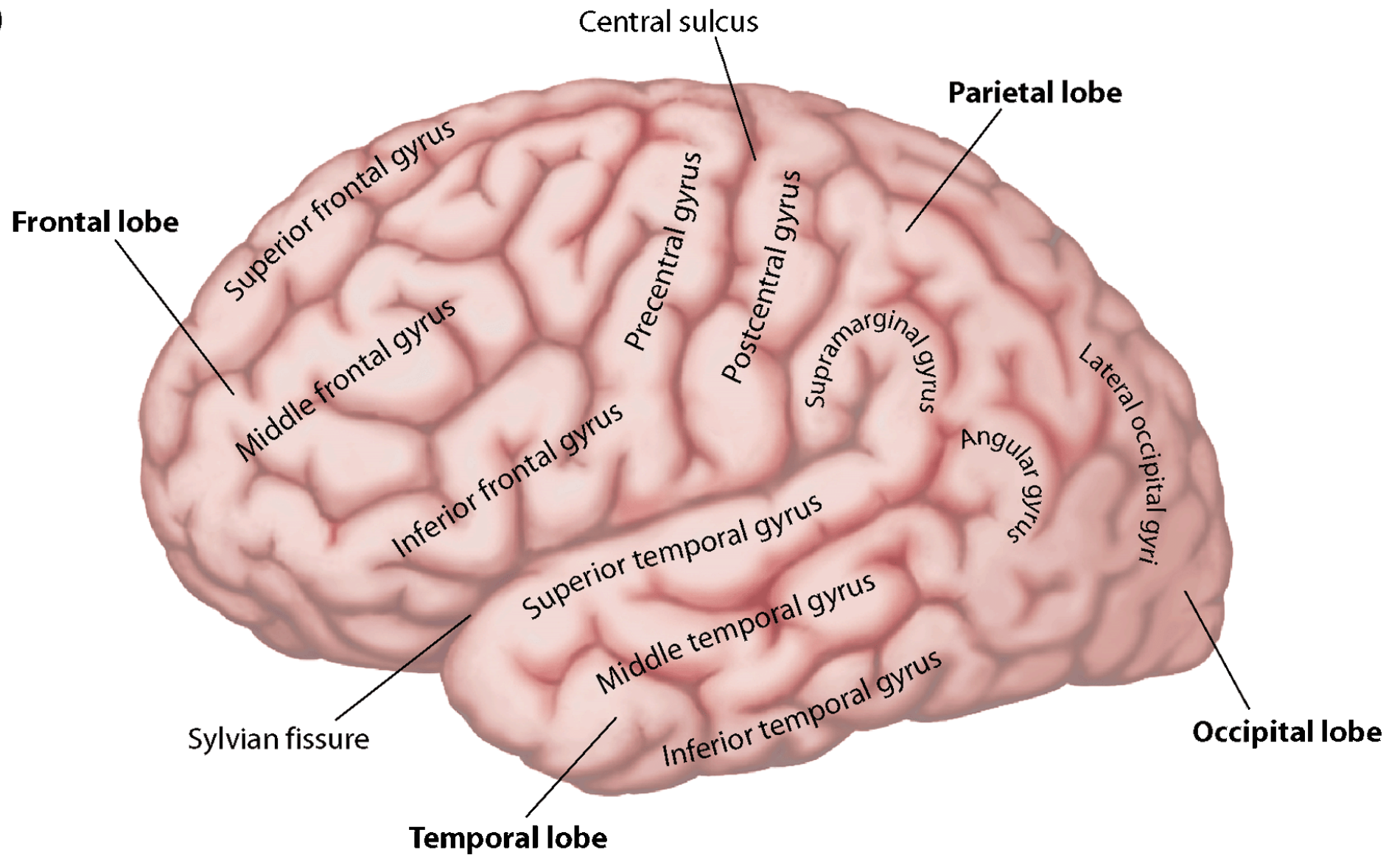


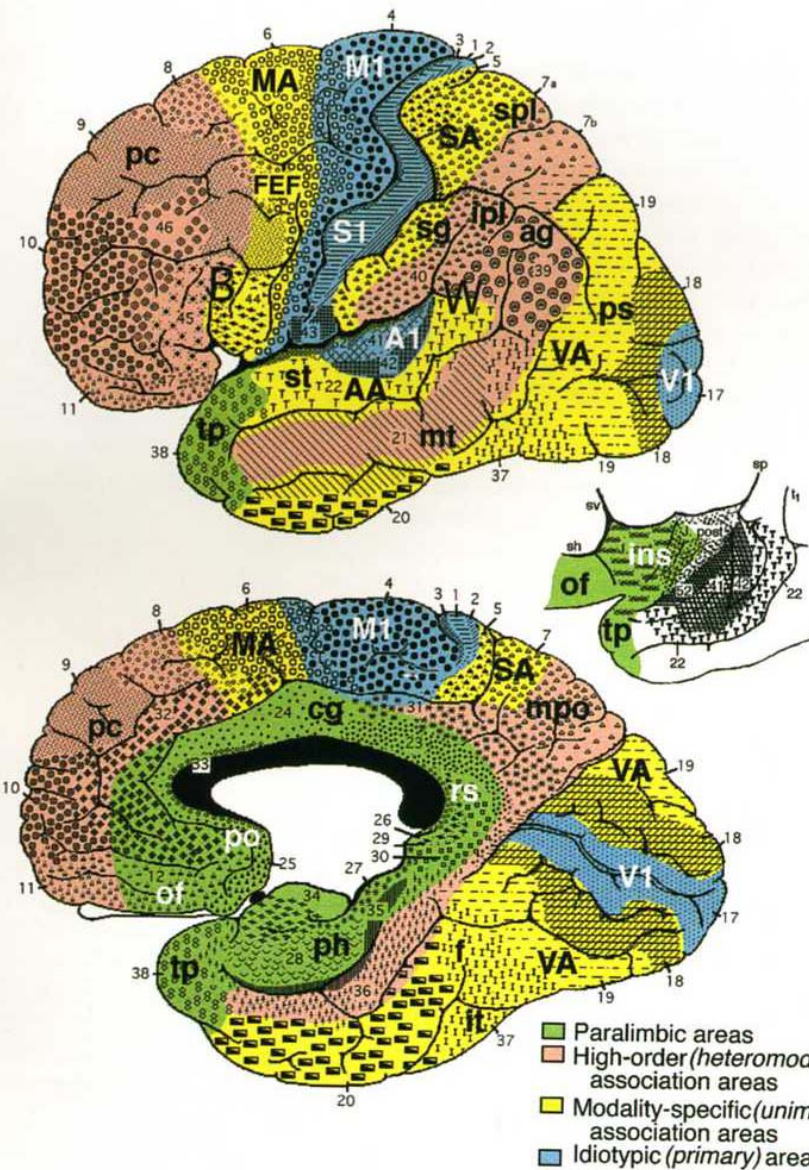
Source: Stangor, C. *Introduction to Psychology*. Flatworld Knowledge, 2010. Courtesy of Flatworld Knowledge.



Adapted from Stangor, C. *Introduction to Psychology*. Flatworld Knowledge, 2010. Courtesy of Flatworld Knowledge.

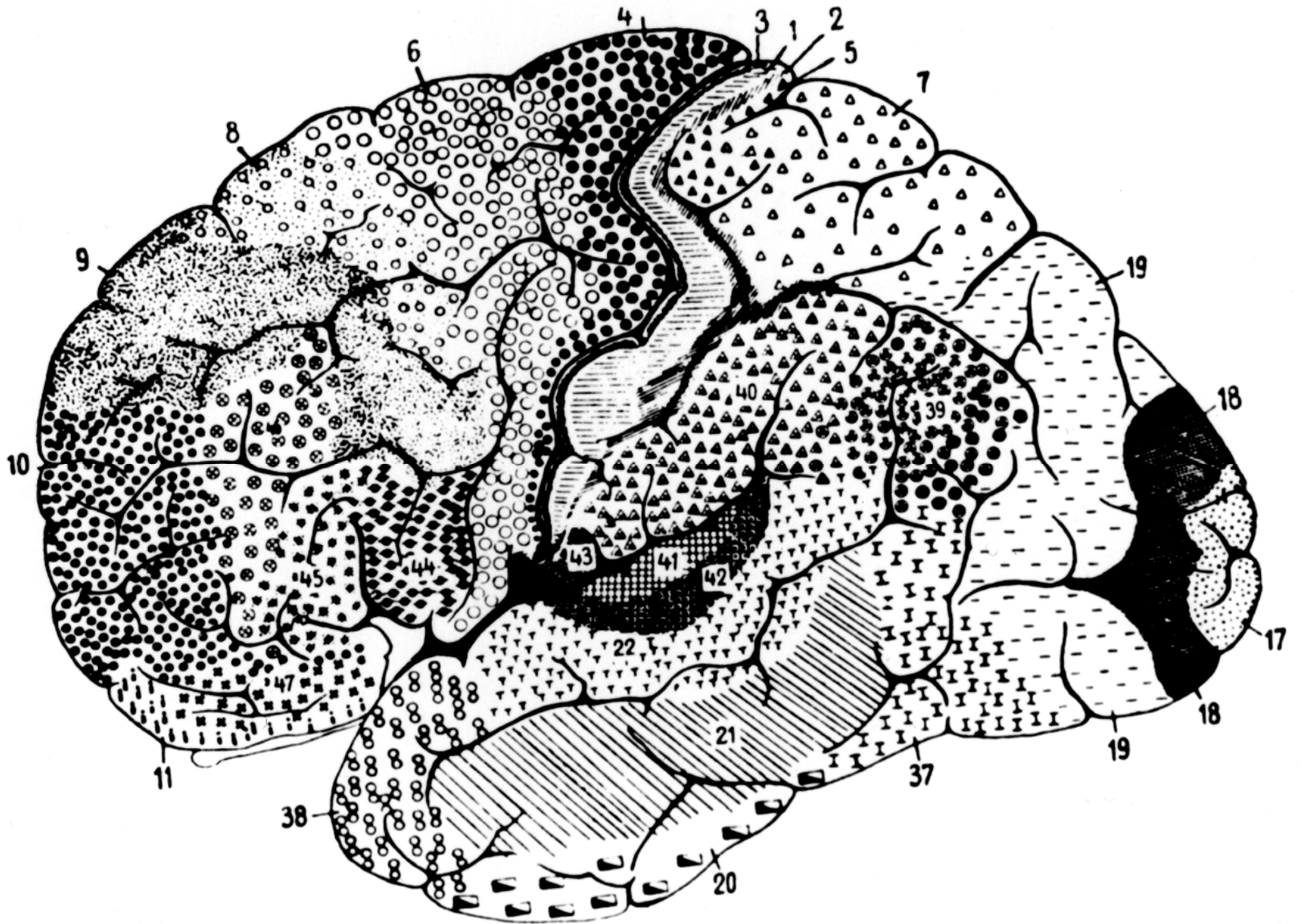
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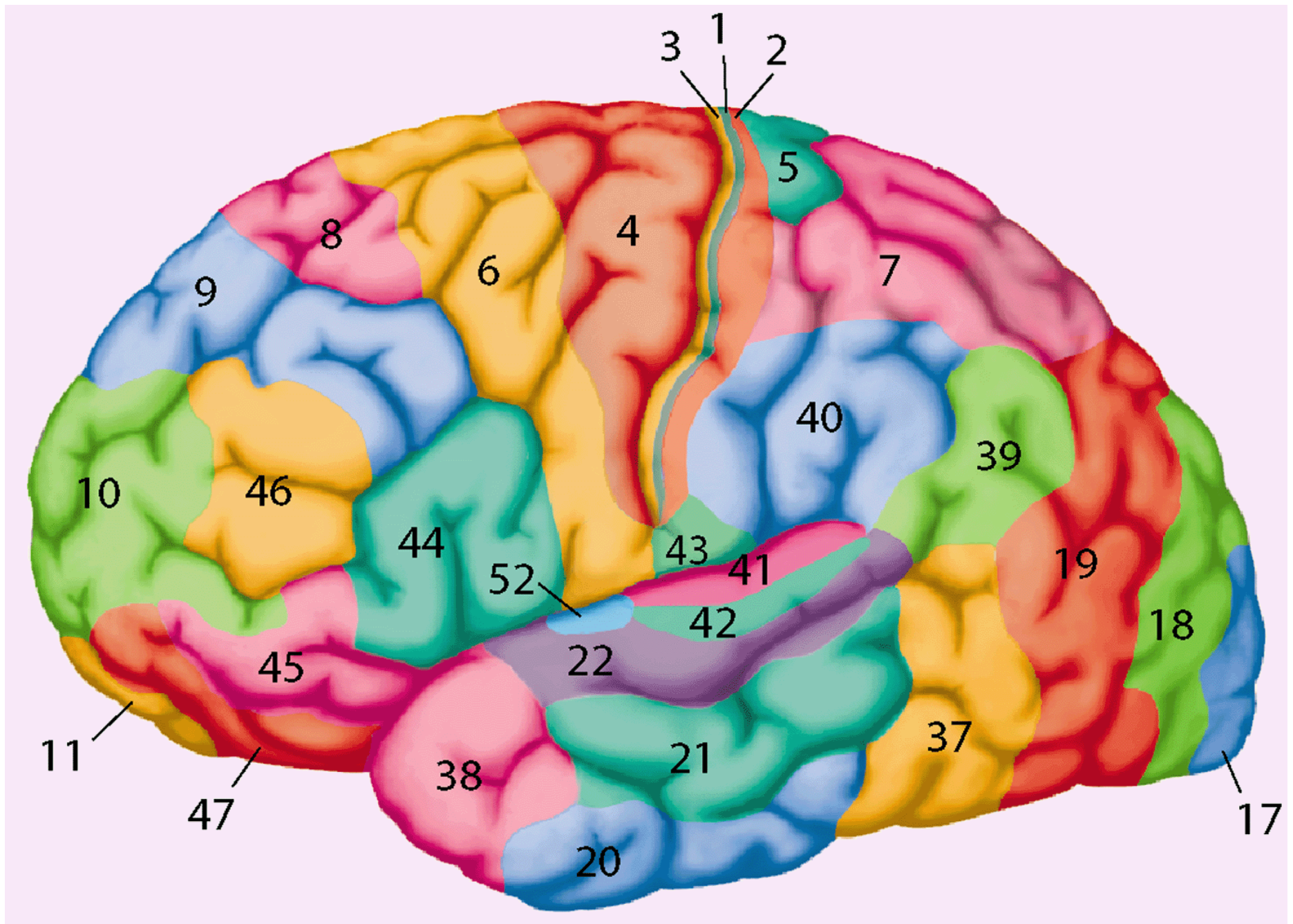


Distribution of functional zones in relationship to Brodmann's map of the human brain

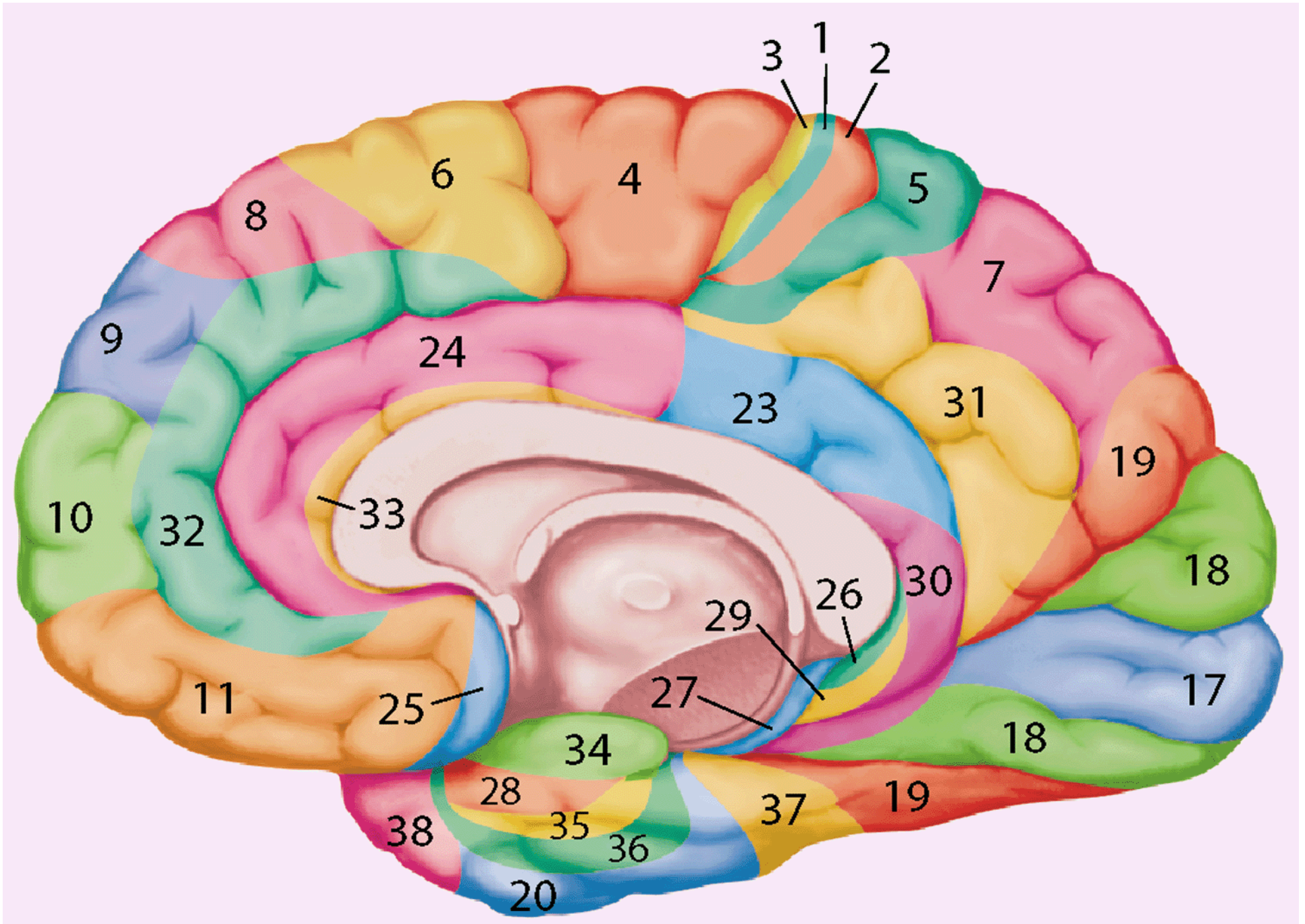
Colorized version © source unknown, based on Brodmann, 1909 (public domain). All rights reserved. This content is excluded from our Creative Commons license. For more information, see <http://ocw.mit.edu/fairuse>.



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Localization of Function

Distributed/Local

Franz Joseph Gall (1758-1828)



Public domain image.

**“Science” of Phrenology
19th century**

LOCALIZATION & PHRENOLOGY

- Franz Gall (1758-1828)
- Johann Casper Spurzheim (1776-1832)

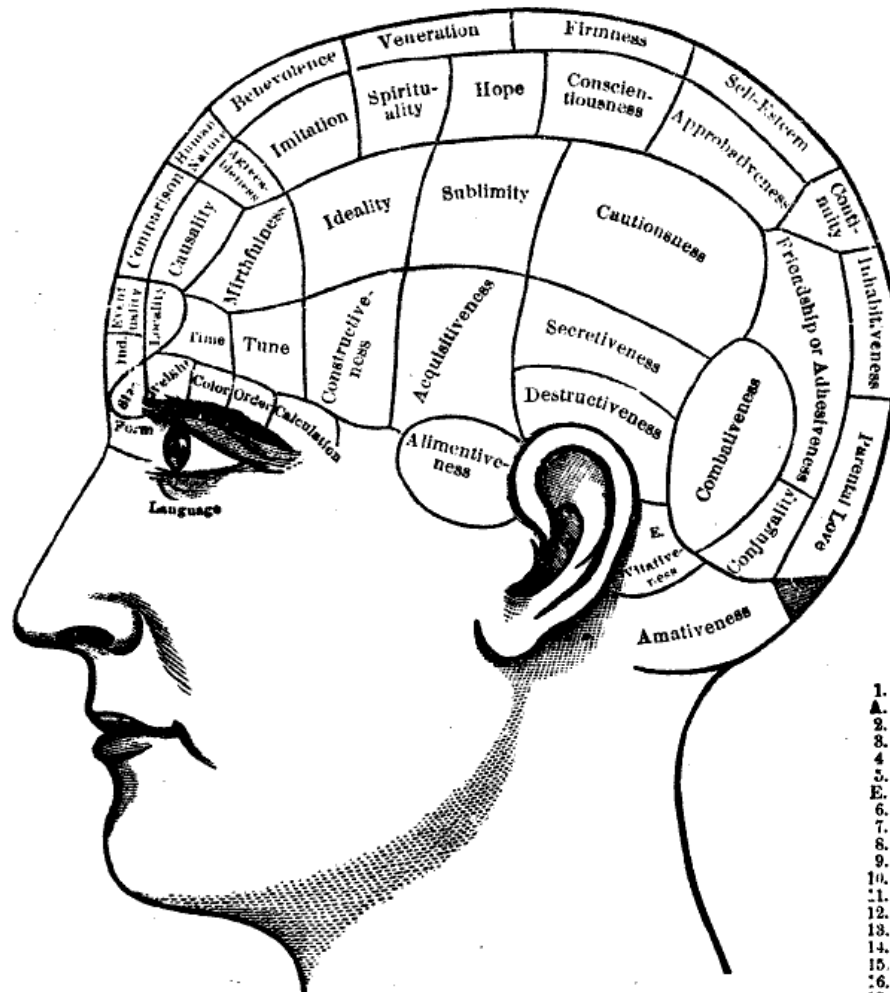
good neuroanatomists

- cortex is composed of cells connected to subcortical structures
- crossing of the pyramidal tracts & gray/white matter in spinal cord
- symmetrical hemispheres connected by commissures

not so good neuropsychologists

- behavioral phrenology - amateness, combativeness, acquisitiveness
- Gall - language localized to below the orbit due to a soldier with a knife wound that penetrated left frontal-lobe and become aphasic

Phrenology



NUMBERING AND DEFINITION OF THE ORGANS.

- | | |
|---|---|
| <ol style="list-style-type: none"> 1. AMATIVENESS, Love between the sexes. 2. CONJUGALITY, Matrimony—love of one. [etc.] 3. PARENTAL LOVE, Regard for offspring, pets, 4. FRIENDSHIP, Adhesiveness—sociability. 5. CONTINUITY, One thing at a time. 6. VITATIVENESS, Love of life. 7. DESTRUCTIVENESS, Executiveness—force. 8. ALIMENTIVENESS, Appetite—hunger. 9. ACQUISITIVENESS, Accumulation. 10. SECRETIVENESS, Policy—management. 11. CAUTIOUSNESS, Prudence—provision. 12. APPROBATIVENESS, Ambition—display. 13. SELF-ESTEEM, Self-respect—dignity. 14. FIRMNESS, Decision—perseverance. 15. CONSCIENTIOUSNESS, Justice—equity. 16. HOPE, Expectation—enterprise. 17. SPIRITUALITY, Intuition—faith—credulity. 18. VENERATION, Devotion—respect. 19. BENEVOLENCE, Kindness—goodness. | <ol style="list-style-type: none"> 20. CONSTRUCTIVENESS, Mechanical ingenuity 21. IDEALITY, Refinement—taste—purity. 22. SUBLIMITY, Love of grandeur—infinitude. 23. IMITATION, Copying—patterning. 24. MIRTHFULNESS, Jocoseness—wit—fun. 25. INDIVIDUALITY, Observation. 26. FORM, Recollection of shape. 27. SIZE, Measuring by the eye. 28. WEIGHT, Balancing—climbing. 29. COLOR, Judgment of colors. 30. ORDER, Method—system—arrangement 31. CALCULATION, Mental arithmetic. 32. LOCALITY, Recollection of places. 33. EVENTUALITY, Memory of facts. 34. TIME, Cognizance of duration. 35. TUNE, Sense of harmony and melody. 36. LANGUAGE, Expression of ideas. 37. CAUSALITY, Applying causes to effect. [tion] 38. COMPARISON, Inductive reasoning—illustra- 39. HUMAN NATURE, Perception of motives. 40. AGREEABLENESS, Pleasedness—satisfaction |
|---|---|

Phrenometer

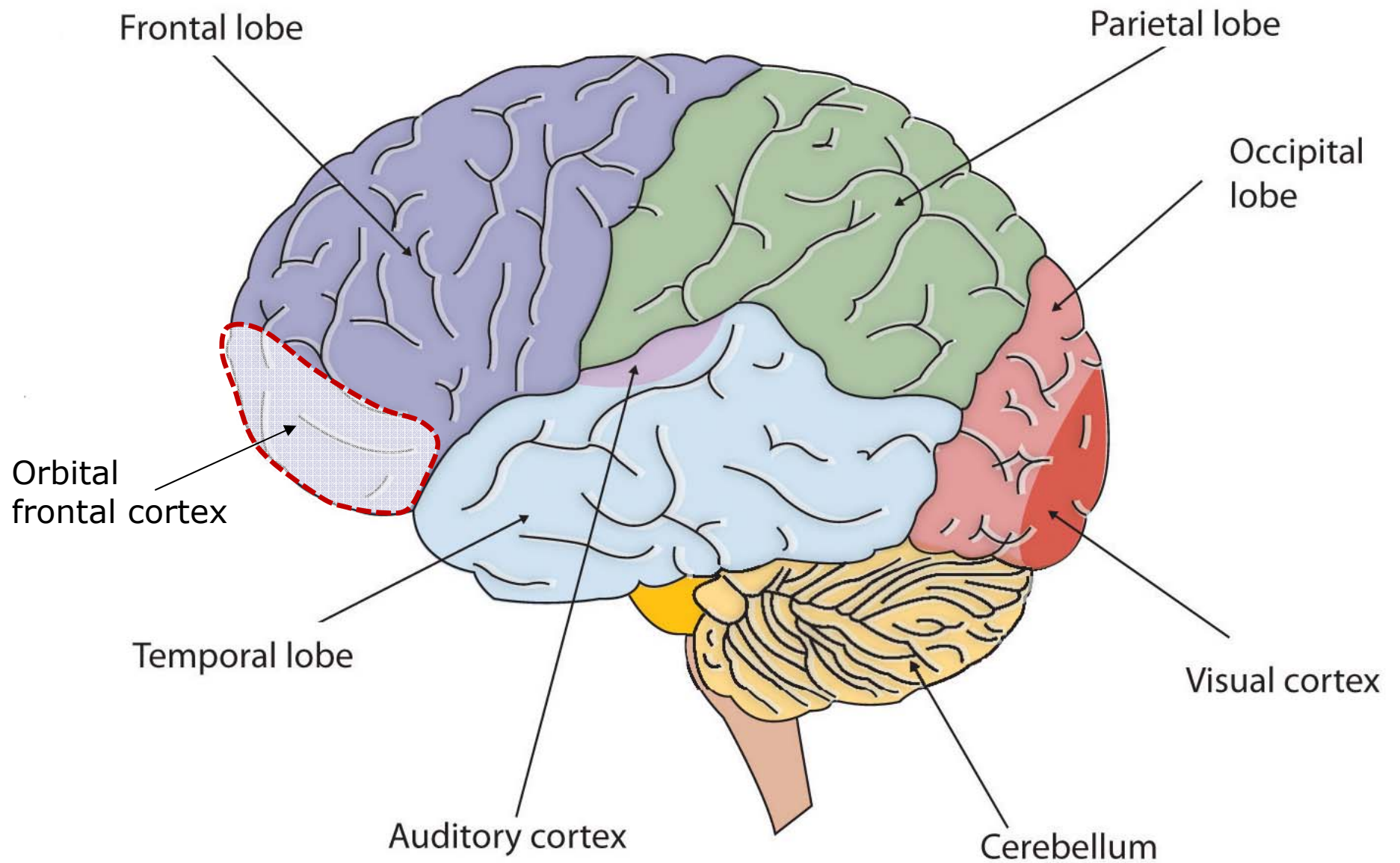
Photo removed due to copyright restrictions.

["Woman Using a Lavery Electric Automatic Phrenometer."](#)

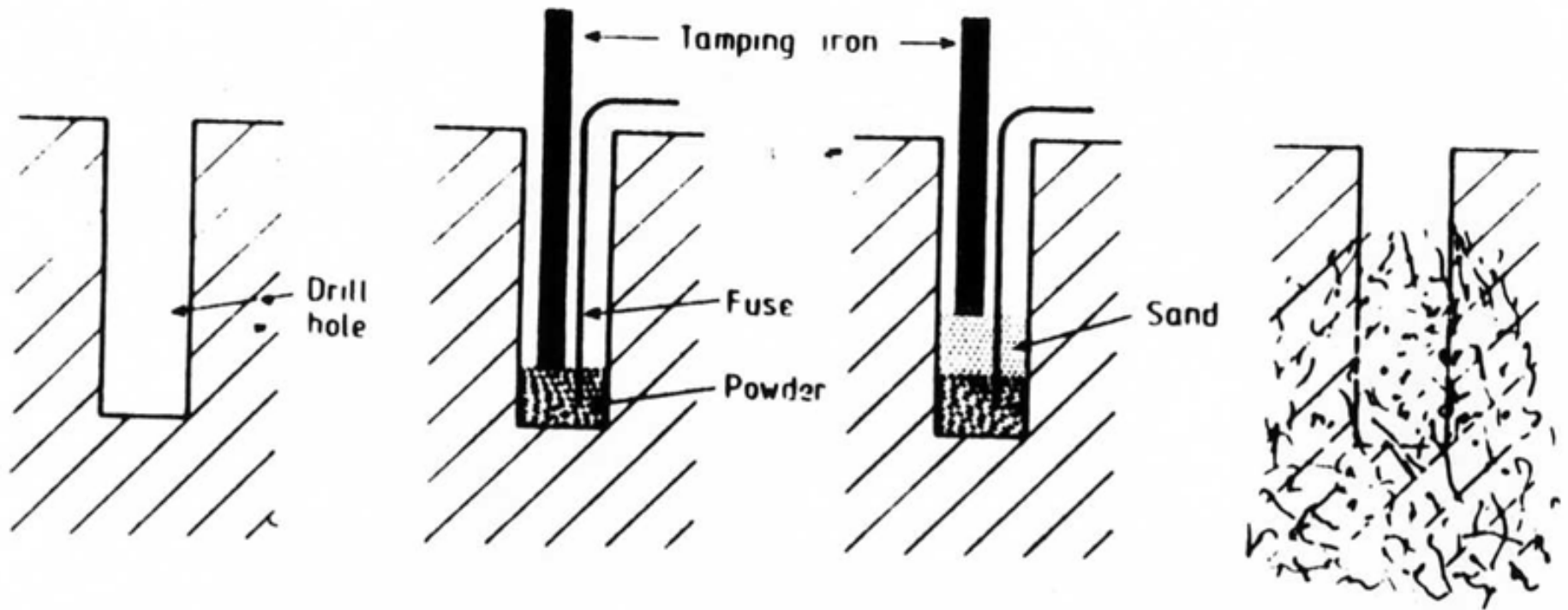
1907

"The famous physiologist, Magendie, preserved with veneration the brain of Laplace. Spurzheim had the very natural wish to see the brain of a great man. To test the science of the phrenologist, Mr. Magendie showed him, instead of the brain of Laplace, that of an imbecile. Spurzheim, who had already worked up his enthusiasm, admired the brain of the imbecile as he would have admired that of Laplace."

Flourens, P. "Psychologie Comparee." (1865).



Adapted from Stangor, C. *Introduction to Psychology*. Flatworld Knowledge, 2010. Courtesy of Flatworld Knowledge.



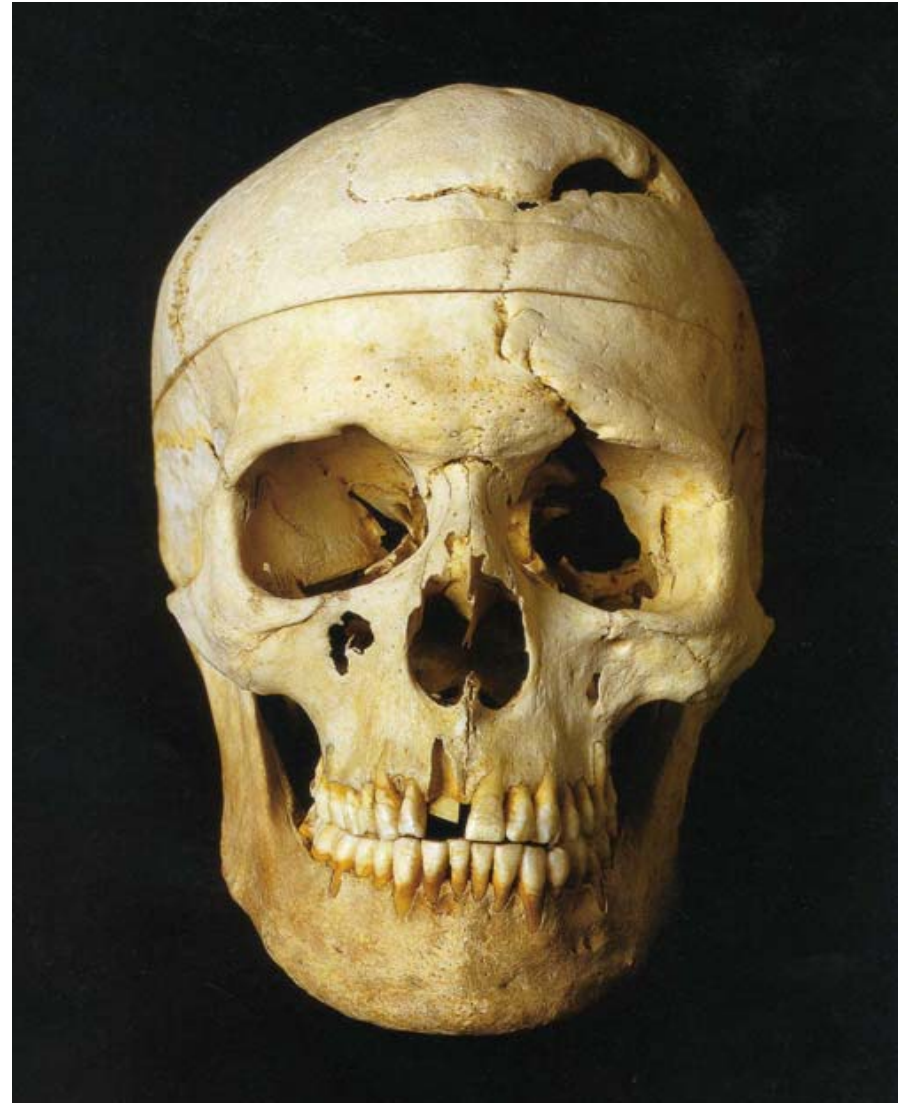
Setting and tamping an explosive charge

Courtesy of Elsevier, Inc., <http://www.sciencedirect.com>. Used with permission.
Source: Macmillan, M. B. "A Wonderful Journey Through Skull and Brains: The Travels of Mr. Gage's Tamping Iron." *Brain and Cognition* 5, no. 1 (1986): 67-107.

Phineas Gage

- **age 25 in 1848**
- **"a well-balanced mind, and was looked upon by those who knew him as a shrewd, smart business man, very energetic and persistent in executing all his plans of operation" (Harlow)**
- **made a foreman and regarded by his superiors as "the most efficient and capable in their employ"**
- **September 13, 1848 in Cavendish, VT**
- **tamping iron - 3 ft 7 in long, 1.25 inches in diameter at larger end, 13.25 pounds**
- **went through his head, landed 30 yards away**
- **March, 1849 - back at work. "His contractors... considered the change in his mind so marked that they could not give him his place again"**

Phineas Gage



Photos from Fleischman, John. *Phineas Gage: A Gruesome but True Story About Brain Science*. © Houghton Mifflin. All rights reserved. This content is excluded from our Creative Commons license. For more information, see <http://ocw.mit.edu/fairuse>.

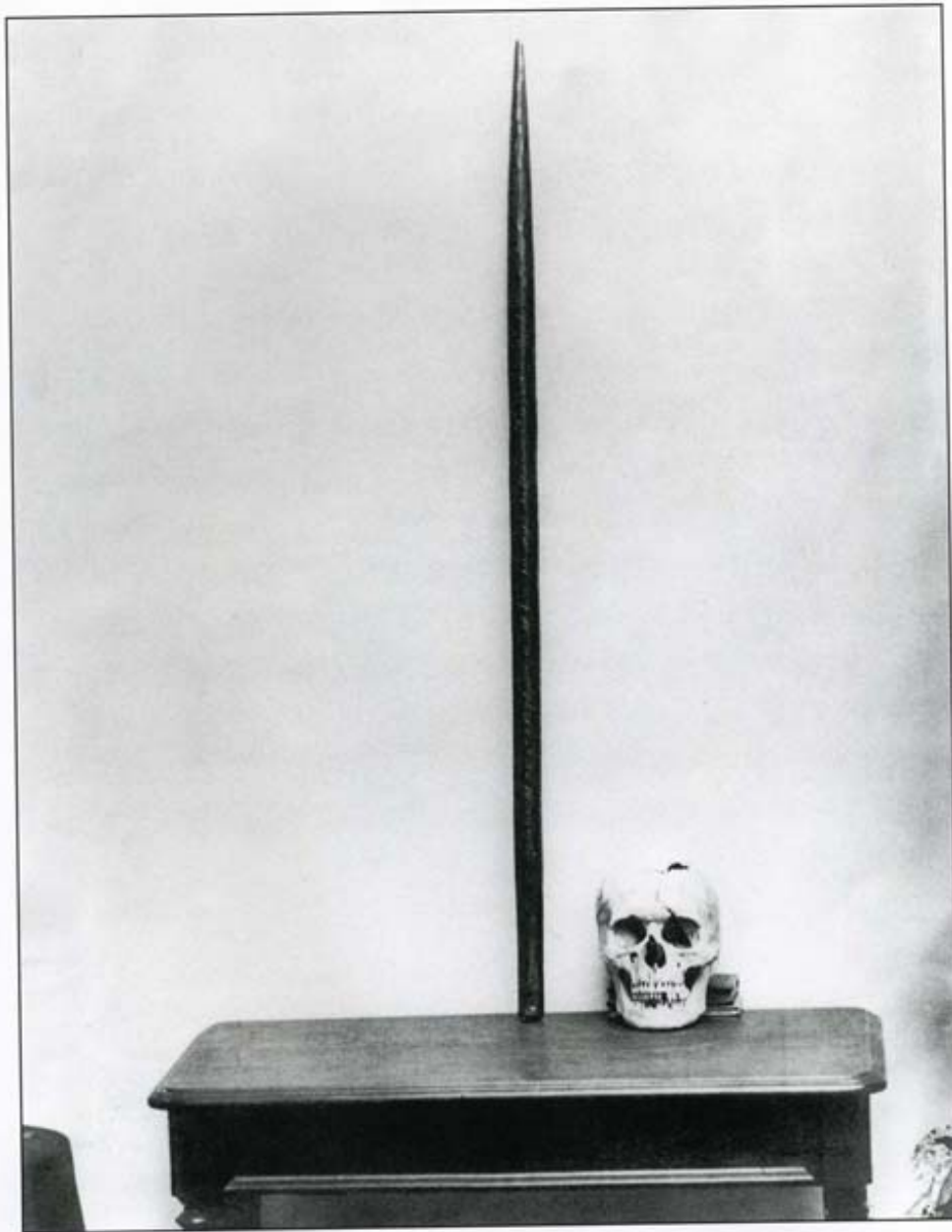
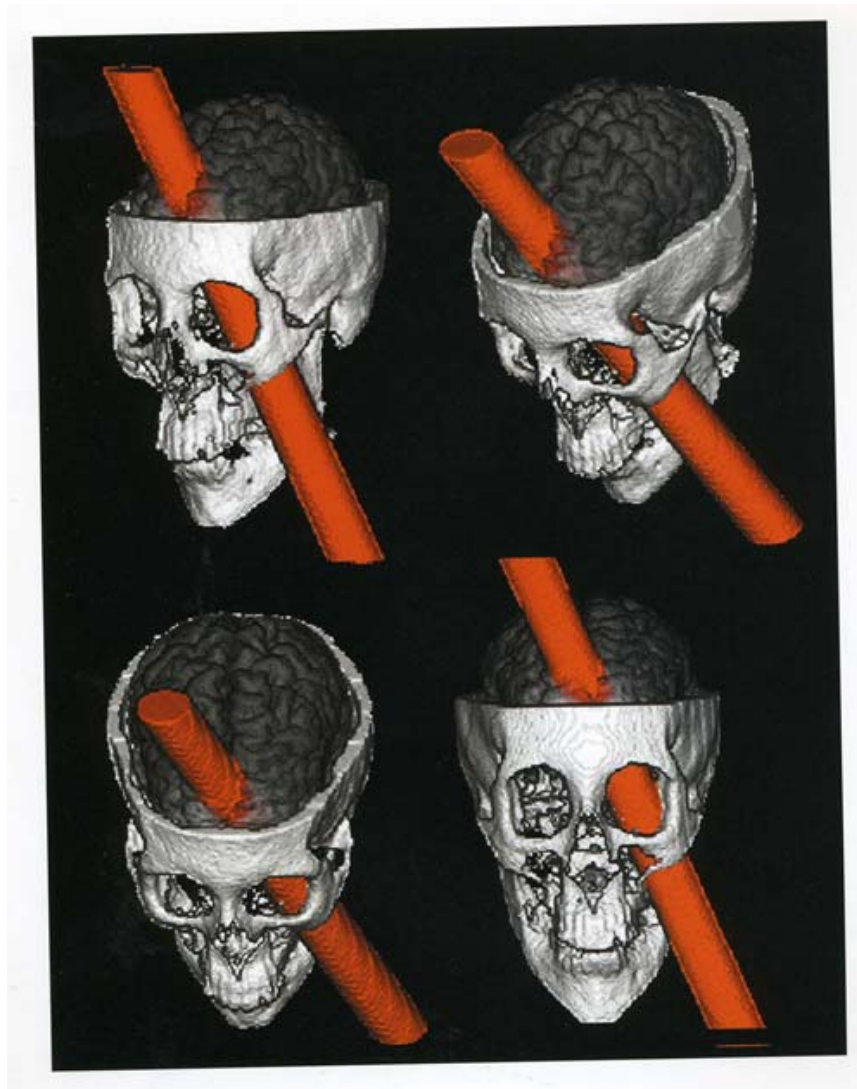


Photo of tamping iron and skull

Public domain image (photo by S. Webster Wyman, 1870).



Computer generated model plotting path of tamping iron (shown in red) through Gage's frontal cortex

Source: Damasio, H., et al. "The Return of Phineas Gage: Clues About the Brain from the Skull of a Famous Patient." *Science* 264, no. 5162 (1994): 1102-5.
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"The equilibrium or balance, so to speak, between his intellectual faculties and his animal propensities, seems to have been destroyed. He is fitful, irreverent, indulging at times in the grossest profanity (which was not previously his custom), manifesting but little deference for his fellows, impatient of restraint or advice when it conflicts with his desires, at times pertinaciously obstinate, yet capricious and vacillating, devising many plans of future operations, which are no sooner arranged than they are abandoned in turn for others appearing more feasible. A child in his intellectual capacity and manifestations, he has the animal passions of a strong man. Previous to his injury, although untrained in the schools, he possessed a well-balanced mind and was looked upon by those who knew him as a shrewd, smart business man, very energetic and persistent in executing all his plans of operation. In this regard, his mind was radically changed, so decidedly that his friends and acquaintances said he was 'no longer Gage'." (Harlow, 1868)

Daguerreotype of Phineas Gage

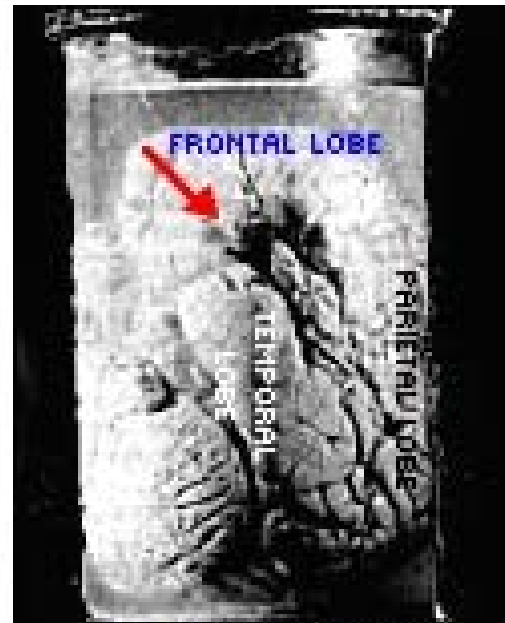


From the collection of Jack and Beverly Wilgus.

Paul Broca (1824-1880)



PAUL BROCA



THE BRAIN OF MR. 'TAN'

Right photo (Mr. Tan's brain) © source unknown. All rights reserved.
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- **Jean Baptiste Bouillaud (1796-1881) argued for left-sided control of speech in 1825**
- **Marc Dax in 1836 reported that in a series of cases disorders of speech followed left hemisphere lesions - published by his son in 1865**
- **Ernest Auburtin (Bouillaud's son-in-law) reported to the Anthropological Society of Paris in 1861 a case "who had lost his speech but understood everything said to him . . . his intelligence is still unimpaired, and speech is wholly abolished... based on the symptoms that he presents, we have diagnosed softening of the anterior lobes"**

- **Paul Broca (1824-1880) heard speech**
- **5 days later received a patient, LeBorgne, who had lost his speech, could only say "tan" and utter an oath - right-sided paralysis - otherwise apparently normal**
- **Tan died on April 17, 1861 and the next day Broca reported to the Anthropological Society of Paris left anterior focus of Tan's lesion - by 1863 8 more cases. "in which the lesion was in the posterior third of the third frontal convolution. This number seems to me to be sufficient to give strong presumptions. And the most remarkable thing is that in all the patients the lesion was on the left side. I do not dare draw conclusions from this. I await new facts."**
- **Broca's aphasia - inability to speak despite presence of intact vocal mechanisms and normal comprehension**

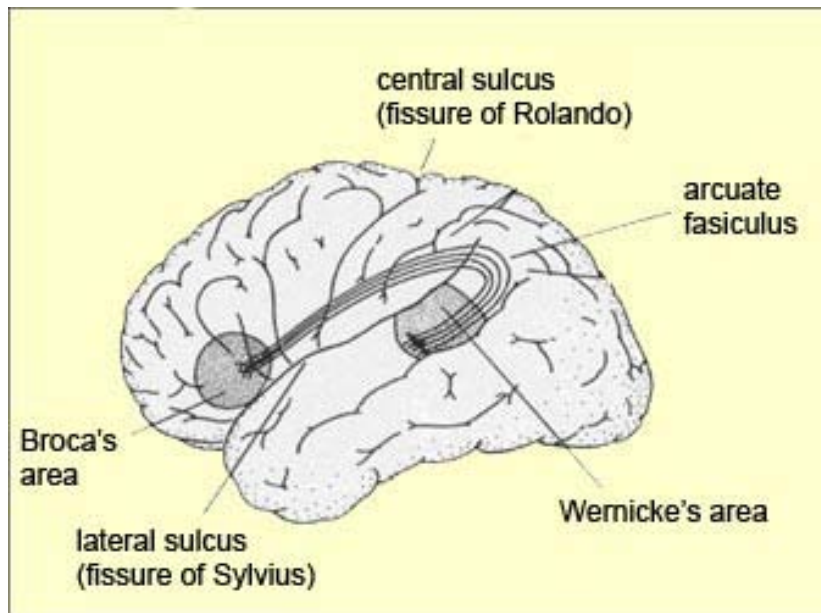
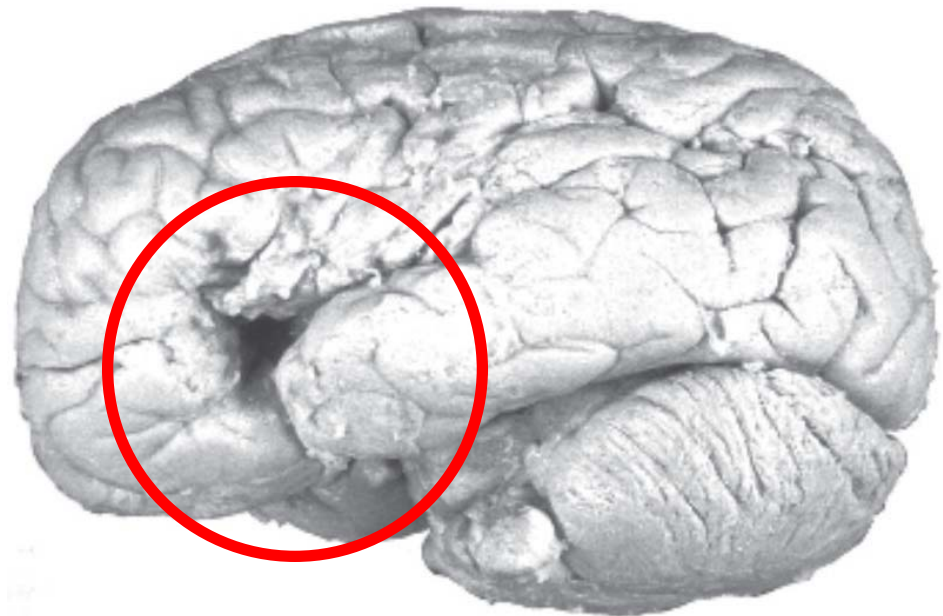


Diagram courtesy of Bruno Dubuc, from *The Brain from Top to Bottom*.



Reprinted by permission from Macmillan Publishers Ltd: *Nature Reviews Neuroscience*. Source: Rorden, Chris and Hans-Otto Karnath. "Using Human Brain Lesions to Infer Function: A Relic from a Past Era in the fMRI Age?" *Nature Reviews Neuroscience* 5 (2004): 812-19. © 2004.

Broca's Area:

- language processing
- speech production and comprehension

Broca's aphasia:

- results from damage to Broca's Area (e.g., lesions)
- unable to create grammatically-complex sentences
- speech described as telegraphic, contains content words only
- comprehension is relatively normal

WADA TEST FOR LANGUAGE LATERALIZATION

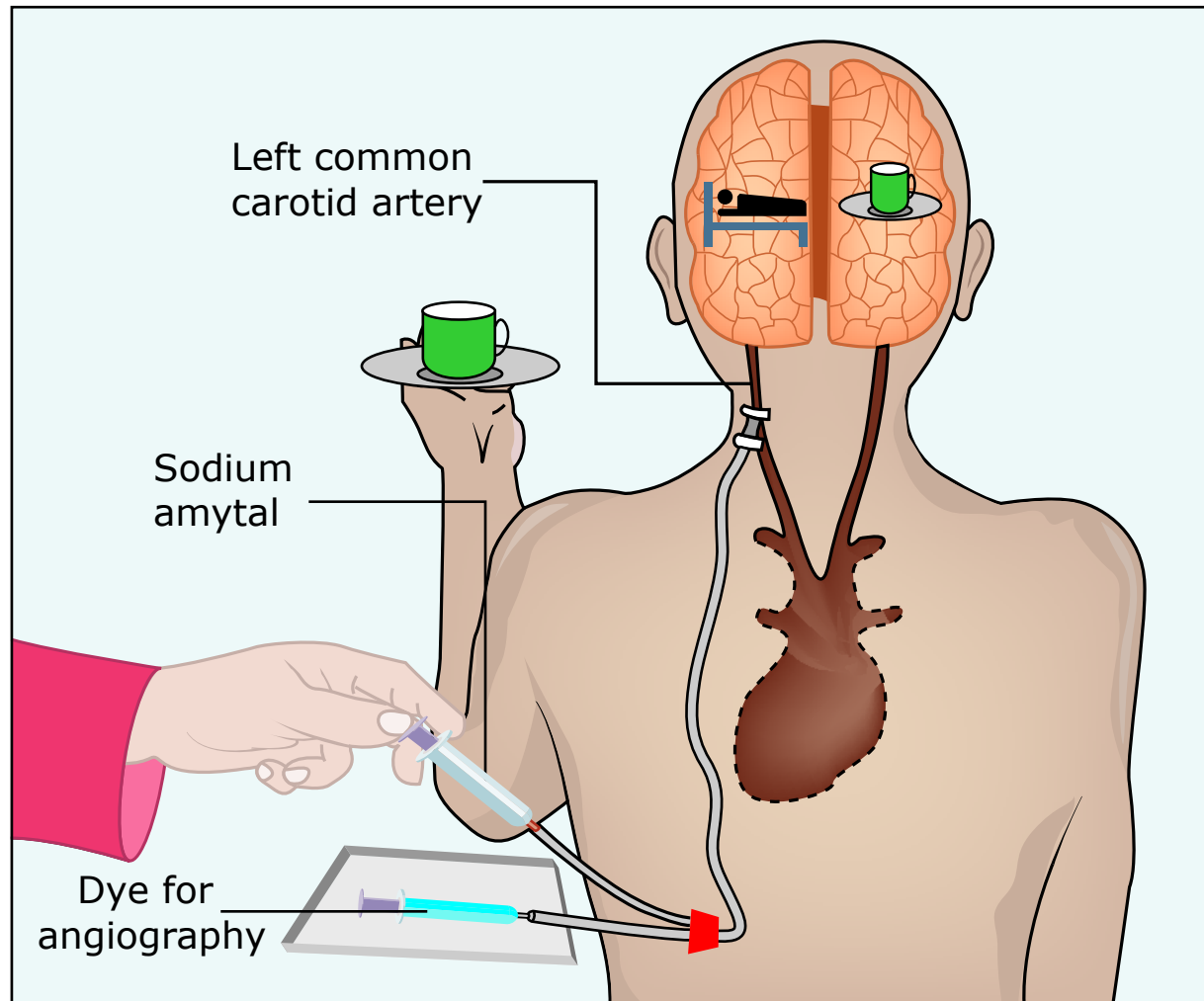
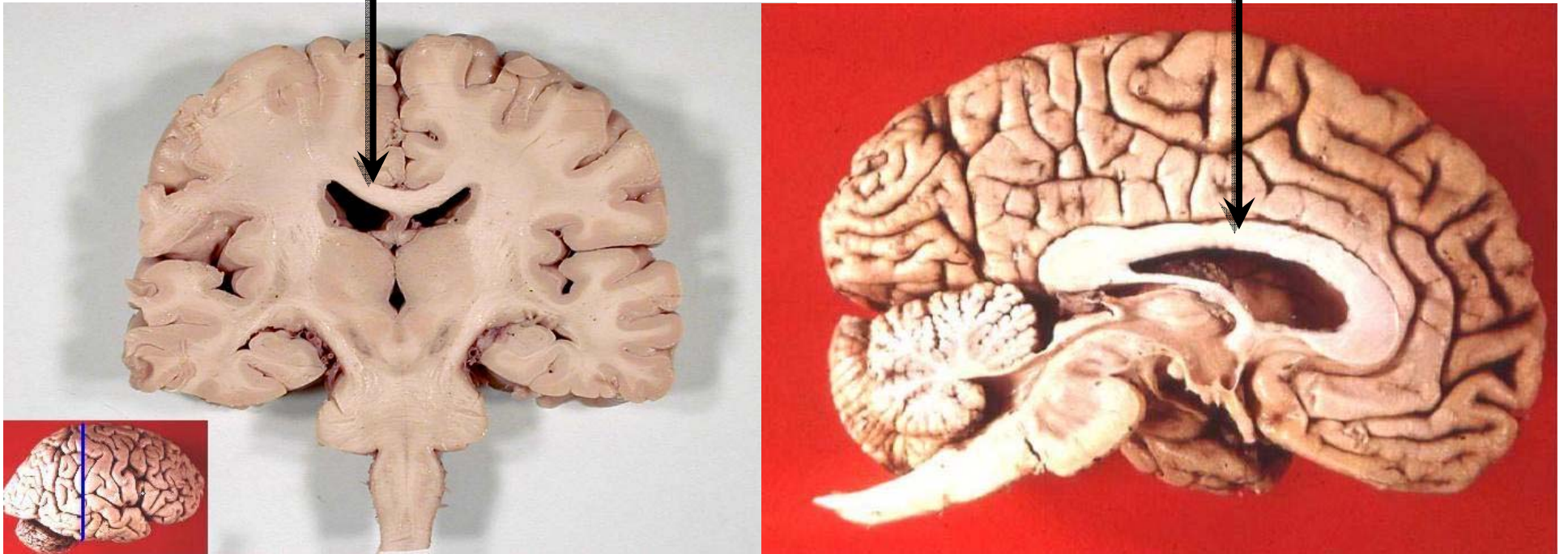


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Corpus Callosum

Corpus callosum



Photos courtesy of John A. Beal, PhD, from [Anatomy of the Human Brain](#). HEAL Collection #40566. License CC BY.

Mystery of the corpus callosum

- 1. Gustav Fechner - 19th century - would a divided brain lead to separate stores of mood, predisposition, knowledge, memory?**
- 2. William McDougall - a founder of British Psychological Society - unity of consciousness does not depend upon continuity of nervous system - volunteered for commissurotomy if he got incurable disease**
- 3. Erickson - 1940 - spread of epileptic discharge from hemisphere to hemisphere by corpus callosum**
- 4. 1957**
 - "corpus callosum is hardly connected with psychological functions at all... it is for transmitting seizure activity from one hemisphere to the other" (Warren McCullough)**
 - "to keep hemispheres from collapsing into one another" (Karl Lashley)**

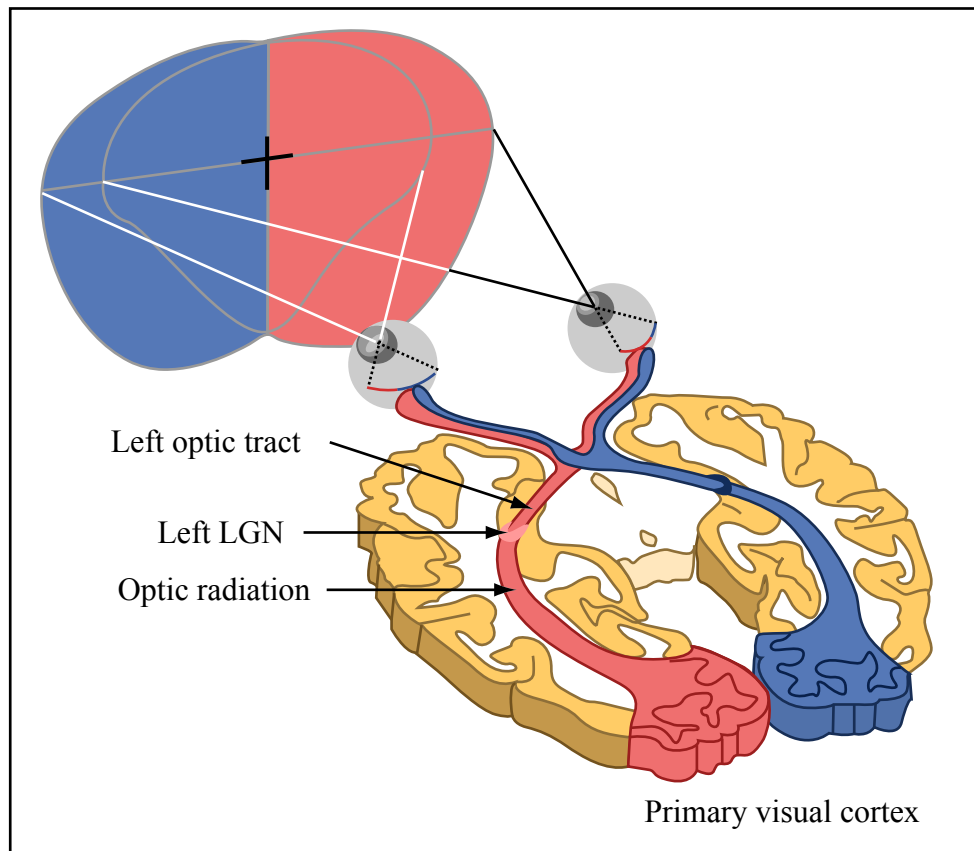
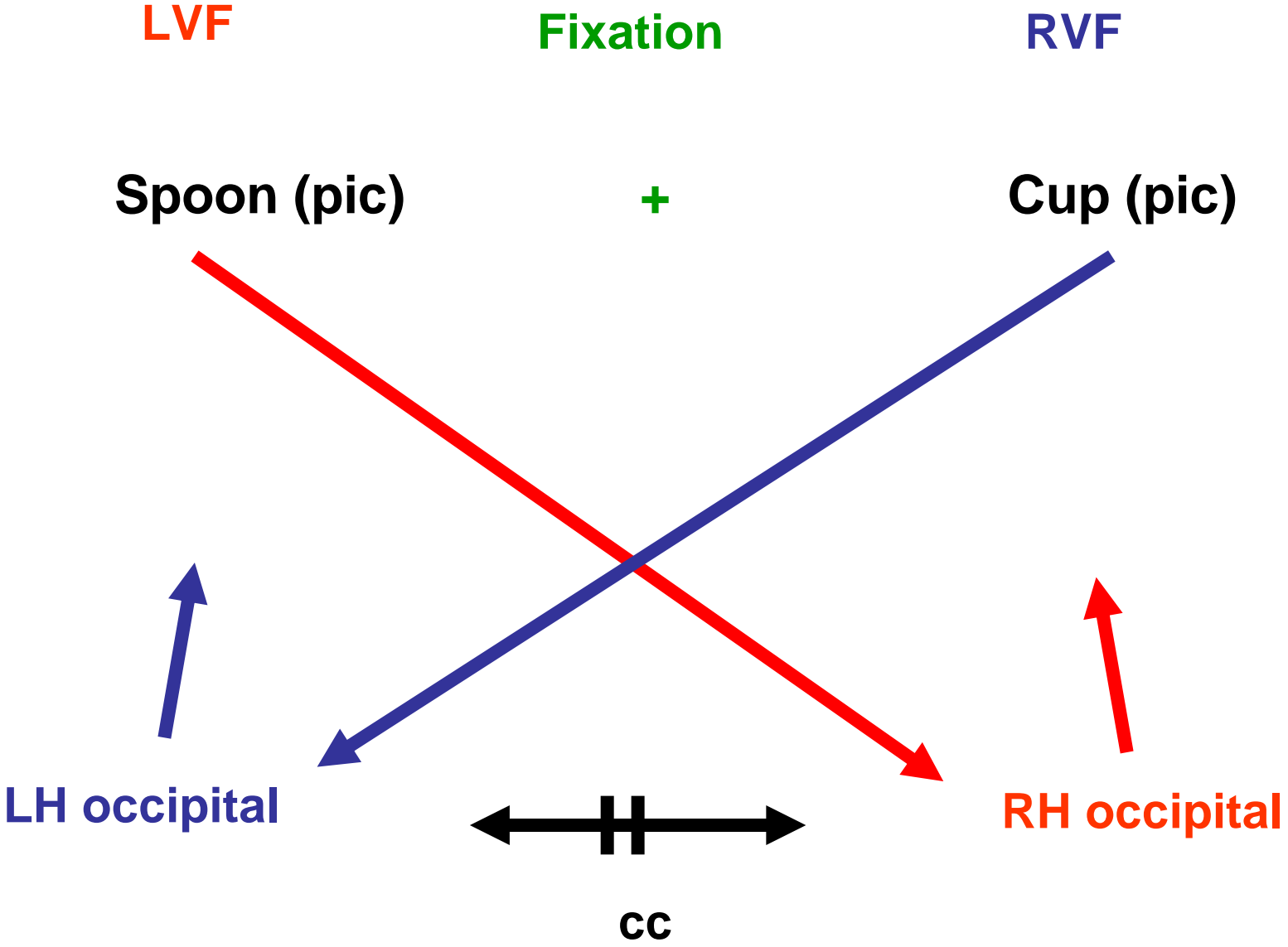


Image by MIT OpenCourseWare. After Figure 10-4b in Bear, Mark F., Barry W. Connors, and Michael A. Paradiso. *Neuroscience: Exploring the Brain*. 3rd ed. Baltimore, MD: Lippincott Williams & Wilkins, 2007. ISBN: 9780781760034.

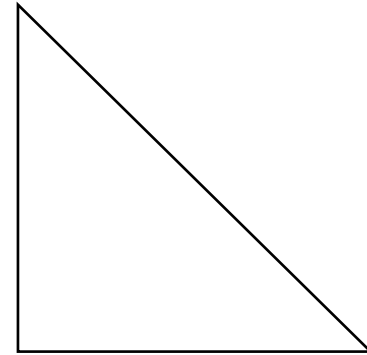


What did you see? CUP

LVF

Mutual Unawareness

RVF



Draws Square

right hand

left hand

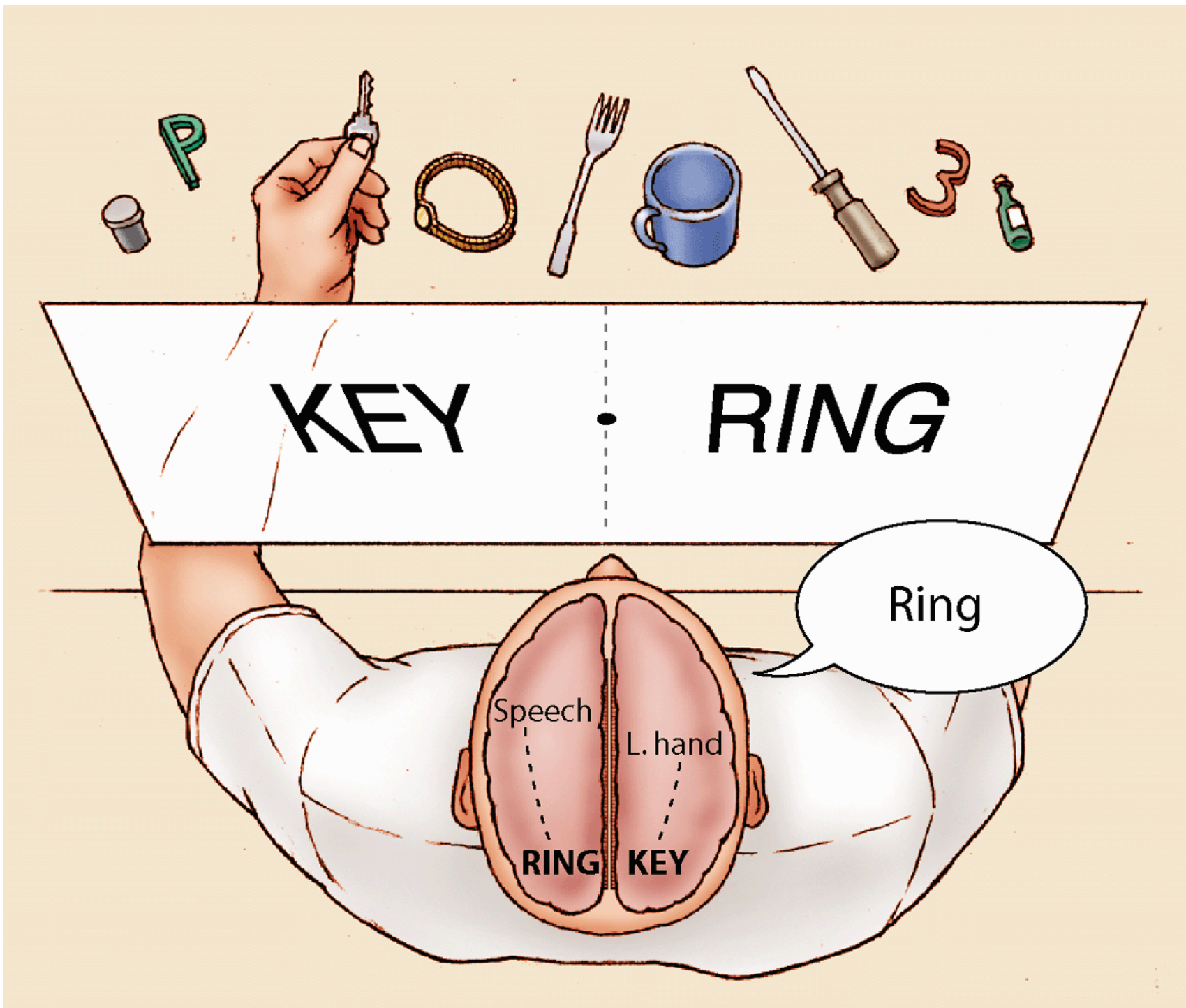


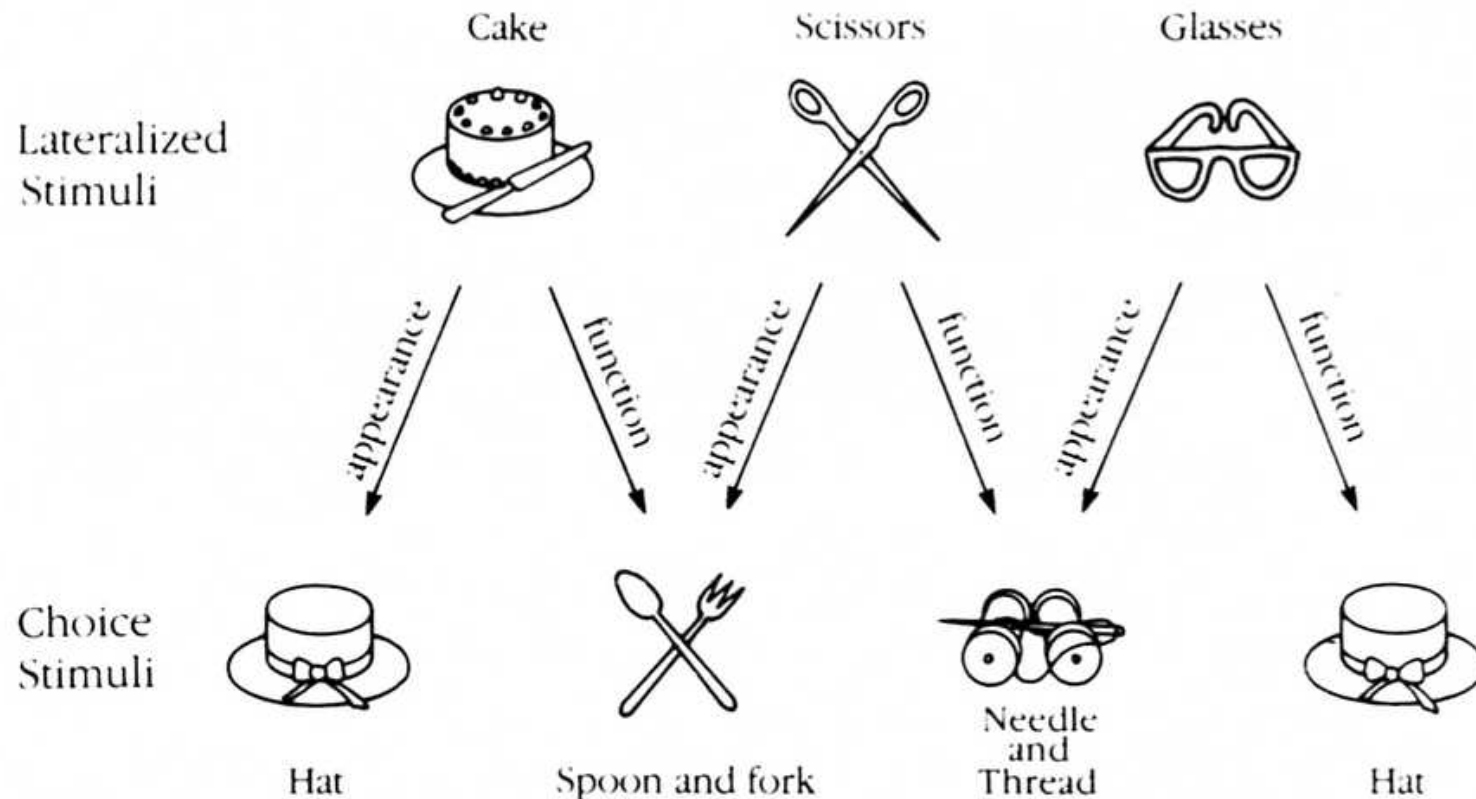
LH

RH



What did you see? - Triangle





Function and appearance matches by split-brain patients

Source: Levy, J., and C. Trevarthen. *Journal of Experimental Psychology: Human Perception and Performance* 2 (1976): 299-312. Courtesy of the American Psychological Association.

PROTOTYPICAL CALLOSOTOMY RESULTS

- 1. patient fixates centrally**
 - picture of cup in RVF - says "cup" –**
 - picture of spoon in LVF - reports seeing nothing –**
 - picks spoon with left hand - what was it? "pencil"**
 - speech production from LH only in most patients**
 - some language comprehension in RH**
- 2. mutual unawareness - modularity**
 - present square to LVF, triangle to RVF -**
 - draw with unseen left hand - draws a square -**
 - what did you see? "a triangle"**
- 3. somesthesia**
 - no cross retrieval of objects**
 - no cross replication of hand postures**
 - no cross localization of fingertips**
- 4. different modes of information processing of the same stimulus in the two hemispheres**
 - LH matched by function**
 - RH matched by appearance**
 - LH analyzes local elements**
 - RH analyses global elements**

PROTOTYPICAL CALLOSOTOMY RESULTS (cont'd)

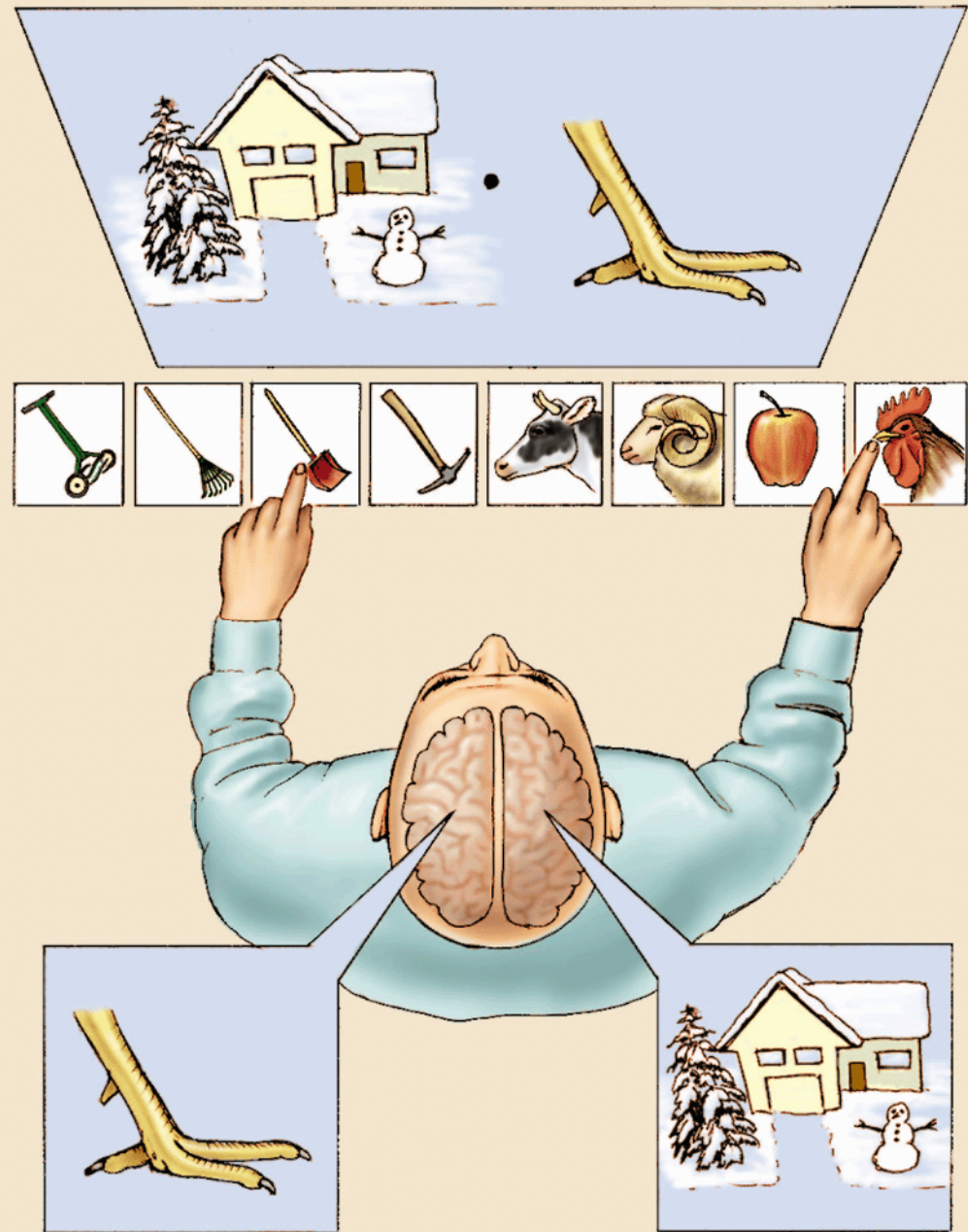
- 5. unity of consciousness usually good in daily life**
- picture of nude woman in LVF - patient blushes, giggles - why laughing? "Oh doctor, you have some machine!" -

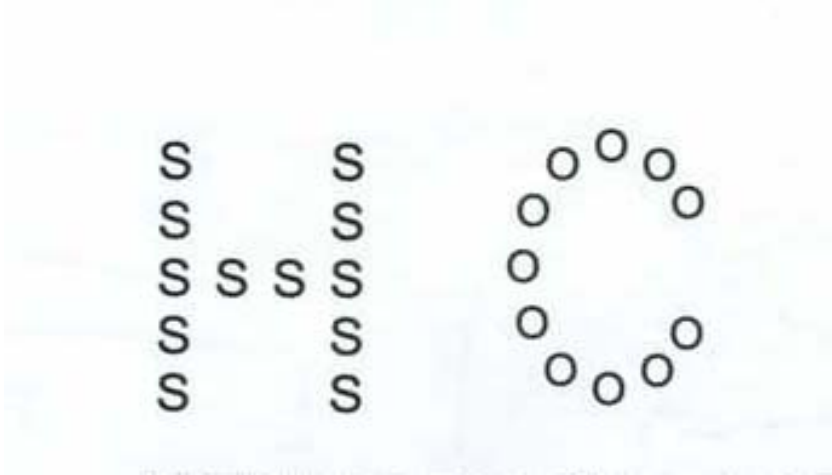
some exceptions - one hand pulling up pants and the other pulling down - angry at wife, one hand forcibly reaching for her, right hand grabbed left to stop it - another patient "I open the closet. I know what I want to wear. As I reach for something with my right hand, my left comes up and takes something different. I can't put it down if it's in my left hand. I have to call my daughter." - another patient working in father's grocery store would stock something into shelf with one hand and remove it with the other

present "walk across room" in LVF - subject gets up, walks across room - "why did you walk across room?" - "I was thirsty"

PS - pairs of pictures in VFs - pick 2/8 in free vision that are related to presented pictures - sees claw in RVF, snow scene in LVF - rh points to chicken, lh to shovel - "I saw a claw and I picked the chicken, and you have to clean out the chicken shed with a shovel."

"I saw a claw
and I picked
the chicken,
and you have to
clean out the
chicken shed
with a shovel."





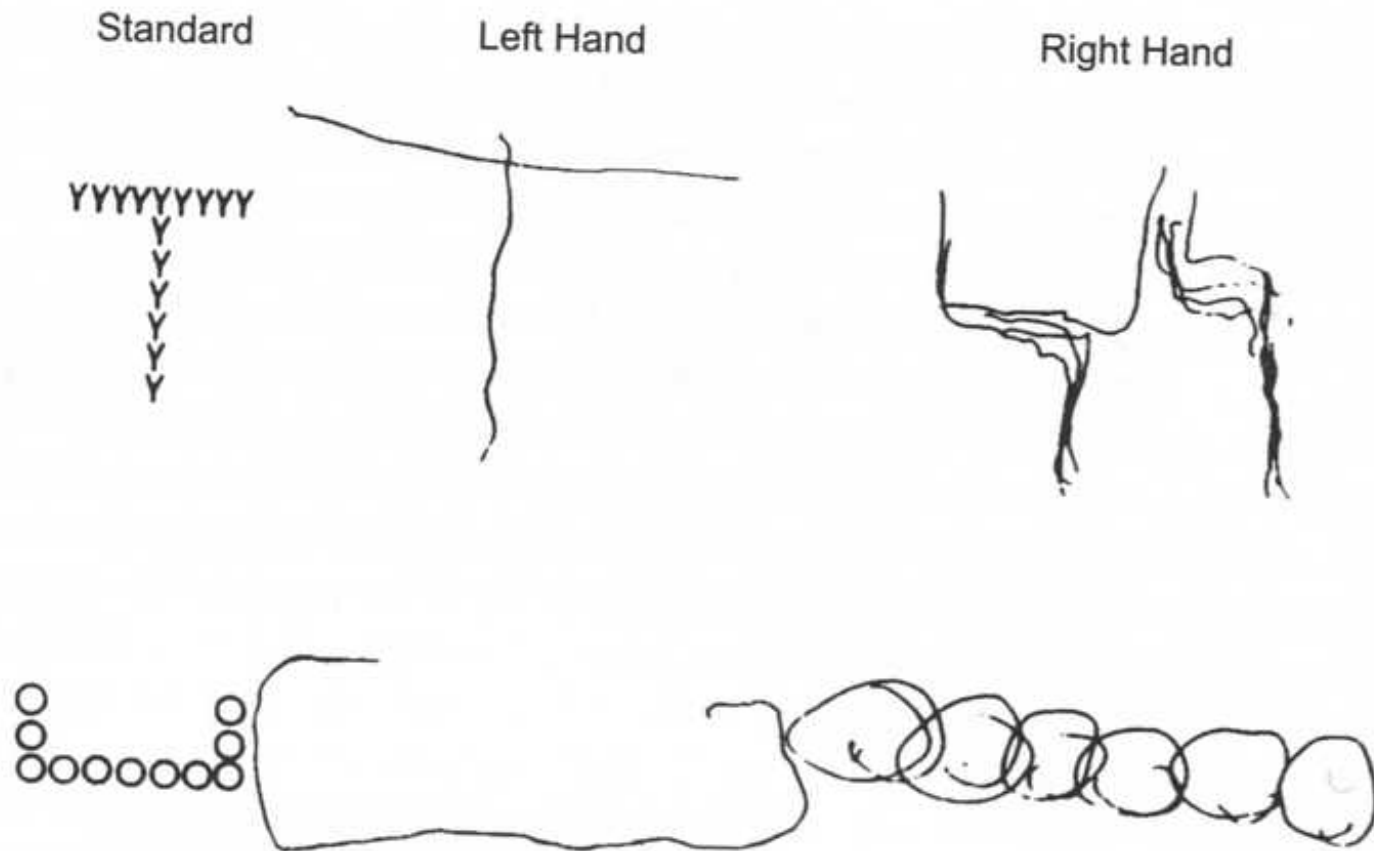


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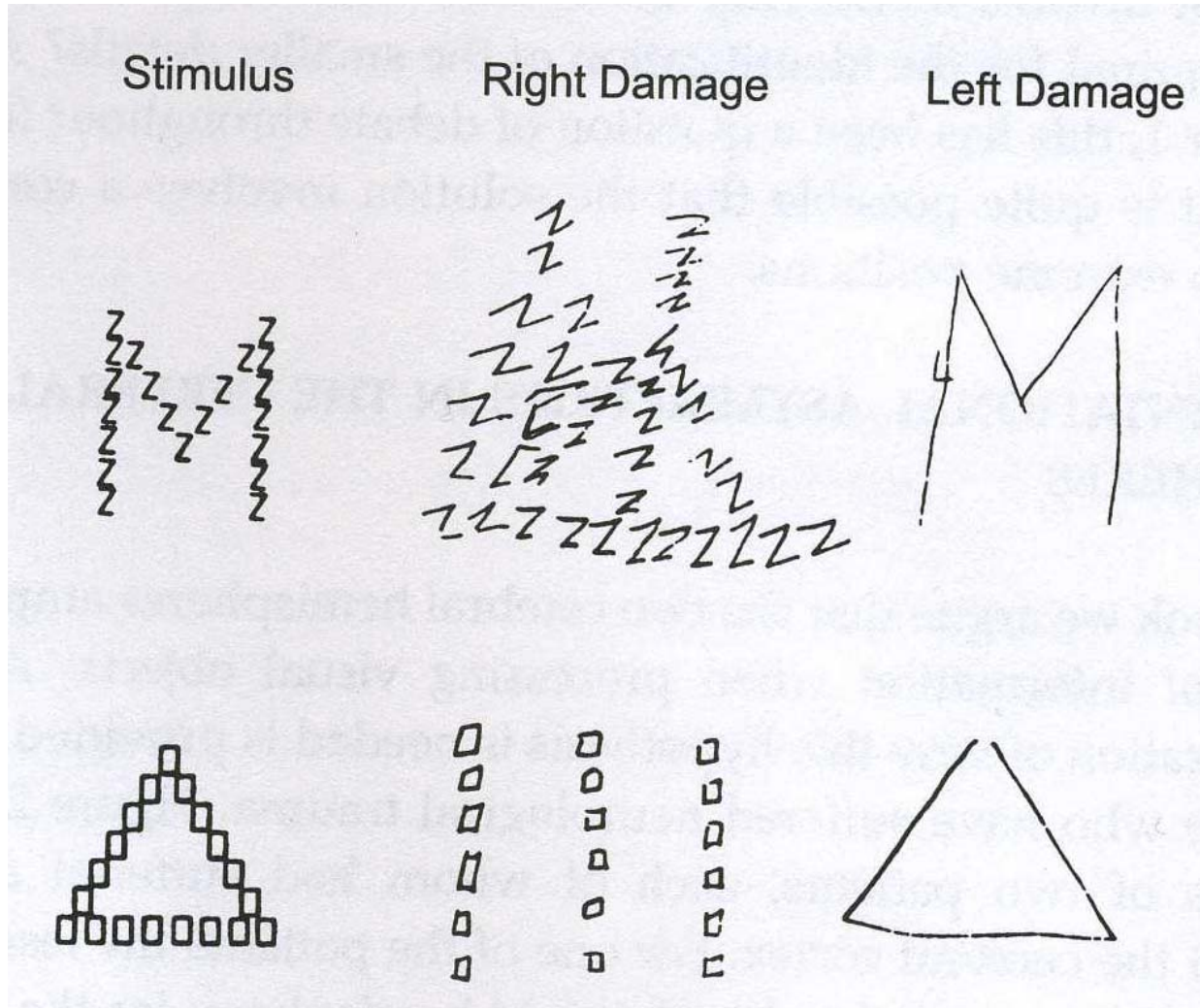
Arcimboldo

1530-1593

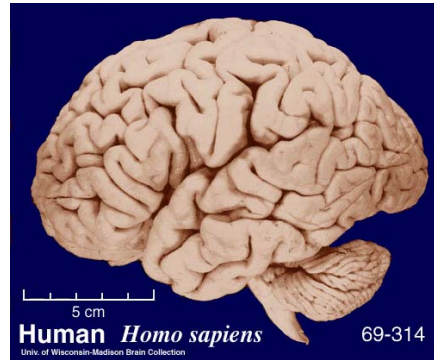
Split-Brain Patient After Surgery



After Stroke



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Human Brain

neurons

gross anatomy

Localization of mental functions in human brain

phrenology

Phineas Gage, moral behavior, orbitofrontal cortex

Broca, Tan, and left lateralization of language

Hemispheric Specialization - parallel processing

appearance (right) vs. function (left)

global (right) vs. local (left)

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