

# **Introduction to Brain and Cognition**

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# *Course Content*

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- Learning Outcomes:
  - Broad knowledge and Appreciation of Brain and Cognition
  - Acquaintance with the Research interests of CogSciLab (CSL) faculty!

# *Learning Assessment*

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- Exam (70 marks)
  - Quizzes (7 in number): 70 marks
  - Expt participation: 10 marks (2 experiments – after informed consent only)
- Recommended textbook:
  - Daniel Reisberg – Cognition , Exploring The Science of the Mind

# Brain & Cognition

- integration of the neurosciences and cognitive sciences

I am given the following words:

- EAT, ME, WANTS and LION

Thinking 1: The lion wants to eat me.

Thinking 2: I want to eat the lion.

- Betsy wanted to bring Jacob a present. She shook her piggy bank. It made no sound. She went to look for her mother. (Charniak, 1972)



# What is Cognition?

- *It* encompasses the mental functions by which knowledge is acquired, retained, and used: perception, learning, memory, and thinking.
- cognicioun, “ability to comprehend, mental act or process of knowing”, from Latin cognoscere “to get to know, recognize,” from assimilated form of com “together” + gnoscere “to know” ..(from <https://www.etymonline.com/word/cognition>).
- Most important is ‘reasoning’

# Understanding the definition/word cognition



- The word seems straightforward, yet it is often a cause of debate in the psychological and neuroscience fields, particularly about whether a behaviour of an animal that happens not to be human is truly “cognitive”, in a similar sense to human cognition.
- Does this mean the birds “know” about the displacement of water by sinking objects?

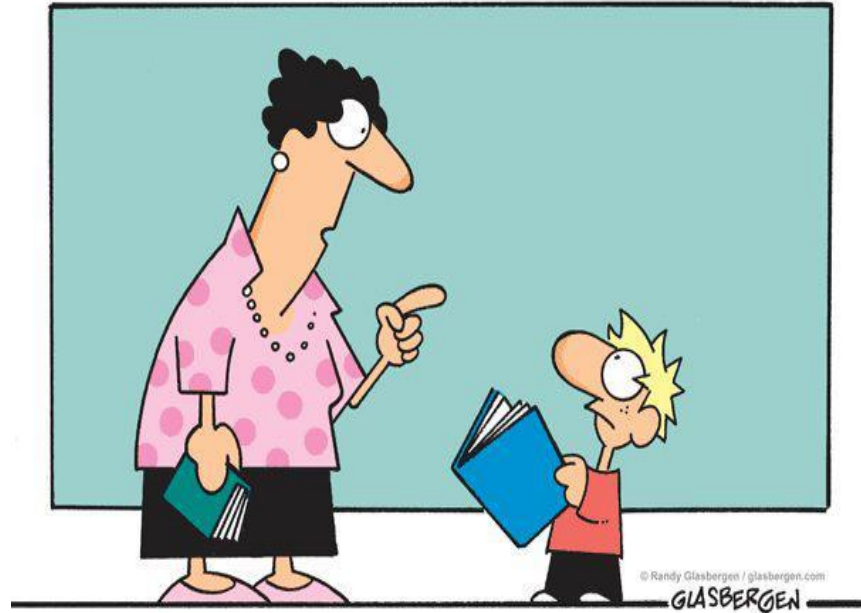


- Researchers have long investigated whether birds possess the mental equivalent of a compass, driven by observation of sun or stars, or a map, driven by geomagnetism.
- That is, mental maps and compass bearings are representations of information that imply specific properties, the bread-and-butter of cognitive theorizing.

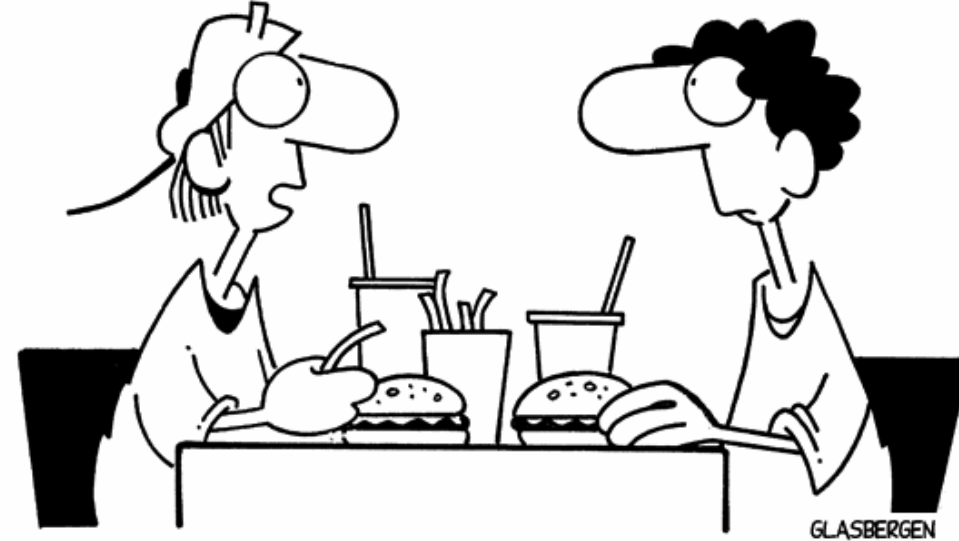


# Cognition in non-human animals

- J. David Smith, Ph.D., a comparative psychologist at the University at Buffalo who has conducted extensive studies in animal cognition, says there is growing evidence that animals share functional parallels with human conscious metacognition -- that is, they may share humans' ability to reflect upon, monitor or regulate their states of mind.
- Among these species are dolphins and macaque monkeys (an Old World monkey species).



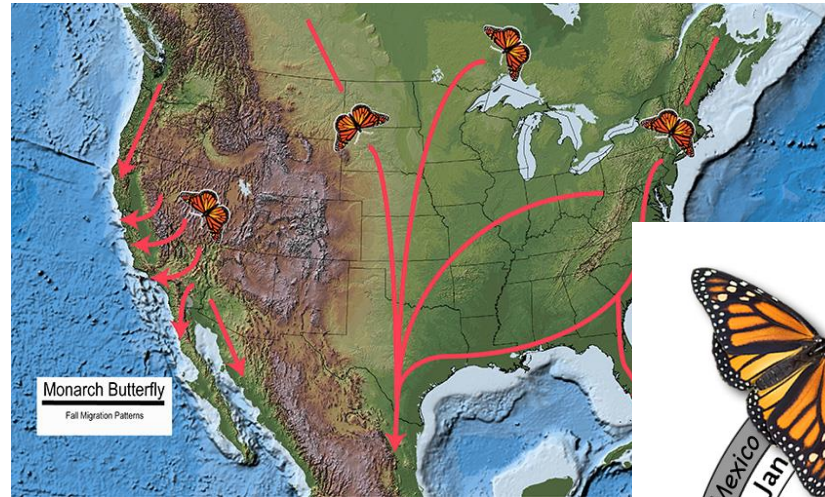
"It's called 'reading'. It's how people  
install new software into their brains"



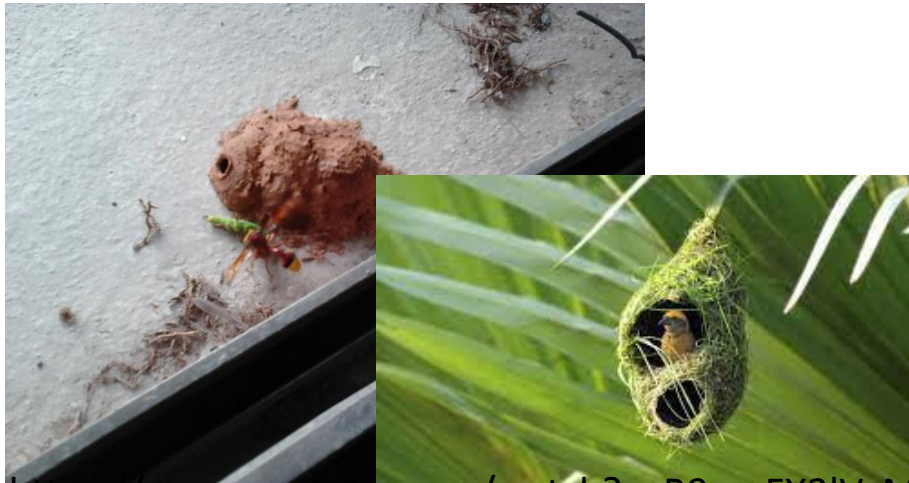
**"I forgot to make a back-up copy of my brain,  
so everything I learned last semester was lost."**

Unsolved Mysteries &  
intriguing research of the  
brain

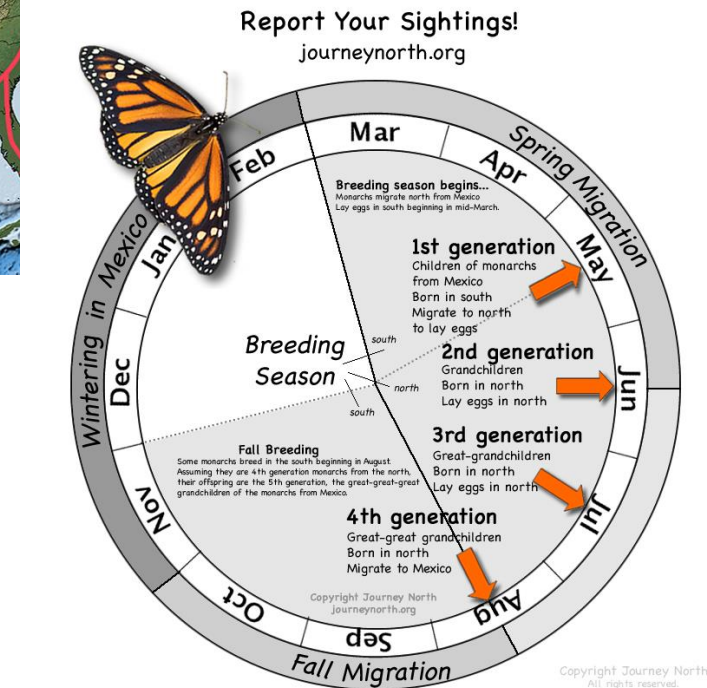
# Migration of the Monarch butterfly



How did the wasp/bird learn to build?



<https://www.youtube.com/watch?v=B9amFX3IVgM>



[https://journeynorth.org/sites/default/files/2019-01/annual\\_cycle\\_wheel.jpg](https://journeynorth.org/sites/default/files/2019-01/annual_cycle_wheel.jpg)

# The case of Anna H

Oliver Sacks

•Dear Dr. Sacks,

My (very unusual) problem, in one sentence, and in non-medical terms, is:

I can't read. I can't read music, or anything else.

In the ophthalmologist's office, I can read the individual letters on the eye chart down to the last line. But I cannot read words, and music gives me the same problem. I have struggled with this for years, have been to the best doctors, and no one has been able to help.

I would be ever so happy and grateful if you could find the time to see me.

Sincerely yours,

Anna H.

# The case of Anna H

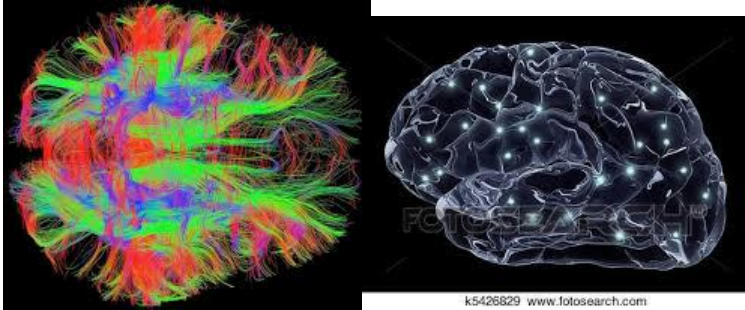
- Given a battery of neuropsychological tests—tests of visual perception, of memory, of verbal fluency, etc.—Mrs. H. did particularly badly in the recognition of drawings: she called a violin a banjo, a glove a statue, a razor a pen, and pliers a banana.
- Shown a photograph of a face, she could perceive that the person was wearing glasses, nothing else
- In contrast to her severe visual problems, her speech comprehension, repetition, and verbal fluency were all normal.
- A PET scan showed lower activity in the posterior Visual cortex (dominantly on the left side)

# The case fo Howard Engel

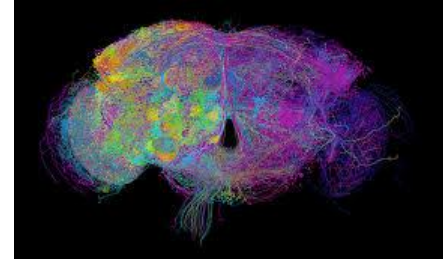
- Howard Engel, a Canadian novelist, who told me that he had a somewhat similar problem following a stroke. “The area affected,” he relates, “was my ability to read. I can write, but I can’t read what I’ve just written. . . . So, I can write, but I can’t rewrite. . . . My vision for the most part is unaffected until I look at a text. Then, whatever I’m looking at turns into unfamiliar blocks of type that could at first glance be taken for Serbo-Croatian. Familiar words, including my own name, are unfamiliar blocks of type and have to be sounded out slowly. Each time a name recurs in an article or review, it hits me as unfamiliar on its last appearance as it does on the first. . . . I have just started [writing] a crime novel in which the hero has similar problems.” Though Engel was a fair sight reader, he told me later, he had no musical alexia



*Caenorhabditis elegans*  
302 neurons and 7,000 connections



86 billion neurons in our brains



*Drosophila melanogaster*  
roughly 135,000 *neurons* in the brain

Aoccdrnig to a rscheearch at Cmabrigde Uinervtisy, it deosn't mttar in waht oredr the ltteers in a wrod are, the olny iprmoetnt tihng is taht the frist and lsat ltteer be at the rghit pclae. The rset can be a toatl mses and you can sitll raed it wouthit porbelm. Tihs is bcuseae the huamn mnid deos not raed ervey lteter by istlef, but the wrod as a wlohe.

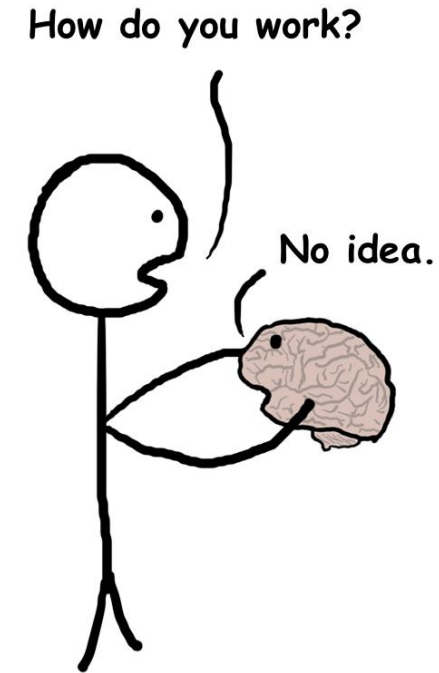


# What is not fully understood?

- **What is the brain made of?**
- **How does the brain change in disease?**
- **How do neurons talk to each other?**
- **How does the brain compute?**
- **What will it mean to understand our brains?**

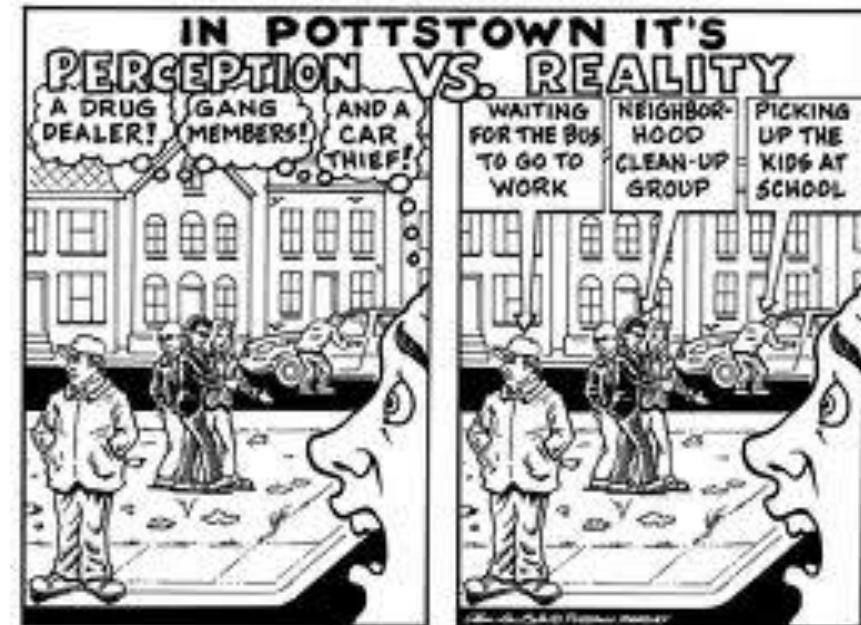
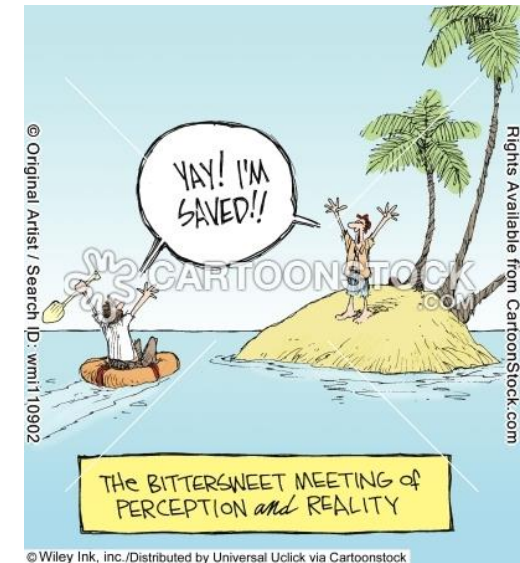
# Top unsolved or most researched topics in neuroscience

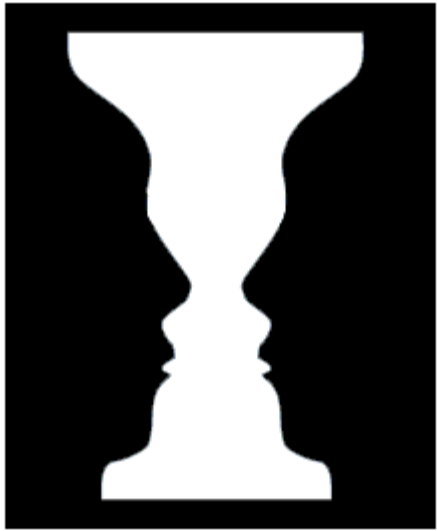
- Perception
- Consciousness
- Learning and memory:
- Neuroplasticity
- Development and evolution:
- Cognition and decisions
- Language
- Diseases



# Perception

- Sensory input into coherent (private) percept's.





# Consciousness:

Neuronal basis of:

- subjective experience
- Cognition
- Wakefulness
- Alertness
- Arousal
- Attention

# How do brains simulate the future?

Essentially, it asks: what is consciousness? Or how do we think?

Is simulation possible without learning & the experience that comes with learning?

Are we conscious of things we have no knowledge off ?

# MUST WATCH

- <http://www.youtube.com/watch?v=X4A6oHFLWSA>

\_ the interview with Nobel Laureate in Medicine, Dr Eric Randel.





# *The Brain*

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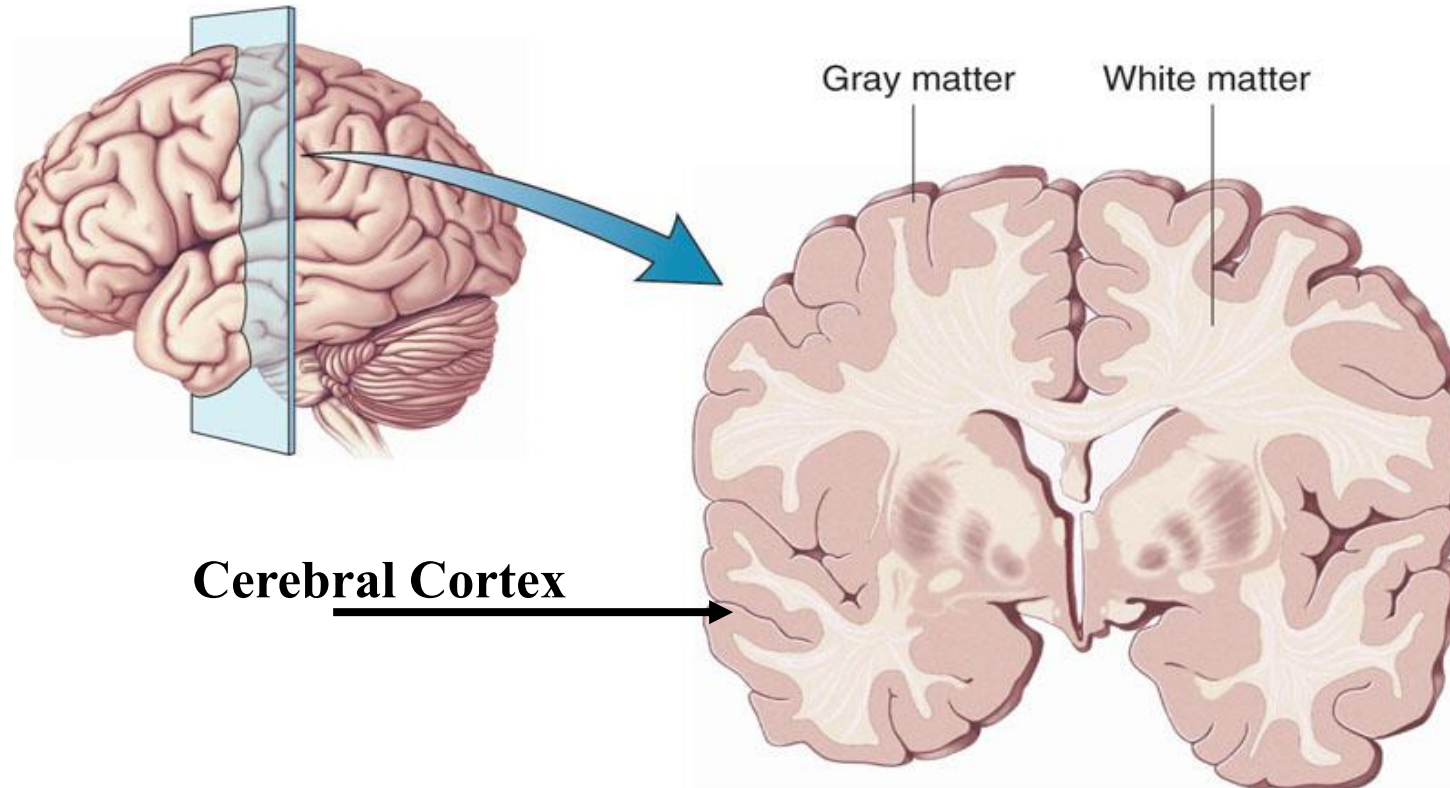
**Cerebrum** -The largest division of the brain. It is divided into two hemispheres, each of which is divided into four lobes.



# *The Brain*

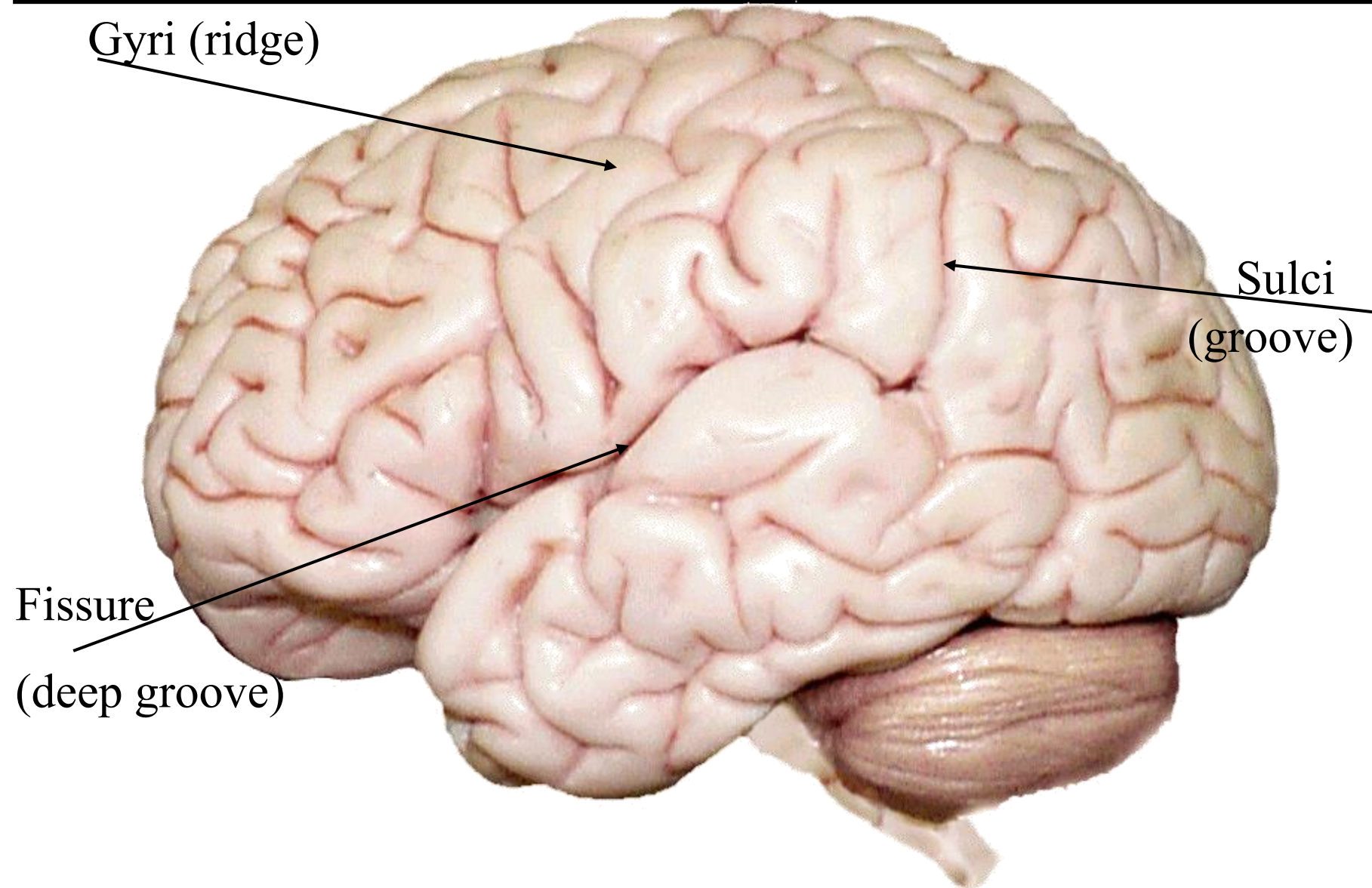
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Cerebral Cortex - The outermost layer of gray matter making up the superficial aspect of the cerebrum.



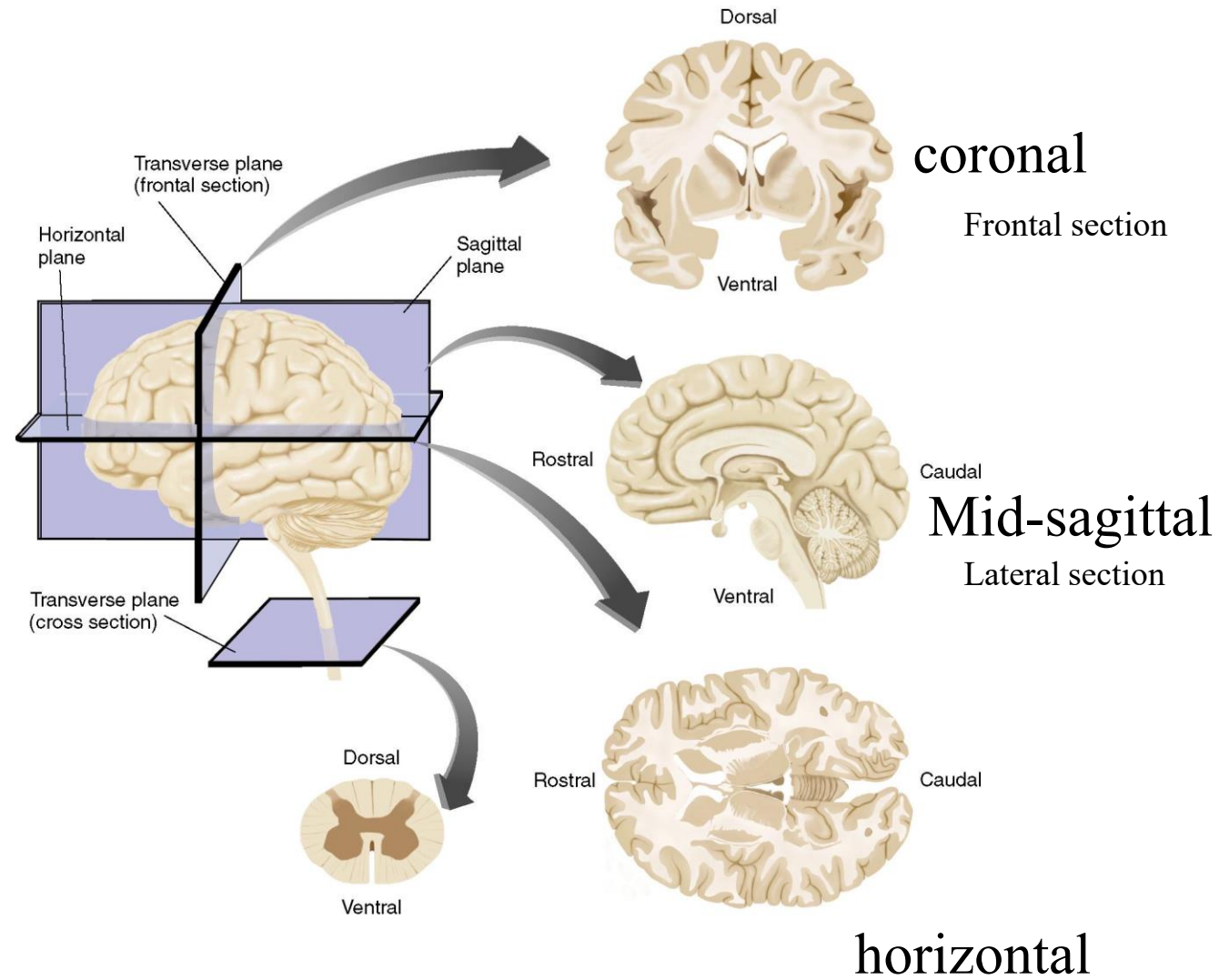
# *Landmarks*

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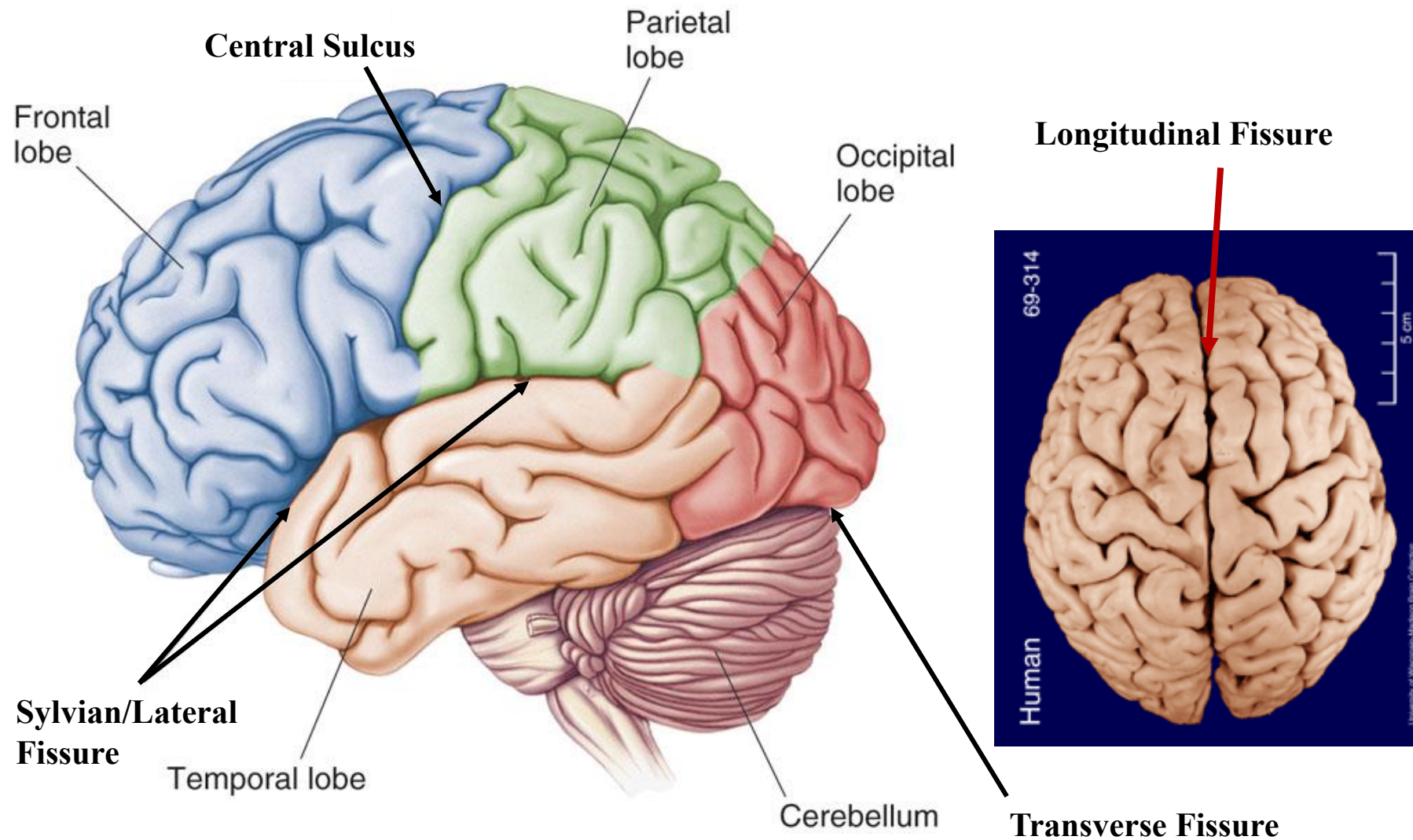
# *Sections of the brain*

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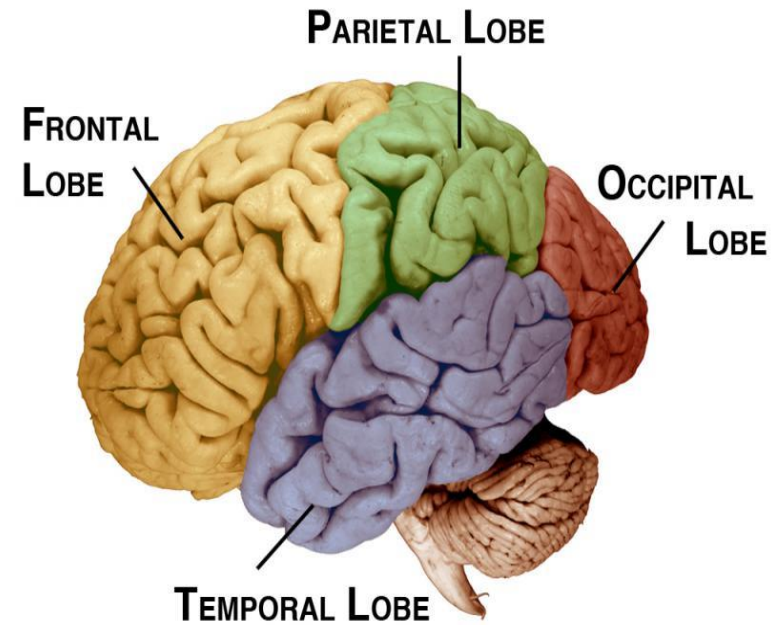
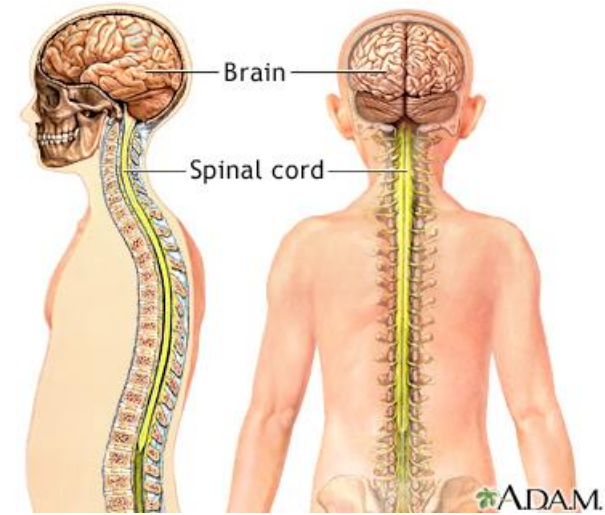
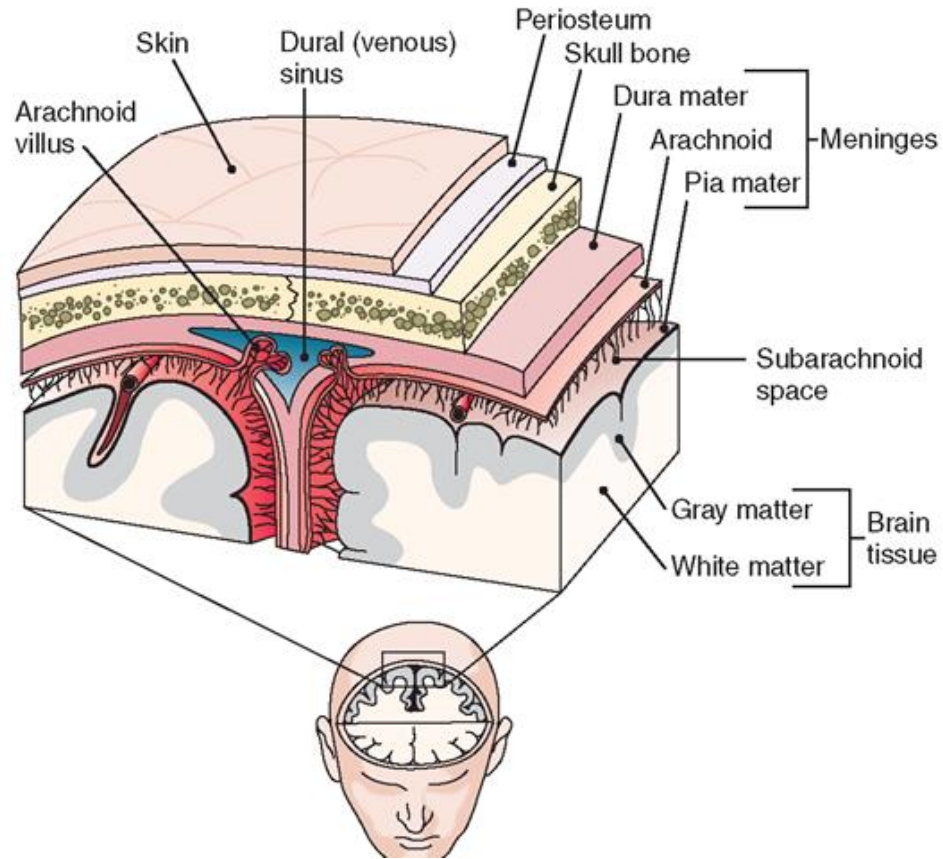




# Landmarks & Lobes



# Brain structure



# *Human Brain*

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2% of the body weight, 3 pounds approx.

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25% of body's oxygen

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70% of glucose

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Never rests and its metabolic rate in both day and night is more or less the same.

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In dreams in fact, the metabolic rate increases slightly

# Hierarchical Brain



Represents approx. 500 million years of evolutionary development and fine tuning.



Core structures of brain are the same in all vertebrates

They govern the physiological functions



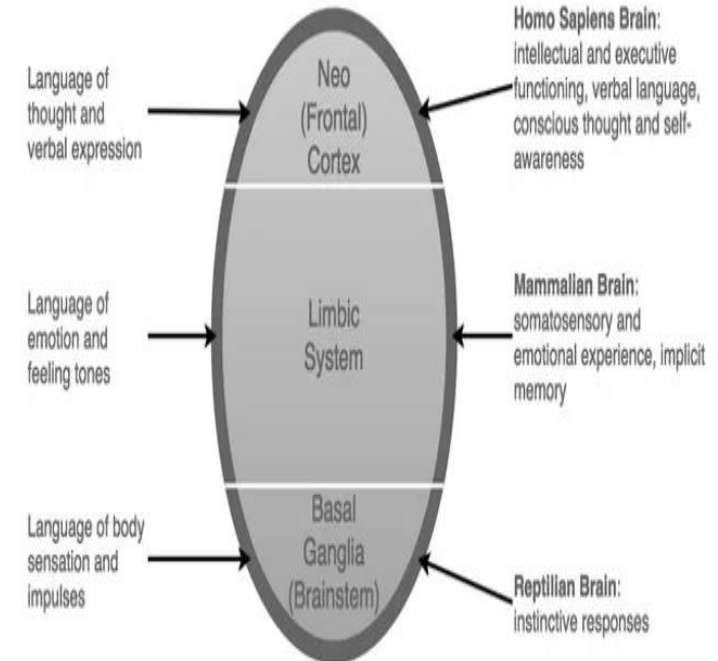
Built upon these are newer systems that involve complex functions – sensing, emoting, thinking, reasoning etc.



Triune brain (Paul MacLean)

Reptilian complex  
Paleomammalian complex (limbic system)  
Neomammalian complex (neocortex)

## The Triune Brain One mind, three brains





# Levels of Organization

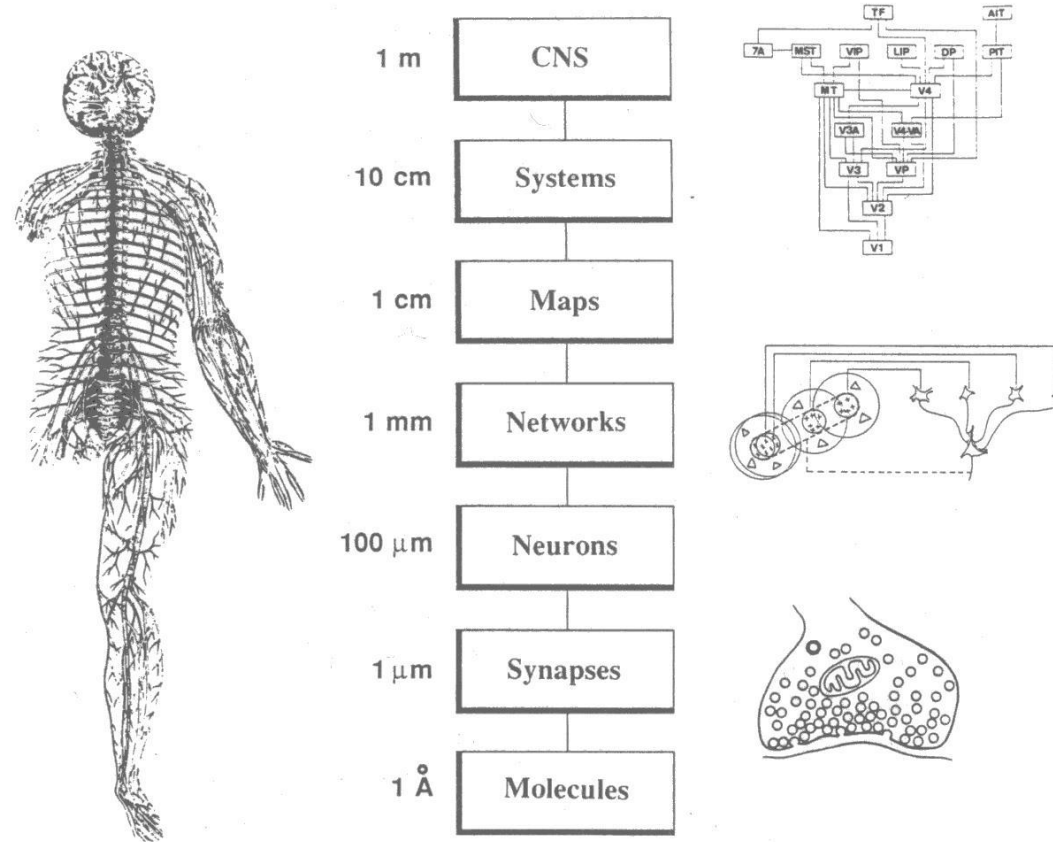
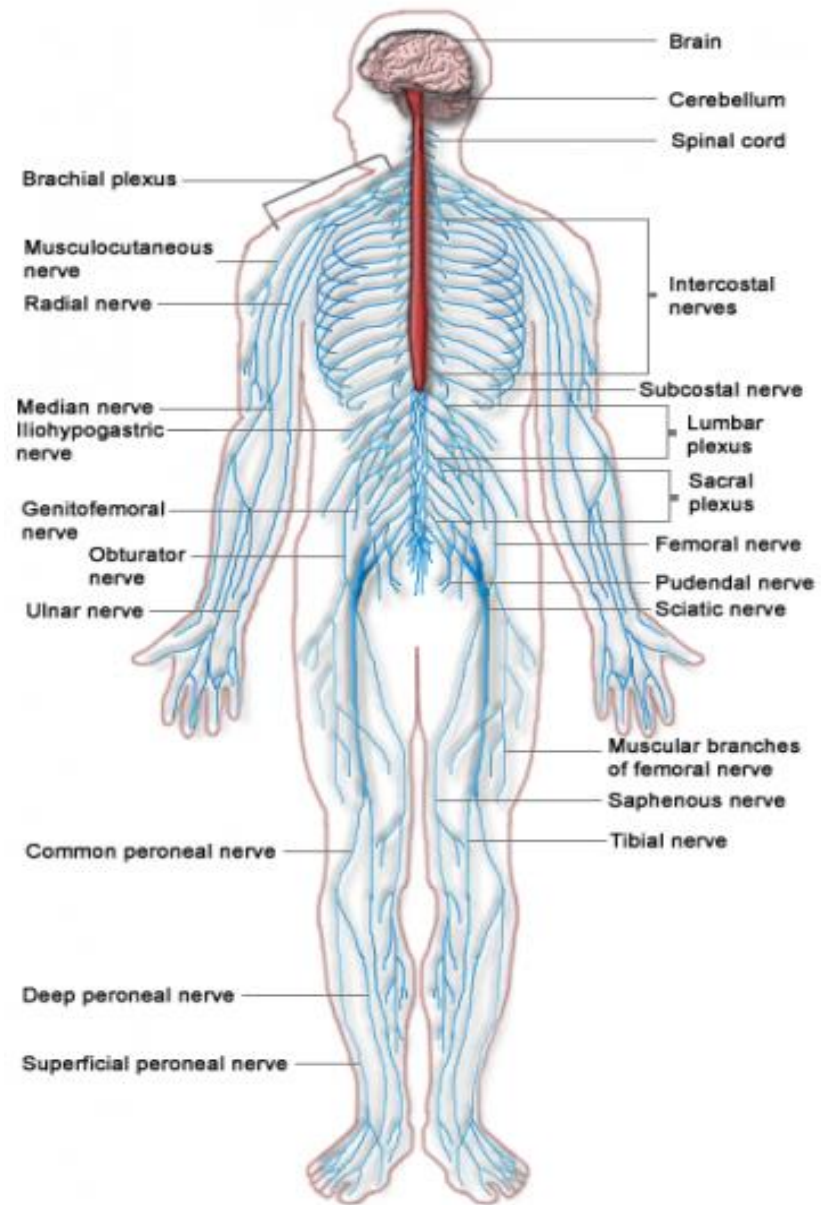
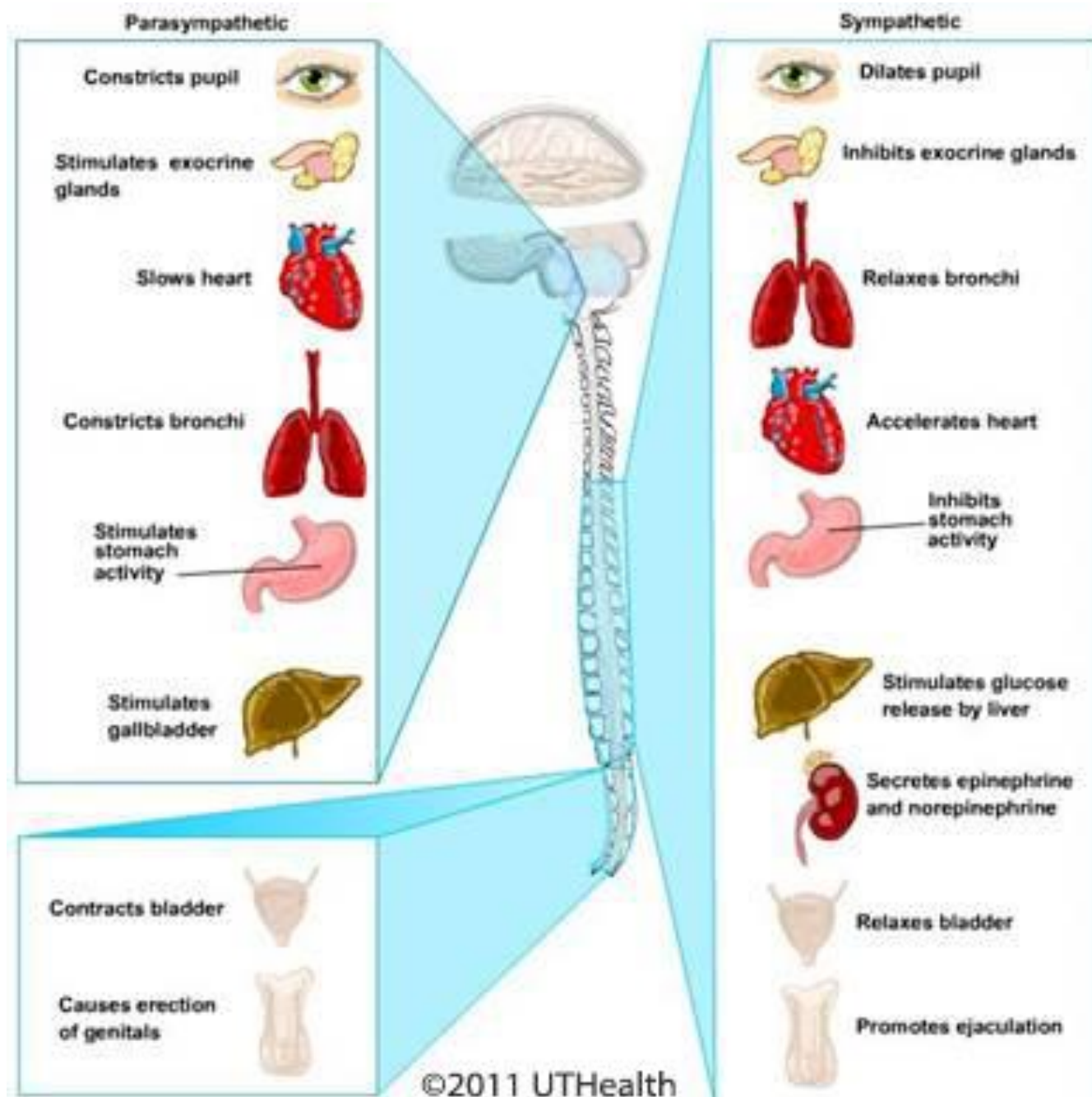


Figure 1.4 Schematic illustration of levels of organization in the nervous system. The spatial scales at which anatomical organizations can be identified varies over many orders of magnitude. Icons to the right represent structures at distinct levels: (top) a subset of visual areas in visual cortex (van Essen and Maunsell 1980); (middle) a network model of how ganglion cells could be connected to simple cells in visual cortex (Hubel and Wiesel, 1962), and (bottom) a chemical synapse (Kandel and Schwartz, 1985). (From Churchland and Sejnowski 1988.)

The CNS : brain & spinal cord





# Levels of Organization

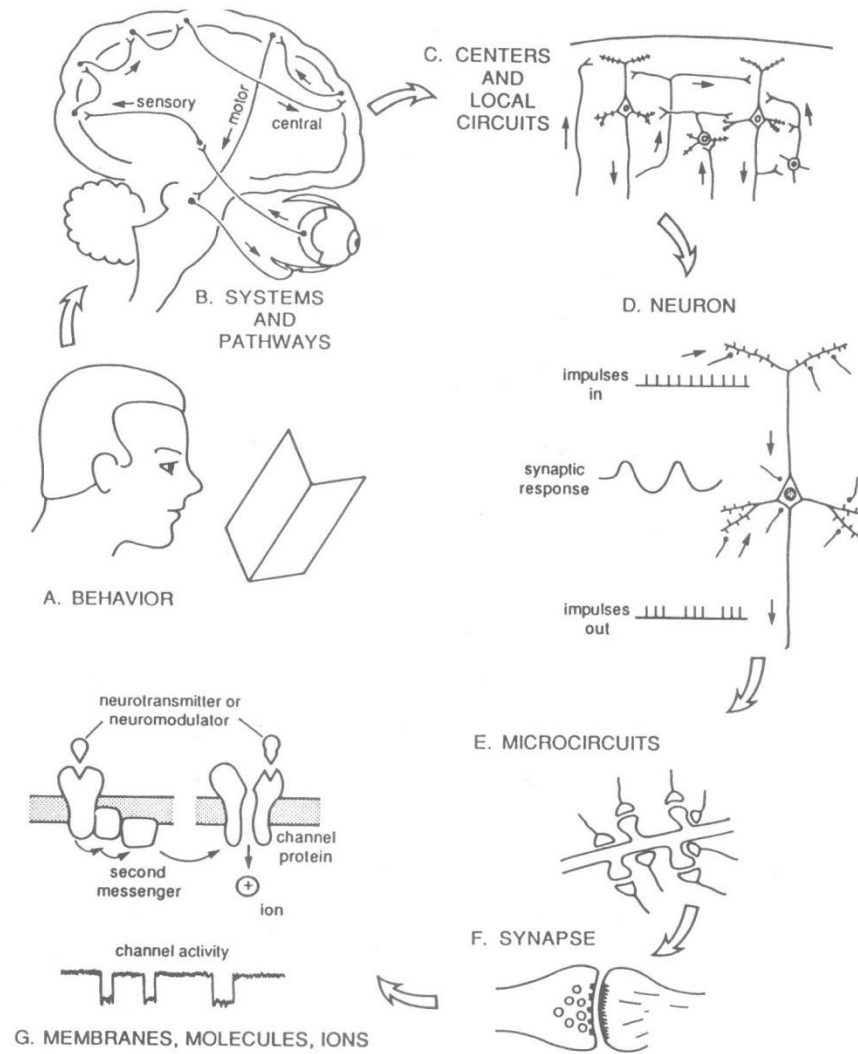


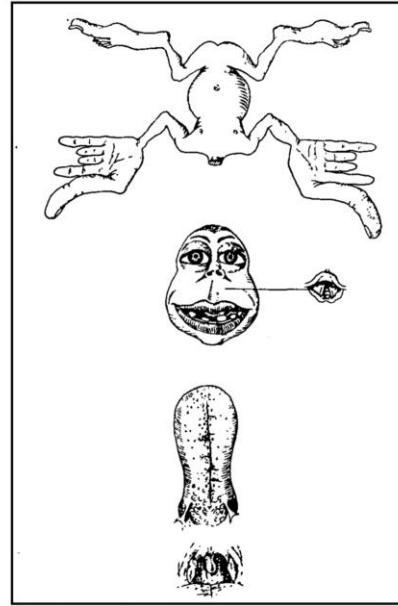
Figure 2.1 Levels of organization in the nervous system, as characterized by Gordon Shepherd (1988a).



Wilder Penfield



Edwin Boldrey



1 December 1937

Reinforced cortical localization as a valid paradigm to understand motor cognition, somatosensory perception and higher cognitive functions

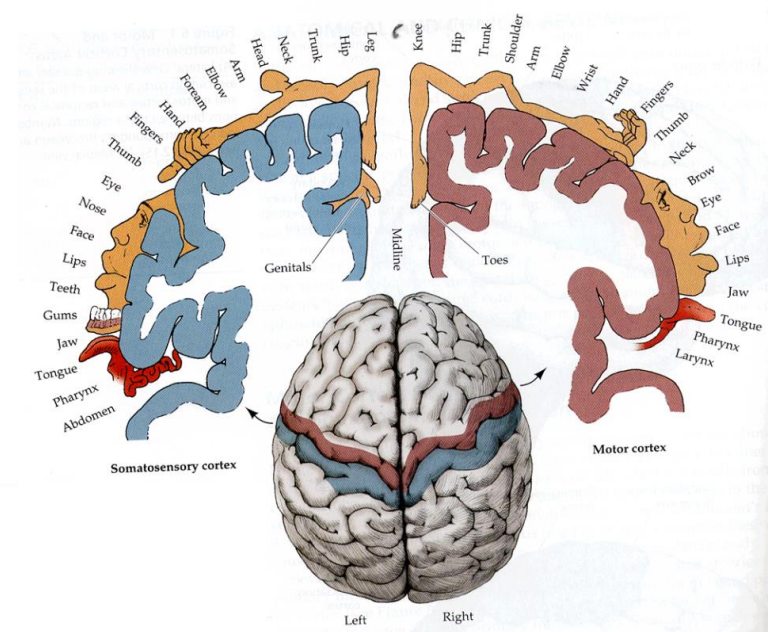
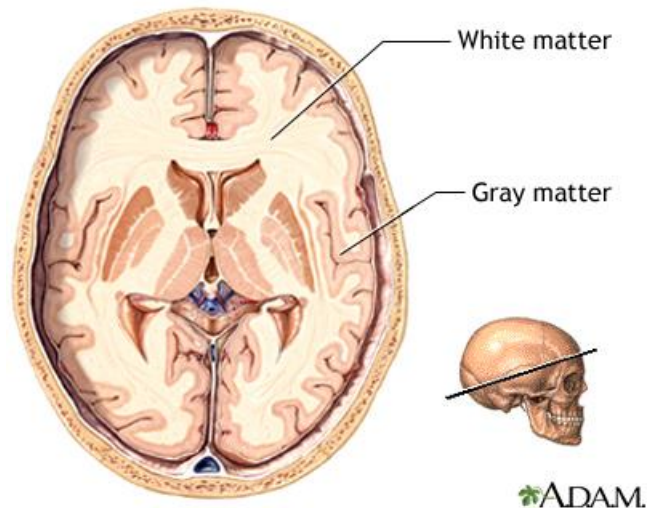
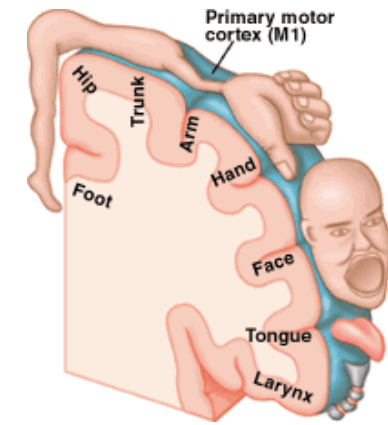
From: A little man of some importance

Brain. 2017;140(11):3055-3061. doi:10.1093/brain/awx270

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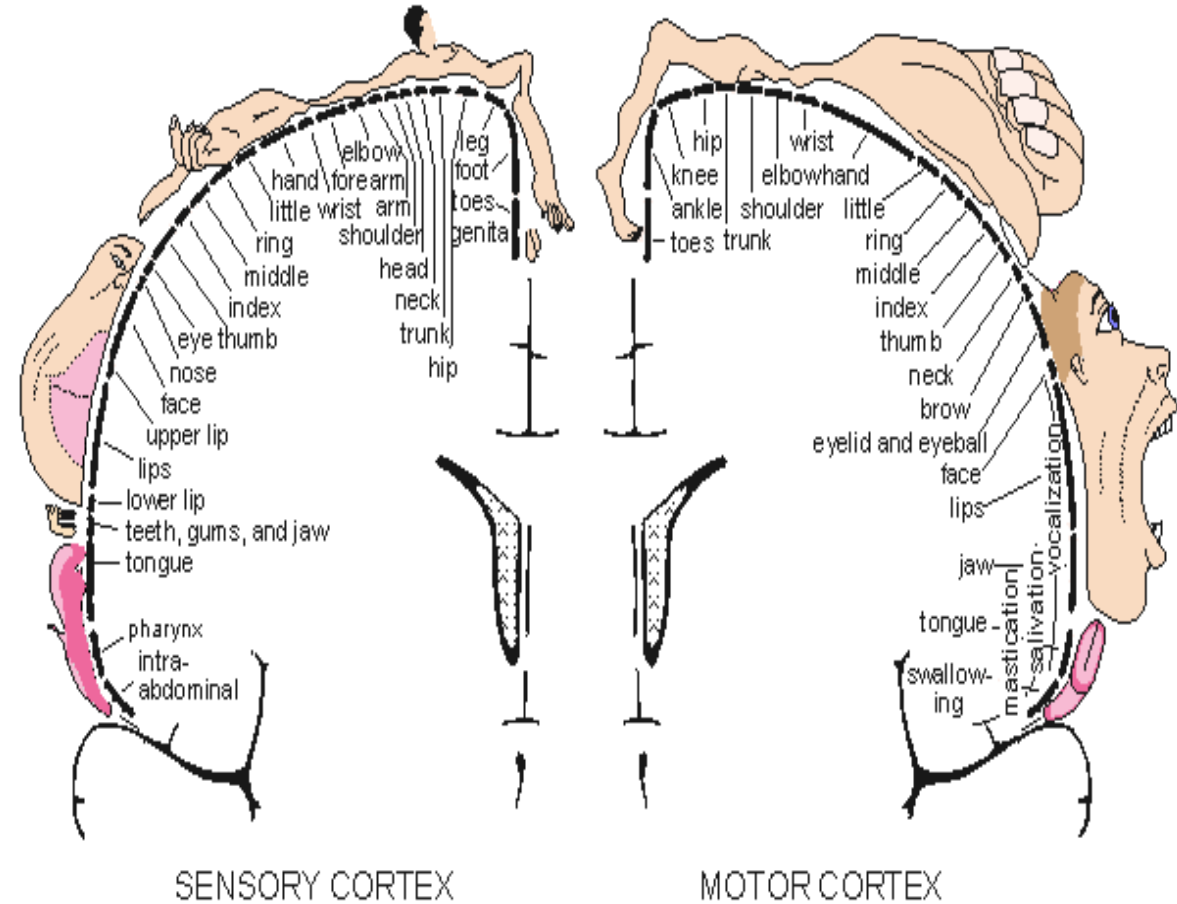
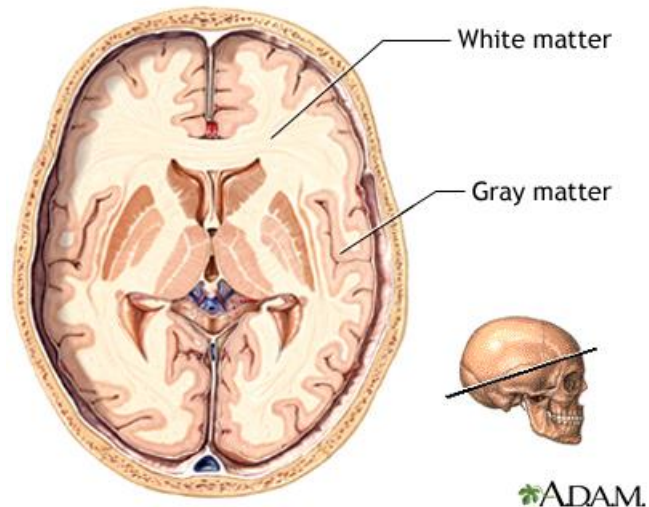


# Homunculus

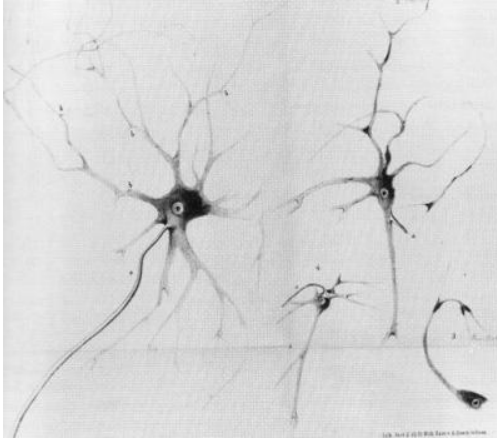


<https://www.youtube.com/watch?v=CTSNgphMZzk>

Watch this video!



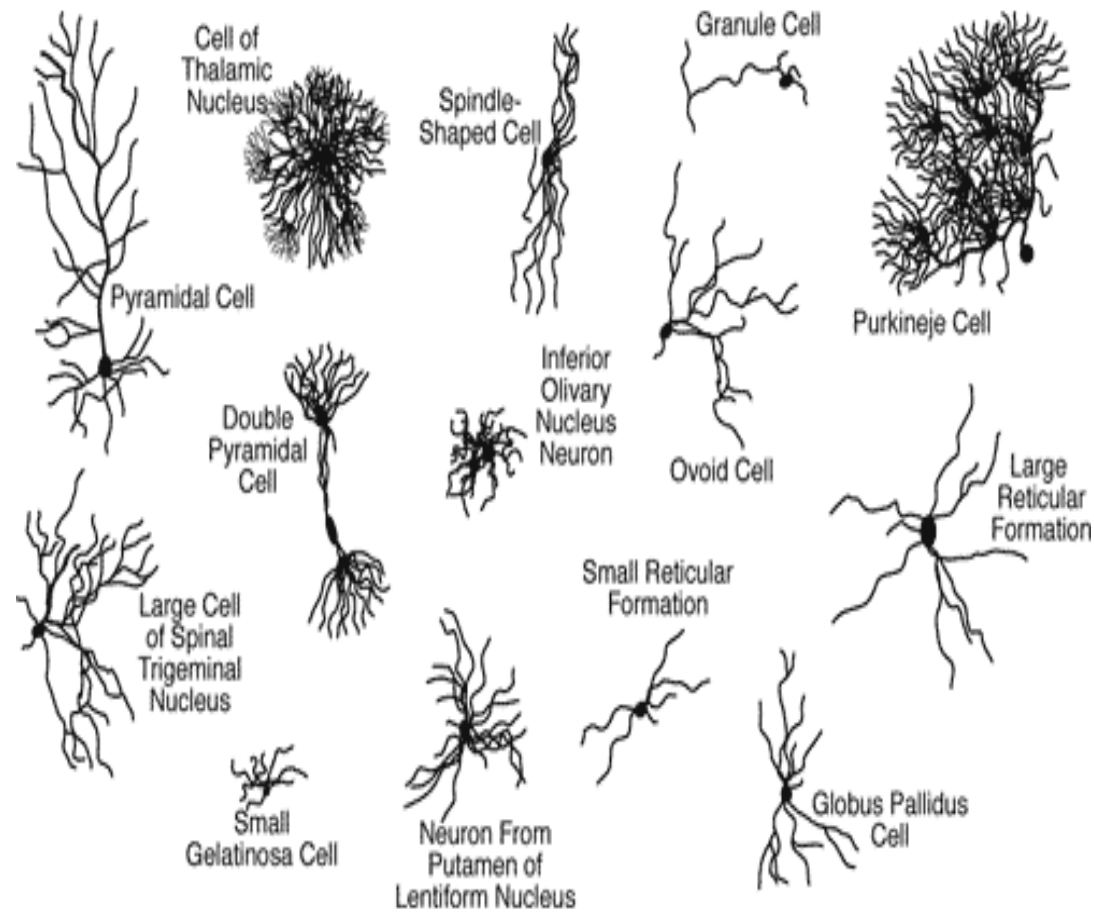
# Discovery of Neuron



Ramony Cajal and Camillo Golgi 1906 Noble Price

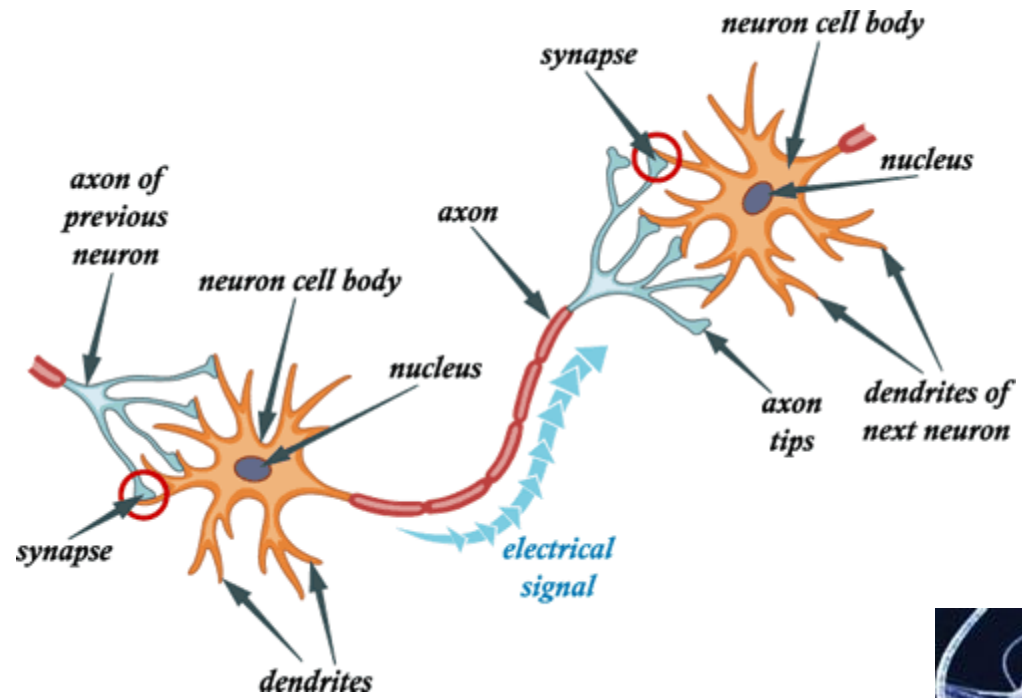


# Types of neurons



- Motor Neurons
- Sensory Neuron
- Interneurons

# neuron



# Neurons and Action Potentials

<https://www.youtube.com/watch?v=oa6rvUJlg7o>

<https://www.youtube.com/watch?v=OvVI8rOEncE>

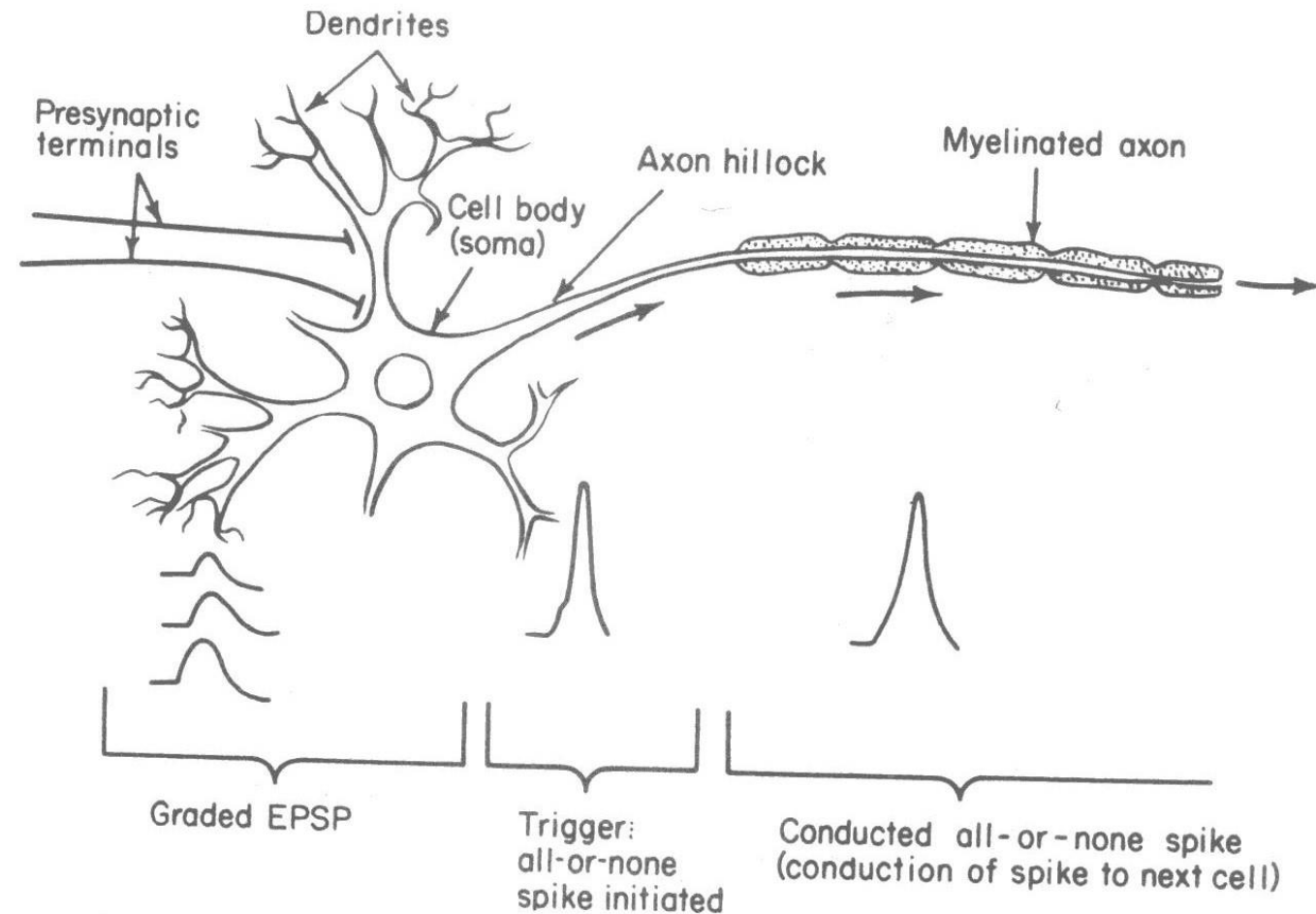
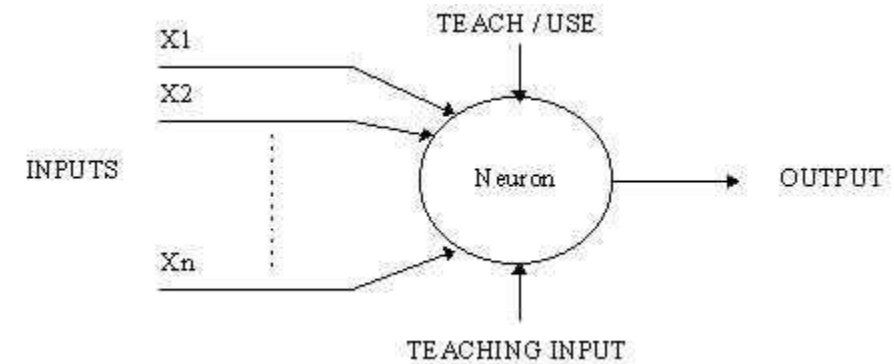
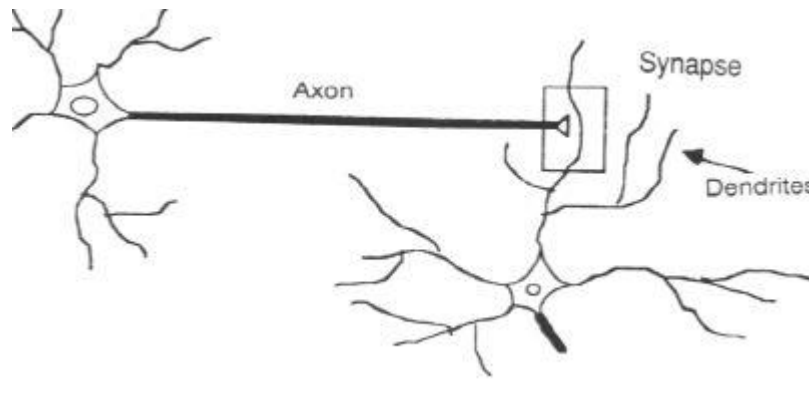
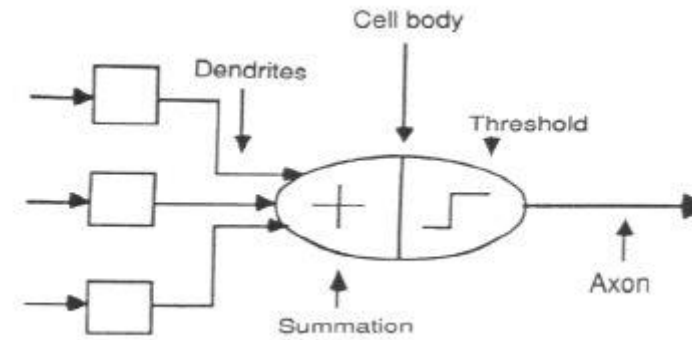
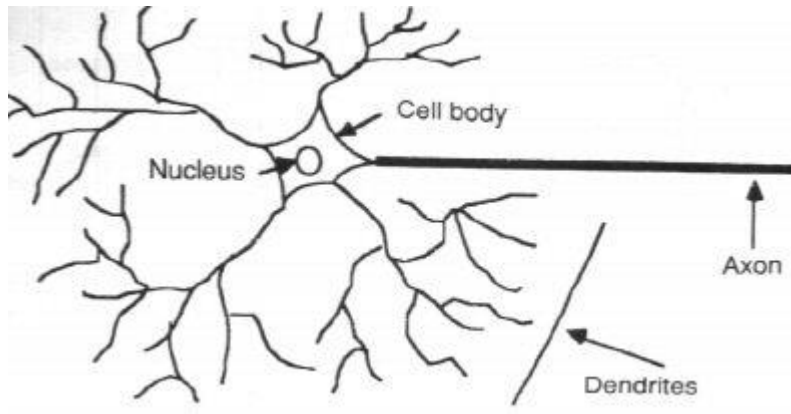


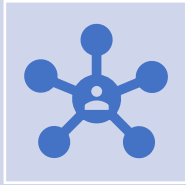
Figure 2.19 Summary diagram showing the location on a motor neuron of various electrical events. In many neurons, dendrites and cell bodies respond with graded EPSPs or IPSPs; the action potential is triggered in the axon hillock and travels undiminished down the axon. (From Thompson 1967.)



*Estimates of the human brain's **memory capacity** vary wildly from 1 to 1,000 terabytes (for comparison, the 19 million volumes in the US Library of Congress represents about 10 terabytes of data).*

# Organizing Principles

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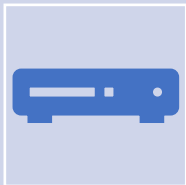
## Specialization of function

Modular organization of the function: Vision, motor, Language, etc.



## Numbers:

Approx.  $10^{12}$  neurons;  
 $10^{15}$  synapses; 1 mm<sup>3</sup> of cortical tissue has  $10^5$  neurons  $10^9$  synapses.



Input is analog (membrane potential is continuous valued) and Output is discrete (neuron spikes or not)

# Organizing Principles

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- Timing:
  - Action Potential (AP) lasts about 1 msec.
  - Synaptic Transmission takes about 5 msec
  - Synaptic potentials last from a millisecond to several minutes
  - Transmission velocity in myelinated axons is  $\sim 10\text{-}100$  meters/sec; in unmyelinated axons is  $< 1$  m/sec
    - Reaction times (*the time elapsed from the onset of stimulus to the onset of reaction of the system*) are around 50-60 msec (thus *switching time* of a neuron is order of milliseconds; processing speed is about 1KHz at 1 msec per operation!!)

# Organizing Principles

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## Receptive field (RF)

- RF is that *region of the sensory field from which an adequate sensory stimulus will elicit a response*
- Size:
  - Ex: Somatosensory: Smaller for fingers but Larger for arms
  - High resolution -> Smaller RF; Low resolution -> Larger RF
- Centre-Surround Organization

## Topographic Organization

## Parallel and Distributed Processing

# *Von Neumann Computer vs Brain*

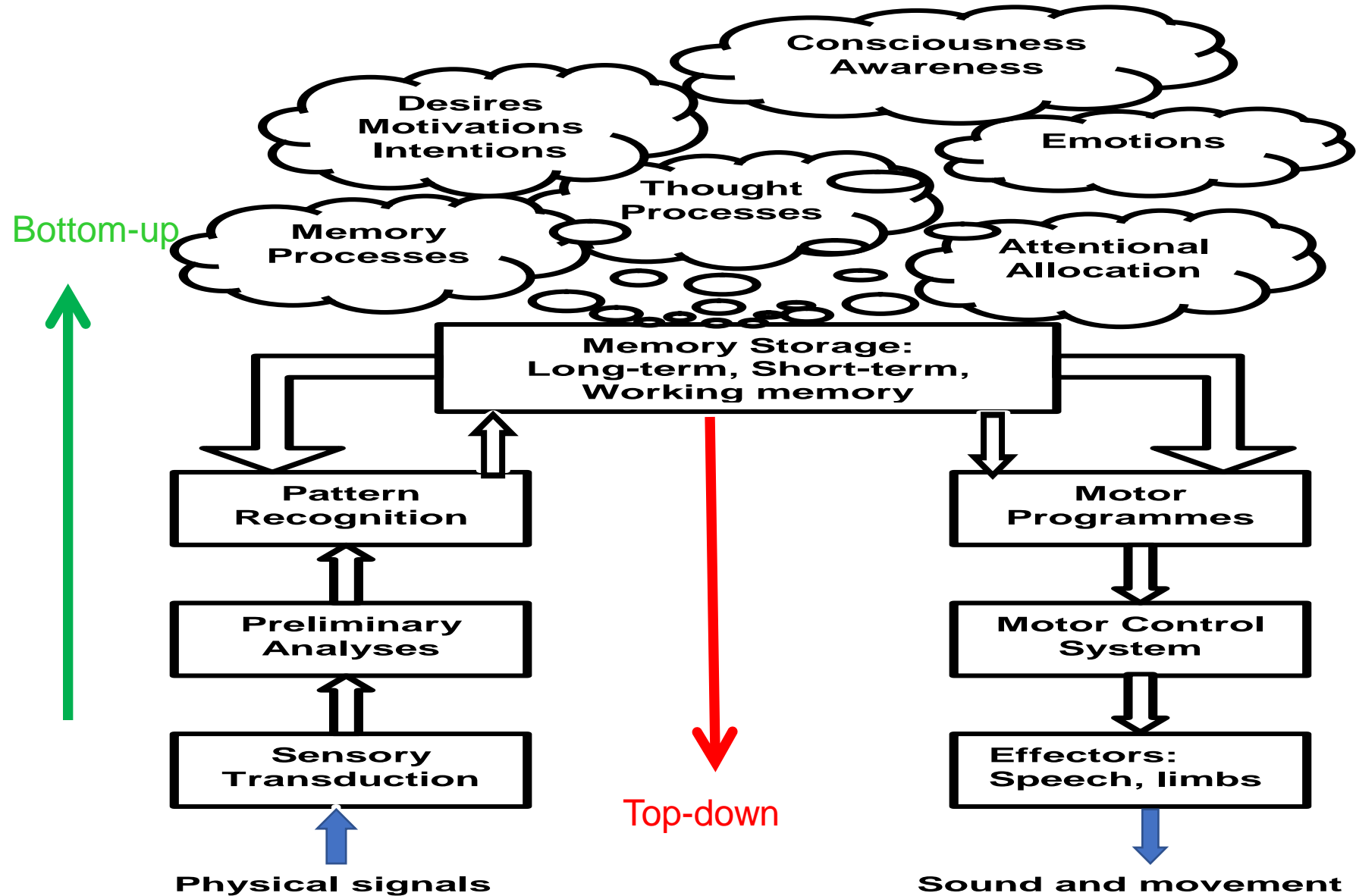
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	Von Neumann computer	Biological computer
Processor	complex	simple
	high speed	low speed
	one or a few	large number
Memory	separate from processor	integrated into processor
	localized	distributed
	non-content addressable	content addressable
Computing	centralized	distributed
	sequential	parallel
	stored programs	self-learning
Reliability	very vulnerable	robust
Expertise	numerical and symbolic manipulations	perceptual problems
Operating environment	well-defined, well-constrained	poorly-defined, unconstrained



# *Human Information Processing System*

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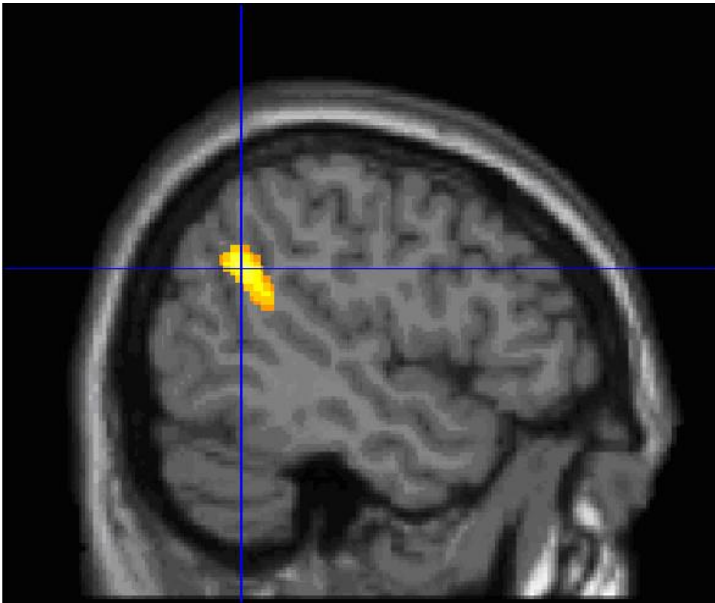


Interesting.....for discussions only

# Dreams

Recalling dreams: The high-recallers and the low-recallers.

- temporo-parietal junction (information-processing hub and attention orienting toward external stimuli) and medial prefrontal cortex



*Credit: © Perrine Ruby / Inserm*

# Visual/mental imagery & vivid projections of images internally!

- The Question is: how is the image formed, stitched and presented.
- Or is visual imagery really visual?



# Sleep walking



- Brutal act: Case of Scott Falater – 43 year old who stabbed his wife & ducked her in the pool in 1997. When interrogated, he claimed does not recall the complete act - When he was tried, the prosecution claimed that after the murder had been committed, Falater changed his clothes, put the murder weapon in a Tupperware container, put the container in a trash bag with his boots and socks, stashed the bag in the spare tire well in the trunk of his car, and took and hid all the items that showed that he was the person who killed her.
- On June 18, 1999 a prosecution expert testified that Falater's actions were "too complex" to have been carried out while sleepwalking. Four weeks later, Scott Falater was found guilty of first degree murder and sentenced to life in prison without chance of parole



## phantom limbs

- the vivid impression that the limb is not only still present, but in some cases, painful.
- Patient recognizes that the sensations are an illusion(unreal vision) not a delusion (false beliefs).
- Case of elaborate sensory memories

Major debates

# Ongoing debates today

- Local versus widespread functions in the brain
- The neuron doctrine (*Advocates of the [neuron](#) doctrine claimed that the nervous system was composed of discrete cellular units. Proponents of the alternative reticular theory, on the other hand, argued that the entire nervous system was a continuous network of cells, without gaps or synapses between the cells*)
- The question of consciousness
- Unconscious inferences in vision
- Capacity limits in the brain
- Short-term and long-term memory: are they separate?
- The biological bases of emotions – to an extent established (the role of hormones & limbic lobe)
- Nature *versus* nurture, genes *versus* environment



# Interesting titbits & myths

- The fastest (simple) reaction time to a stimulus is about 100 milliseconds, and the time it takes for a sensory stimulus to become conscious is typically a few hundred milliseconds.
- Until Andreas Vesalius, a Belgian physician (1514 – 1564), it was widely believed that women had one less rib than men, based on the Biblical story of Adam and Eve.
- Descartes is often considered to be the originator of modern mind/body philosophy.