University of Reading

A bit of neuroanatomy

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2019–2020

Who am I?

- I am French, but relatively fluent in English.
- Associate Professor of Cognitive Science = Background oscillating between Software Engineering and Psychology.
- My office is in Psych Harry Pitt 272. Office hours: Mon 11:00-13:00 or http://doodle.com/meetwithetienne
- I am married to wonderful Mina and amazingly cute Alexis.
- I tend to be very busy and I suck at email, but that shouldn't stop you.
- I will use BlackBoard, but I am really not a big fan.

PYM0FM is a difficult module, on purpose.

- Aims
  The purpose of this module is to provide students with practical experience of analysing fMRI data. The module interweaves lectures and hands-on experience of data processing, using the University cloud computing infrastructure. Students will familiarise themselves with each step of a typical processing pipeline, learn how to script and automate analyses, and be introduced to the best practices in reproducible neuroimaging.

PYM0FM is a difficult module, on purpose.

- Assessable learning outcomes

By the end of the course, students should be able to:

1) Understanding theoretical issues in fMRI data analysis (e.g., haemodynamic response, motion and other artifacts in the time series, the multiple statistical comparisons problem)
2) Understand and perform preprocessing of fMRI time series (e.g., realignment, registration to standard space, spatial smoothing)
3) Set up a general linear model capturing experimental and nuisance effects in data and try out one or more ways of fitting the model to the data
4) Understand and navigate coordinate system for reporting activations (stereotaxic space)
5) Make statistical comparison of activation level across the brain between two experimental conditions (contrasts, t-test) for a single subject
6) Compare activation in two experimental conditions at the group level

Before Hippocrates, our understanding was all over the place.

- Thoughts/feelings were associated to different organs of the body—see acupuncture.
- Theories are reflective of their time and the knowledge available then—this is very true today.
- Egyptians did not consider the brain actually mattered, and did not preserve it with other organs for mummification.

After Hippocrates, our understanding was still all over the place.

- Hippocrates (BC 460–370) first ascribed sensations and intelligence to the brain.
- Galen (AD 129–199/217) proposed humous (fluid) theory
  Personality traits are due to different concentrations of humours.
- Descartes (1596–1650) describes Mind-Body relationship
  — The body and the brain are made of “pipes” that transport the “spirit”; pineal gland is the core.
  — Dualism: Mind (immaterial) and Body (material) are separate entities, but they interact
- Willis (1621–1675) linked brain damage to specific behavioural deficits.

The Moderns started to focus (a bit too much).

- Gall (1758–1828) founds Phrenology
  The brain is organised around functions
  (e.g. perception, maths, self-esteem)
- Broca (1824–1880) demonstrates localizationism (Father Tan)
- Golgi (1843–1926) + Cajal (1852–1934)
  — (Nobel laureates)
  — Stain visualization techniques
  — The brain is a network of neurons
  — Neurons are functional units

The Post-Moderns started to get organised.

- 1850–1950 Behaviourism
  e.g. Pavlov, Watson, Skinner..
  "The science of the black box"; S → R
- 1950 Cognitive Revolution
  e.g. Miller, Marr, Gardner..
  Opening the "black box"; S → Brain → R
- 1970 Cognitive Neuroscience = NSci + Psychology
  Coined by Gazzaniga and Miller, at the back of a cab in New York

The “computational” perspective (Marr, 1982)

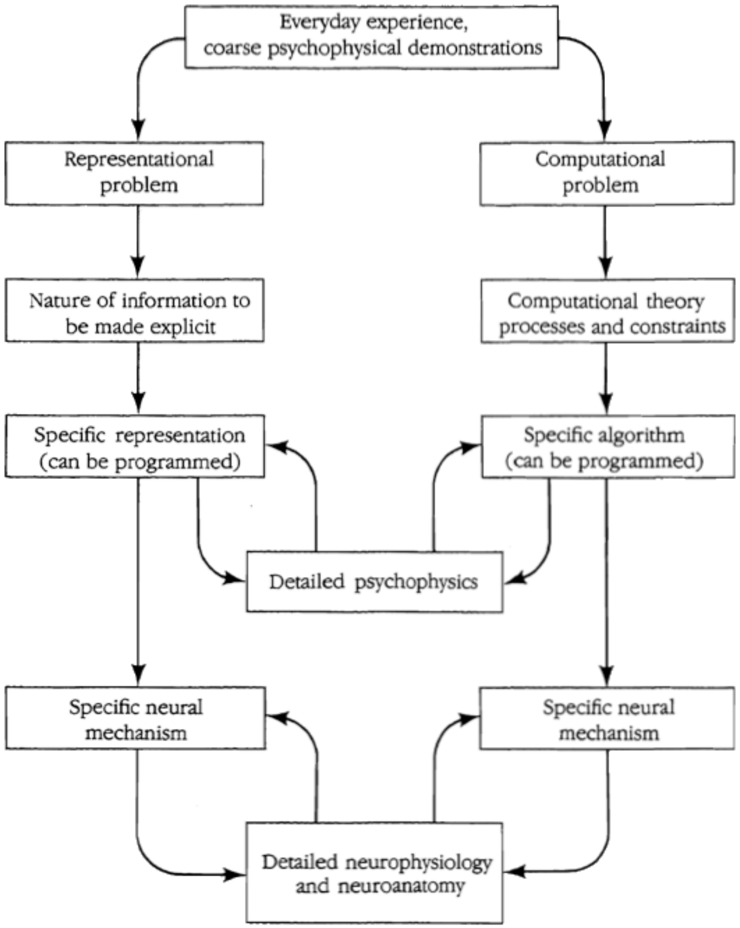


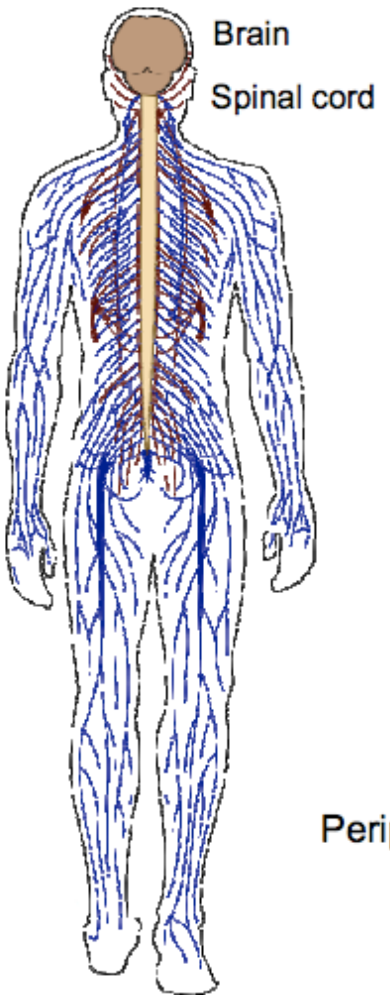
Figure 6–1. Relationships between representations and processes.

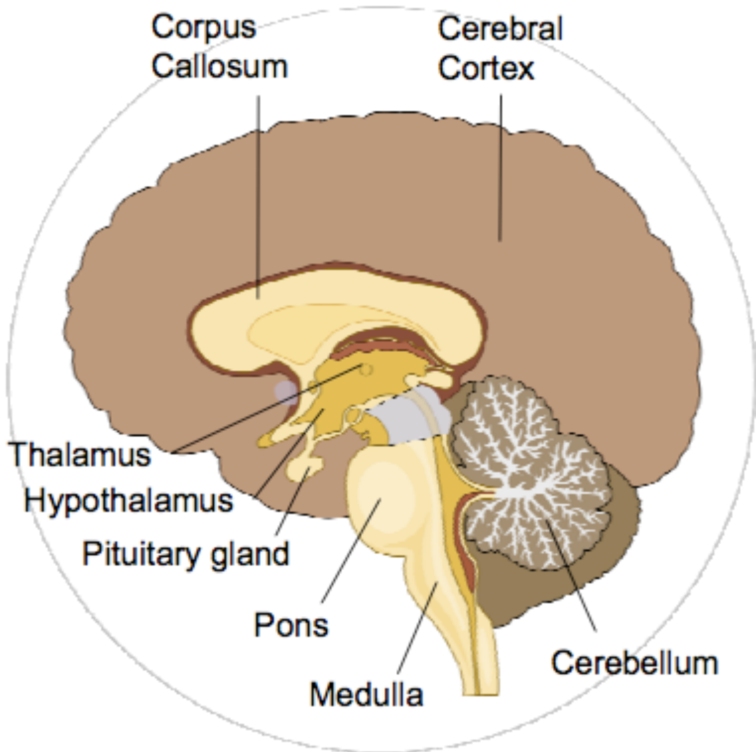
- Focus on the sequence of processes
- Separates the function from the implementation
- Brain != Computer

Definitions

	Cognitive Psychology	Cognitive Neuropsych.	Cognitive Neuroscience	Cognitive Science
Formal object: Healthy cognitive system	Yes	Yes	Yes	Yes
Computational perspective	Yes	Yes	Yes	Yes/No
Use data from “healthy” people	Yes	Yes (controls)	Yes	Yes
Use data from “patients”		Yes	Yes	Yes
Use data about the workings of the brain			Yes	Yes
Use any kind of data available				Yes

The nervous system(s) = ANS + CNS





Peripheral nervous system
Somatic (blue)
Autonomic (red)

The autonomic nervous systems (ANS)

- Sympathetic
  “spends energy”

- Para-sympathetic
  “regulates energy”

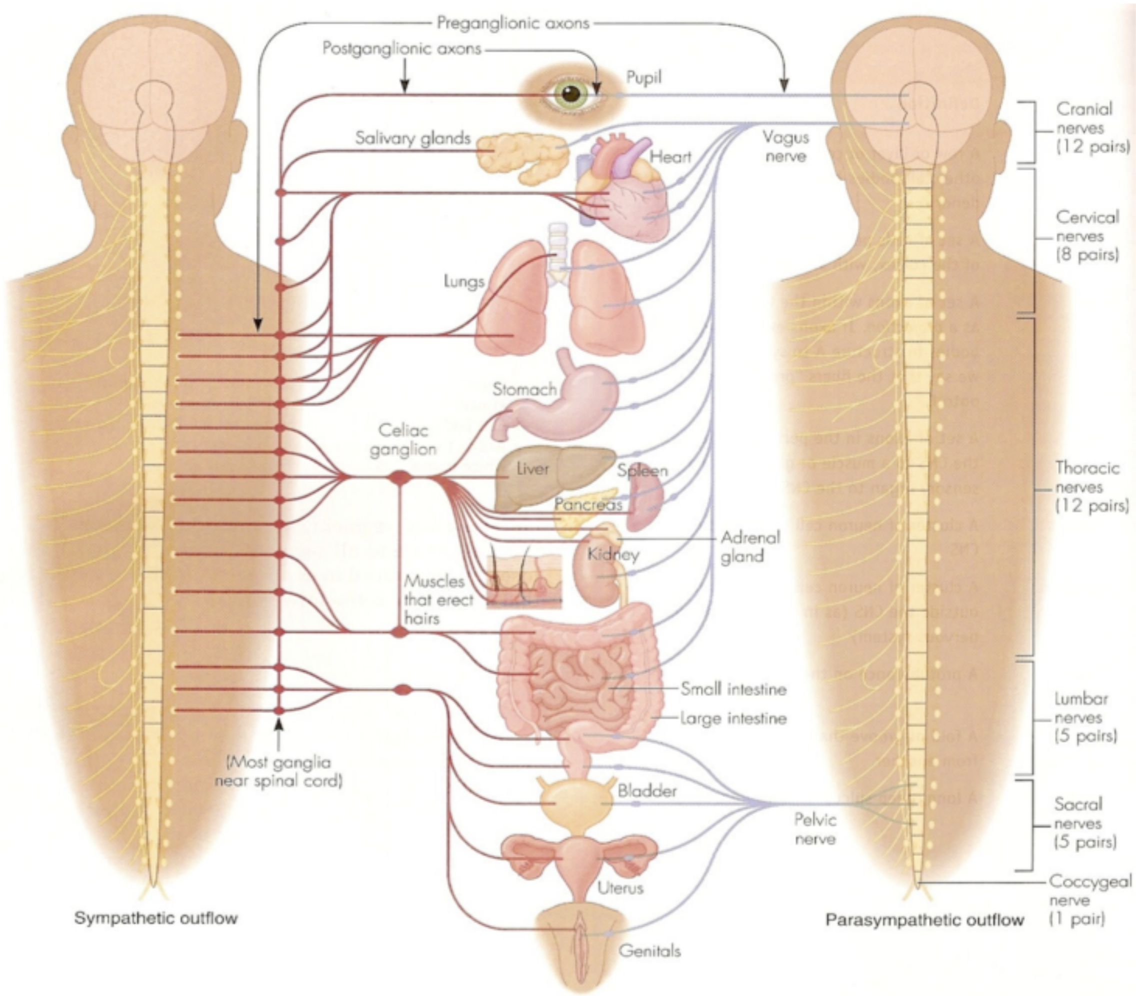
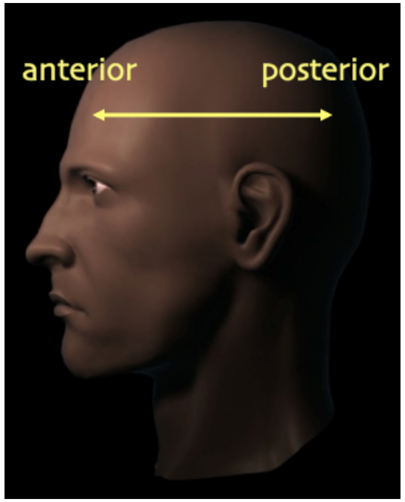
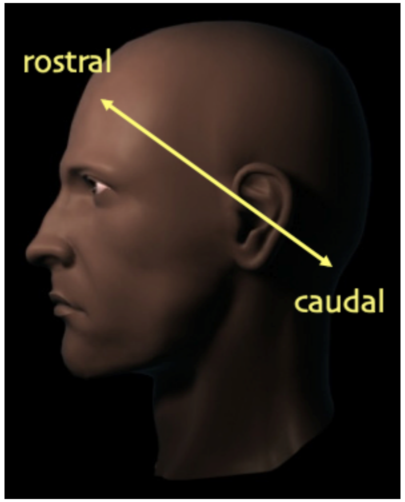
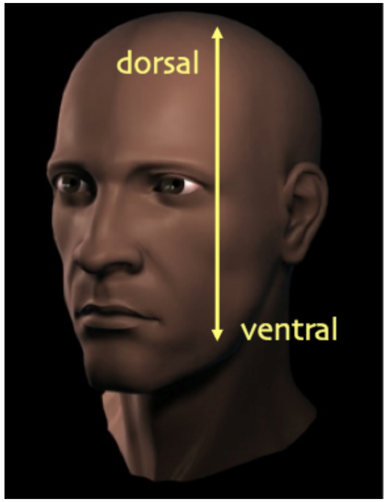


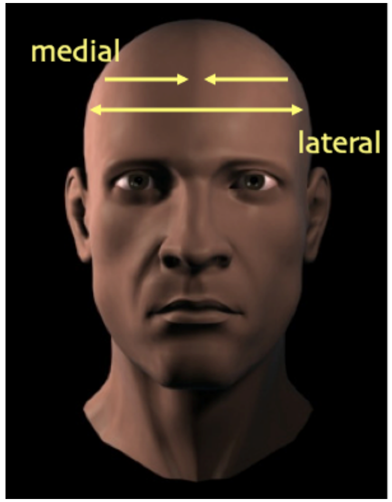
Figure 4.6 The sympathetic nervous system (red lines) and parasympathetic nervous system (blue lines)
Note that the adrenal glands and hair erector muscles receive sympathetic input only. *(Source: Starr & Taggart, 1989)*

The central nervous system (CNS)… is 3D.

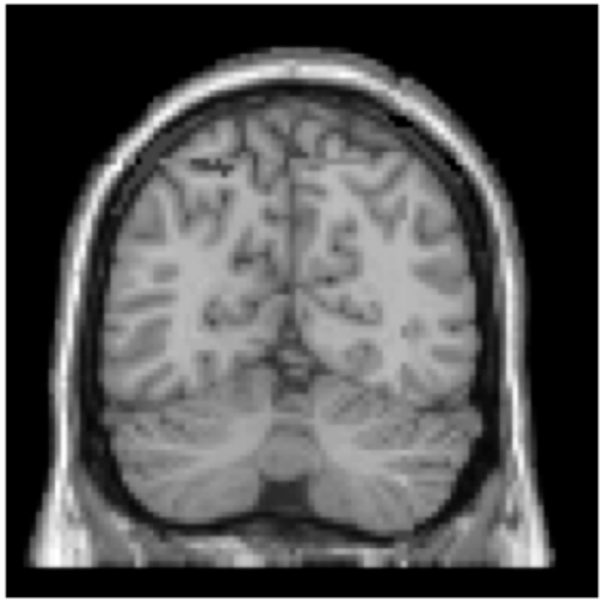


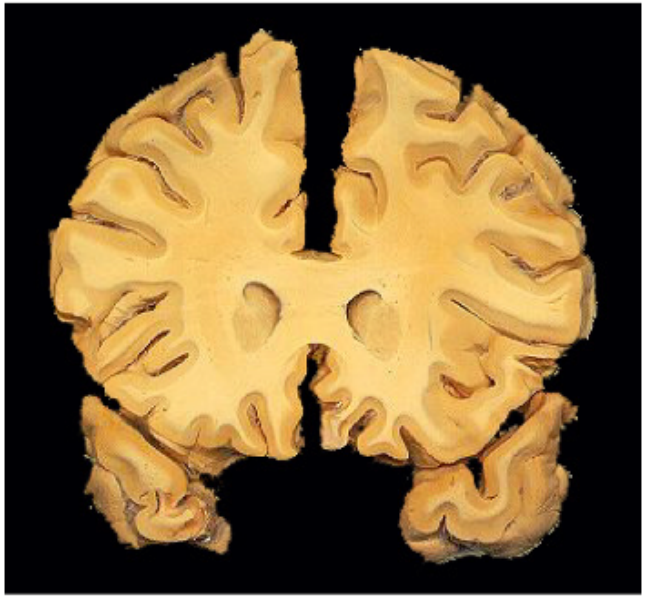




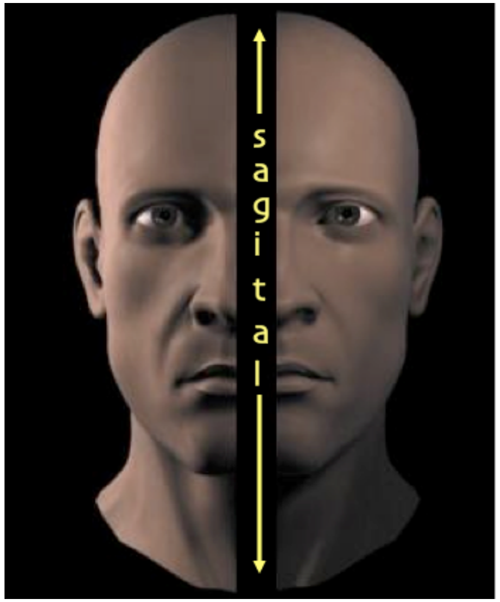


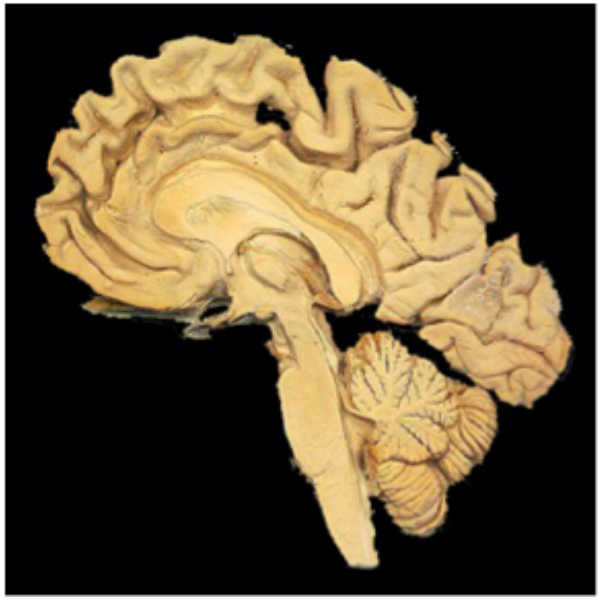
Coronal slicing



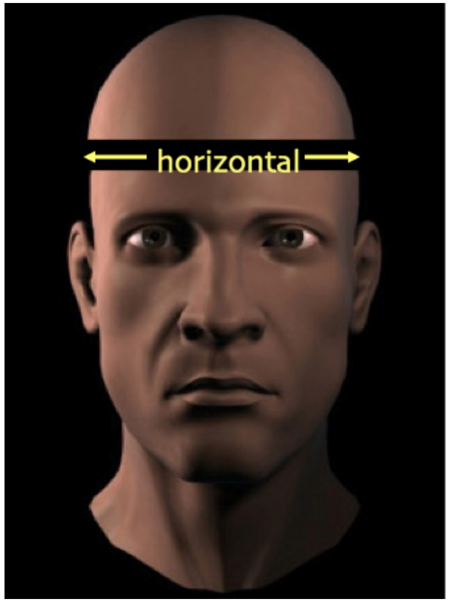


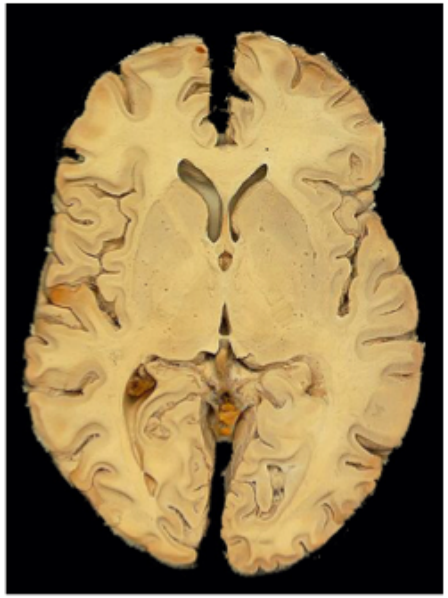
Sagital slicing



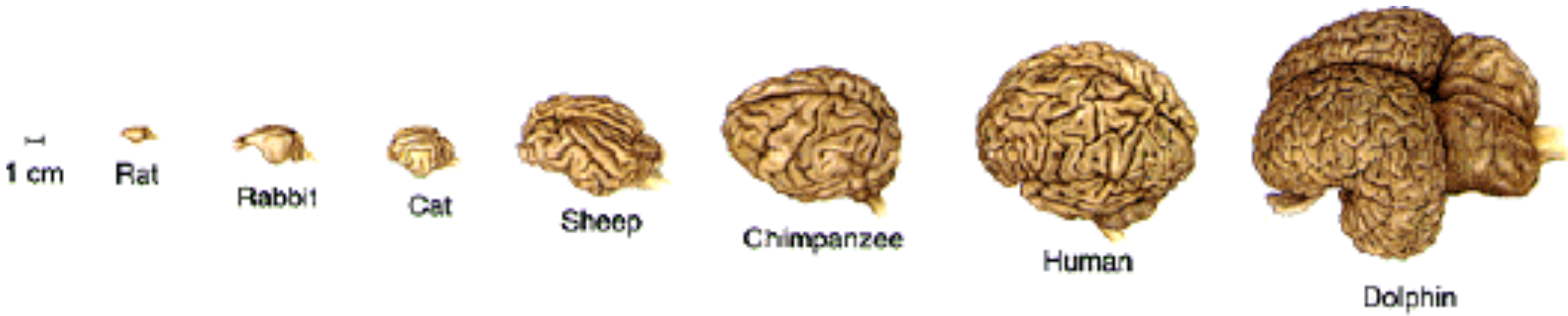


Horizontal slicing

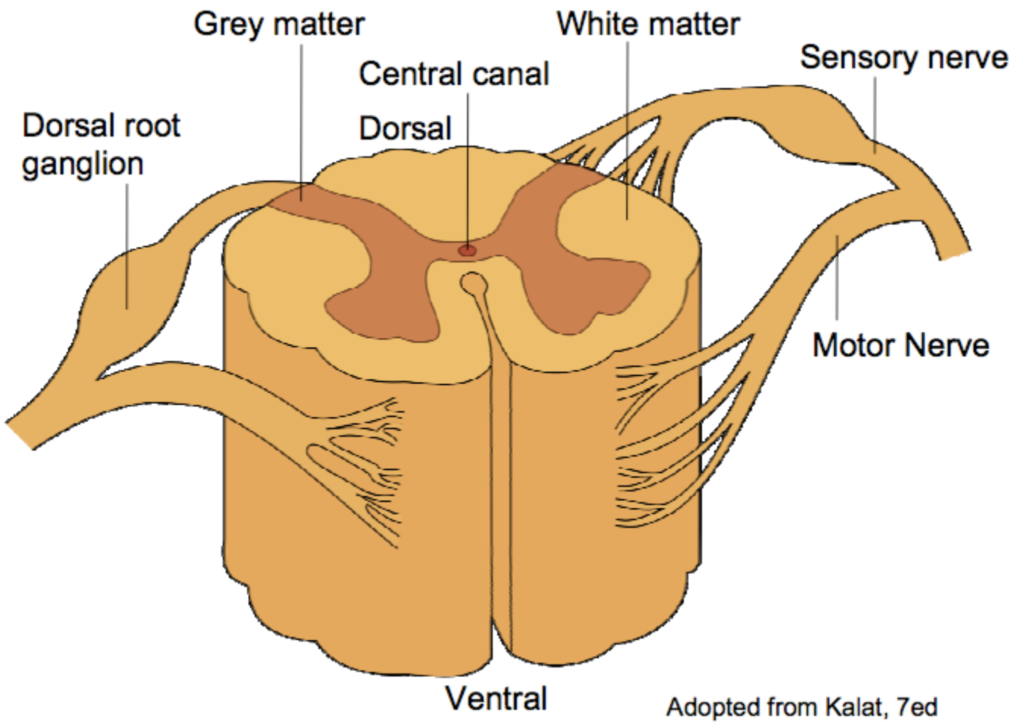




Size does not always matter.



The spinal cord hides the vertebrae.



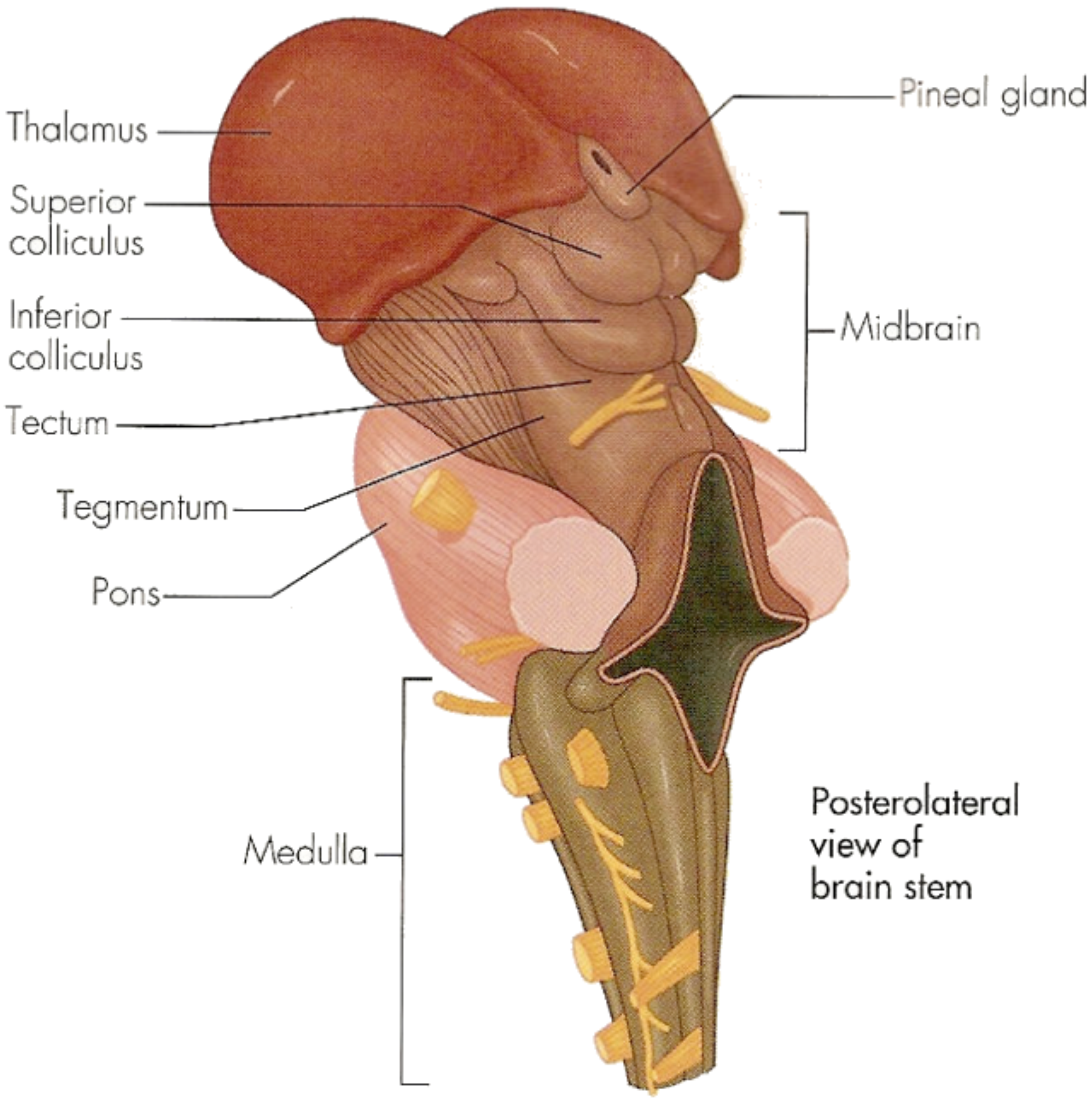
Part of the CNS within the spinal column

Communicates with muscles and organs

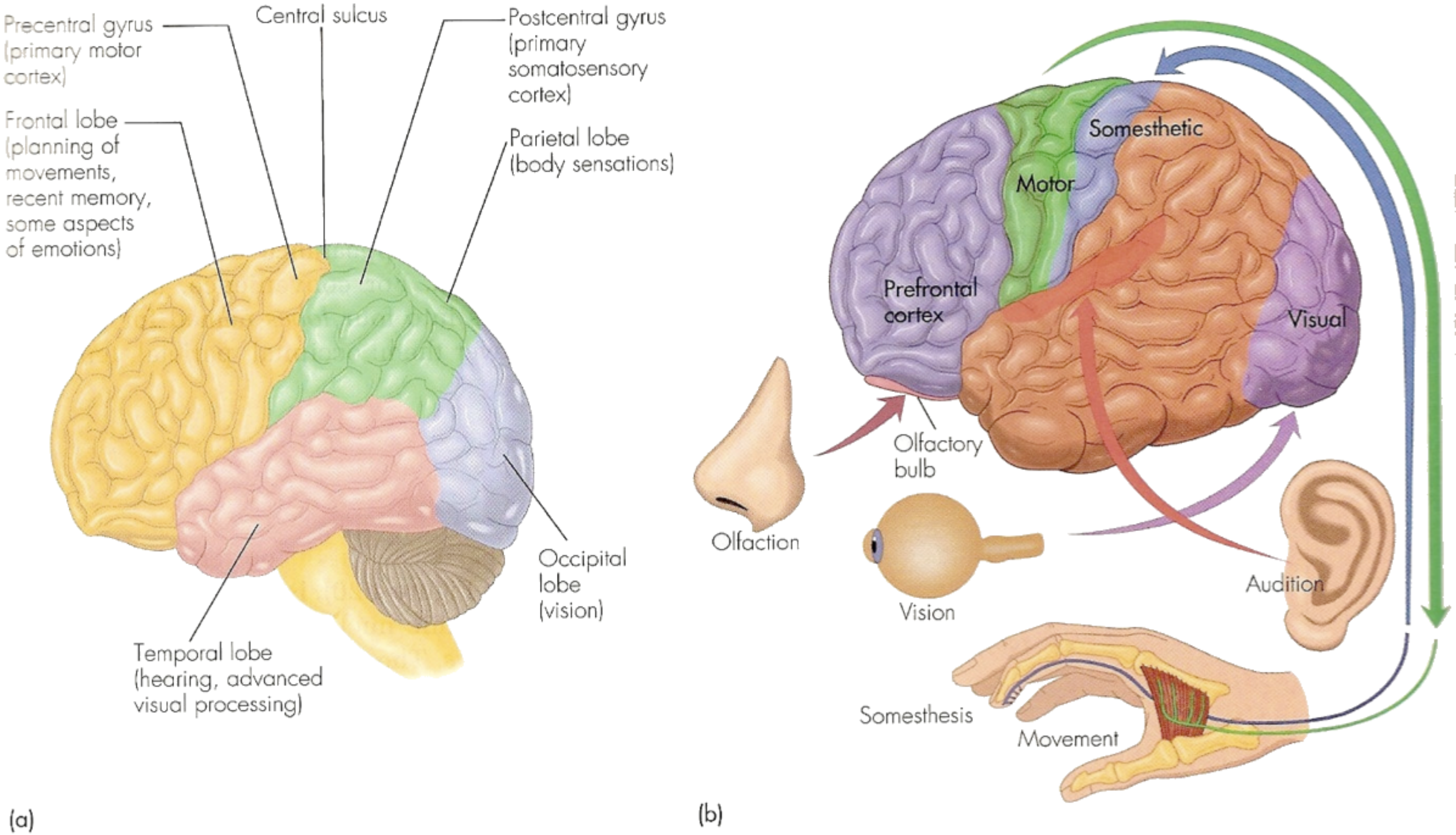
Grey matter consists of densely packed cell bodies and dendrites

White matter consists of myelinated axons

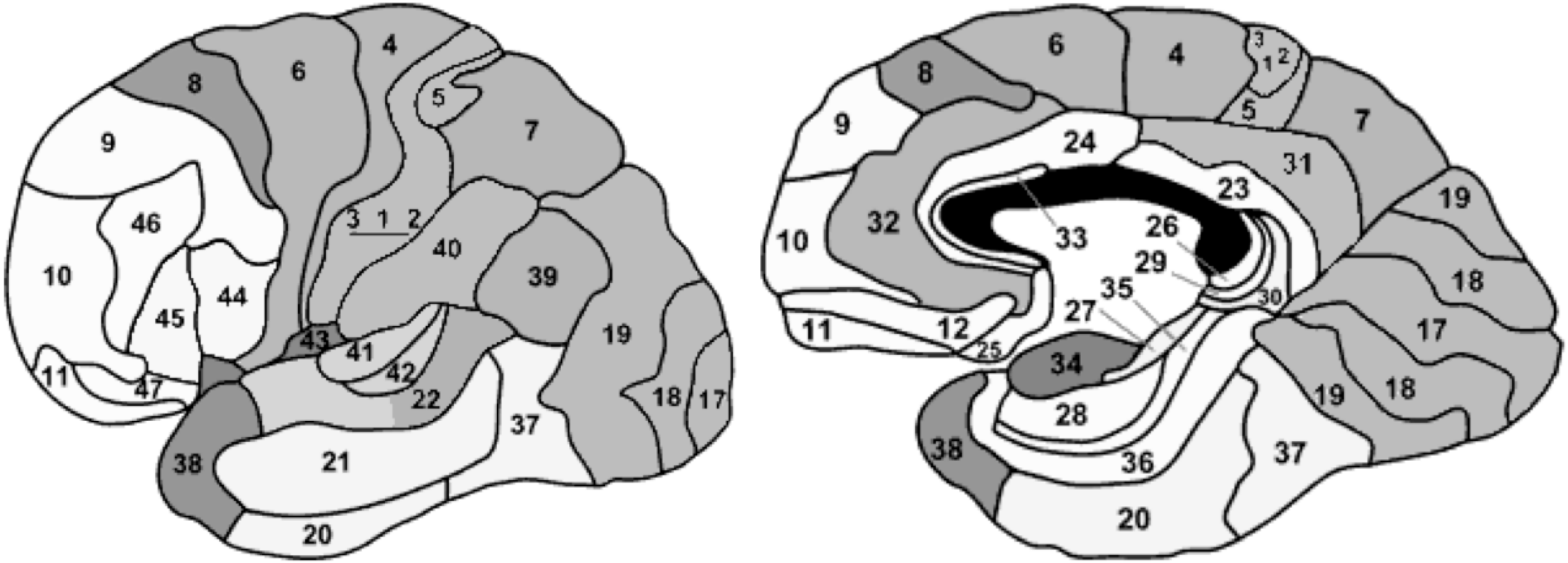
The brain stem links vertebrae to the brain.



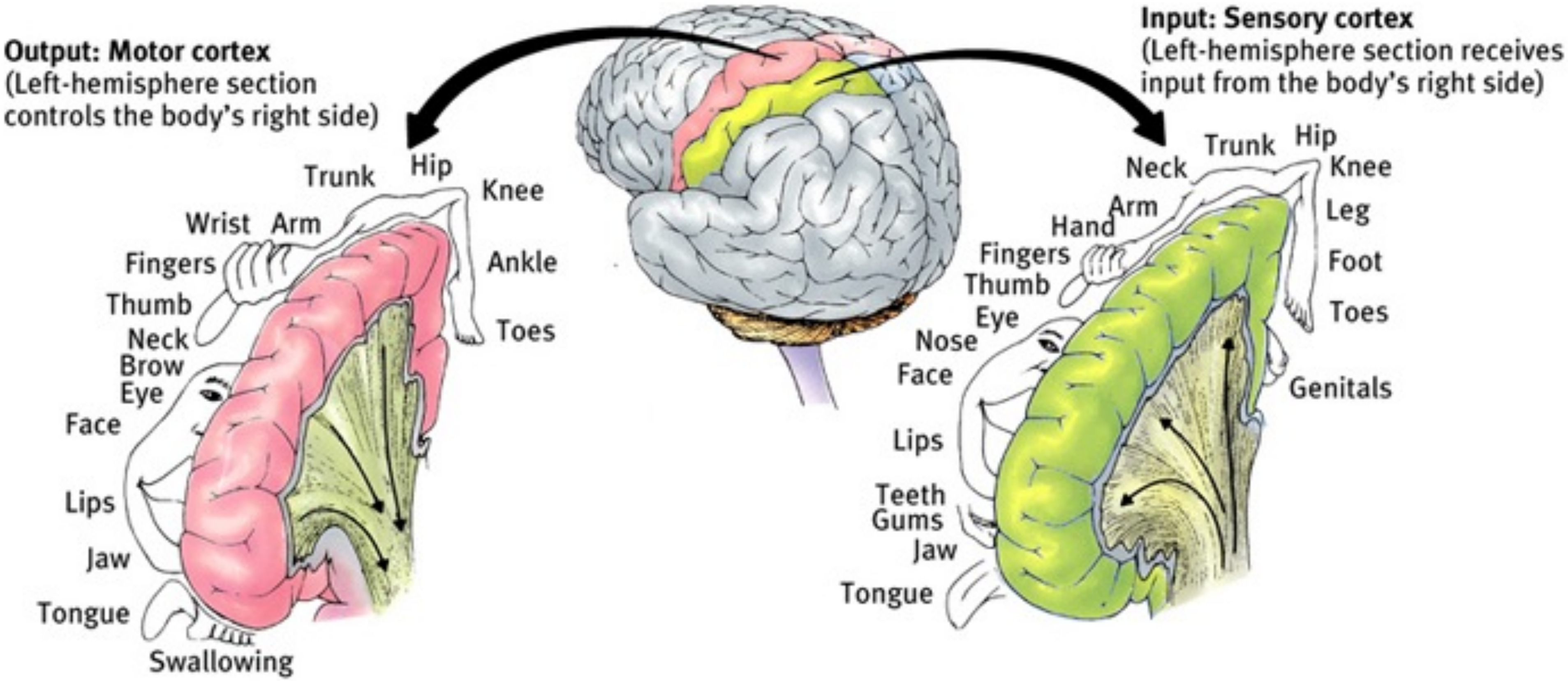
The brain is traditionally divided into lobes.
(Sulcus = groove; Gyrus = ridge)



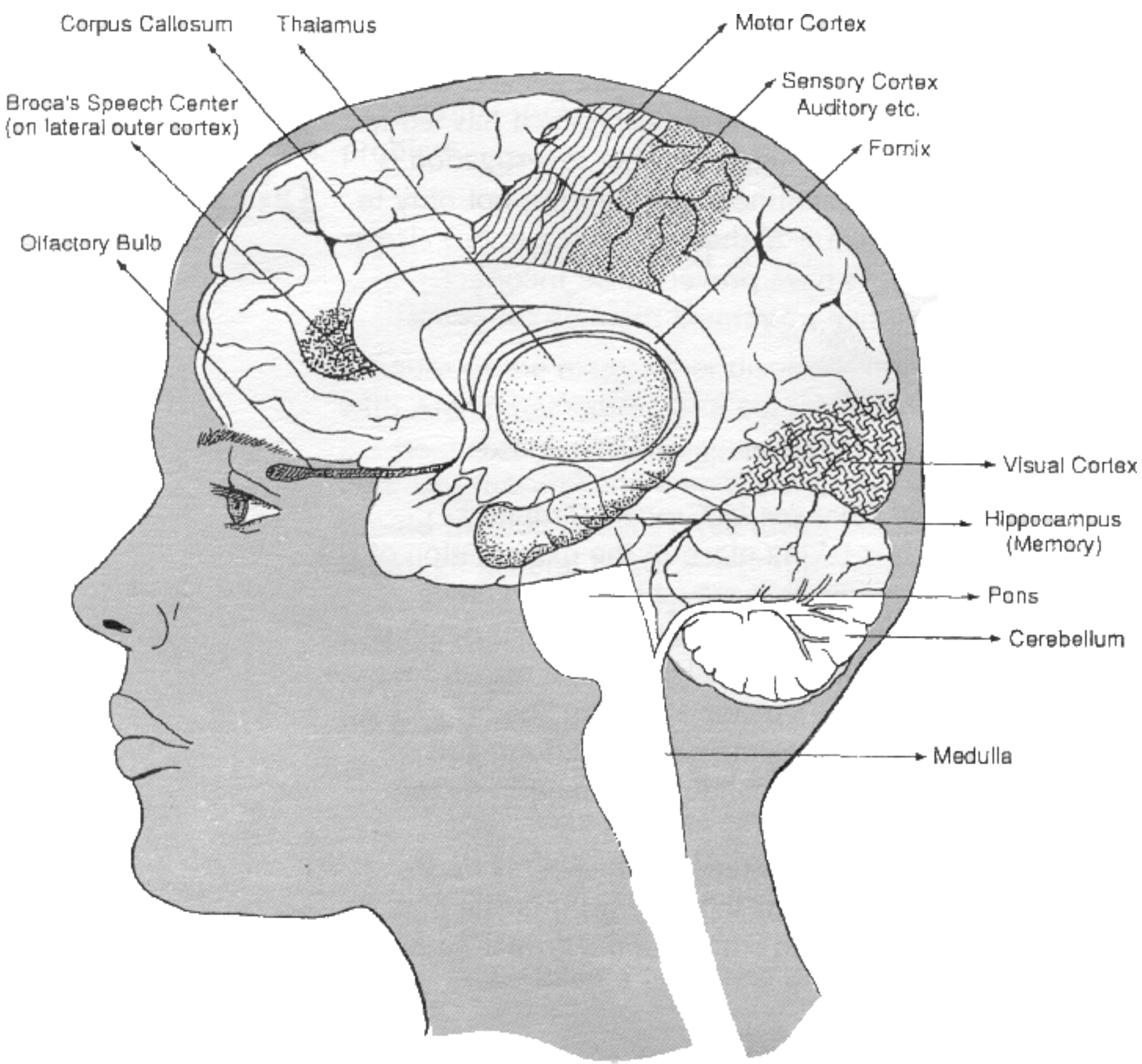
Cytoarchitecture of the cortex (Brodmann, 1909)



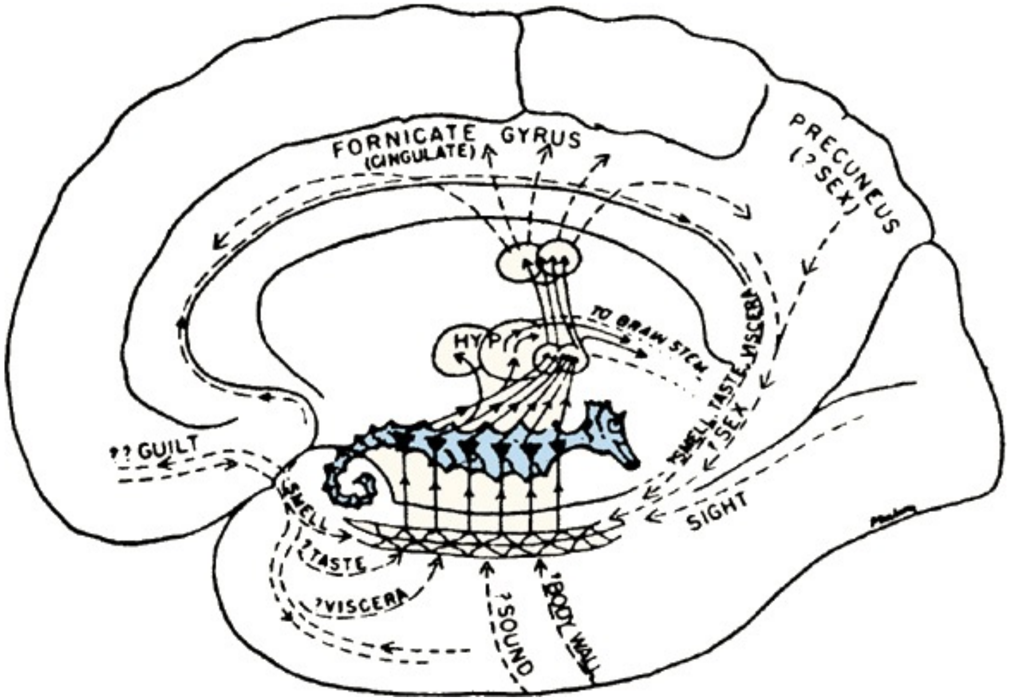
Cortical representation of the body: the Homunculus (Penfield, 1951)



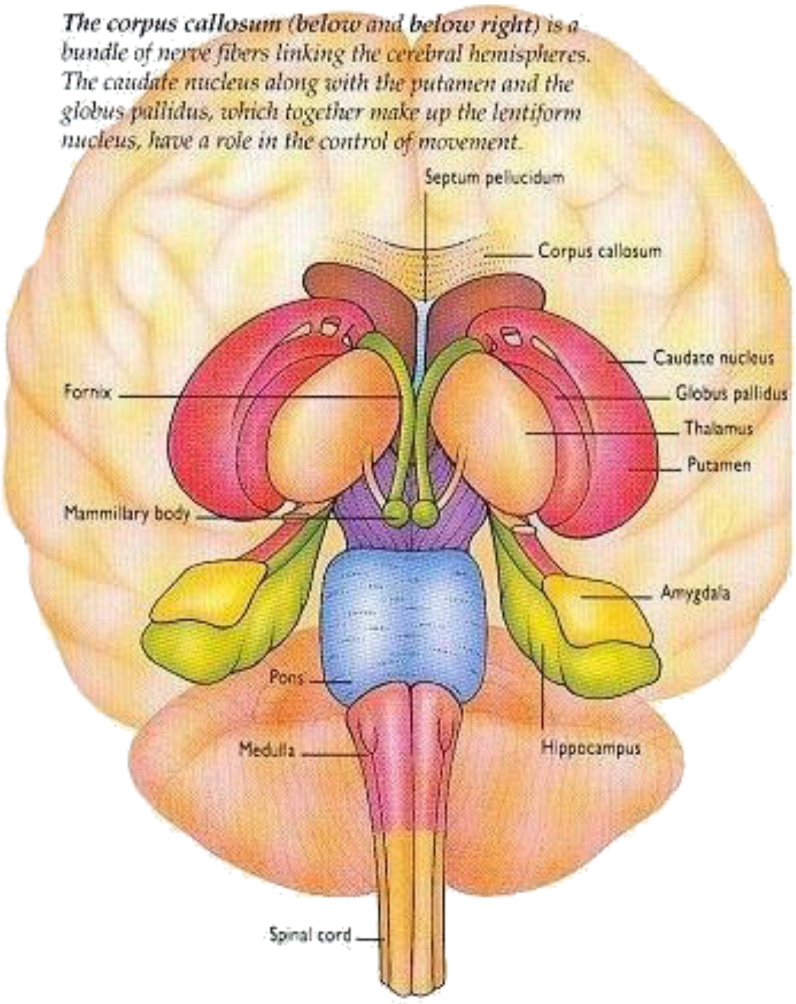
Cortical vs Subcortical

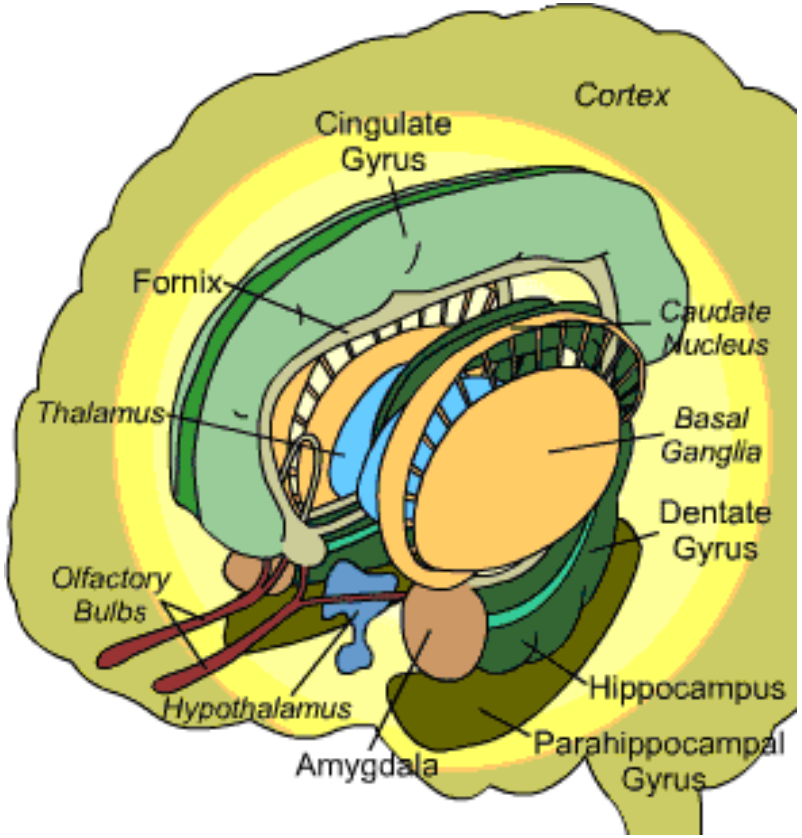


Maclean’s triurne-brain hypothesis (1970)

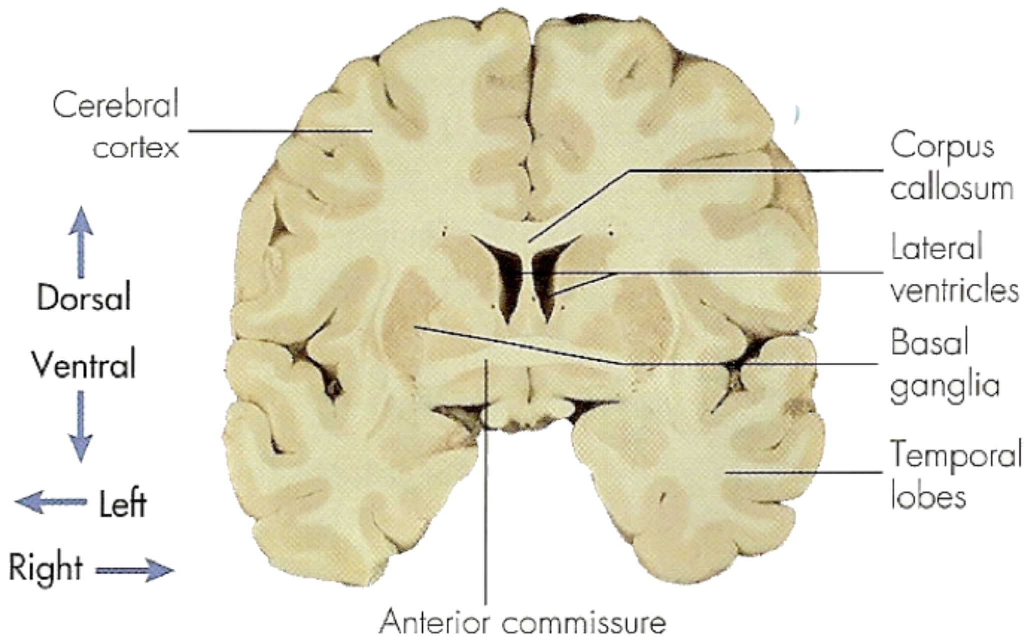


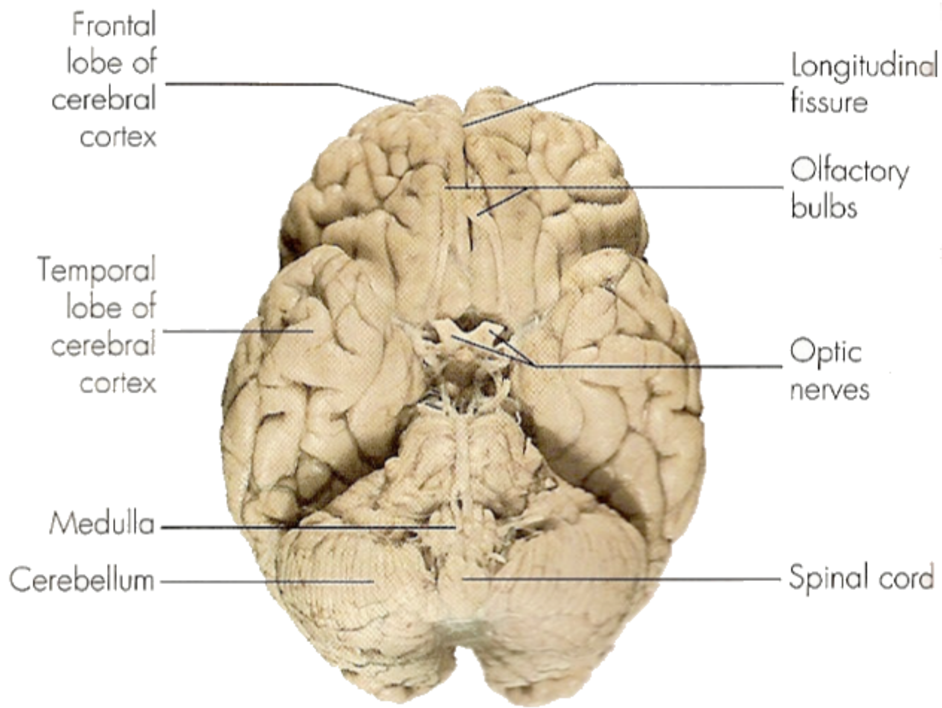
The limbic system



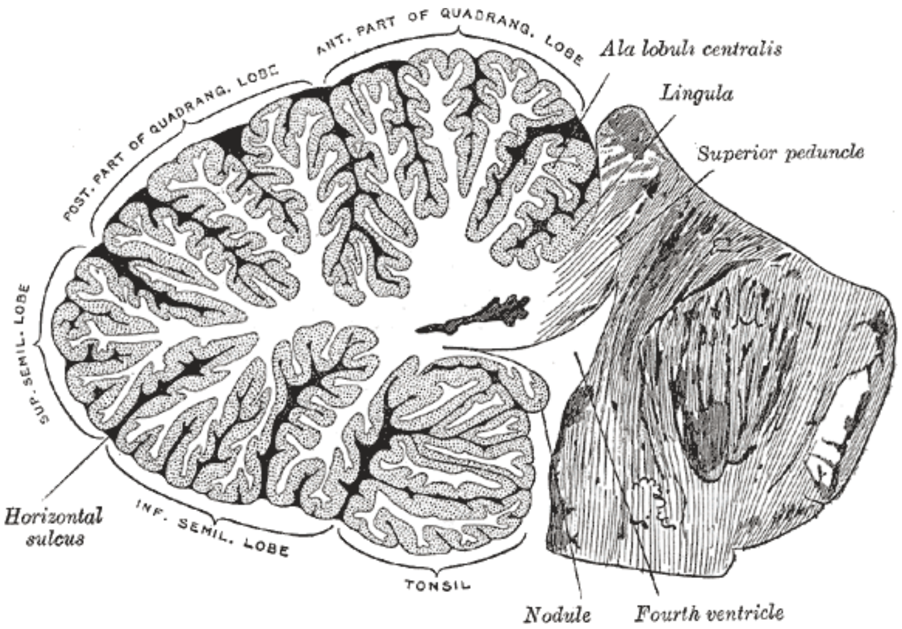


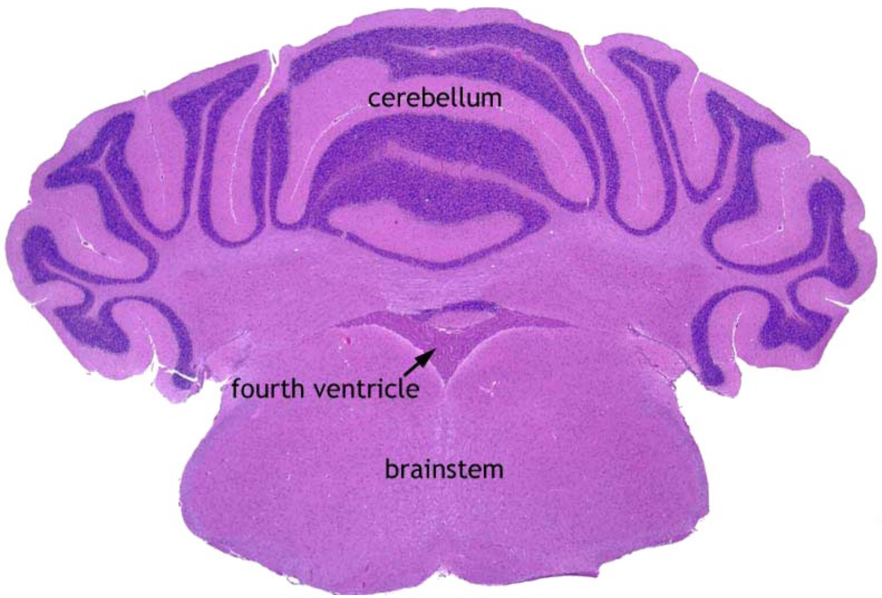
The brain .. irl



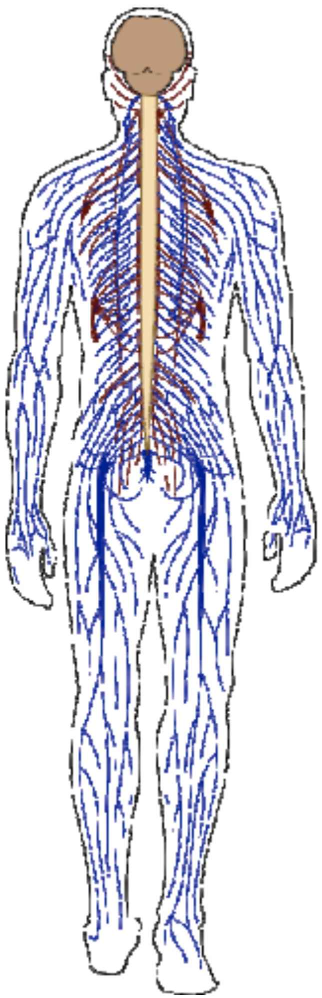


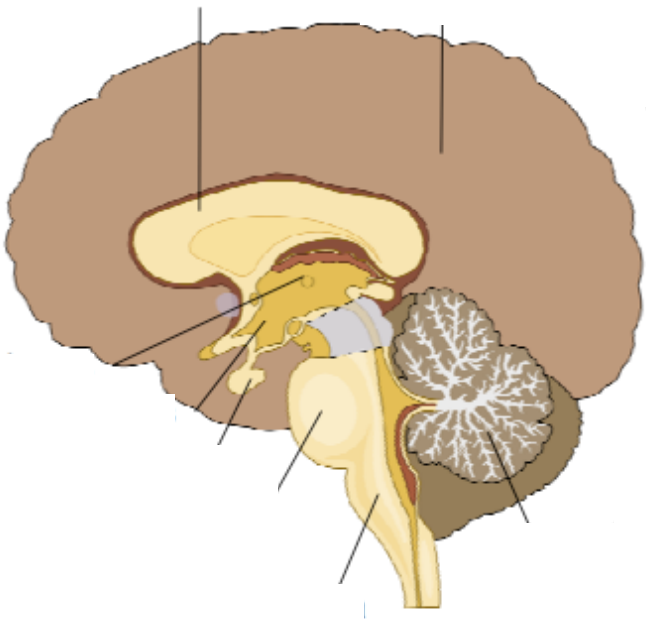
The cerebellum





Quiz – What can you see?





The autonomic nervous systems (ANS)

- Sympathetic
  "spends energy"

- Para-sympathetic
  "regulates energy"

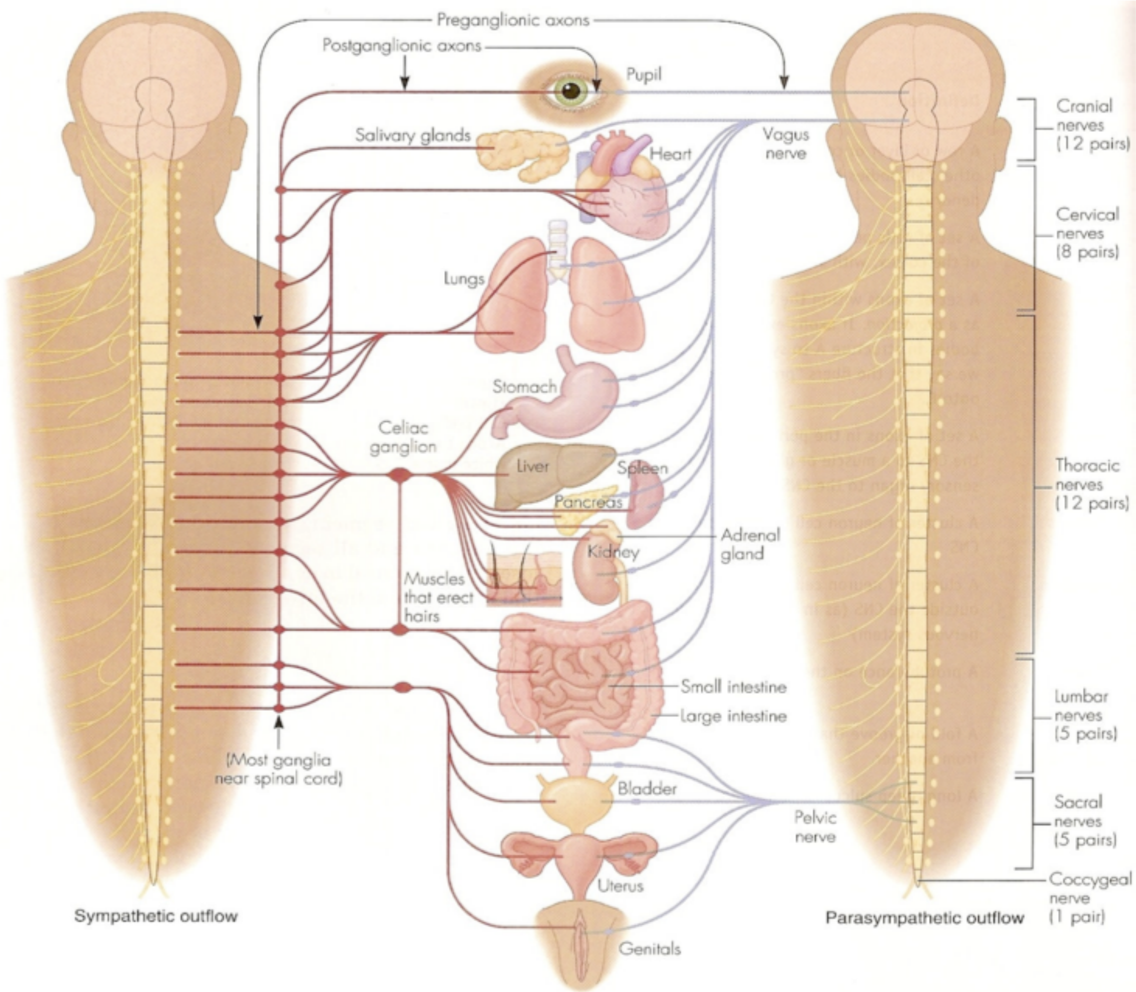
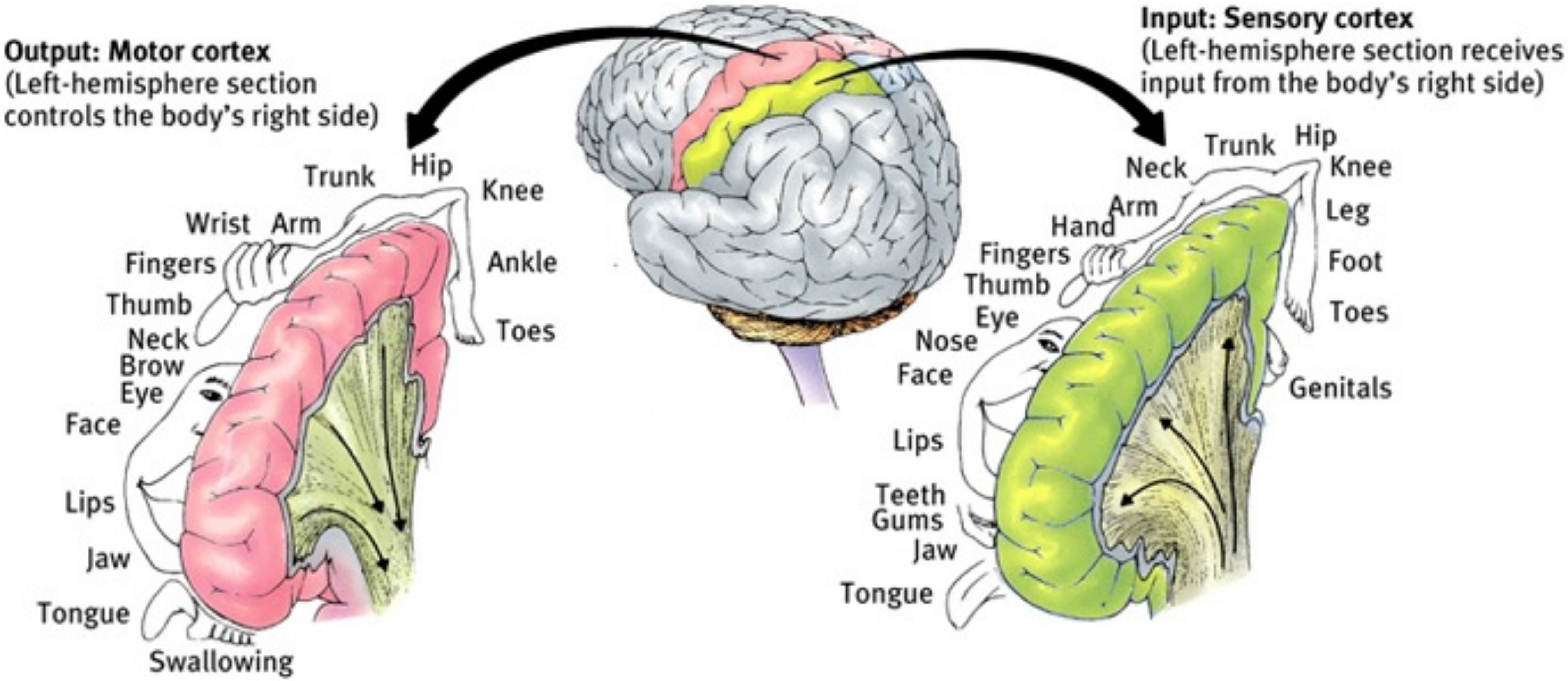


Figure 4.6 The sympathetic nervous system (red lines) and parasympathetic nervous system (blue lines)
Note that the adrenal glands and hair erector muscles receive sympathetic input only. *(Source: Starr & Taggart, 1989)*

Quiz – Explain.



Quiz – The "computational" perspective (Marr, 1982)

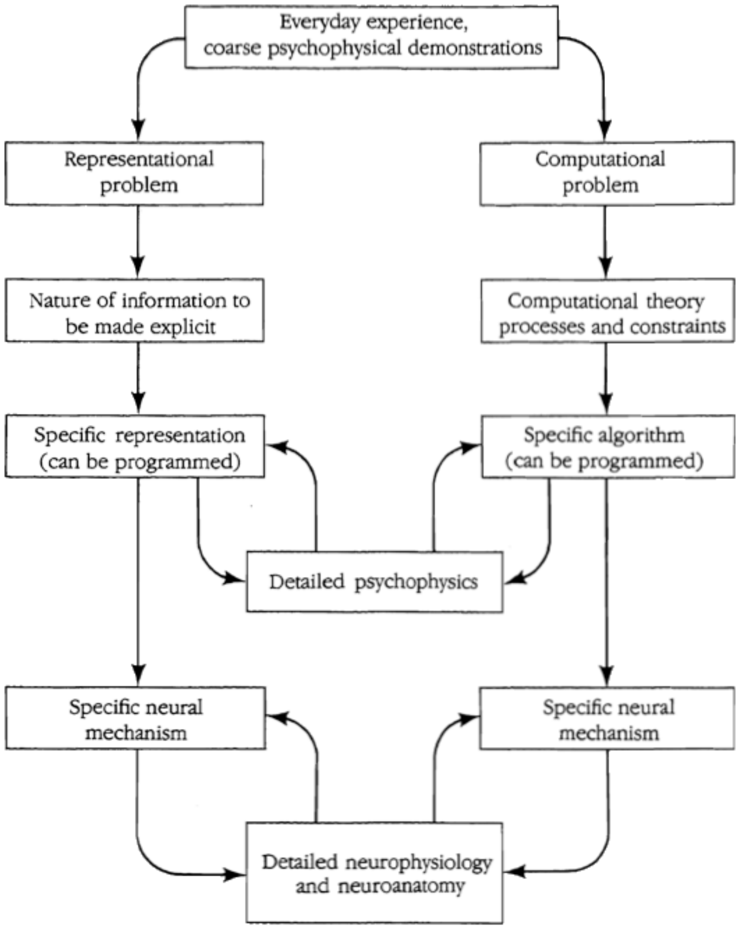
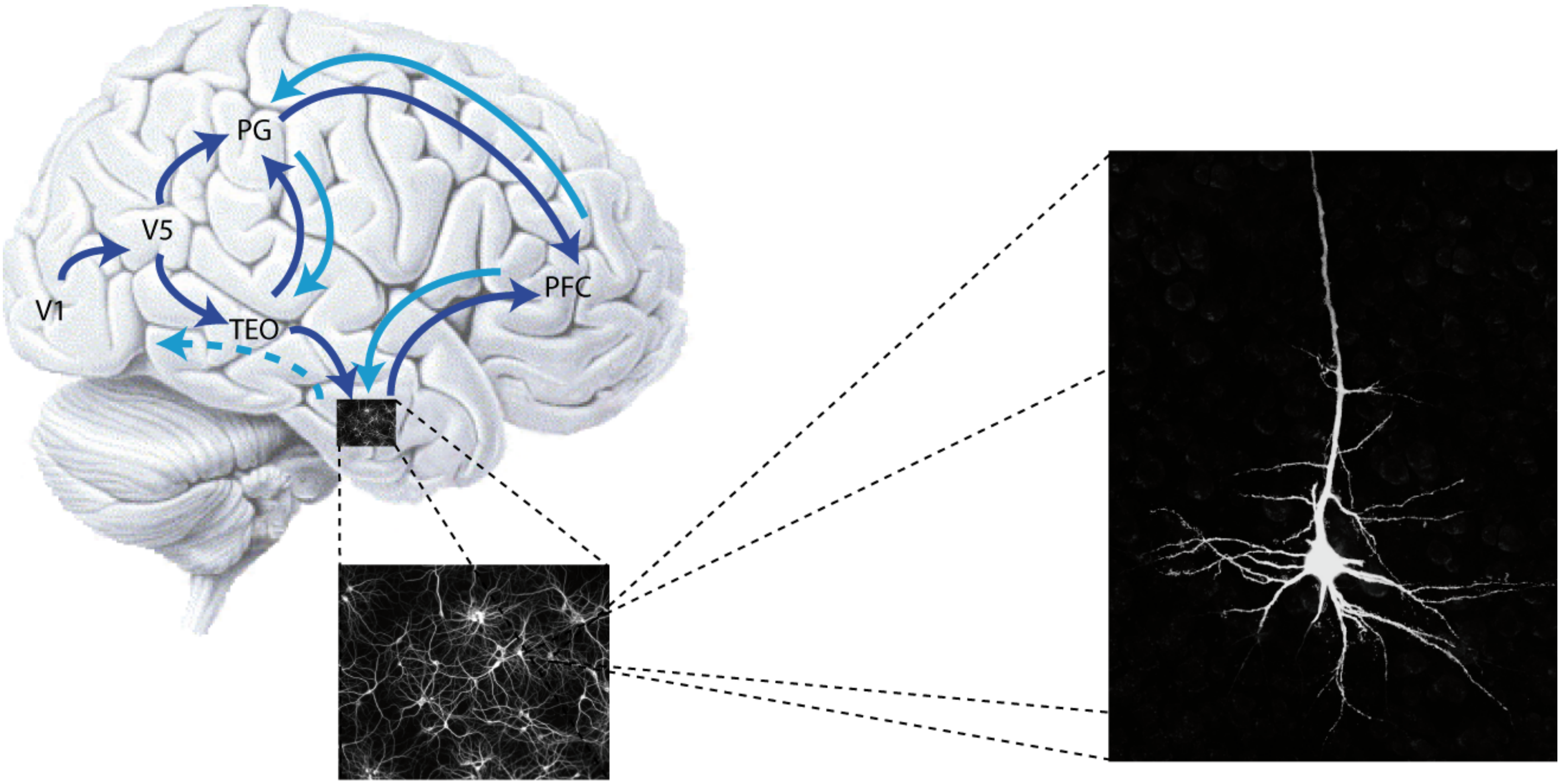


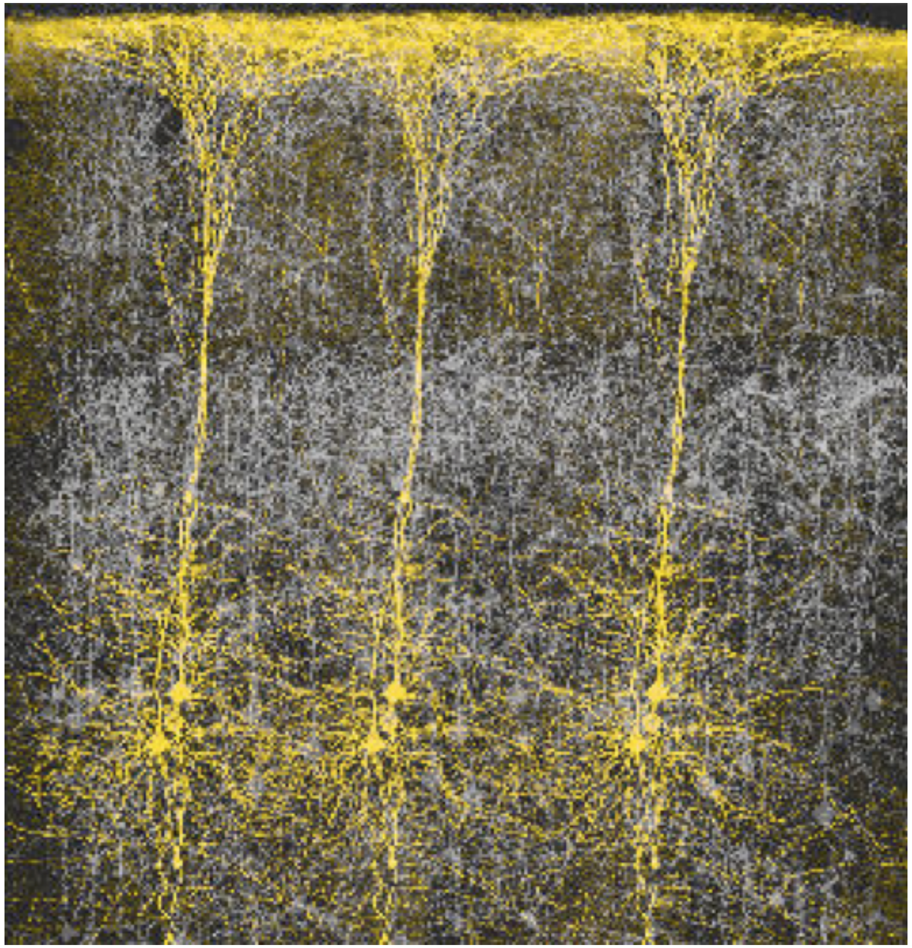
Figure 6–1. Relationships between representations and processes.

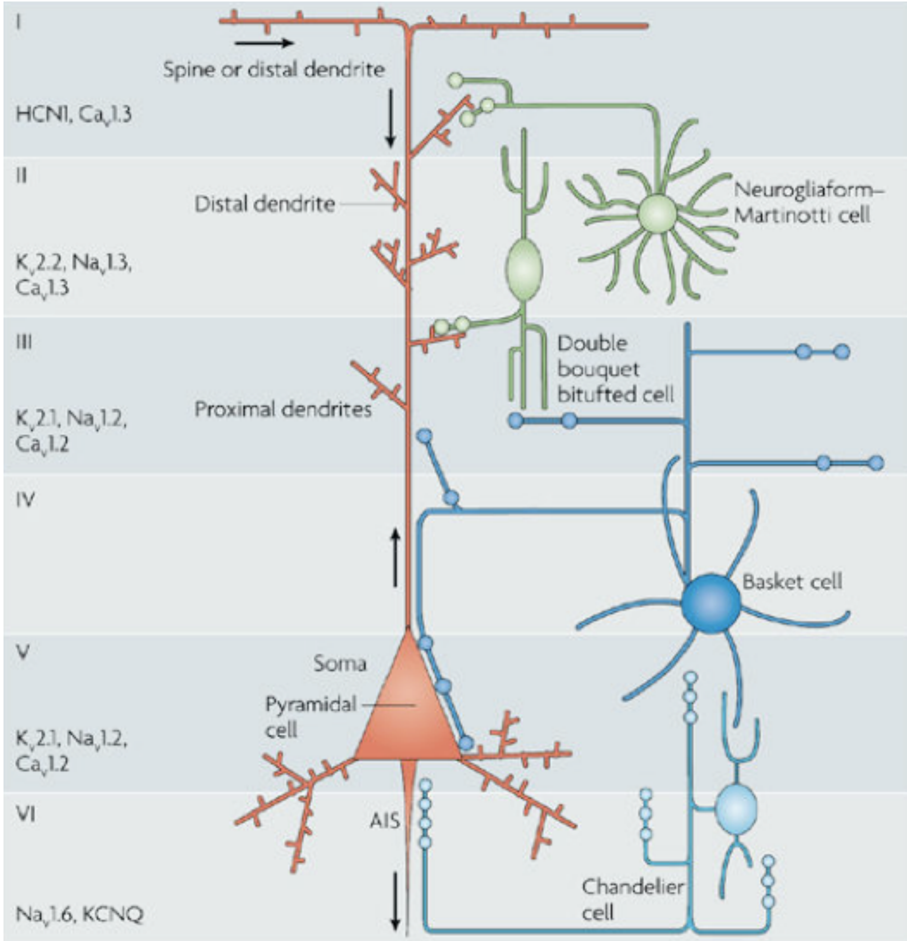
- (Explain)
- Focus on ..
- Separates the .. from the ..
- ..

The neuron

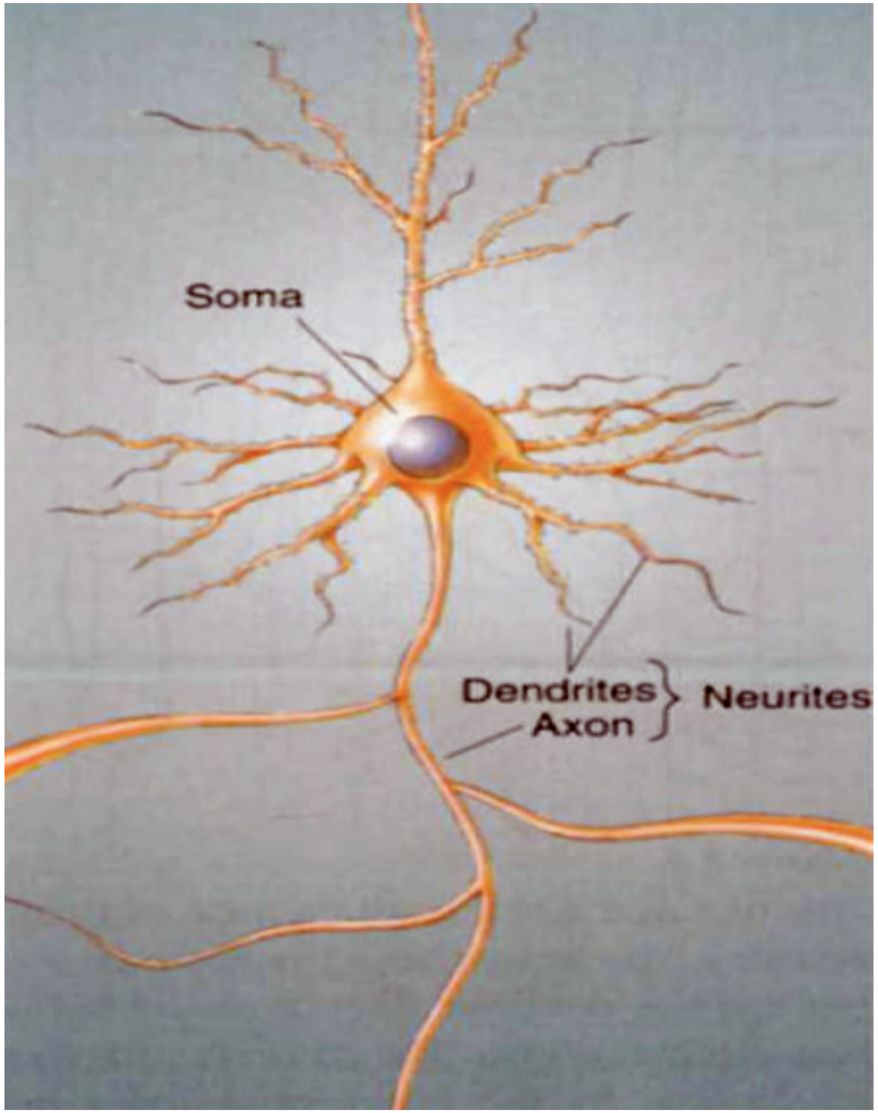


The brain is a structured collection of cells: e.g. cortex



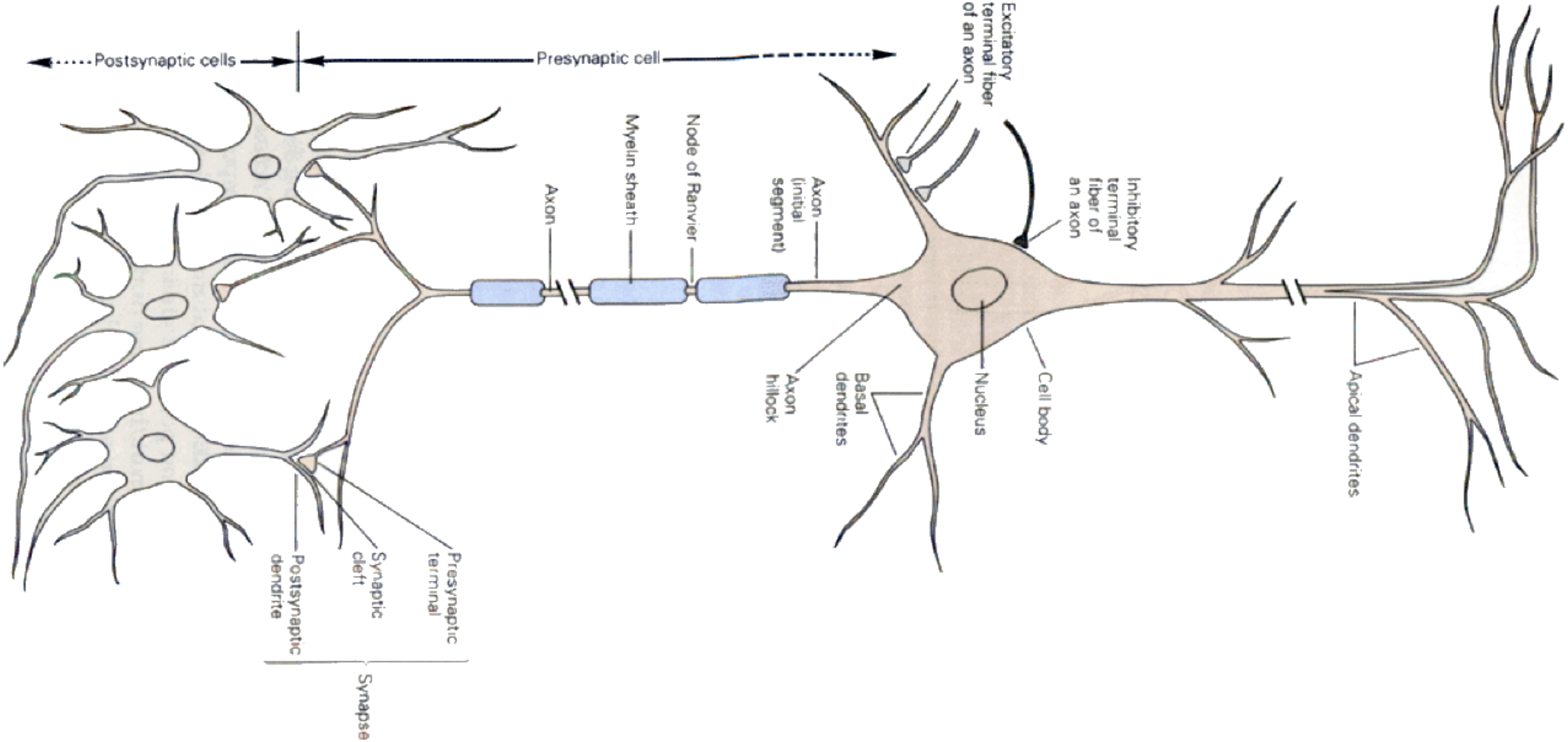


One neuron

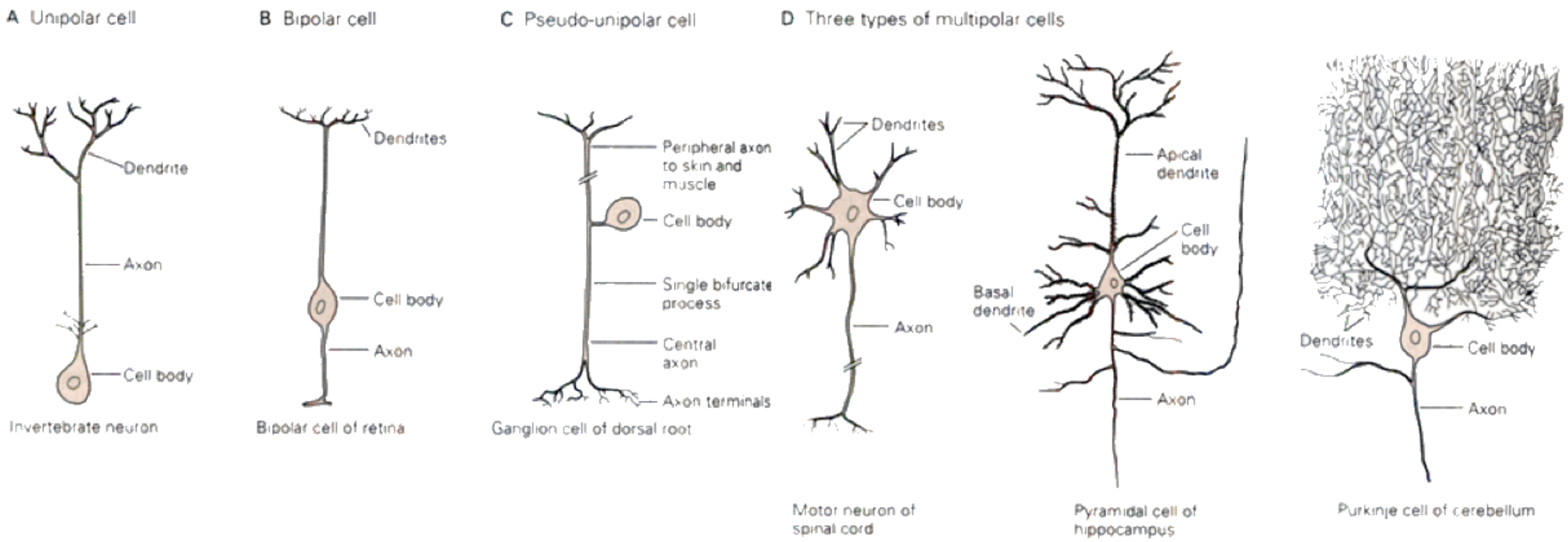


- A regular cell with a particular shape
- — Input component that received information
- — Trigger component that produces an action potential
- — Conductile component that conduces the AP
- — Output component that transmits the AP

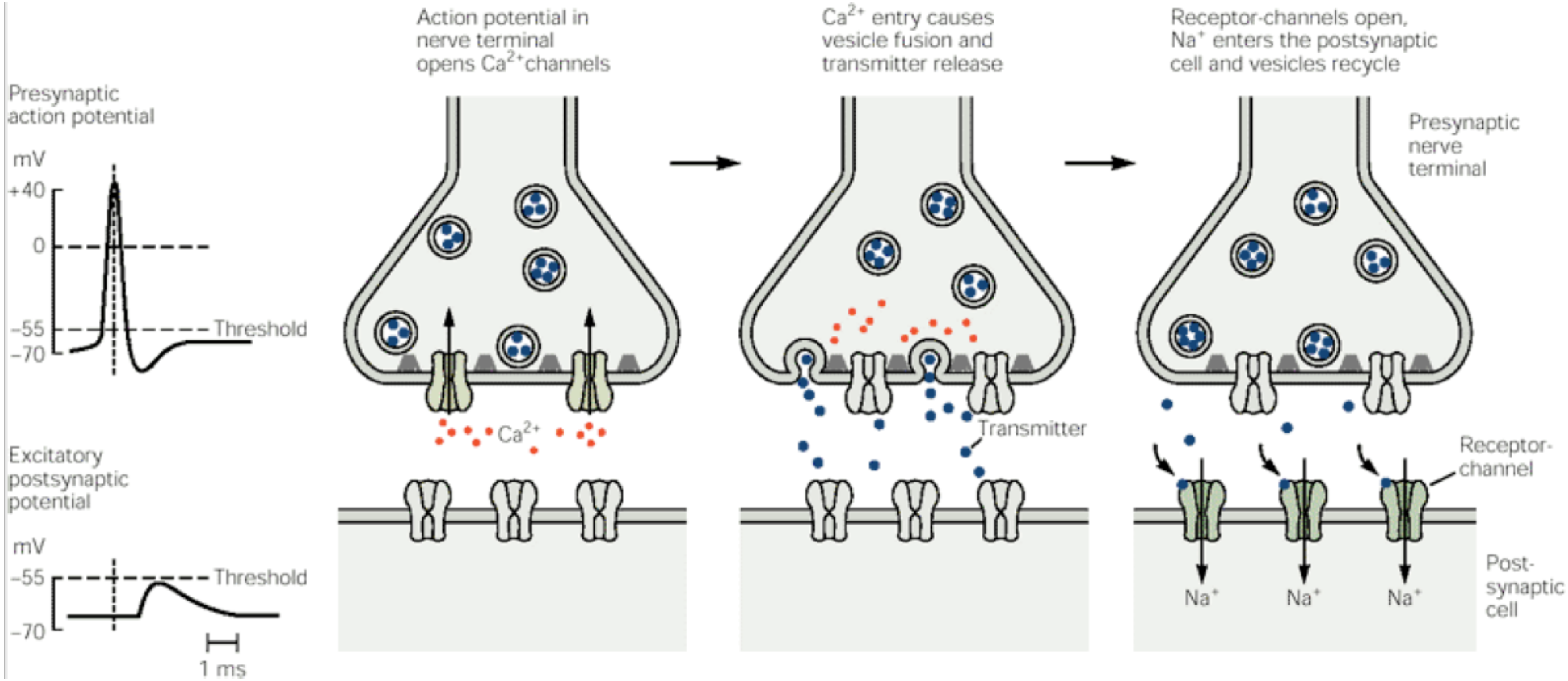
Several neurons



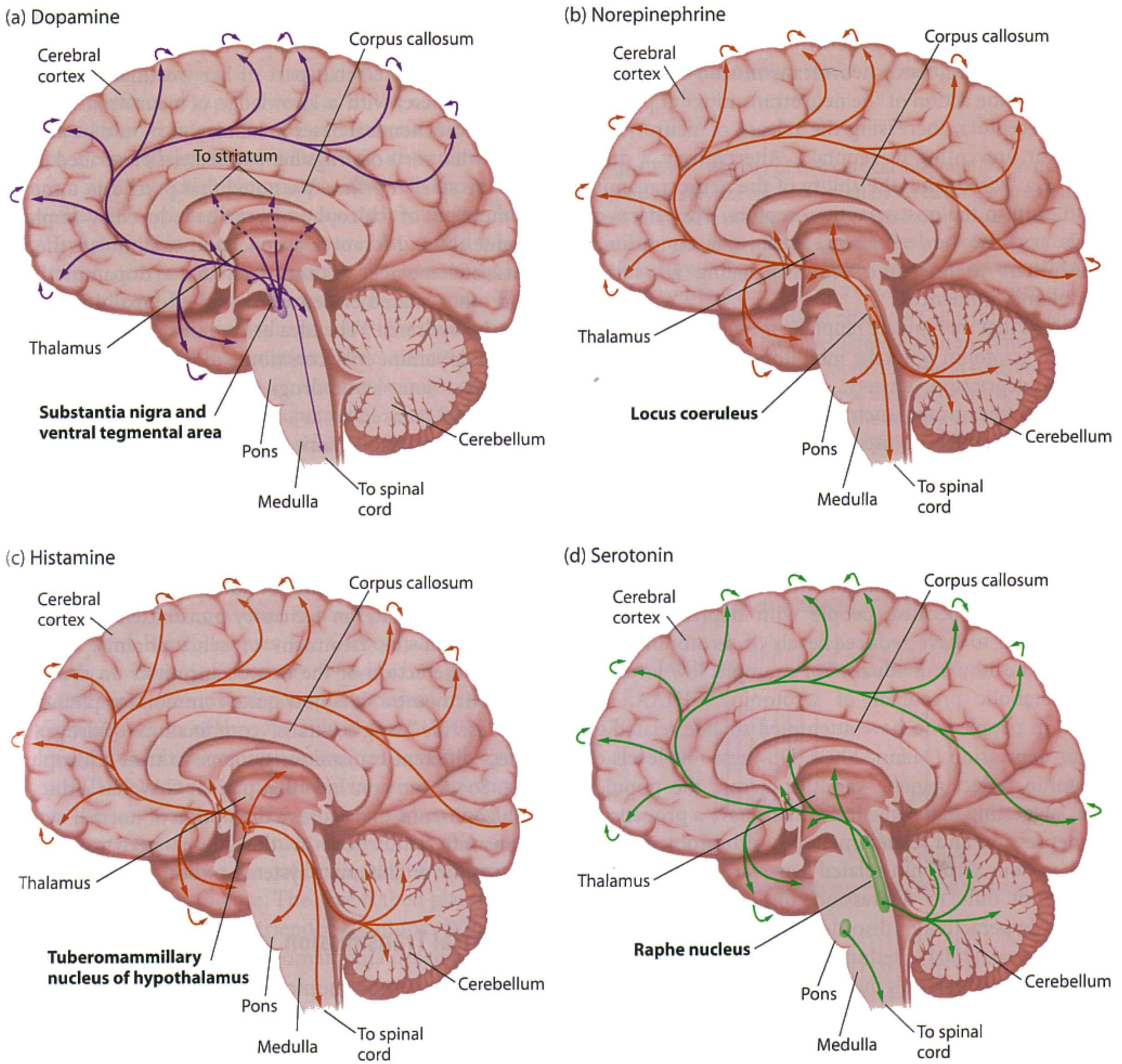
Several types of neurons



The input component: Dendrites

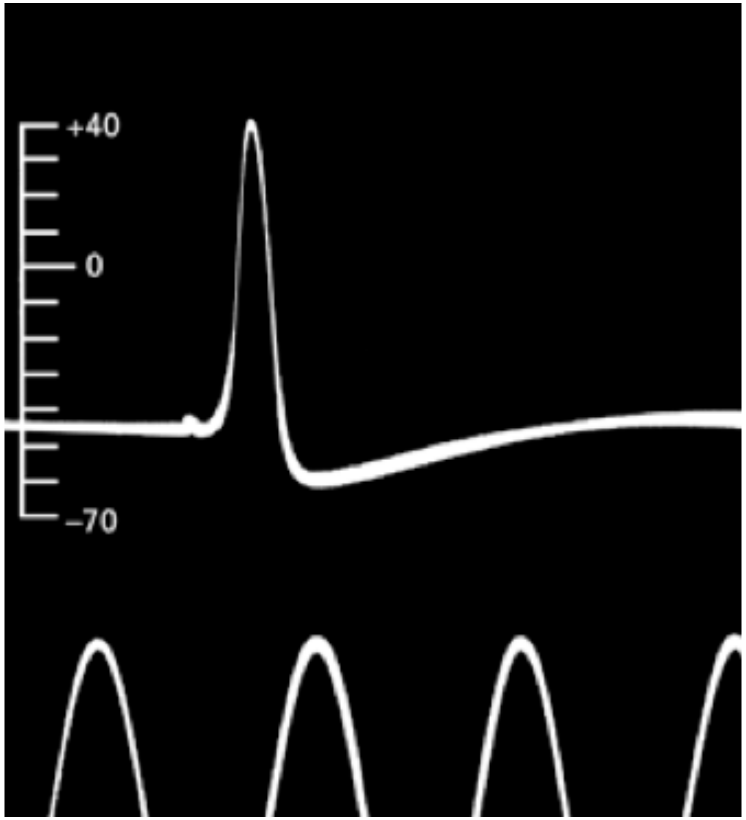


Neurotransmitters

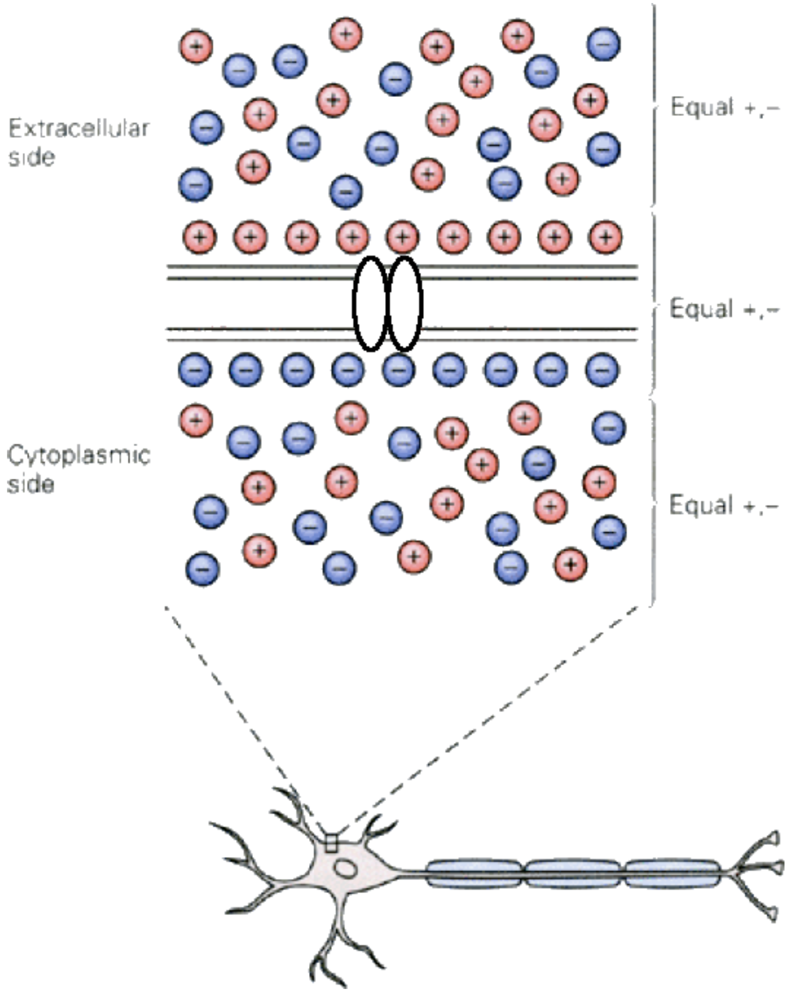


The Action Potential (Hodgkin & Huxley, 1939)

- Measured in mV
- Lasts 1 msec
- Burst of electrical activation = 100 mV
- Potential between inside and outside the soma

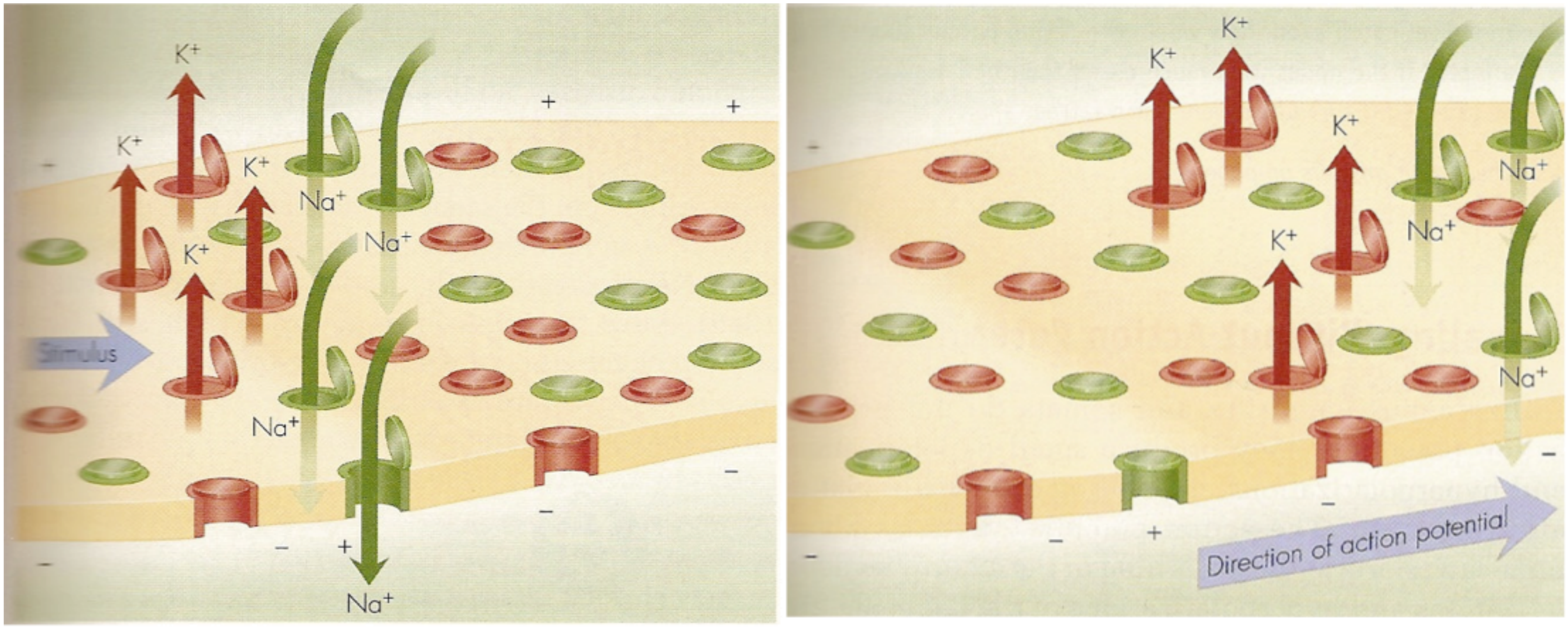


The (changing) membrane potential



- Resting potential = –65 mV
- Na^+ – K^+ pumps keep the balance

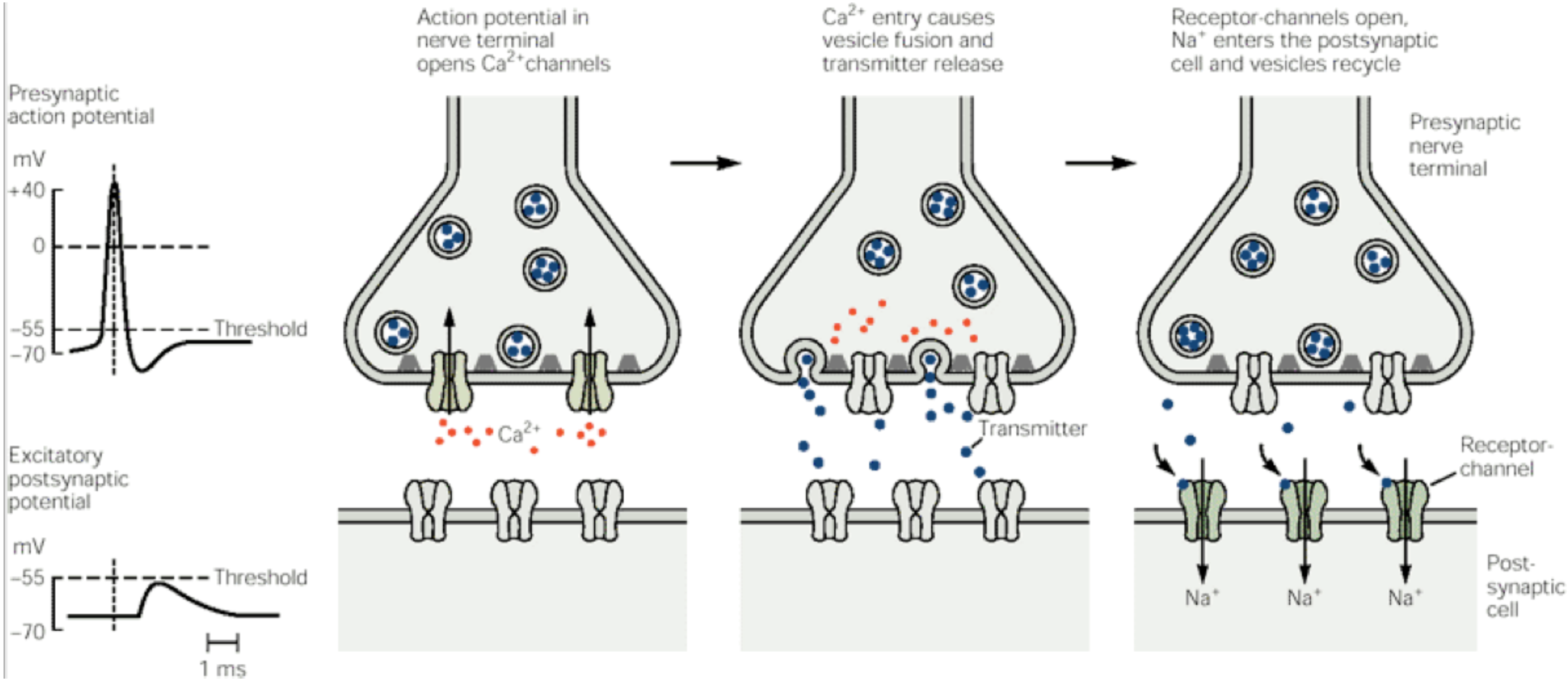
The conductive component: The Axon



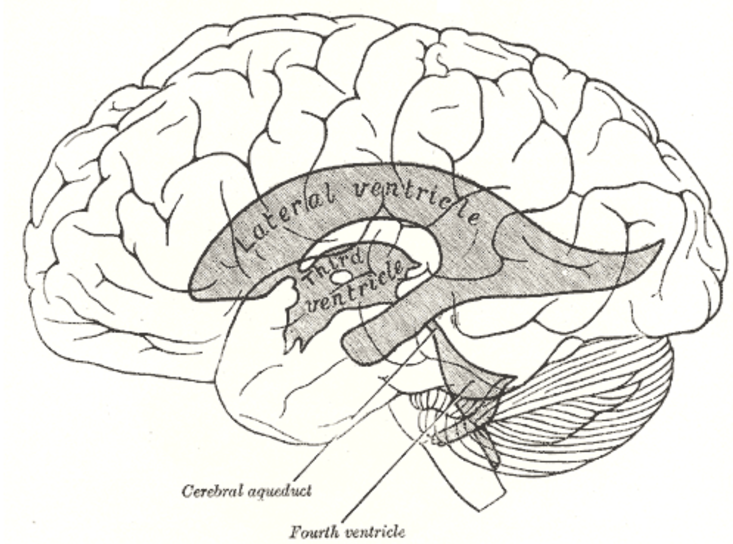
a) b)

Figure 2.18
Current that enters an axon at the point of the action potential flows down the axon, thereby depolarizing adjacent areas of the membrane. The current flows more easily through relatively thick axons. Behind the area of sodium entry, potassium ions exit.

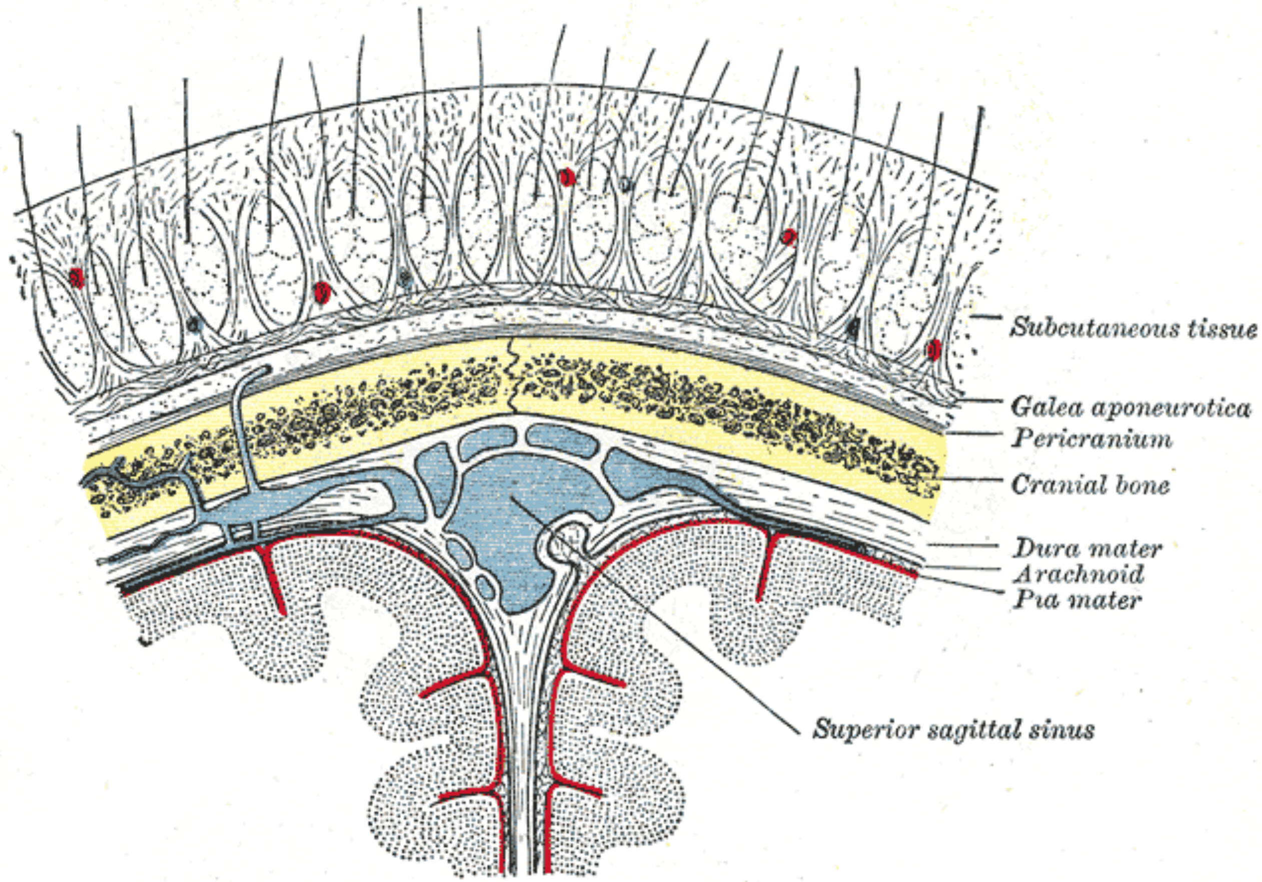
The output component: the Synapse



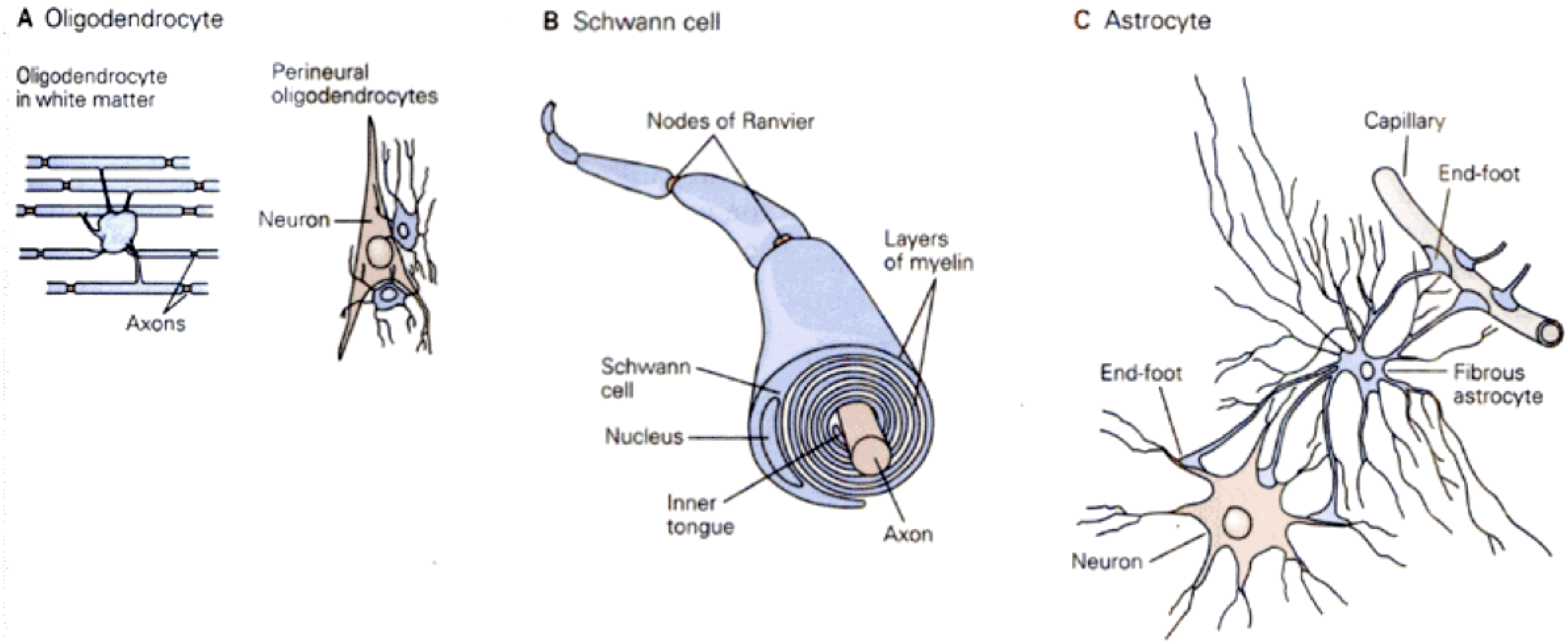
“The world is a vampire, sent to drain.”



The cerebrospinal fluid protects, feeds and cleans.



Other types of cells in the brain. (some).



Outline

- Useful information
- History & Definitions
- (A bit of) Neuroanatomy
- Methods
  — Lesion studies
  — Functional Magnetic Resonance Imaging
  — Electro-Encephalography / Event-Related Potentials
- Conclusions

The very first experiment on the brain.

Angelo Mosso
Italian physiologist
(1846-1910)

“[In Mosso’s experiments] the subject to be observed lay on a delicately balanced table which could tip downward either at the head or at the foot if the weight or either end were increased. The moment emotional or intellectual activity began in the subject, down went the balance at the head-end, in consequence of the redistribution of the blood in his system.” (William James, 1890)

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BRAIN
A JOURNAL OF NEUROLOGY

DORSAL COLUMN

Letter to the Editor

Weighing brain activity with the balance: a contemporary replication of Angelo Mosso's historical experiment

David T. Field[1] and Laura A. Inman[2]

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Sir, Sandrone *et al.* (2012, 2013) rediscovered, translated, and commented on the manuscripts of Angelo Mosso (1882, 1884), in which Mosso described his 'human circulation balance'; James (1890) described this as a

> 'delicately balanced table which could tip downwards either at the head or the foot if the weight of either end were increased'.

Mosso claimed that the balance allowed him to observe changes in cerebral blood volume associated with mental effort and emotional responses, and consequently the balance is regarded as the direct forerunner of modern non-invasive functional neuroimaging techniques. However, Sandrone *et al.* (2012, 2013) stated that

> 'we have no direct evidence that the balance was really able, as stated, to measure changes in cerebral blood flow during acts of cognition . . . despite its proven ability to measure blood volume changes in various organs (e.g. lungs, feet, hands)'.

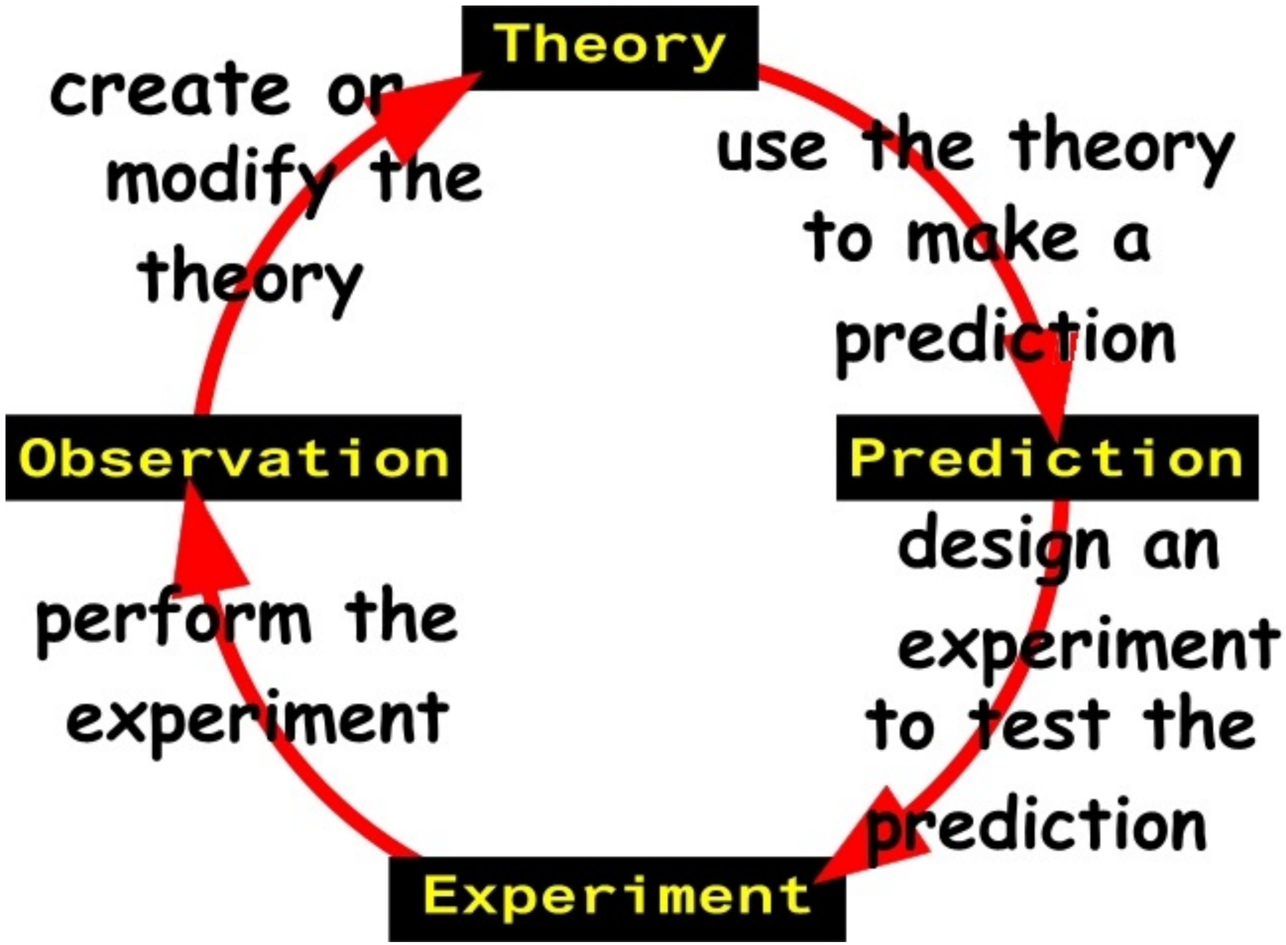
In our laboratory, we recently constructed a balance similar to Mosso's, and using modern data collection and analysis methods that were unavailable to Mosso, we investigated whether the balance was sensitive to changes in cerebral blood volume produced by modulating the level of mental activity. The construction and mechanism of our balance is depicted and explained in Fig. 1, and may be compared with Figs 3 and 8 in Sandrone *et al.* (2013), which show Mosso's apparatus. The balance is a class 1 lever, in which the moment of a force measured at the fulcrum is proportional to the magnitude of the force and its distance from the fulcrum. With a participant lying on the balance across the fulcrum, if mental activity produces a net shift of blood towards or away from the head then this will produce a slight change in the centre of mass of the participant relative to the fulcrum of the lever, consequently changing the force exerted at the end of the lever.

Mosso went to great lengths to keep his balance in equilibrium, i.e. able to tip back and forth rather than coming to rest on one end, and employed a counterweighting system to dampen the respiratory fluctuations, which have a large effect on the location of the centre of mass. Instead of mechanically dampening the respiratory fluctuations, our approach was to allow one end of the balance to rest stationary on a set of electronic scales and measure the variation in force exerted over time. Like Mosso, we additionally observed a slow increase in force exerted beneath the head as blood redistributed from the legs to the upper body when supine. Mosso removed this factor from his data by asking subjects to rest on the balance for 1 h before the experiment so that the redistribution of blood was completed. Our alternative approach was to model the linear increase in force produced by this factor over time using regression, which allowed us to remove it from the data.

Initial recordings made with our apparatus of a participant at rest revealed an additional high frequency signal that Mosso's apparatus was not sensitive to, probably because of the mechanical damping he applied. We assume that this signal arises from the heartbeat, and we largely removed its influence on our time course data by temporal smoothing. The heartbeat and respiration signals present in the data are shown in Fig. 2A and C. Comparing these with panel A of Fig. 5 in Sandrone *et al.* (2013) illustrates that Mosso's balance was sensitive to respiration but not heartbeat.

Advance Access publication January 9, 2014

To survive, you must breathe the scientific method.



The cognitive neuroscience toolbox.