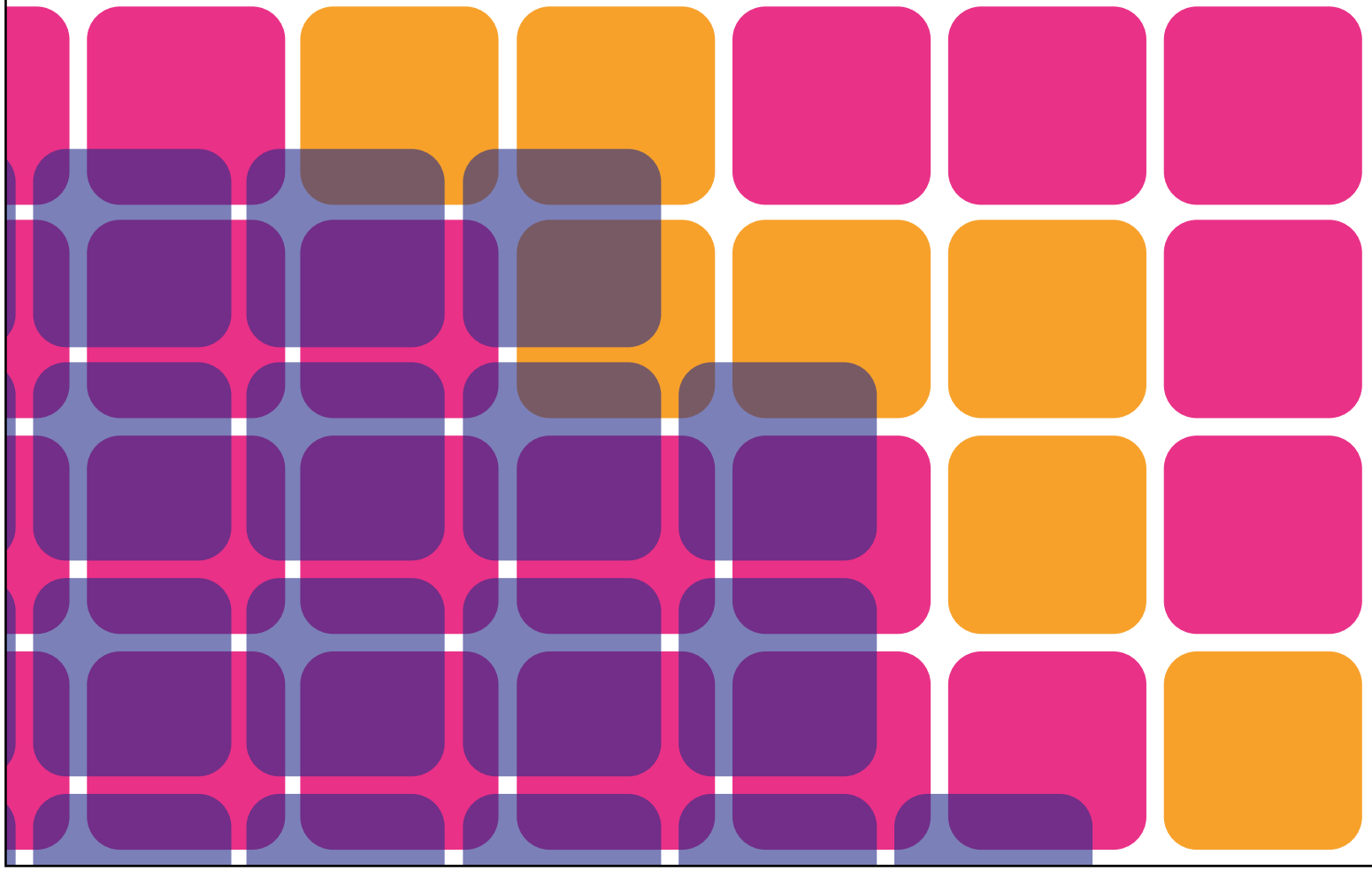
Organization of the nervous system

Lecture 1 ; Sept 10, 2013



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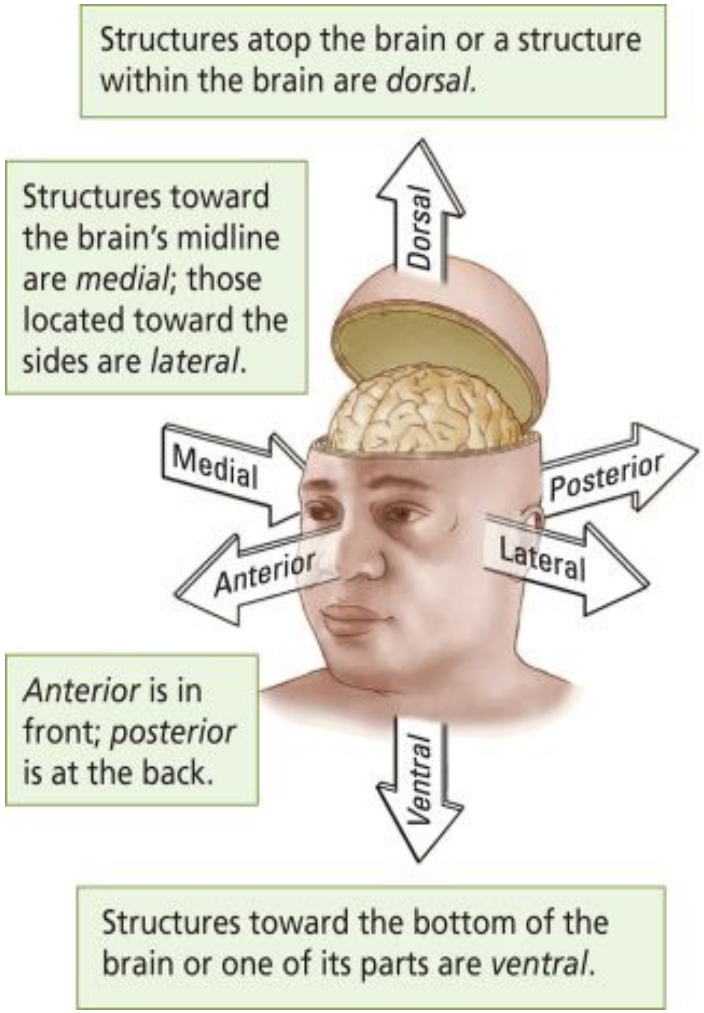
Directional terminology



In biology, directional terms are given with respect to the organism's body axis.

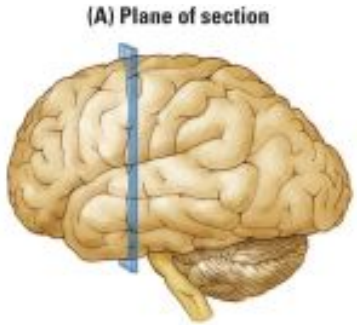
These terms are important for navigating creatures with unusual body plans or lifestyles.

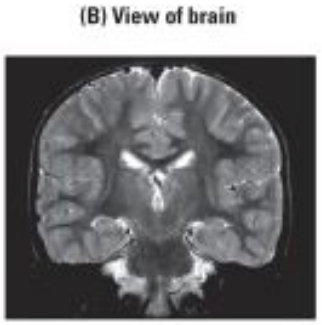
Shark dorsal fin – a sure sign of trouble

Illustration from Kolb & Wishaw, *An Introduction to Brain and Behavior*. Sinauer, 2014

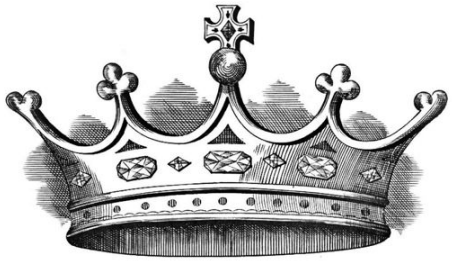
Directional terminology

Coronal section

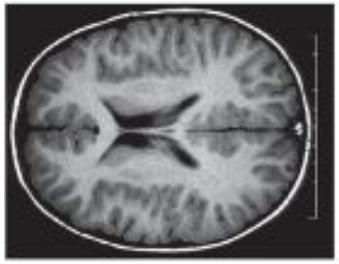




A *coronal section* is cut in a vertical plane, from the crown of the head down, yielding a frontal view of the brain's internal structures.

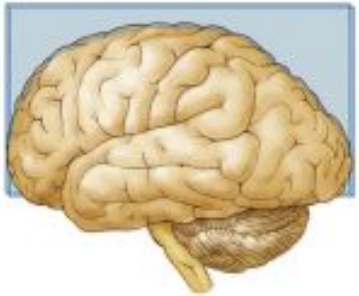


Horizontal section



A *horizontal section*, so-called because the view or the cut falls along the horizon, is usually viewed looking down on the brain from above—a dorsal view.

Sagittal section



A *sagittal section* is cut lengthways from front to back and viewed from the side, a medial view. Imagine the brain oriented as an arrow—in Latin, *sagitta*.

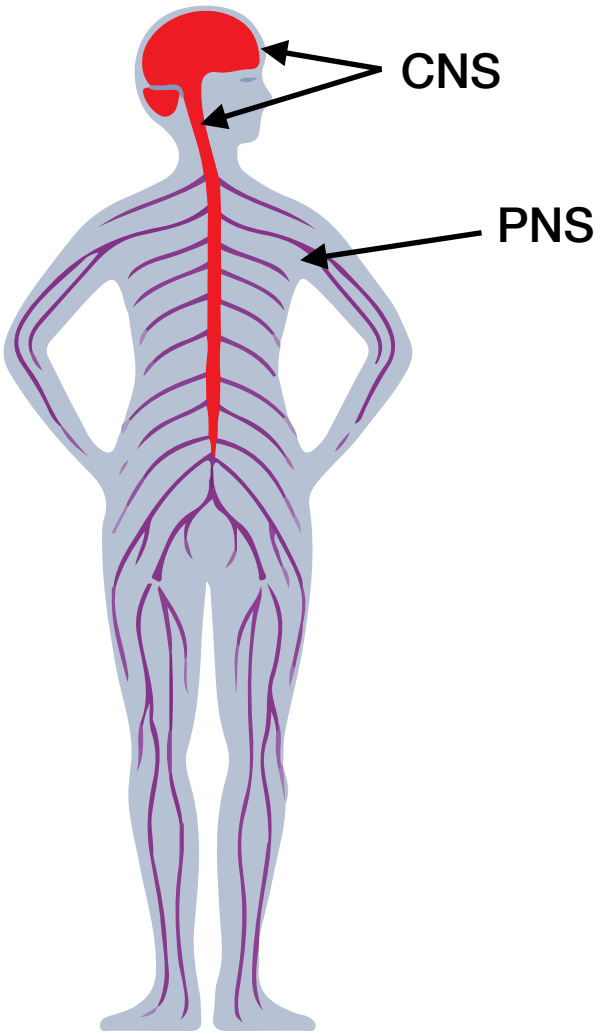
Illustration from Kolb & Wishaw, *An Introduction to Brain and Behavior*. Sinauer, 2014

Organization of the nervous system

- The nervous system is organized into the **central** and **peripheral** divisions.

- Central Nervous System (**CNS**)
  - Brain
  - Spinal cord

- Peripheral Nervous System (**PNS**)
  - Somatic Nervous System
  - Autonomic Nervous System



Organization of the nervous system

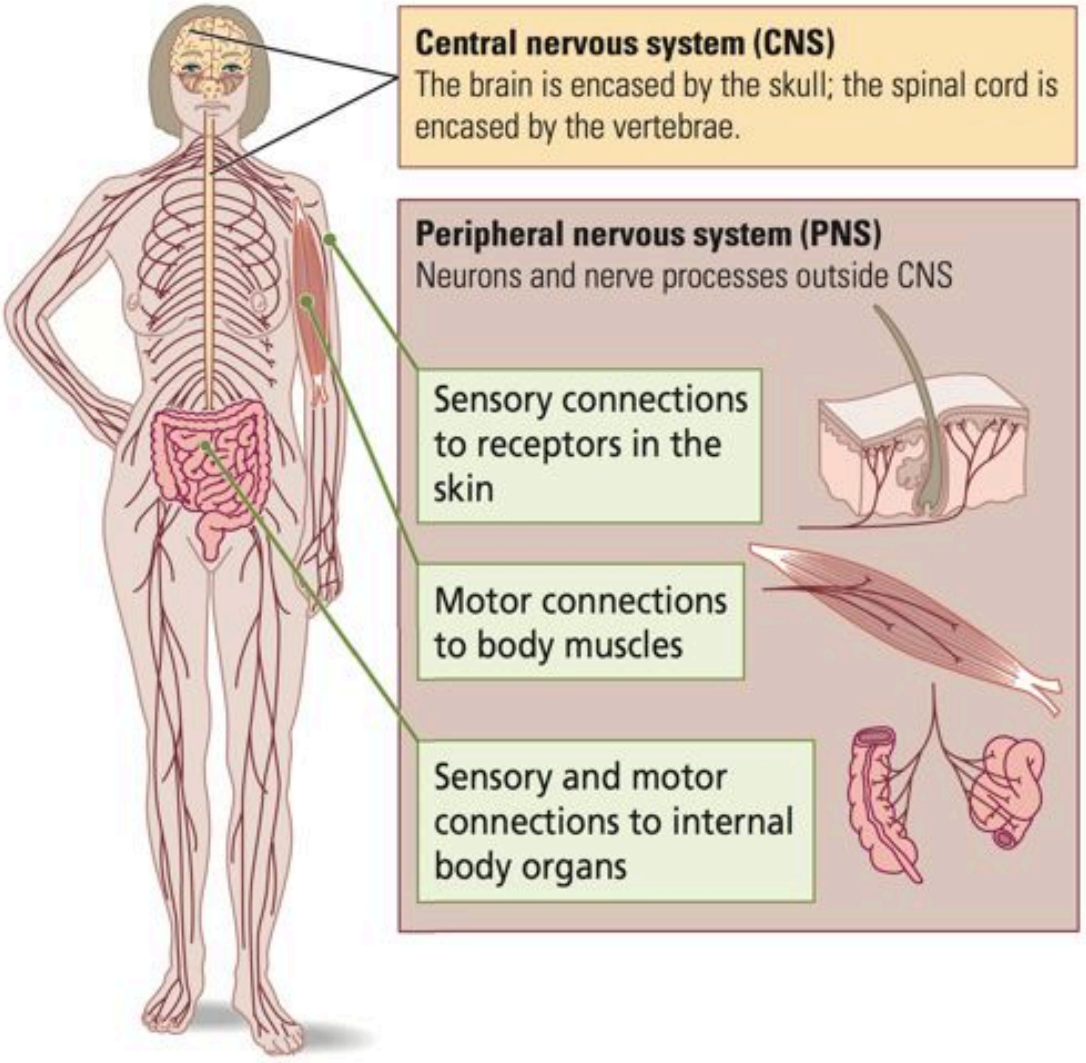


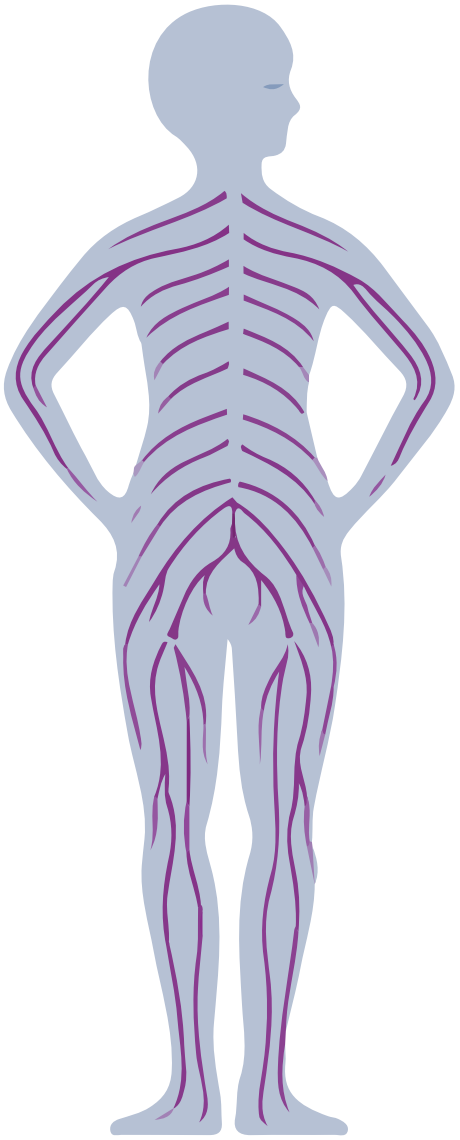
Illustration from Kolb & Wishaw, *An Introduction to Brain and Behavior*. Sinauer, 2014

Organization of the PNS

- The PNS has two divisions, each of which has its own sub-divisions:

- Somatic nervous system:
  - *Efferent* (outgoing) nerves: Motor nerves that connect the CNS to the skeletal muscles.
  - *Afferent* (incoming) nerves: Sensory nerves that carry information from the sense organs to the CNS.

- Autonomic nervous system: Regulates homeostasis.
  - *Sympathetic nervous system (SNS)*: Arousing. "Fight or flight."
  - *Parasympathetic nervous system (PNS)*: Calming. "Rest and digest."



Organization of the autonomic nervous system

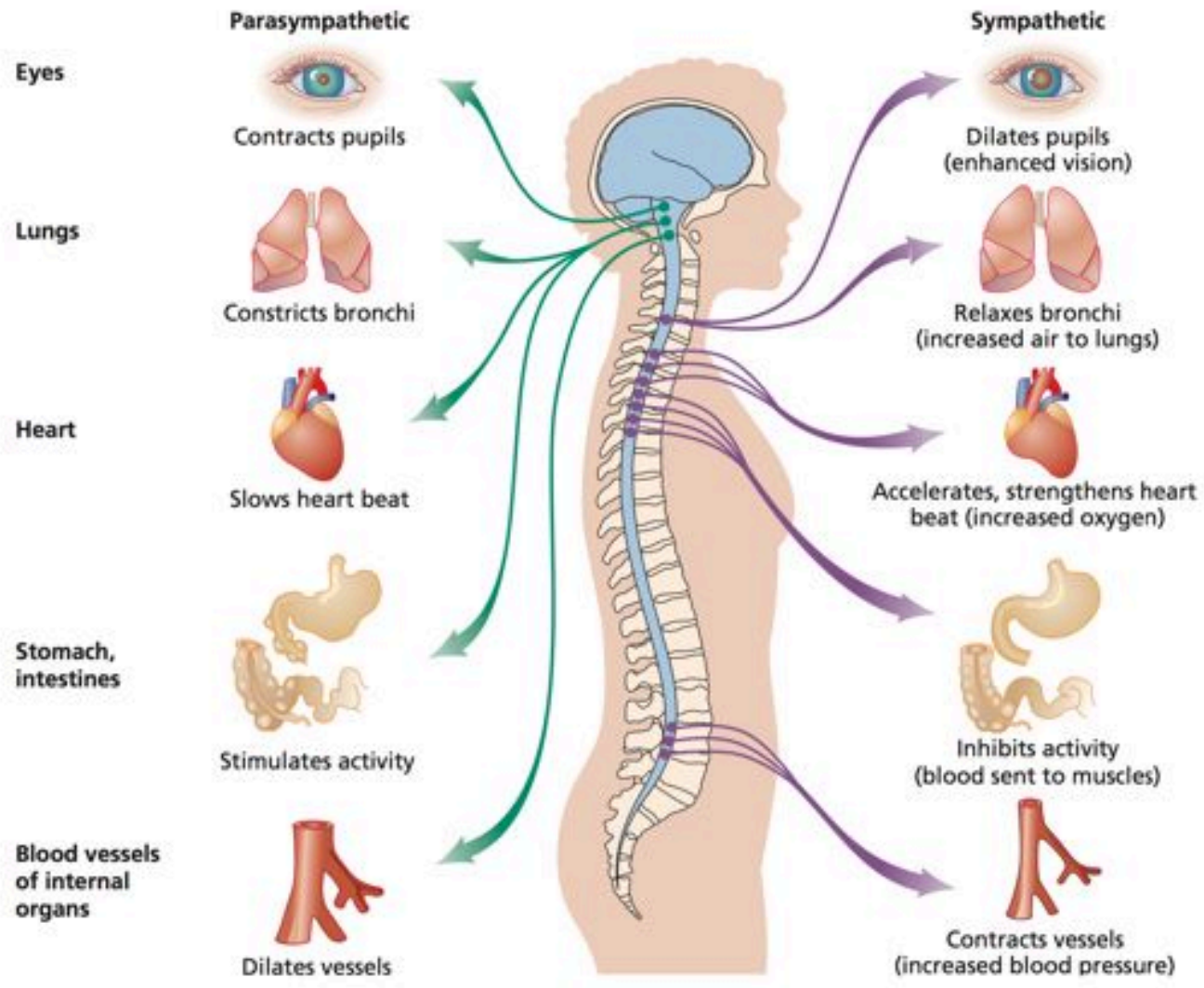


Illustration from Kolb & Wishaw, *An Introduction to Brain and Behavior*. Sinauer, 2014

The sympathetic nervous system

A hemi-sympathectomized cat. The sympathetic nervous system was removed from the right half of her body. Note that by placing her in a cold room, the hairs on her intact left side stand on end (piloerection), but those on her right do not (Cannon 1929).

The ventricular system

The brain is cushioned and supported by a series of inter-connected hollow spaces called "**ventricles.**"

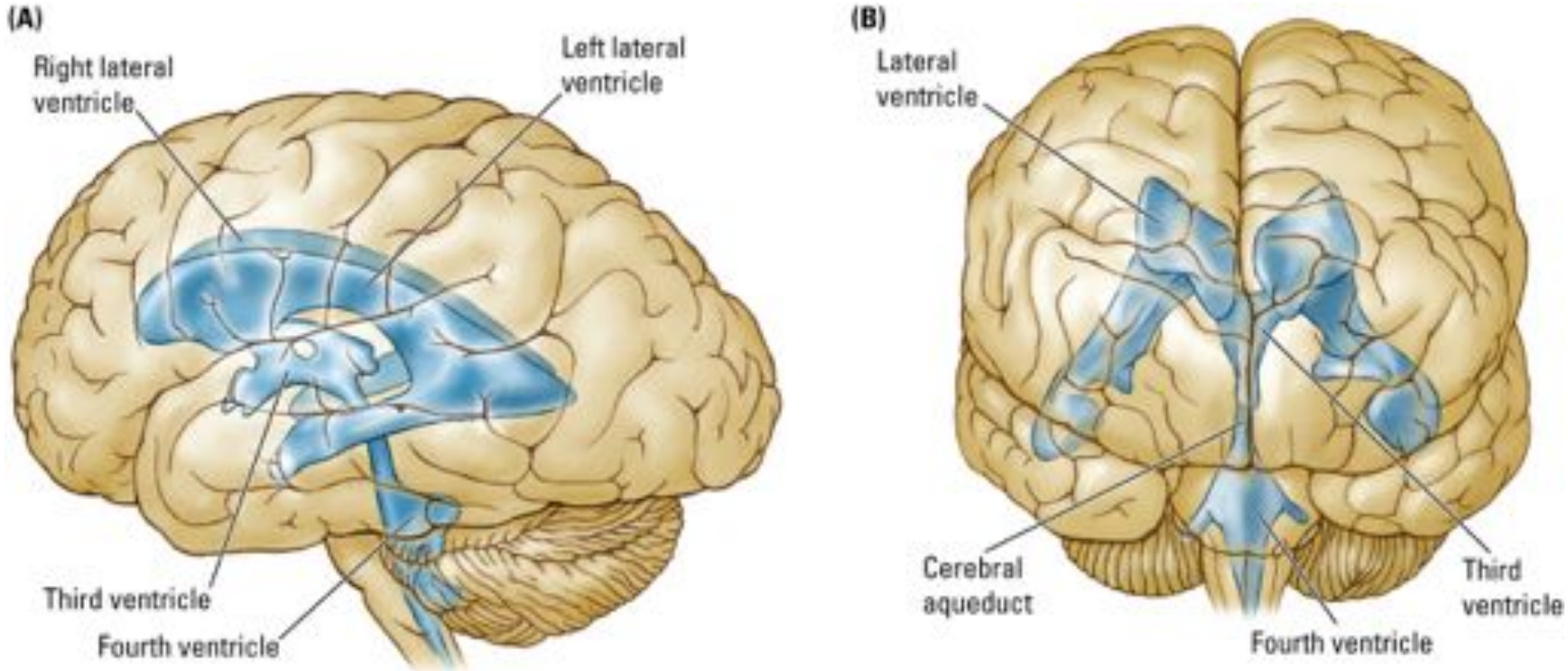
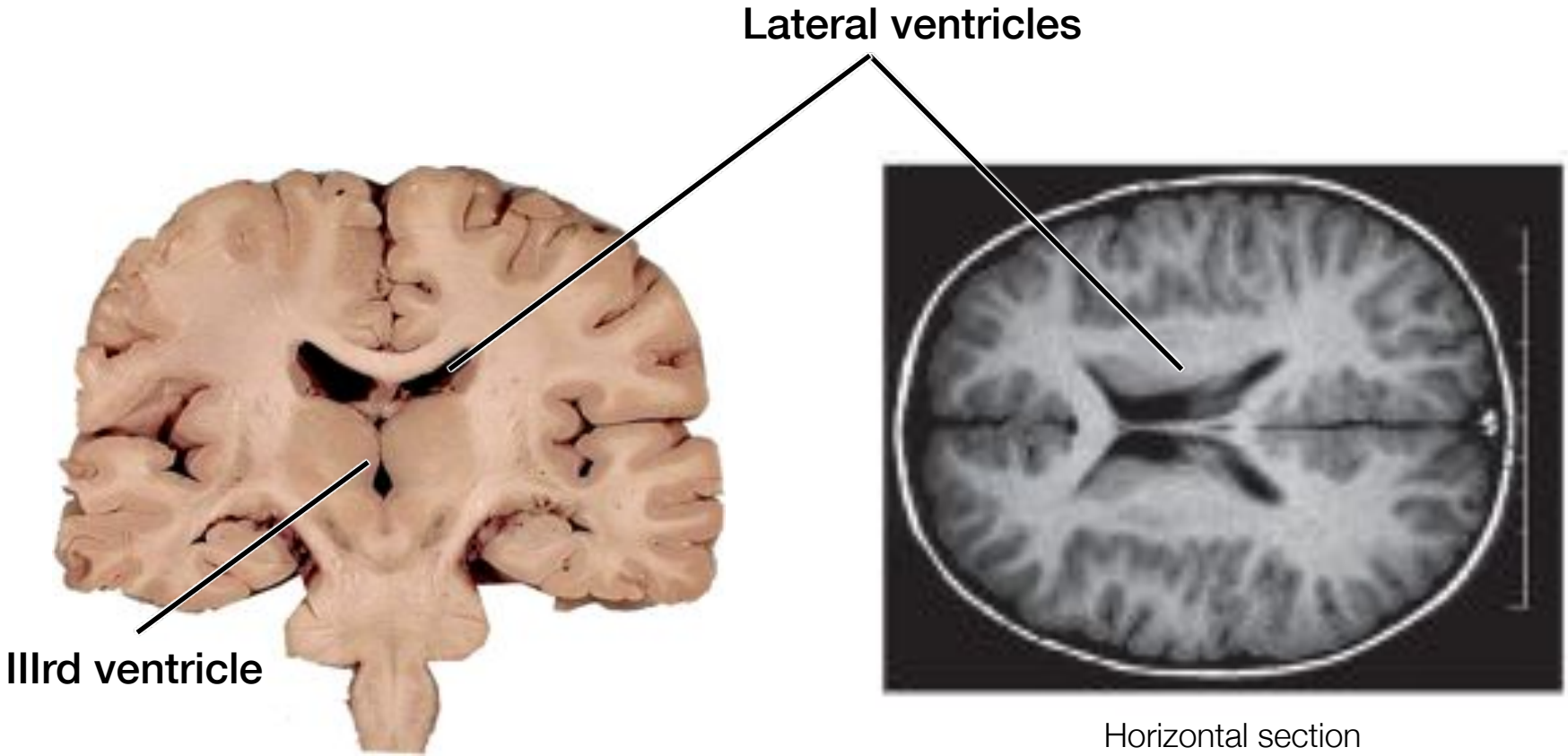


Illustration from Kolb & Wishaw, *An Introduction to Brain and Behavior*. Sinauer, 2014

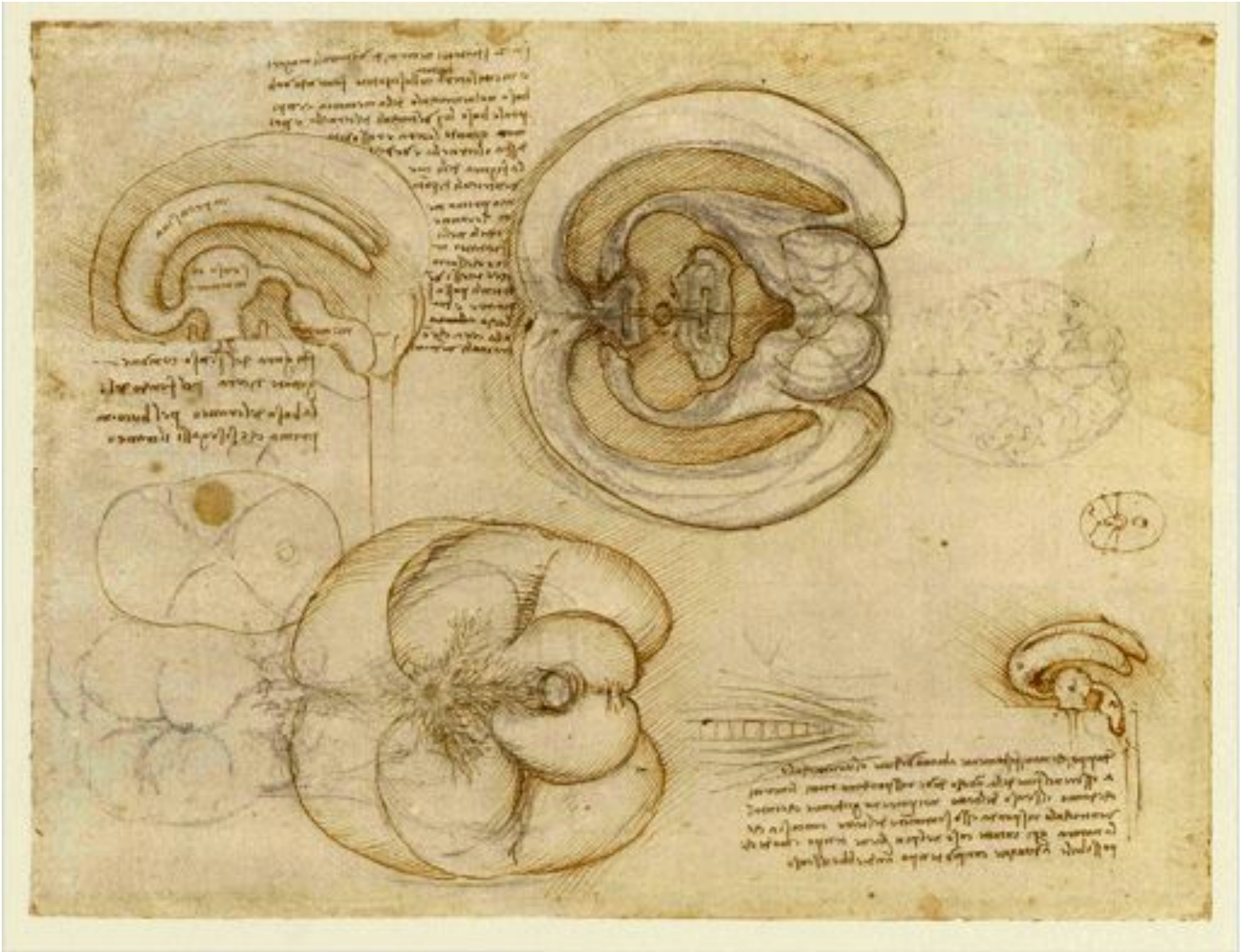
The ventricular system

The ventricles are clearly visible in coronal and horizontal sections of the brain.



Coronal section

Horizontal section



Anatomical study of the ventricles.
Leonardo da Vinci - ca. 1508

The meninges & cerebrospinal fluid (CSF)

- The brain and spinal cord are protected by special membranes called **meninges.**
  - When these membranes are infected, *meningitis* results.

- **Cerebrospinal fluid (CSF)** fills the ventricles and circulates around the brain and spinal cord.
  - Like plasma, CSF contains glucose, various salts, and minerals, but unlike plasma it contains very little protein.
  - CSF possesses a similar density to the brain. This allows the brain to float comfortably in the skull.

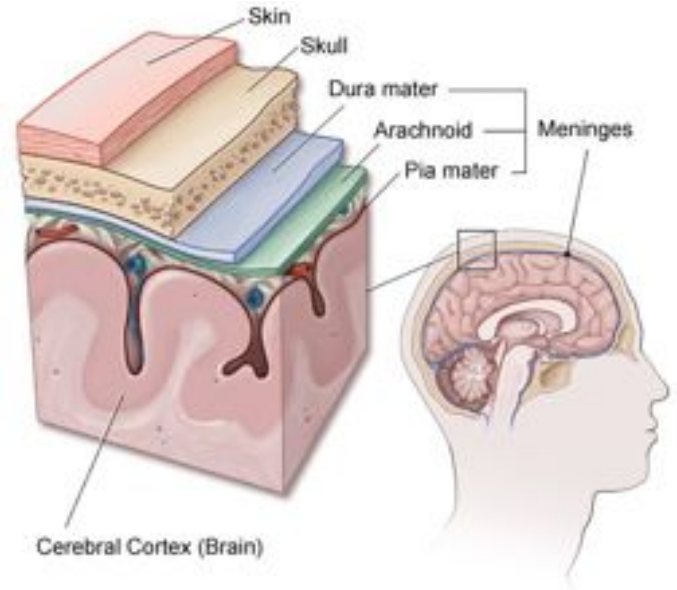
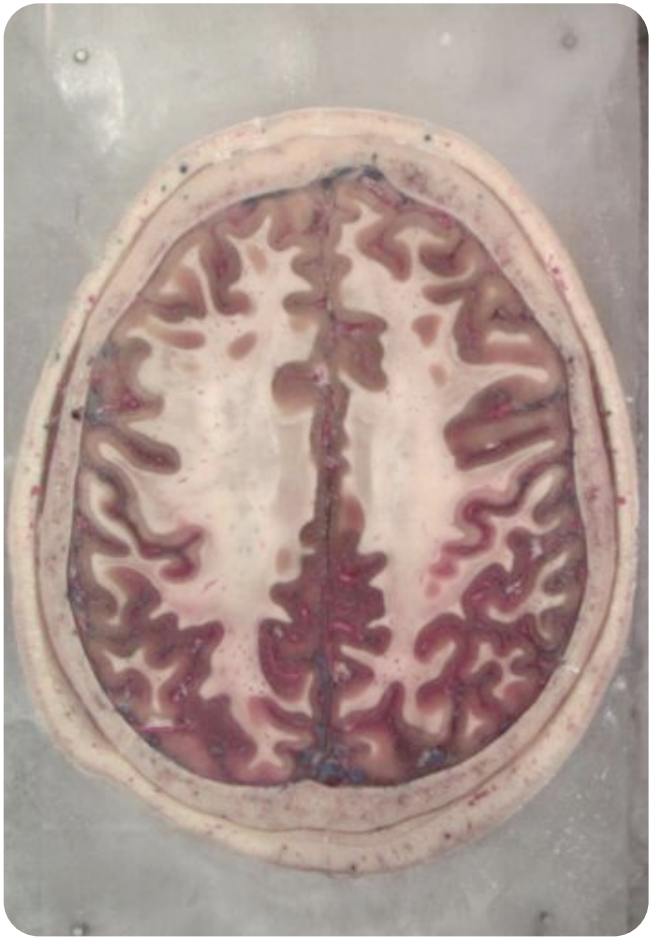
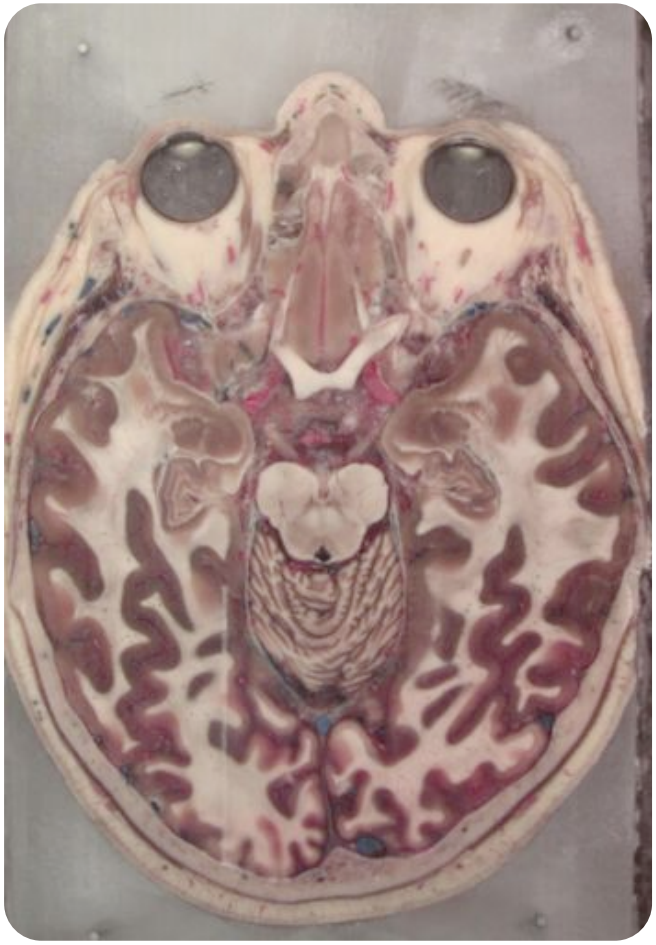


Illustration from Kolb & Wishaw, *An Introduction to Brain and Behavior*. Sinauer, 2014

The meninges & cerebrospinal fluid

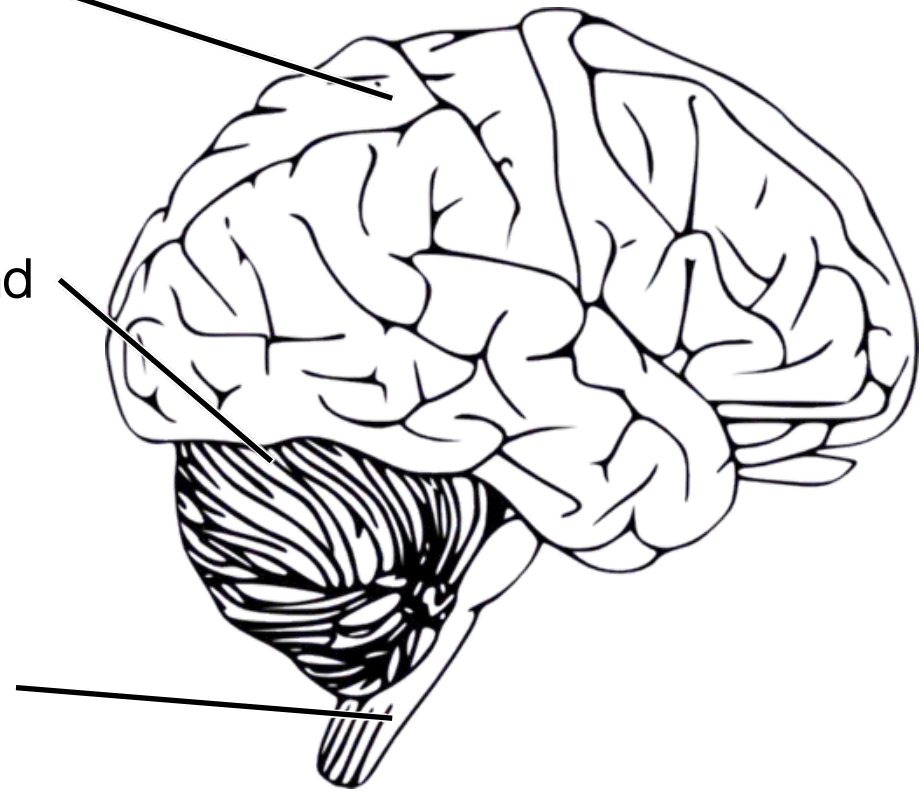




A few millimeters of skin, muscle, and bone are all that separate the brain from the dangers of the outside world.

External features of the brain

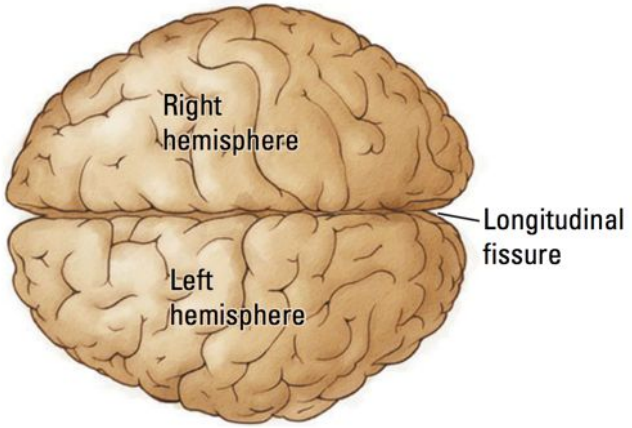
- **Cerebrum** - "*brain (L.)*"
  - Major structure of the forebrain consisting of two virtually identical hemispheres (left & right).
- **Cerebellum** – "*little brain (L.)*"
  - Involved in motor coordination, and possibly other mental processes.
- **Brainstem**
  - Comprises the deep structures of the brain. Connects the brain to the spinal cord.
  - Critical for sustaining life (respiration, blood pressure, etc.,)



The cerebral cortex

- The cerebral cortex is divided into two **hemispheres**, each of which has four **lobes**.

- **Frontal** lobe
  - Motor control.
  - Executive functions.
- **Occipital** lobe – "*back of skull (L.)*"
  - Vision
- **Parietal** lobe – "*wall (L.)*"
  - Touch sensation.
  - Sense of self in space.
- **Temporal** lobe
  - Auditory sensation.
  - Language perception.
  - Gustatory (taste) functions.



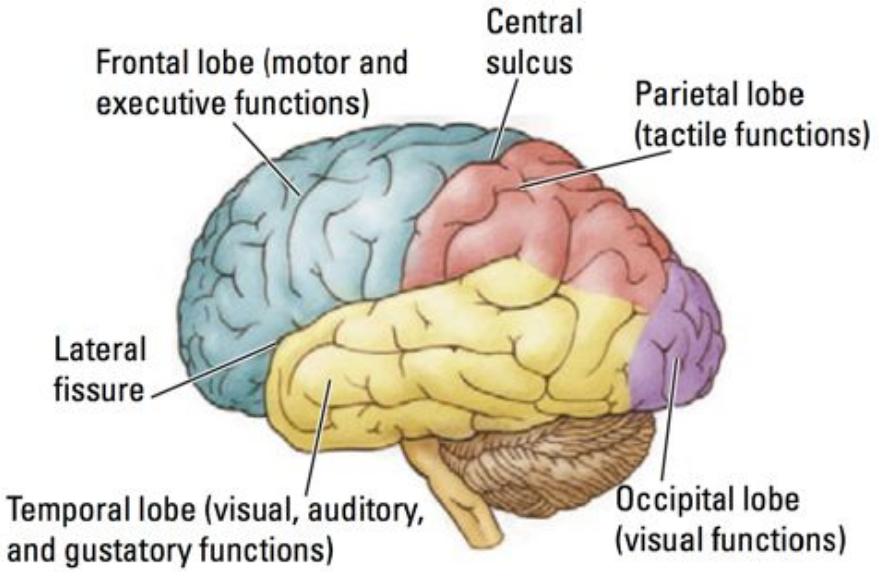
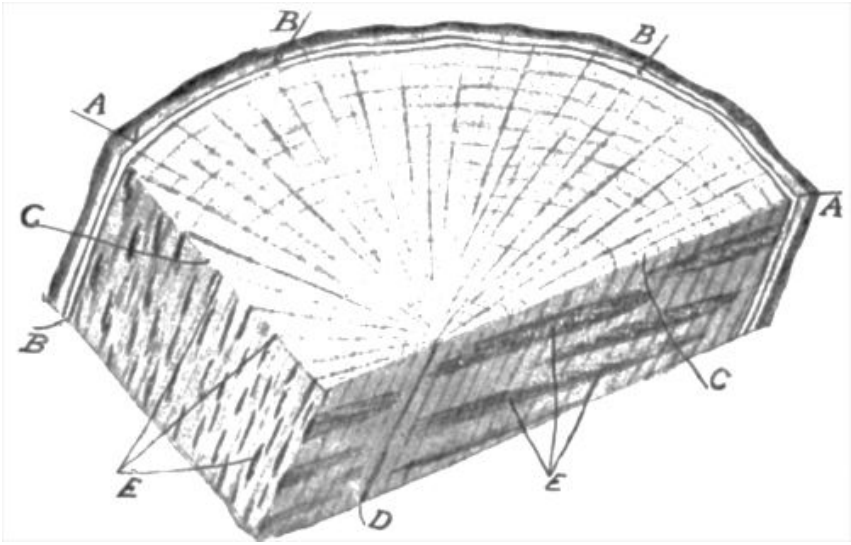


Illustration from Kolb & Wishaw, *An Introduction to Brain and Behavior*. Sinauer, 2014

The cerebral cortex

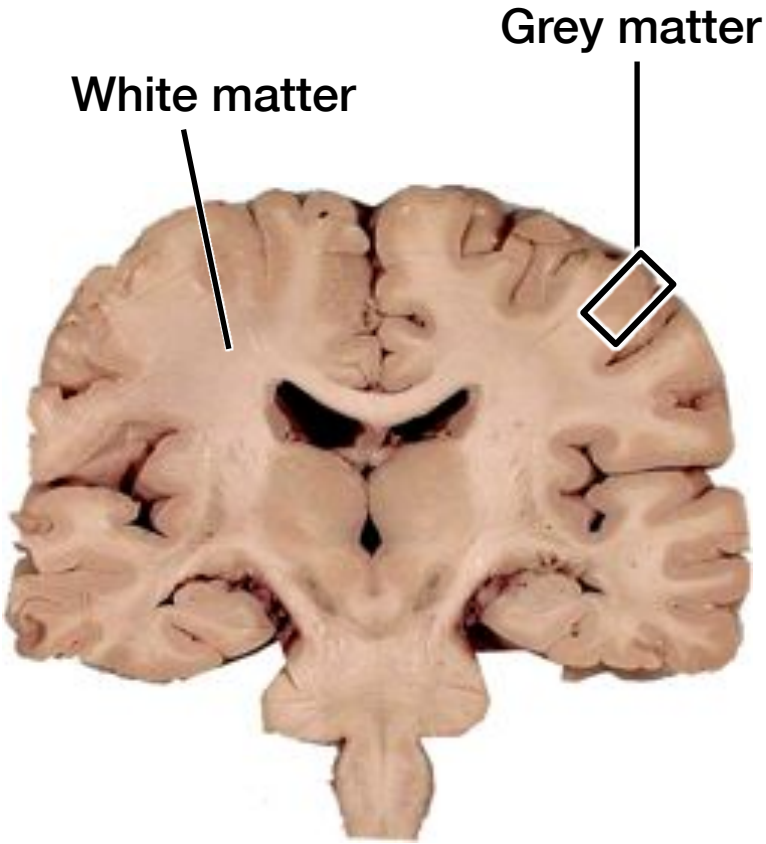
- The brain's outer layer of grey matter is called the **cerebral cortex** - "*bark (L.)*"
- The site of higher brain functions and conscious thought (probably).
- Composed of **grey matter**.



Grey matter & white matter

- **Grey matter**
  - Areas of the nervous system composed of cell bodies and blood vessels.
    - Ex. Cerebral cortex, subcortical nuclei, etc.,

- **White matter**
  - Areas of the nervous system rich in fat-sheathed neural axons.
    - Ex. Subcortical white matter, corpus callosum, etc.,



Coronal section

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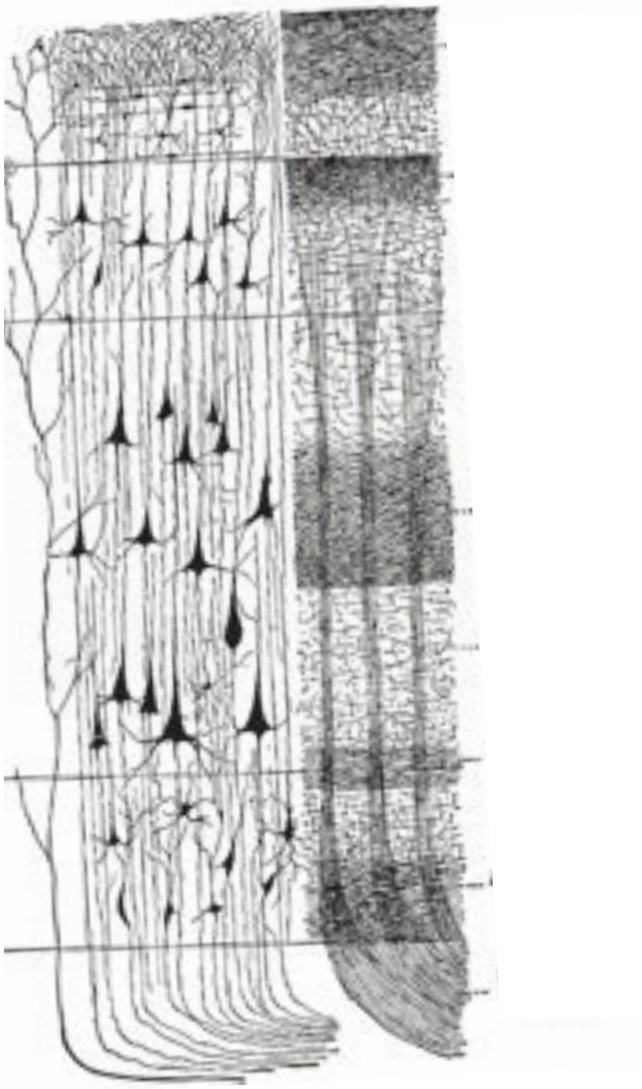
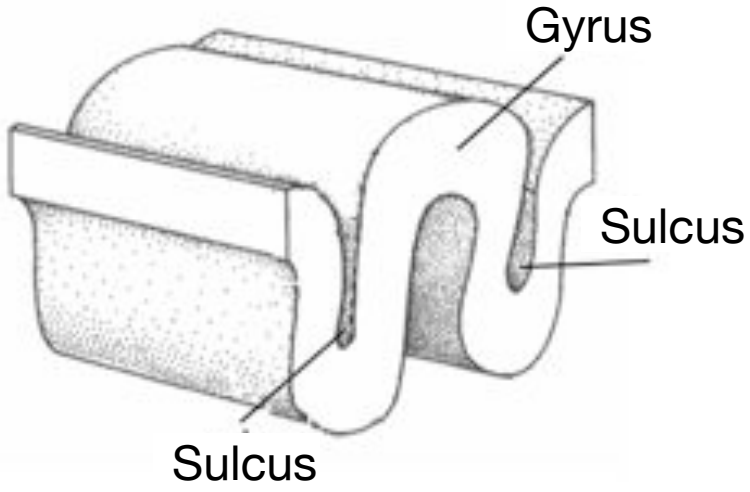


External features of the brain

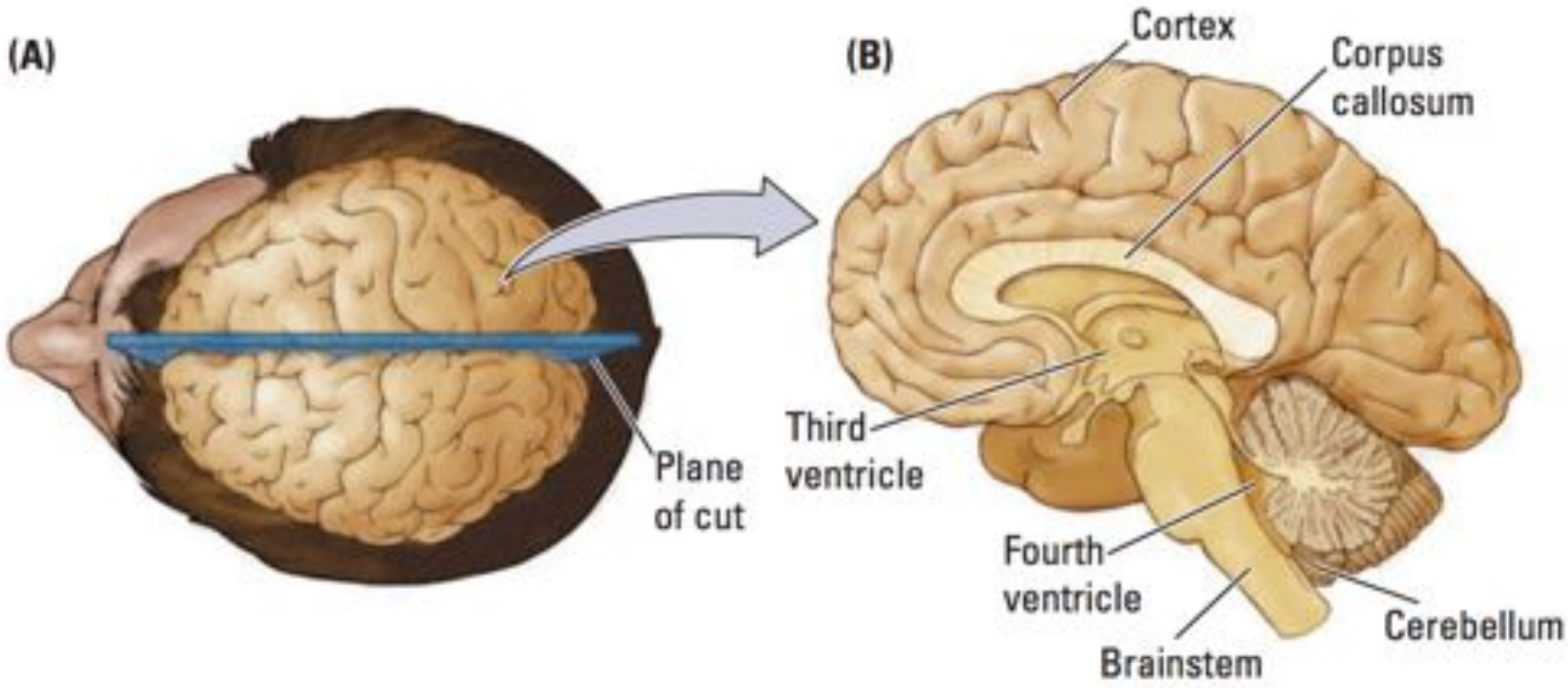
- The cerebral cortex has a characteristically wrinkled appearance. By folding and wrinkling itself up, the brain is able to fit more cortex into the skull.

- **Gyrus** (pl. gyri) – "*ring, circle (G.)*"
  - A bump or convolution between grooves.

- **Sulcus** (pl. sulci) – "*furrow, trench (L.)*"
  - A groove between gyri.



The corpus callosum



The **corpus callosum** - *"firm body (L.)"* - connects the two cerebral hemispheres, allowing both sides of the brain to work together.

The limbic system

- The **limbic system** – *"edge/border (L.)"* – is important for emotions, memories, and can be affected by psychological disorders and drug addiction. It consists of *three* major parts.

- **Cingulate cortex** – *"encircling/belt (L.)"*
  - Involved in emotional processing and memory.
- ***Amygdala*** – *"almond (G.)"*
  - Involved in fear, aggression, and emotionally charged memories.
- **Hippocampus** – *"seahorse (G.)"*
  - Involved in the formation of long-term memories.

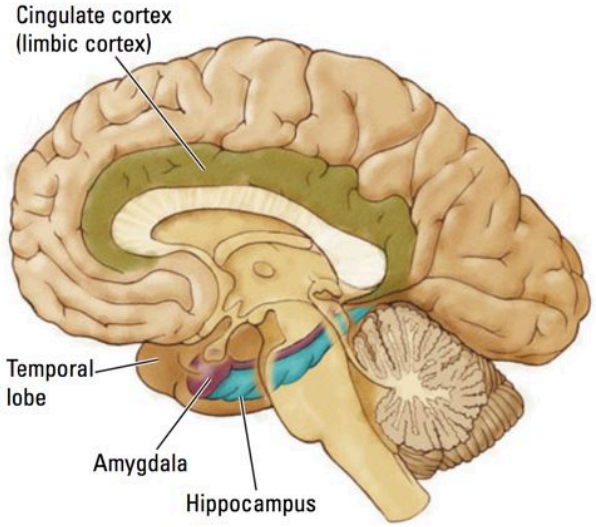


Illustration from Kolb & Wishaw, *An Introduction to Brain and Behavior*. Sinauer, 2014

The basal ganglia

- The **basal ganglia** are involved in *controlling* movement. They are also important in learning and memory, and in particular learning "habits". The **basal ganglia** consist of three main parts:

- The **caudate nucleus** – *"tail (L.)"* - and **putamen** – *"shell (L.)"* - are together known as the **striatum** – *"striped (L.)".*

- The **globus pallidus** – *"pale globe (L.)"*

- The **substantia nigra** – *"black substance (L.)"* - is part of the **midbrain**. It contains numerous dopaminergic neurons that project into the **basal ganglia**.
  - Parkinson's Disease involves the death of DAergic neurons in the substantia nigra.

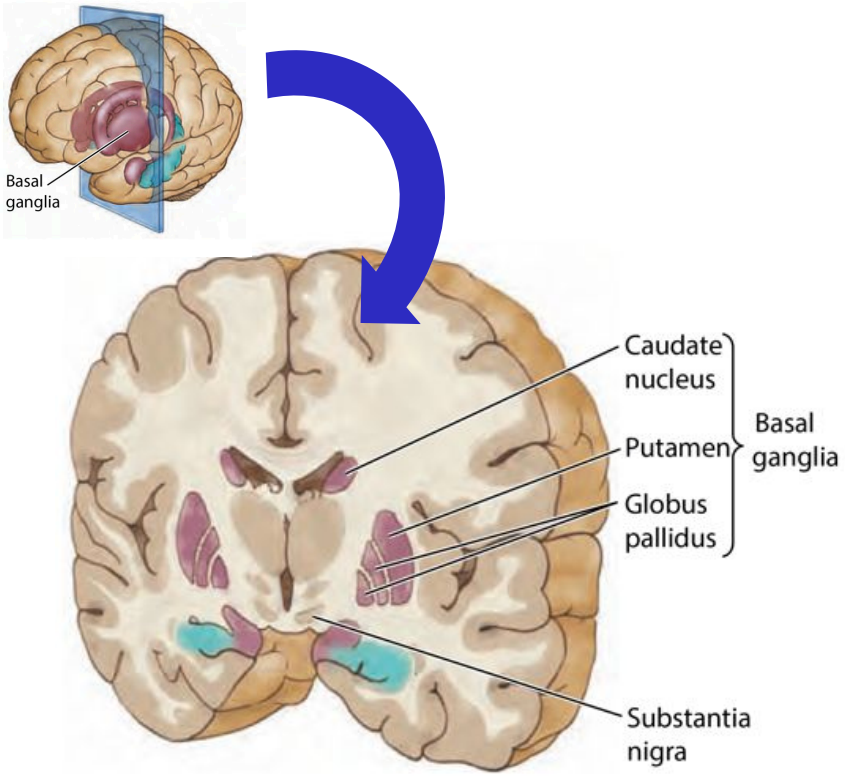


Illustration from Kolb & Wishaw, *An Introduction to Brain and Behavior*. Sinauer, 2014

The brainstem

- The brainstem is divided into three basic regions.

- **Diencephalon:**
  - Thalamus – *"inner chamber (L.)"*
    - All sensory information (except smell) passes through the thalamus en route to the cortex.
  - Hypothalamus – *"below/under (G.) thalamus"*
    - Controls homeostasis, regulates hormone secretion from the pituitary gland.

- **Midbrain:**
  - Contains neurons that produce *dopamine* that project to various other brain regions.

- **Hindbrain:**
  - Pons – *"bridge (L.)"*
    - Connects the cerebellum to the brainstem.
  - Medulla – *"marrow (L.)"*
    - Controls breathing & heart rate.
    - Connects the brain to the spinal cord.

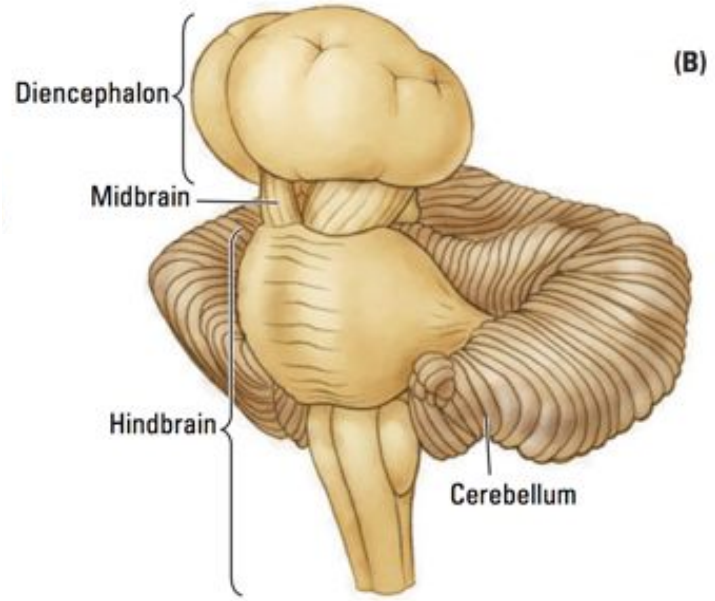


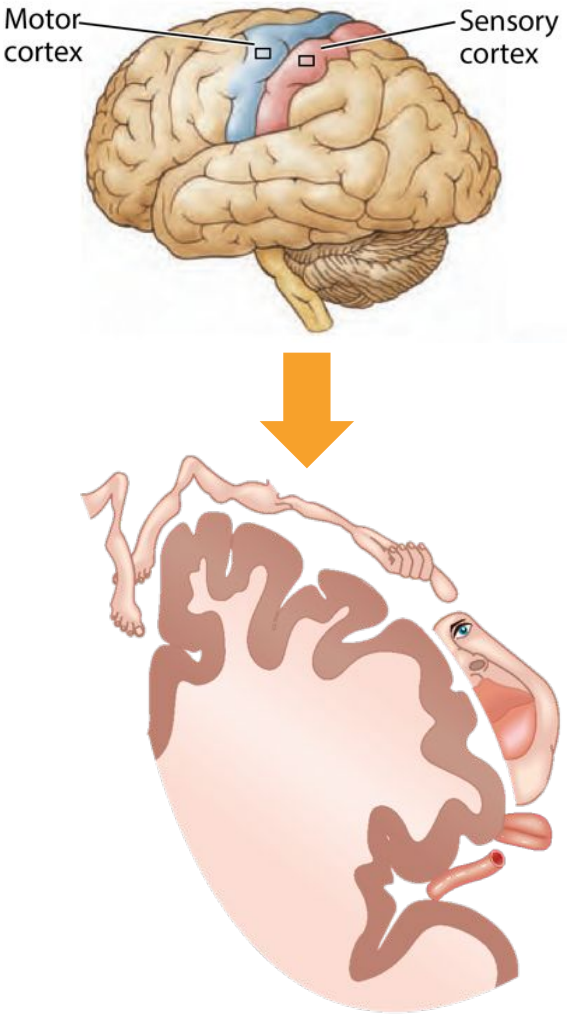
Illustration from Kolb & Wishaw, *An Introduction to Brain and Behavior*. Sinauer, 2014

Motor and sensory pathways

- Fine-touch sensation from the skin reaches the **sensory cortex** via the **thalamus**.

- Voluntary muscle control is governed by the **motor cortex**. Axons from the **motor cortex** project directly to motor neurons in the **spinal cord** (and these in turn connect directly with target muscles).

- The **sensory** and **motor cortices** are not in proportion to the body. Areas of the body that require finer motor control, or a finer sense of touch (e.g. face, hands, etc.,) have a relatively larger area of the cortex devoted to them.



Coronal section of the sensory cortex, showing the relative surface area devoted to each part of the body.

Illustration from Kolb & Wishaw, *An Introduction to Brain and Behavior*. Sinauer, 2014

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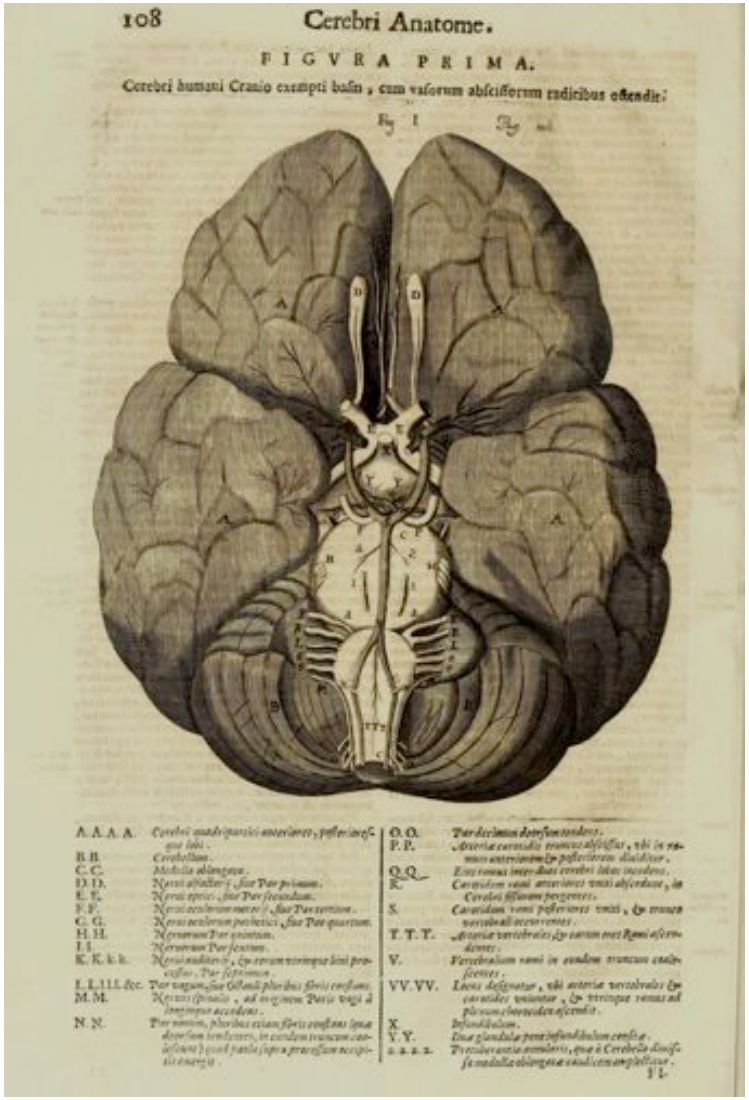
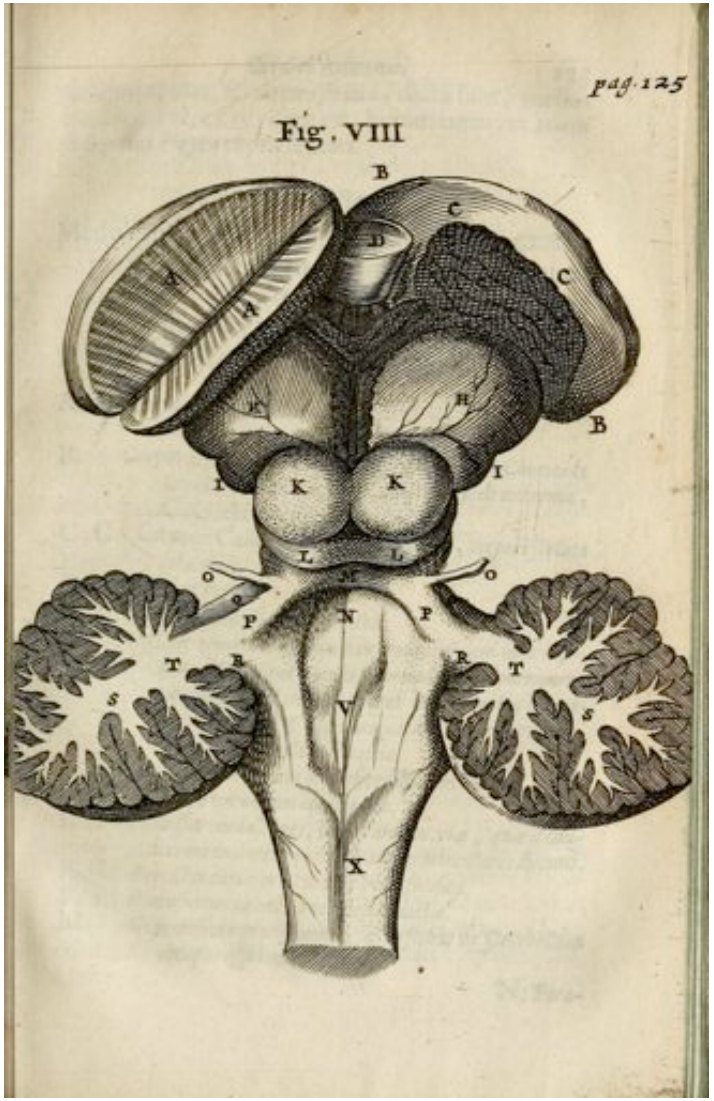
The somatosensory homunculus: an image of how a human would look if their body was in proportion to the cortical representation given to its various parts.

Coronal section of the sensory cortex, showing the relative surface area devoted to each part of the body.

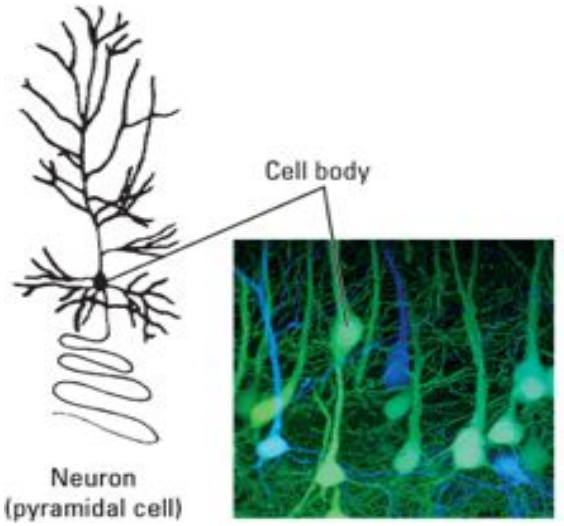




Thomas Willis & Christopher Wren, 1664

Two main types of brain cells

- **Neurons**
  - The basic information processing units of the brain.
  - Approximately 80 billion in the human brain.



- **Glial cells** – *"glue (G.)"*
  - Support and modulate neurons' activities.
  - Creates the *myelin sheath.*
  - Approximately 100 billion in the human brain.

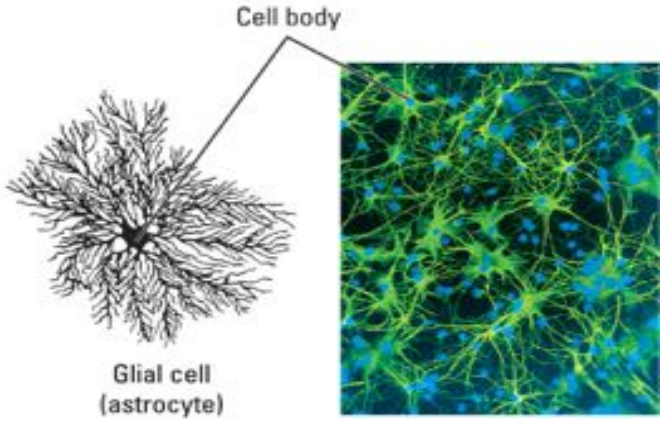
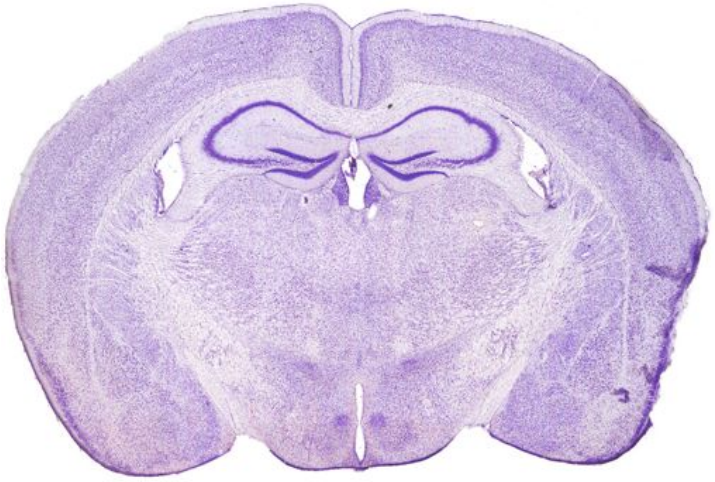


Illustration from Kolb & Wishaw, *An Introduction to Brain and Behavior*. Sinauer, 2014

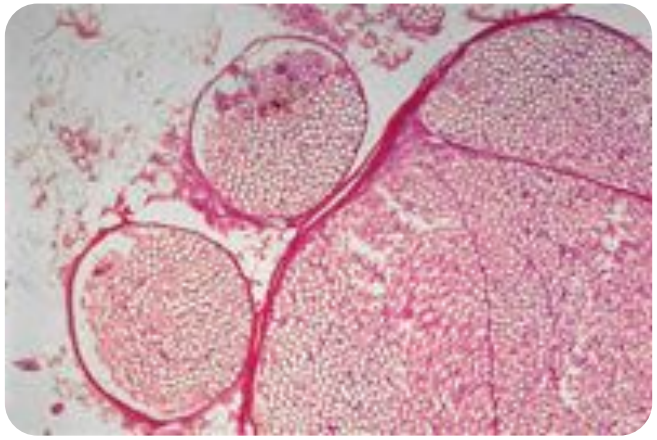
Some terms

- **Nucleus** (pl. nuclei)
  - A group of neurons forming a cluster that can be identified with special stains to form a functional grouping.
    - Examples: Ventral Tegmental Area (VTA), Arcuate Nucleus (ARC) etc.,
  - Groups of neurons in the CNS are called nuclei, those in the PNS are called ganglia*.

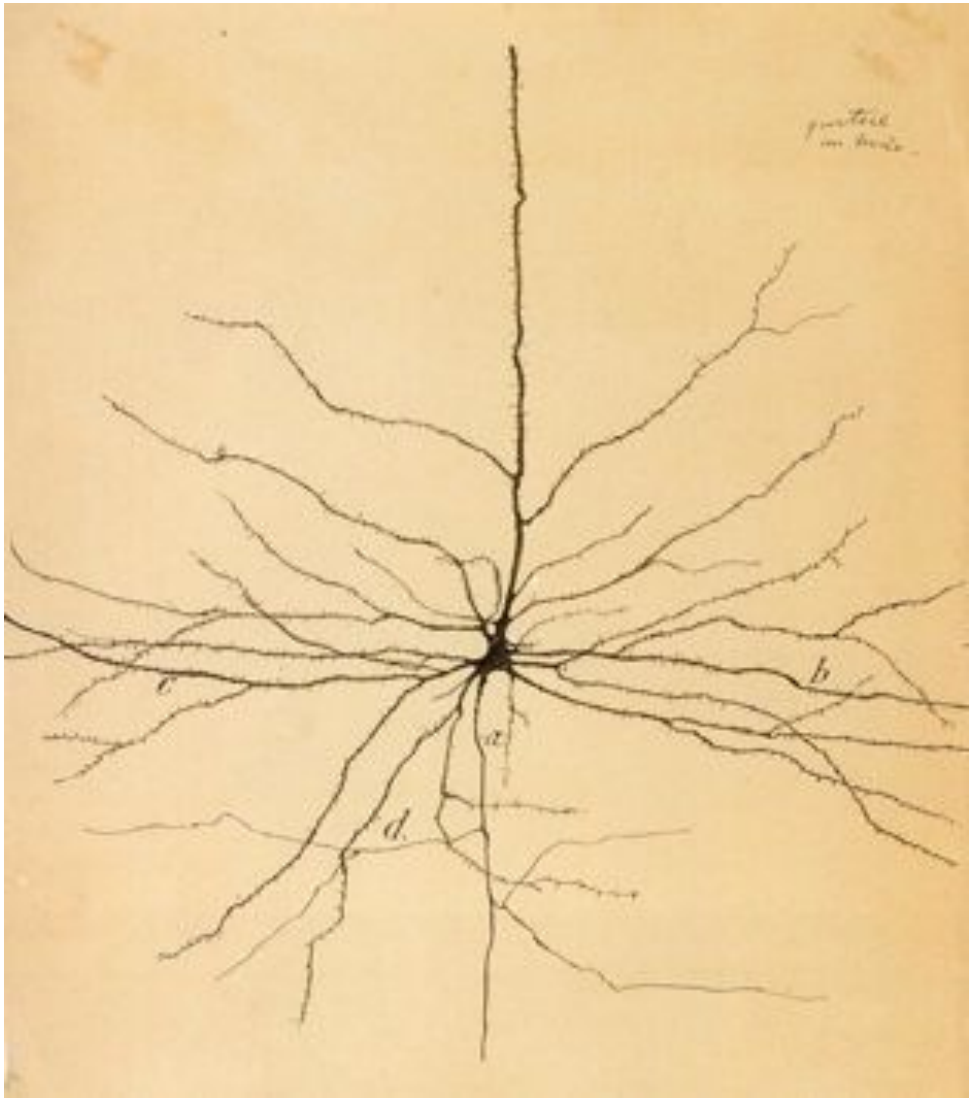


Coronal section of mouse brain. Darker areas are clusters of cells (nuclei).

- **Nerve**
  - A large collection of axons forming connections in the PNS.
    - Examples: Phrenic nerve (arising from C3-C5, it controls the diaphragm).
  - Large collections of axons in the CNS are called tracts.
    - Example: Corticospinal tract (connects the motor cortex to the motor neurons of the spinal cord).

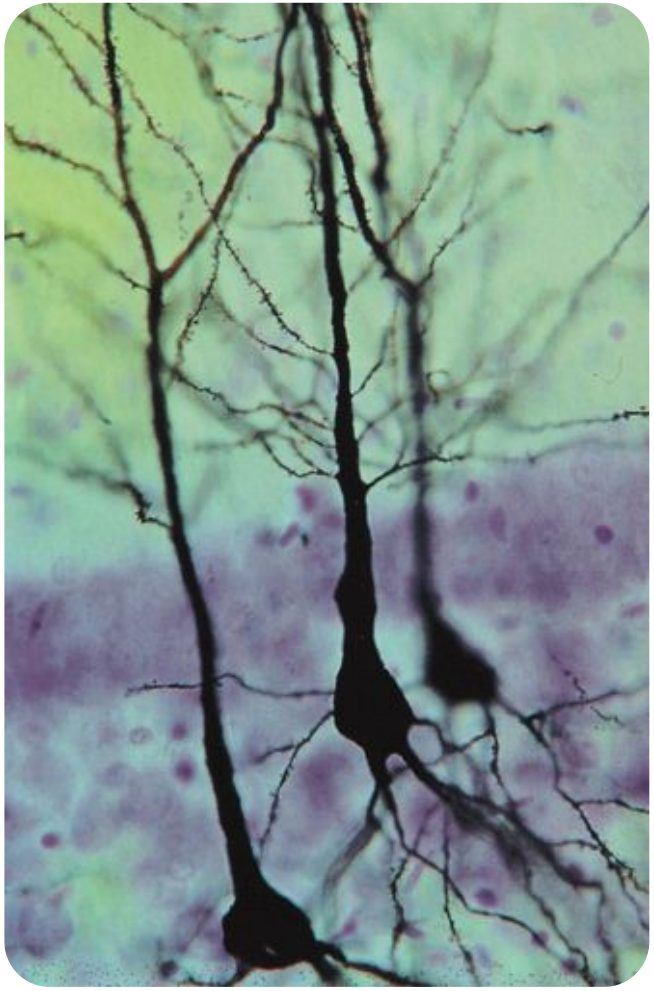


Cross section of nerves in PNS. Large bundles are nerves, small circles are cross sections of individual axons.



Pyramidal neuron.
Santiago Ramón y Cajal – 1899

Introducing the neuron



Golgi stained pyramidal **neurons** in the **cerebral cortex**.

Neurons transmit information

- **Neurons** are specialized cells that are specialized for transferring information from one place to another.

- **Neurons** have specialized structures for this purpose.
  - Dendrites – *"tree (G.)"*
    - Gather information from other neurons.
  - Cell body
    - Core region; contains the nucleus and DNA.
  - Axon hillock
    - Junction of the cell body and axon, where the *action potential* begins.
  - Axon
    - Carries information to be passed onto other cells.
  - Terminal button
    - Knob at the tip of an axon that conveys information to other neurons.
    - Connects with dendrites of other neurons.

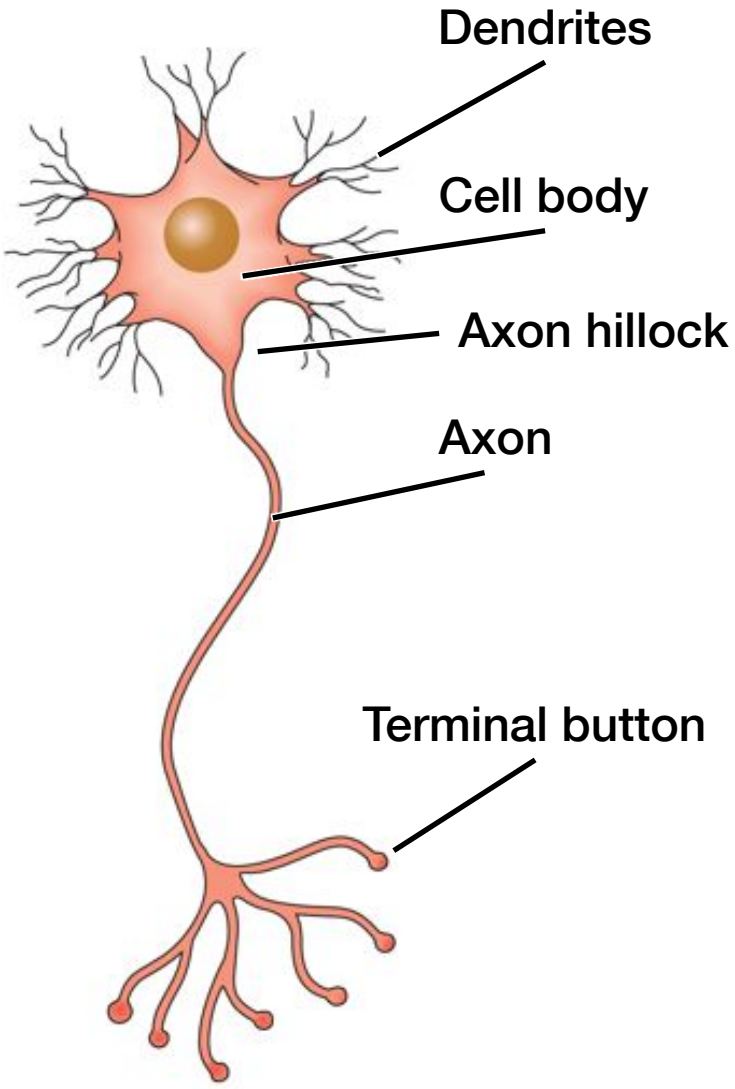


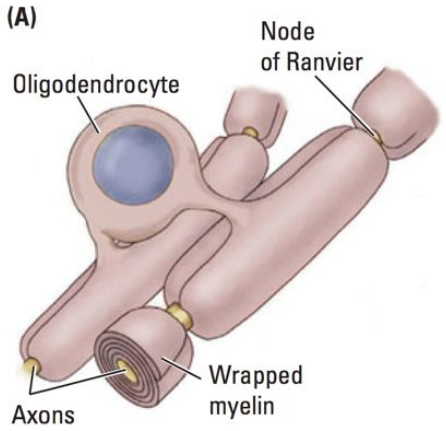
Illustration from J.P.J. Pinel, *Biopsychology*. Allyn & Bacon, 2011

Neurons transmit information

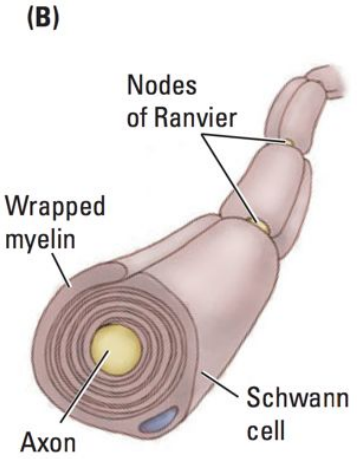
- **Axons**, especially longer ones, are usually covered with a **myelin sheath**.

- **Myelin** is a fatty substance produced by glial cells. **Myelin** insulates the **axon**, increasing the speed and efficiency of electrical signal conduction.

- The fatty nature of **myelin** gives **white matter** its color.



Oligodendrocytes myelinate axons in the CNS



Schwann cells myelinate axons in the PNS

Illustration from J.P.J. Pinel, *Biopsychology*. Allyn & Bacon, 2011