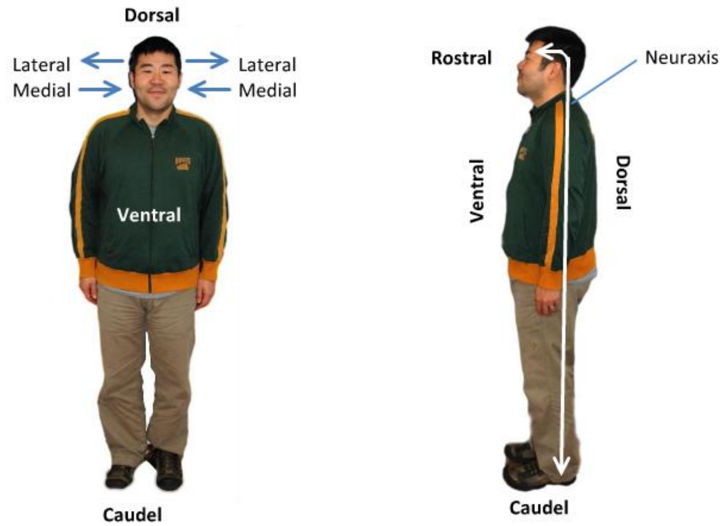
Psych 1XX3 – Notes on Neuroscience II – Jan 27th, 2010



- In humans, the nervous system axis, or "neuraxis", curves as you can see in this diagram.
- Dorsal always refers to the back of the axis, and ventral means to the front of the axis or "to or the belly".
- Because of the curve in the neuraxis, at the level of the head dorsal is up, but at the level of the spinal cord dorsal is to the back. The term rostral means towards the top of the axis, and caudal means towards the bottom of the axis.
- Finally, locations in the brain that are more central or towards the midline of the brain are medial, and regions towards the outside of the brain are lateral. These terms can be combined to locate a very specific brain region.

located toward the *top* of the brain	dorsal
located toward the *front* of the brain	rostral
located toward the *side* of the brain	lateral
located toward the *bottom* of the brain	caudal

Studying the Brain:

- Neuroscientists have long been interested in case studies of accidental brain injury which can link anatomy with associated cognitive and behavioural deficits that are observed.

Lesion Studies:

- Consider the famous case study of Phineas Gage. In 1848, Gage was the victim of a tragic accident, resulting in the blasting of a 3 foot iron rod completely through his left cheekbone and through the top of his skull. Remarkably; Gage survived, and he recovered completely. However, once an upbeat, polite and caring person, Gage became prone to selfish behaviour and bursts of profanity. He became erratic and unreliable, and had trouble forming and following through on plans. Gage's case provided support for the view that the brain has specialized structures for complex behaviours.

- Case studies such as Phineas Gage have given neuroscientists tantalizing hints to the relationship between structure and function in the brain.
- A limitation of most case studies of human brain lesions is that they are rarely isolated to specific brain structures. This certainly makes a more difficult task of assigning impaired function to specific brain areas.
- This problem can be overcome by studying specific brain lesions induced in animal models. In such ablation studies, a researcher destroys, removes or inactivates a defined brain region and observes the result on behaviour.
- The accuracy of this emerging understanding of structure and function can depend on the precision of the lesion. Even so, because the brain is so highly interconnected, often a variety of behaviours are affected by a single lesion.

Stimulation and Signal Cell Recording:

- An alternative approach to lesioning is to electrically stimulate an area of the brain and observe the result on behaviour to build an anatomical map related to function.
- This technique was used extensively by the Canadian neurologist Penfield as he performed brain surgery to treat patients with severe epileptic seizures.

Single Cell Recording:

- Penfield revolutionized techniques in brain surgery as he perfected his "Montreal Procedure" to treat patients experiencing severe seizures.
- In doing so, he had to be sure that critical areas of the brain were left intact. Because the brain itself does not have pain receptors, a patient undergoing surgery could be under local anaesthetic and fully conscious, working with Penfield to probe the exposed brain to locate and remove the scarred tissue that caused the seizures.
- Penfield used a thin, wire carrying a small electric charge to stimulate the cortex. This stimulation leads individual neurons to fire, and thus Penfield could very accurately map perceptual processes and behaviours to specific brain regions.
- For example, if an area of the visual cortex was stimulated, a patient reported seeing flashes of light and if an area of the motor cortex was stimulated, a patient would experience a muscle twitch.
- Penfield’s pioneering work revealed specific function to previously unmapped regions of the brain.

- Electrodes can also be used to record ongoing electrical activity in the brain through single cell recording techniques.
- A small electrode is inserted into the nervous tissue of a live animal model with its tip held just outside the cell body of an individual neuron.
- From this electrode, neural activity is recorded while the animal performs a task or a stimulus is presented. The pattern of firing reveals a particular neuron’s functional role.
- For example, in your study of Vision, you will encounter the seminal work of Hubel and Wiesel. In a typical experiment, cats were presented with specific visual stimuli while recording from single cells in the visual cortex.
- In this wary, individual cell types were identified that responded to specific categories of visual stimuli.
- Limitation: it only provides information about a limited area in the brain.

Structural Neuroimaging:

- To study large-scale structure and function of brain regions, neuroscientists use structural and functional neuroimaging techniques.
- The first structural neuroimaging technique developed was computed tomography (or CT).
- During a CT scan, a series of X ray slices of the brain are taken and pieced together to produce a relatively quick and inexpensive picture of the brain.
- These scans are often helpful to diagnose brain injuries.
- Limitation: its relatively low resolution.
- For a more detailed structural image of the brain, neuroscientists use MRI, or magnetic resonance imaging. In an MRI machine, powerful magnetic fields are generated which align the hydrogen atoms found throughout the brain.
- While these atoms are aligned, an MRI can be used to localize tissue very precisely throughout the brain.

Functional Neuroimaging:

- Cognitive neuroscientists can use a functional imaging technique such as positron emission tomography (or PET scan), to learn how brain function relates to cognitive tasks such as language and memory.
- In a PET scan, a radioactive tracer of glucose or oxygen, is injected into the bloodstream. The radioactive molecules make their way to the brain and are used in metabolic processes, which are detected by the PET scan.
- The logic is that more active brain areas will use more metabolic resources, and so an image of the brain's relative pattern of activity can be constructed.
- Disadvantage: requires a radioactive tracer to be injected, a relatively invasive procedure.

- Functional magnetic resonance image (fMRI) is often preferred because it can produce a relatively clear image of the brain's activity without the need for a radioactive tracer.
- fMRI works by measuring the blood oxygen dependent signal, and uses many of the same principles as the MRI.
- It is able to measure the relative use of oxygen throughout the brain and operates under the same basic assumption as the PET scan - more active areas of the brain require more metabolic resources.
- Popular, but has limitations: Provides a very rough image of brain activation. Oxygen use by the brain often spikes a few seconds later than the spikes of activity in the brain - and a few seconds can be a very long time in terms of brain function.
- As such, fMRI is not the best method to use if a researcher is interested in the precise timing of brain activation and function.

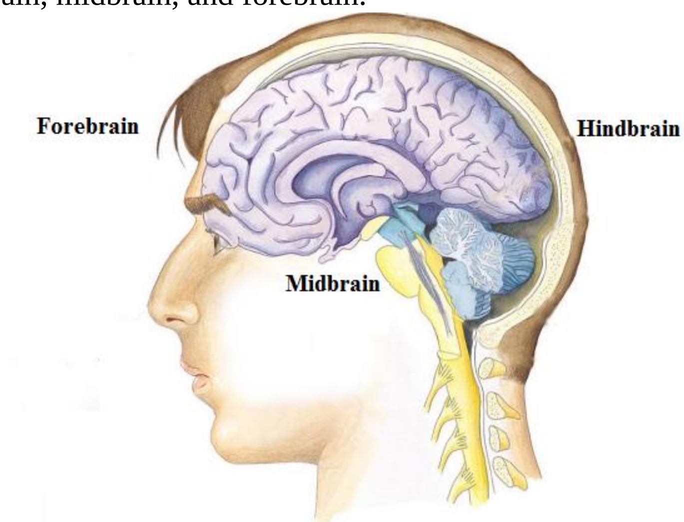
- A final neuroimaging method to consider is the electroencephalogram (EEG). The electrical activity of the brain can recorded through the scalp by wearing a cap of very sensitive electrodes.
- The EEG provides only a very rough image of the brain's overall activity, from populations of neurons. However, with a few clever modifications, the EEG can become more informative.
- In an event related potential (or ERP) experiment, a specific stimulus is presented to the subject repeatedly while the EEG is recording. Although the

EEG will generally produce very noisy waves, the specific stimulus presented can have a small and consistent effect on the readout.

- By averaging the EEG signal across many trials, the noise can be balanced out, and what remains is a characteristic signal.
- These ERP signals can still be difficult to interpret, but there are a number of reliable signals reported throughout the literature that serve as markers for different types of neural processes.
- Example: one such marker is called the N170 wave, which is thought to correspond to face processing → when combined with a behavioural measure, EEG and ERP signals can be highly informative markers, with very precise temporal resolution, on the order of milliseconds.

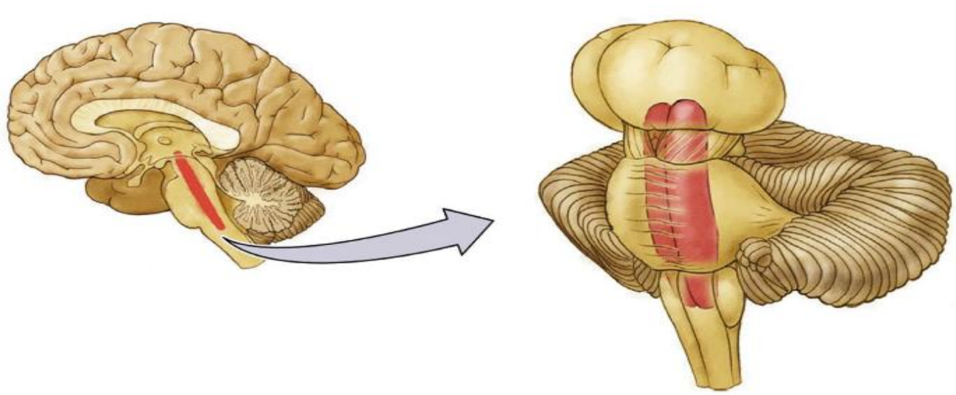
The Brain Regions (See image below.)
Introduction:

- Your look at the brain will progress through three broad regions: the hindbrain, midbrain, and forebrain.



The Hindbrain: (See image below.)
Def'n: Region at base of brain that connects the brain to the spinal cord.

- All information into and out of the brain travels through cranial nerves or through the spinal cord, which connects to the hindbrain at the very base of the brain.
- The hindbrain consists of the medulla, pons, reticular formation, and the cerebellum.
- These structures are evolutionarily the oldest parts of the brain and found in some form in nearly every vertebrate species. And so it's not surprising that they are primarily involved in the regulation of vital bodily functions.



The Hindbrain: The Medulla →

- The medulla is the most caudal part of the hindbrain and lies directly above the spinal cord. Structurally, it looks like an extension of the spinal cord and plays an important role in vital functions such as breathing, digestion and regulation of heart rate.

The Hindbrain: The Pons →

- The pons is a small structure that is rostral to the medulla. The pons relays information about movement from the cerebral hemispheres to the cerebellum.
- The pons also contains a number of nuclei that are generally part of the reticular formation.
- Additionally the pons processes some auditory information and is thought to be involved in some aspects of emotional processing.

The Hindbrain: The Reticular Formation →

- The reticular formation is a set of interconnected nuclei found throughout the hindbrain (excluding the cerebellum).
- The reticular formation has two main components: (1) The ascending reticular formation (also called reticular activating system or RAS) is primarily involved in arousal and motivation, and may be a part of a large network responsible for your conscious experience.
- Beyond that, the RAS plays an important role in circadian rhythms. Damage to the RAS leads to devastating losses in brain function, and in the extreme case a permanent coma.
- (2) The descending reticular formation is involved in posture and equilibrium, and plays a role in motor movement.

The Hindbrain: The Cerebellum

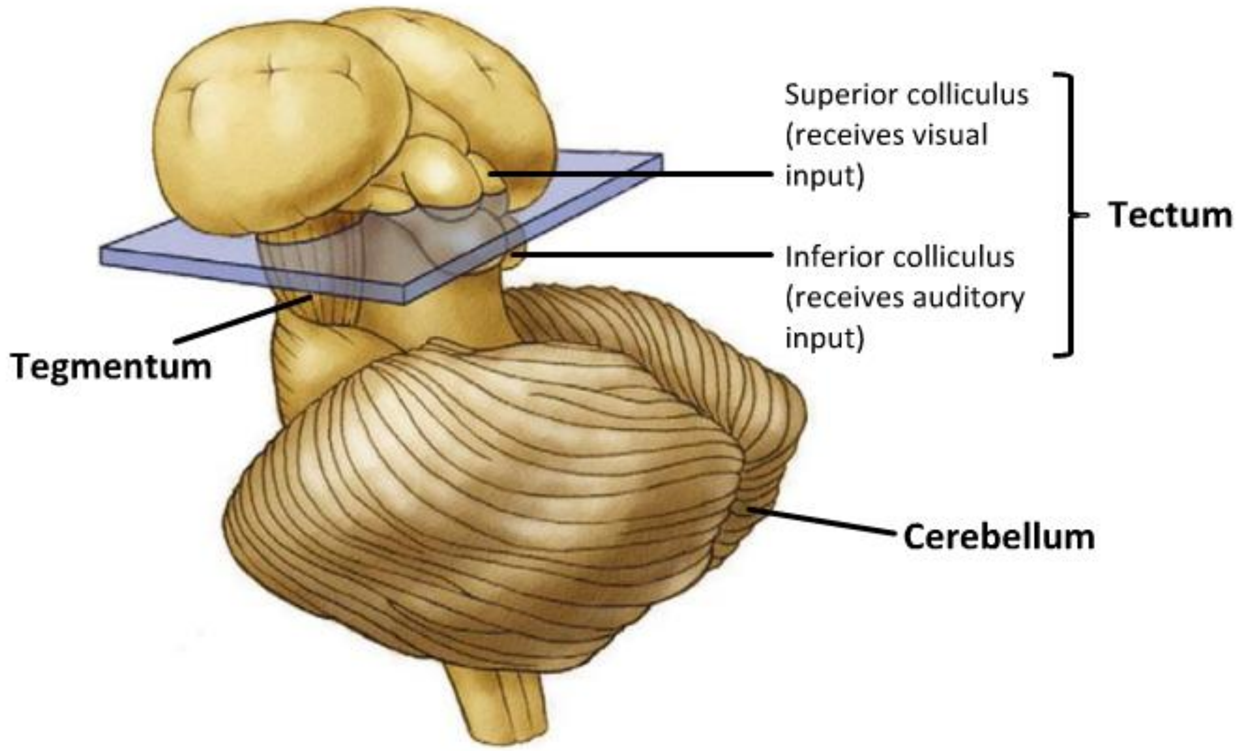
- The cerebellum translates to "little brain" and resembles a miniature version of the entire brain.
- The cerebellum is the maestro of the orchestra that coordinates all movement. Motor commands pass through the cerebellum as they signal muscles to contract, and during the production of movement, sensory signals return to the cerebellum for immediate error correction.
- The importance of this structure is apparent in patients with damage to the cerebellum who display exaggerated, jerky movements overshooting or missing targets completely.

The Midbrain:

- The midbrain is a relatively small region that lies between the hindbrain and the forebrain.
- Generally, the midbrain contains two major subdivisions: the tectum and the tegmentum.

The Tectum: (Image shown on next page.)

- Within these regions are a number of structures involved in a variety of functions, including perception, arousal, and motor control.
- The tectum is located in the dorsal portion of the midbrain and contains two primary structures: the superior and inferior colliculi.
- These two structures are involved in functions related to perception and action.
- The superior colliculus is thought to be involved in eye movements and visual reflexes, while the inferior colliculus is thought to be involved in auditory integration.

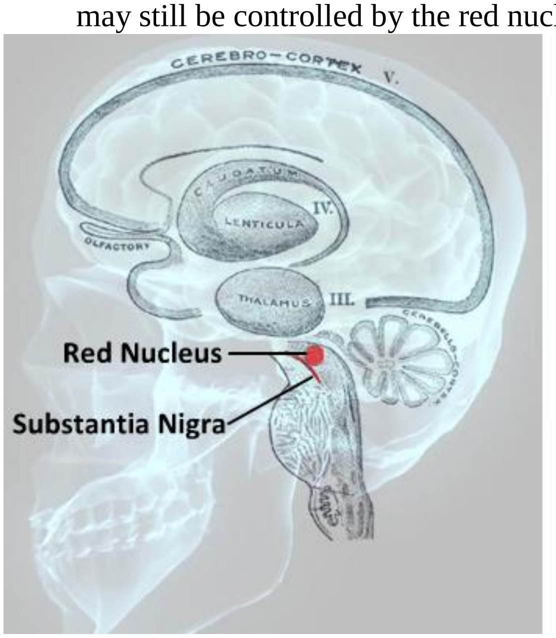


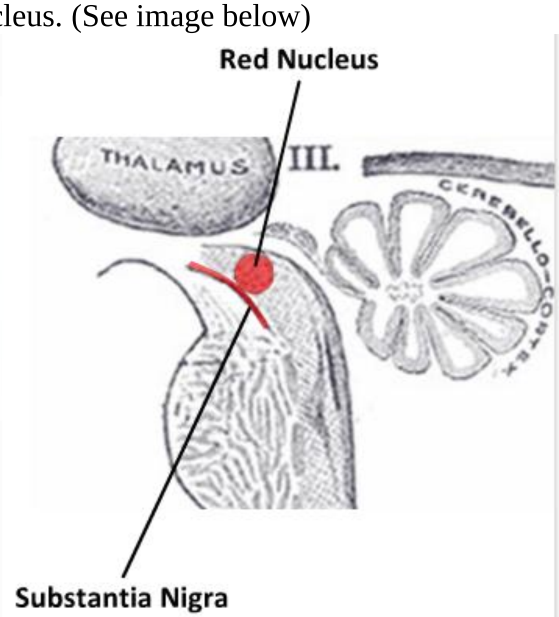
The Tegmentum:

- The tegmentum contains important structures, including nuclei of the reticular formation, the red nucleus, and the substantia nigra.

The Red Nucleus:

- The red nucleus is an important structure involved in the production of movement. In vertebrates with less complex brains, it is one of the most important structures for the regulation and production of movement, as it projects directly to the cerebellum and spinal cord.
- In humans, with their relatively advanced fore brain structures, the red nucleus plays a lesser role in the production of movement, and instead serves primarily as a relay station for information from higher motor areas to and from the cerebellum and spinal cord.
- However, in the still developing brain of young infants, many motor behaviours may still be controlled by the red nucleus. (See image below)





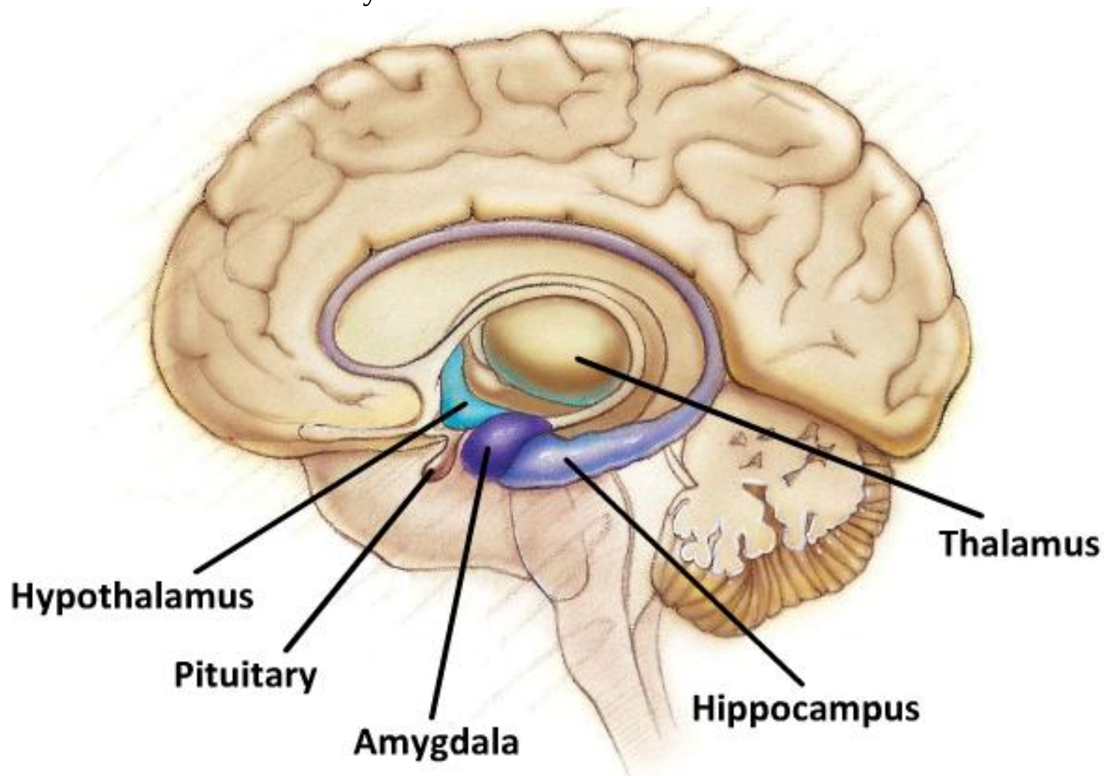
The Substantia Nigra (See Image on Prev. Page):

- The substantia nigra is another important and highly interconnected region of the midbrain, with projections into a variety of forebrain regions.
- The substantia nigra is involved in such tasks as motor planning and learning, and reward seeking → contains neurons that produce the neurotransmitter dopamine, which is released in high concentrations during a variety of rewarding behaviours.
- Artificial rewards such as drugs of abuse act to increase the amount of dopamine in the synaptic cleft to unnatural levels, which may contribute to the addictive properties of these drugs.
- At the other extreme, damage to dopaminergic neurons in the substantia nigra leads to reduced levels of dopamine; this has been directly implicated in motor tremors that are characteristic of Parkinson's Disease.

The Forebrain:

- The forebrain contains structures involved in complex functions such as emotion, memory perception, and thought. It is the largest region of our brain → Two sections: (1) subcortical structures of the limbic system and (2) the cortex.

The Structures of the Limbic System



The Hypothalamus:

- The hypothalamus controls several integrative functions including directing stress responses, regulating energy metabolism by influencing feeding, digestion and metabolic rate, and regulating reproduction through hormonal control of mating, pregnancy and lactation.
- Generations of students have summarized these roles as the 4 F's: Fight, Flight, Feeding and Reproduction
- The hypothalamus exhibits these regulatory roles through neurons that are capable of producing a variety of regulatory hormones and via connections with the pituitary gland and key subcortical structures that lie below the surface of the cortex.

The Pituitary:

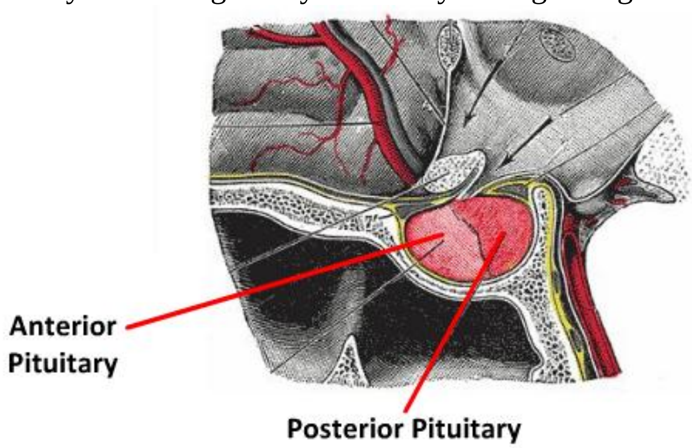
- In humans, the pituitary gland is about the site of a garbanzo bean and lies inferior to the hypothalamus.
- It contains a variety of vital hormones it regulates and releases (often called the master gland of the endocrine system.)
- The pituitary contains two subregions, the (1) anterior and (2) posterior (See image below)

The Anterior:

- The anterior pituitary receives signals from the brain, usually via the hypothalamus, and releases stimulating hormones to regulate other important endocrine glands such as the thyroid, testes, ovaries, and adrenals.

The Posterior:

- The posterior pituitary is actually an extension of the hypothalamus and releases two hormones called oxytocin and vasopressin.
- Oxytocin is involved in basic physiological functions such as lactation and uterine contractions in women and may also play a role in bonding, love, and trust.
- Vasopressin is a vital blood hormone that, among other things, regulates your levels of thirst by interacting with your kidneys to regulate glucose levels.



The Thalamus:

- A large structure near the centre of the brain that is often called the "relay station" to the cerebral cortex.
- Axons from every sensory modality (with the exception of olfaction) synapse in the thalamus, which processes and relays the information selectively to areas of the cerebral cortex.
- Output from the cerebellum and limbic system also first relay through the thalamus on its way to the cortex

The Amygdala:

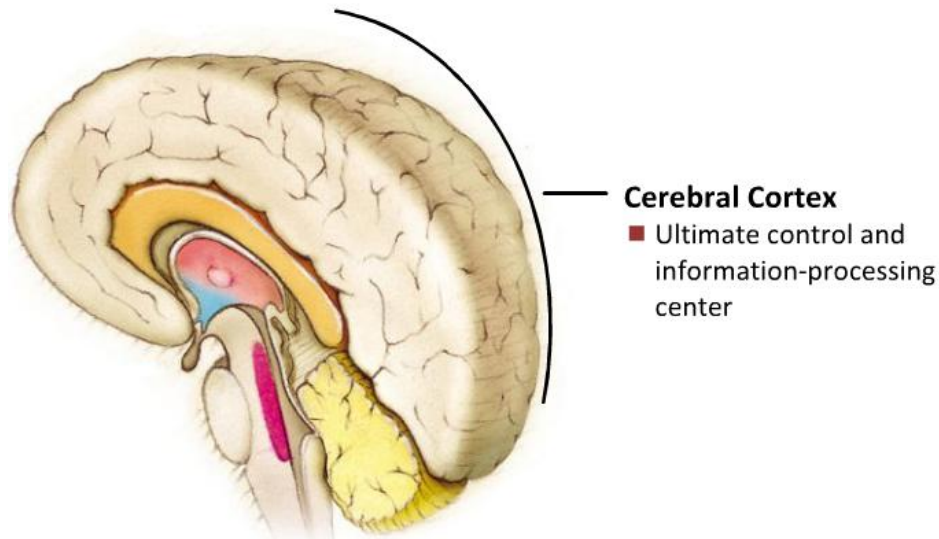
- The amygdalae are two symmetrical almond shaped structures located just below the surface of each temporal lobe.
- The amygdala receives sensory information from the thalamus and contains nuclei which, among other things, play a role in decoding emotions → particularly stimuli that may be threatening. (During intense emotions such as fear the amygdala becomes very active.)
- When the nuclei of the amygdala are damaged, animals often show deficits in classical conditioning of fear responses, and amygdale functions have been implicated in disorders such as post-traumatic stress disorder

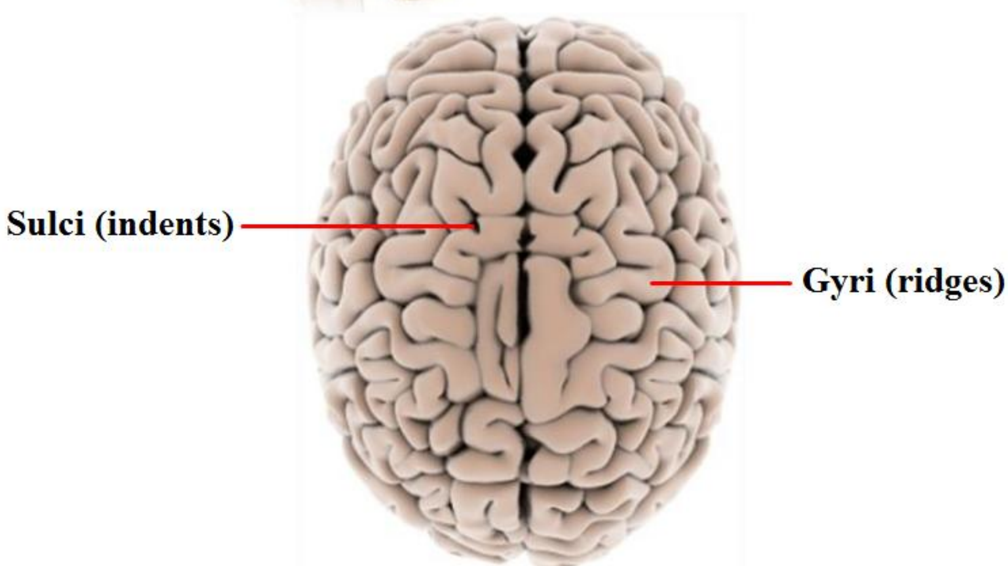
The Hippocampus:

- A horseshoe shaped structure in the temporal lobe. → it seems to be involved in the process of memory formation.
- Activity in the hippocampus is related to your ability to hold short term memories, and may be involved in the process of transferring short-term memories to long-term memory
- The hippocampus is connected to the amygdala, which may be one reason why strong emotions may be triggered by particular memories.
- Beyond that, the hippocampus plays a vital role in your ability to navigate through the world, and in fact the hippocampus may contain a "spatial map" of the world around us
- The hippocampus is one of the few regions of the brain in which neurogenesis continues throughout adulthood. The production of new neurons in the hippocampus is thought to be intimately related to memories, be they spatial, short-term, or long term. → Damage to the hippocampus has been implicated in Alzheimer’s Disease, and extreme trauma to the hippocampus can lead to severe amnesia.

The Cerebral Cortex: (See image below)

- The cortex lies on the outside of the brain, and it is often the structure people think of when they imagine the brain.

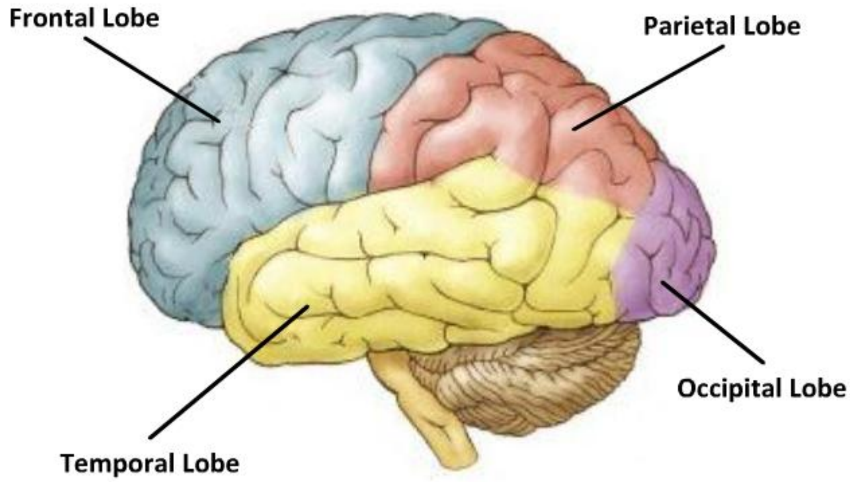




- The cortex is evolutionarily the newest part of the brain. Most of the actual information processing, complex behaviours and cognitive functions that make you human takes place in the cortex.
- One of the signature features of the cortex is its ridged structure. The cortex folds over itself and forms gyri and sulci. (See image on previous page.)
- A gyrus is a ridge on the cortex, or a bulge outward, while a sulcus is the indent, or gap between them.
- These folds provide a clever solution to the problem of increasing the surface area of the cortex within the confines of being encased in the skull; this maximizes the space dedicated to cortical processing.
- Very deep sulci are known as fissures which often divide major areas of the cortex.

The Four Lobes of the Cortex (AKA Cortical Lobes):

- The frontal lobe lies at the front of your brain, behind your forehead. The occipital lobe lies at the very back of the brain. Between these lobes lies the parietal lobe. The temporal lobes wrap around both sides of the brain, near your temples.

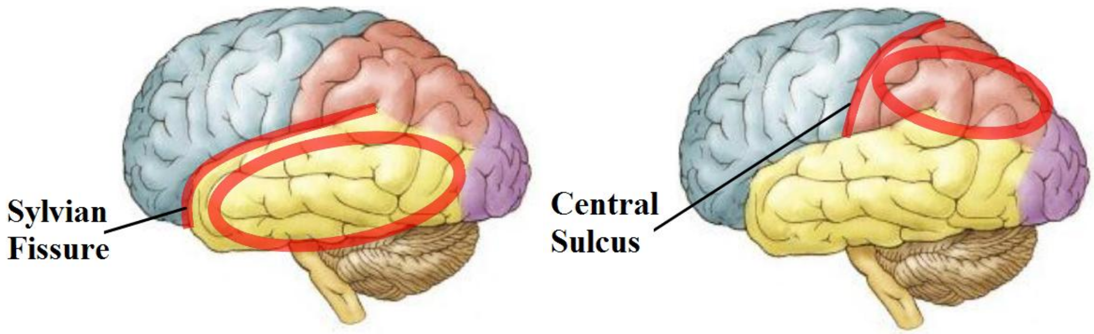


The Occipital Lobe:

- The occipital lobe is exclusively responsible for visual processing and contains the primary visual cortex (called V1) and other visual areas.
- It is here where more complex processing of visual information begins. TF: an individual with healthy eyes but damage to the occipital lobe may become functionally blind.

The Temporal Lobe:

- The temporal lobe lies at the sides of the brain below the sylvian fissure (See image on next page).
- Through projections from the occipital lobe, the temporal lobe contains a number of areas responsible for processing the form and identity of visual stimuli.
- Additionally, the temporal lobe is the location of the primary auditory cortex, or area A1. It is here that auditory processing begins.
- Finally, the temporal lobes are at least partially responsible for the processing of memory and language.
- Individuals with severe temporal lobe damage may show deficits in the production of speech, amnesia, and auditory processing.



The Parietal Lobe:

- The parietal lobe lies anterior to the occipital lobe, above the sylvian fissure and terminates rostrally at the central sulcus. (See image above.) Directly along the central sulcus, at the connection point with the frontal lobe, lies the primary somatosensory cortex, where the processing of touch begins.
- The parietal lobe is also involved in a number of complex visual and spatial functions. For example, through projections from the occipital lobe, the parietal lobe processes the location and movement of visual objects.
- Beyond that, the parietal lobe contains a spatial representation of the world that may be involved in visual attention and guiding eye and body movements.
- Damage to the parietal lobes can result in deficits in somatosensory processing or even a loss of sensation completely. In addition, parietal damage can lead to deficits in orienting, attention, coordination of targeted movements, and in extreme cases, complete loss of attention to particular spatial regions.

The Frontal Cortex

- The frontal cortex is perhaps the most complex and least understood of the cortical lobes
- Along the central sulcus, where the frontal lobe meets the parietal, lies the primary motor cortex, where motor commands originate. However, the frontal lobe does much more: it makes you human.
- It is here where your most complex decision making processes occur → Consider the common behaviours of young children and how it mirrors the state of the still developing frontal lobe. Children can be notorious for their lack of inhibition and underdeveloped social skills and forward planning.
- The frontal lobe contains a variety of areas responsible for complex functions important to these goals such as language, strategy formation, inhibition, and manipulation of items in short-term memory.
- Individuals with damage to the frontal lobe can suffer a variety of dysfunctions depending on the specific area of the lesion. These deficits can include spontaneous inappropriate behaviour, motor deficits, loss of motivation, deficits in decision making and learning, and difficulty understanding language.

Brain Lateralization:

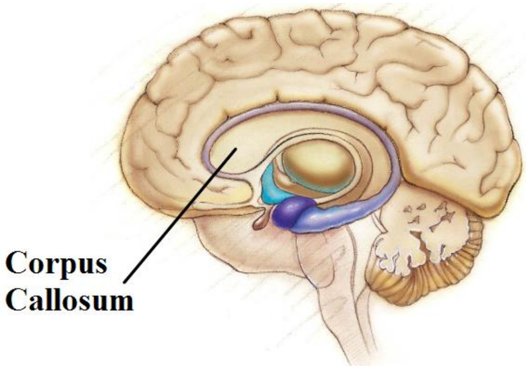
- Although many brain structures are found on both sides of the brain, neuroscientists have indeed found cases of function specialized to one side of the brain. This property is also called asymmetry or brain lateralization.

Asymmetries in the Brain:

- How can you conclude that a particular cortical region has a unique function on only one side of the brain? → The best evidence comes from lesion studies that can demonstrate a double dissociation; damage to a specific cortical region on one side of the brain, produces a specific behavioural deficit, whereas damage to other areas, surrounding the region or on the other side of the brain, do not lead to the behavioural deficit.

- An early case study came from Paul Broca. His research involved a patient who suffered a speech deficit known as an aphasia: "Tan" was one of the few words he could properly articulate.
- In the autopsy, Broca noted a lesion in the left frontal lobe that is now called Broca's Area → This area is vital for the motor production of speech.
- The neurologist Wernicke noted that some language deficits were not motor production problems, but rather deficits in language comprehension, Wernicke found that damage to the left temporal gyrus, an area now known as Wernicke's Area, is important for language comprehension.
- In both cases, language deficits seem to be caused by damage restricted to specific areas in the left hemisphere.
- What then is the right hemisphere involved in processing? → It seems that the right hemisphere contains a number of specialized regions involved in the processing of spatial representations of the world.

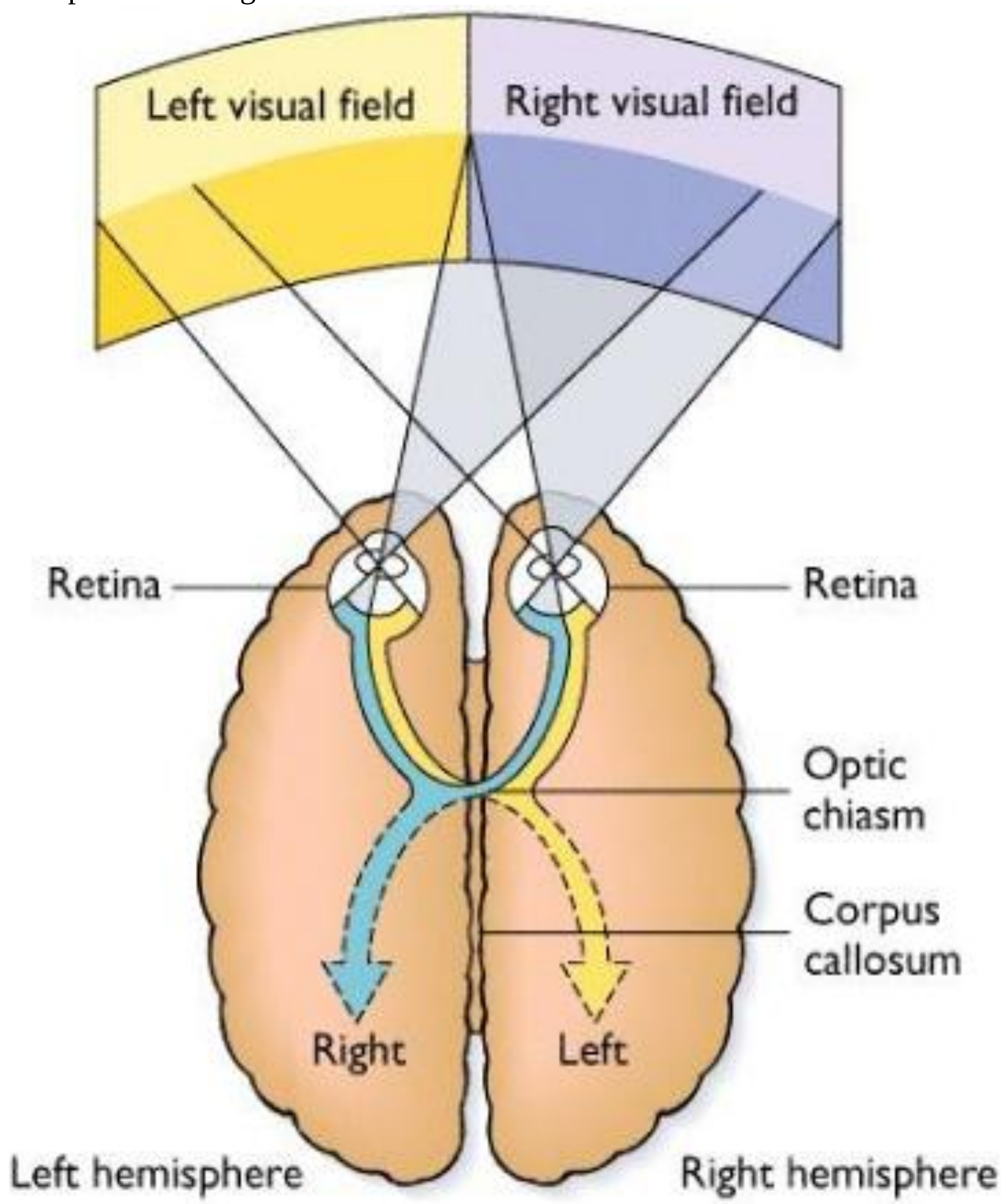
The Corpus Collosum



- In normal individuals, this lateralization of function across the hemispheres is not noticeable because the two hemispheres of the brain communicate through a thick bundle of axons called the corpus callosum.
- The corpus callosum passes through the centre of the brain, and carries information from one side of the brain to the other very rapidly.
- In the early 1960s, neuroscientists Sperry and Gazzaniga conducted groundbreaking research on patients in which the corpus callosum had been severed.
- These patients experienced the Split Brain Syndrome, effectively having two independently operating hemispheres!
- In normal patients, sensory and motor information crosses over from one side of the body to the contralateral, or opposite side of the brain through the thalamus. Normally, this information would also be available to the same side or ipsilateral hemisphere by travelling through the corpus callosum.
- However, in split-brain patients, once the information arrives on the contralateral side of the brain, it is trapped there and unable to travel to the other hemisphere because the corpus callosum is severed.
- So what happens with information processing in split brain patients? → It's as if the left side of the brain is a separate entity, unaware of what the right brain has received. For most of the everyday activities performed by split brain patients, the disorder has little influence on their lives, because most stimuli arrive on both sides of the body simultaneously.

- Sperry and Gazzaniga conducted a clever set of experiments where this was not the case. → Example: A split brain patient stares straight ahead at a fixation point. Suppose you then present a picture of a cup to the left visual field of a split brain patient. Because visual stimuli are organized into visual fields and not by eyeballs, the image of the cup travels to the right hemisphere of the brain. If you ask the subject to name the object she just saw she will be unable to do so, because language is preferentially processed by the left side of the brain, which at this point has no knowledge of the cup whatsoever.
- But here‘s an interesting twist: ask the split brain patient to close her eyes and feel through a set of objects to pick out the object she was presented. This is a distinctly spatial task, and she will have no problem identifying the presented cup!
- What if you presented the image of the cup to the right visual held instead? In this case, the image is processed in the left hemisphere, so the patient will be able to name it, but will not be able to pick it out using the distinctly spatial task.

Visual hemispheres in image shown below:



General Functions: Left- and Right- Hemisphere Dominance →