Review for Midterm Exam 2

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Course News

Office Hours with Dr. McLoon

Monday (Oct 22)
12:00-1:00pm and 2:30-3:30pm

Jackson Hall 4-158

Course News

Review Session

Tuesday (Oct 23)
4:00-5:00pm

in MCB 3-146B (the main lab room)

with Dr. Riedl

Course News

Midterm Exam Wednesday (Oct 24)

The exam will cover lectures 12-20 and labs 3-5.

A –L last names in MoosT 2-650
M – Z in MoosT 2-620

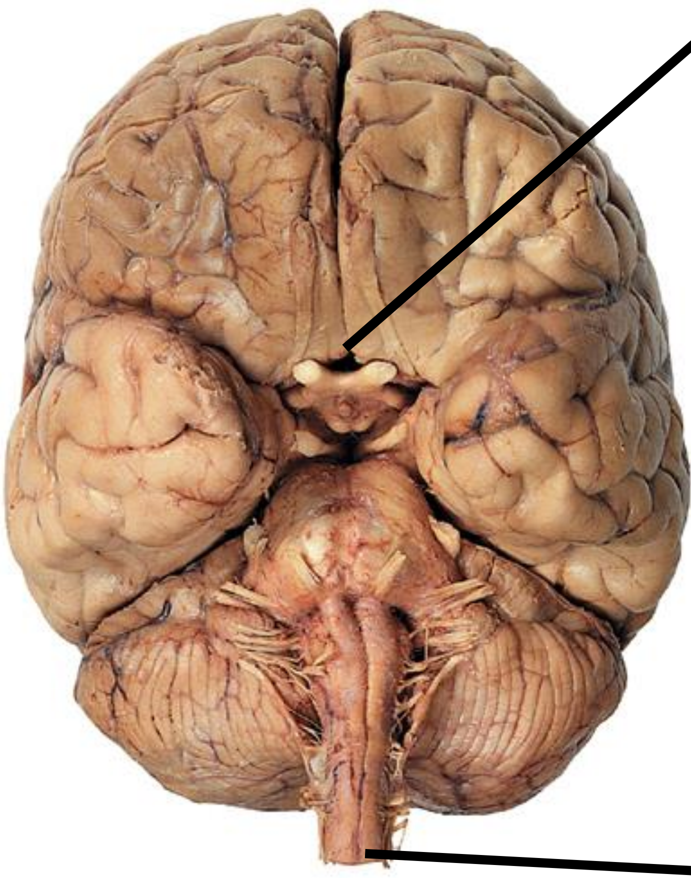
An extra hour will be available for those who need it.

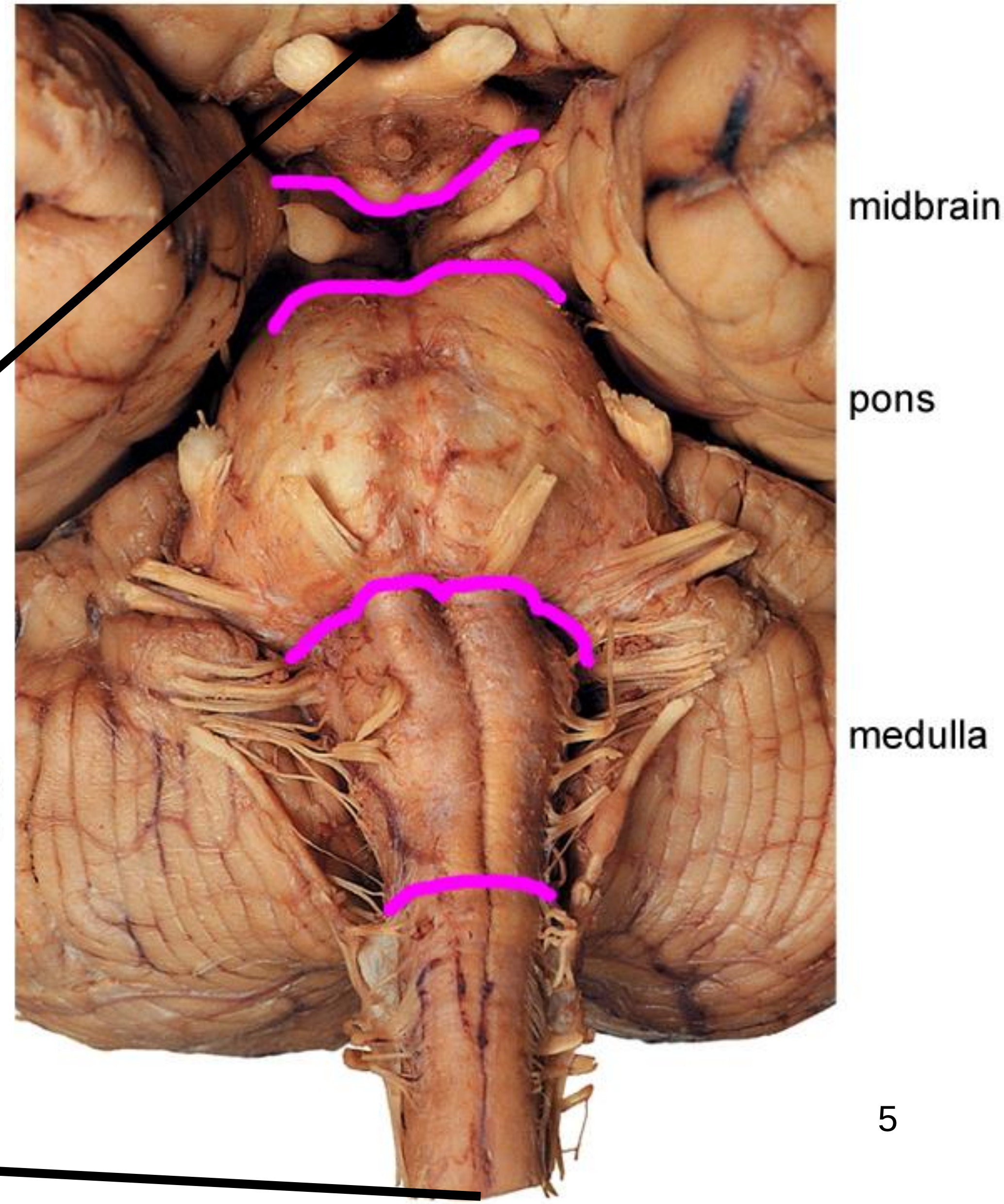
PLEASE BRING #2 PENCILS!!!

Be sure to check out last year’s exam on the course website!!!

Brainstem Geography

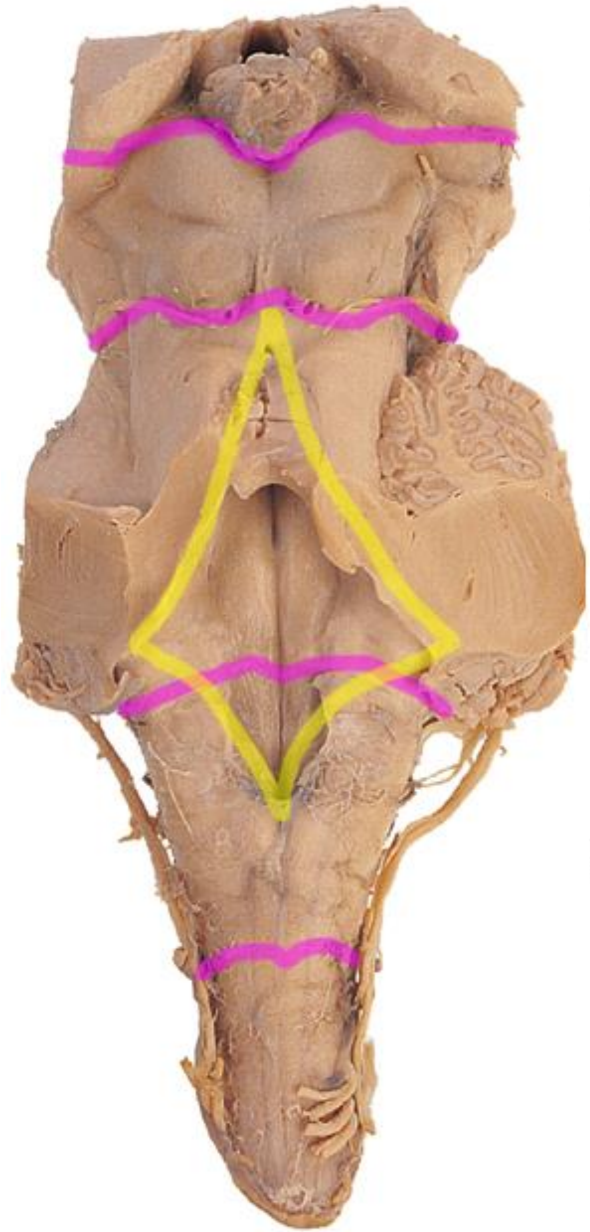
- Brainstem includes the medulla, pons and midbrain.
- All regions are visible on the ventral side of the brain.





Brainstem Geography

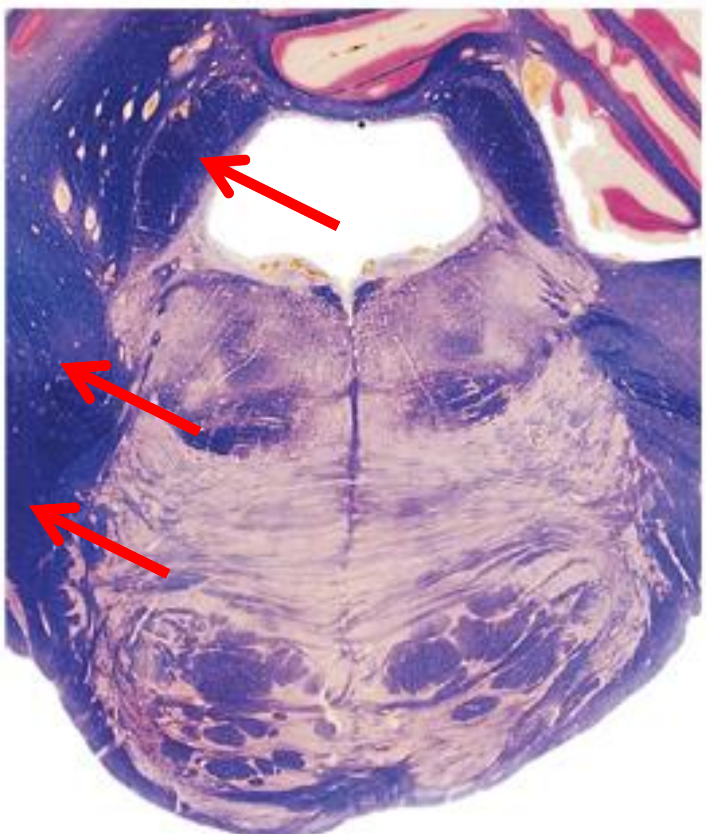
- The cerebellum covers the IV ventricle on the dorsal surface of the brainstem.
- The IV ventricle spans the entire pons and upper half of the medulla.



Brainstem Geography

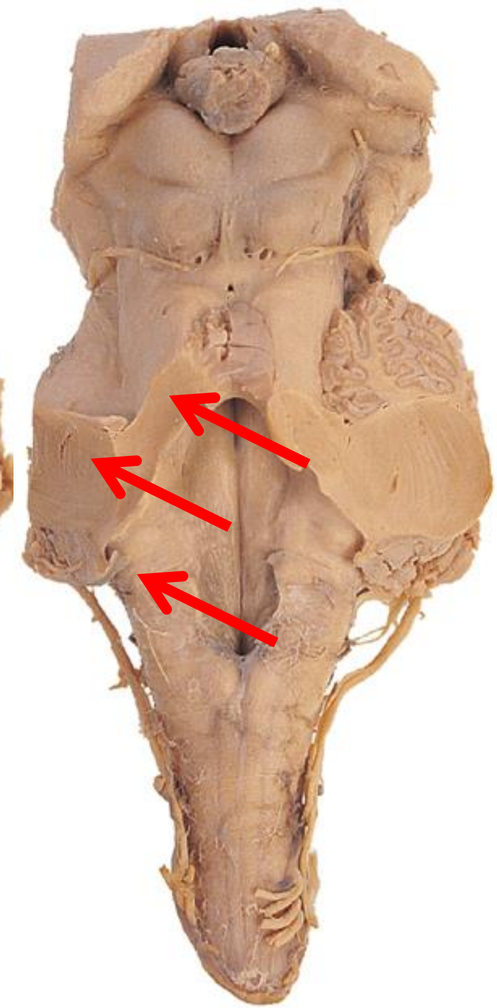
- Cerebellum is attached to the pons via the superior, middle and inferior cerebellar peduncles

dorsal



ventral

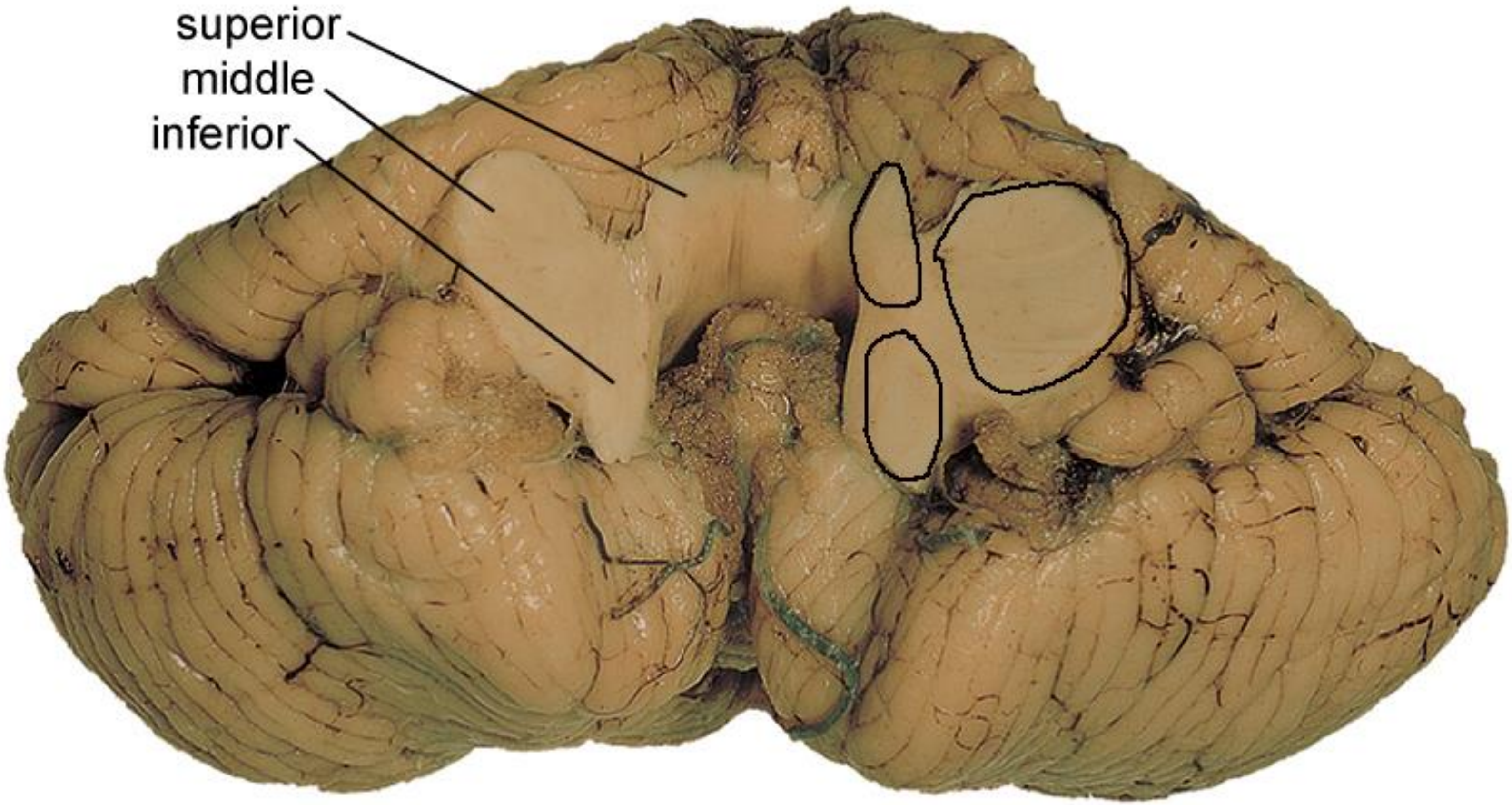
ventral



dorsal

Brainstem Geography

- Superior, middle and inferior cerebellar peduncles

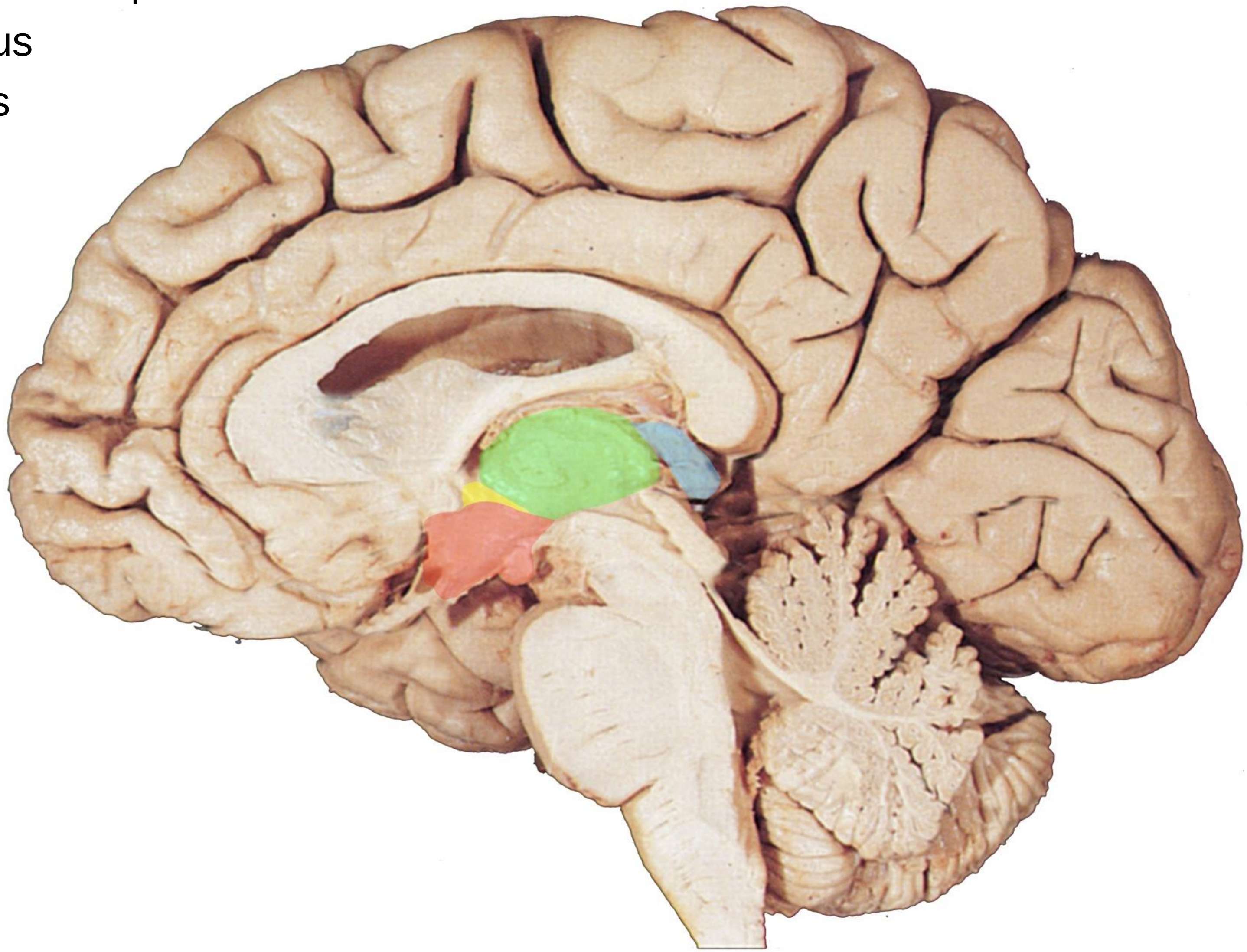


Ventral surface of the cerebellum

Diencephalon

The parts of the diencephalon are:

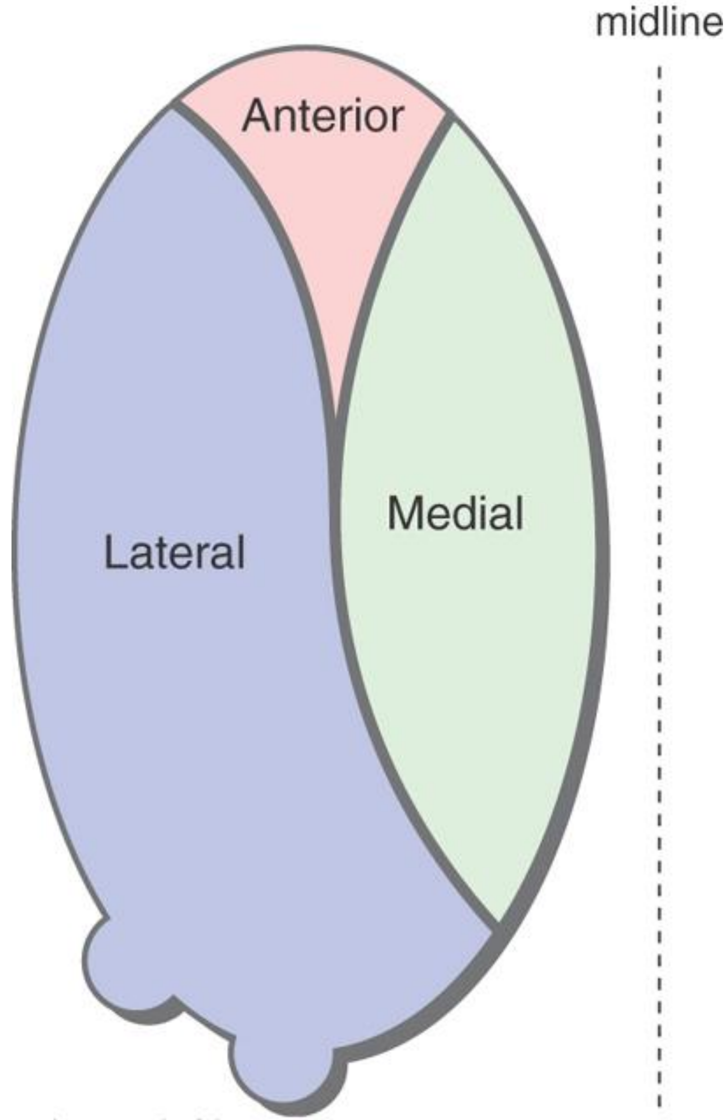
- Hypothalamus
- Subthalamus
- Thalamus
- Epithalamus



Thalamus

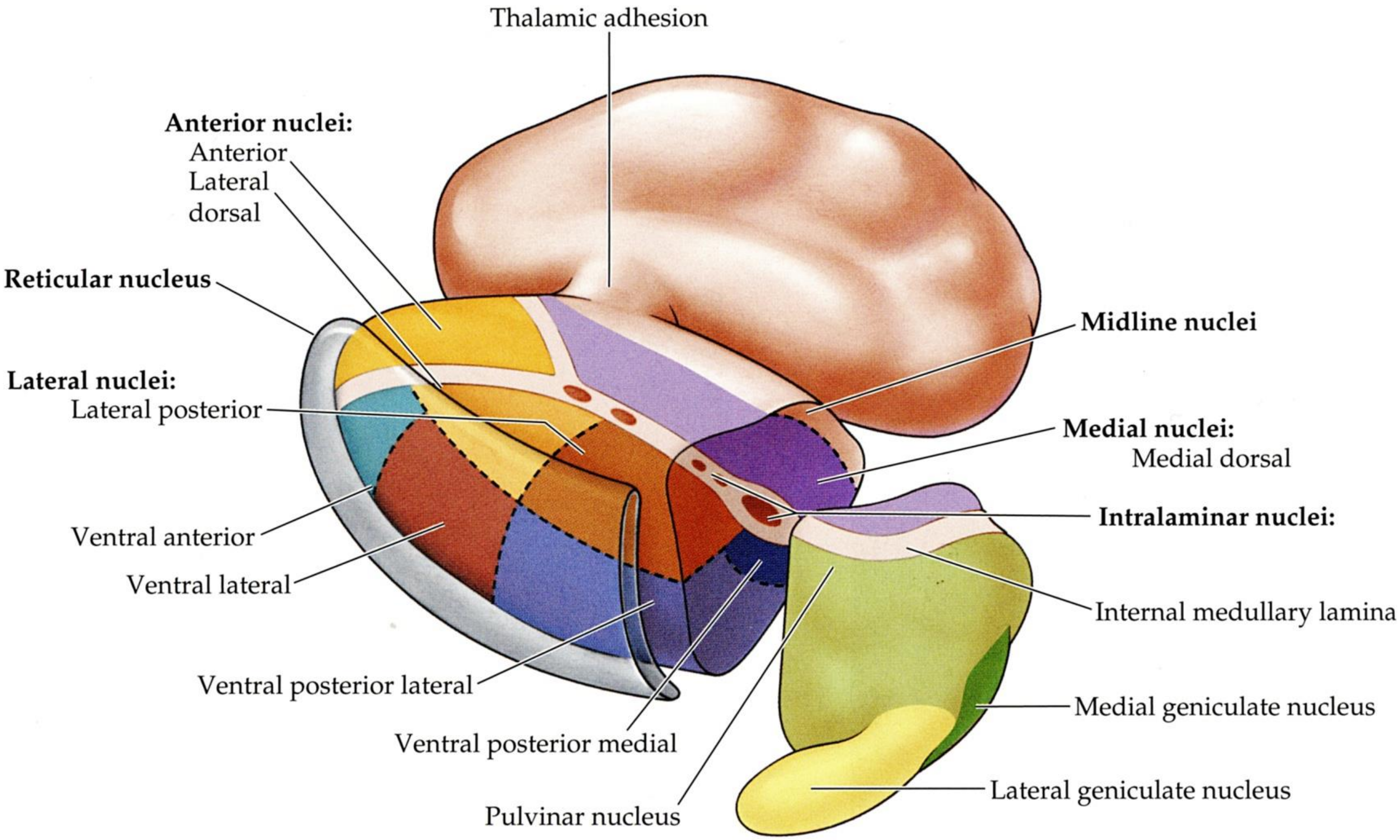
A sheet of myelinated axons, the internal medullary lamina, divides the thalamus into three major regions:

- Anterior (anterior nucleus)
- Medial (dorsomedial nucleus)
- Lateral (lateral group of nuclei)



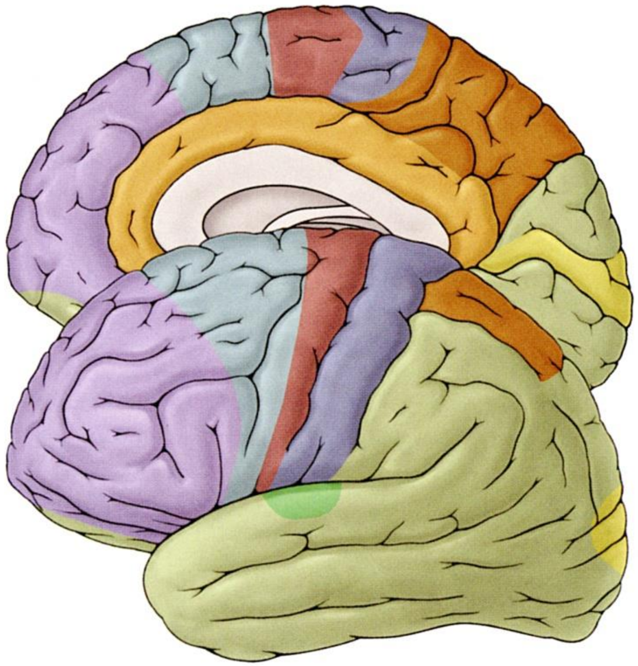
Thalamus

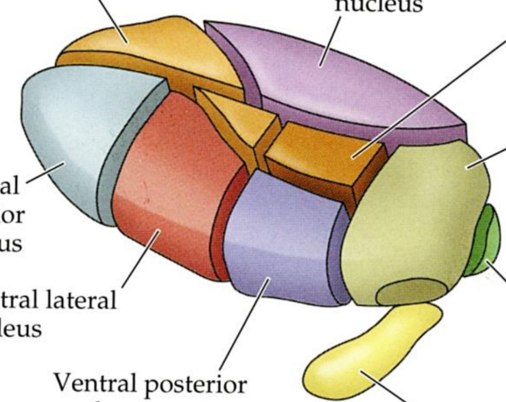
The thalamus is further divided into nuclei based on their connections (functions).



Thalamus

- Thalamus sends axons to cortex.





Thalamus

- Input and output relationships of the major relay nuclei:

Input	Nucleus	Output
hypothalamus hippocampus	anterior	cingulate cortex (limbic)
basal ganglia	ventral anterior	suppl. motor cortex
cerebellum	ventral lateral	motor cortex
somatosensory visceral sensory	ventral posterior (lateral & medial)	somatosensory cortex visceral cortex
retina	lateral geniculate	visual cortex
inferior colliculus	medial geniculate	auditory cortex
cortex & other areas	other nuclei	association cortex

Thalamus

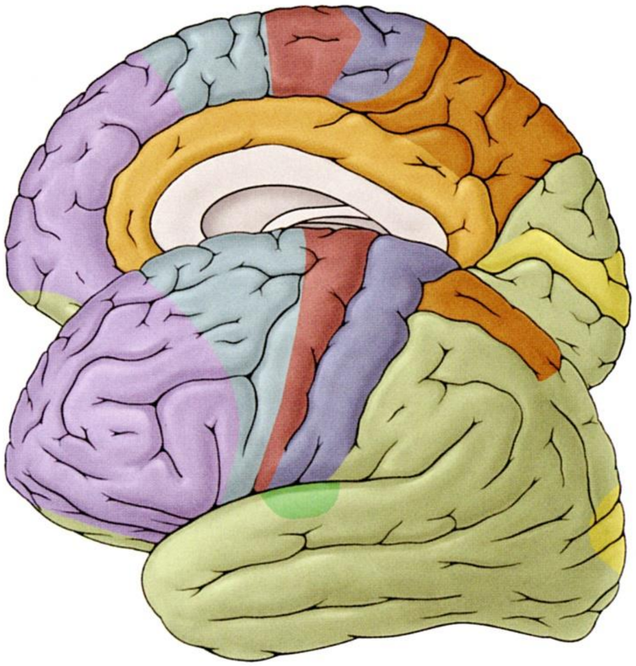
Other thalamic nuclei carry multiple modalities and project to association cortex. For example:

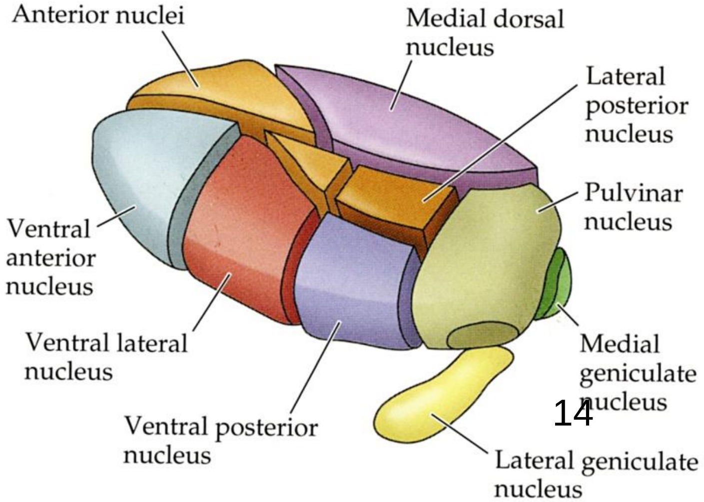
- dorsomedial nucleus ⟶

  prefrontal association cortex

- pulvinar ⟶

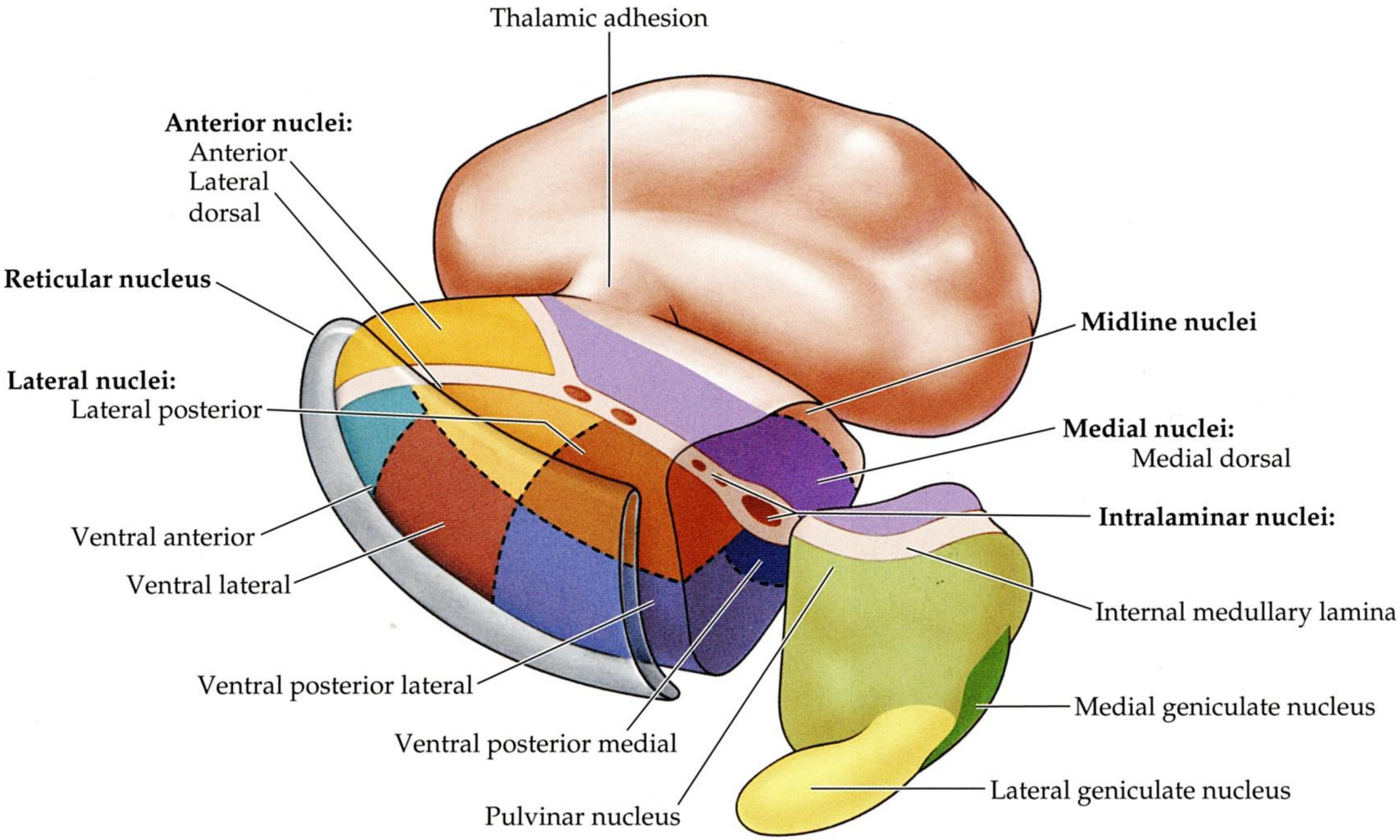
  parietal-occipital-temporal assoc. cortex





Thalamus

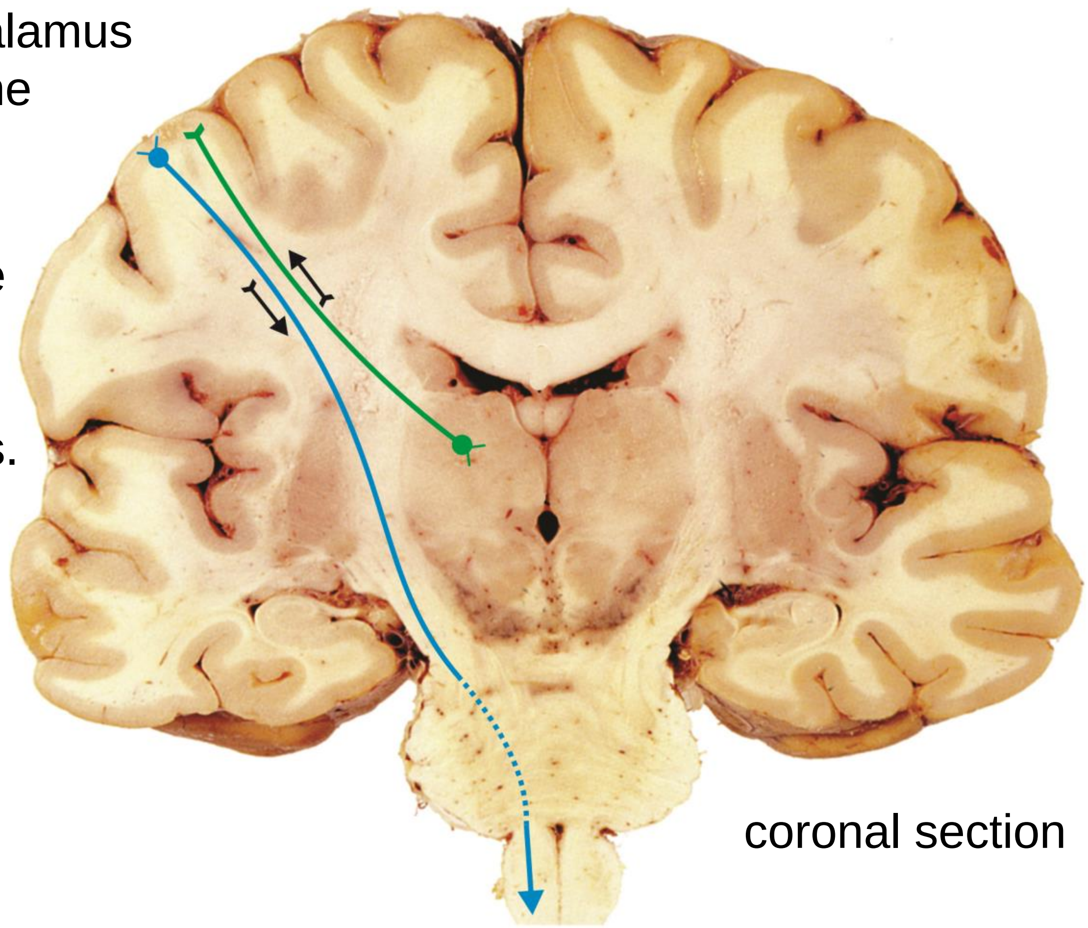
The flow of information from the thalamus to cortex is gated by inputs from the brainstem reticular activating system and the cortex via the reticular nucleus of the thalamus.



Internal Capsule

- Axons from neurons in thalamus ascend to the cortex via the internal capsule.

- Axons from neurons in the cortex descend via the internal capsule and pass just lateral to the thalamus.



coronal section

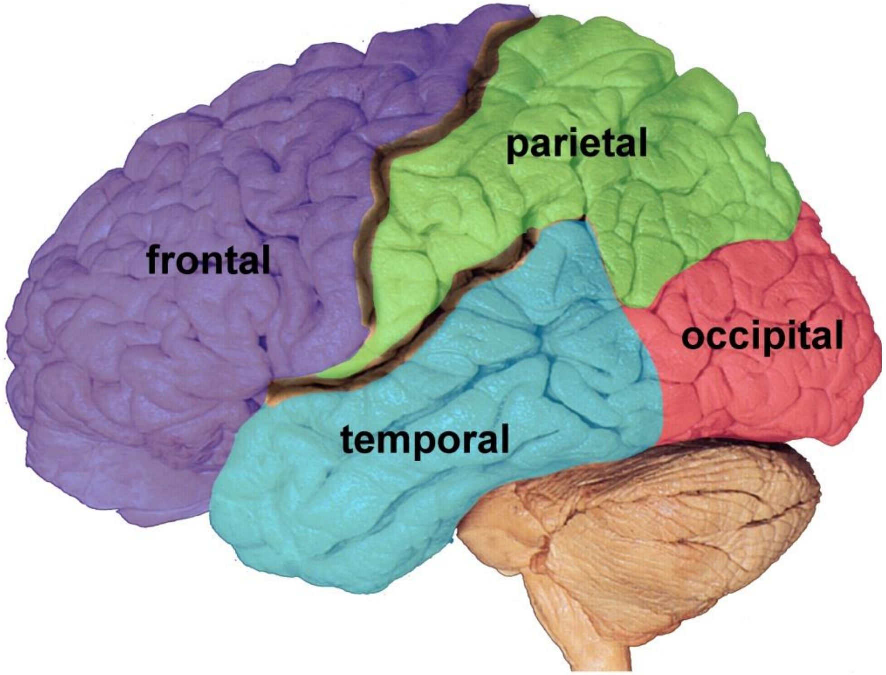
Telencephalon

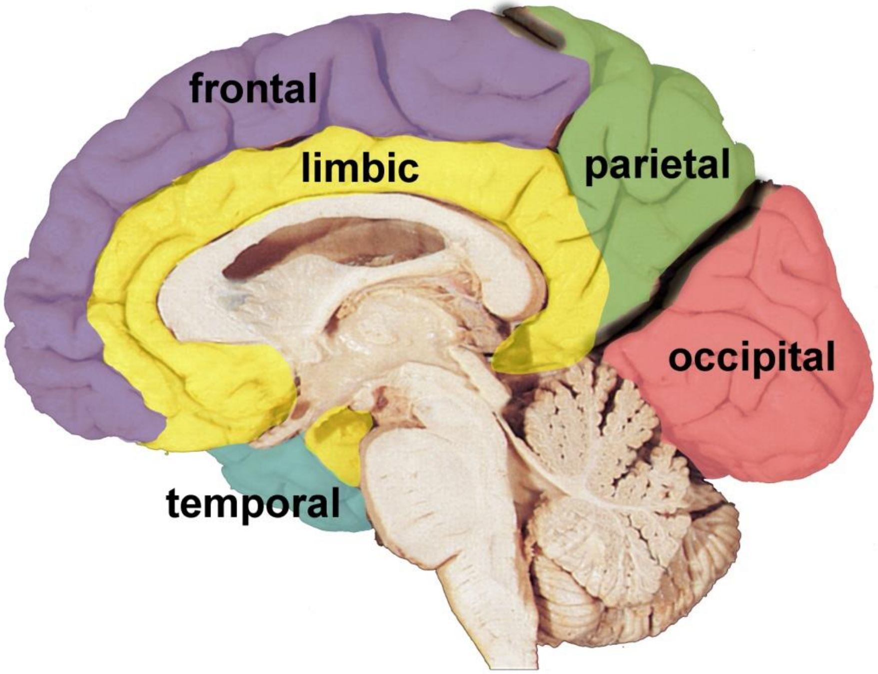
It is convenient to think of telencephalon as having three parts that are highly interrelated:

- Neocortex (cortex)
- Limbic system (old cortex)
- Basal ganglia

Cerebral Cortex

Cortex is divided into five lobes.





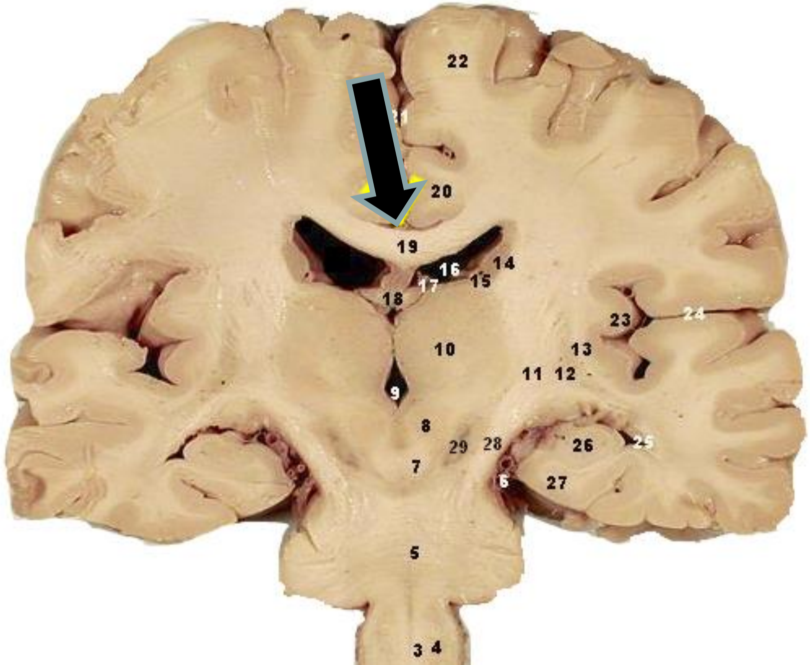
Cerebral Commissures

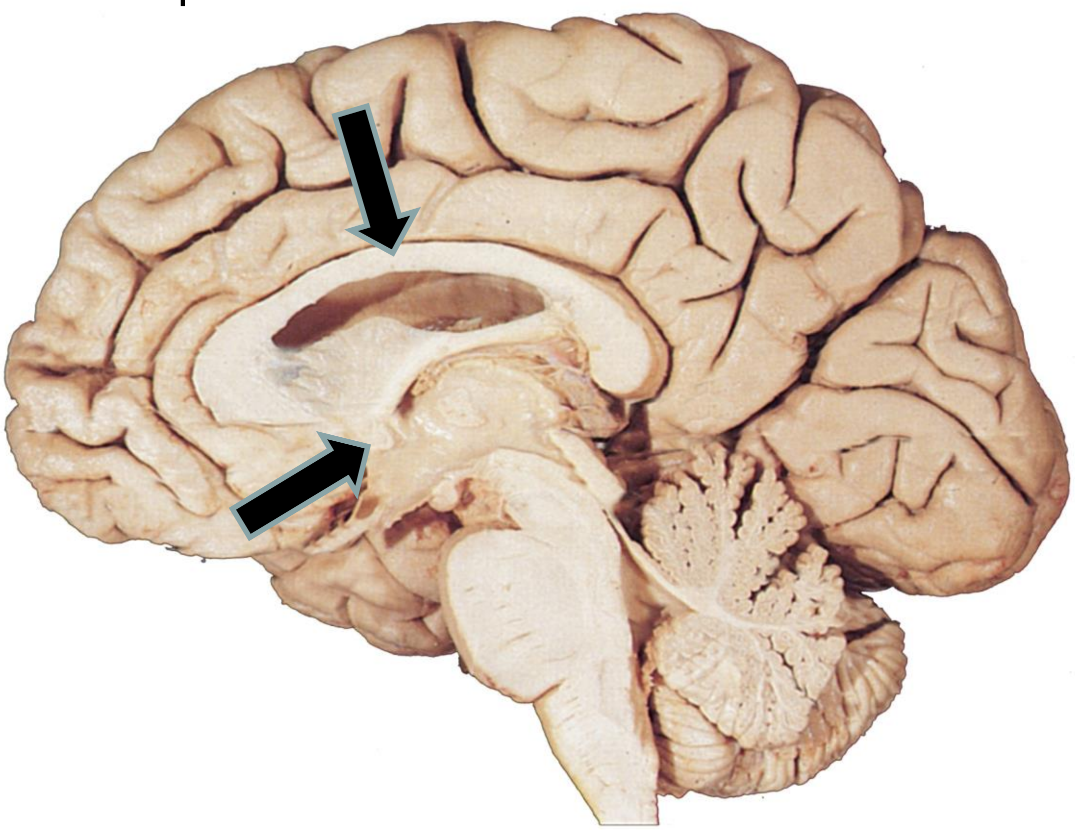
Commissures are discrete bundles of axons that cross the midline.

Typically, a region of cortex on one side of the brain communicates with the same region on the other side.

Two commissures interconnect the hemispheres of the cerebral cortex:

- Corpus callosum
- Anterior commissure



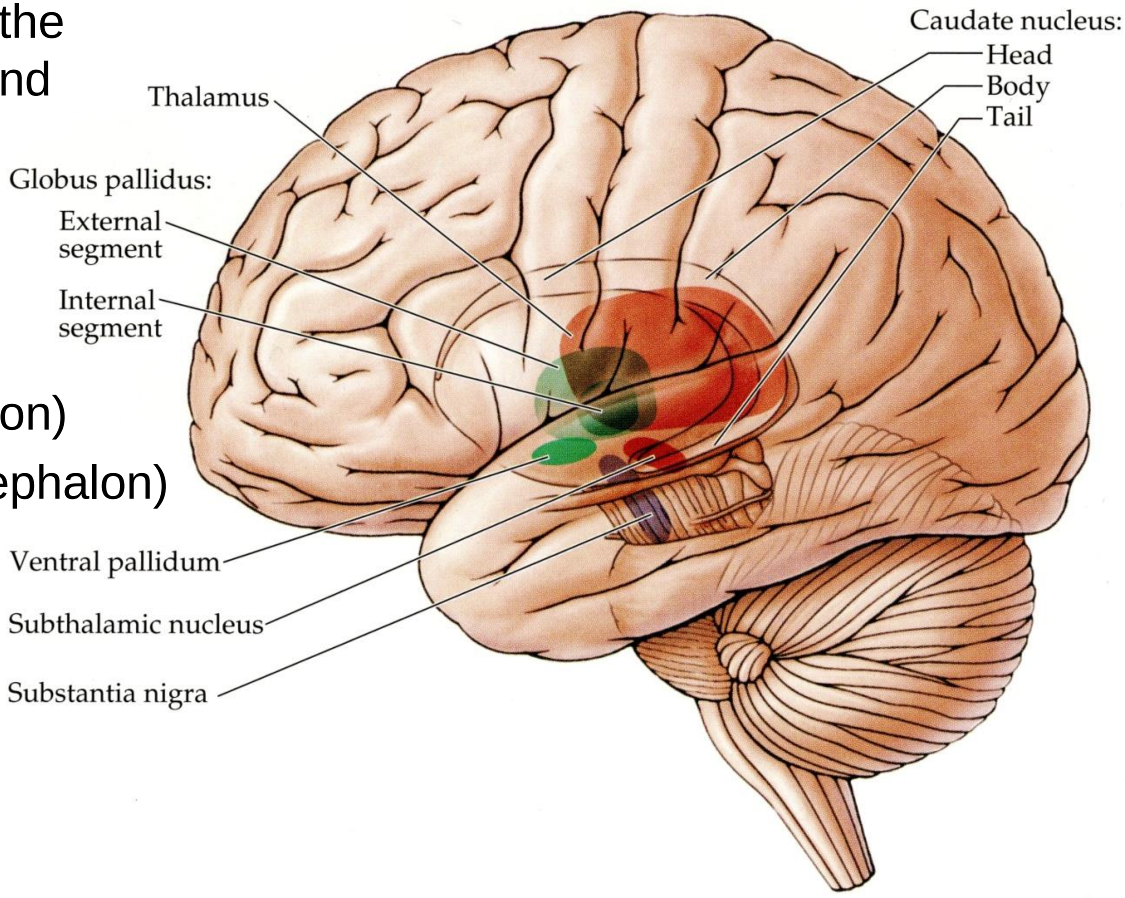


Basal Ganglia Anatomy

The basal ganglia consist of a number of nuclei in the basal region of the telencephalon, diencephalon and midbrain.

The largest nuclei are:

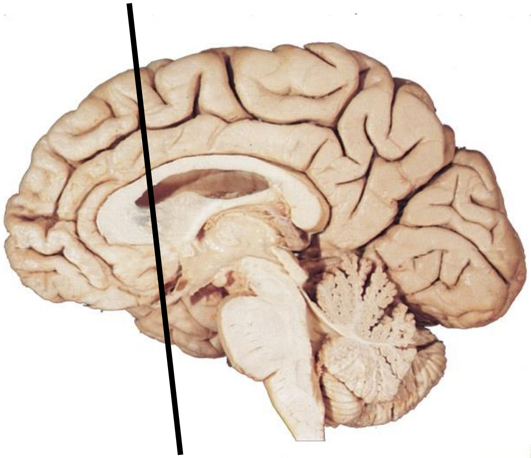
- Striatum (telencephalon)
- Globus pallidus (telencephalon)
- Subthalamic nucleus (diencephalon)
- Substantia nigra (midbrain)



Basal Ganglia Anatomy

- The striatum is composed of three nuclei:
  - caudate nucleus
  - putamen
  - nucleus accumbens

- The striatum is more like one nucleus divided by the internal capsule, which comes together at the front of the internal capsule.



Striatum:

- caudate nucleus
- putamen
- nucleus accumbens

Cranial Nerves

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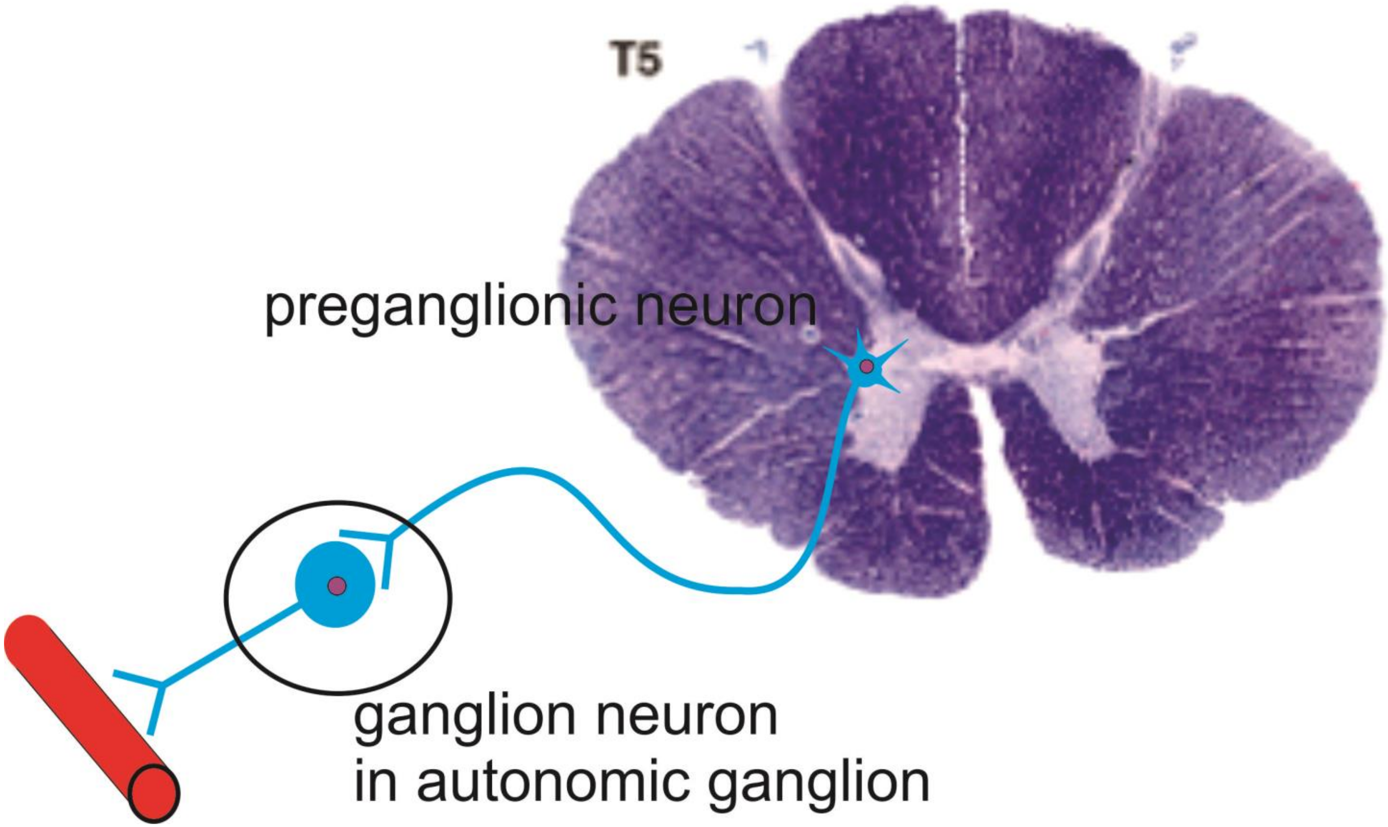
Autonomic Motor System

- The autonomic motor system controls smooth muscle, the heart, glands, blood vessels, etc.
- It is a two neuron output system, a preganglionic neuron in the brainstem or spinal cord and a ganglion neuron in a ganglion.



Autonomic Motor System

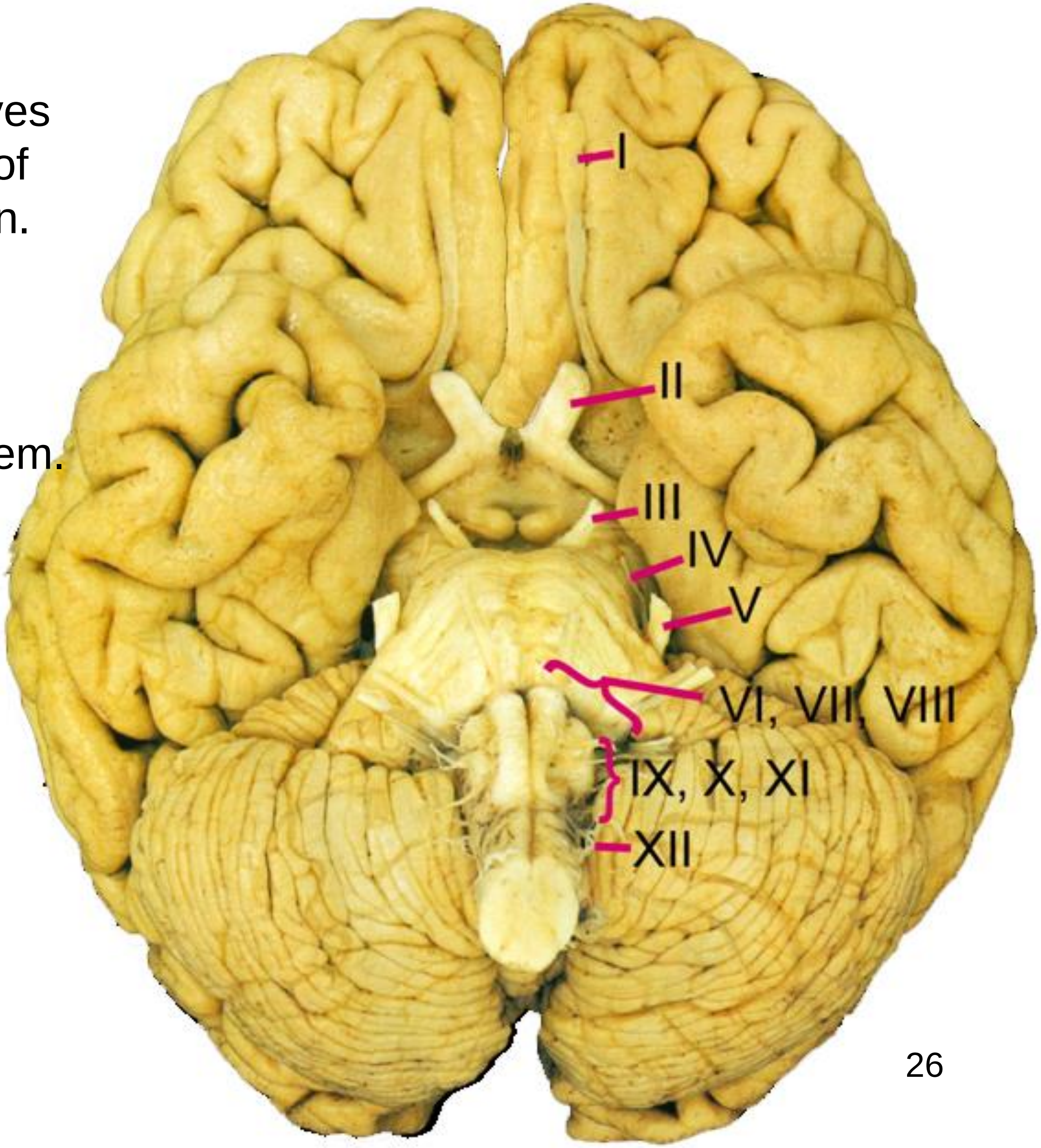
The autonomic system has two subdivisions:

- Sympathetic system
  - Preganglionic neurons are in the thoracic spinal cord.
  - Ganglion neurons are in sympathetic ganglia on both sides of the vertebral column.
  - Preganglionic axons are short and postganglionic axons are long.

- Parasympathetic system
  - Preganglionic neurons are in the brain stem and sacral spinal cord.
  - Ganglion neurons are in parasympathetic ganglia near their targets.
  - Preganglionic axons are long and postganglionic axons are short.

Twelve Pairs of Cranial Nerves

- The 12 pairs of cranial nerves are numbered in the order of their attachment to the brain.
- The first two cranial nerves attach to the forebrain; the others attach to the brainstem.



cranial nerve		function			
		general motor	parasympathetic	general sensory	special sensory
I	Olfactory				X (olfaction)
II	Optic				X (vision)
III	Oculomotor	X[a]	X		
IV	Trochlear	X[a]			
V	Trigeminal	X[b]		X[c]	
VI	Abducens	X[a]			
VII	Facial	X[b]	X	X	X (taste)
VIII	Vestibulocochlear				X (auditory & vestibular)
IX	Glossopharyngeal	X[b]	X	X[c]	X (taste)
X	Vagus	X[b]	X	X[c]	X (taste)
XI	Accessory *	X[a]			
XII	Hypoglossal	X[a]			

* cervical component; cranial component included with vagus

[a] somatic motor – innervates muscles that develop from somites

[b] branchial motor – innervates muscles that develop from pharyngeal arches

[c] includes visceral sensory as well as somatosensory

Sensory Systems

- Somatosensory
- Visceral sensory
- Special sensory
  - Vision
  - Auditory
  - Vestibular
  - Gustatory (taste)
  - Olfactory (smell)

Somatosensory System

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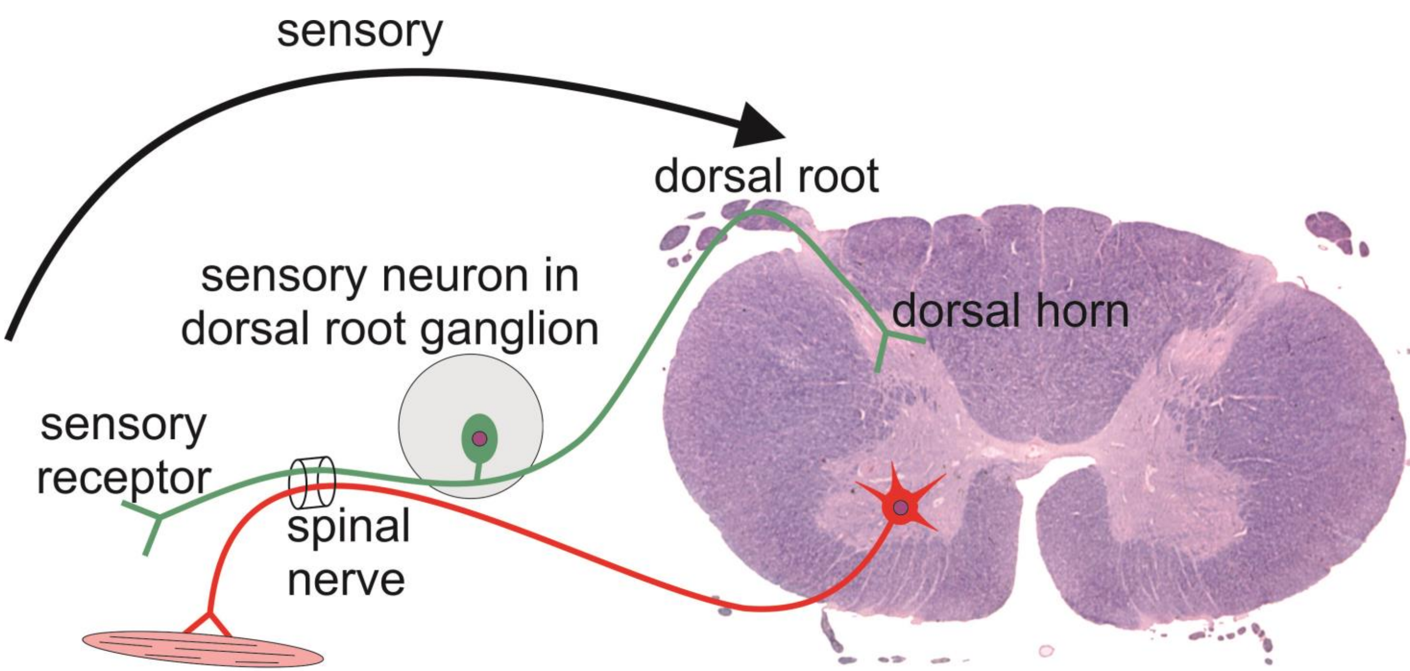
Primary Somatosensory Neurons

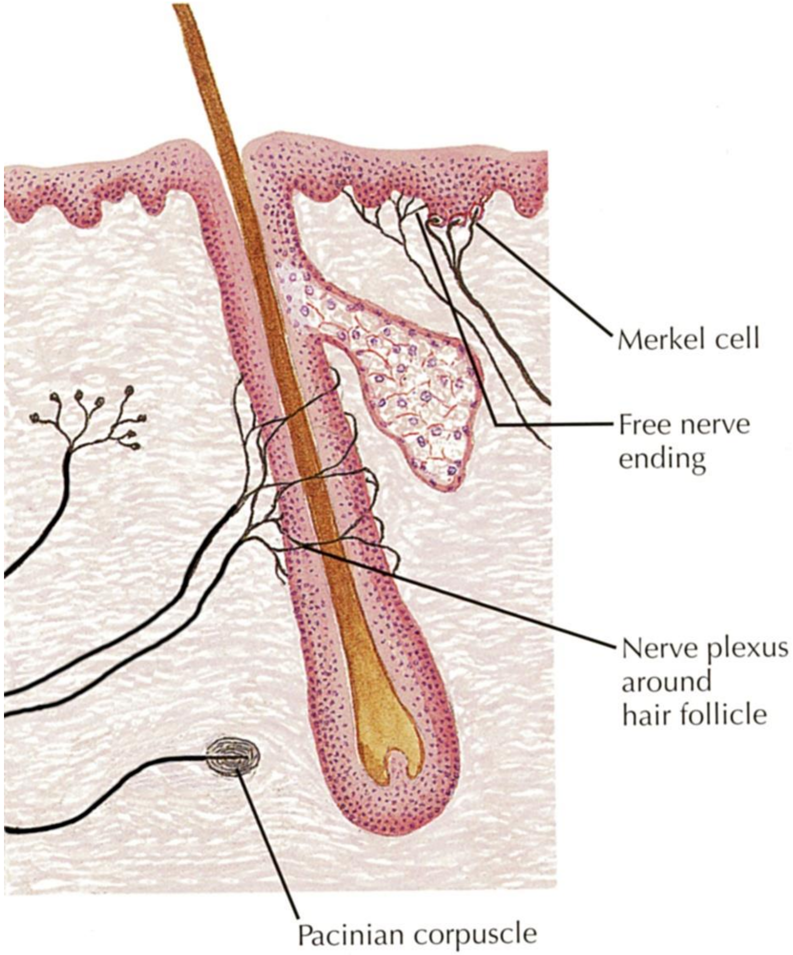


The somatosensory system detects multiple sensations.

- Touch
  - Fine touch
  - Pressure
  - Vibration
  - Movement against the skin
- Proprioception (limb & trunk position, movement & load)
- Thermoception (temperature)
  - Heat
  - Cold
- Nociception (pain – tissue damage)
- Pruritic reception (itch)

Somatosensory Receptors

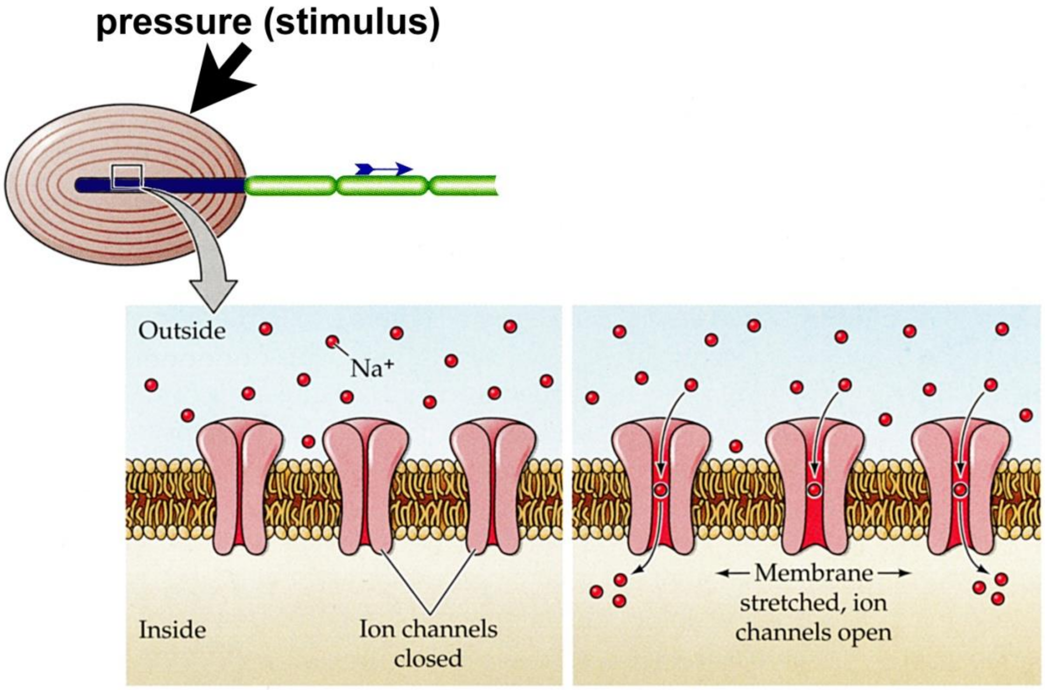
- Receptor neurons can have free nerve endings or can be encapsulated by other cells.
- Encapsulation changes the nature of the stimulus.



pacinian corpuscles in skin

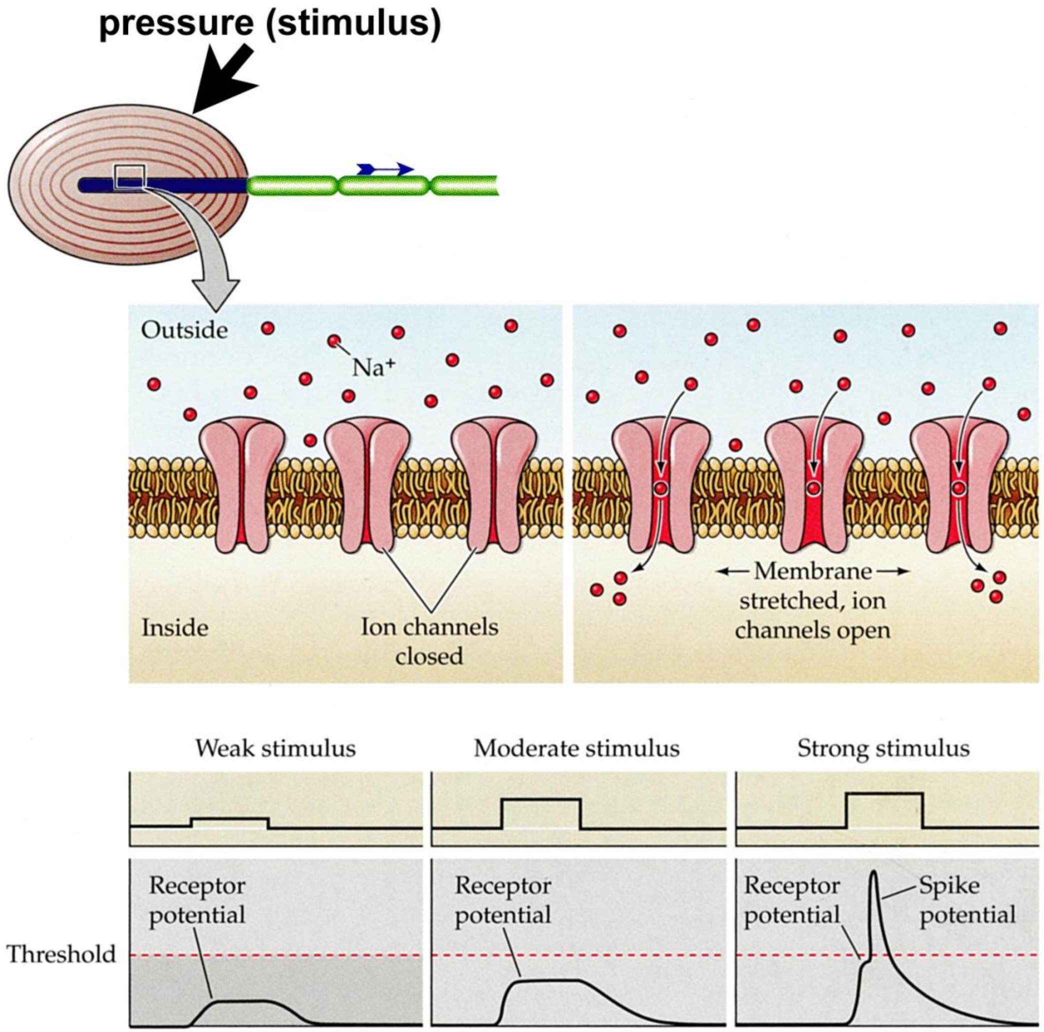
Somatosensory Receptors

- An appropriate stimulus results in the opening of ion channels and an influx of sodium in the receptor. This results in a graded membrane potential.



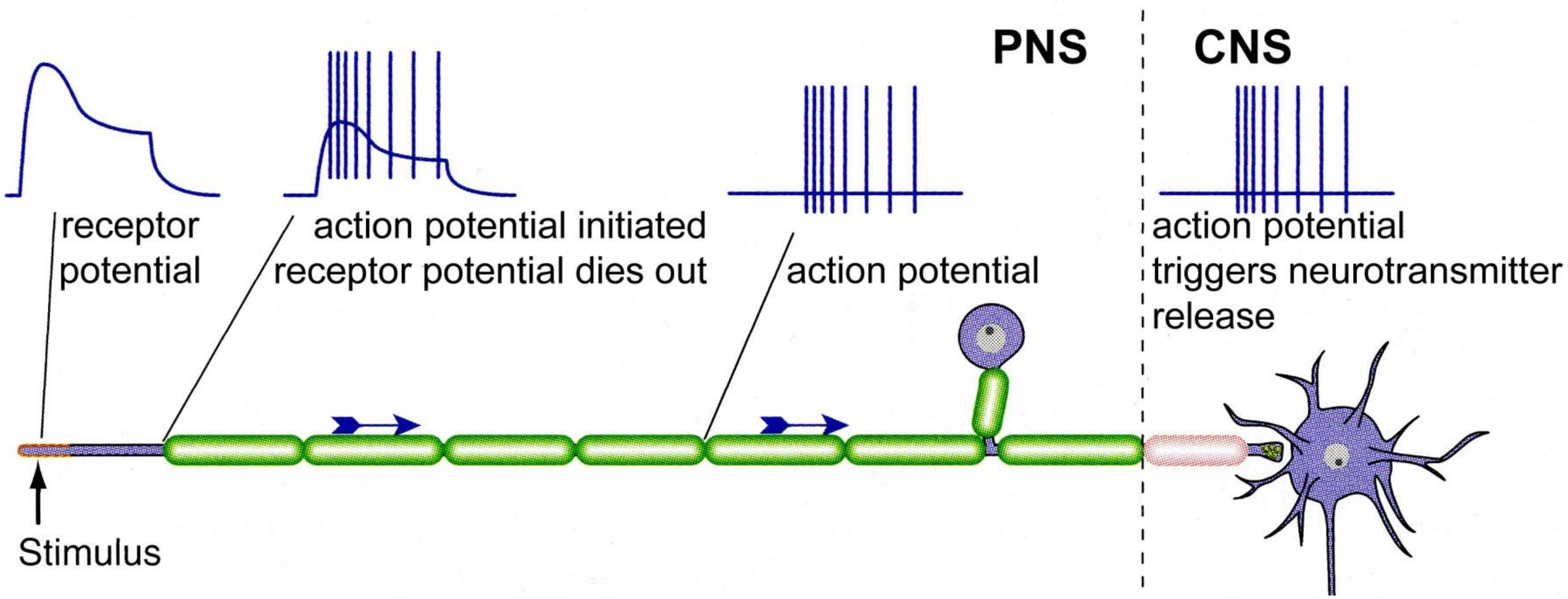
Somatosensory Receptors

- The stronger the stimulus, the larger the membrane potential.



Somatosensory Receptors

- With sufficient depolarization, the initial segment initiates an action potential, which is all-or-none and self propagated up the axon.
- The number of action potentials encodes the strength and duration of the stimulus.



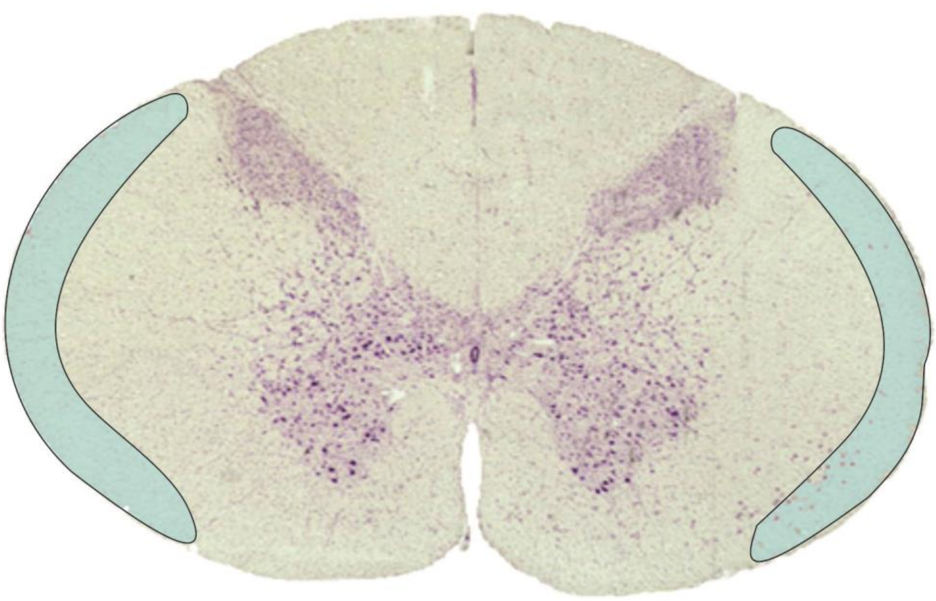
Spinocerebellar Pathway

- Primary sensory neurons carrying proprioceptive information synapse deep in the dorsal horn.
- Second order neurons ascend on both sides of the spinal cord in the spinocerebellar tracts.
- These axons synapse on the ipsilateral side of the cerebellum.
- The cerebellum has important roles in maintaining balance and coordinating movements.

Spinocerebellar Pathway

- The spinocerebellar tracts are in the lateral funiculus of the spinal cord.

[Note how tracts are often labeled by their origin and target.]



Somatosensory Projection to Cortex

Two pathways:

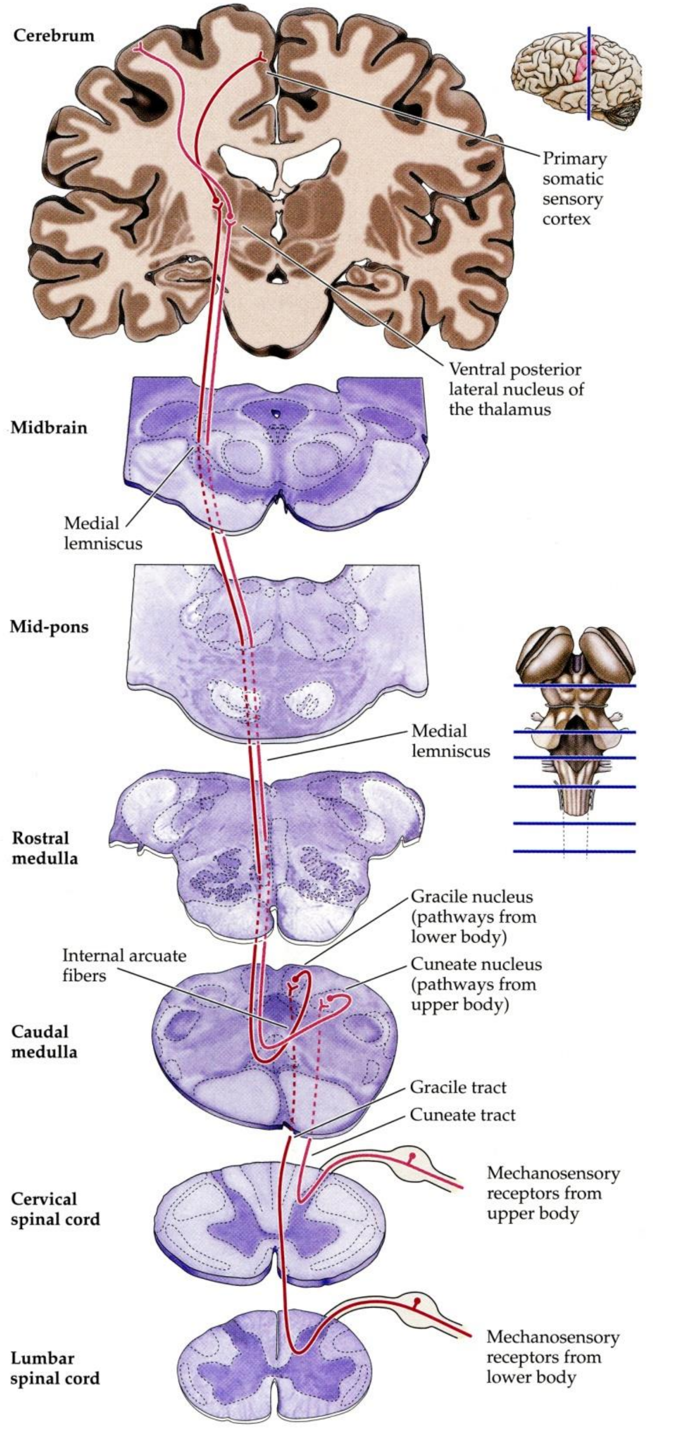
- Proprioception and touch via the dorsal columns.

- Pain, temperature and light touch via the spinothalamic tracts.

Somatosensory Projection to Cortex

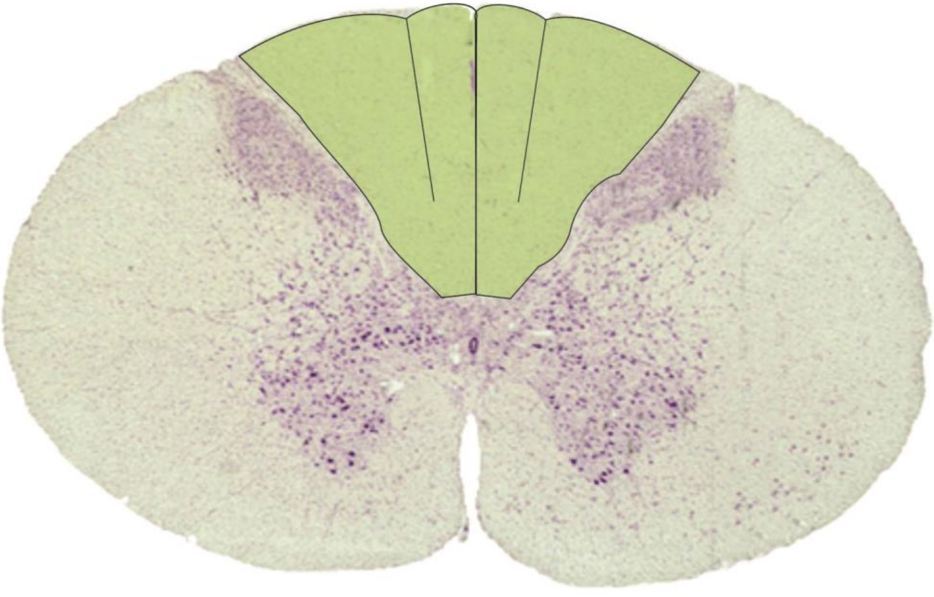
Dorsal column projection:

- Primary sensory axons for proprioception and touch enter the dorsal horn and ascend in the dorsal columns.
- These axons synapse in nucleus gracilis (from lower body) and nucleus cuneatus (from upper body) in the medulla.
- Axons from these nuclei cross the medulla and ascend to thalamus.
- They synapse in the ventral posterolateral nucleus (VPL) of the thalamus.
- Axons from the VPL neurons project to somatosensory cortex.



Somatosensory Projection to Cortex

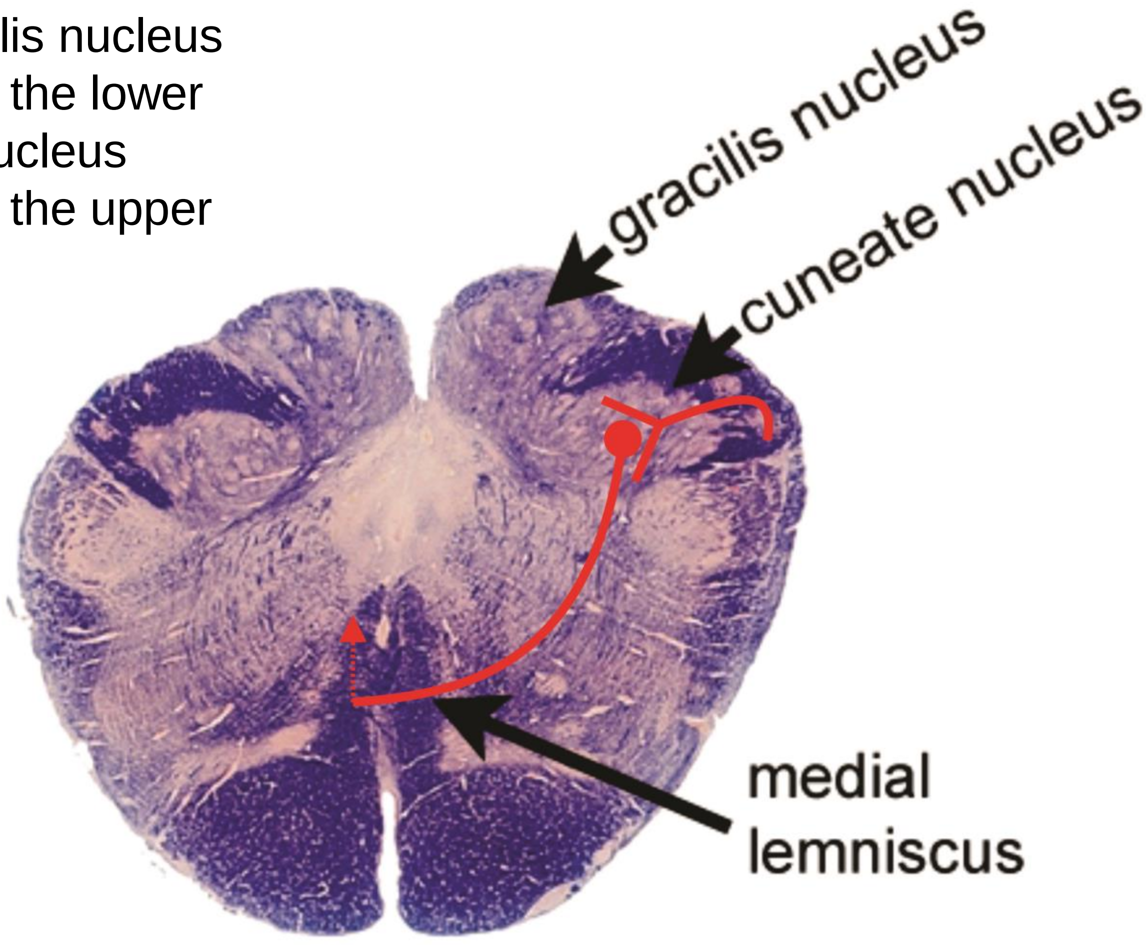
- The dorsal columns are in the dorsal funiculus of the spinal cord.



Somatosensory Projection to Cortex

- In the medulla, the gracilis nucleus receives the axons from the lower body and the cuneate nucleus receives the axons from the upper body.

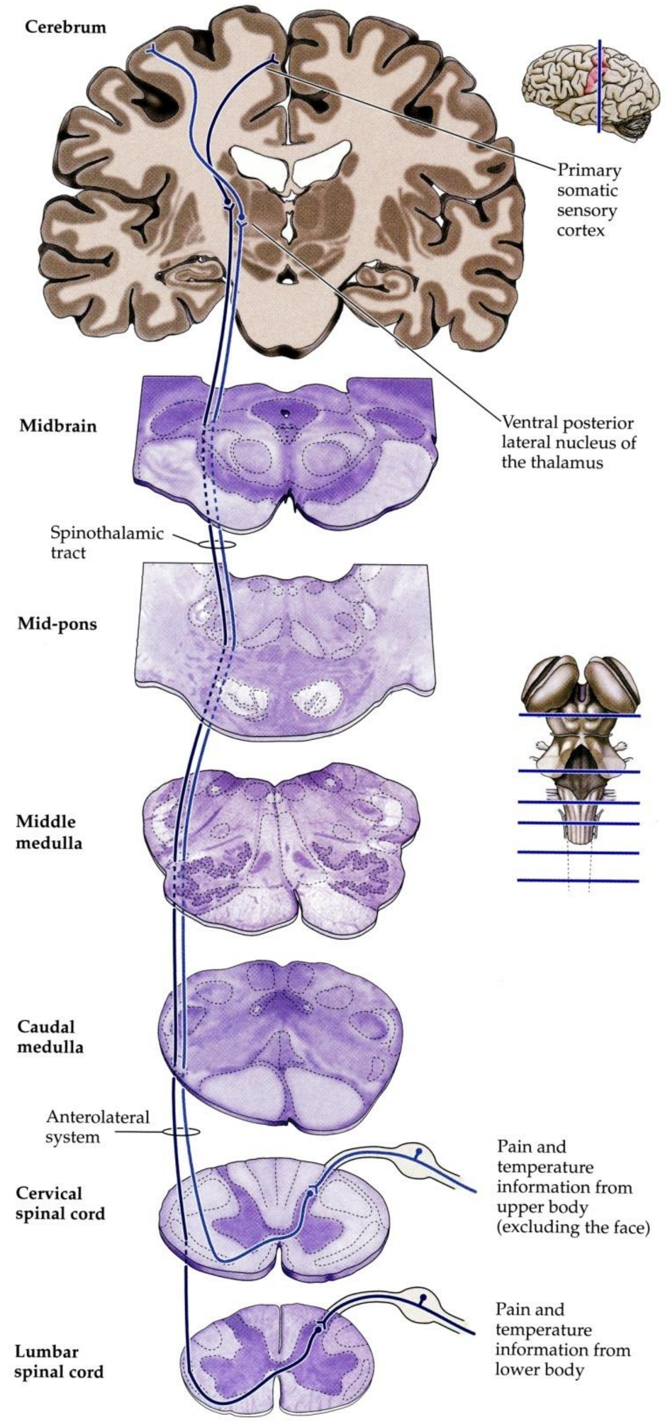
- Axons from these nuclei cross and ascend to the thalamus in the medial lemniscus.



Somatosensory Projection to Cortex

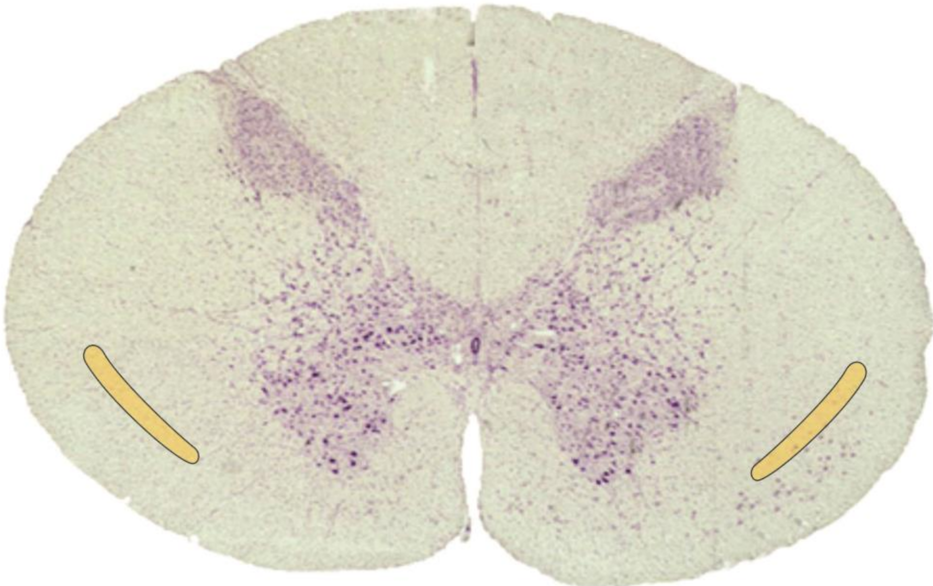
Spinothalamic projection:

- Primary sensory axons for pain, temperature and light touch synapse on neurons in the dorsal horn.
- Axons of these dorsal horn neurons cross the spinal cord and ascend in the spinothalamic tract.
- They synapse in the ventral posterolateral nucleus (VPL) of the thalamus.
- Axons from the VPL neurons project to somatosensory cortex.



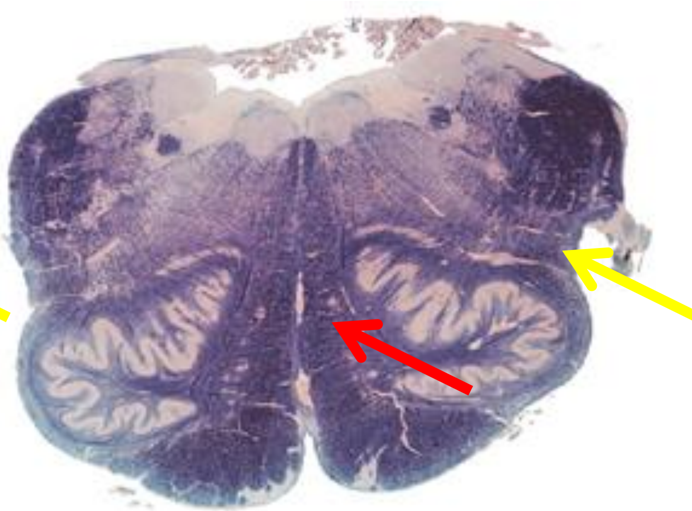
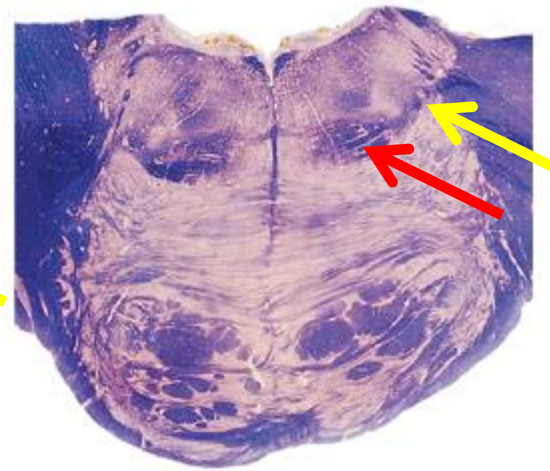
Somatosensory Projection to Cortex

- The spinothalamic tracts are in the lateral funiculus of the spinal cord.



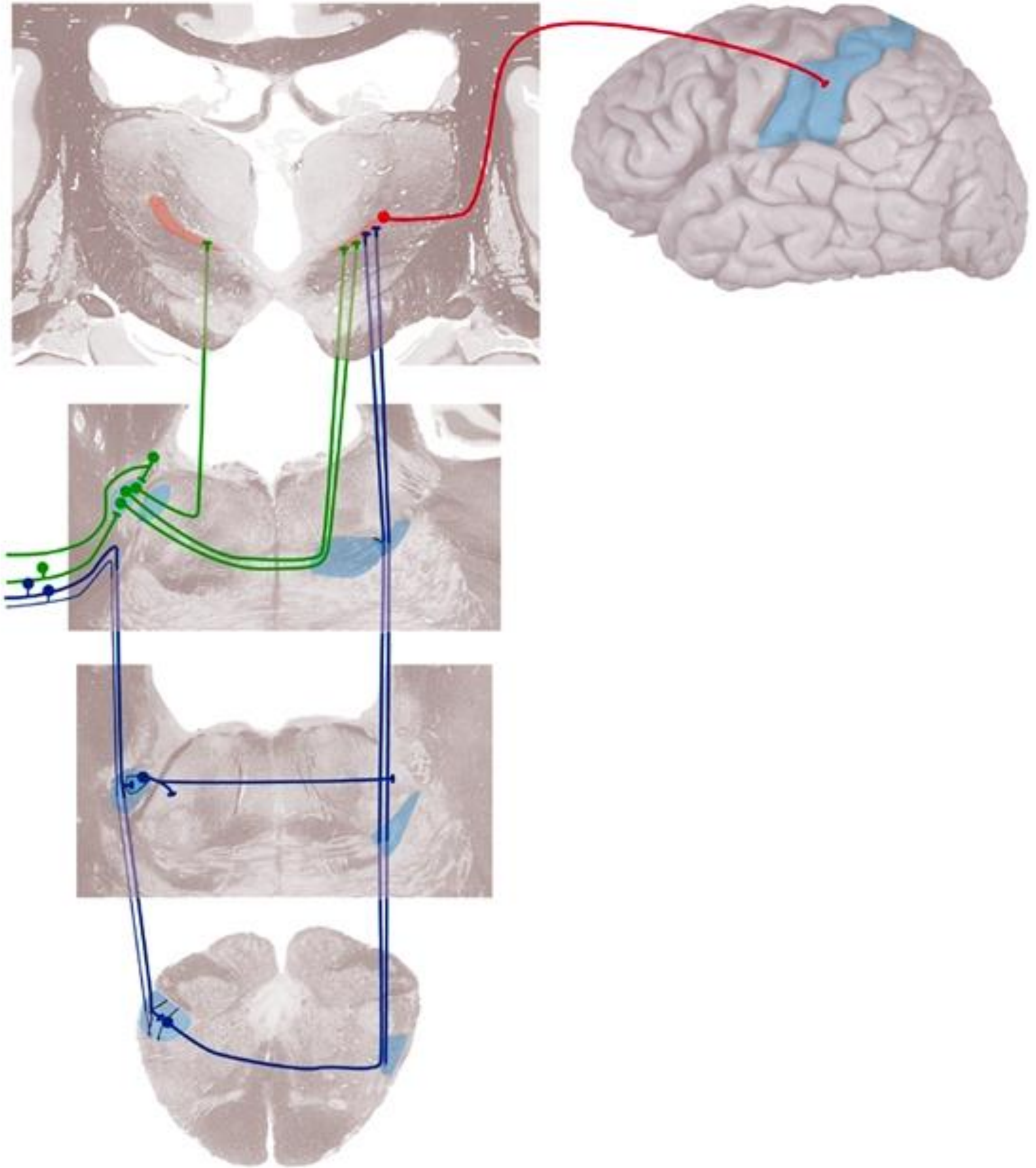
Somatosensory Pathway

- Medial lemniscus (red) and spinothalamic (yellow)

Trigeminal Nerve (cn V)

- Trigeminal sensory pathway in the brain is similar to that for the rest of the body.

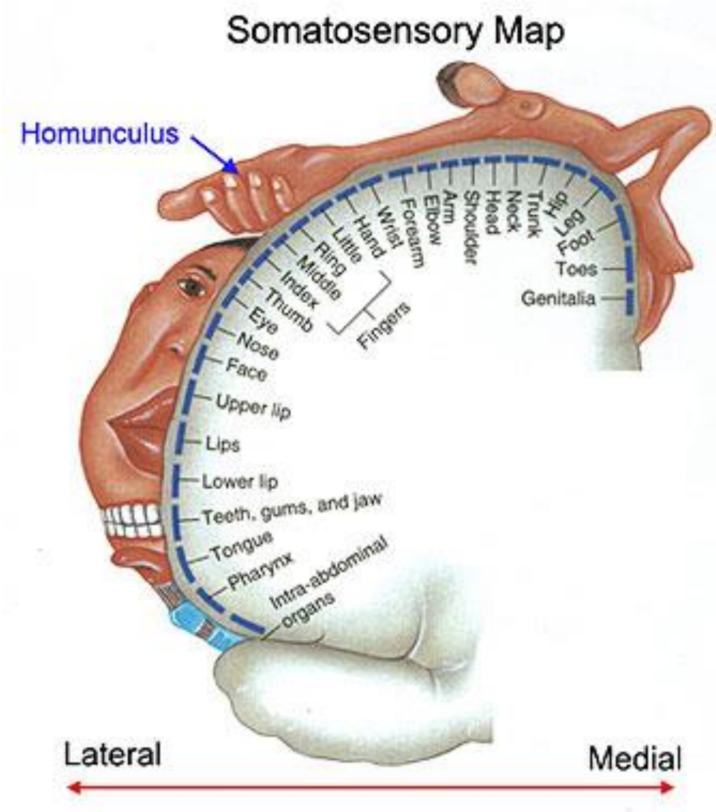


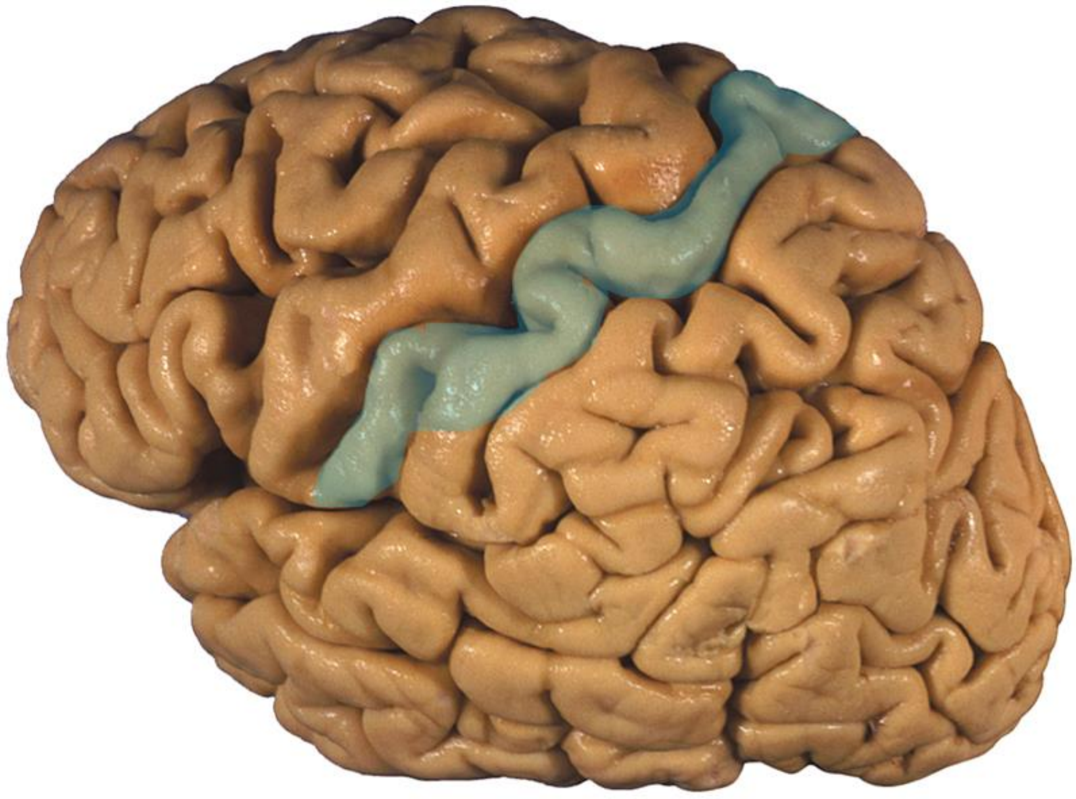
Somatosensory Projection to Cortex

- Somatosensory cortex is in the <u>postcentral gyrus</u>.

- The somatosensory projection has a <u>somatotopic</u> organization throughout the pathway

- The pattern of the projection to cortex is said to be a homunculus (little person).





Somatosensory Projection to Cortex

- A stroke in the right side of the cerebellum can affect movements the right side of the body.
- A stroke in the right somatosensory cortex can affect sensory perception on the left side of the body.

Vision

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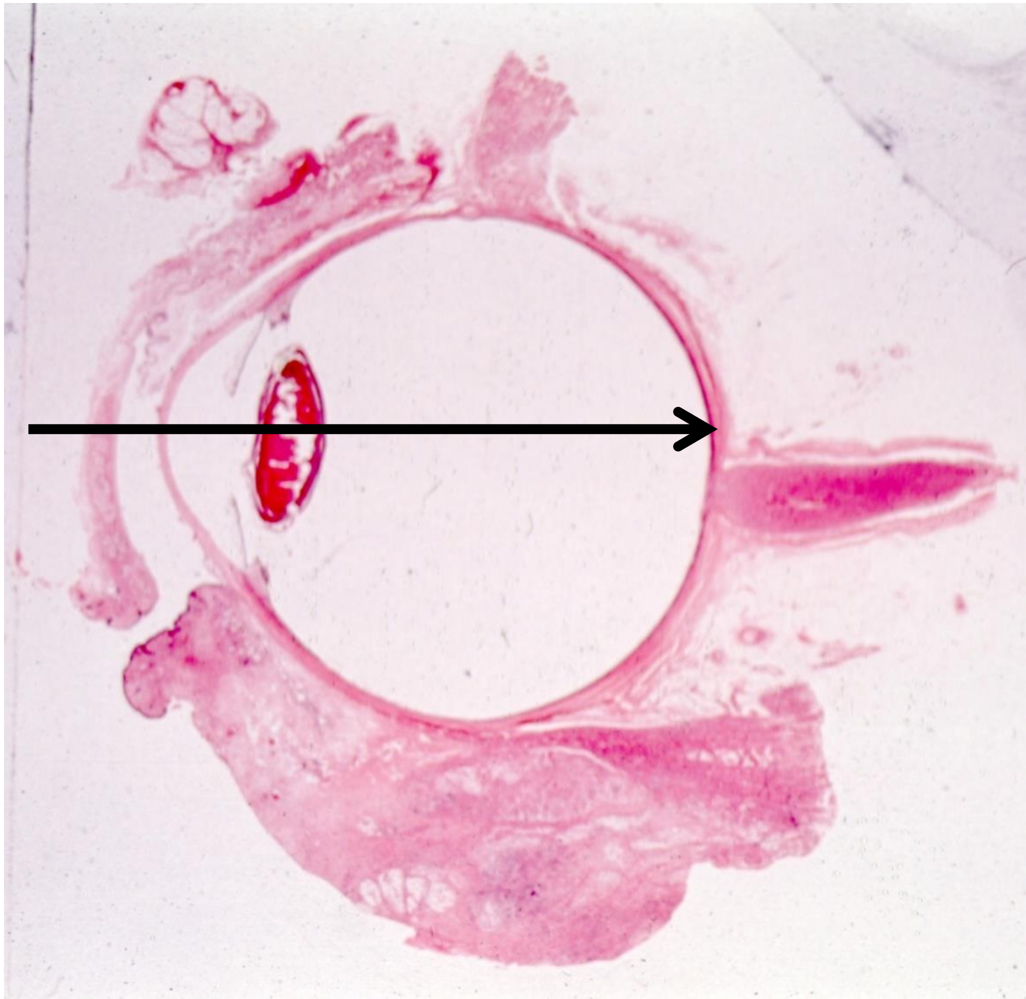
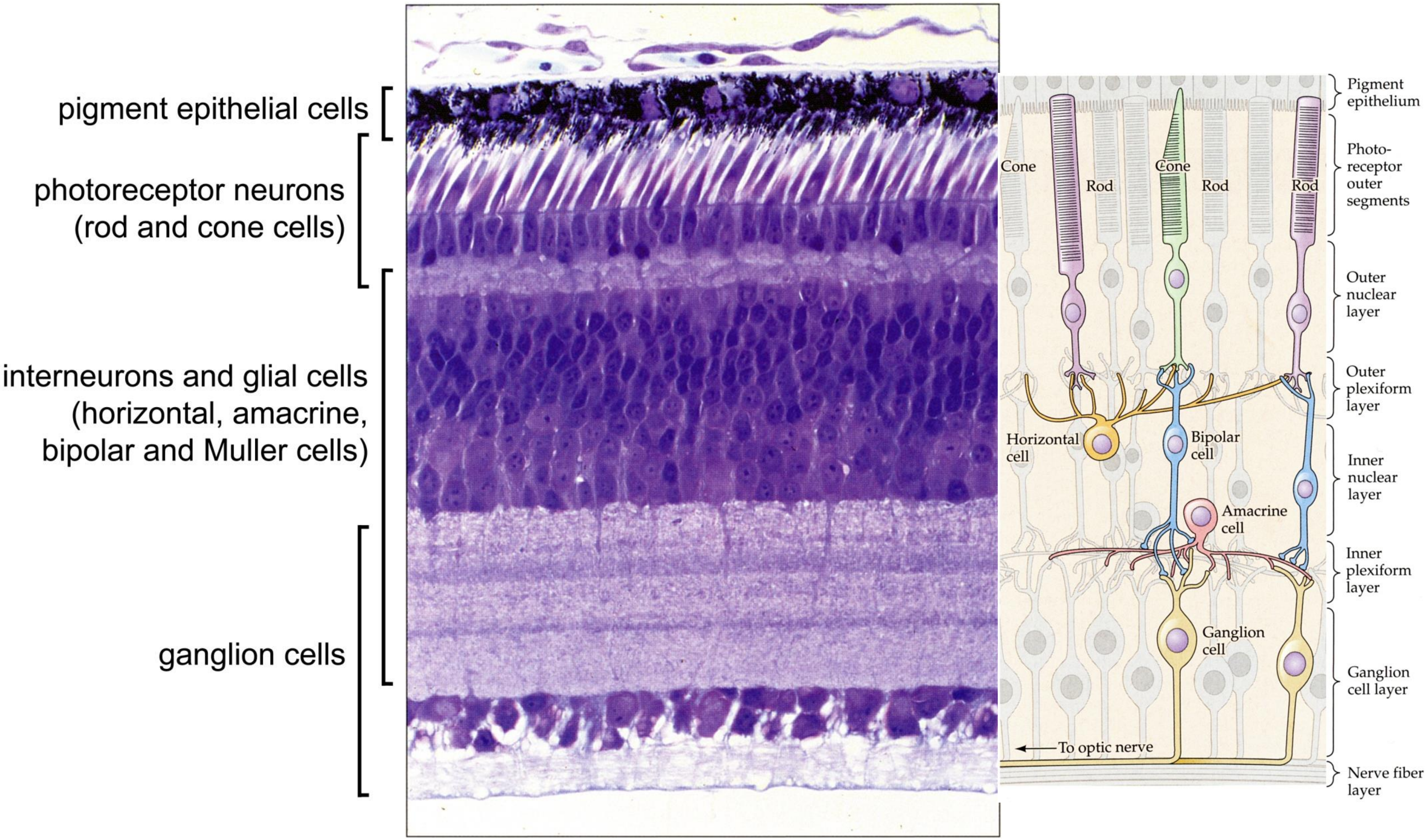
Eye

Path of light:

- Cornea
- Anterior chamber
- Pupil
- Posterior chamber
- Lens
- Vitreous chamber
- Retina

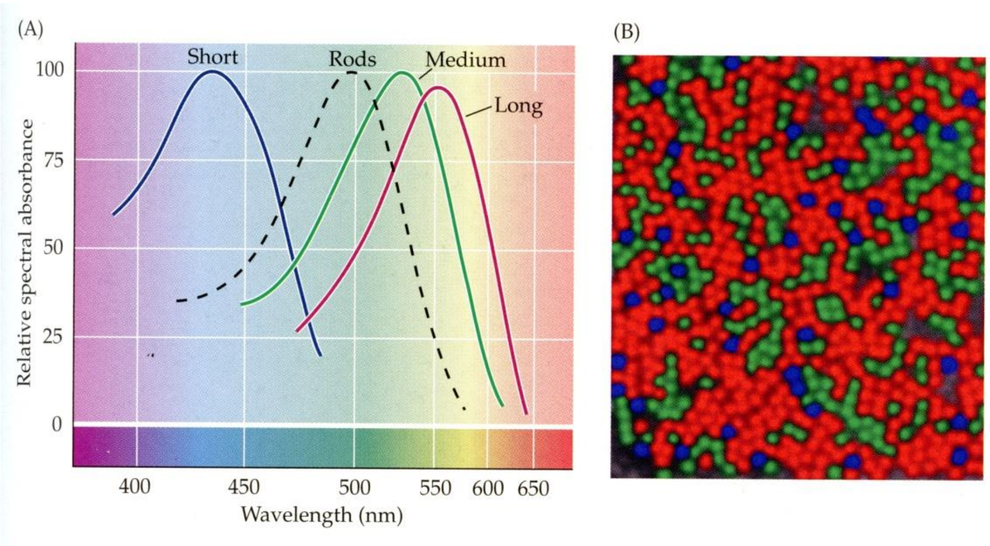


Retina


pigment epithelial cells
photoreceptor neurons (rod and cone cells)
interneurons and glial cells (horizontal, amacrine, bipolar and Muller cells)
ganglion cells
Pigment epithelium
Cone
Rod
Cone
Rod
Rod
Photo-receptor outer segments
Outer nuclear layer
Outer plexiform layer
Horizontal cell
Bipolar cell
Inner nuclear layer
Amacrine cell
Inner plexiform layer
Ganglion cell
Ganglion cell layer
To optic nerve
Nerve fiber layer

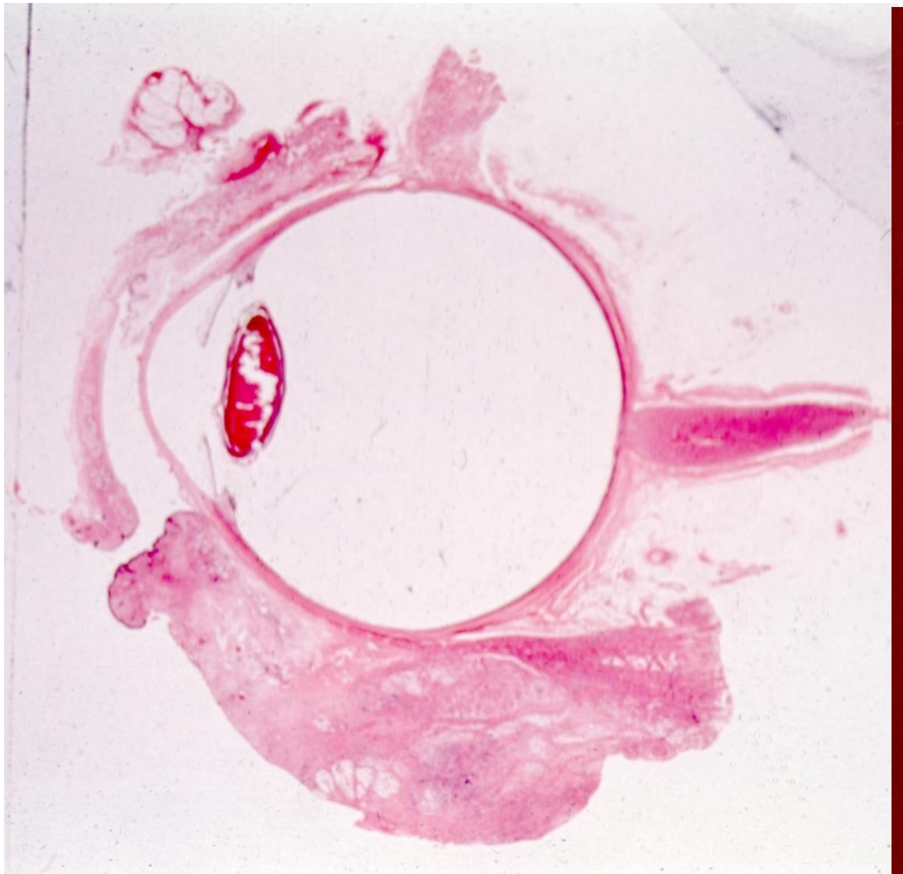
Retina

- Opsins are light sensitive proteins in photoreceptors; opsins bind retinal, which is a vitamin A derivative.
- Different opsins are sensitive to different wavelengths of light.
- There are three types of cone cells, each with a different opsin and sensitive to a different wavelength.



Optic Nerve (CN II)

- The axons from retinal ganglion cells across the retina run to the optic nerve head.
- The optic nerve head is the start of the optic nerve.
- There is no retina at the optic nerve head (blind spot).
- The retinal axons become myelinated at the optic nerve head.



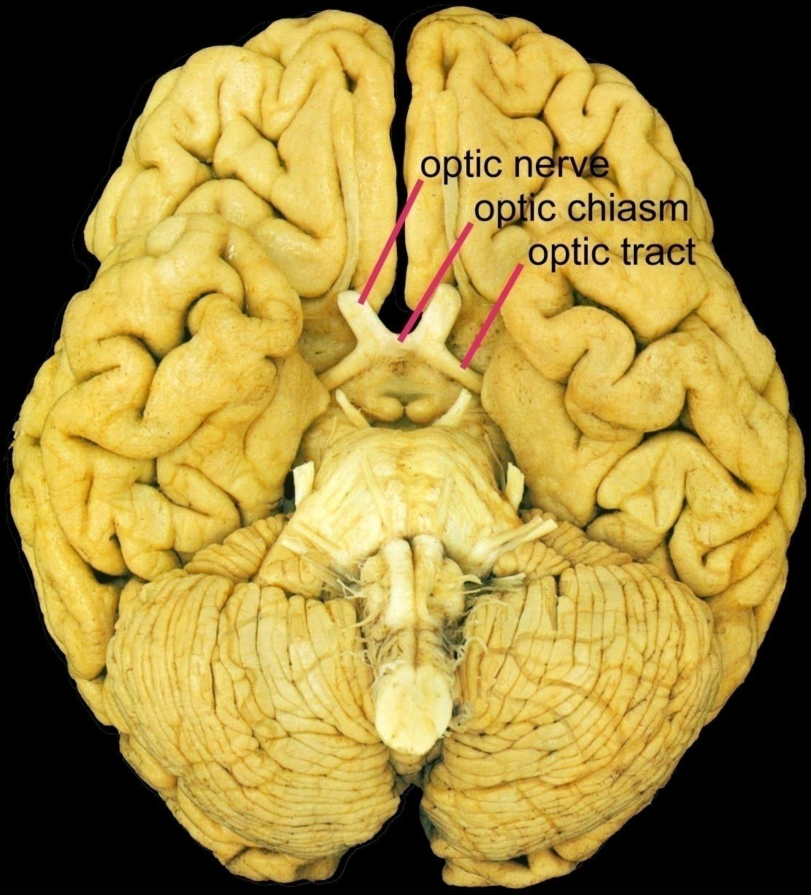
Retina

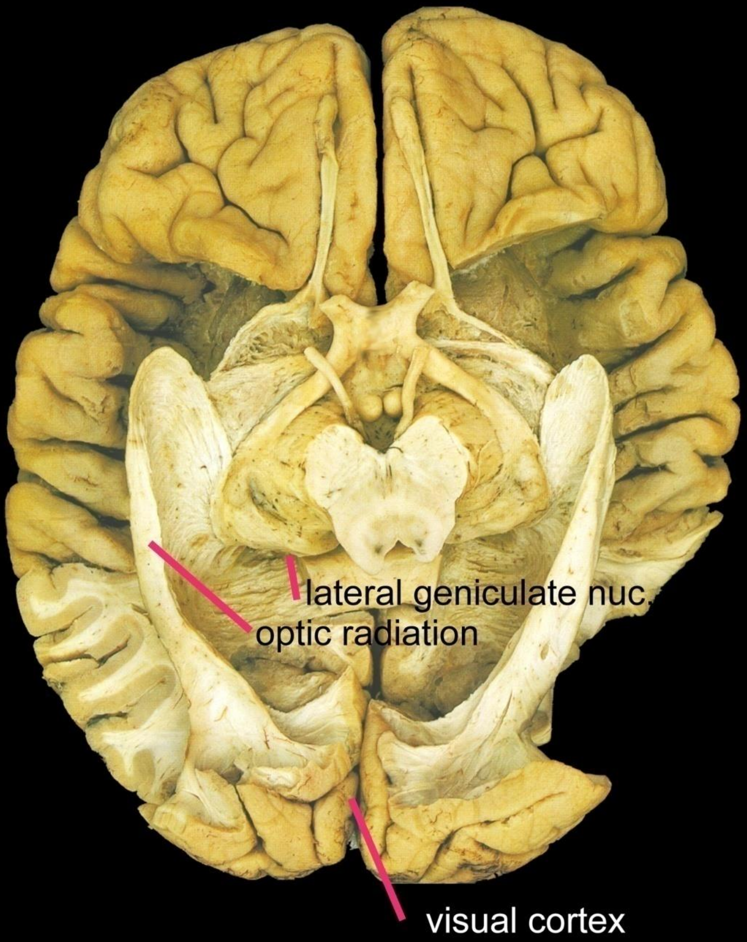
Retina can be examined non-invasively with an ophthalmoscope:

- Central artery & vein
- Macula & fovea
- Optic nerve head

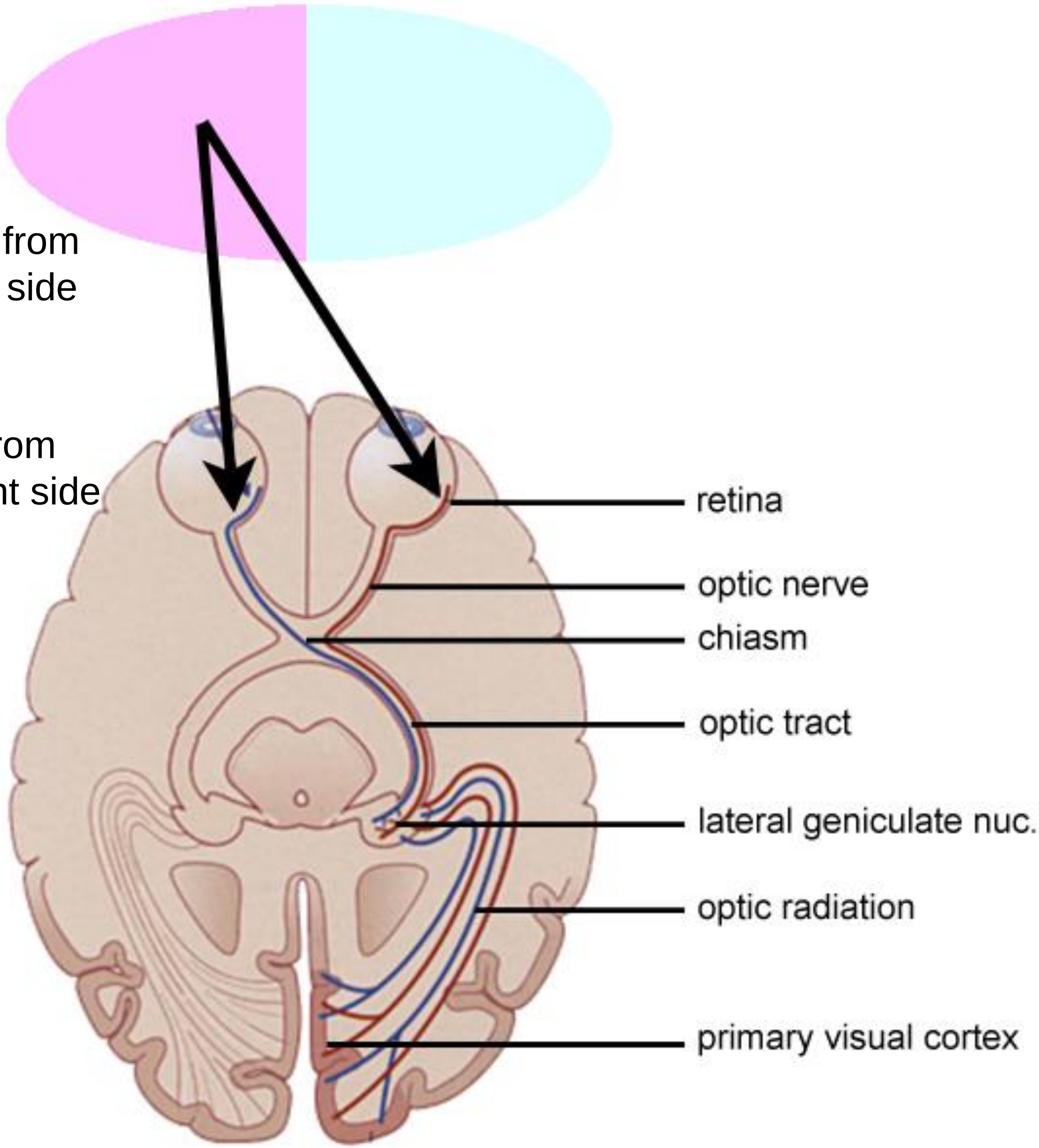
Central Visual Pathways

- The optic nerve attaches to the brain at the optic chiasm.
- Retinal axons from the nasal side of retina cross in the chiasm.
- The retinal axons continue in the optic tract.



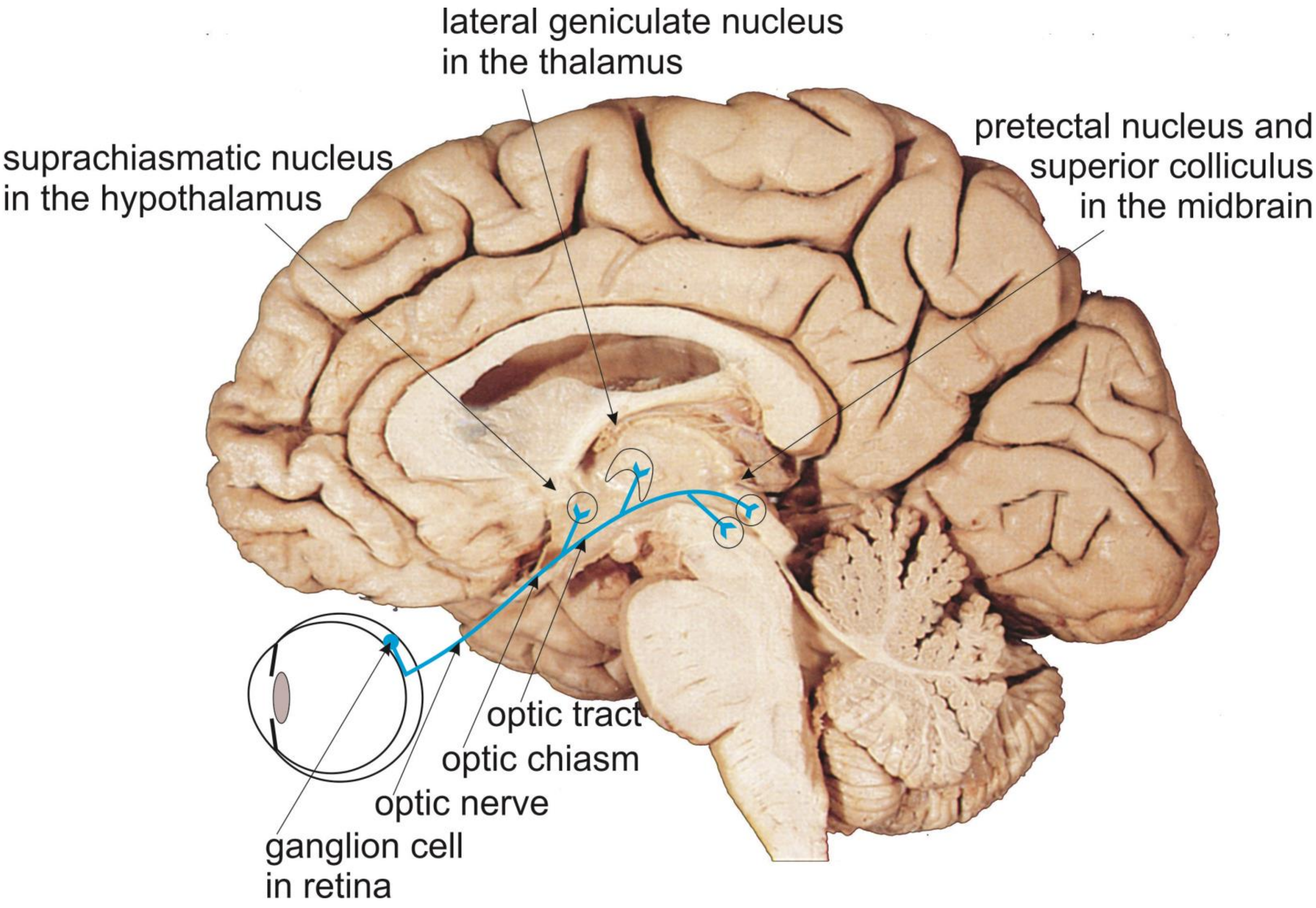


- The right visual hemifield from both eyes goes to the left side of the brain.
- The left visual hemifield from both eyes goes to the right side of the brain.



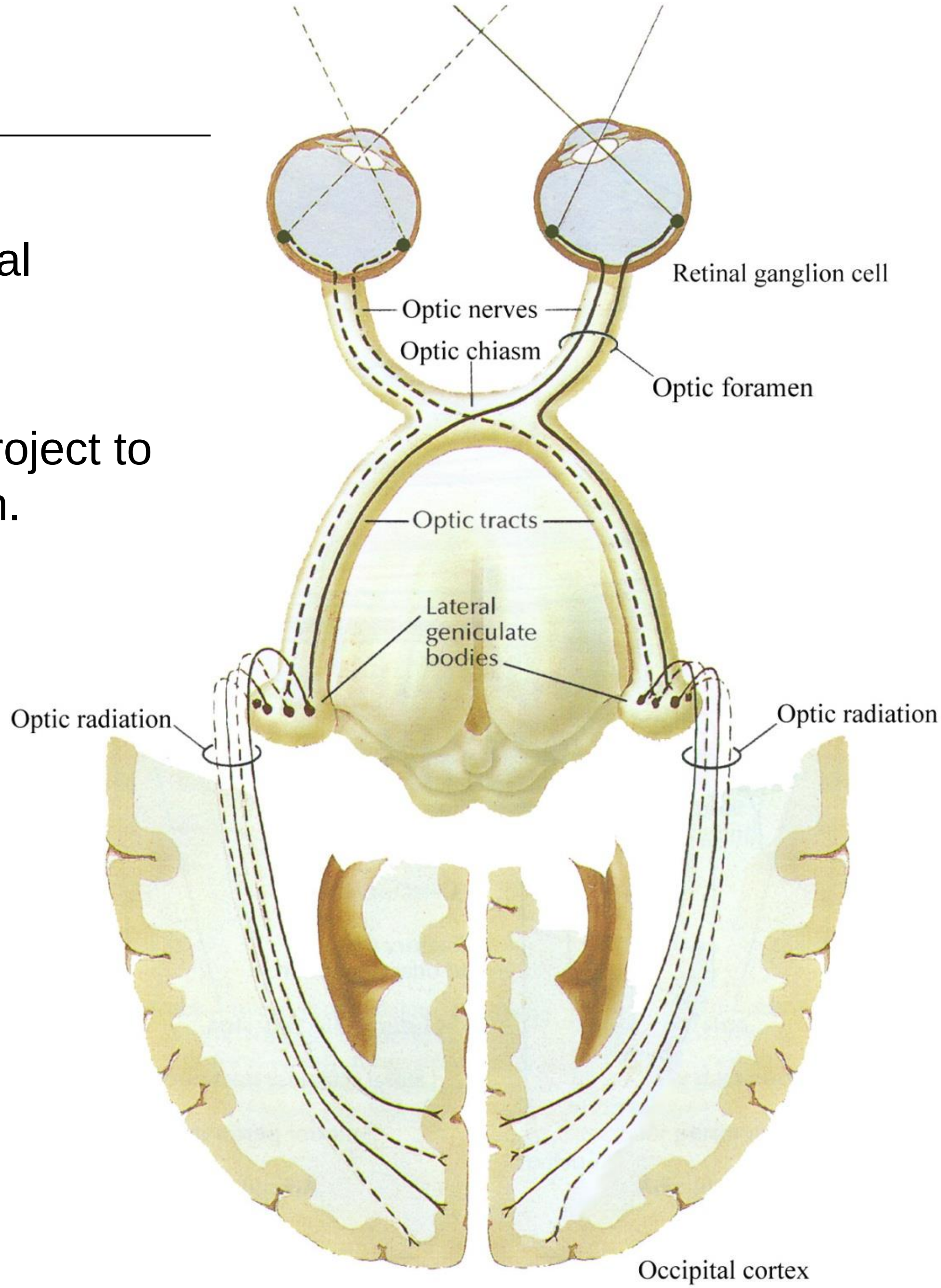
Central Visual Pathways

- Retinal axons synapse in several visual centers in the brain.



Central Visual Pathways

- Retinal axons synapse in the lateral geniculate nucleus (LGN).
- Axons from neurons in the LGN project to visual cortex via the optic radiation.



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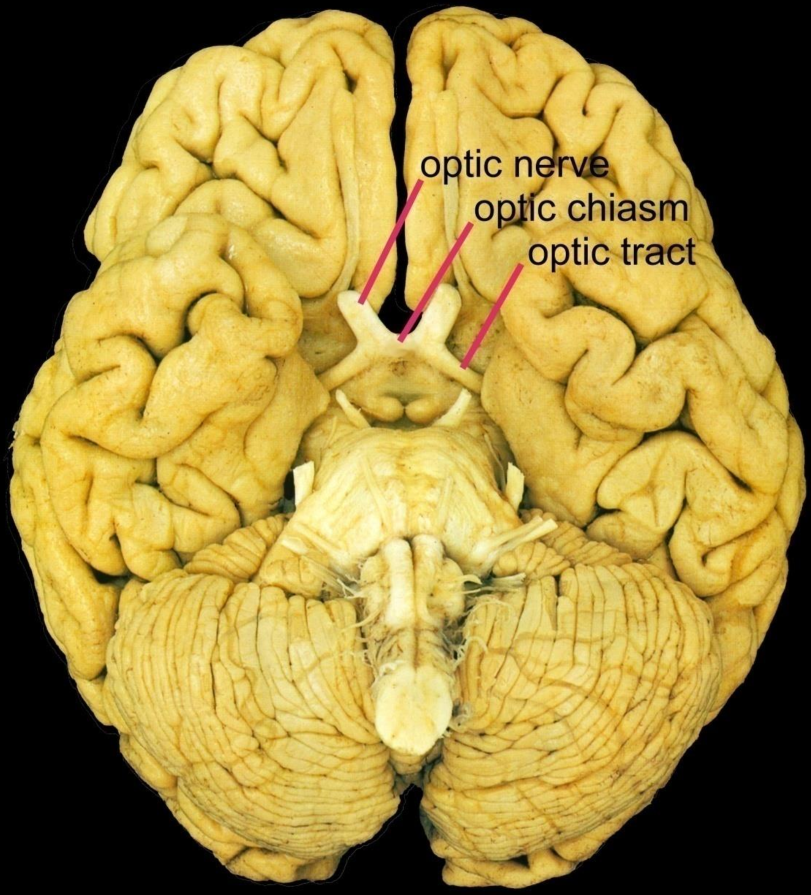
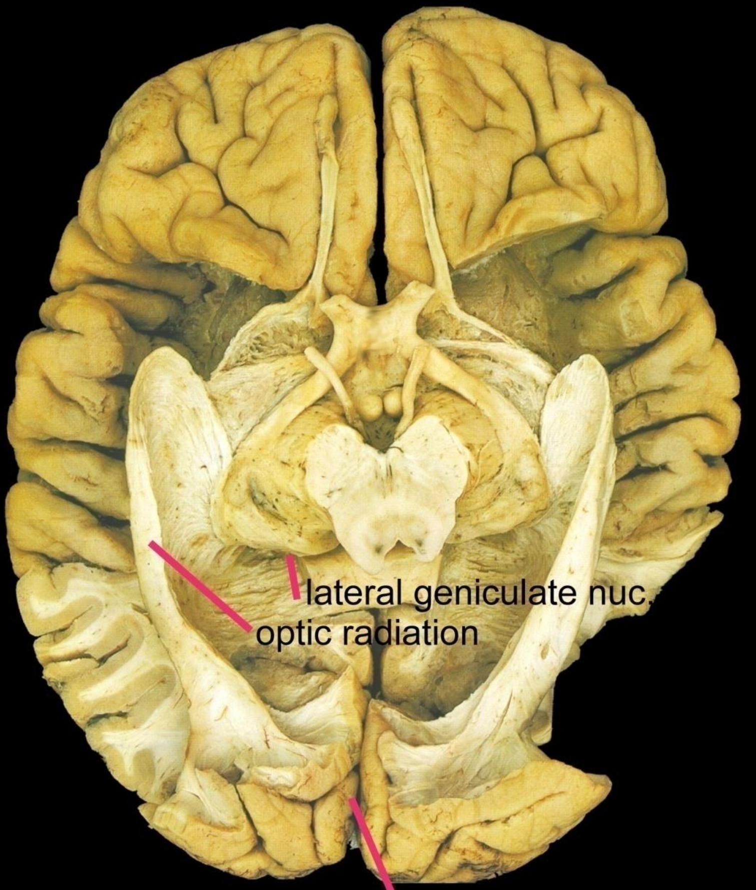
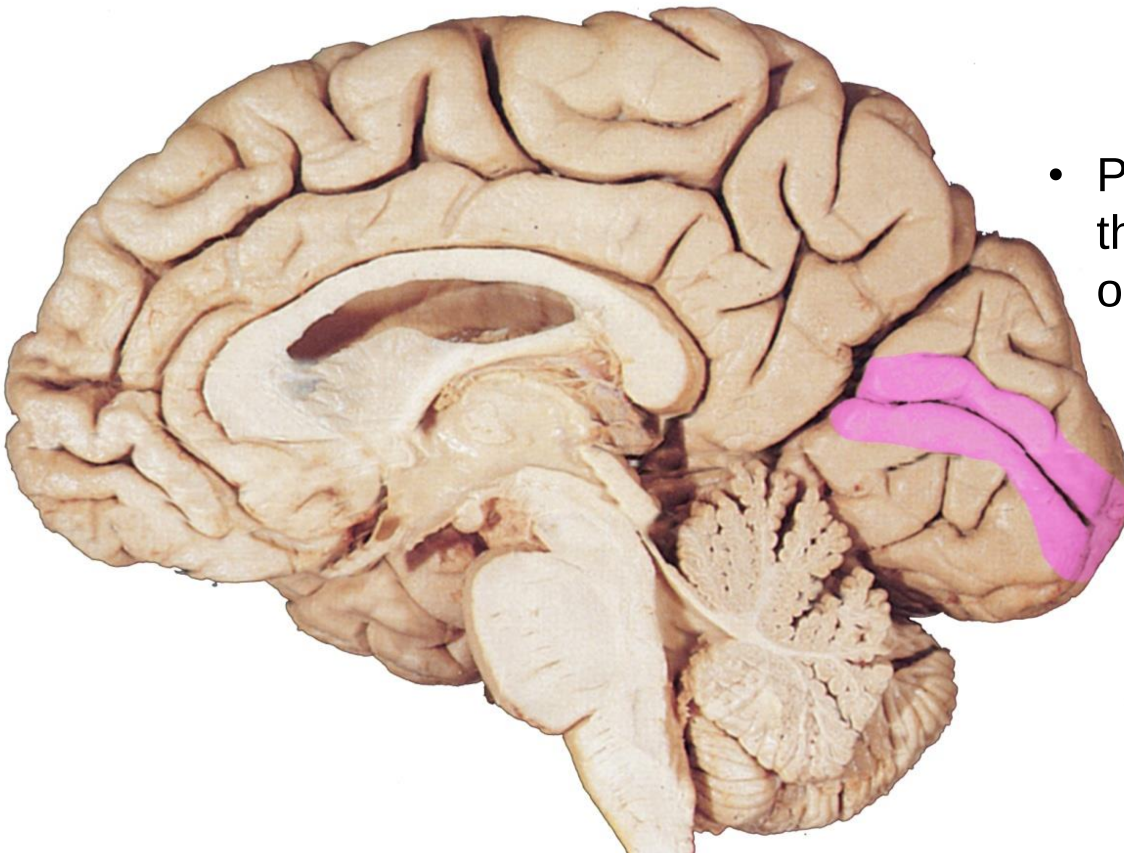




Central Visual Pathways

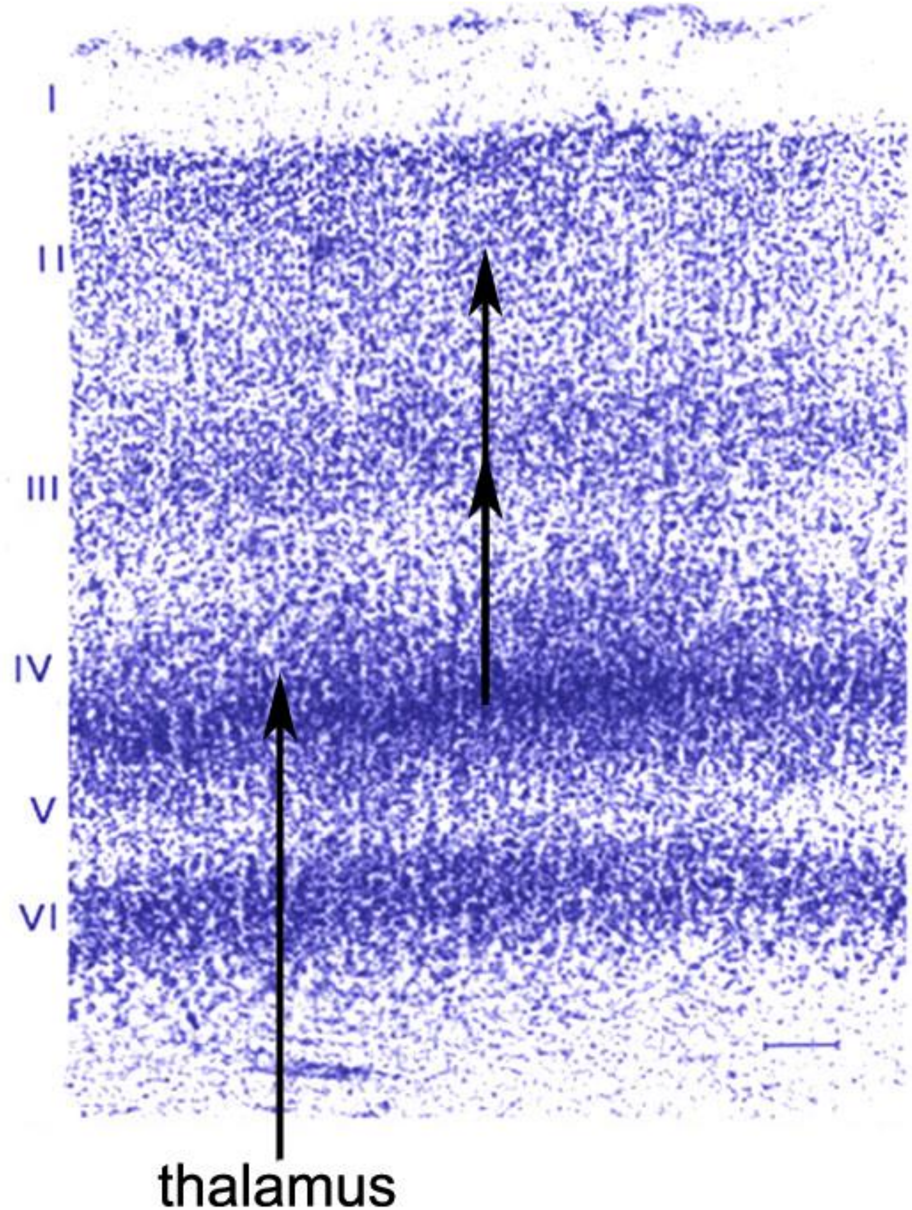
- Visual cortex is essential for conscious visual perception.
- Neurons in visual cortex send axons to secondary visual areas of cortex and to pulvinar (in the thalamus) for distribution to association cortex.



- Primary visual cortex is in the calcarine fissure of the occipital lobe.

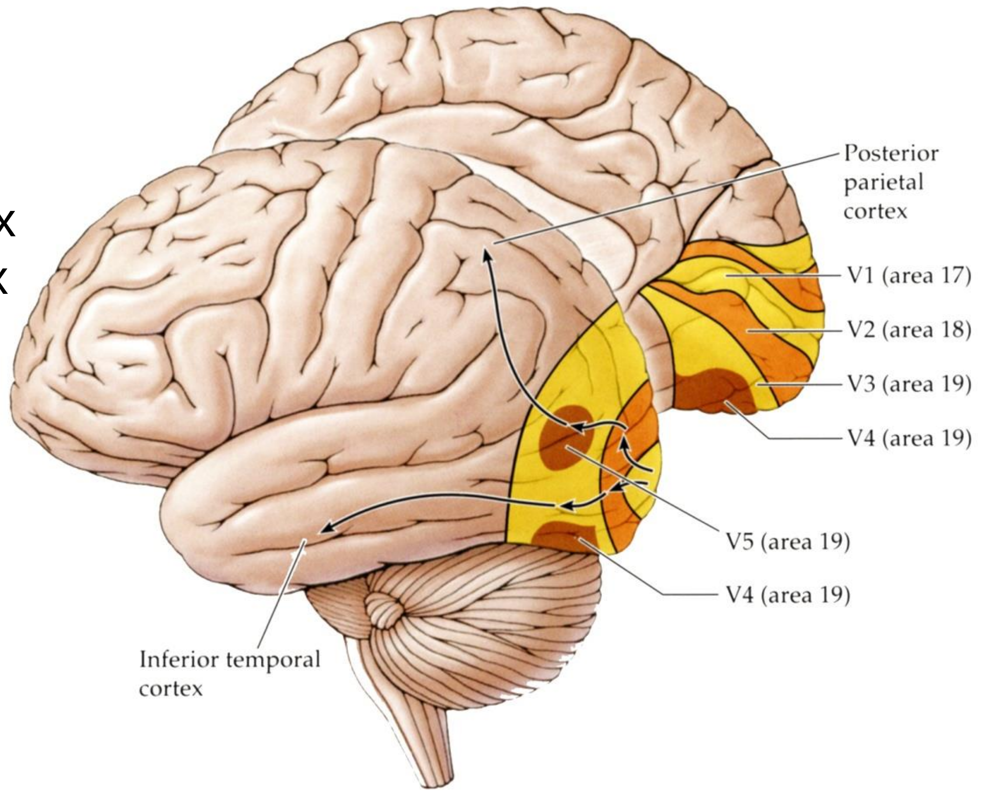
Central Visual Pathways

- Neocortex has six cell layers.
- Inputs from thalamus synapse in layer IV.
- Layer IV neurons send axons to layers II & III.



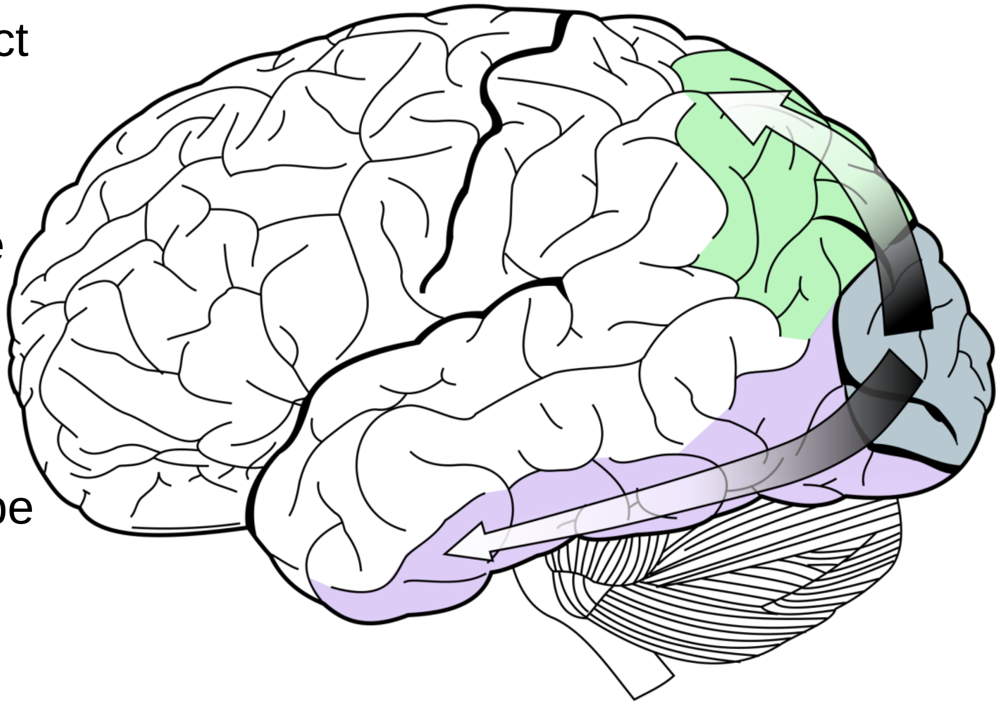
Central Visual Pathways

- Neurons in primary visual cortex send axons to secondary visual cortex (V2 or area 18).
- Neurons in secondary visual cortex send axons to tertiary visual cortex areas.



Central Visual Pathways

- Accessory visual cortical area project to other cortical areas in two main streams:
  - dorsal stream into parietal lobe carrying information for motion and location analysis (M pathway)
  - ventral stream into temporal lobe carrying information for color and object recognition (P pathway)



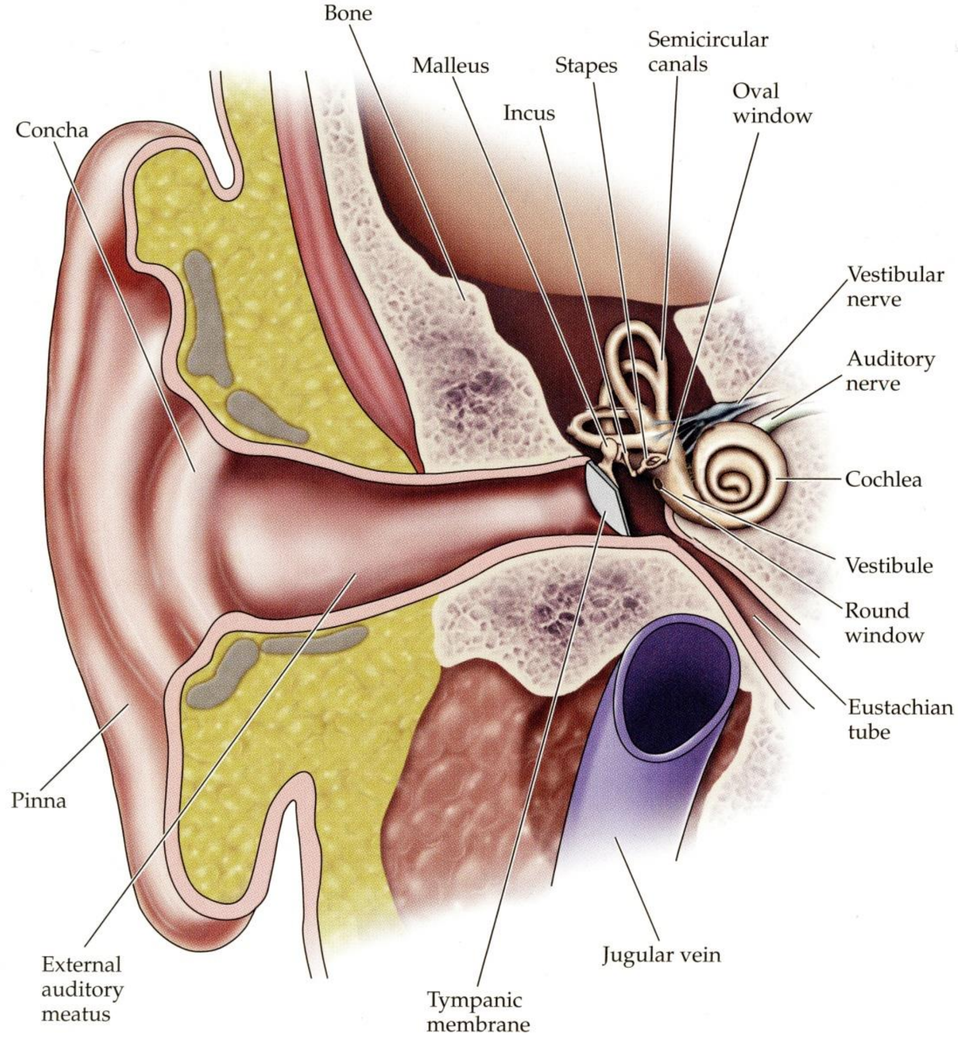
Auditory & Vestibular Systems

Steven McLoon
Department of Neuroscience
University of Minnesota

Auditory System

External ear:

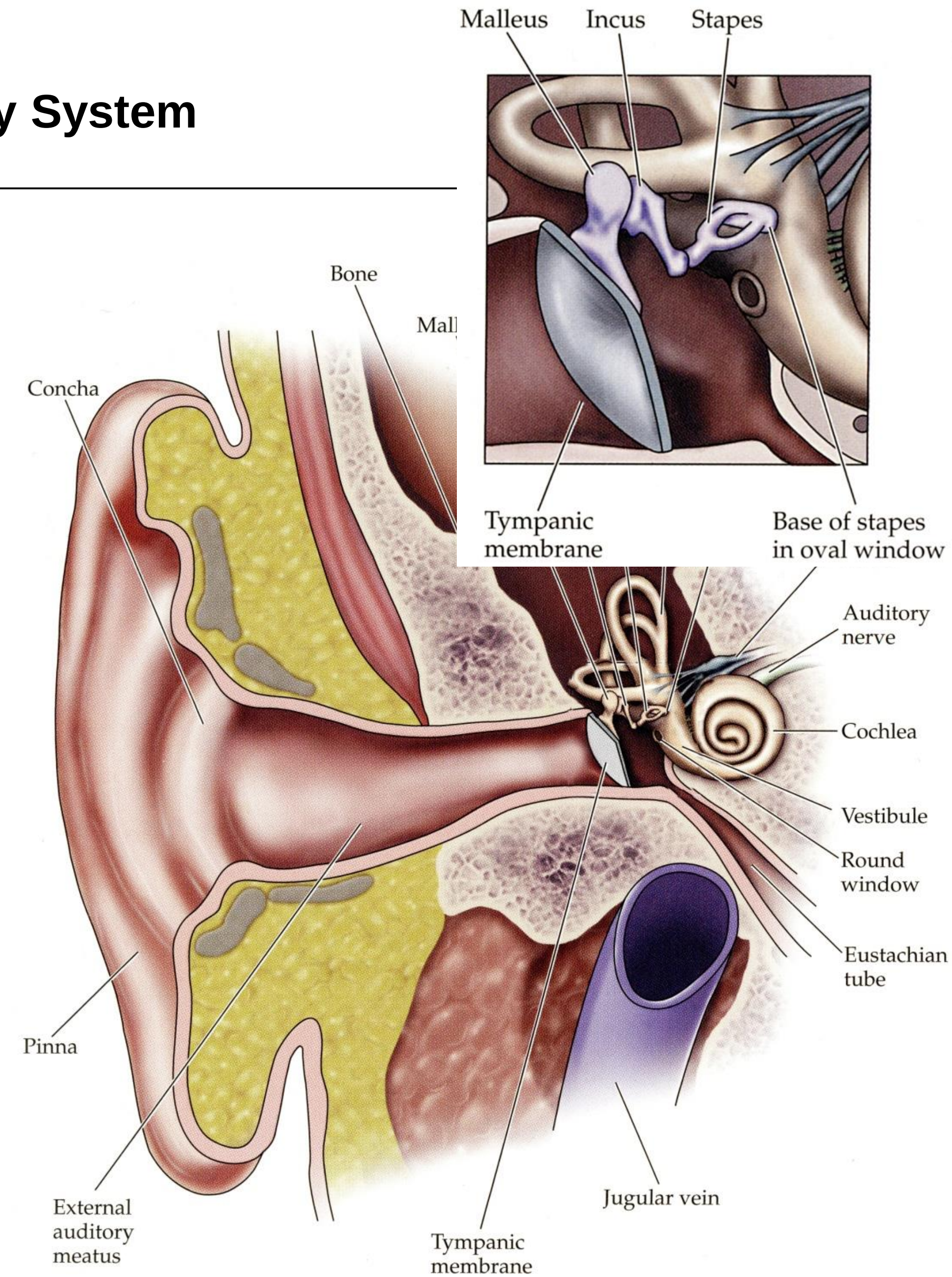
- includes the pinna, external auditory meatus (ear canal) and tympanic membrane (ear drum).
- The pinna and canal collect sound and guide it to the tympanic membrane.
- The tympanic membrane vibrates in response to sound.



Auditory System

Middle ear:

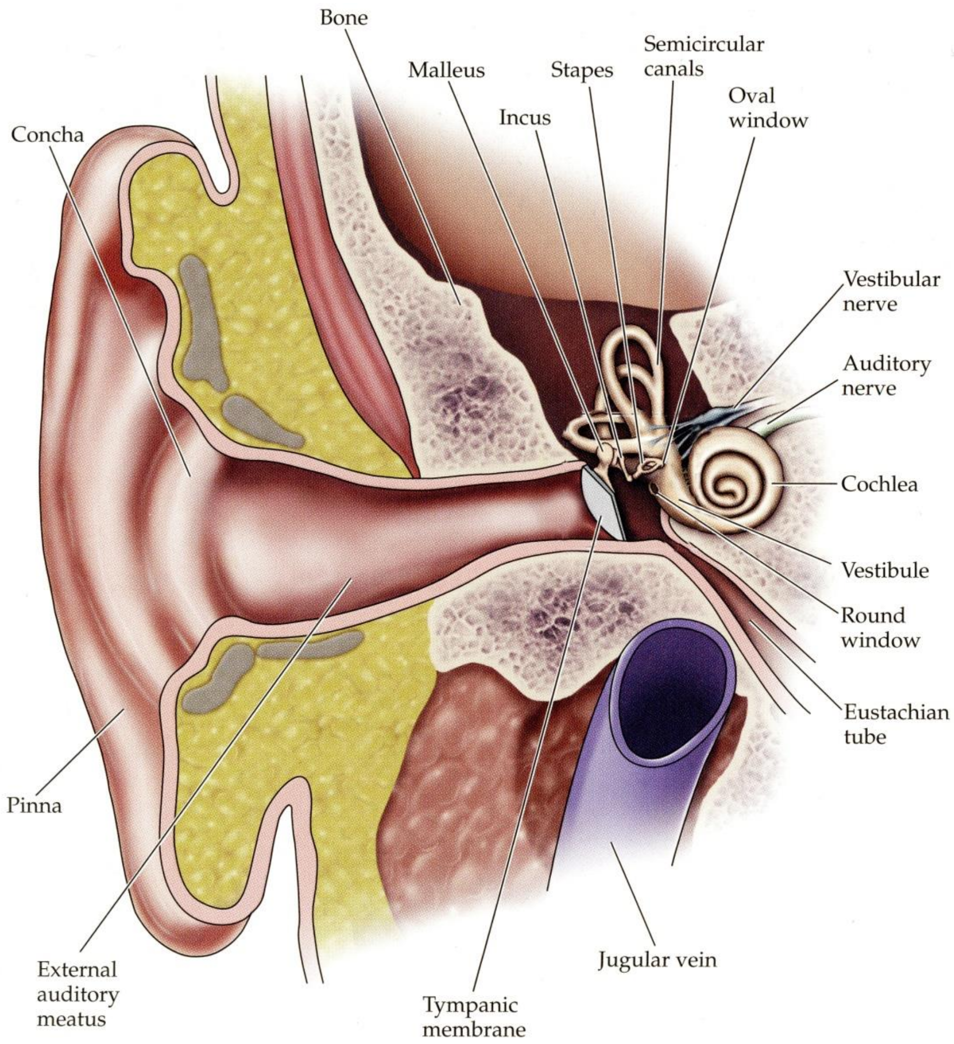
- It is an air filled chamber.
- The eustachian tube (auditory tube) connects the middle ear chamber with the pharynx (throat).
- Three tiny bones in the chamber transfer the vibration of the tympanic membrane to the oval window of the inner ear.



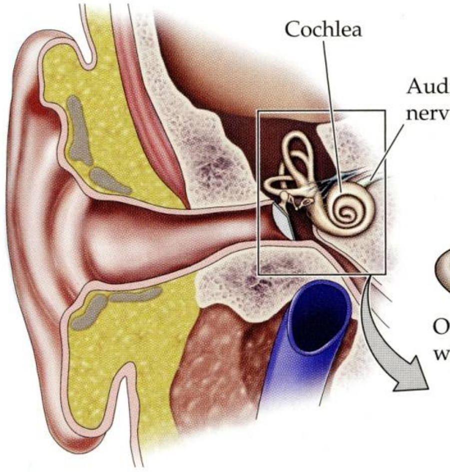
Auditory System

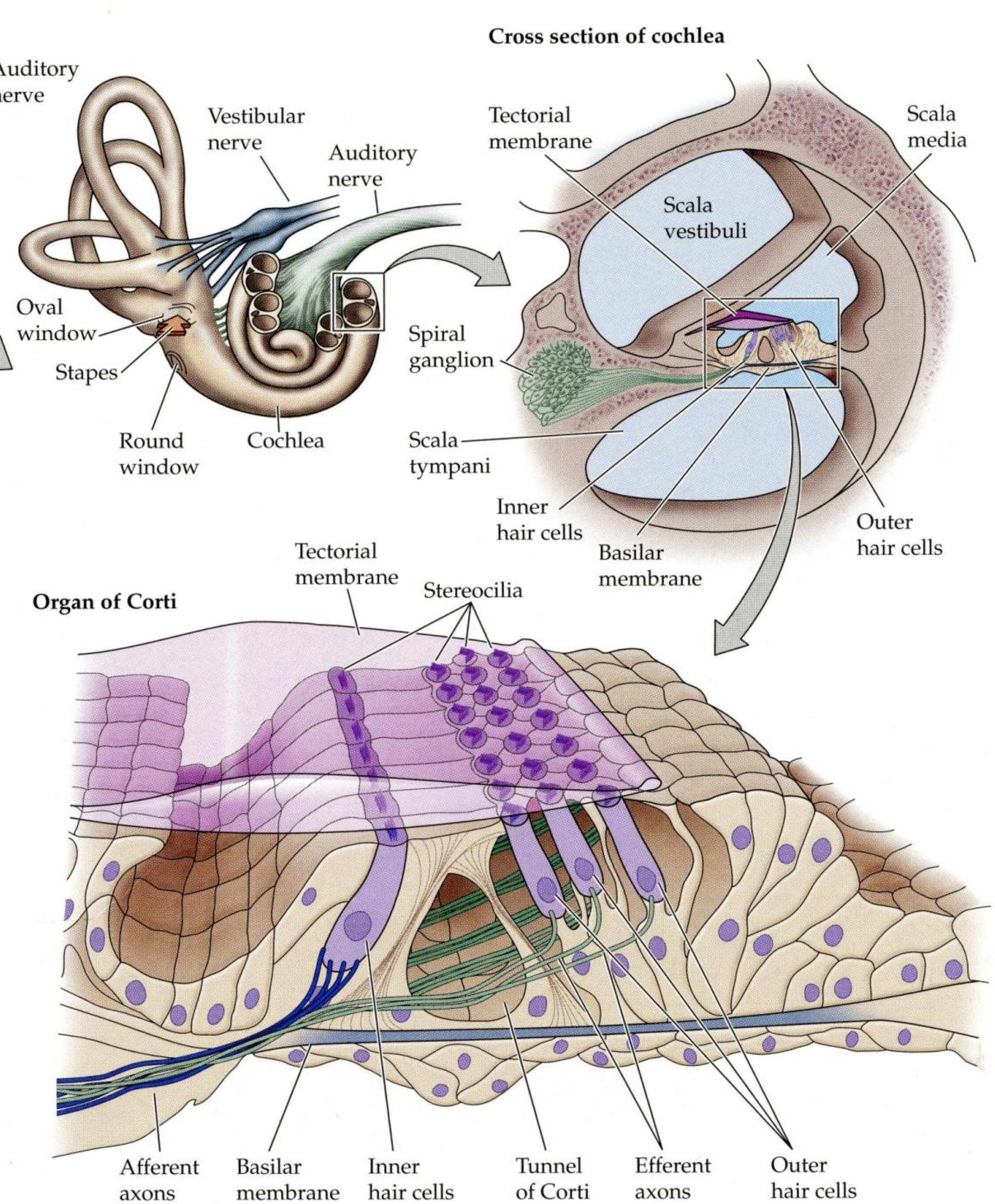
Inner ear:

- The cochlea is a snail shaped tube incased in bone.
- The cochlea has two membrane covered openings into the middle ear, the oval and round windows.
- The auditory nerve, a branch of the vestibulochochlear (CN VIII) runs into the cochlea.



Auditory System



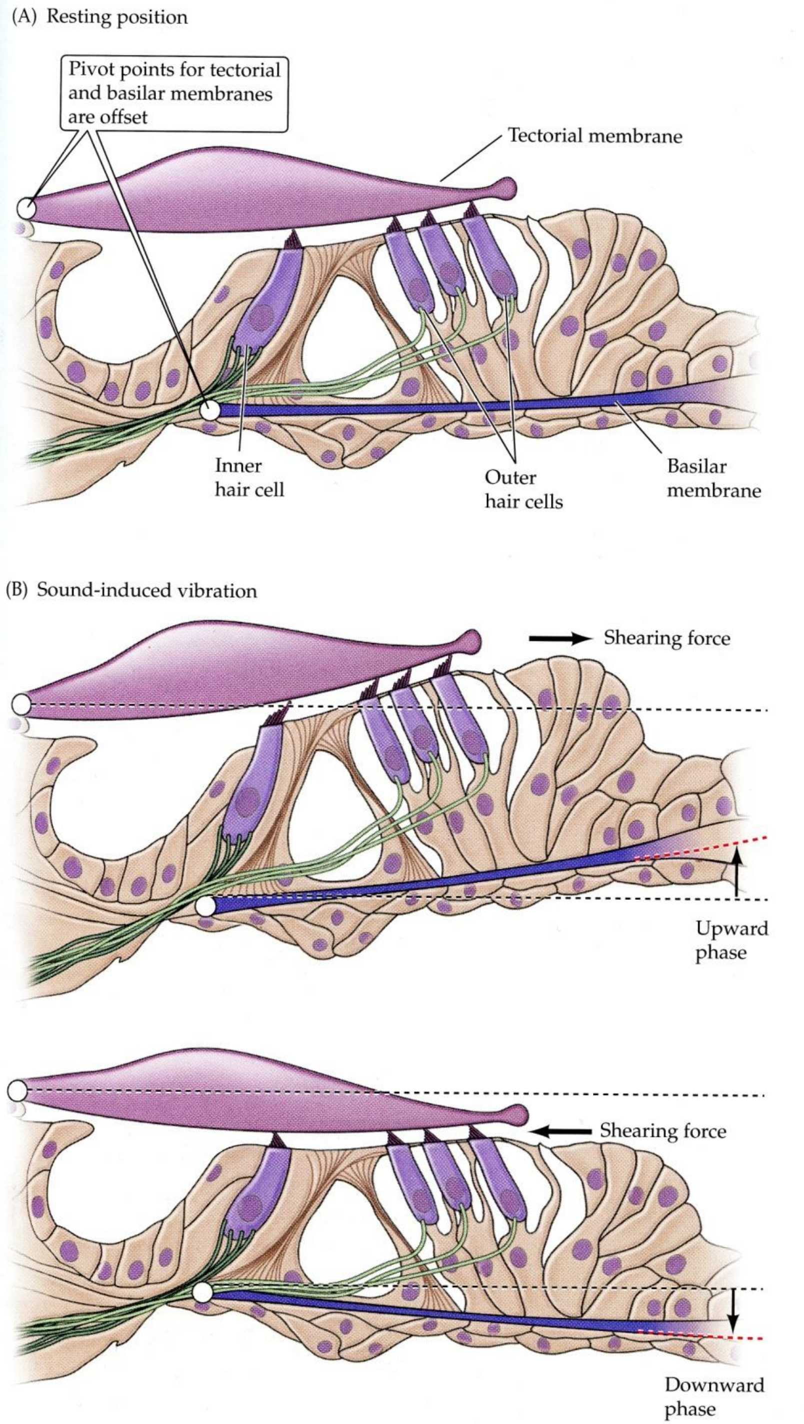


- Suspended within the bony tube is a membranous tube, which contains the organ of corti.

- The hair cells, the auditory receptor neurons, are in the basilar membrane of the organ of corti.

Auditory System

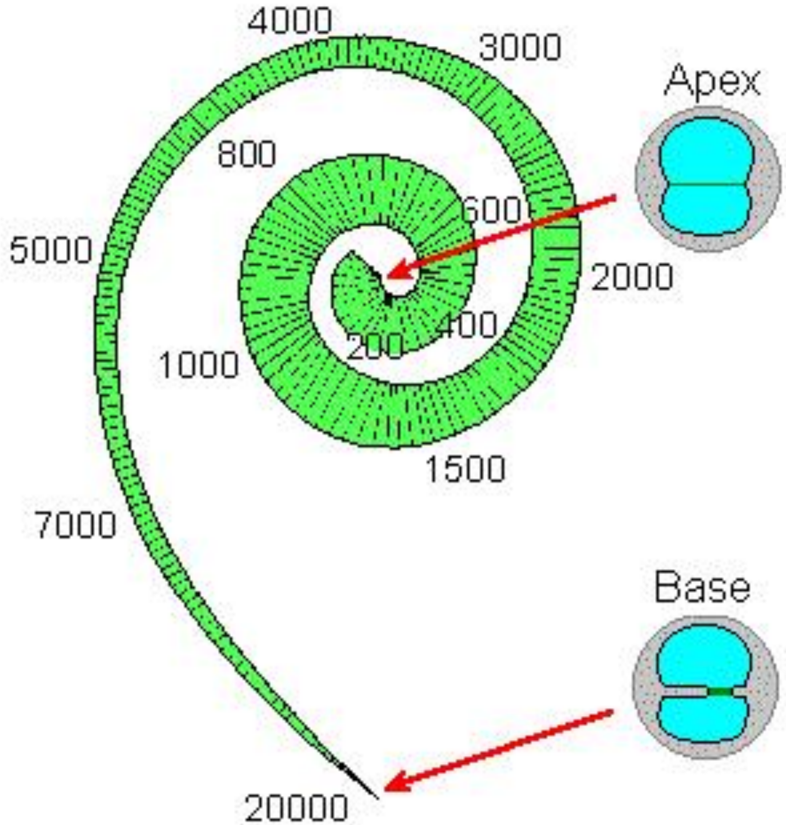
- A sound vibration entering via the oval window travels up the cochlea.
- This causes vibration of the basilar membrane, which distorts the stereocilia bundles of the hair cells that is in contact with an overlying membrane.
- The mechanosensory hair cells are depolarized by movement of their stereocilia.
- The depolarized hair cells release neurotransmitter that activates the auditory nerve axons.

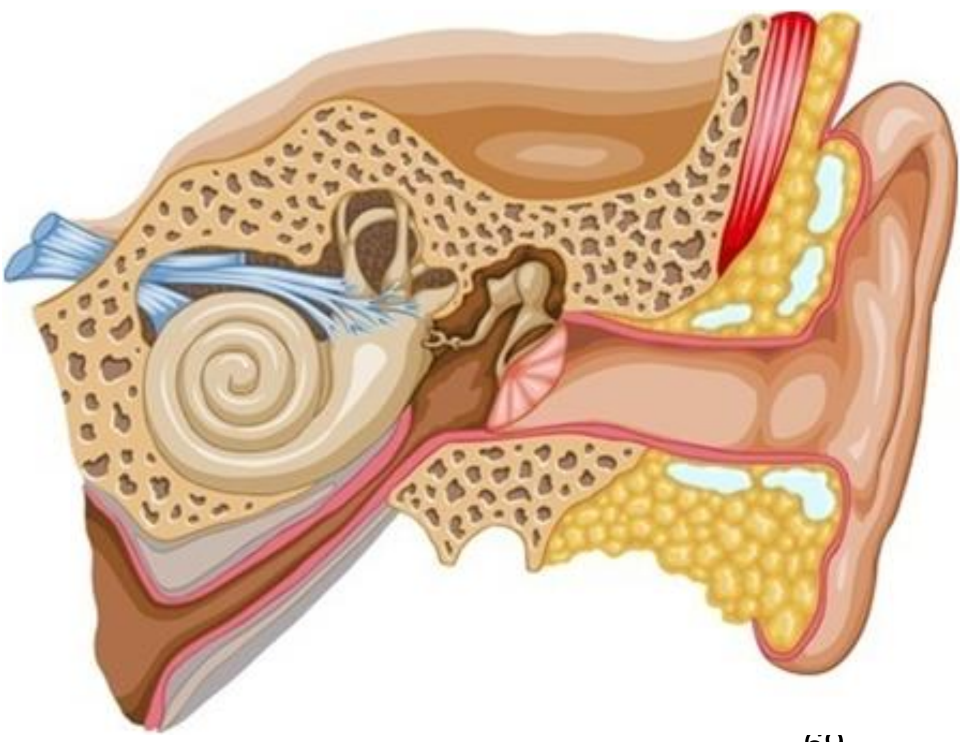


Auditory System

- Hair cells in different parts of the cochlea are sensitive to different frequencies.

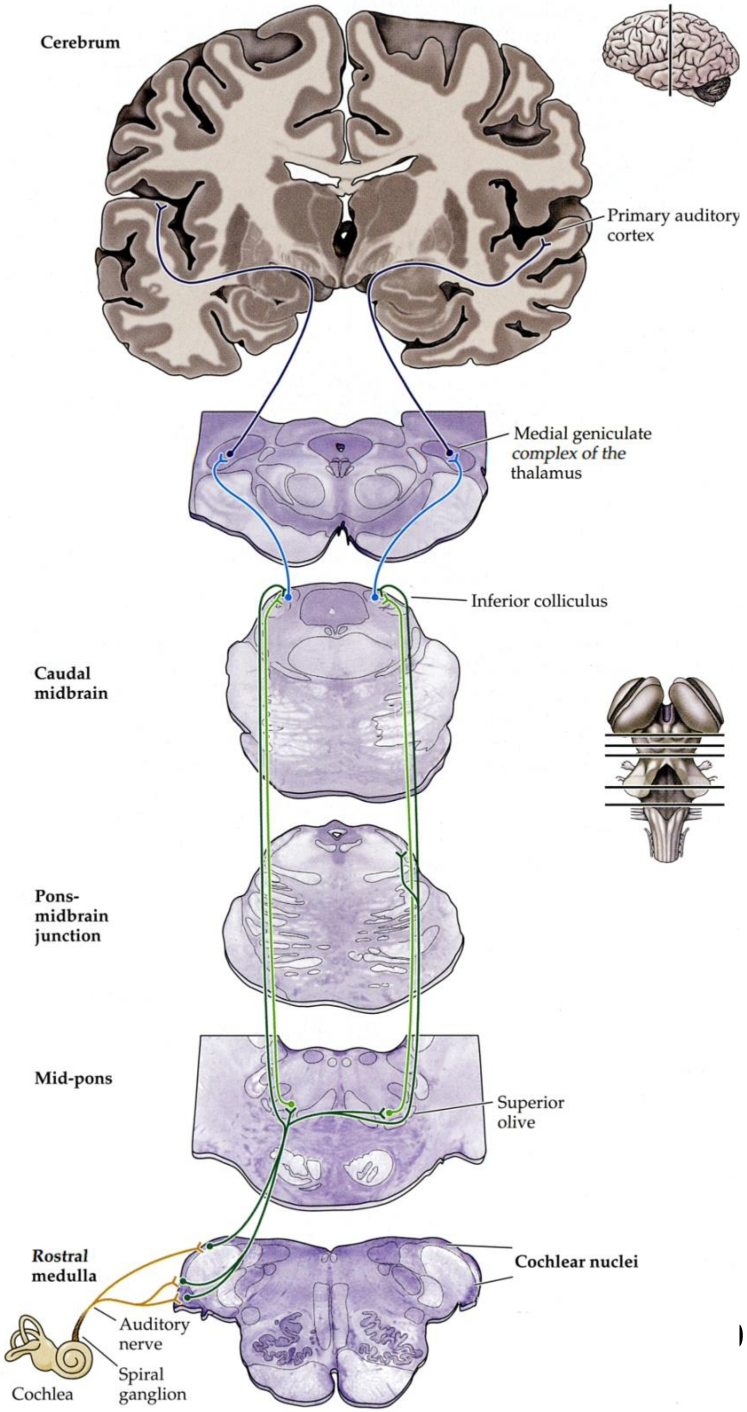
  Hair cells at the base of the cochlea are sensitive to high frequency sound; hair cells at the apex are sensitive to low frequency sound.





Auditory System

- Auditory nerve axons synapse in the cochlear nuclei in the upper medulla.
- Neurons in the cochlear nuclei project bilaterally to the inferior colliculus (and other places).
- Neurons in the inferior colliculus project to the medial geniculate nucleus in the thalamus.
- Neurons in the medial geniculate project to the auditory cortex in the temporal lobe.

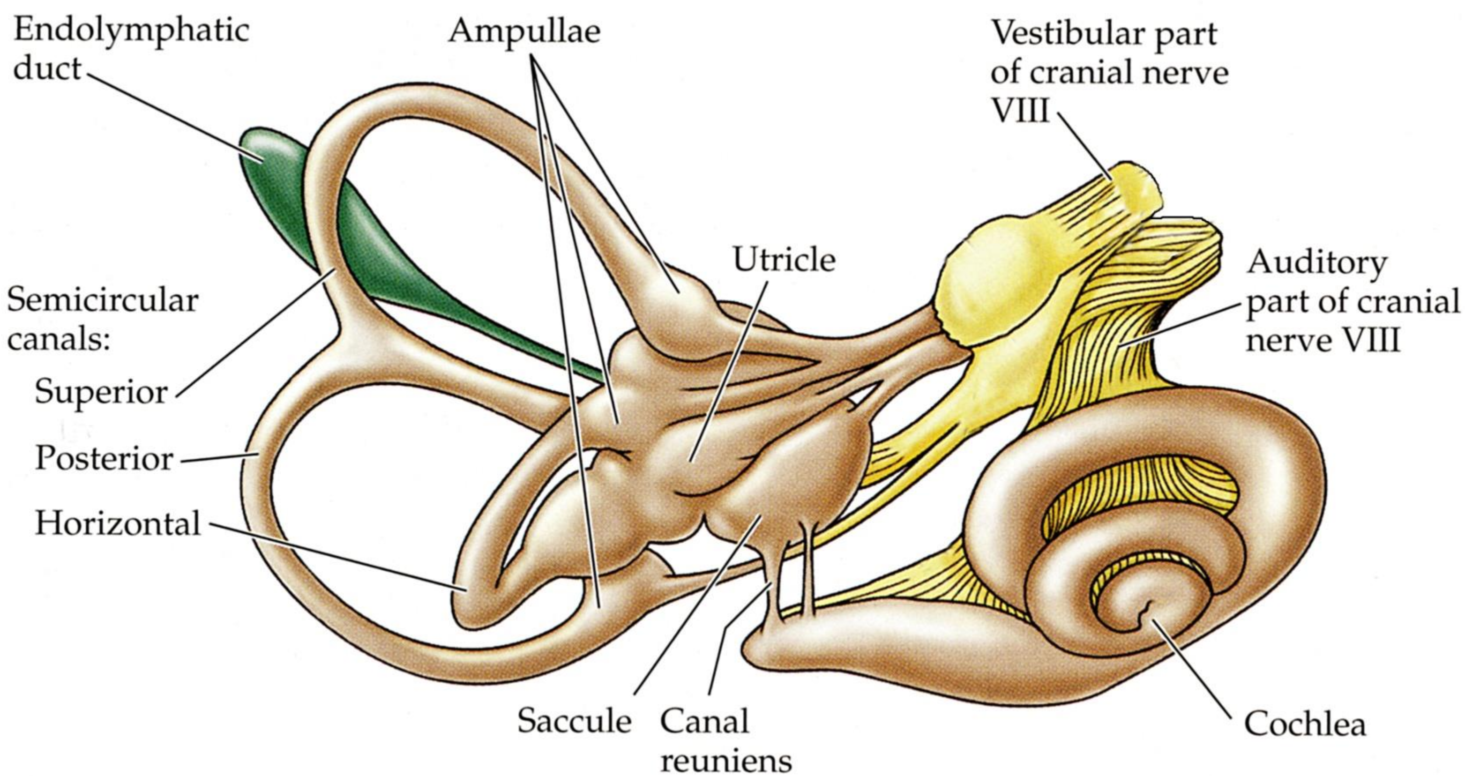


Vestibular System

- The vestibular sensory apparatus in each inner ear includes:

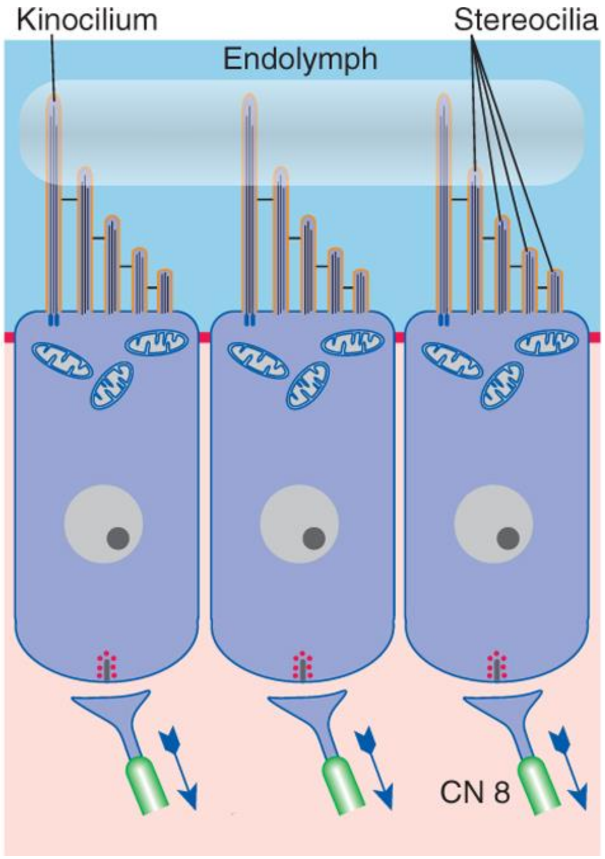
  3 semicircular canals

  2 otoliths (utricle and saccule)



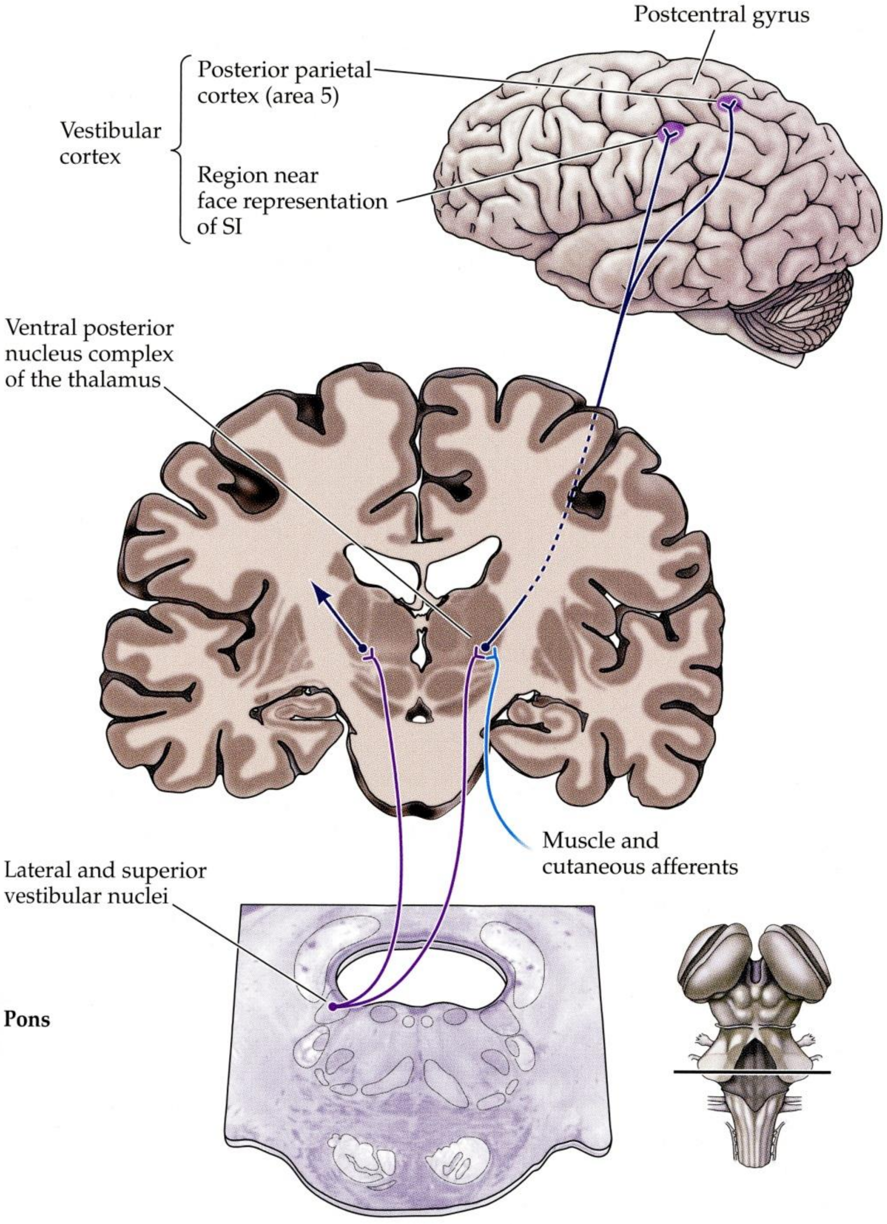
Vestibular System

- Each semicircular canal and otolith has a sensory apparatus with hair cells that have stereocilia extending into a gelatinous weight.
- When the head moves in the optimal orientation for the particular sensor, the fluid in the chamber, the endolymph, moves, thus moving the weight.
- Movement of the weight depolarizes the hair cells.
- Hair cells synapse with the neurons of the vestibular nerve, a component of the vestibulocochlear nerve (CN VIII).



Vestibular System

- Vestibular sense is conveyed to the ventral posterior thalamus and then relayed to regions of parietal cortex.

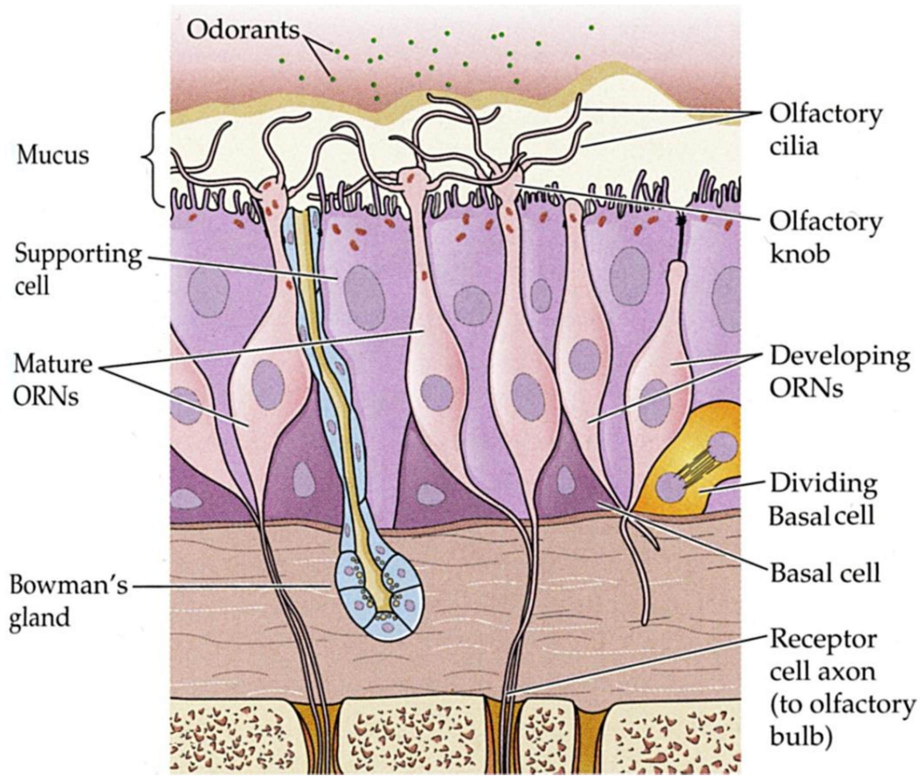


Chemical Senses:
Taste and Smell

Steven McLoon
Department of Neuroscience
University of Minnesota

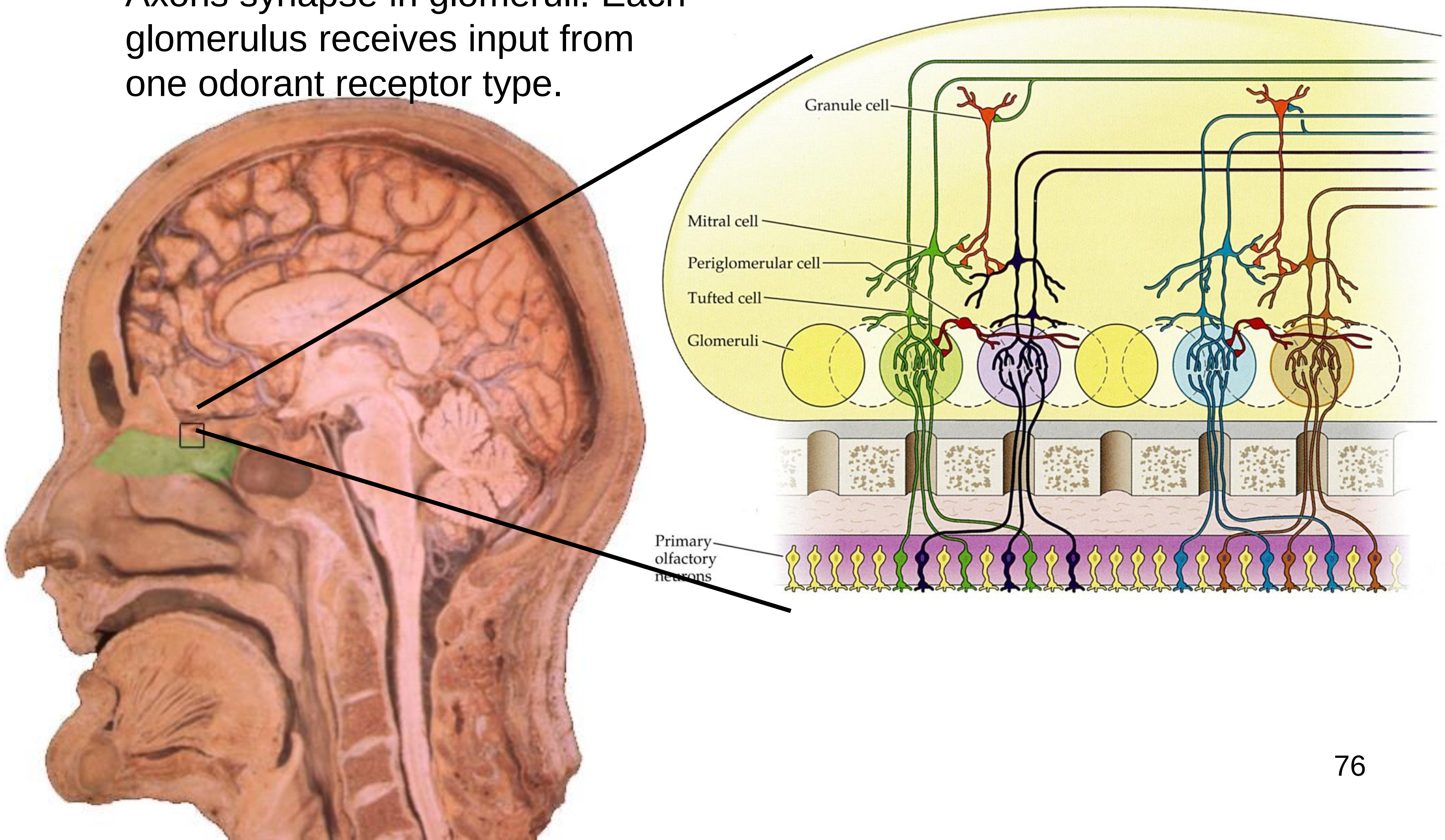
Olfaction

- The receptor neurons have cilia in the mucus.
- The odorant receptor proteins are in the membrane of the cilia.
- Each receptor neuron has only one type of odorant receptor.
- Humans have 339 different odorant receptor types.
- The receptor neurons continually die and are replaced by division of basal cells.



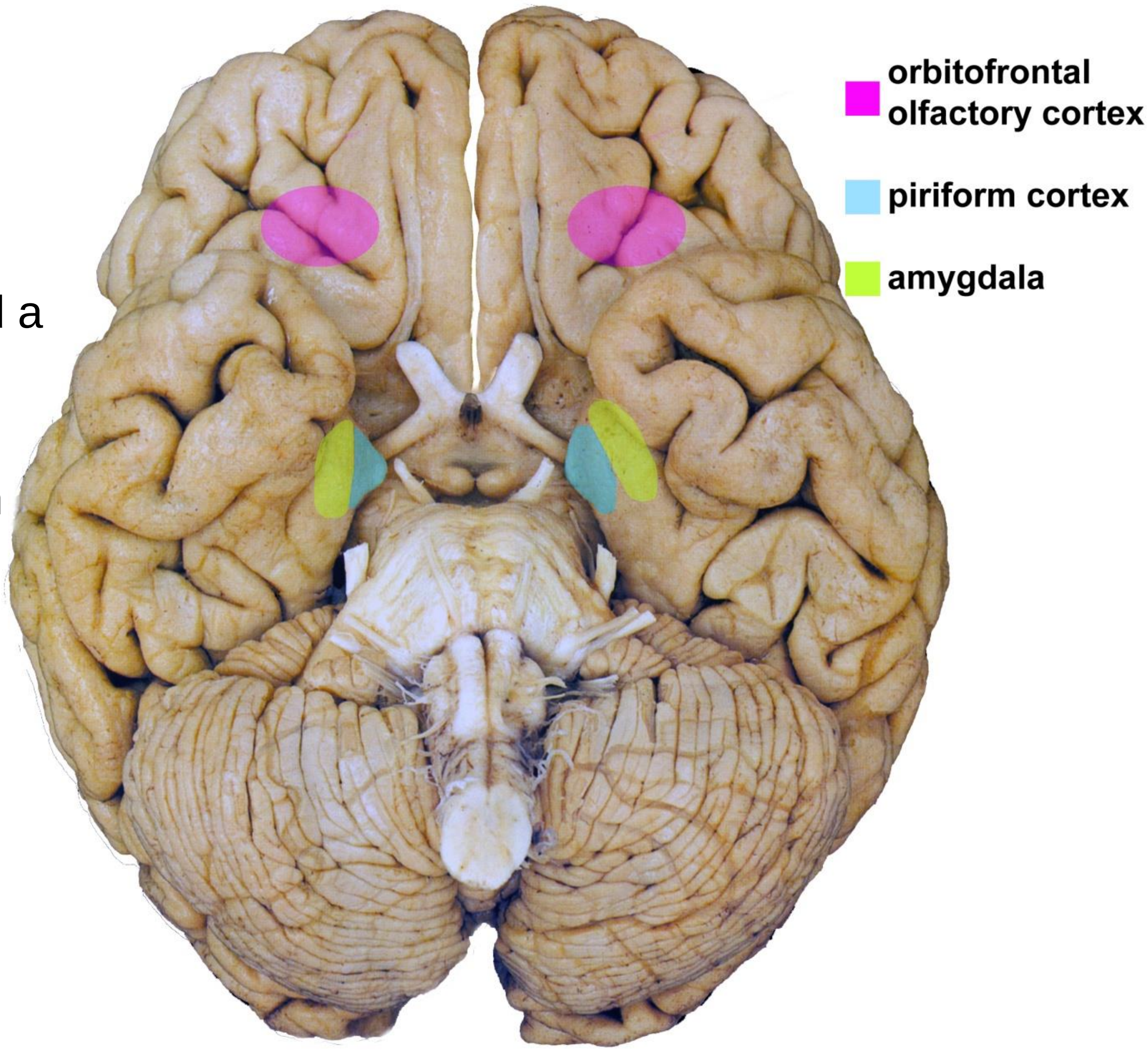
Olfaction

- Olfactory receptor neuron axons synapse in the olfactory bulb. Axons synapse in glomeruli. Each glomerulus receives input from one odorant receptor type.



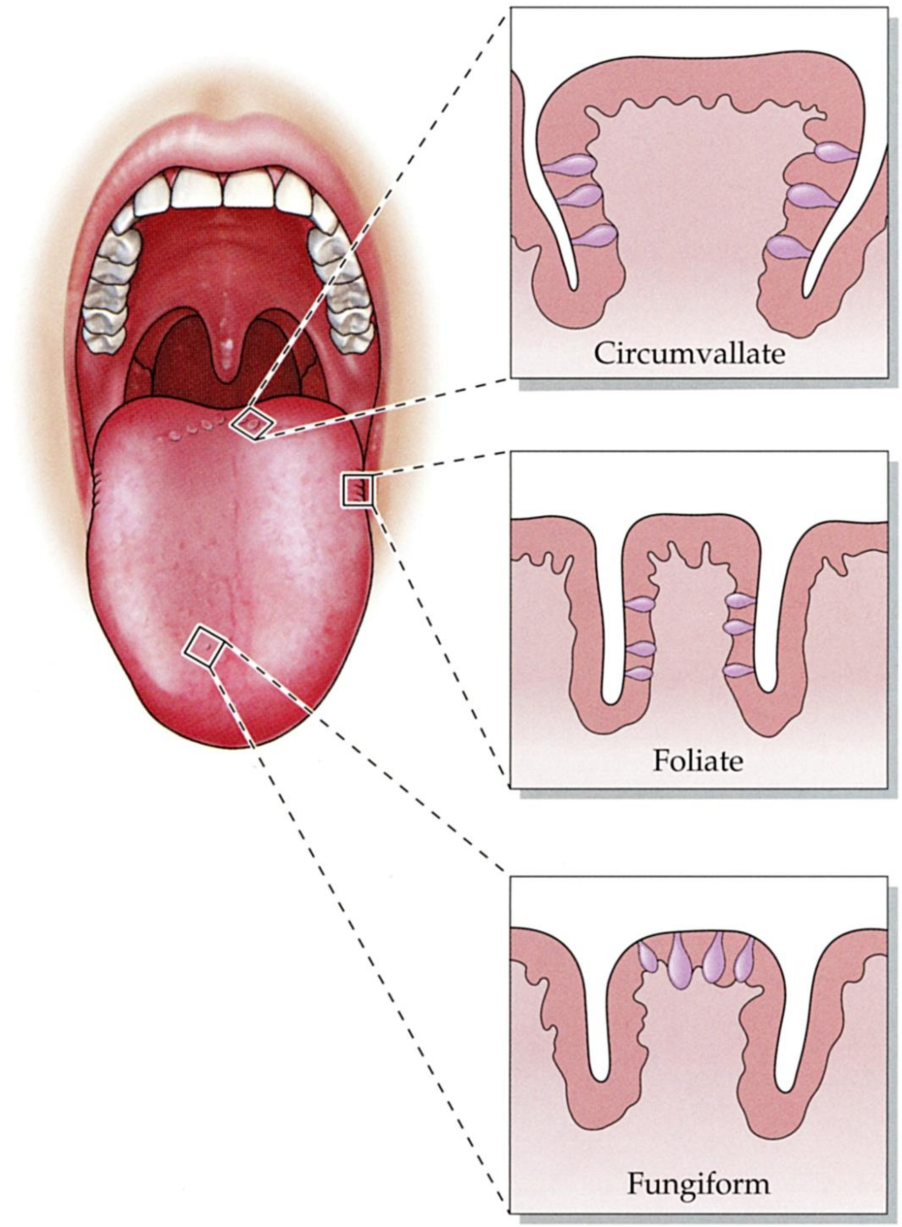
Olfaction

- Several forebrain areas receive axons from olfactory bulb including piriform cortex and amygdala.
- Amygdala connects with hypothalamus, thalamus and a number of limbic areas.
- Piriform cortex connects with orbitofrontal cortex.



Taste

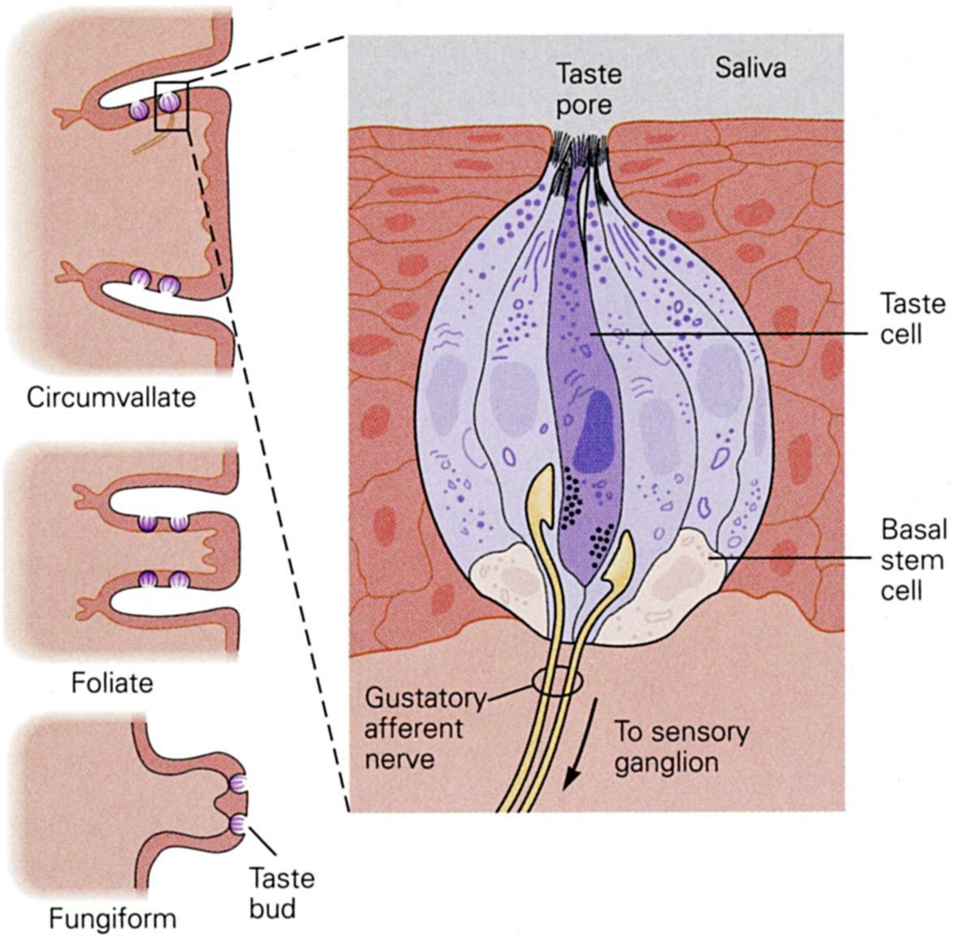
Taste buds are on papillae of the tongue and pharynx.



Taste

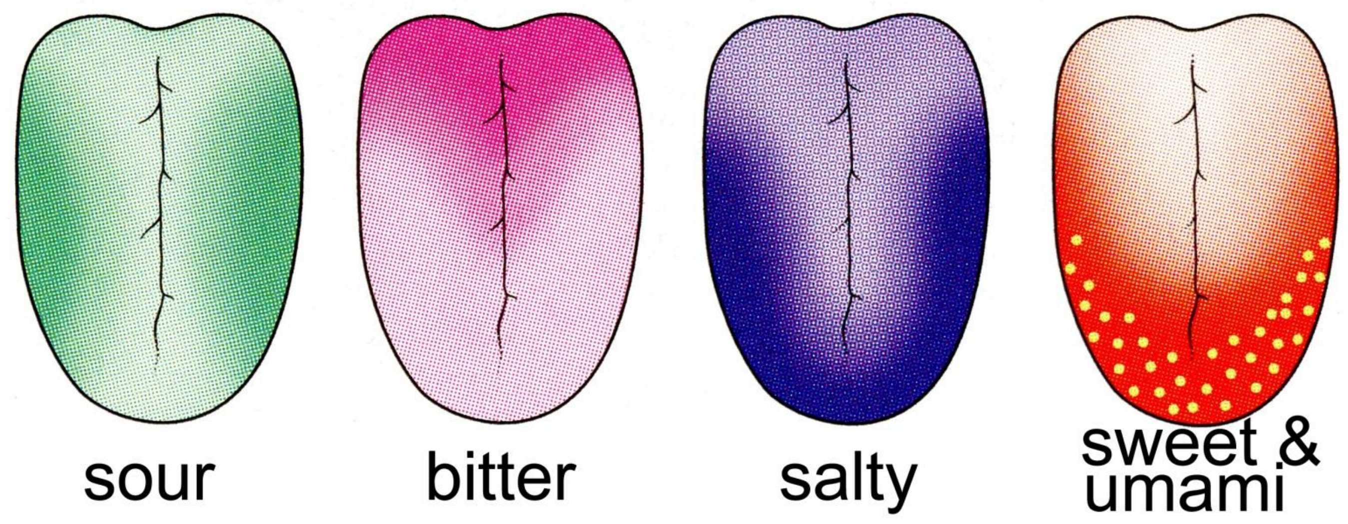
Taste receptor cells in tastebuds:

- non-neuronal cells
- exposed to chemicals on tongue via a taste pore
- communicate with sensory neuron via a chemical synapse; uses ATP as the transmitter



Taste

- Taste receptors are sensitive to one of five tastes.
  - Sour (rotting food)
  - Bitter (poisonous plants)
  - Salt (electrolytes)
  - Sweet (high calories)
  - Umami (amino acids or protein)

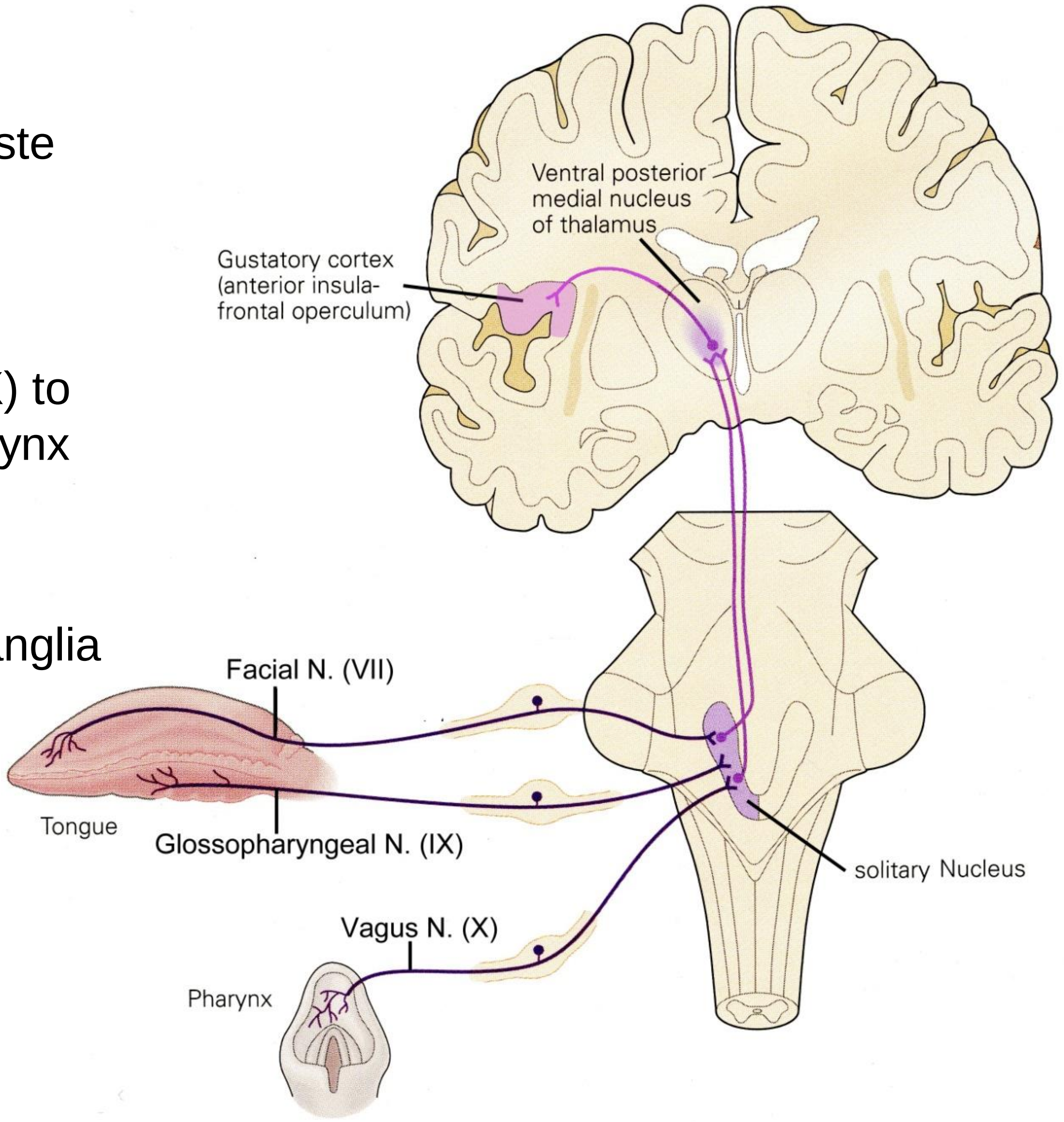


Taste

Sensory neurons for taste:

- Three cranial nerves have taste neurons.
    - Facial N. (VII) to front of tongue
    - Glossopharyngeal N. (IX) to back of tongue and pharynx
    - Vagus N. (X) to pharynx

- Cell bodies are in sensory ganglia for each nerve.

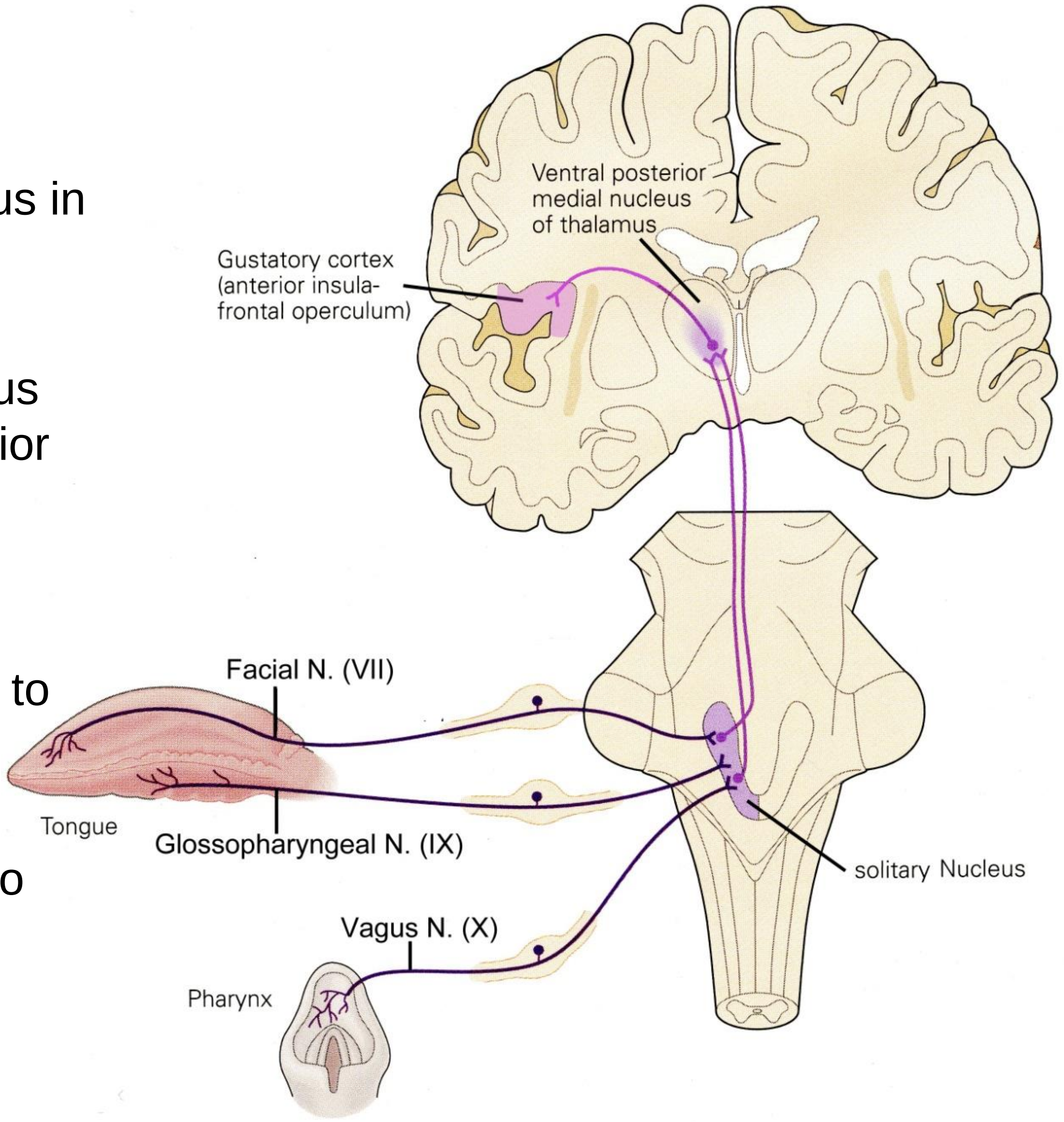


Taste

Taste pathway:

- All sensory neurons for taste synapse in the solitary nucleus in the brainstem.
- Neurons in the solitary nucleus synapse in the ventral posterior medial nucleus (VPM) in the thalamus.
- VPM sends taste information to the insular cortex.

(Taste is an ipsilateral pathway to cortex.)

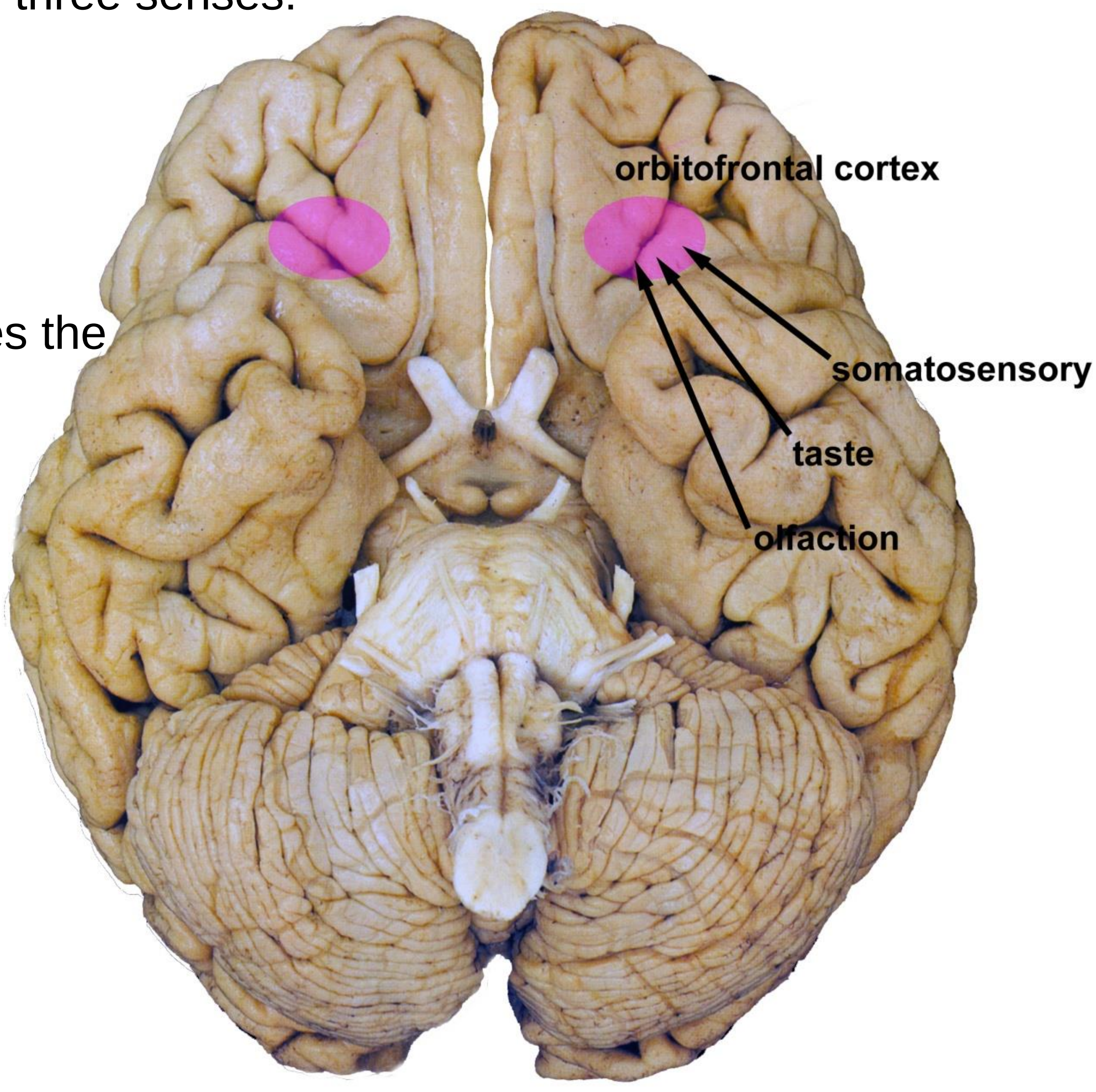


Taste

The perception of taste involves three senses:

- taste
- olfaction
- somatosensory

- Orbitofrontal cortex integrates the three senses.



Course News

Midterm Exam Wednesday (Oct 24)

The exam will cover lectures 12-20 and labs 3-5.

A –L last names in MoosT 2-650
M – Z in MoosT 2-620

An extra hour will be available for those who need it.

PLEASE BRING #2 PENCILS!!!

Be sure to check out last year’s exam on the course website!!!