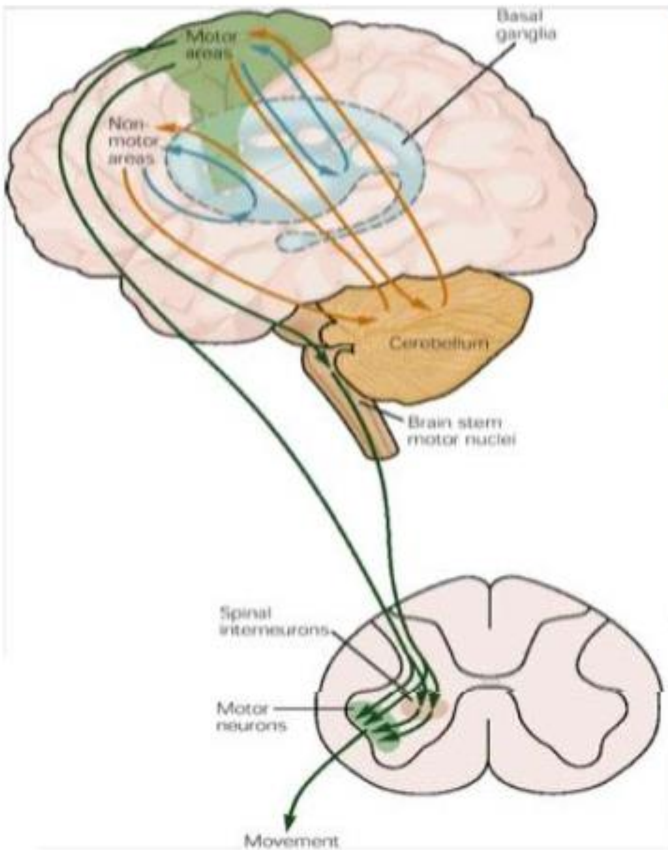
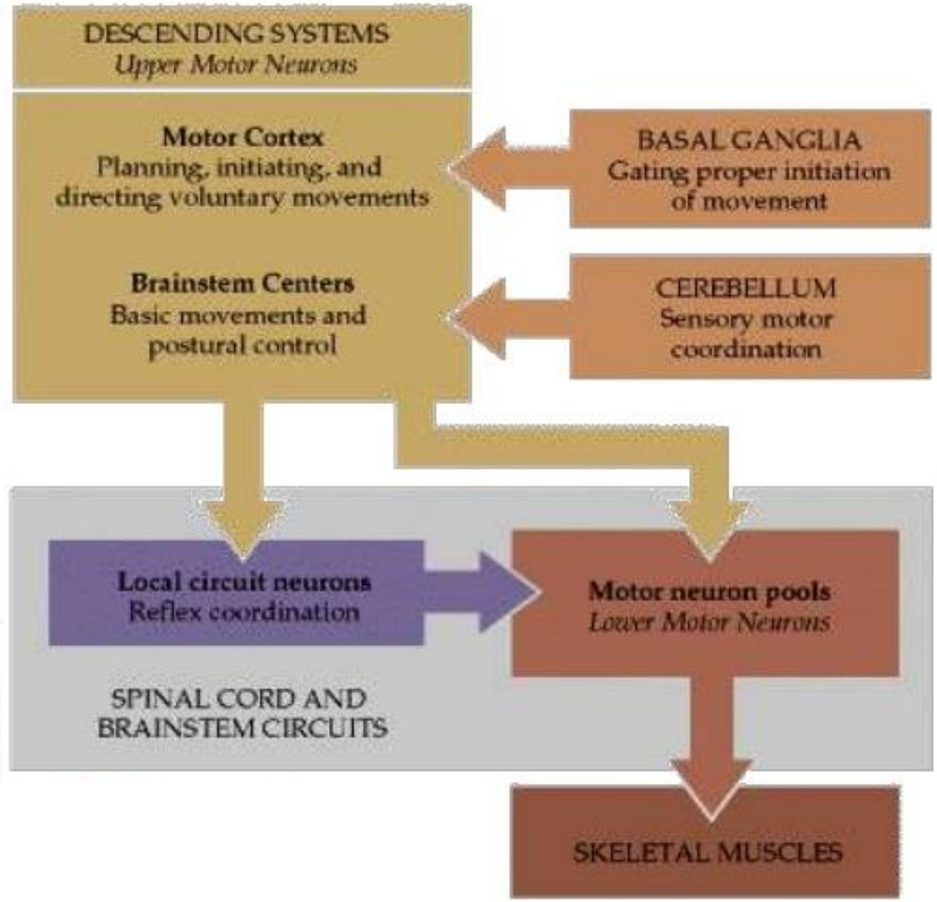
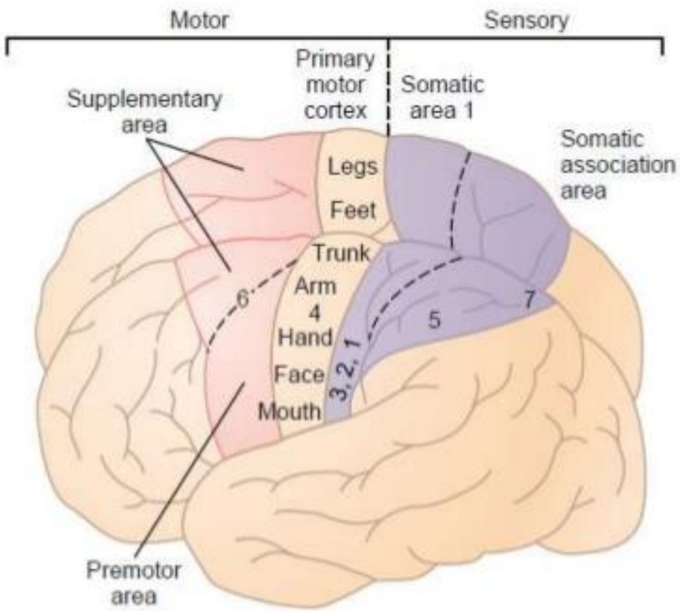
Motor Systems Review

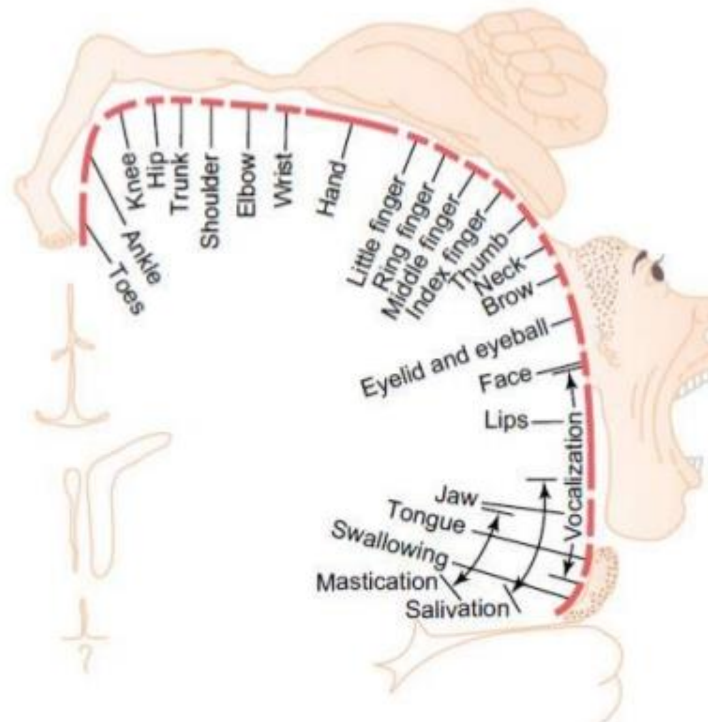
Angie Nietz


Motor areas
Basal ganglia
Non-motor areas
Cerebellum
Brain stem motor nuclei
Spinal interneurons
Motor neurons
Movement

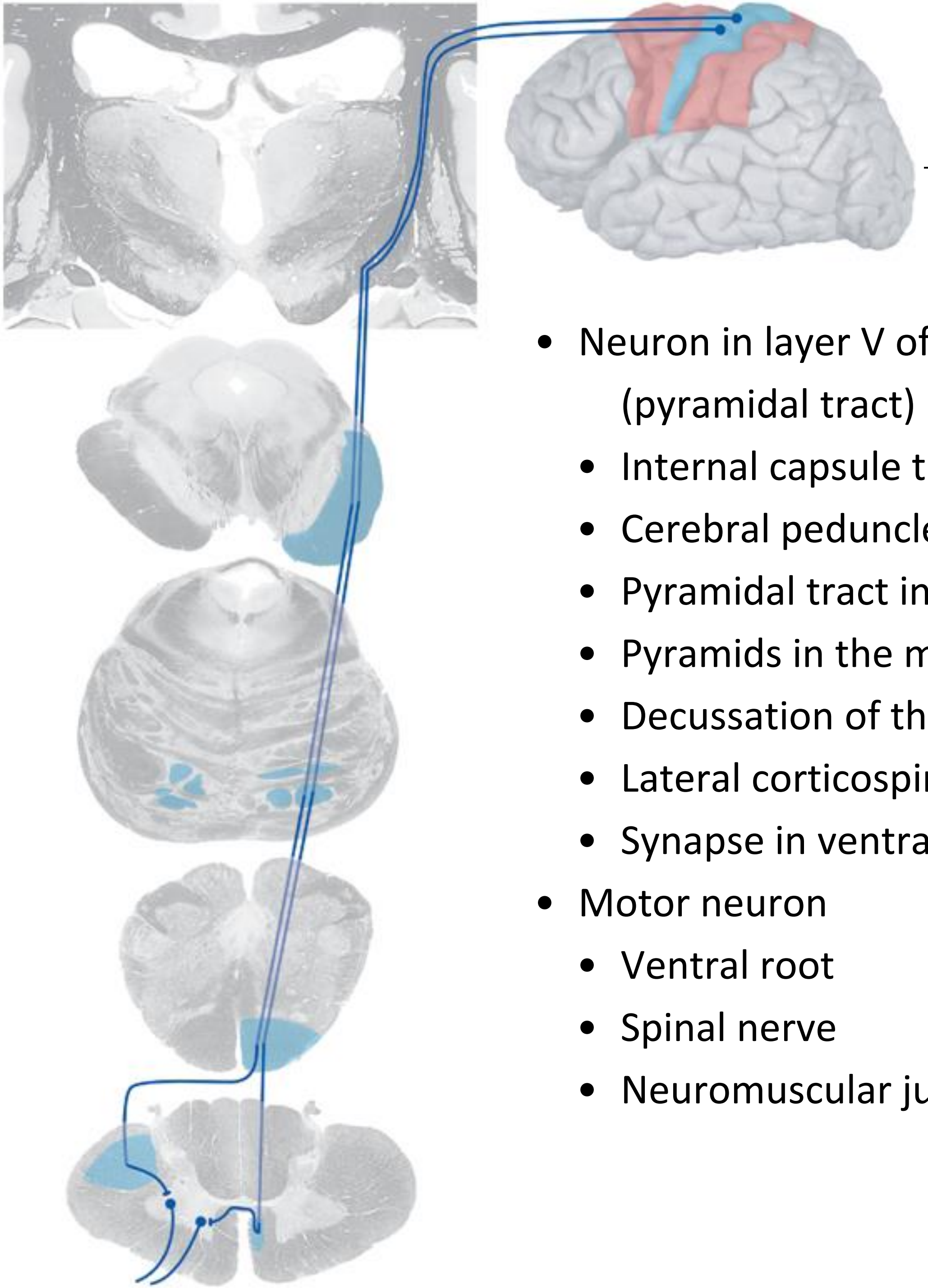

DESCENDING SYSTEMS
Upper Motor Neurons
Motor Cortex
Planning, initiating, and directing voluntary movements
Brainstem Centers
Basic movements and postural control
BASAL GANGLIA
Gating proper initiation of movement
CEREBELLUM
Sensory motor coordination
Local circuit neurons
Reflex coordination
Motor neuron pools
Lower Motor Neurons
SPINAL CORD AND BRAINSTEM CIRCUITS
SKELETAL MUSCLES

Organization of the motor cortex





- Go to the white board. Draw the circuitry from primary motor cortex to the right biceps muscle in the arm. Your drawing should include a simple cross-section of each level of the brainstem and spinal cord with the relevant axons labeled.

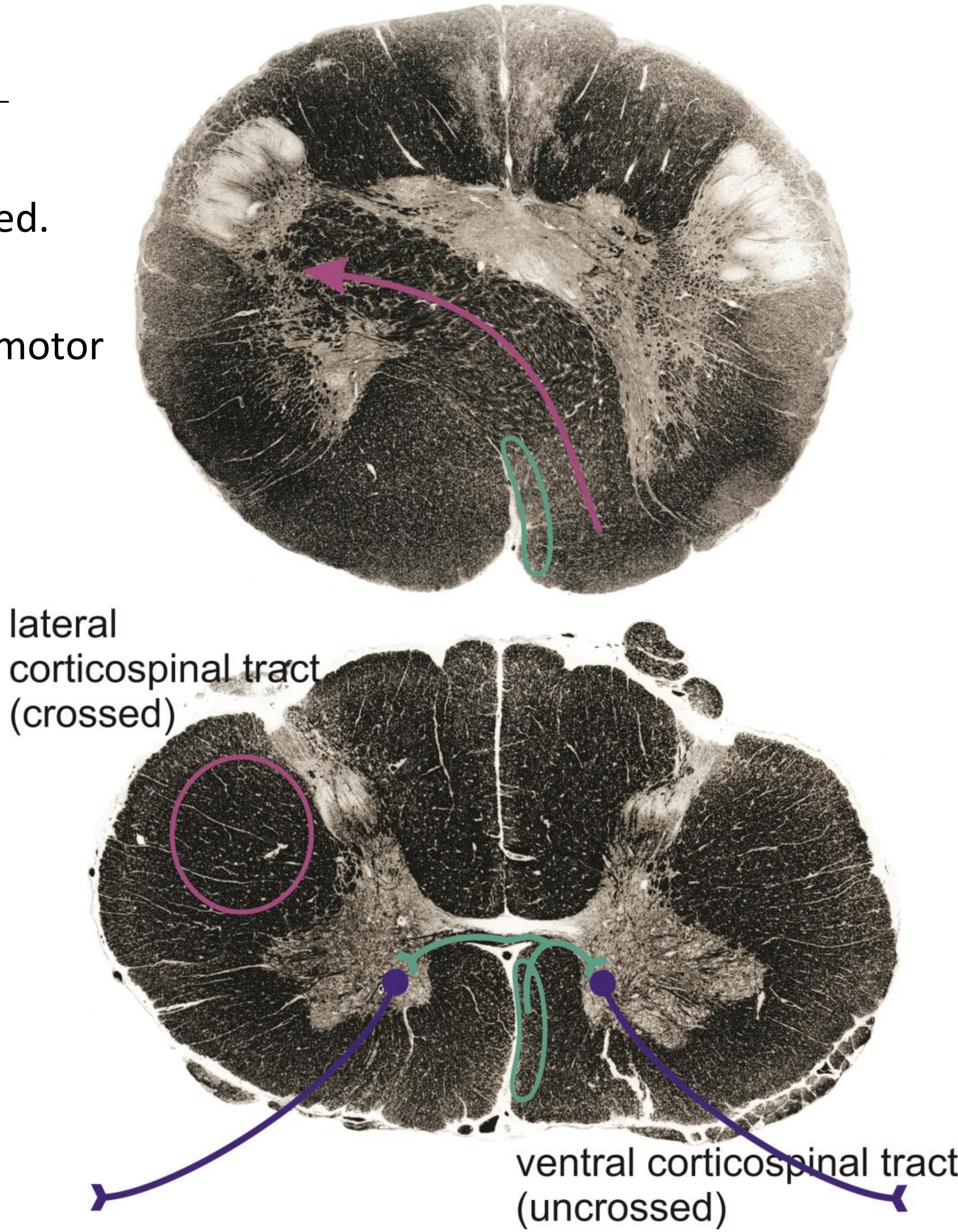


Corticospinal Tracts

- Neuron in layer V of motor cortex (precentral gyrus) (pyramidal tract)
  - Internal capsule through the forebrain
  - Cerebral peduncle in the midbrain
  - Pyramidal tract in the pons
  - Pyramids in the medulla
  - Decussation of the pyramids in the lower medulla
  - Lateral corticospinal tract in the spinal cord
  - Synapse in ventral horn in the cervical spinal cord
- Motor neuron
  - Ventral root
  - Spinal nerve
  - Neuromuscular junction

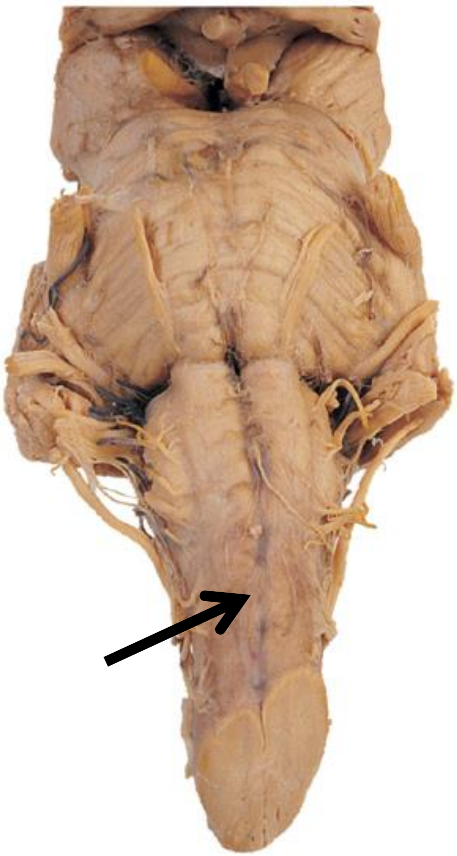
Ventral Corticospinal Tract

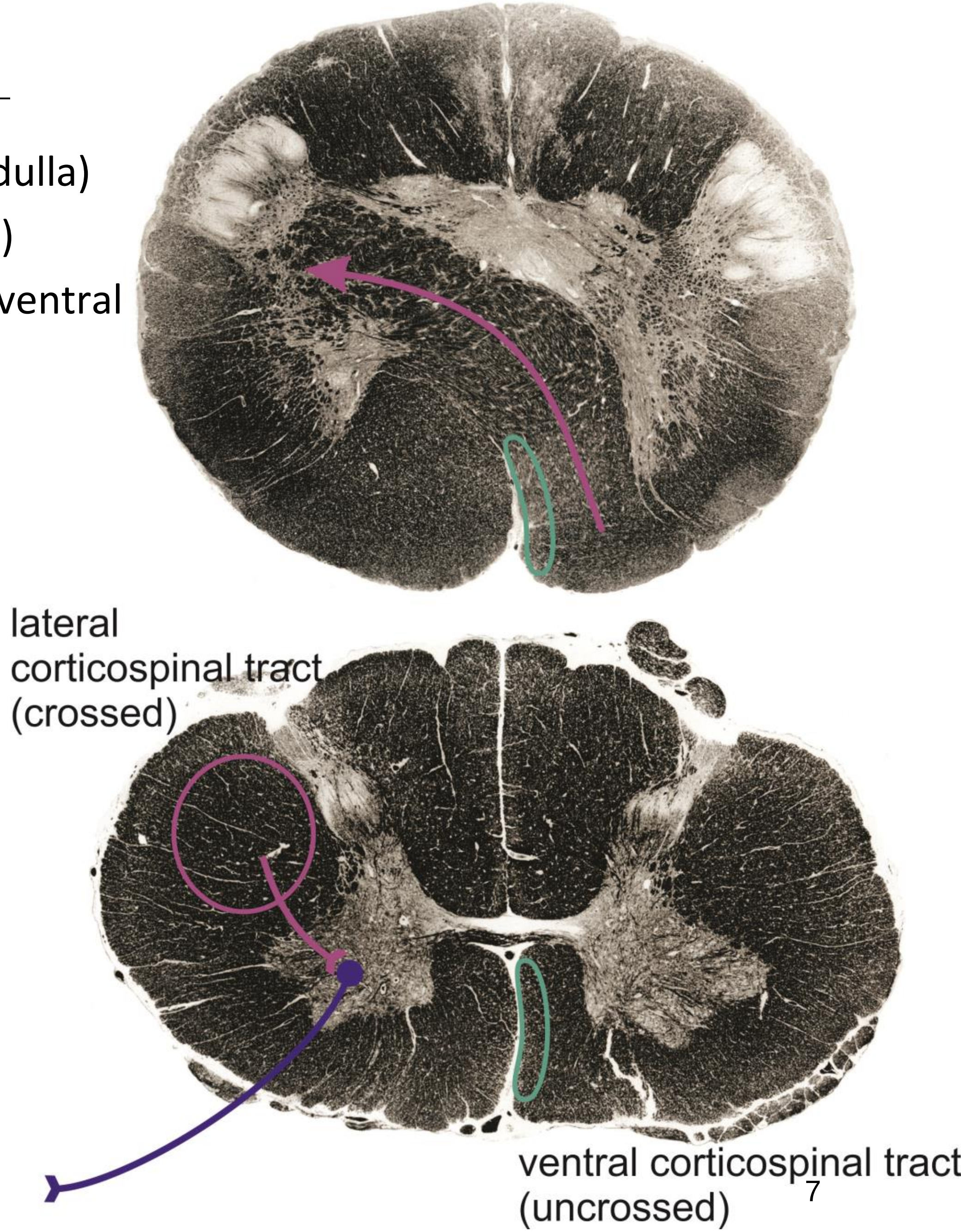
- descends in the spinal cord uncrossed.
- projects bilaterally mainly to lower motor neurons for trunk musculature.



Lateral Corticospinal Tract

- Decussation of the pyramids (lower medulla)
- to lateral corticospinal tract (spinal cord)
- to synapse with lower motor neuron in ventral horn of spinal cord





Muscle Unit

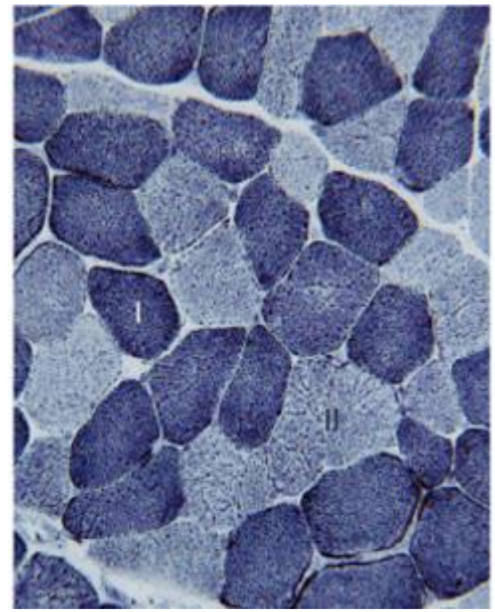
- A motor neuron can synapse with one or more muscle fibers.

- One motor neuron and all the fibers with which it synapses is a motor unit.
  - Muscles with fine control have small motor units (e.g. finger muscles).
  - Muscles with only course control have large motor units (e.g. gluteus maximus muscle in your butt).

Types of muscle fibers

- Muscle fibers are of three types:

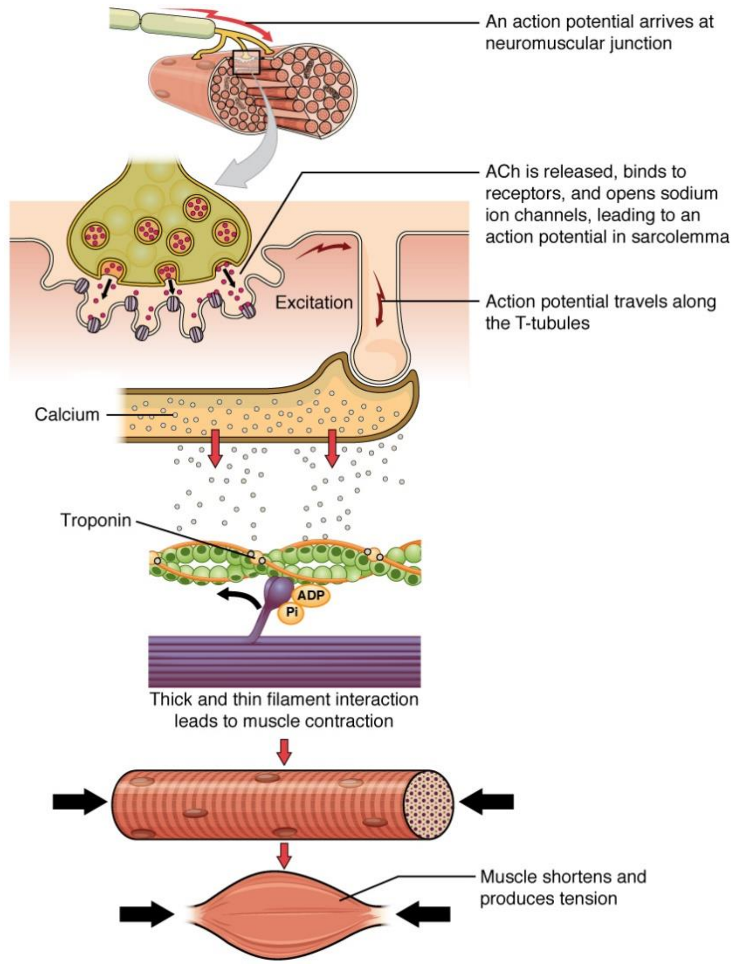
type	*size*	*speed*	*force*	*fatigability*
I	thin	slow, long	low	slowly
IIa	thick	intermediate	intermediate	intermediate
IIb	thick	fast, short	high	rapidly



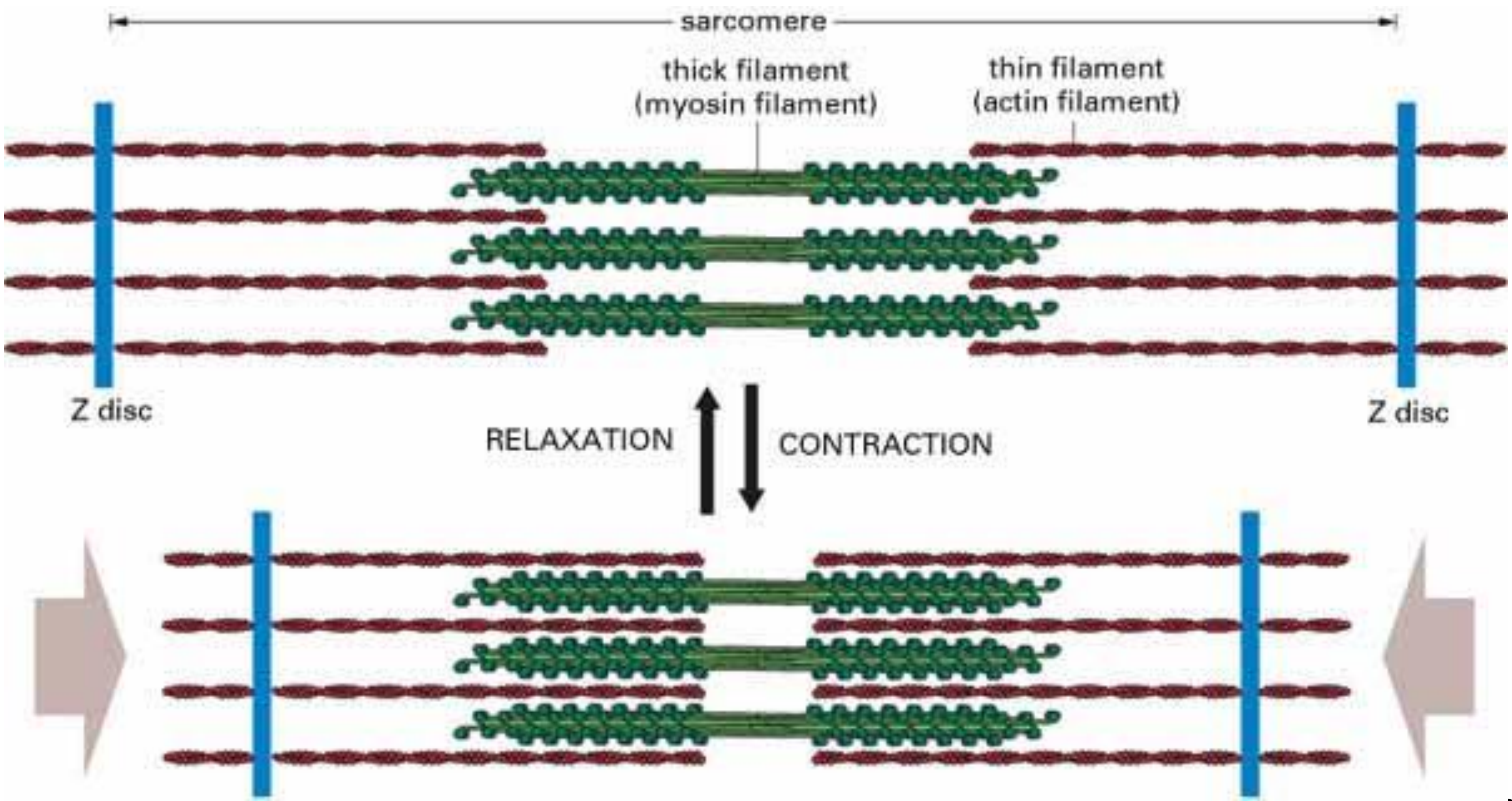
Muscle Physiology

- Acetylcholine activates acetylcholine receptors on the myofiber.
- The receptors are ligand-gated ion channels; activation results in an influx of sodium (Na^+) into the muscle fiber and an outflow of potassium (K^+).
- Depolarization spreads along the muscle fiber like an action potential.
- Depolarization causes release of calcium (Ca^{++}) inside the muscle fiber.
- Calcium initiates sliding of myosin filaments on the actin filaments, i.e. a shortening of the muscle fiber.

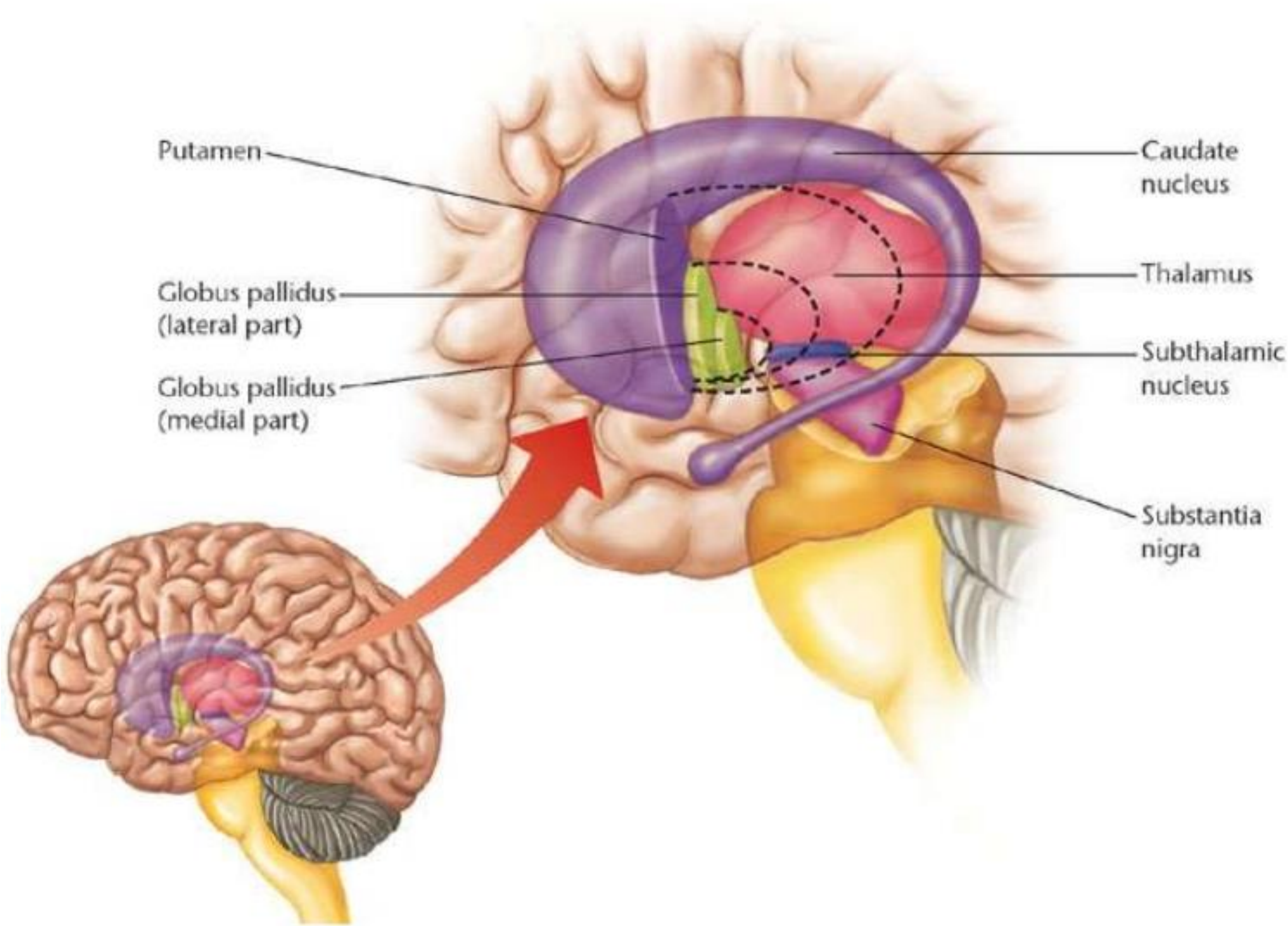
Muscle Physiology

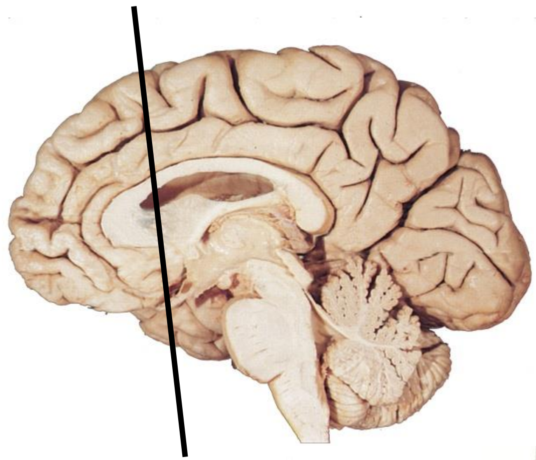


- During muscle contraction, the myosin filaments ‘slide’ on the actin filaments along the length of the muscle fiber so that the fiber shortens.



Basal Ganglia

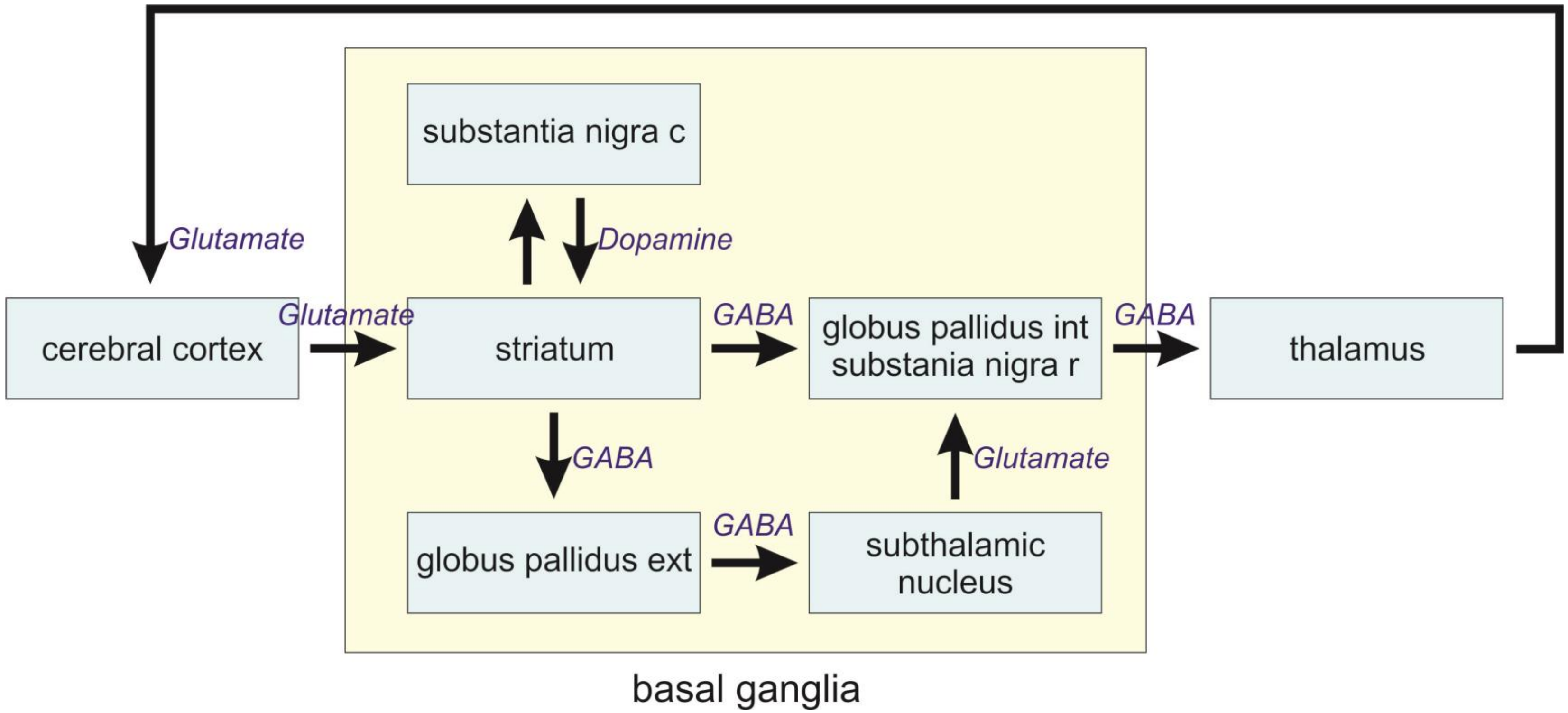




Striatum:

- caudate nucleus
- putamen
- nucleus accumbens

Basal Ganglia Circuitry



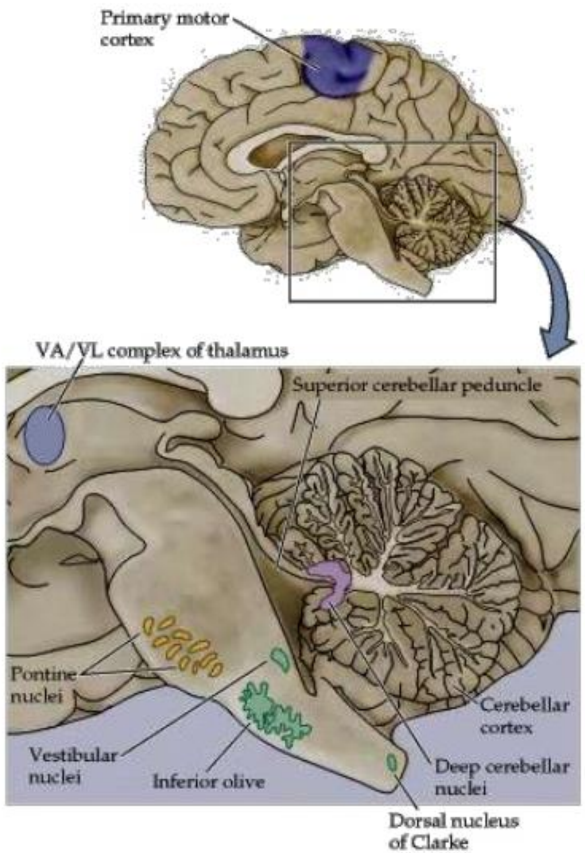
Parkinson's Disease

- Symptoms (hypokinesia):
  - resting tremor, pronounced in the hands
  - all muscles resist being moved by another person (rigidity)
  - difficulty initiating movements (akinesia) and slower movements (bradykinesia)

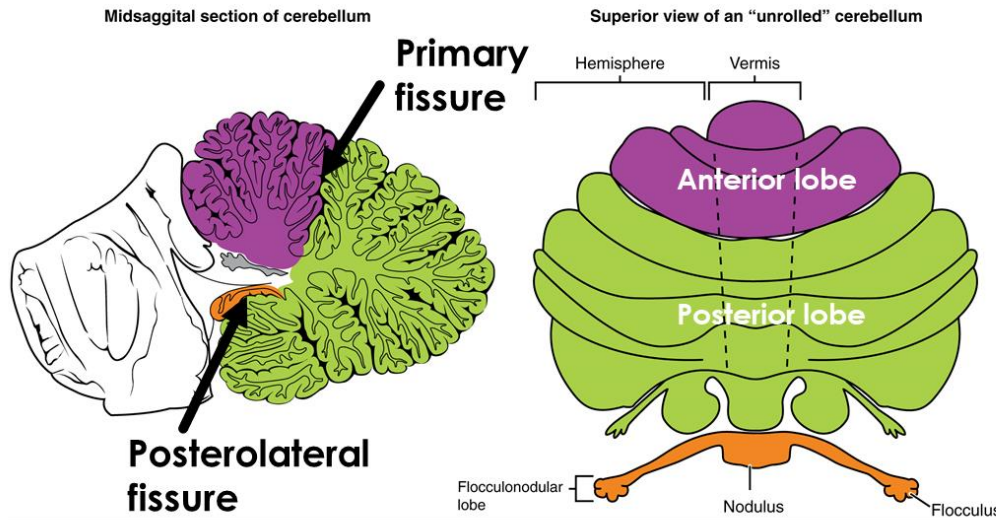
Huntington’s Disease

- Degeneration of medium spiny neurons in the striatum causes Huntington’s disease or Huntington’s chorea.
- The main symptom is hyperkinesia: involuntary rapid, random movements of the trunk and limbs; writhing of the hands is common.
- Symptoms typically appear midlife, 35-45 years of age.
- Huntington’s disease is due to an inherited, dominant mutation.

Cerebellum



Primary motor cortex
VA/VL complex of thalamus
Superior cerebellar peduncle
Pontine nuclei
Cerebellar cortex
Vestibular nuclei
Inferior olive
Deep cerebellar nuclei
Dorsal nucleus of Clarke



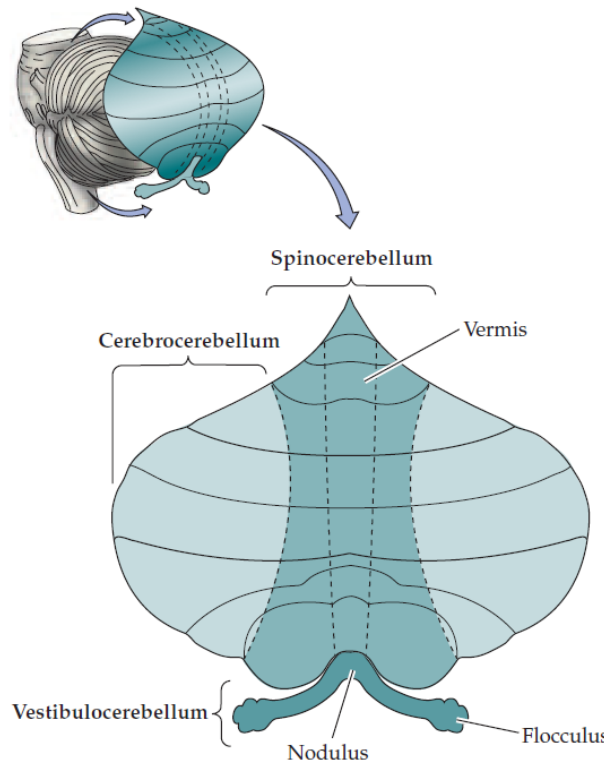
Midsaggital section of cerebellum
Primary fissure
Posterolateral fissure
Superior view of an “unrolled” cerebellum
Hemisphere
Vermis
Anterior lobe
Posterior lobe
Flocculonodular lobe
Nodulus
Flocculus

Functional regions of the cerebellum

Cerebrocerebellum (lateral hemispheres) - coordination and planning of voluntary skilled movements

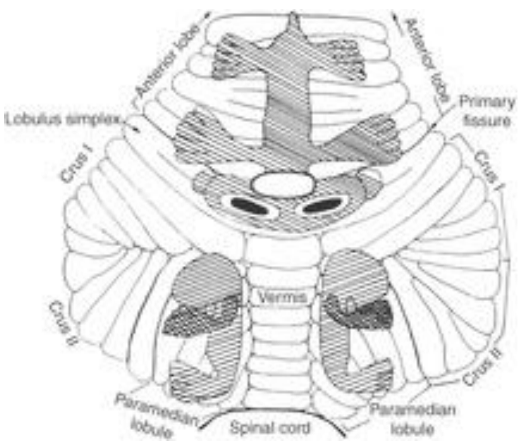
Spinocerebellum (vermis and intermediate parts of the hemispheres) – participates in motor control (walking), coordination and correction, posture

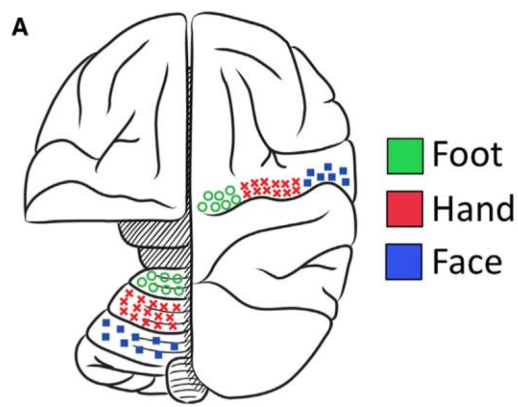
Vestibulocerebellum (flocculonodular lobe) – posture and balance maintenance and eye movements

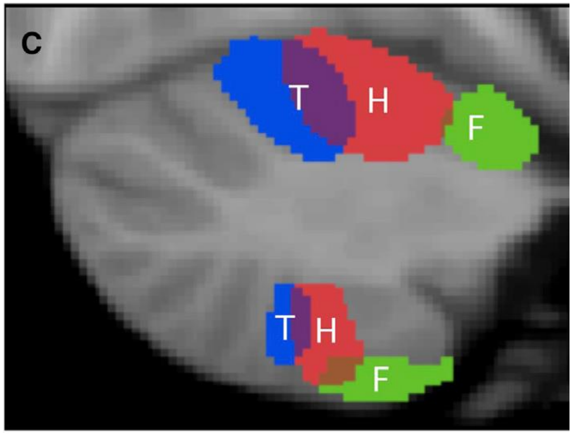


Purves 2004

Somatotopic maps







Schmahmann 2012; Buckner 2013

Cerebellar inputs

Inferior cerebellar peduncle

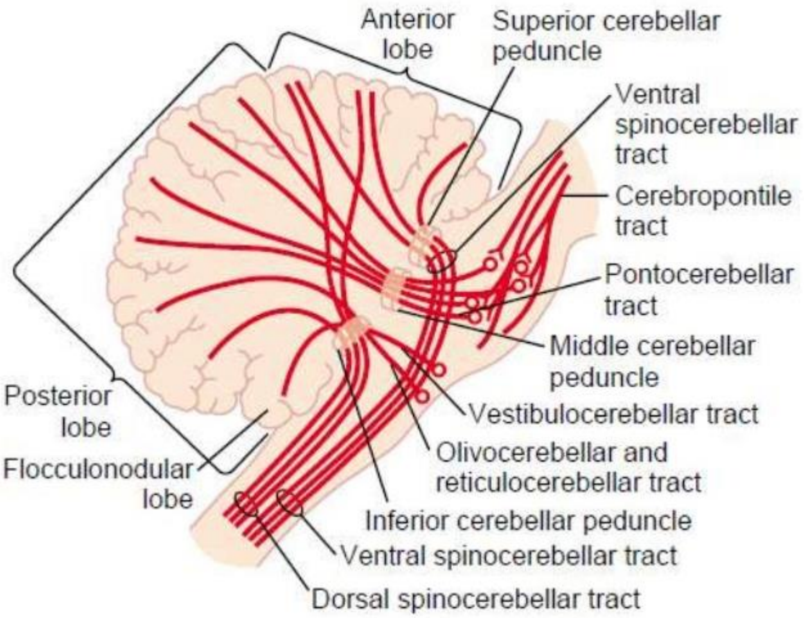
- Brings input from body via spinal cord, reticular formation, vestibular nuclei, and inferior olive

- Tells the cerebellum where the body is

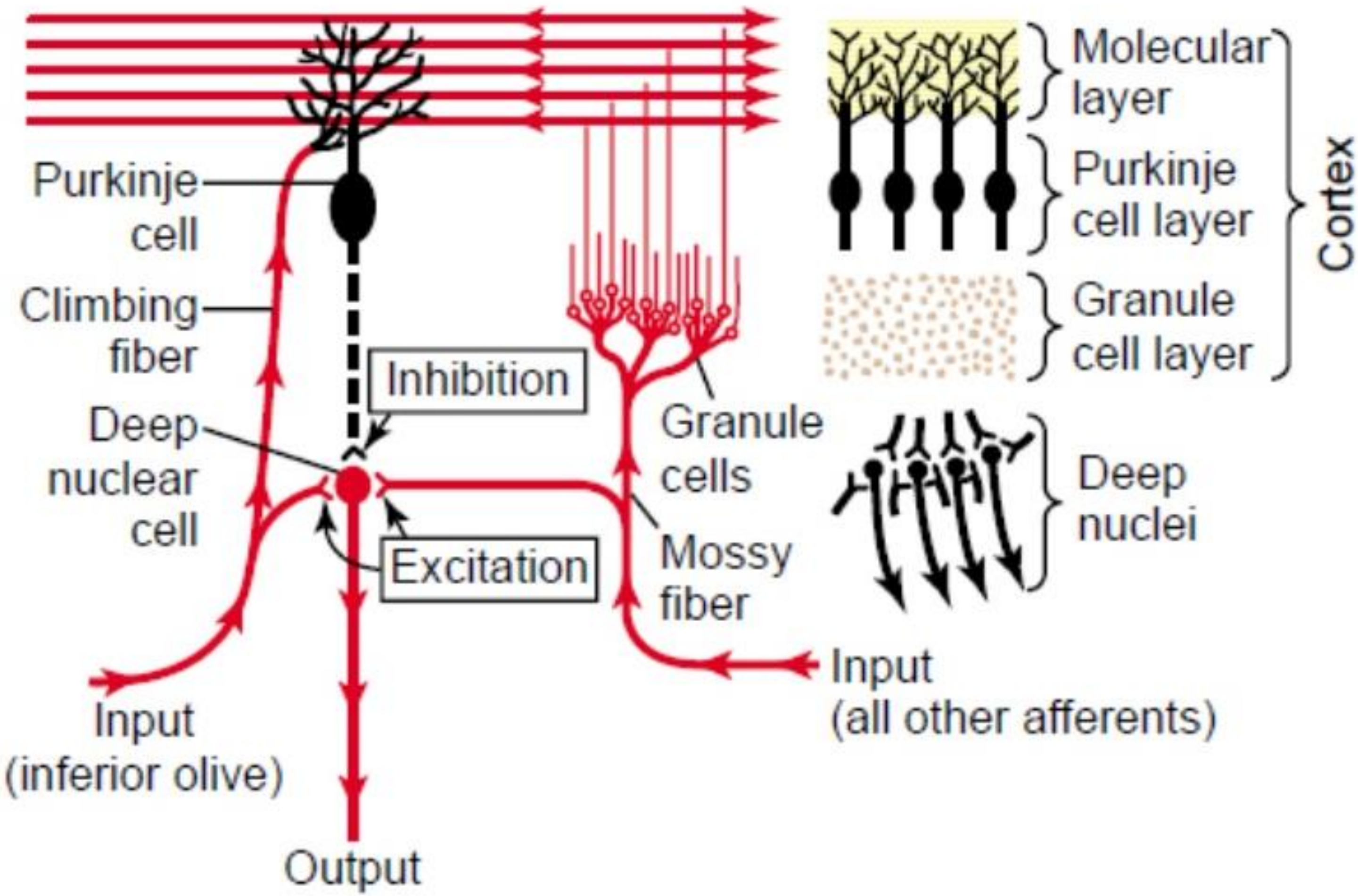
Middle cerebellar peduncle

- Brings input from motor cortex to the pontine nuclei which is transmitted to cerebellum

- Tells the cerebellum where the body wants to be.



Internal cerebellar circuit



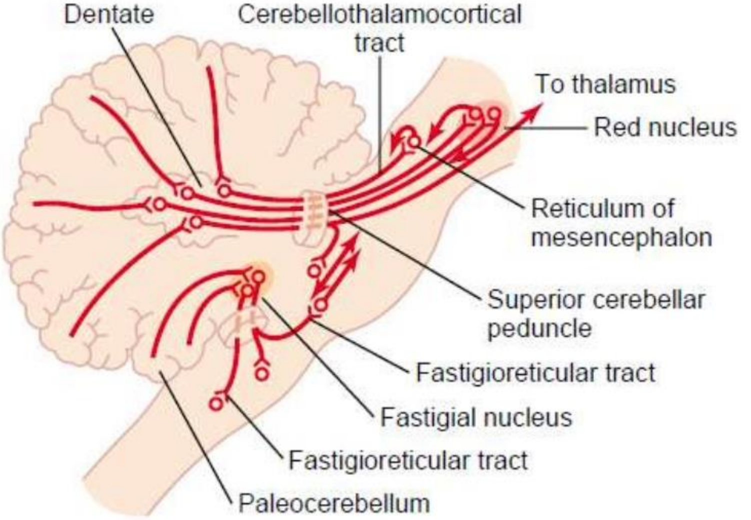
Cerebellar Output (Deep Cerebellar Nuclei)

- Sole output of the cerebellum
- Axons travel through the **superior cerebellar peduncle**

Dentate: outputs to **Ventral Lateral (VL)** nucleus of the thalamus and then to cortex

Globose/Eboliform: output to the **red nucleus** then to spinal cord and cranial nuclei

Fastigial: output to the vestibular nuclei and spinal cord



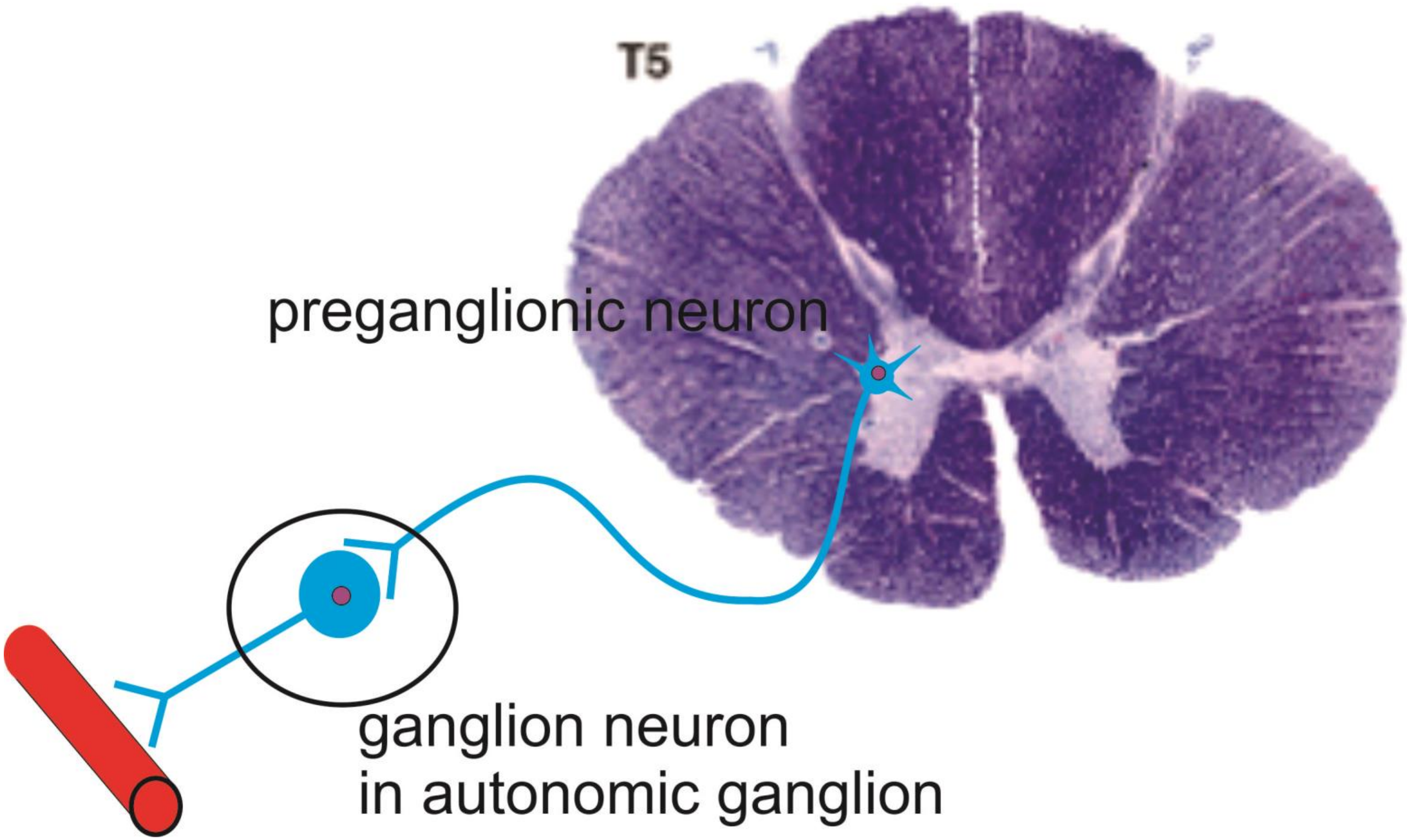
Autonomic Nervous System

The autonomic system has three subdivisions:

- Sympathetic nervous system
- Parasympathetic nervous system
- Enteric nervous system

Sympathetic and Parasympathetic Systems

- These are two-neuron output systems, a preganglionic neuron in the brainstem or spinal cord and a ganglionic neuron in a ganglion. The postganglionic axon synapses with its target.



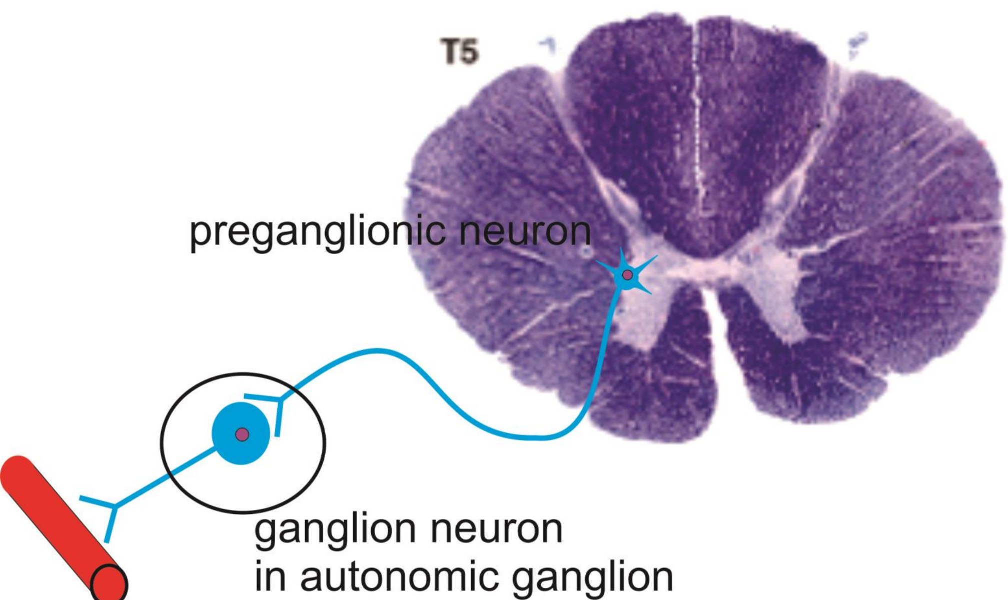
Sympathetic Nervous System

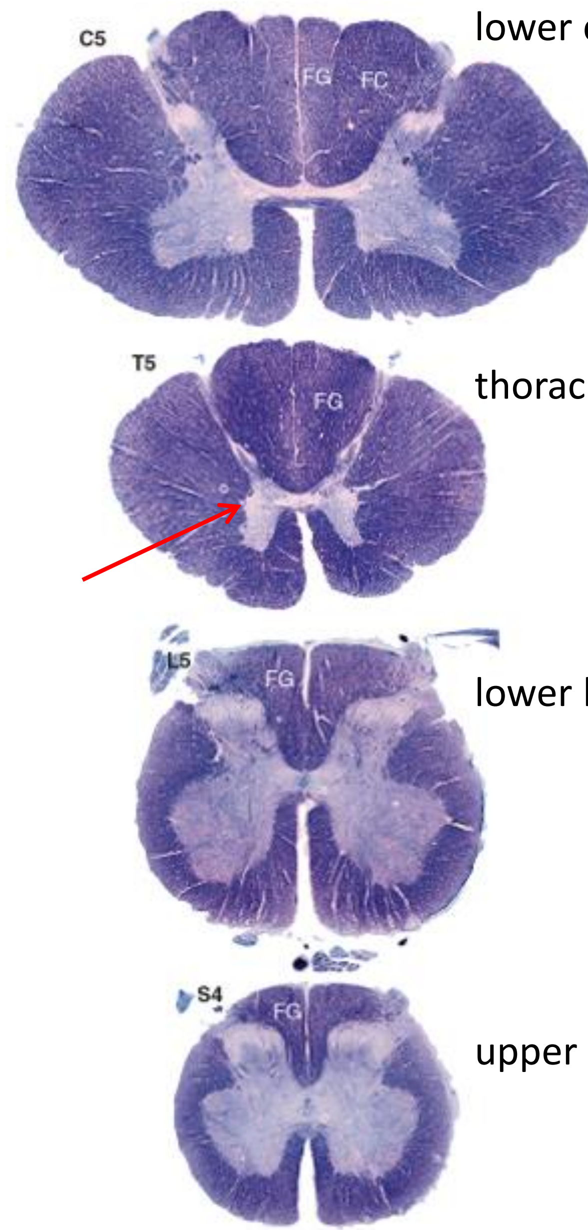
- Preganglionic neurons are in thoracic and upper lumbar spinal cord.
- Ganglion neurons are in sympathetic ganglia , which mostly are near the CNS.
- Preganglionic axons typically are short, and postganglionic axons typically are long.
- Norepinephrine (noradrenaline) is the primary neurotransmitter used by most sympathetic ganglion neurons.
- The sympathetic system is the ‘fight or flight’ system; it helps the body deal with stresses.

Sympathetic Nervous System

- Preganglionic sympathetic neurons are in the intermediolateral cell column (lateral horn) in thoracic and upper lumbar spinal cord (spinal segments T1 to L2).

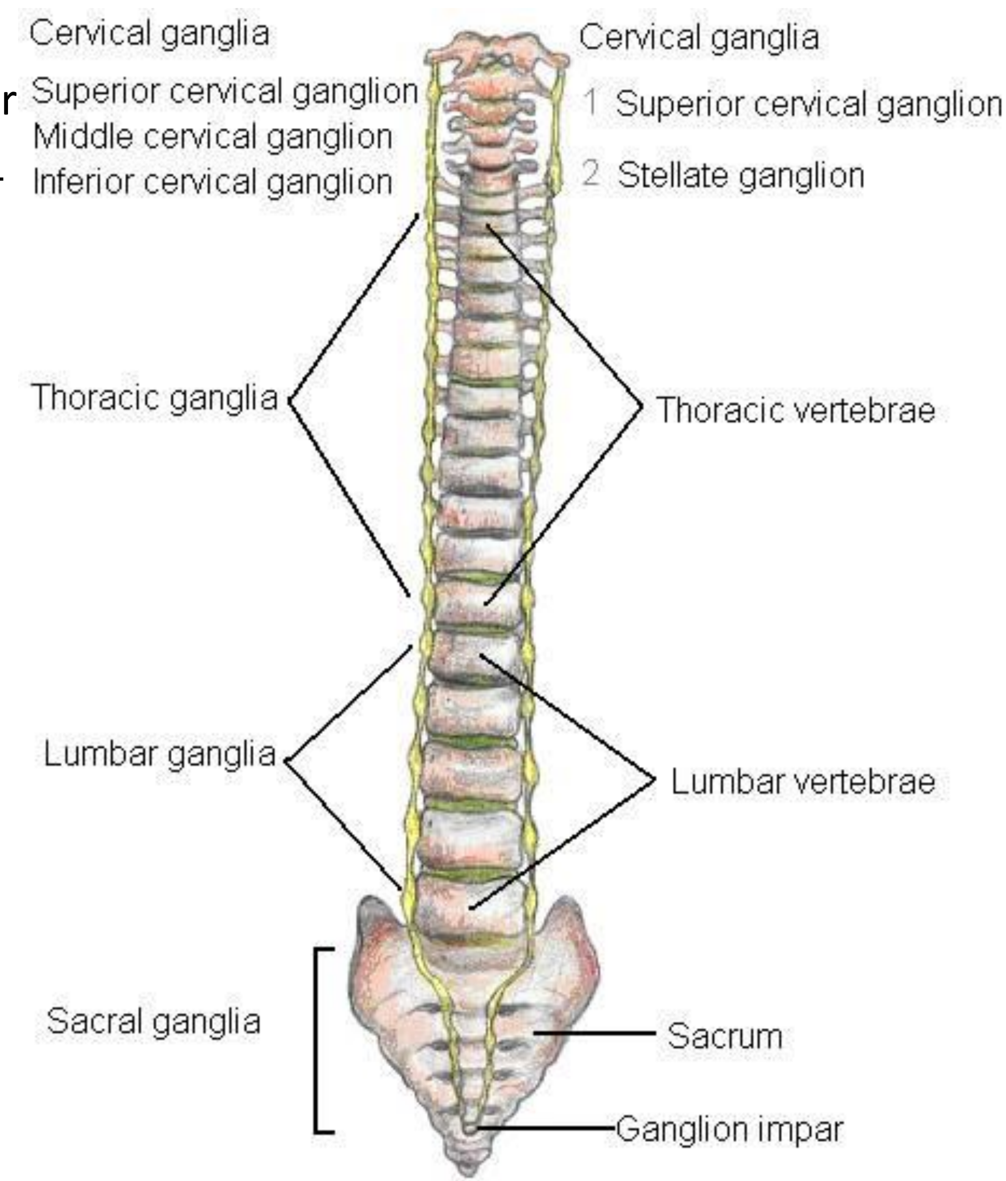
- Preganglionic axons exit the spinal cord in the ventral root with other motor axons.





Sympathetic Nervous System

- Preganglionic axons can ascend or descend in the sympathetic chain on the sides of the vertebrae.

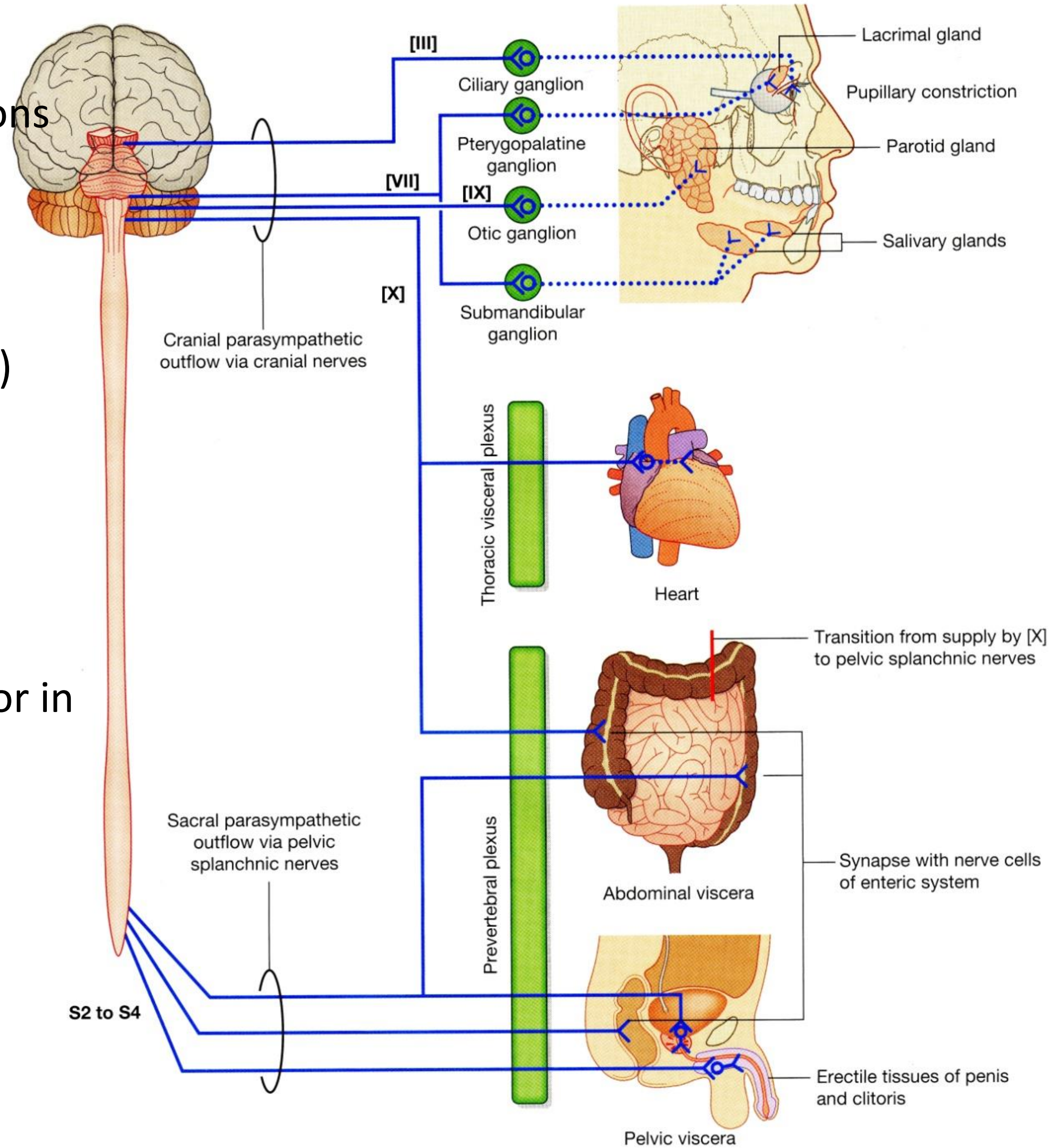


Parasympathetic Nervous System

- Preganglionic neurons are in the brainstem and sacral spinal cord.
- Ganglion neurons are in parasympathetic ganglia, which are typically near their target tissues.
- Preganglionic axons typically are long, and postganglionic axons typically are short.
- Acetylcholine is the primary neurotransmitter used by most parasympathetic ganglion neurons.
- The parasympathetic system is the ‘rest and digest’ system; it is restorative.

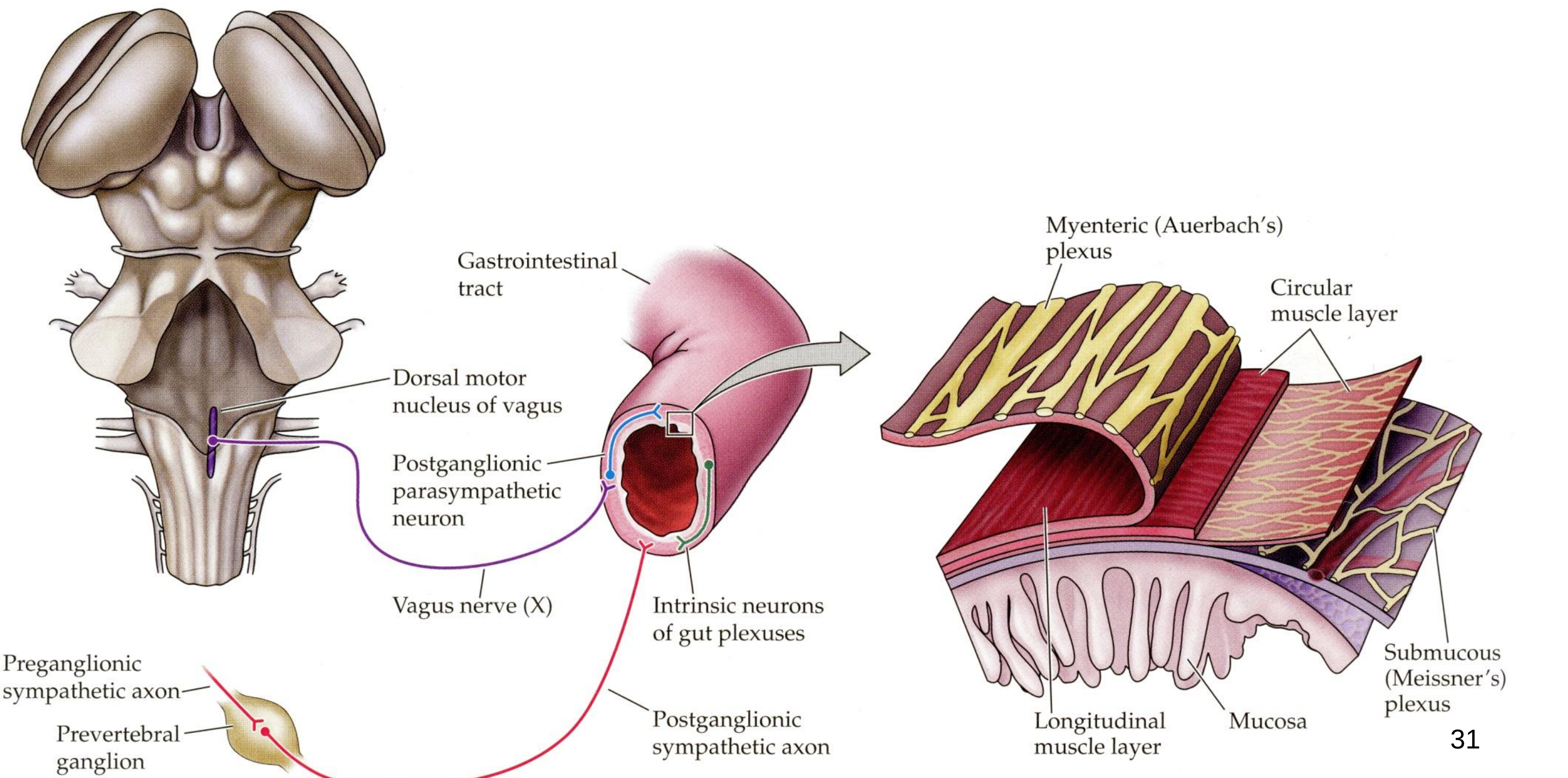
Parasympathetic Nervous System

- Preganglionic parasympathetic axons run in:
  - •Oculomotor nerve (CN III)
  - •Facial nerve (CN VII)
  - •Glossopharyngeal nerve (CN IX)
  - •Vagus nerve (CN X)
  - •Sacral spinal nerves
- Parasympathetic ganglia are near or in their target tissues.
- Postganglionic axons synapse with tissues throughout the body.



Autonomic Function

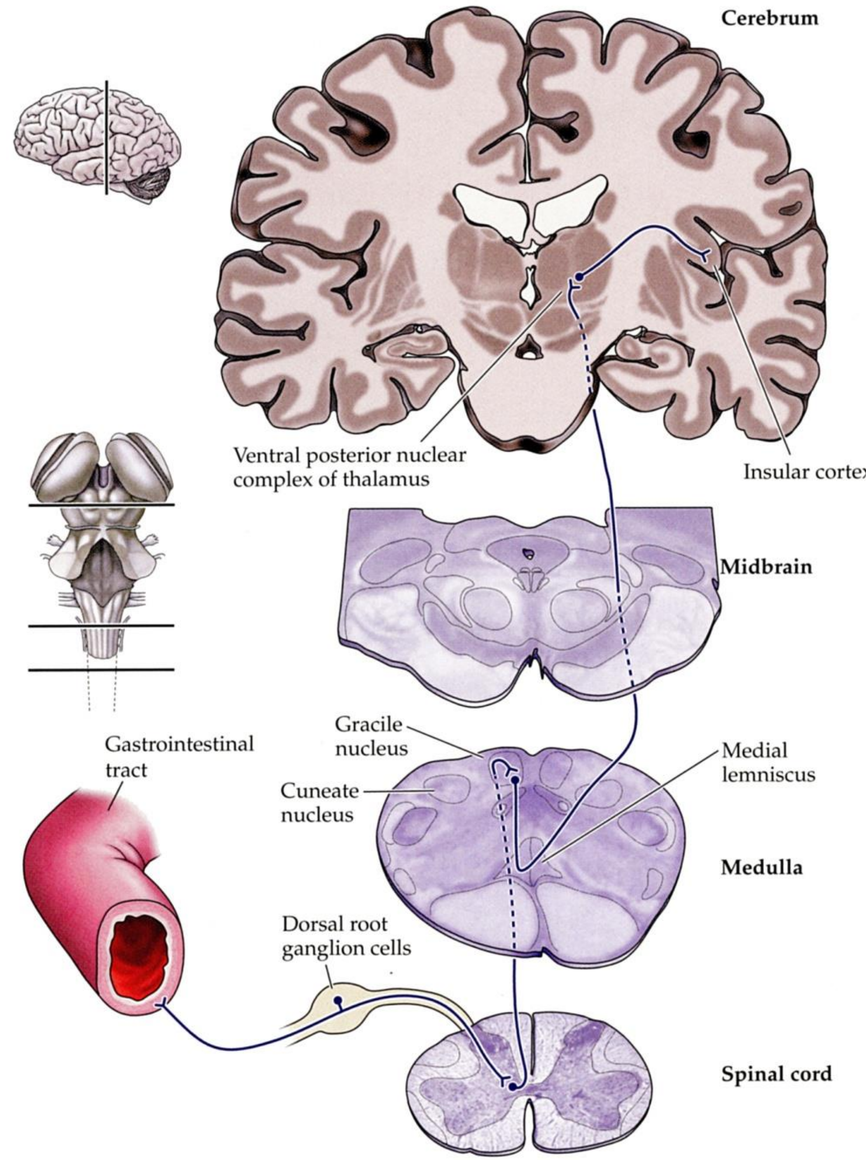
- Enteric neurons regulate gut motility, secretion into the gastrointestinal system, and water and ion movement across the gastrointestinal epithelium.



Visceral Sensory System

- Sensory information from the viscera is carried to the cortex in a path slightly different than the somatosensory system.

- Visceral sensation is represented in insular cortex.

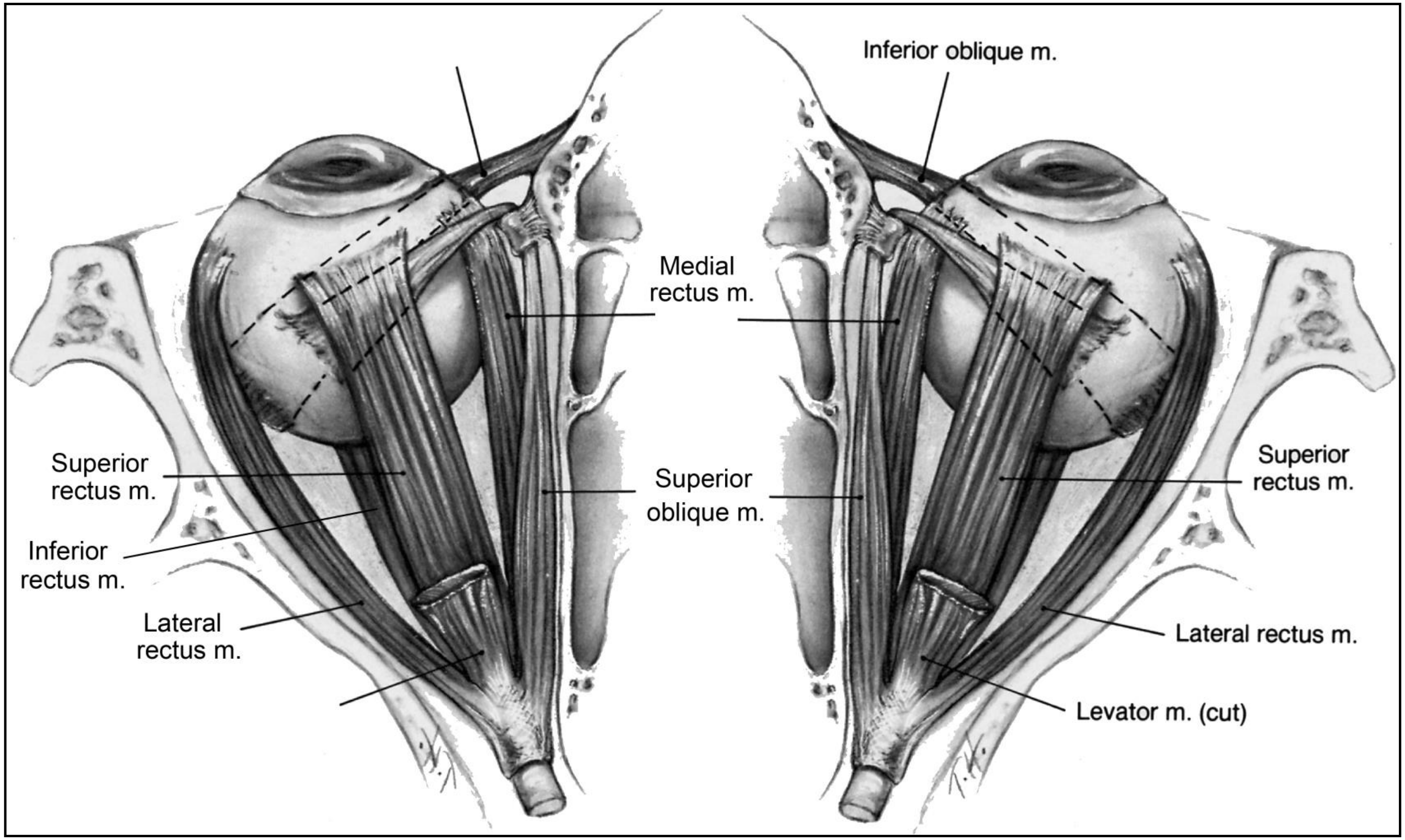


EYE MOVEMENTS

Six Fundamental Tasks of the Ocular Motor System

1. Fixation: Maintenance of focus on a particular spot in the visual world. In other words, your eyes need to stay still.
2. Saccades: Rapid conjugate shifts in gaze attention.
3. Smooth pursuit: Continued fixation on slowly moving objects when the head is stationary.
4. Vestibulo-ocular reflex (VOR): Fixation on a stationary object during brief head movements.
5. Optokinetic nystagmus (OKN): Fixation on stationary images during sustained head rotations or continued small eye movements to moving images in the visual field.
6. Vergence: For viewing close stationary objects - head is stationary. Eyes both turn toward the midline.

Extraocular Muscles

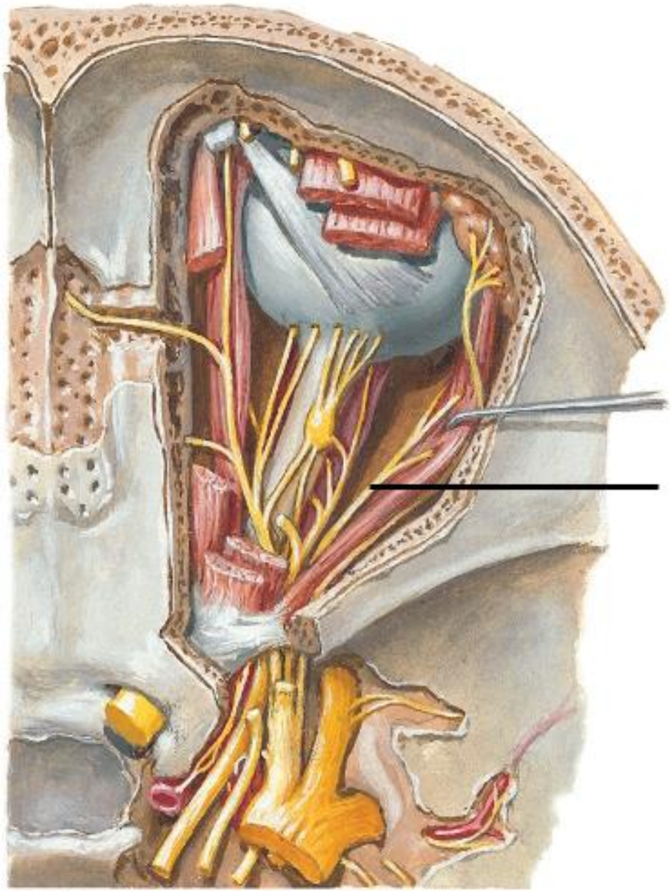


In each orbit:

4 rectus muscles: superior, medial, inferior, lateral

2 oblique muscles: superior, inferior

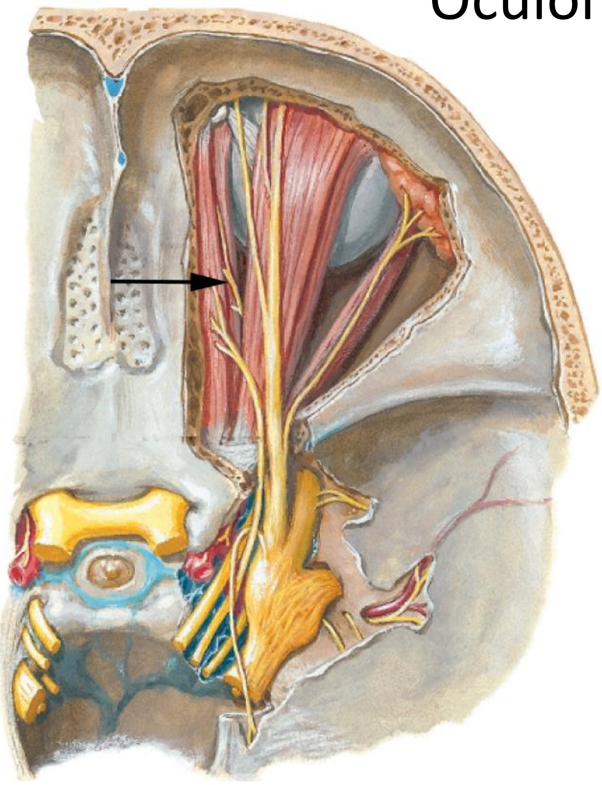
Innervation of the Extraocular Muscles

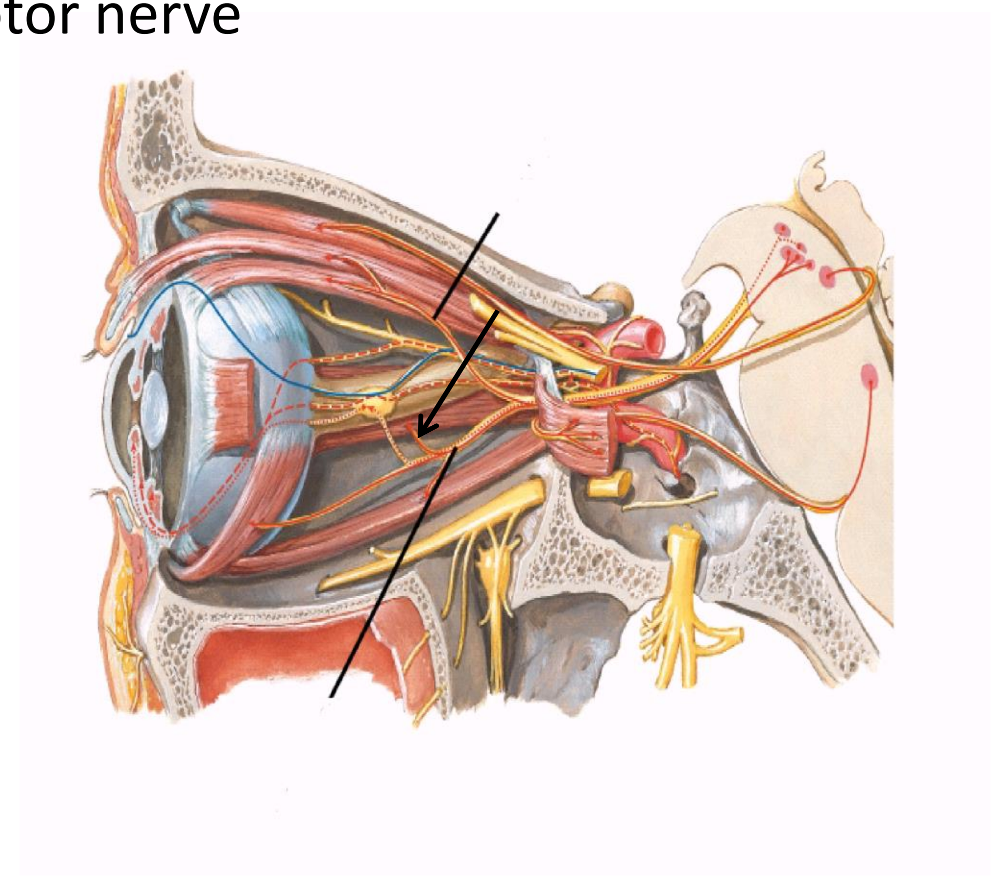


The abducens nerve (cranial nerve 6 - CNVI) innervates the lateral rectus muscle.

Innervation of the Extraocular Muscles

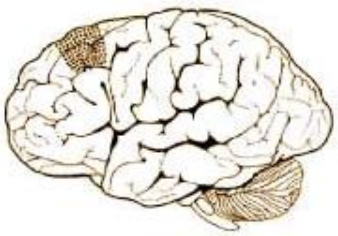
Oculomotor nerve

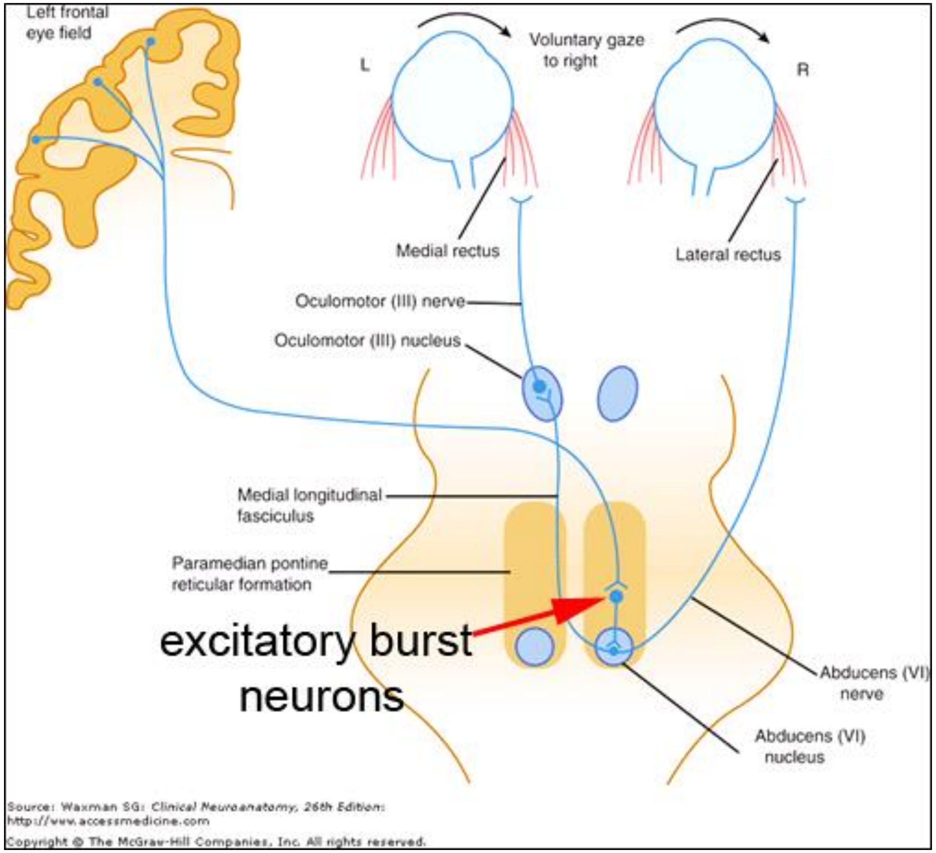




The oculomotor nerve (cranial nerve 3 – CNIII) innervates the other four muscles: superior rectus, medial rectus, inferior rectus and inferior oblique (plus the levator palpebrae superioris).

What Brain Region Controls the Motor Neurons in Horizontal Gaze Shift?

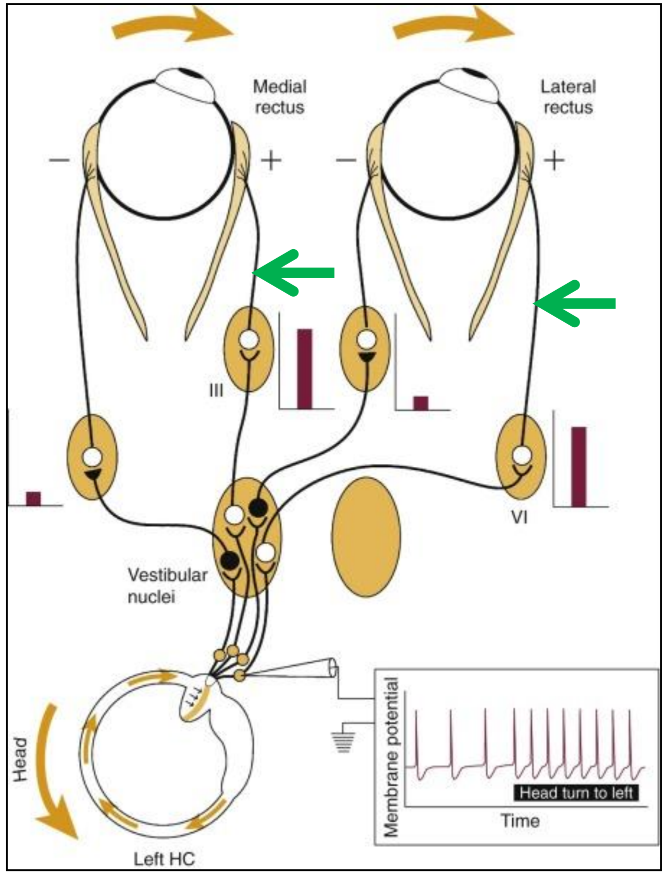




Frontal eye field → excitatory burst neurons → abducens motor neurons → internuclear neurons → oculomotor neurons on the contralateral side

Vestibular Ocular Reflex (VOR): 3 Neuron Arc

3 NEURON ARC



Leftward head movement
Rightward eye movement

O excitatory
● inhibitory

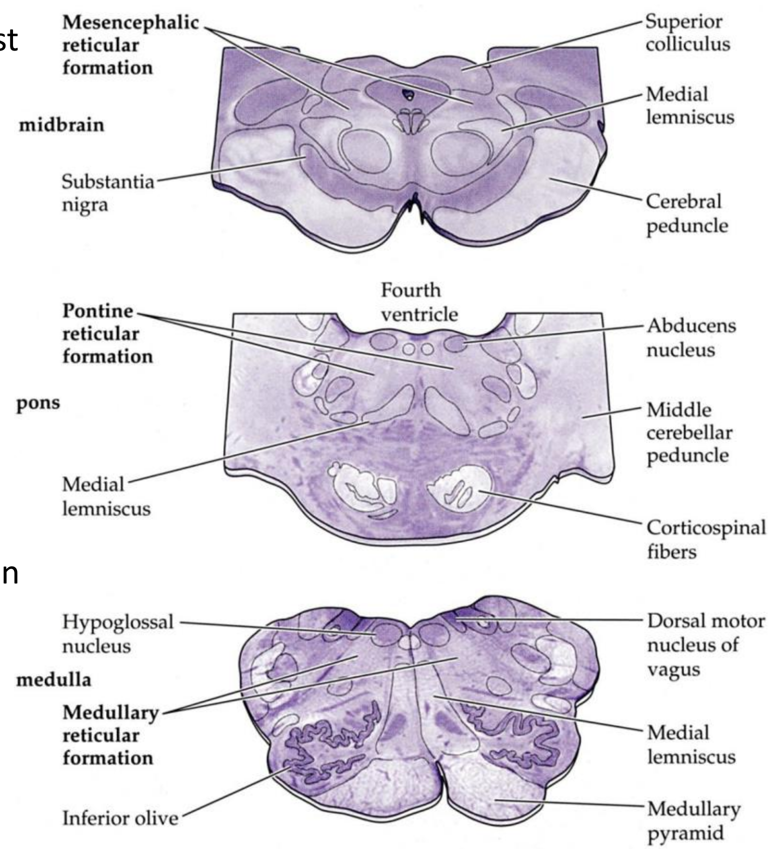
Leftward head movement

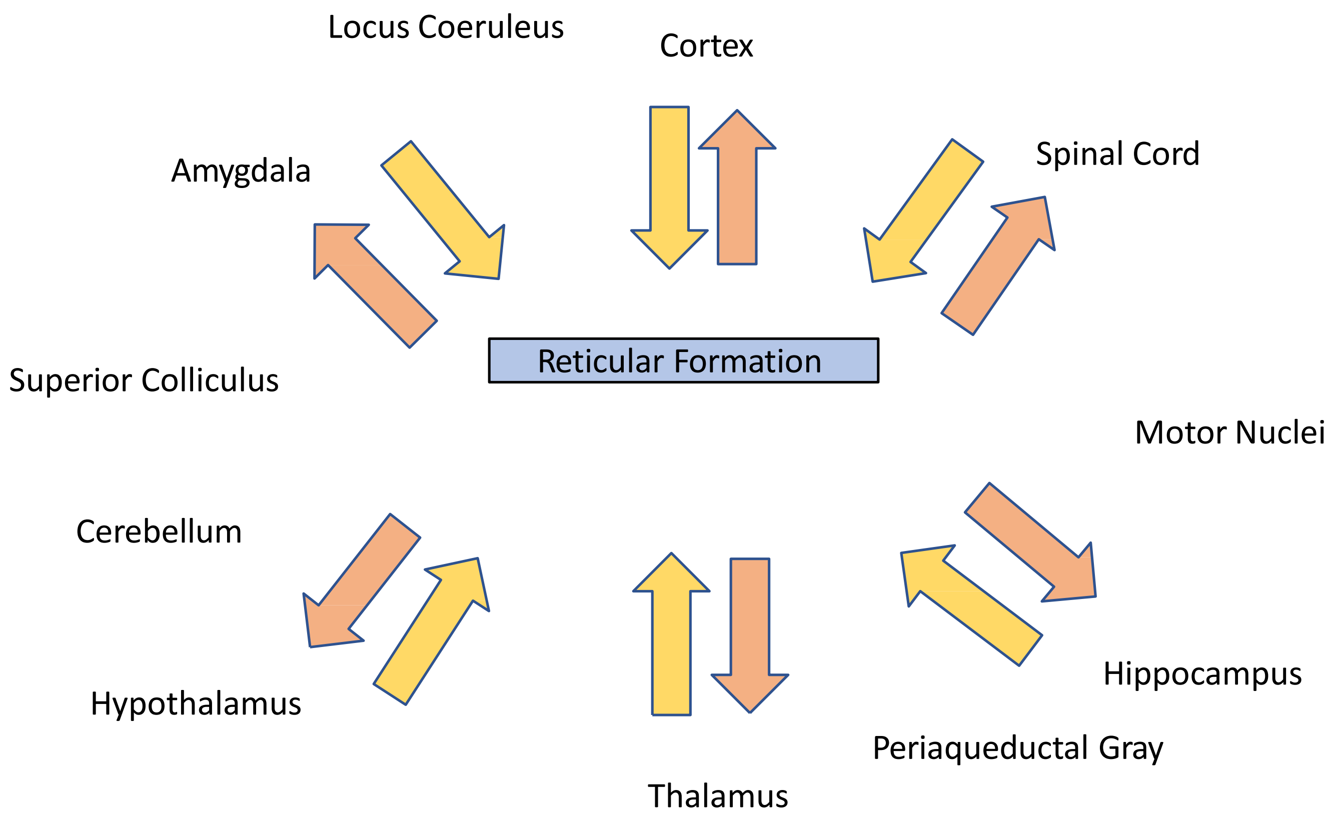
Leftward head movement **excites** left horizontal semicircular canal, which sends excitatory input to left vestibular nuclear neurons. These send excitatory signals to left oculomotor nucleus and the right abducens nucleus and inhibitory signals to the right oculomotor nucleus and the left abducens nucleus. These in turn send **excitatory signals to the left medial rectus and right lateral rectus muscles** and inhibitory signals to the left lateral rectus and right medial rectus muscles. **This pathway is FAST and does not require vision**.

Flint, Physiology of the Vestibular System

Reticular Formation

- The reticular formation is the oldest part of our nervous system phylogenetically.
- It is present throughout the midbrain, pons and medulla.
- Typically, the reticular formation is regions of the brainstem between clearly defined nuclei and tracts
- It is groups of neurons embedded in a seeming disorganized mesh of axons and dendrites.



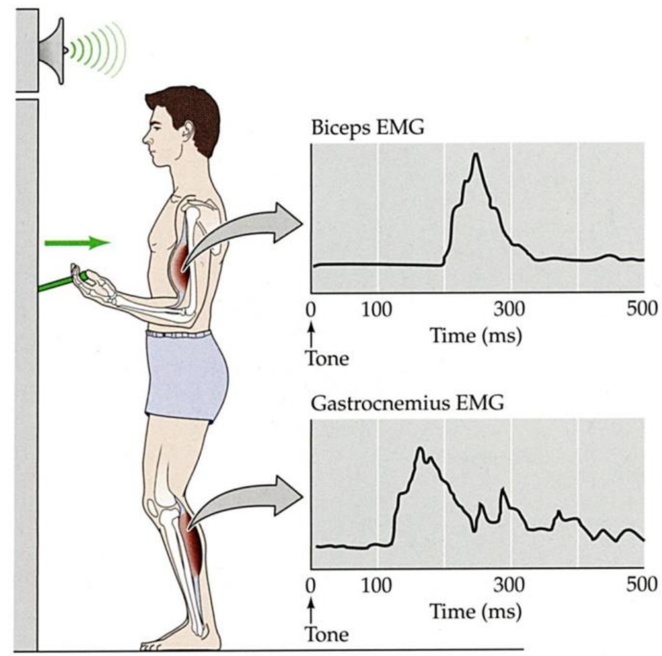

Locus Coeruleus
Cortex
Amygdala
Spinal Cord
Superior Colliculus
Reticular Formation
Motor Nuclei
Cerebellum
Hippocampus
Hypothalamus
Periaqueductal Gray
Thalamus

Reticular Formation

- The reticular formation has a major role in regulation of:
    - Motor control
    - Sensory attention
    - Autonomic nervous system
    - Eye movements
    - Sleep and wakefulness

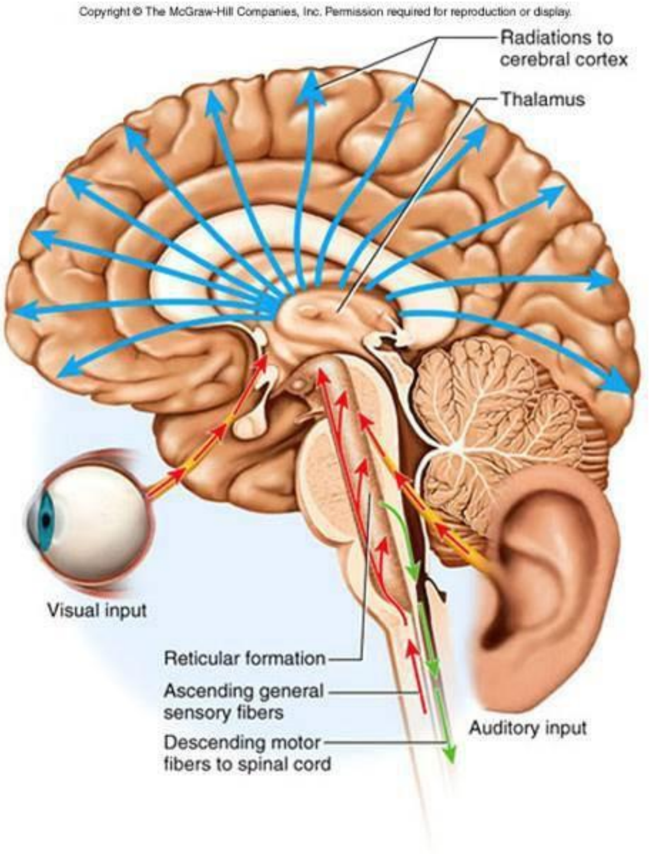
Reticulospinal & Reticulbulbar Projections

- Reticular formation (RF) initiates 'accompanying' movements.
- Accompanying movements are subconscious and are needed in support of a consciously initiated movement. These movements are often needed to maintain balance.
- Accompanying movements may precede the conscious movement.
- RF is required for this type of movement.



Sensory Attention

- Helps in filtering sensory information via reticulo-thalamic neurons
- Touch, temperature, pain, auditory, and visual stimuli
- Can help to reduce irrelevant stimuli



Sleep & Wakefulness

- Sleep and wakefulness are **both** active processes.
- Sleep and wakefulness are controlled by areas of the reticular formation in the midbrain and upper pons.

Sleep & Wakefulness

Non REM or Slow Wave Sleep (SWS)

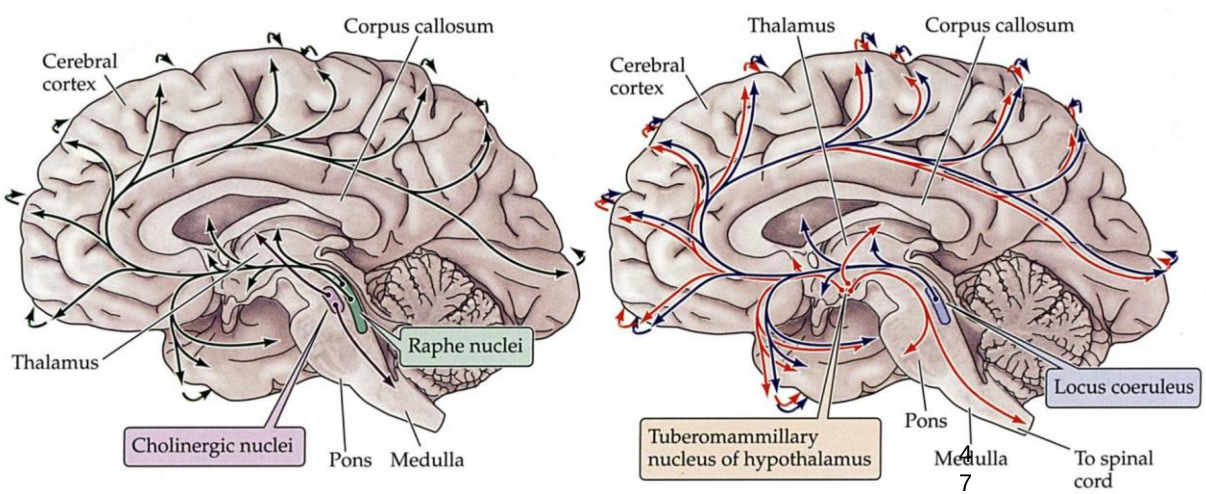
- Muscle Activity
- Little dreaming
- Few eye movements
- Slowing of breathing
- Reduced BP

Rapid Eye Movement (**REM**) Sleep

- Reduced muscle activity
- Frequent dreaming
- Increased eye movements
  Enhanced breathing
- Increased BP

Sleep & Wakefulness

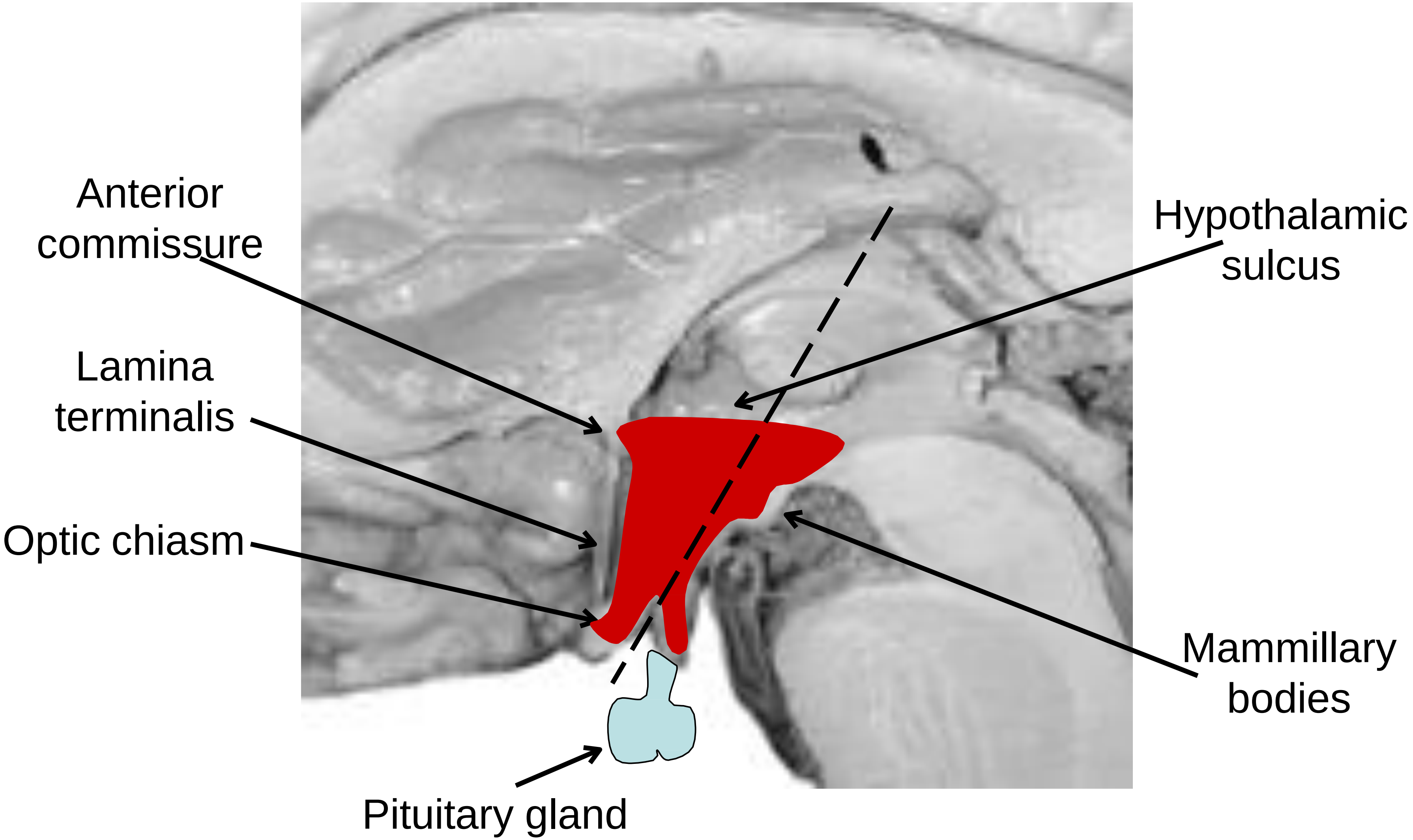
- The reticular activating system from midbrain and pons is required for wakefulness.
- Noradrenergic neurons in the locus coeruleus and serotonergic neurons in the raphe nucleus of the reticular formation project to cortex and are required for wakefulness.



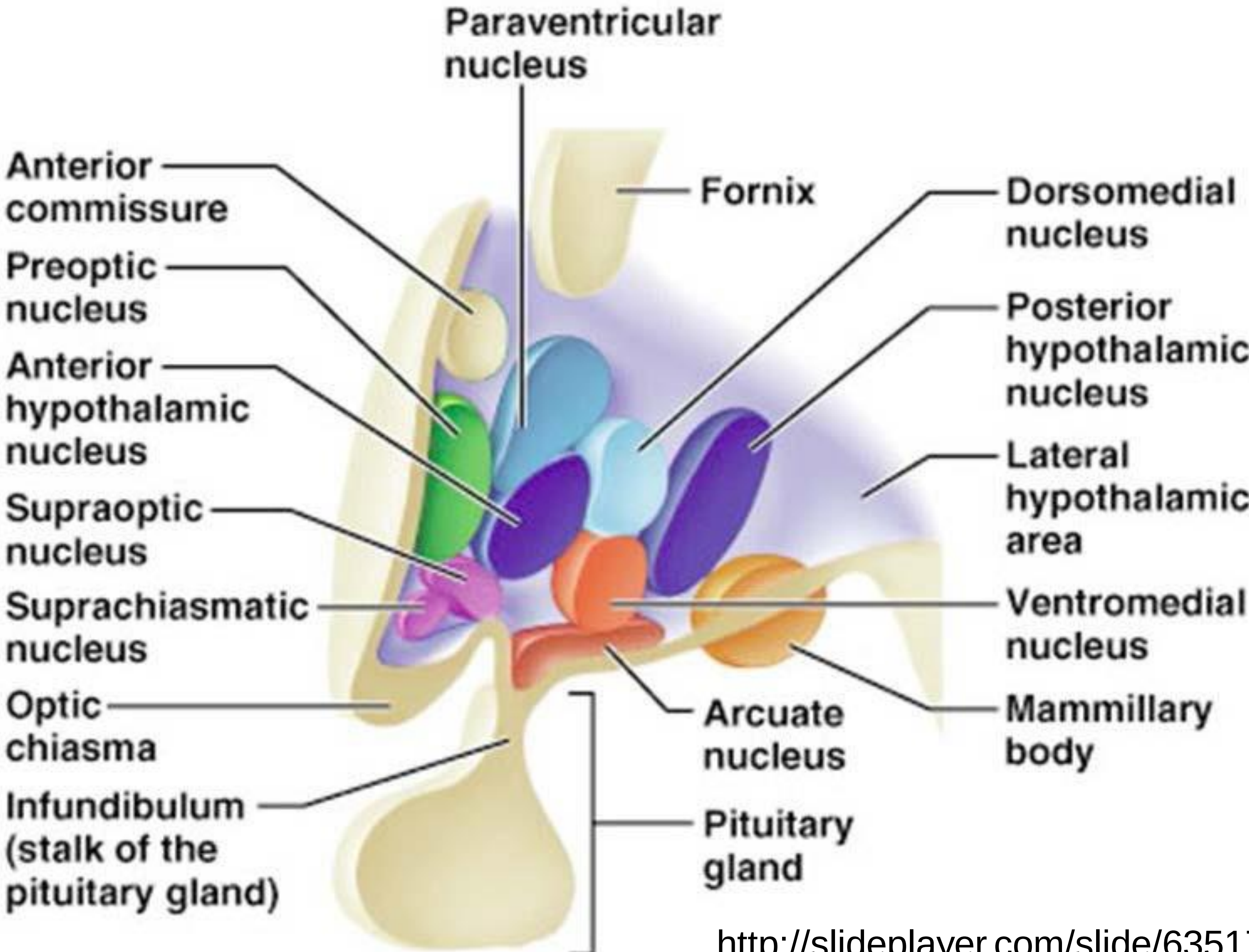
Hypothalamus

- Located at the junction between the brain stem and the forebrain
- Medial hypothalamus: interface between the brain and the endocrine system
  - Blood volume
  - Metabolic rate
  - Lactation
  - Stress
- Hypothalamus: major interface between the limbic system & the autonomic nervous system
  - Eating
  - Thermoregulation
  - Blood pressure
- Hypothalamus also sets our biological clock
  - Sleep/wakefulness

Hypothalamus: anatomy

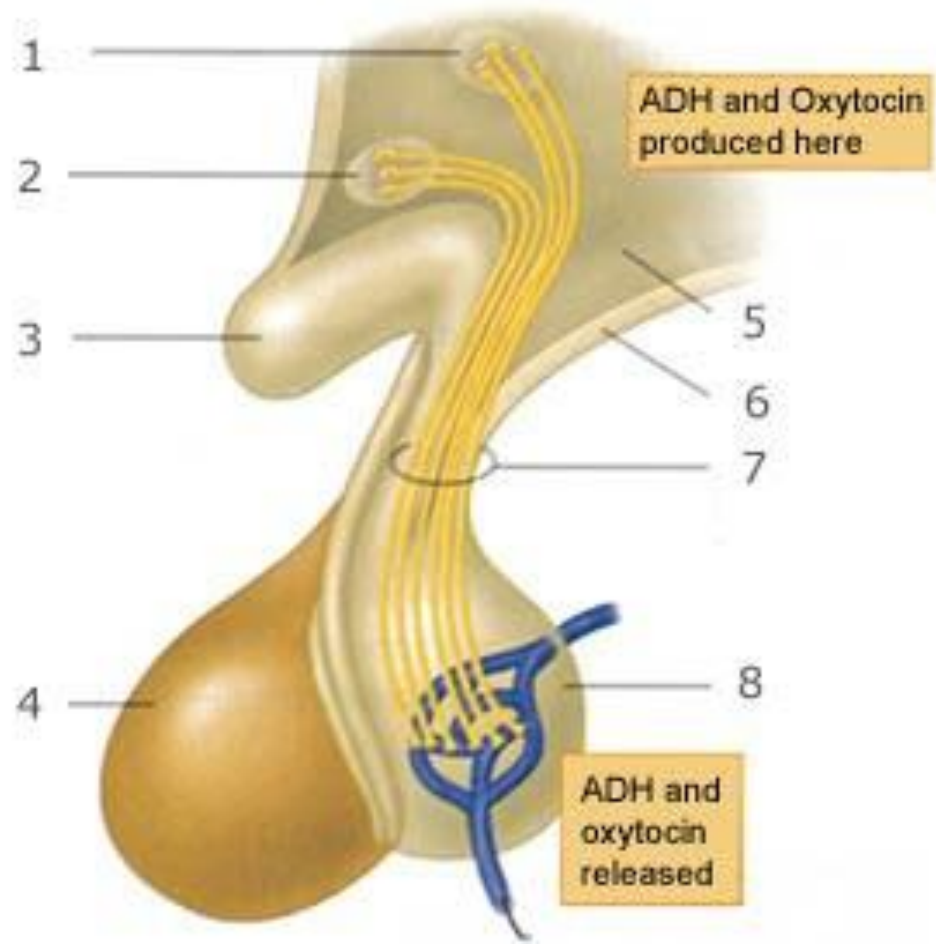


Hypothalamus: anatomy



http://slideplayer.com/slide/6351731/

- ***Hypothalamus directly projects*** to posterior pituitary
  - Vasopressin
  - Oxytocin

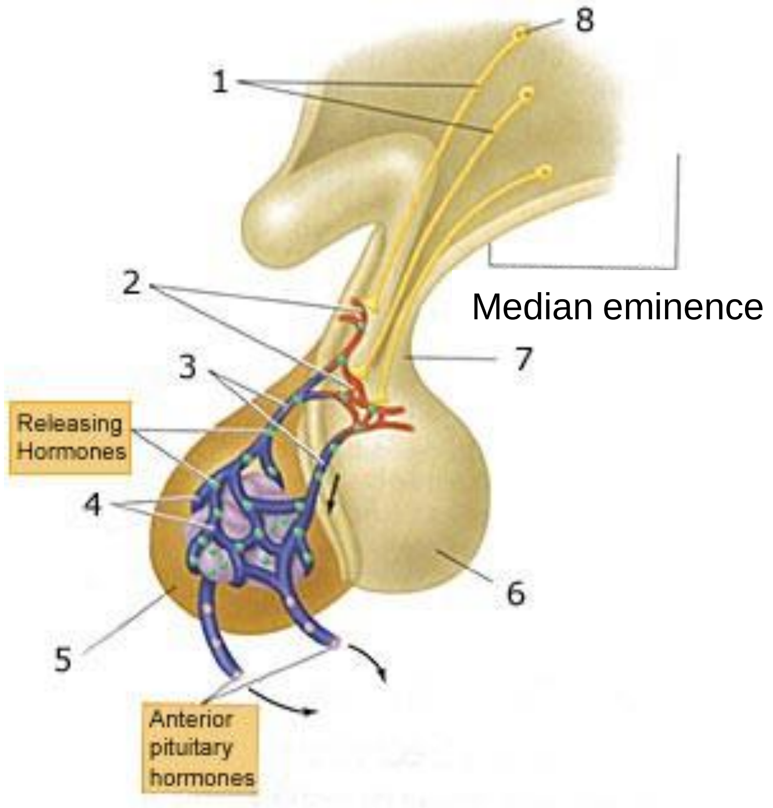


- Cells in supraoptic n. & paraventricular n.
- Axons release these hormones into blood in posterior pituitary

http://homepage.smc.edu/wissmann_paul/intranetstuff/dept/scienceLRC/wissmann_site/pituitary.htm

Hypothalamus as an endocrine organ

- ***Indirect connection*** to anterior pituitary
  - Hormone in neurons in arcuate n. & paraventricular n. (ventromedial hypothalamus)
  - Hormones released into *hypothalamic-hypophyseal portal system*
  - Blood carries hormones to pituitary → modulate release of pituitary hormones



http://homepage.smc.edu/wissmann_paul/intranetstuff/dept/scienceLRC/wissmann_site/pituitary.htm

Hypothalamic-hypophyseal portal system

- arteries → arterioles → ventral hypothalamus (capillaries of median eminence) → portal veins (pituitary stalk) → capillaries of anterior pituitary → venules → veins

Hypothalamus vs. pituitary: Keeping hormones straight

- Pituitary hormones
  - Adrenocorticotropic hormone (ACTH)
  - Thyroid stimulating hormone (TSH)
  - Growth hormone (GH)
  - Etc.
- Hypothalamic hormones: ***hyphenated*** (mostly)
  - Corticotropin-releasing hormone (CRH)
  - Thyrotropin-releasing hormone (TRH)
  - Growth hormone-releasing hormone (GH-RH)
  - **Exception**: somatostatin

Hypothalamus & the autonomic nervous system

- Classical autonomic effects
  - Blood pressure
  - Thermoregulation
  - Urination
- Autonomic effects not mediated directly through sympathetic or parasympathetic nervous systems
  - Feeding
  - Circadian rhythms

TEST ON MONDAY STARTING AT 12:50 PM