

# **Vestibular System, Somatosensory System, & Motor Control**

Tricia Ngoon  
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## **Vestibular System**

## The woman who couldn't stand

- Cheryl Schiltz suffered from extreme imbalance.
- Antibiotics had damaged her **semi-circular canals**.
- Her doctor gave her a helmet with a tongue strip attached to a computer
- The tongue strip detected head movements and eventually formed a new pathway within the brain



[from Norman Doidge's book "The Brain that Changes Itself"]

## What are the semicircular canals?

- Consist of 3 looped structures that are affected by \_\_\_\_\_.
- Hair cell receptors are embedded in the gelatinous \_\_\_\_\_ in a mound of cells called the crista ampullaris within each canal's \_\_\_\_\_.
- As the head rotates the duct moves but the \_\_\_\_\_, the fluid within the canals, lags behind owing to inertia.
- This deflects the cupula and bends the hair cells within.
- The bending of these cells does what?
- The fluid eventually catches up with the duct movement, and the sensation of acceleration is stopped.

## What are the semi-circular canals?

- Consist of 3 looped structures that are affected by **head rotation**.
- Hair cell receptors are embedded in the gelatinous **cupula** in a mound of cells called the crista ampullaris within each canal's **ampullae**.
- As the head rotates the duct moves but the **endolymph**, the fluid within the canals, lags behind owing to inertia.
- This deflects the cupula and bends the hair cells within.
- The bending of these cells does what? **Alters an electric signal that is transmitted to the brain.**
- The fluid eventually catches up with the duct movement, and the sensation of acceleration is stopped.

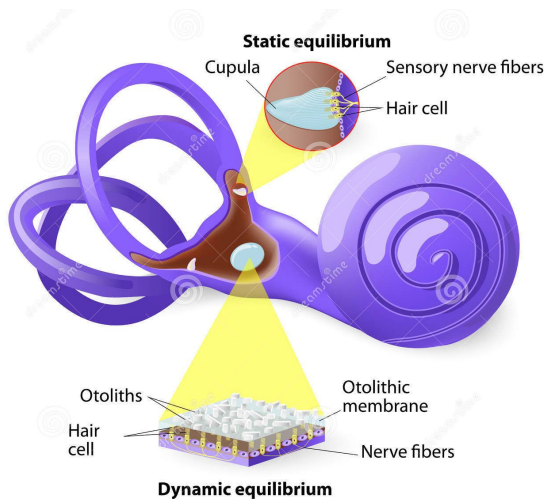
## What are otoliths?

- (Calcium/Potassium) carbonate crystals located in the \_\_\_\_\_ and \_\_\_\_\_ of the inner ear.
- When the head is (turned/tilted), gravity shifts the crystals, which sends signals to the CNS that the head is no longer level.

## What are otoliths?

- (**Calcium**/Potassium) carbonate crystals located in the **utricle** and **sacculle** of the inner ear.
- When the head is (turned/**tilted**), gravity shifts the crystals, which sends signals to the CNS that the head is no longer level.

## Vestibular System: Keeping you in Balance

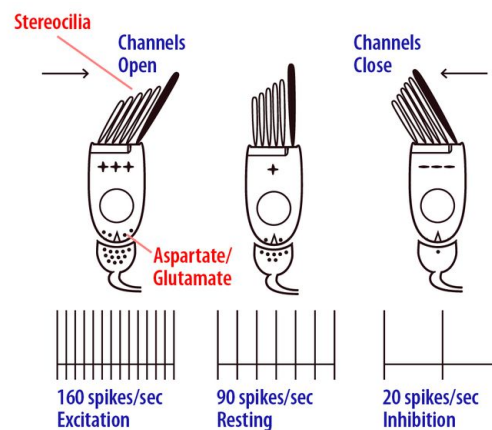


## How are vestibular responses made?

- Hair cells produce (spontaneous/graded) potentials, meaning they fire based on how much stimulus they receive.
- Bending toward the long cilium opens \_\_\_\_ gates and causes (hypo/hyper)-polarization and (increases/decreases) spontaneous firing rate

## How are vestibular responses made?

- Hair cells produce (spontaneous/**graded**) potentials, meaning they fire based on how much stimulus they receive.
- Bending toward the long cilium opens **K<sup>+</sup>** gates and causes (**hypo**/hyper)-polarization and (**increases**/decreases) spontaneous firing rate



# Somatosensory System

## Identify these somatosensory receptors

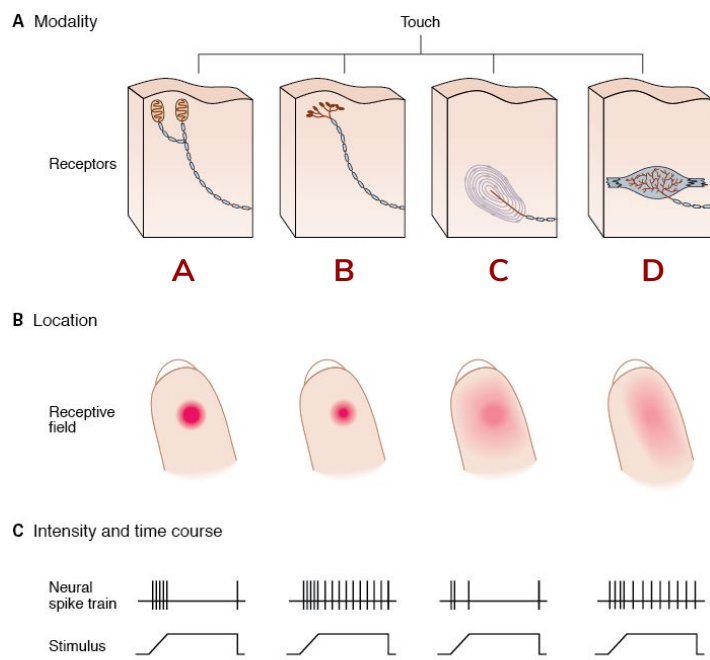
- Detect pain and itch:
- Respond to touch:
- Detect temperature:
- Respond to proprioception:

## Identify these somatosensory receptors

- Detect pain and itch: **nociceptors, free nerve endings**
- Respond to touch: **mechanoreceptors, encapsulated nerve endings**
- Detect temperature: **thermoceptors, free nerve endings**
- Respond to proprioception: **proprioceptors, encapsulated nerve endings**

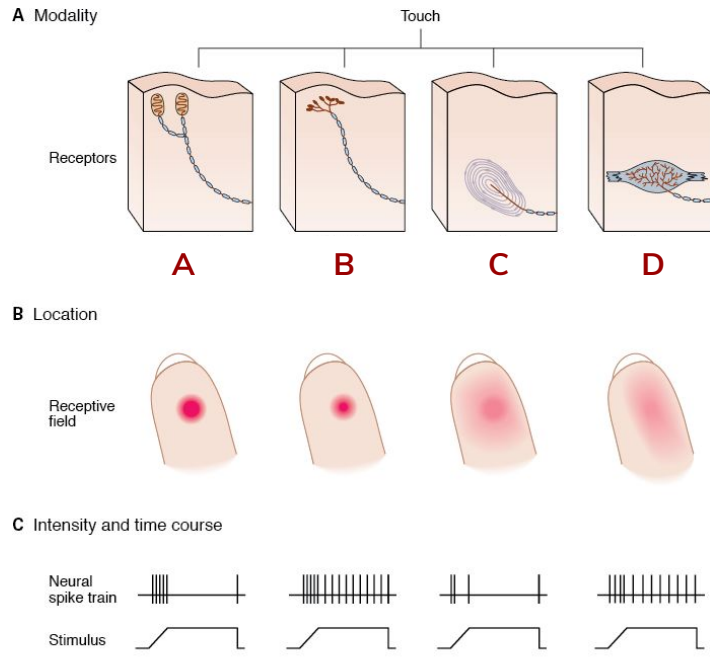
## Match these mechanoreceptors

- Merkel cell
- Pacinian corpuscle
- Ruffini endings
- Meissner's corpuscles



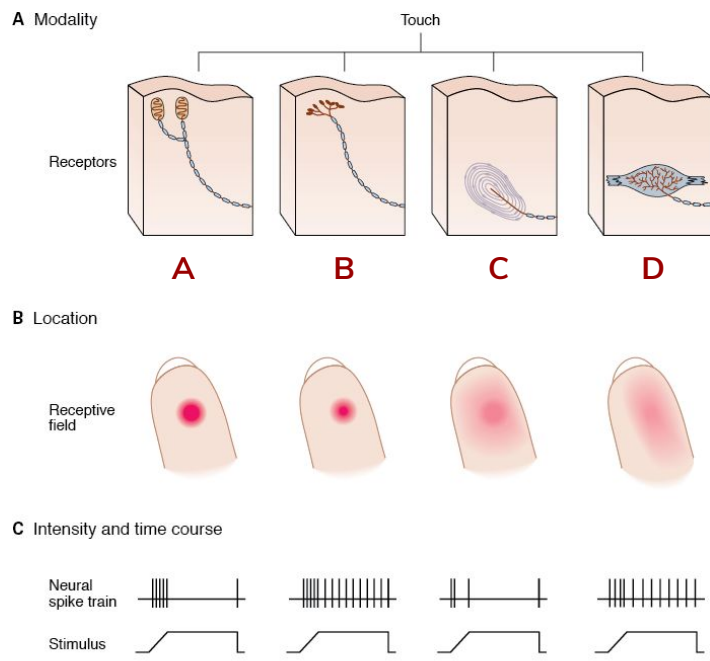
## Match these mechanoreceptors

- Merkel cell **B**
- Pacinian corpuscle **C**
- Ruffini endings **D**
- Meissner's corpuscles **A**



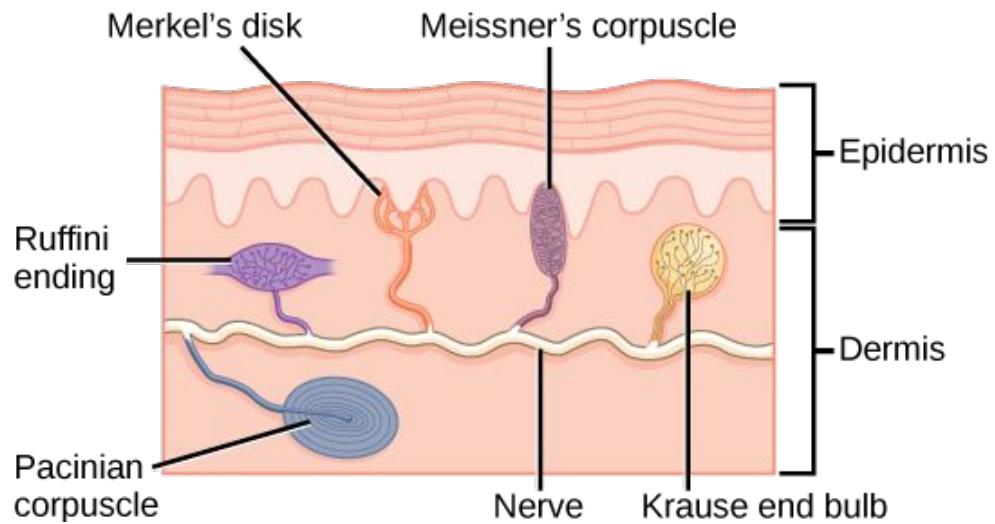
## Match these mechanoreceptors

- Merkel cell - **detail discrimination**
- Pacinian corpuscle - **large-scale changes**
- Ruffini endings - **large-scale events**
- Meissner's corpuscles - **rapid changes**





## Under the skin



**What happens when you put cold hands into warm water?**

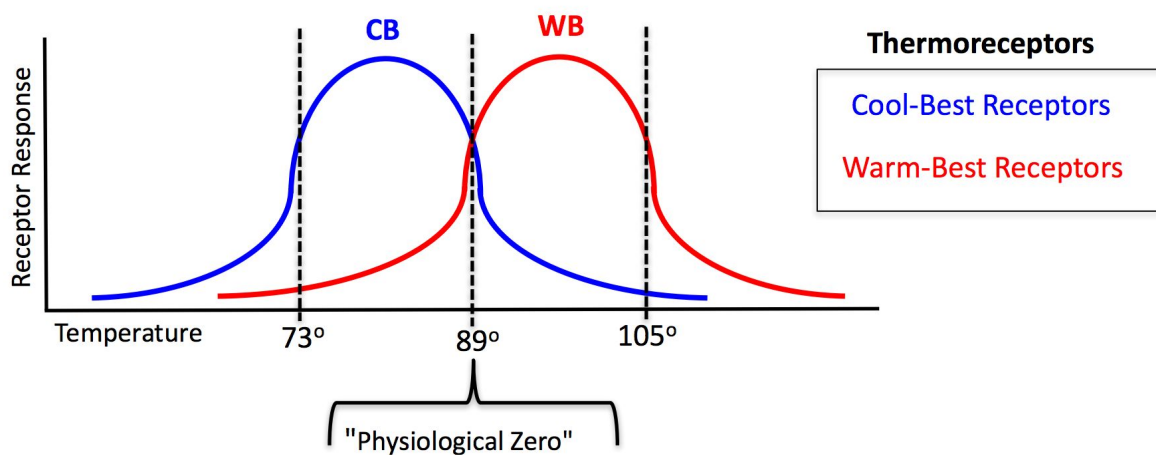


What happens when you put cold hands into warm water?



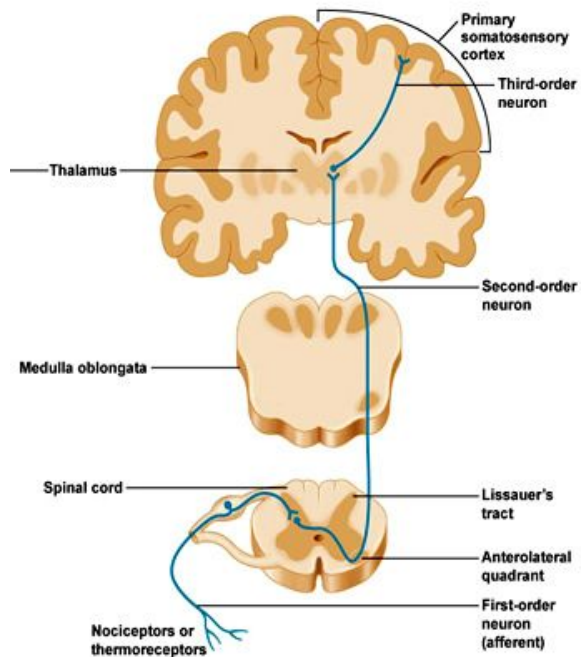
Selective Adaptation

## Across-fiber coding



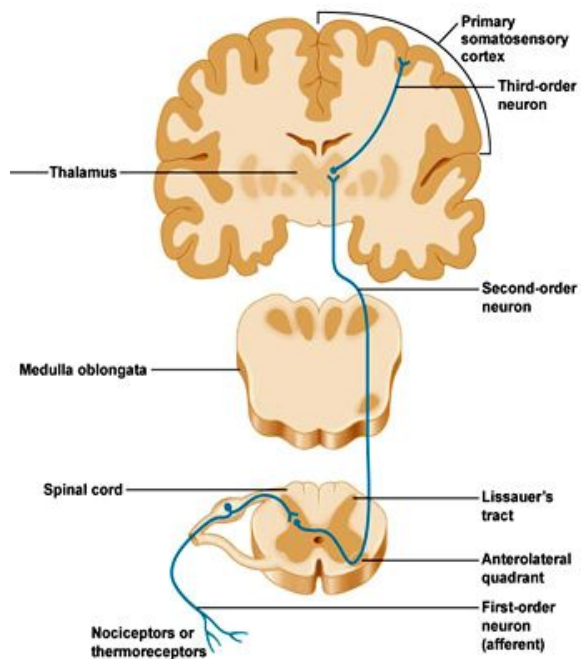
## Describe the spinothalamic pathway

- Carries (free/encapsulated) nerve ending sensations (hot, cold, sex).
- Sensory fibers enter the spinal cord via the \_\_\_\_\_ and synapse.
- Fibers ascend and connect with (first/second) order neuron, which crosses to contralateral side and synapses with VPN (\_\_\_\_\_) of thalamus.
- Nerves are (small/large) and (myelinated/unmyelinated).



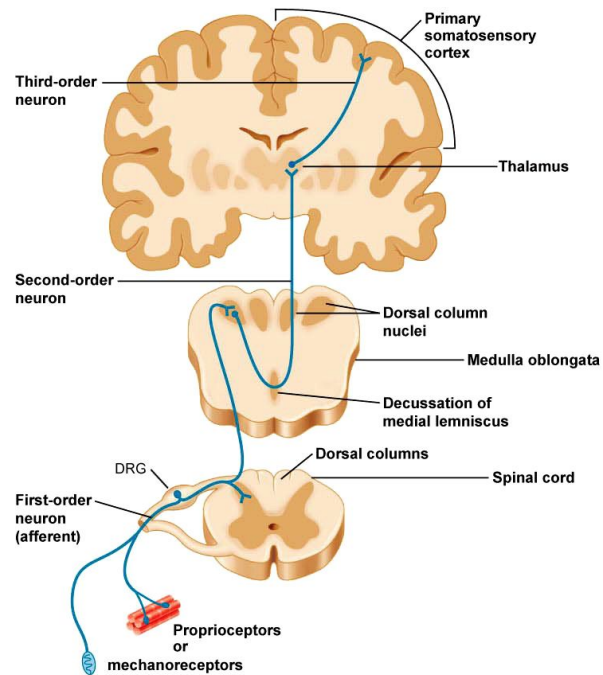
## Describe the spinothalamic pathway

- Carries (**free**/encapsulated) nerve ending sensations (hot, cold, sex).
- Sensory fibers enter the spinal cord via the **dorsal root** and synapse.
- Fibers ascend and connect with (first/**second**) order neuron, which crosses to contralateral side and synapses with VPN (**Ventral Posterior Nucleus**) of thalamus.
- Nerves are (small/**large**) and (**unmyelinated**/myelinated).



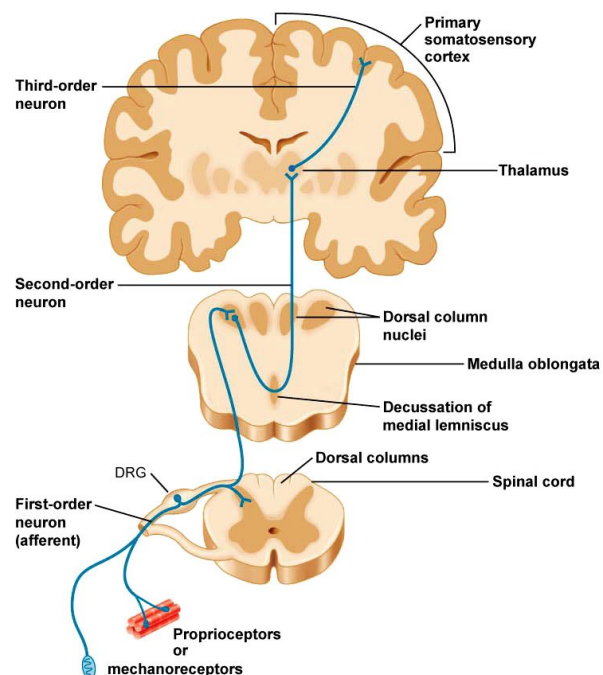
## Describe the Medial Lemniscal Pathway

- (Free/Encapsulated) nerve ending sensations enters through dorsal root of spinal cord where \_\_\_\_\_ axon synapses.
- Main fiber ascends on ipsilateral side to the \_\_\_\_\_.
- Second-order neuron will cross to contralateral side through the brainstem and synapse on VPN.
- Nerves are (small/large) and (unmyelinated/myelinated).



## Describe the Medial Lemniscal Pathway

- (Free/**Encapsulated**) nerve ending sensations enters through dorsal root of spinal cord where **collateral** axon synapses.
- Main fiber ascends on ipsilateral side to the **medulla**.
- Second-order neuron will cross to contralateral side through the brainstem and synapse on VPN.
- Nerves are (**small**/large) and (unmyelinated/**myelinated**).



Why do you rub or hold a body part after an injury?



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- **Gate control theory** - pain impedes inhibitory interneurons (what NT?)
- Large fiber activity excites these interneurons (SG cell), inhibiting \_\_\_ cells from reacting to the pain NT.
- Which region releases endorphins to counteract pain?

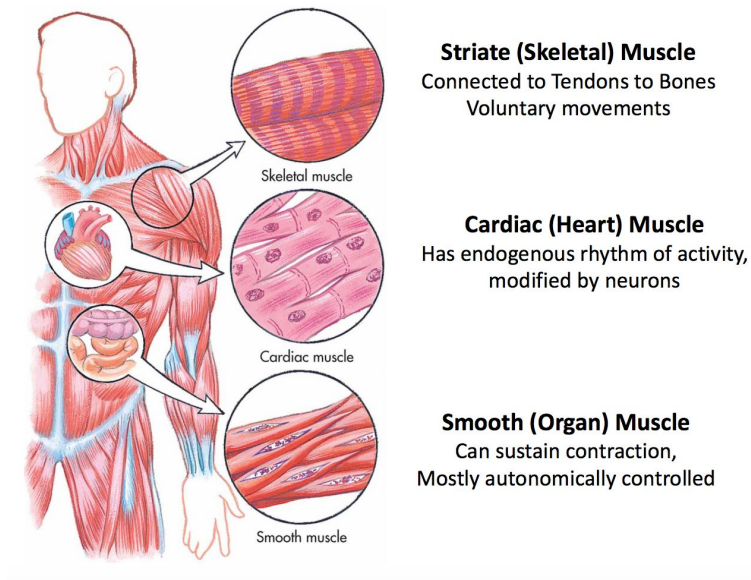
## Why do you rub or hold a body part after an injury?



- **Gate control theory** - pain impedes inhibitory interneurons (**substance P**)
- Large fiber activity excites these interneurons (SG cell), inhibiting **T** cells from reacting to the pain NT.
- Which region releases endorphins to counteract pain?  
**Periaqueductal Gray Area**

## Movement

## 3 types of muscles



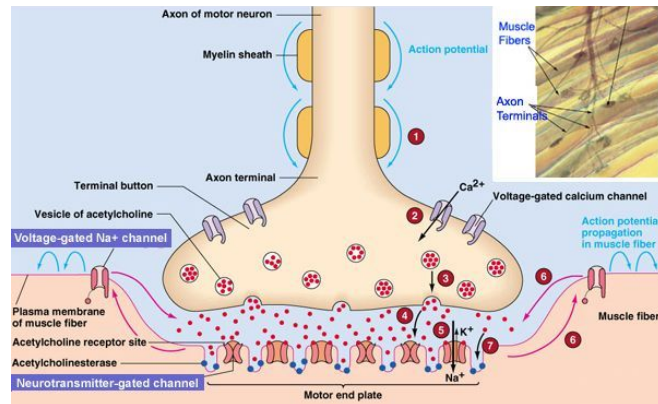
## What is the neuromuscular junction?

- Chemical synapse where a motor neuron can transmit signal to muscle fiber, causing muscle \_\_\_\_\_.
- Motor neurons release what NT onto muscle fibers?
- $\text{Na}^+$  gates open, depolarizing the cell and allowing \_\_\_\_ gates to open.
- This activates \_\_\_\_\_ to contract the muscle.



## What is the neuromuscular junction?

- Chemical synapse where a motor neuron can transmit signal to muscle fiber, causing muscle **contraction**.
- Motor neurons release what NT onto muscle fibers? **Acetylcholine**
- $\text{Na}^+$  gates open, depolarizing the cell and allowing  $\text{Ca}^{++}$  gates to open.
- This activates **sarcomeres** to contract the muscle.



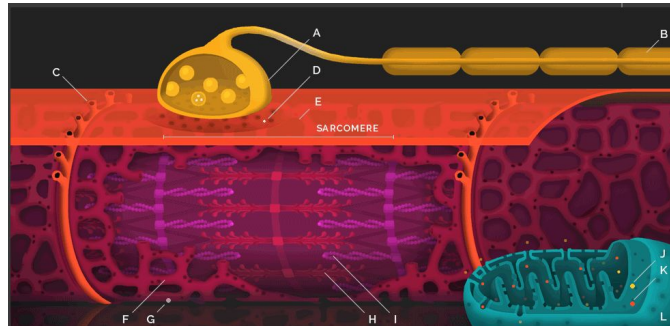
## How do muscles contract?

- Sarcomeres consist of 2 proteins: Myosin is a (thin/thick) protein filament and actin is a (thin/thick) protein filament.
- Myosin head binds to \_\_\_\_\_, which is the source of energy for muscle movement.
- Myosin binds to actin when  $\text{Ca}^{++}$  enters cell and activates the \_\_\_\_\_.



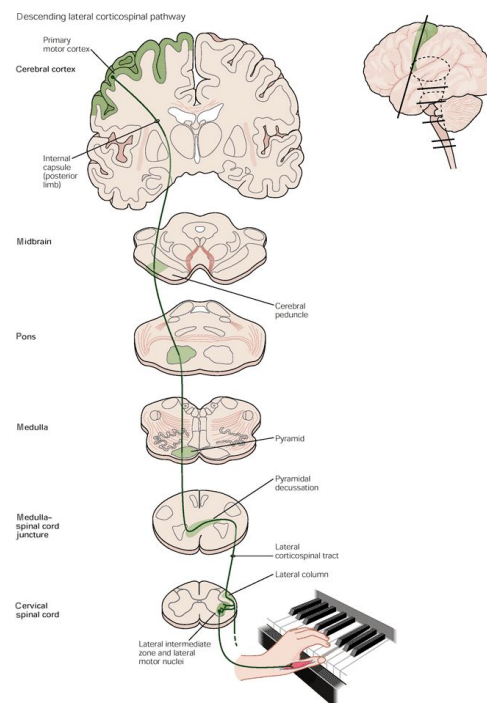
## How do muscles contract?

- Sarcomeres consist of 2 proteins: Myosin is a (thin/**thick**) protein filament and actin is a (**thin**/thick) protein filament.
- Myosin head binds to **ATP**, which is the source of energy for muscle movement.
- Myosin binds to actin when  $\text{Ca}^{++}$  enters cell and activates the **cross bridges**.



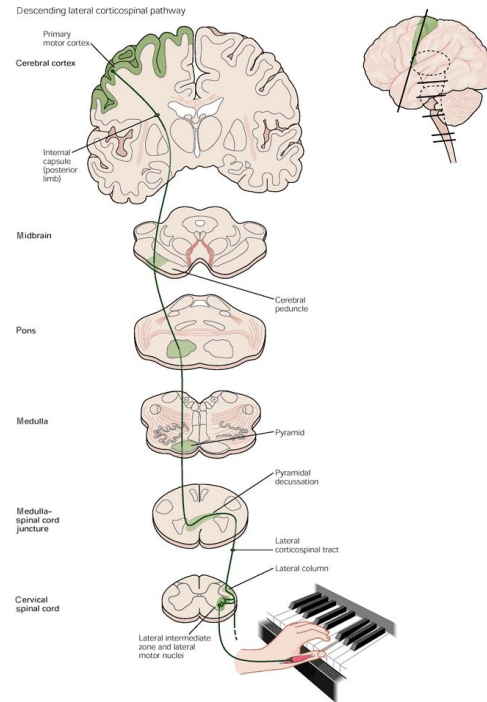
## Describe the corticospinal tract

- Controls (involuntary/voluntary) movement on contralateral side
- (Unmyelinated/myelinated) tract and designed for what?
- Crosses over in pons to synapse on \_\_\_\_\_ nerve to face.



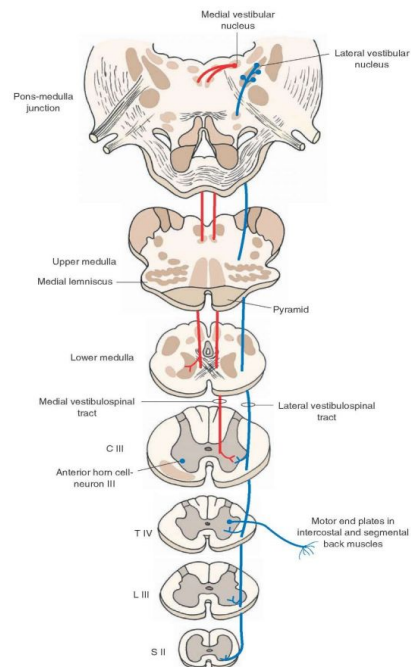
## Describe the corticospinal tract

- Controls (involuntary/**voluntary**) movement on contralateral side
- (Unmyelinated/**Myelinated**) tract and designed for what?
- Crosses over in pons to synapse on **trigeminal** nerve to face.



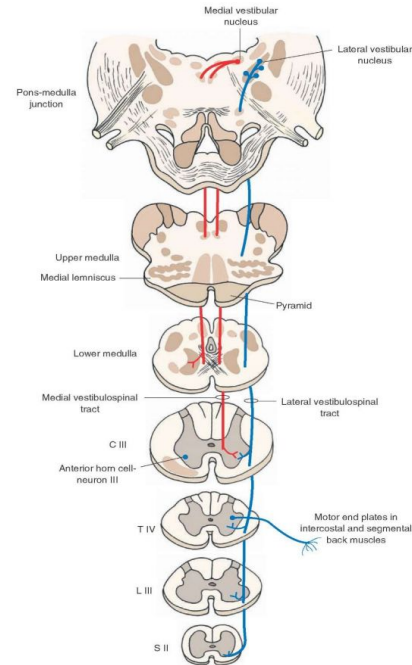
## Describe the ventromedial tracts?

- Bilateral and (ipsi/contra)lateral
- What is an important note about the parts of the body and the movements the ventromedial tracts control?



## Describe the ventromedial tracts?

- Bilateral and (**ipsi**/contra)lateral
- What is an important note about the parts of the body and the movements the ventromedial tracts control? **Primarily controls movements where one side cannot move without the other.**



## Describe the mechanism of Parkinson's disease

- \_\_\_\_\_ axons degenerate from the substantia nigra to striatum.
- What are some symptoms of Parkinson's?
- Globus pallidus is inhibited, meaning what?
- What is used to treat Parkinson's?

## Describe the mechanism of Parkinson's disease

- **Dopaminergic** axons degenerate from the substantia nigra to striatum.
- What are some symptoms of Parkinson's? **Tremors, difficulty in initiating and executing movement, paralysis**
- Globus pallidus is inhibited, meaning what? **Thalamic excitation is decreased**
- What is used to treat Parkinson's? **L-Dopa**

