A close-up photograph of several vibrant pink roses in full bloom, set against a background of green leaves and some blurred blue flowers. The roses are the central focus, with their petals showing detailed texture and color variations from light pink to deeper magenta.

# Physiology of Proprioception in Balance

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**College of Medicine**  
**King Saud University**

# OBJECTIVES

## Pathways of proprioception

At the end of this lecture the student should be able to:-

1-Identify the major sensory pathways

Describe the components, processes and functions of the sensory pathways

2-appreciate the dorsal column system in conscious proprioception (anatomy&functions)

3- describe the pathway of spinocerebellar tract in unconscious proprioception from muscles,tendons,and joints

4-differentiate between sensory and motor ataxia

- **Introduction**
- **Sensory receptors**
- **major sensory pathways**
- **dorsal column system**
- **spinocerebellar tract**
- **sensory and motor ataxia**

# INTRODUCTION

# Organization of the Nervous System

## 2 big initial divisions:

### Central Nervous System

The brain + the spinal cord

The center of integration and control

### Peripheral Nervous System

The nervous system outside of the brain and spinal cord

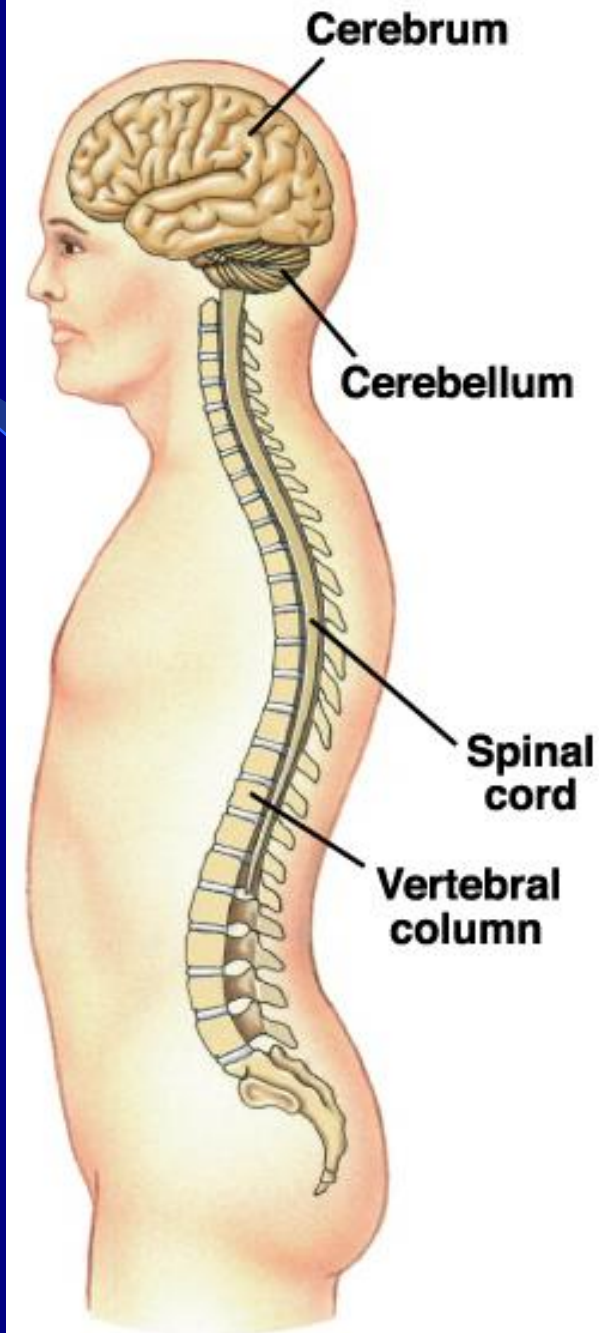
Consists of:

31 Spinal nerves

Carry info to and from the spinal cord

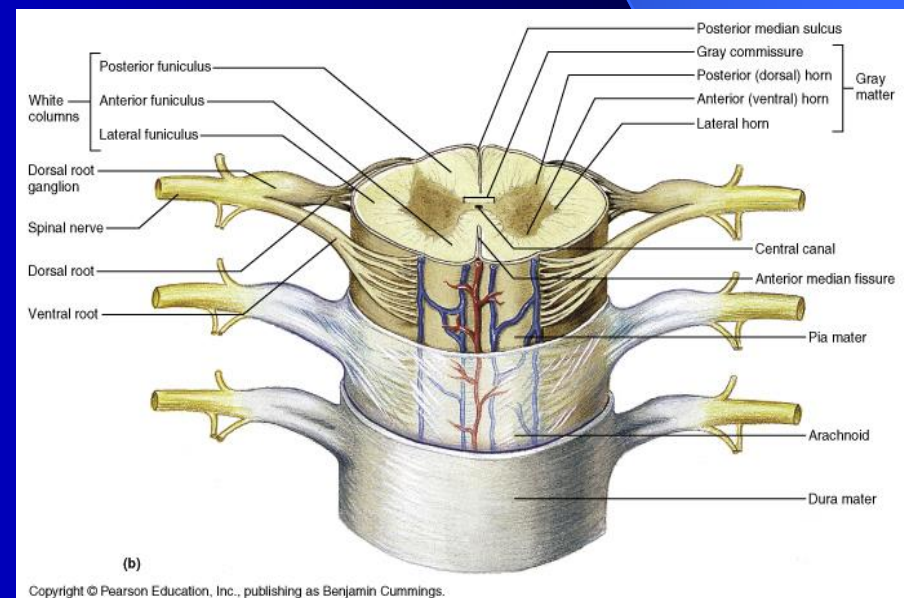
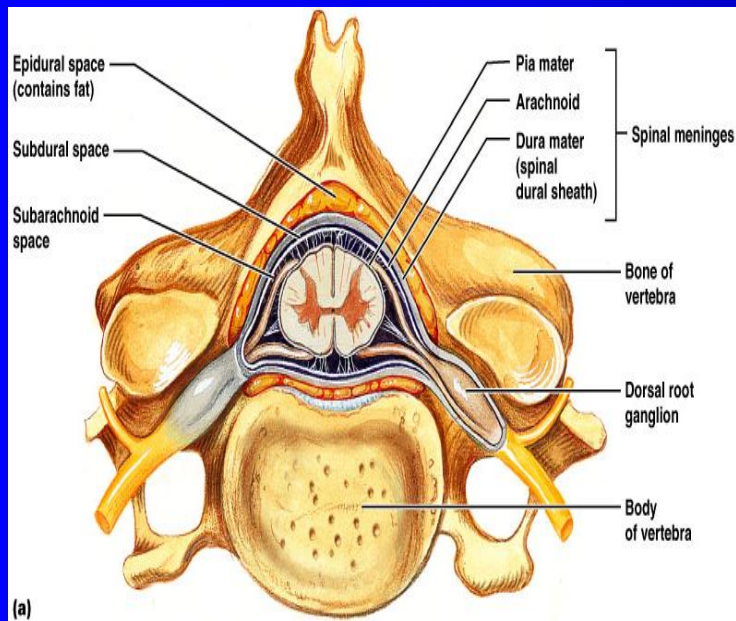
12 Cranial nerves

Carry info to and from the brain



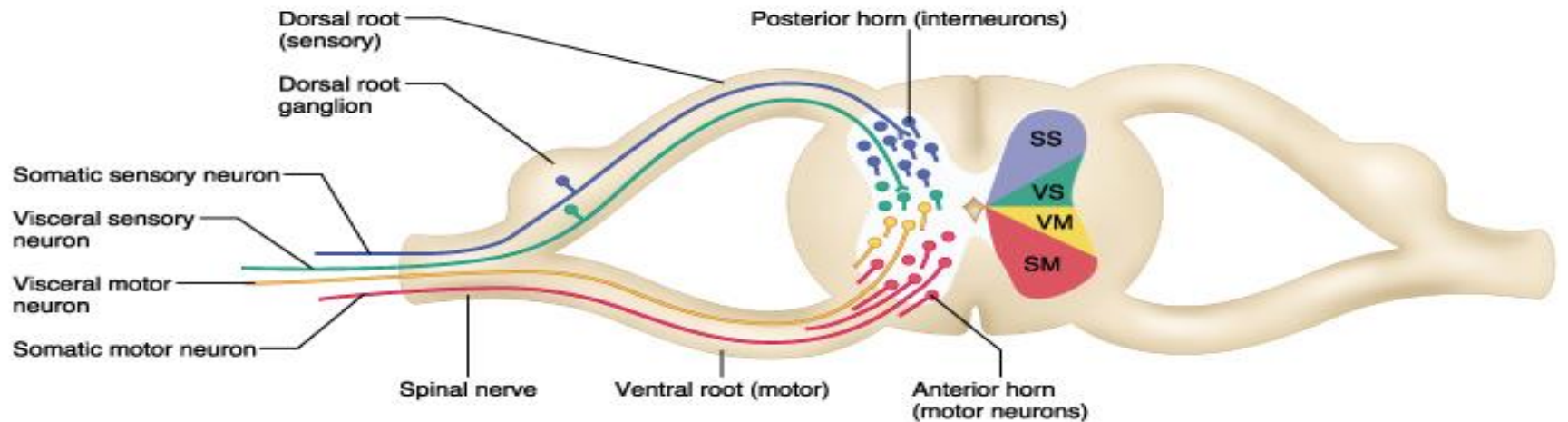
# ● Spinal cord

- A Cross-section view of spinal cord- wider laterlly than anteroposteriorly. In the middle on the dorsal side is a shallow groove called the posterior median sulcus and on the ventral side is the anterior median fissure (deeper).
- center consist of gray matter shaped like a butterfly and there is an opening at the center
- Spinal cord is protected by three layers of meninges. The only difference from the brain is that the dural matter does not attach to bone. The dural matter is surrounded externally by a layer of cushioning fat called epidural space.



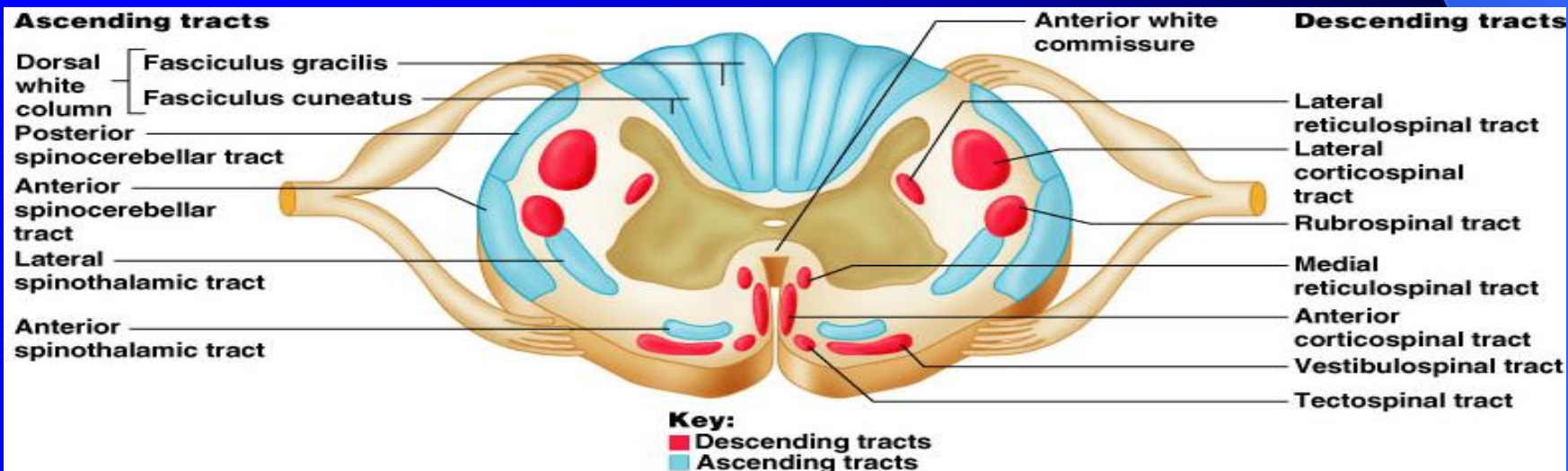
# Gray Matter: Organization

- Dorsal half – sensory roots and ganglia
- Ventral half – motor roots
- Dorsal and ventral roots fuse laterally to form spinal nerves
- Four zones are evident within the gray matter – somatic sensory (SS), visceral sensory (VS), visceral motor (VM), and somatic motor (SM)



# White Matter in the Spinal Cord

- Fibers run in three directions – ascending, descending, and transversely
- Divided into three funiculi (columns) – posterior, lateral, and anterior
- Each funiculus contains several fiber tracks
  - Fiber tract names reveal their origin and destination
  - Fiber tracts are composed of axons with similar functions





- **Introduction**
- **Sensory receptors**
- **major sensory pathways**
- **dorsal column system**
- **spinocerebellar tract**
- **sensory and motor ataxia**

# Sensory Receptors

A decorative graphic element on the right side of the slide, consisting of a blue gradient shape that curves from the top right towards the bottom right, resembling a stylized 'L' or a corner piece.

# Somatic Receptors

- Somatic receptors are specialized structure present at the peripheral terminations of afferent fibers.
- Receptors are detectors and transducers which transduce different form of energy into action potential
- They are found in many parts of the body including the skin (cutaneous receptors), skeletal muscles, bones and joints (proprioceptors)
- They differ from specific receptors that mediate the special senses of vision, hearing, smell, taste and equilibrium.

# Classification of Sensory Receptors-1

A/Based on their location (Sherrington 1906):

- **① Exteroceptors:** concerned with the external environment
  - Found on the surface of the body
  - E.g. touch and temperature receptors
- **② Interoceptors:** concerned with the internal environment e.g. chemoreceptors, osmoreceptors.
- **③ Proprioceptors:** concerned with position of the body in the space.
  - Are found in joint, tendons and muscles.

# Classification of Sensory Receptors-2

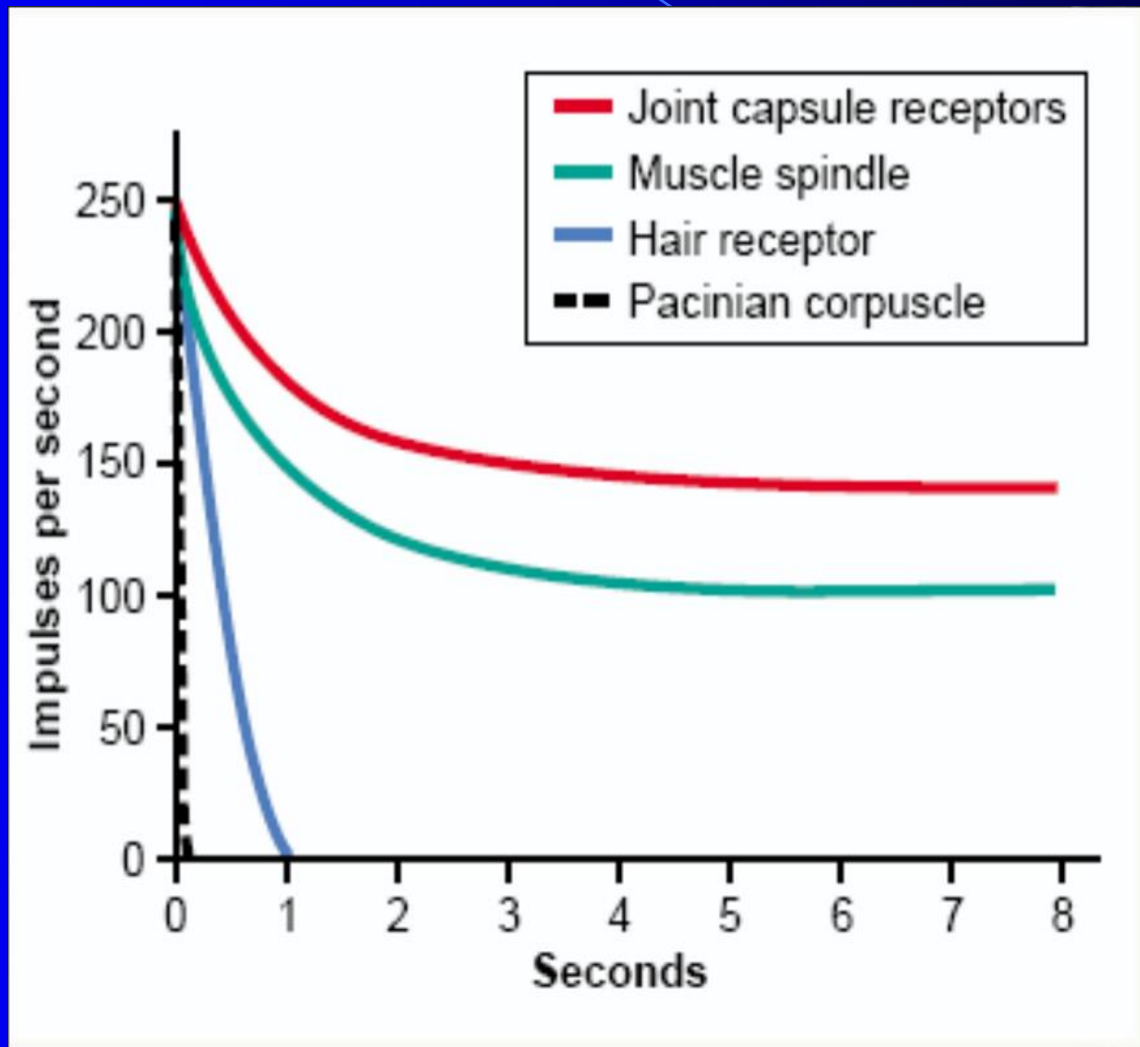
## B/Based on their adequate stimulus

- ❖ *(Adequate stimulus is the particular form of energy to which the receptors is most sensitive)*
- **Mechanoreceptors** :which detect mechanical compression or stretching of the receptor or of tissues adjacent to the receptor eg **proprioceptors**
- **Thermoreceptors** which detect changes in temperature, some receptors detecting cold and others warmth.
- **Chemoreceptors**, which detect taste in the mouth, smell in the nose, oxygen level in the arterial blood, osmolality of the body fluids, carbon dioxide concentration, and perhaps other factors that make up the chemistry of the body. Eg chemo R in carotid bodies
- **Electromagnetic receptors**, which detect light on the retina of the eye eg rods and cones.
- **Nociceptors** (pain receptors) , which detect damage occurring in the tissues, whether physical damage or chemical damage eg **free nerve endings**

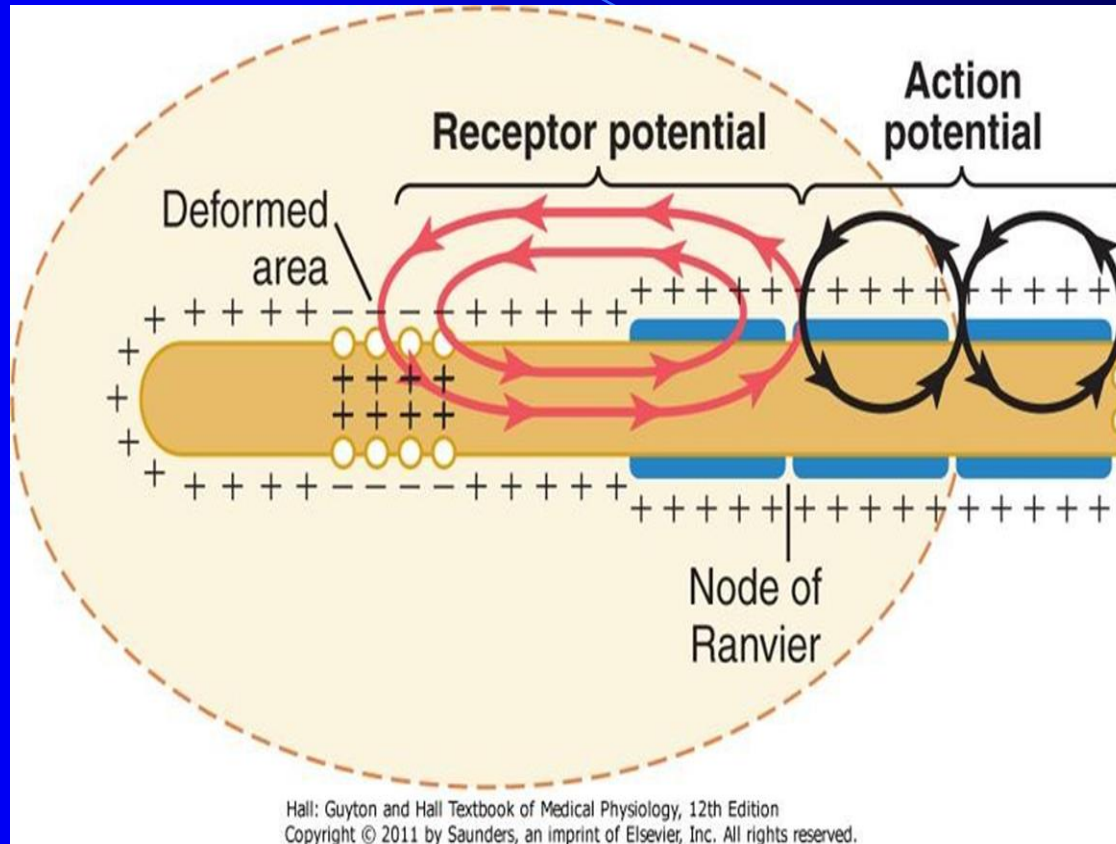
# Classification of Sensory Receptors-3

## C. Based on their speed of adaptation

- Adaptation means when a continuous sensory stimulus is applied, the receptor responds at a high impulse rate at first and then at a progressively slower rate until finally the rate of action potentials decreases to very few or often to none at all.
- Accordingly receptors can be classified into:
- **Slowly adapting (SA) or tonic receptors:**
  - Muscle spindle, joint receptors, baroreceptors .
  - Pain receptors do not adapt at all.
- **Rapidly adapting (RA) or phasic receptors:**
- eg meissner's corpuscles(touch), pacinian corpuscles(vibration)



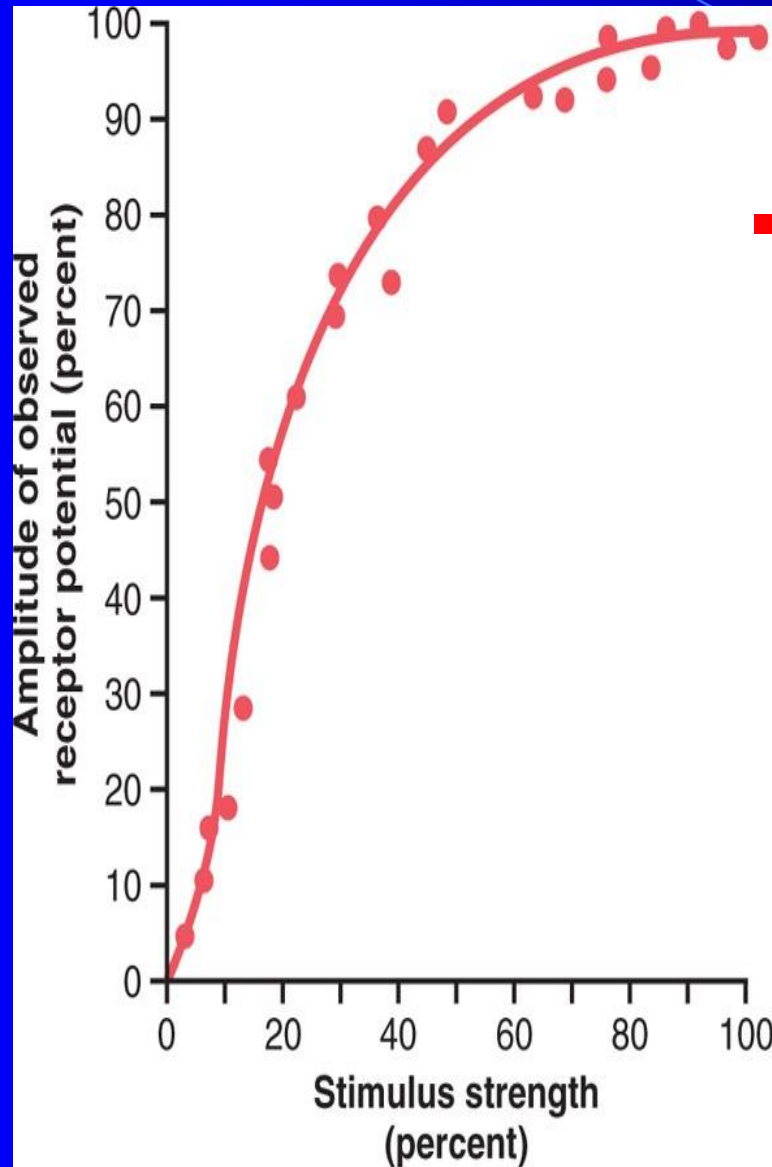
# Activation of Sensory Receptors: Generation of Receptor Potential (RP)



Stimuli (mechanical, thermal, chemical) cause deformation in the sensory receptors  
This causes influx of positive ions and generation of RP

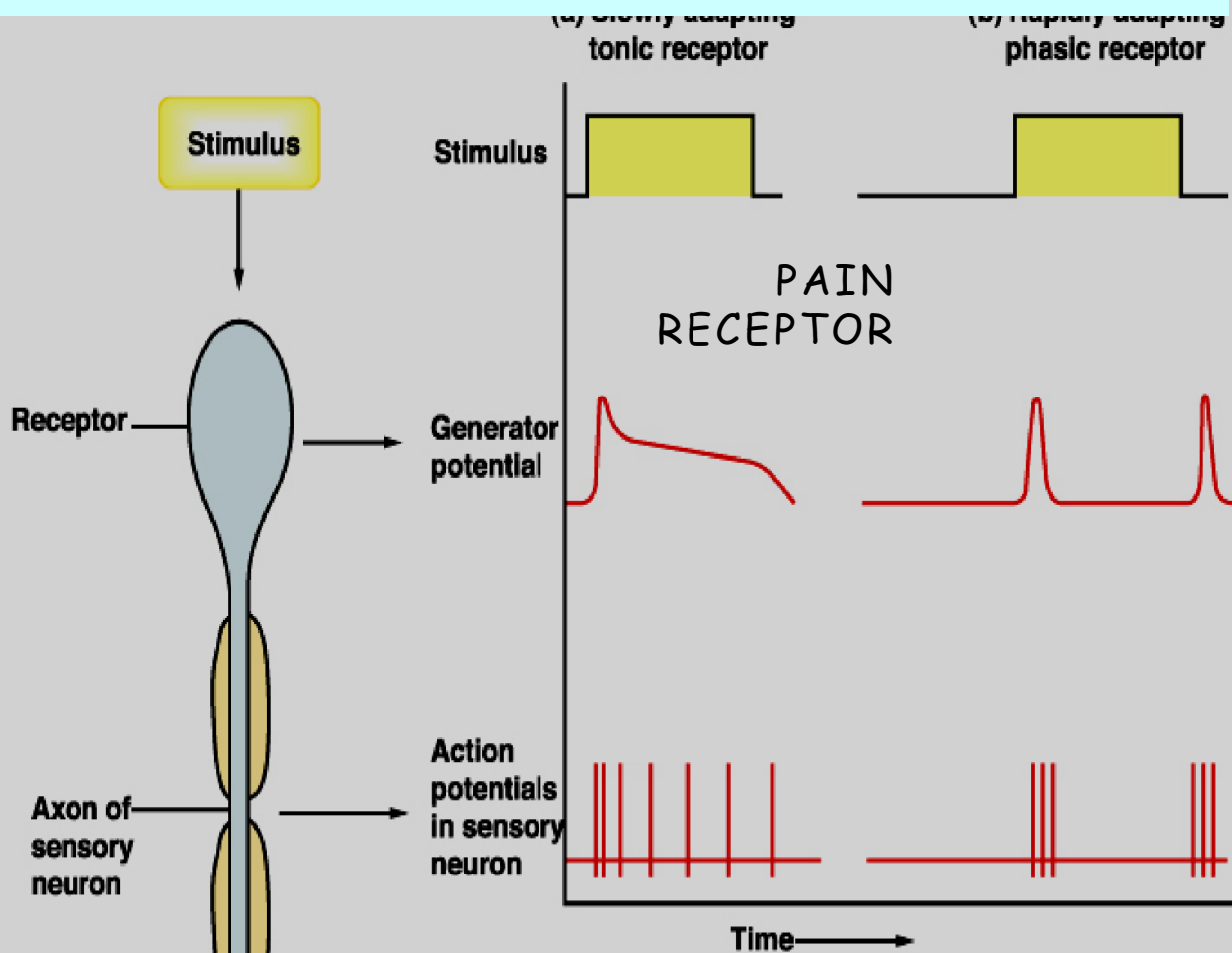


# Relation Between Stimulus Strength & Receptor Potential Amplitude



- Receptor potential is directly related to stimulus strength

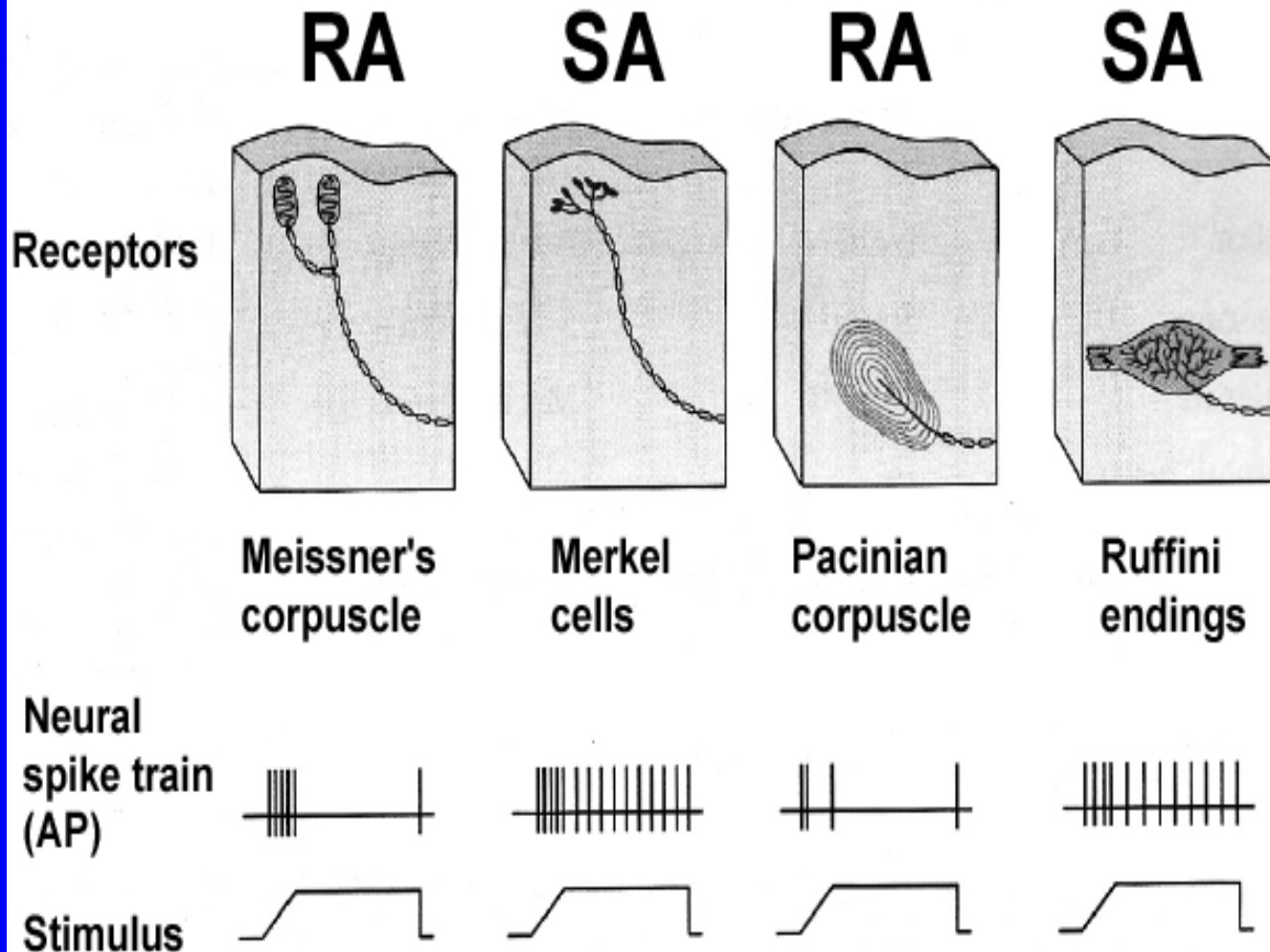
# Generation of a Receptor Potential



Slowly adapting receptors detect **presence** of stimulus and its **continuous strength**

Rapidly adapting receptors detect **change** in stimulus

# Examples of RA and SA Receptors



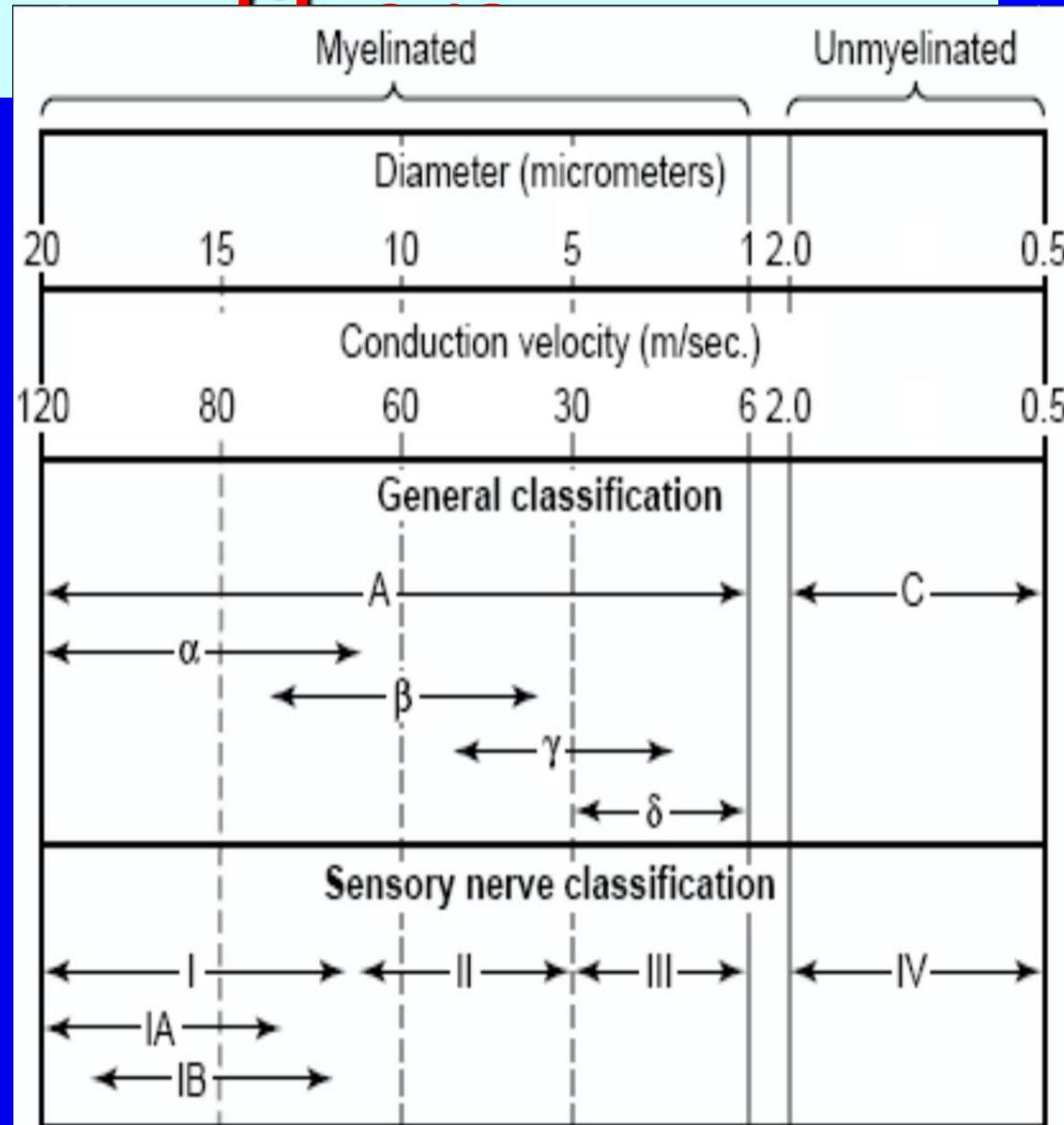
**Muscle spindles & nociceptors are other examples of SA receptors**

# What Are the Stimulus Features That Are Mediated by Sensory Receptors?

Sensory receptors mediate 4 features of a stimulus:

- **Modality:** is what we perceive after a stimulus
  - Many sensory modalities: vision, hearing, smell, taste, touch and temperature
  - Each modality has many sub-modalities (e.g. taste can be sweet, bitter, sour, salty), Temperature sub-modalities: cold and heat
- **Intensity:** depends on the stimulus strength and is encoded by action potential frequency.
- **Location:** the site on the body or space where the stimulus originated.
- **Duration:** time from onset to offset of a stimulus.
  - If persists for long time, the perceived intensity diminishes (adaptation)

# Classification of Nerve



**Myelinated**  
**(A-fiber)**

**A $\alpha$**  (thickly myelinated)

**A $\beta$**  (intermediate m.)

**A $\delta$**  (thinly myelinated)

**Unmyelinated**  
**(C-fiber)**

**TABLE 4-1** Types of mammalian nerve fibers.

Fiber Type	Function	Fiber Diameter ( $\mu\text{m}$ )	Conduction Velocity (m/s)	Spike Duration (ms)	Absolute Refractory Period (ms)
A $\alpha$	Proprioception; somatic motor	12–20	70–120		
A $\beta$	Touch, pressure	5–12	30–70	0.4–0.5	0.4–1
A $\gamma$	Motor to muscle spindles	3–6	15–30		
A $\delta$	Pain, temperature	2–5	12–30		
B	Preganglionic autonomic	<3	3–15	1.2	1.2
C, Dorsal root	Pain, temperature	0.4–1.2	0.5–2	2	2
C, Sympathetic	Postganglionic sympathetic	0.3–1.3	0.7–2.3	2	2

**TABLE 4-2** Numerical classification of sensory nerve fibers.

Number	Origin	Fiber Type
Ia	Muscle spindle, annulo-spiral ending	A $\alpha$
Ib	Golgi tendon organ	A $\alpha$
II	Muscle spindle, flower-spray ending; touch, pressure	A $\beta$
III	Pain and cold receptors; some touch receptors	A $\delta$
IV	Pain, temperature, and other receptors	Dorsal root C

# Ascending Sensory Tracts

- There are several ascending sensory systems
- Each system carries different types of sensations or MODALITIES: touch, proprioception, pain, temperature, ... etc.,
- Main ascending sensory pathways
- ① Spinothalamic pathway: carries signals of pain, temperature, deep pressure, and crude touch.
- ② Dorsal column pathway: carries signals of fine touch, pressure, vibration, and proprioception.
- ③ Posterior (dorsal) spinocerebellar pathway
- ④ Anterior (ventral) spinocerebellar pathway
- The latter pathways (3 & 4) carry subconscious proprioception.
- Objective: Identify the major sensory receptors & pathways



# What is Proprioception ?

- Proprioception stems from the Latin word proprius which means "one's own" or "individual"
- It is the sense of one's own body position
- It is also called proprioceptive/position sense
- It is the awareness of body position and of movements of body parts
- It can be divided into:
  - **Static proprioception:** conscious perception of the orientation of the different parts of the body with respect to one another,
  - **Dynamic proprioception:** rate of movement sense (also called kinesthesia)

# Types of Proprioception

- There are two types of proprioception:

- ① **Conscious proprioception:**

- It reaches the level of sensory cerebral cortex (cerebrum) via the dorsal column-medial lemniscus pathway

- ② **Unconscious proprioception:**

is communicated to the cerebellum primarily via:

- The dorsal spino-cerebellar tract (dSCT)
- The ventral spino-cerebellar tract (vSCT)
  - *These are main ascending sensory pathways for proprioception*

# Role of Proprioception

Proprioception informs us about:

- The location of a body part in relation to other parts
- The rate of movement of a body part when it is moving
- The degree to which our muscles are being contracted or stretched
- The amount of tension created in our tendons
- The head orientation in relation to the ground and in response to movement
- Proprioceptive information is carried from periphery to the CNS by proprioceptors and other somatic receptors

# Types of Proprioceptors

## ① Muscle spindles

Detect how much a muscle is stretched \*

## ② Golgi tendon organs

Detect tension of a muscle on its tendon \*

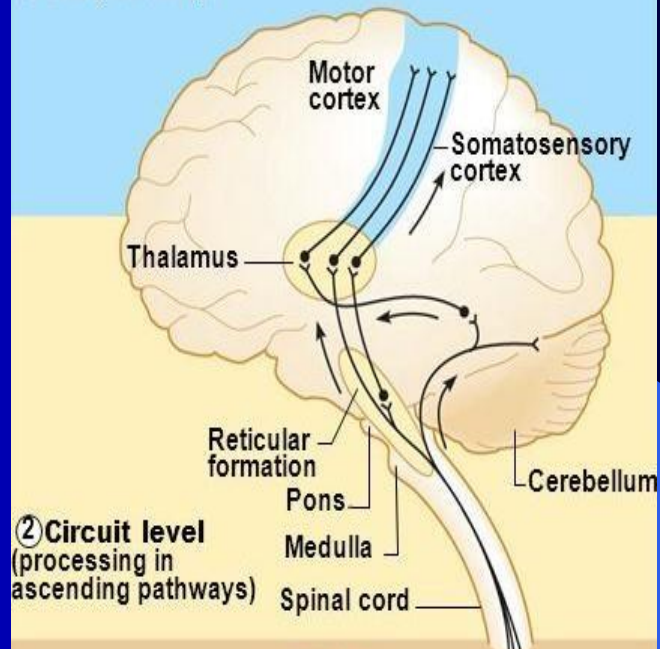
Provide information about the strength of contraction & tension \*

## ③ Joint Kinesthetic receptors

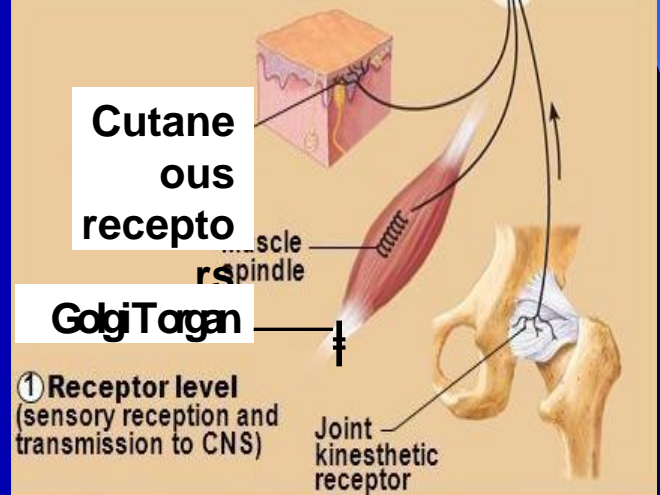
Are mechanoreceptors in the joint capsules; they detect

**Cutaneous & deep receptors also contribute to proprioception**

③ Perceptual level (processing in cortical sensory centers)



② Circuit level (processing in ascending pathways)



① Receptor level (sensory reception and transmission to CNS)

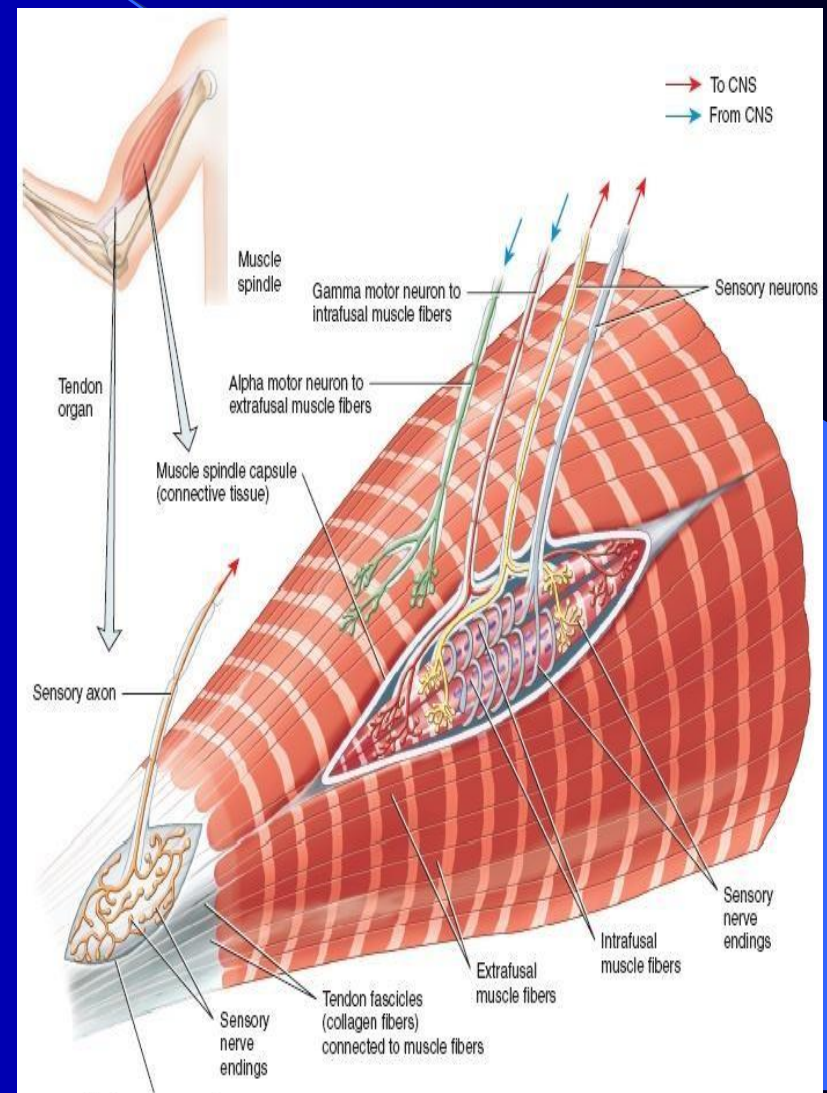
# Muscle Spindles & Golgi Tendon Organs

## ① Muscle spindles

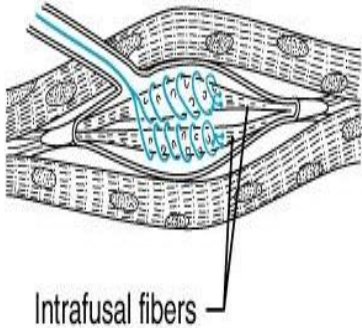
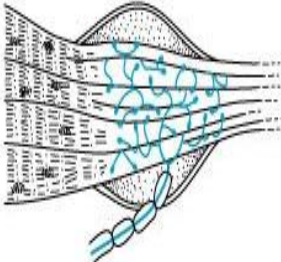
- They detect changes in the length of muscle.
- They convey length information to the CNS via group I and II afferent neurons
- This information is important for determining the position of body part

## ② Golgi tendon organ

- They detect changes in muscle tension



## General Sensory Receptors Classified by Structure and Function *(continued)*

Structural Class	Illustration	Functional Class According to Location (L) and Stimulus Type (S)	Body Location
<b>PROPRIOCEPTORS</b>			
Muscle spindles	 <p>Intrafusal fibers</p>	L: Proprioceptors S: Mechanoreceptors (muscle stretch)	Skeletal muscles, particularly those of the extremities
Golgi tendon organs		L: Proprioceptors S: Mechanoreceptors (tendon stretch)	Tendons
Joint kinesthetic receptors (Pacini and Ruffini endings, free nerve endings, and receptors resembling Golgi tendon organs)		L: Proprioceptors S: Mechanoreceptors and nociceptors	Joint capsules of synovial joints

- **Introduction**
- **Sensory receptors**
- **major sensory pathways**
- **dorsal column system**
- **spinocerebellar tract**
- **sensory and motor ataxia**

# An Overview of Sensory Pathways and the Somatic Nervous System

## Neural pathways

- Afferent pathways

- Sensory information coming from the sensory receptors through peripheral nerves to the spinal cord and to the brain .

- Efferent pathways

- Motor commands coming from the brain and spinal cord, through peripheral nerves to effector organs .



# Sensory pathways

The background is a dark blue gradient. A thin, light blue curved line starts from the top left and arcs across the top. On the right side, there is a larger, semi-transparent blue shape that looks like a stylized arrow or a corner element pointing towards the center.

# Sensory pathways

- Sensory systems allow us to detect, analyze and respond to our environment
- “ascending pathways”
- Carry information from sensory receptors to the brain
- Conscious: reach cerebral cortex
- Unconscious: do not reach cerebral cortex
- Sensations from body reach the opposite side of the brain

- **Spinal tracts**- These are known as sensory and motor pathways consisting of multineuron pathways connecting the CNS to the PNS. At some point most pathways crossover (decussate),

- A. **Ascending (sensory) Pathways** :-

- 1. **Dorsal column pathway**- carries signal of fine touch, pressure, vibration, stereognosis and **conscious proprioception**, ascends up dorsal white column in fasciculus gracilis or cutaneatus to medulla oblongata to the thalamus to primary somatosensory cortex (post central gyrus).

- 2. **Posterior and anterior spinocerebellar pathways**- carry **subconscious proprioception**. Dorsal gray horn- to lateral column- to medulla oblongata- to pons – to cerebellum.

- 3. **Spinothalamic pathway**- carries signals of pain, temperature, deep pressure, and coarse touch. From posterior gray horn decussate into lateral and anterior funiculi up to the thalamus to primary somatosensory cortex (postcentral gyrus).

# ANTEROLATERAL SYSTEM

## Ventral & lateral spinothalamic tracts

- Pain
- Thermal sensations, (warmth & cold)
- Crude touch and pressure sensations capable only of crude localizing ability on the surface of the body
- Tickle and itch sensations
- Sexual sensations

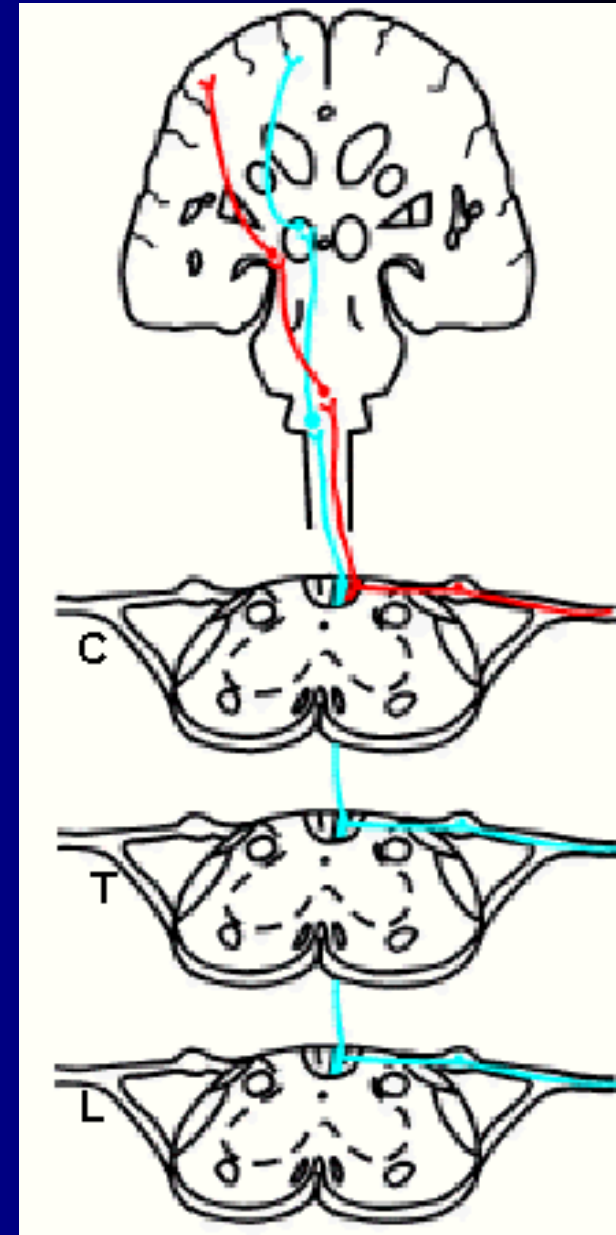
# Sensory pathways: 3 neurons

- 1<sup>st</sup>: enters spinal cord from periphery
- 2<sup>nd</sup>: crosses over (decussates), ascends  
in spinal cord to thalamus
- 3<sup>rd</sup>: projects to somatosensory cortex

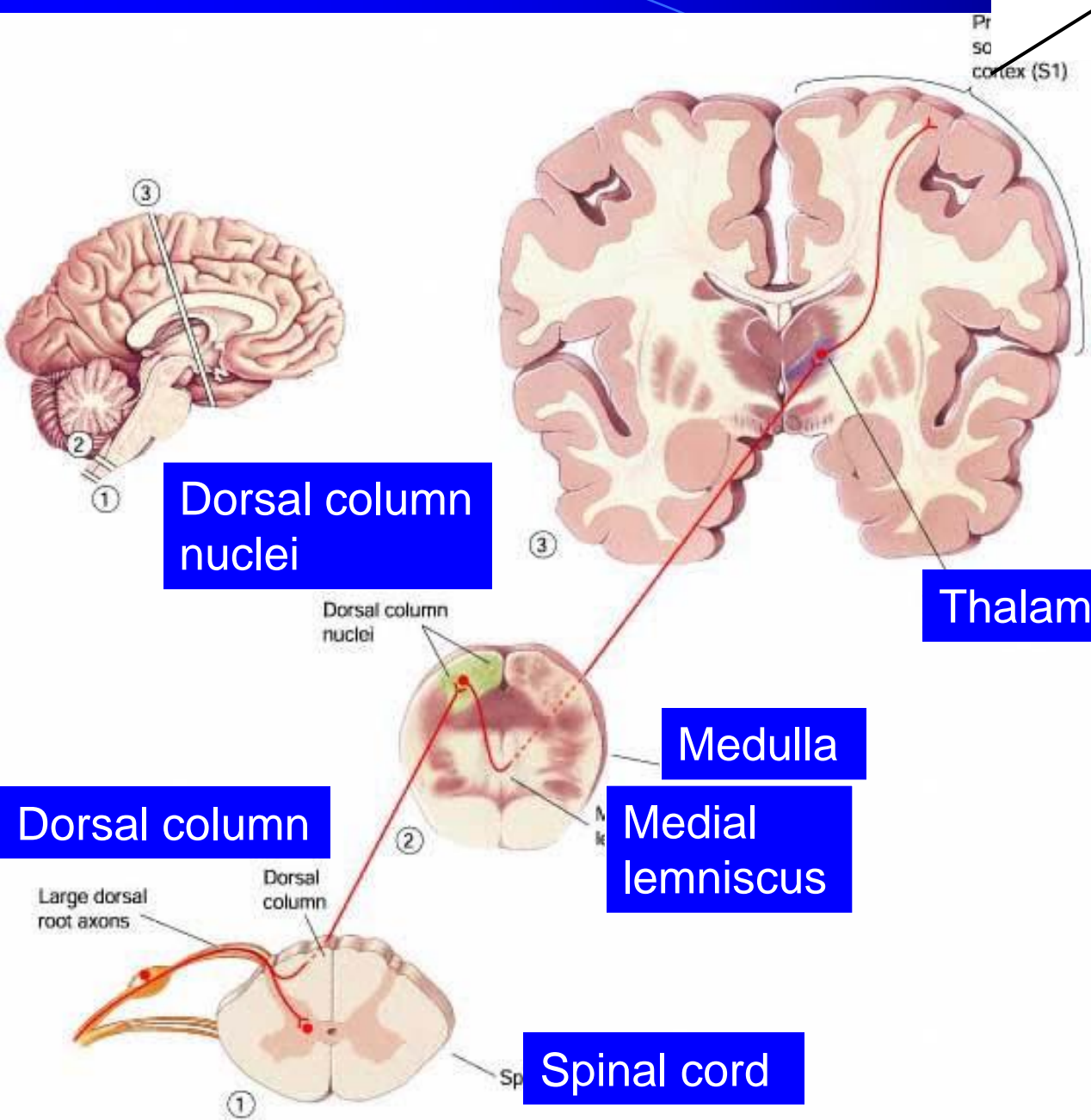
- **Introduction**
- **Sensory receptors**
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- **spinocerebellar tract**
- **sensory and motor ataxia**

# Dorsal column pathway

- Carries fine touch, two point discrimination, pressure, vibration, stereognosis and conscious proprioception signals
- 1<sup>st</sup> neuron enters spinal cord through dorsal root; ascends to medulla (brain stem)
- 2<sup>nd</sup> neuron crosses over in medulla; ascends to thalamus
- 3<sup>rd</sup> neuron projects to somatosensory cortex



# Dorsal column pathway



Primary somatosensory cortex (S1) in parietal lobe

Dorsal column nuclei

Thalamus

Dorsal column nuclei

Medulla

Medial lemniscus

Dorsal column

Large dorsal root axons

Dorsal column

Spinal cord

Pr  
so  
cortex (S1)

3

2

1



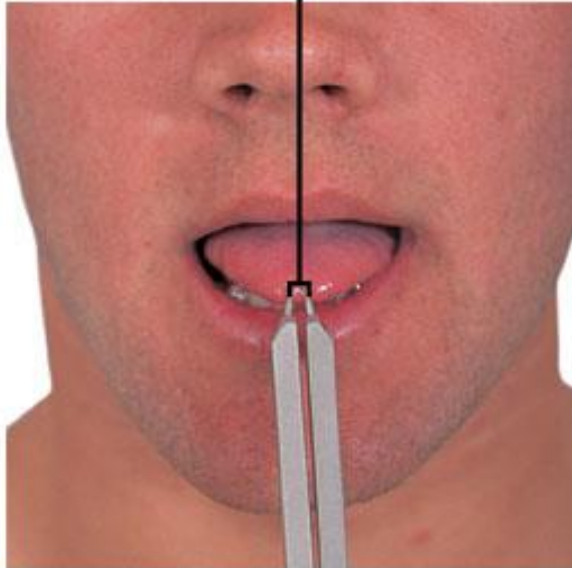
# Dorsal Column–Medial Lemniscal System

- Touch sensations requiring a high degree of localization and high intensity of discrimination (i.e. fine)
- Rapidly repetitive sensation such as vibration
- Joints Position sensations (Proprioception)
- Pressure sensations characterized by high intensity discrimination (i.e. fine touch)

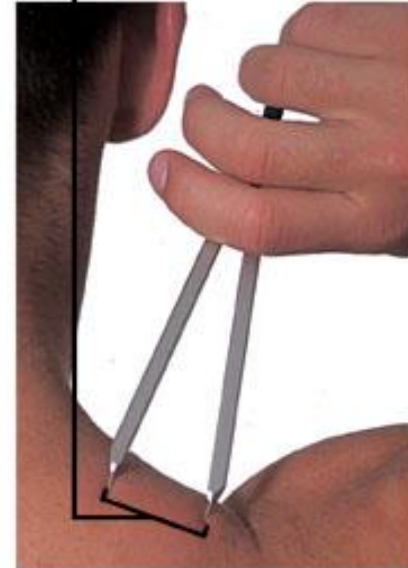
# Two-Point Discrimination

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**2 mm**



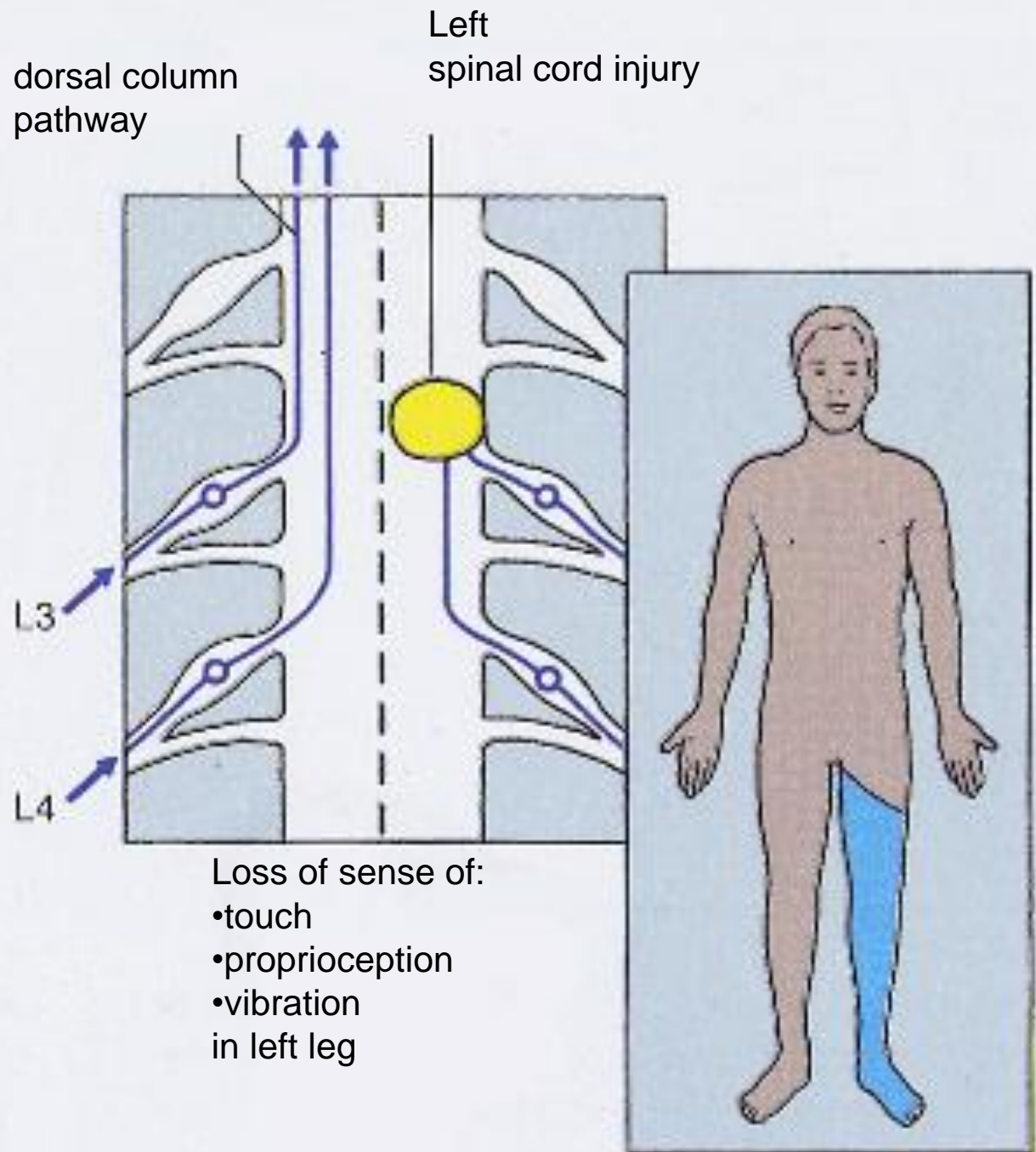
**64 mm**



**4 mm**



# Dorsal column damage



# Dorsal column damage

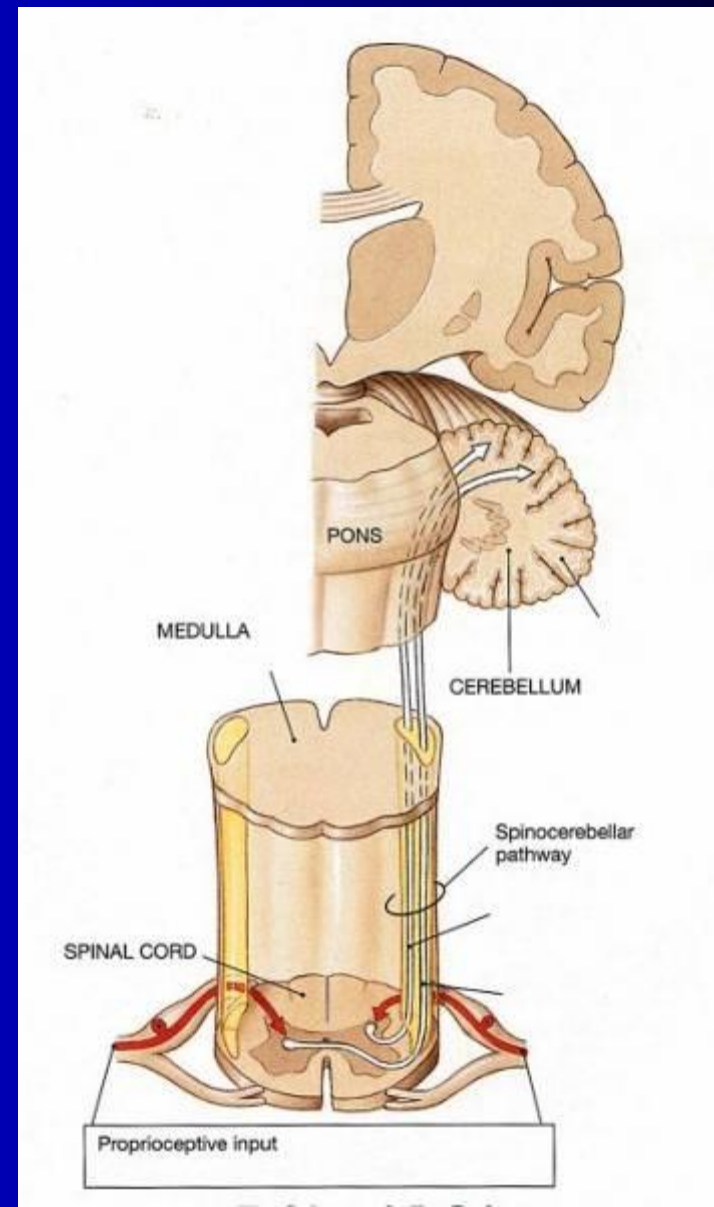
- Sensory ataxia
- Patient staggers; cannot perceive position or movement of legs
- Visual clues help movement



- Introduction
- Sensory receptors
- major sensory pathways
- dorsal column system
- **spinocerebellar tract**
- sensory and motor ataxia

# Spinocerebellar pathway

- Carries unconscious proprioception signals
- Receptors in muscles & joints
- 1<sup>st</sup> neuron: enters spinal cord through dorsal root
- 2<sup>nd</sup> neuron: ascends to cerebellum
- No 3<sup>rd</sup> neuron to cortex, hence **unconscious**




# Spinocerebellar tract damage

- Cerebellar ataxia
- Clumsy movements
- Incoordination of the limbs (intention tremor)
- Wide-based, reeling gait (ataxia)
- Alcoholic intoxication produces similar effects!

- Introduction
- Sensory receptors
- major sensory pathways
- dorsal column system
- spinocerebellar tract
- **sensory and motor ataxia**





Motor  
&  
Sensory  
Ataxia

# Ataxia and Gait Disturbances

- Pathophysiology
  - Result from any condition that affects the central and peripheral nervous systems
  
  - Ataxia: Types
    - Motor ataxia
    - Sensory ataxia

# Ataxia and Gait Disturbances

- Motor Ataxia

- Caused by cerebellar disorders

- Intact sensory receptors and afferent pathways
- Integration of proprioception is faulty
- Midline cerebellar lesions cause truncal ataxia
- Lateral cerebellar lesions cause limb ataxia
- Thalamic infarcts may cause contra lateral ataxia with sensory loss
- N.B cerebellar ataxia will discussed later with cerebellum lecture.

# Ataxia and Gait Disturbances

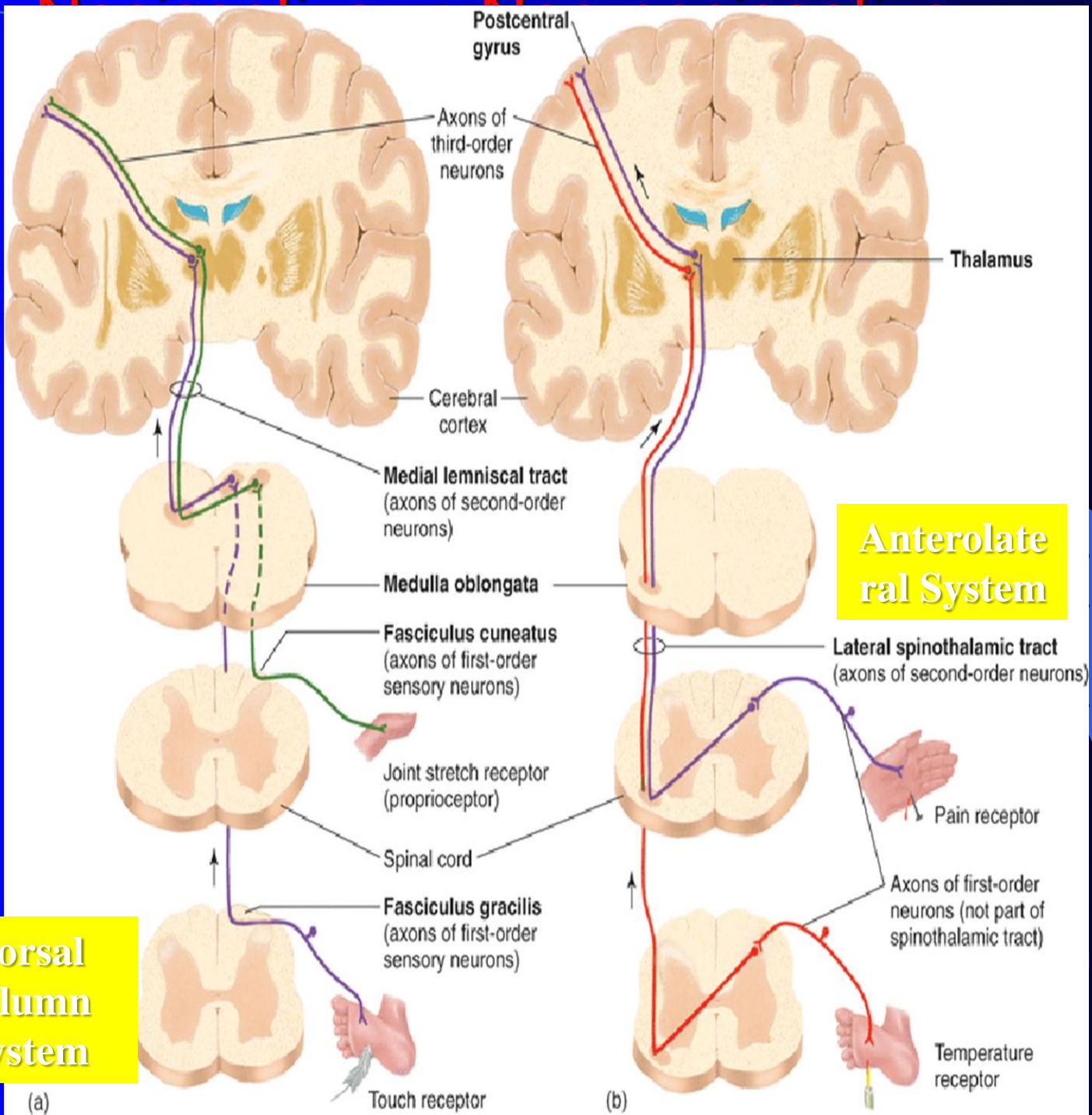
- Sensory Ataxia

- Failure of proprioceptive information to the CNS
- May be due to disorders of spinal cord or peripheral nerves
- Can be compensated for by visual inputs

Thank you

# Extra informations

A decorative graphic element consisting of a light blue arc that starts at the top left and curves towards the bottom right. A darker blue, semi-transparent shape follows the curve of the arc, extending from the top right towards the bottom right corner of the slide.



**Dorsal column System**

**Anterolateral System**

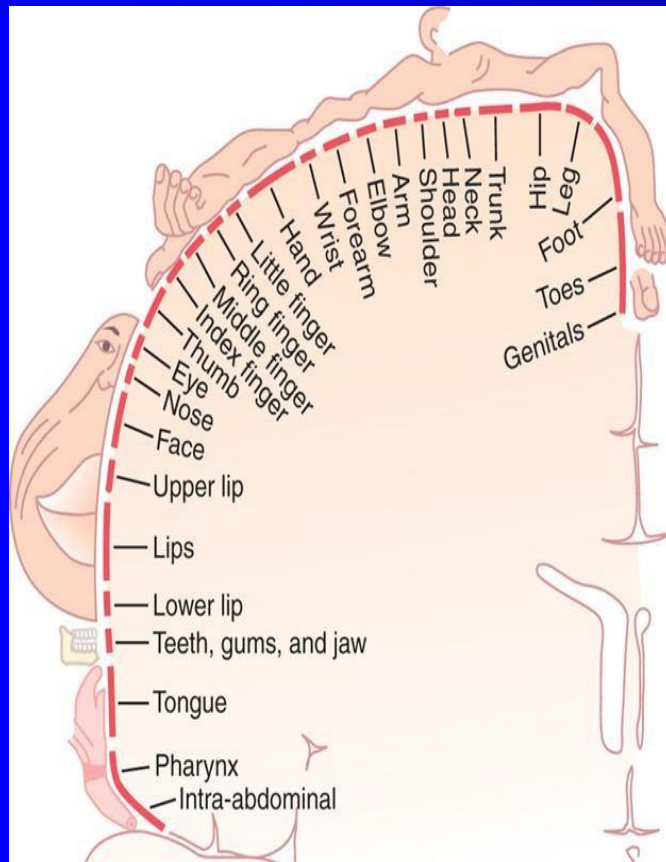
(a)

(b)

# Sensory Homunculus

## (Little Man)

- Body is represented upside-down, with large representation of hands & lips
- The extent of representation is proportional to the **density of sensory receptors**





# Dorsal column damage

- Sensory ataxia
- Patient staggers; cannot perceive position or movement of legs
- Visual clues help movement

Positive Romberg test The test • depends on the integrity of proprioception from the joints of the legs



# The Dorsal & Ventral Spinocerebellar Tracts

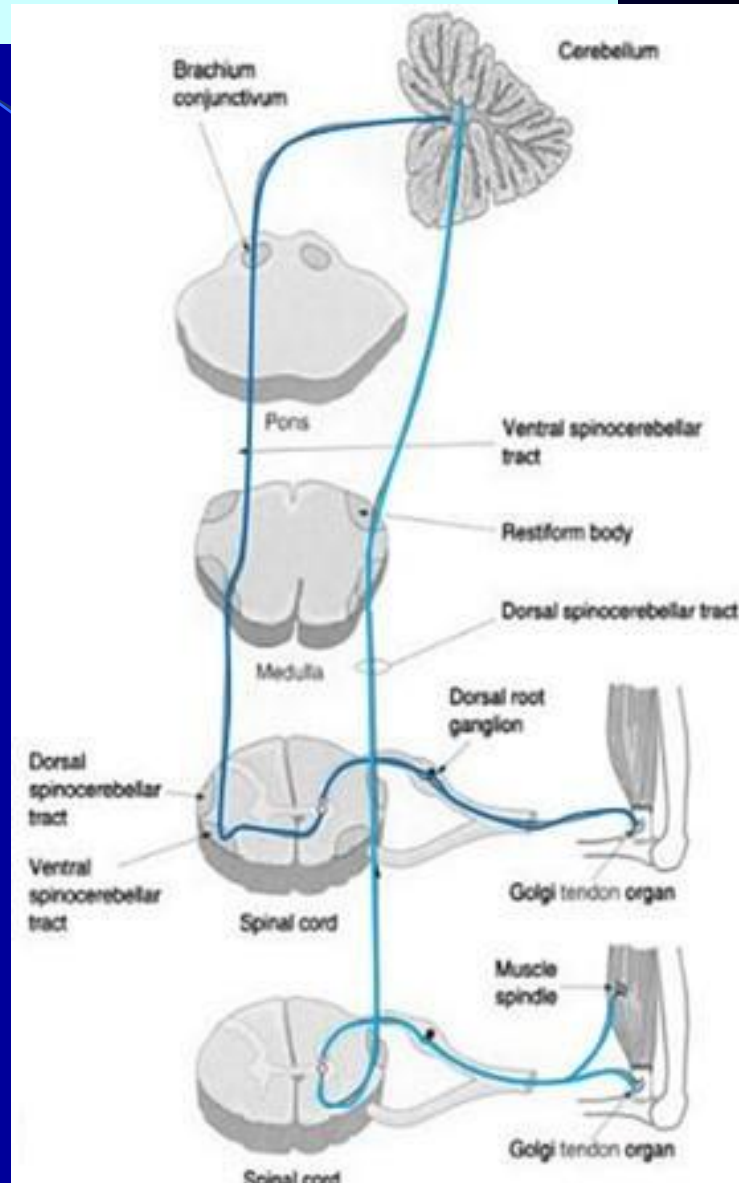
- They carry subconscious proprioception signals

## 1 The Dorsal Spinocerebellar tract (dSCT)

- Carry signals directly to cerebellum at a speed of up to 120 m/s mainly from muscle spindles, but also from GTO, skin receptors & joint receptors
- Enter cerebellum through inferior cerebellar peduncle
- Terminate in vermis & intermediate zone

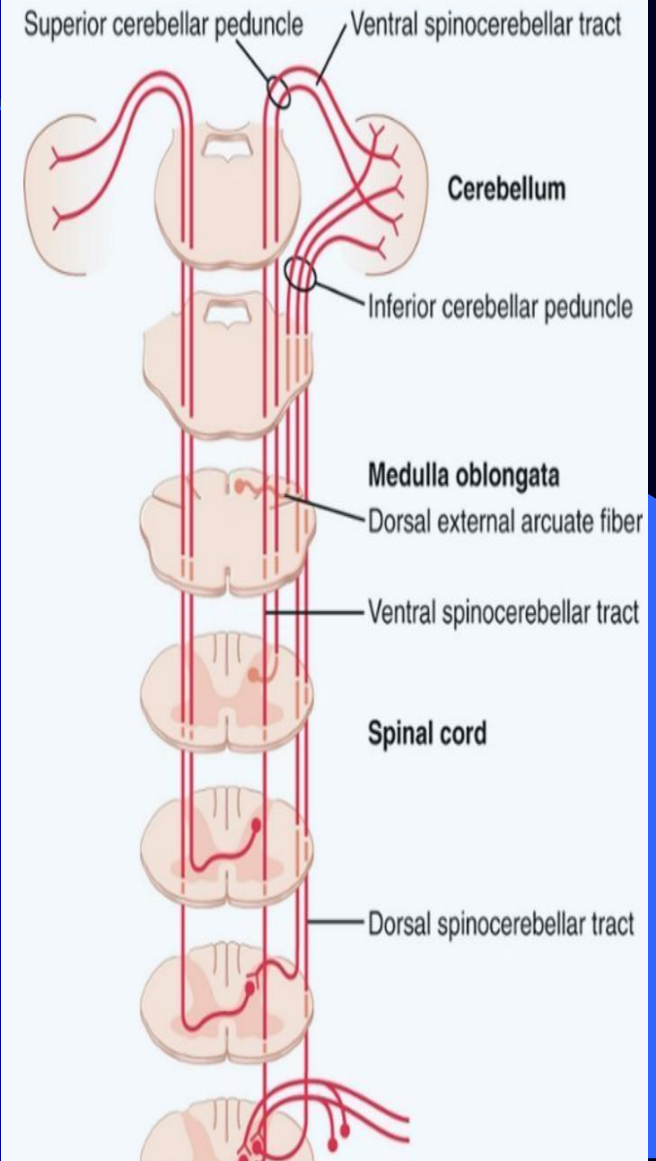
### Function of dSCT:

- informs the cerebellum about:
  - Muscle length and contraction
  - Degree of tension on tendons
  - Position and rate movement of parts of body.
  - Forces acting on the body surfaces



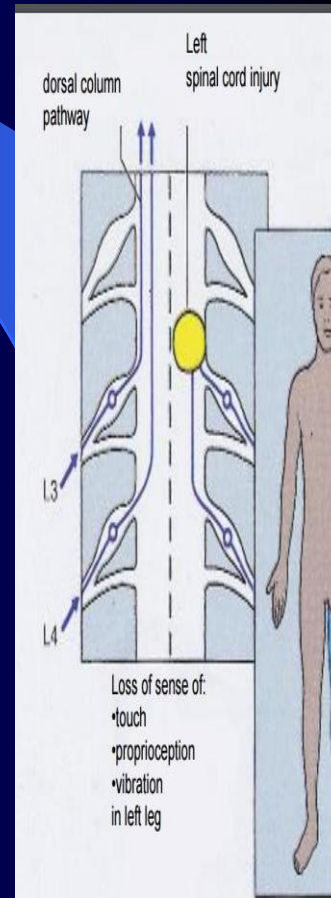
# The Dorsal & Ventral Spinocerebellar Tracts

- **The Ventral Spinocerebellar tract (vSCT):**
- Carry some signals from periphery (mainly from Golgi tendon organs) directly to cerebellum, but excited mainly by descending motor signals from brain (corticospinal & rubrospinal tracts) and from the spinal cord itself
- Enter cerebellum through superior cerebellar peduncle and terminate on both sides of cerebellum
- **Function of vSCT:**
- informs the cerebellum about:
- Which motor signals have arrived to the spinal cord.



# Ataxia and Gait Disturbances-1

- **Ataxia:**
- inability to coordinate voluntary muscular movements that is due to nerve damage (CNS or PNS) and not due to muscle weakness (called also incoordination)
- Types of Ataxia: ① Sensory ataxia ② Motor ataxia
- Pathophysiology of sensory ataxia:
  - PNS lesions (e.g. polyneuropathy)
    - injury to sensory receptors and afferent neurons
  - Dorsal column lesion
    - Loss of proprioception, vibration and touch
    - Ataxia is made worse in the dark or no vision
  - Lesion in thalamus & sensory cortex
  - Romberg's test. Ask the patient to close the eyes while standing with feet together.
  - The affected patient becomes unstable (+ Romberg's test)

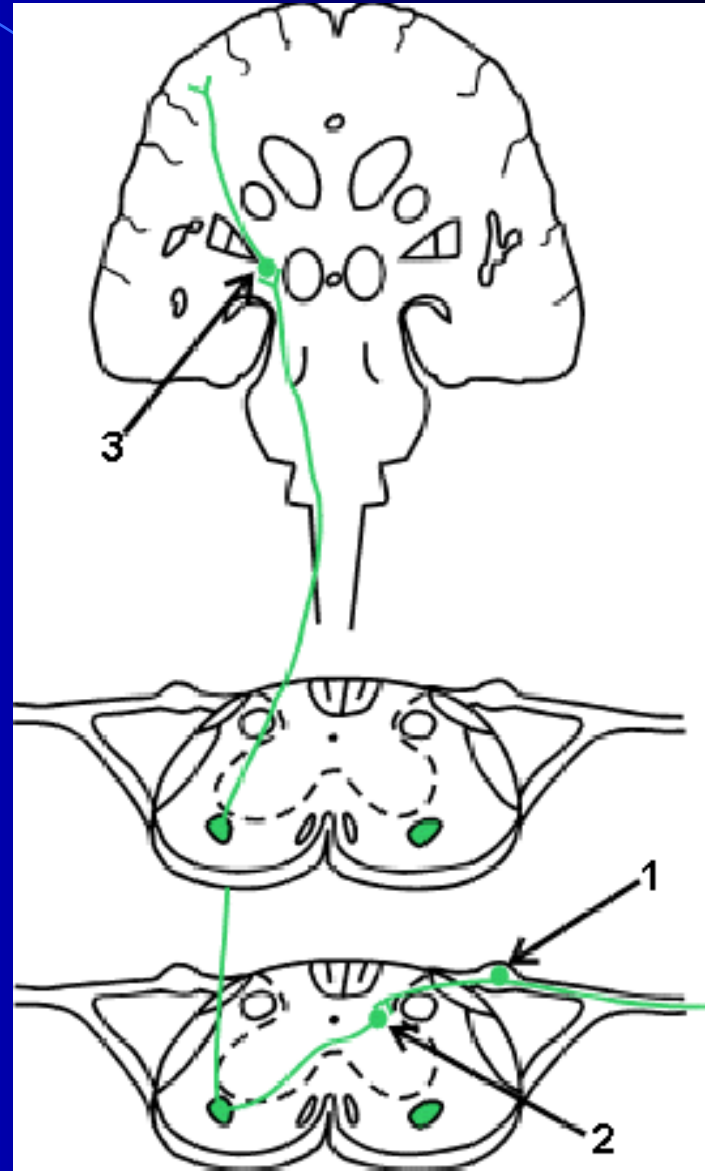


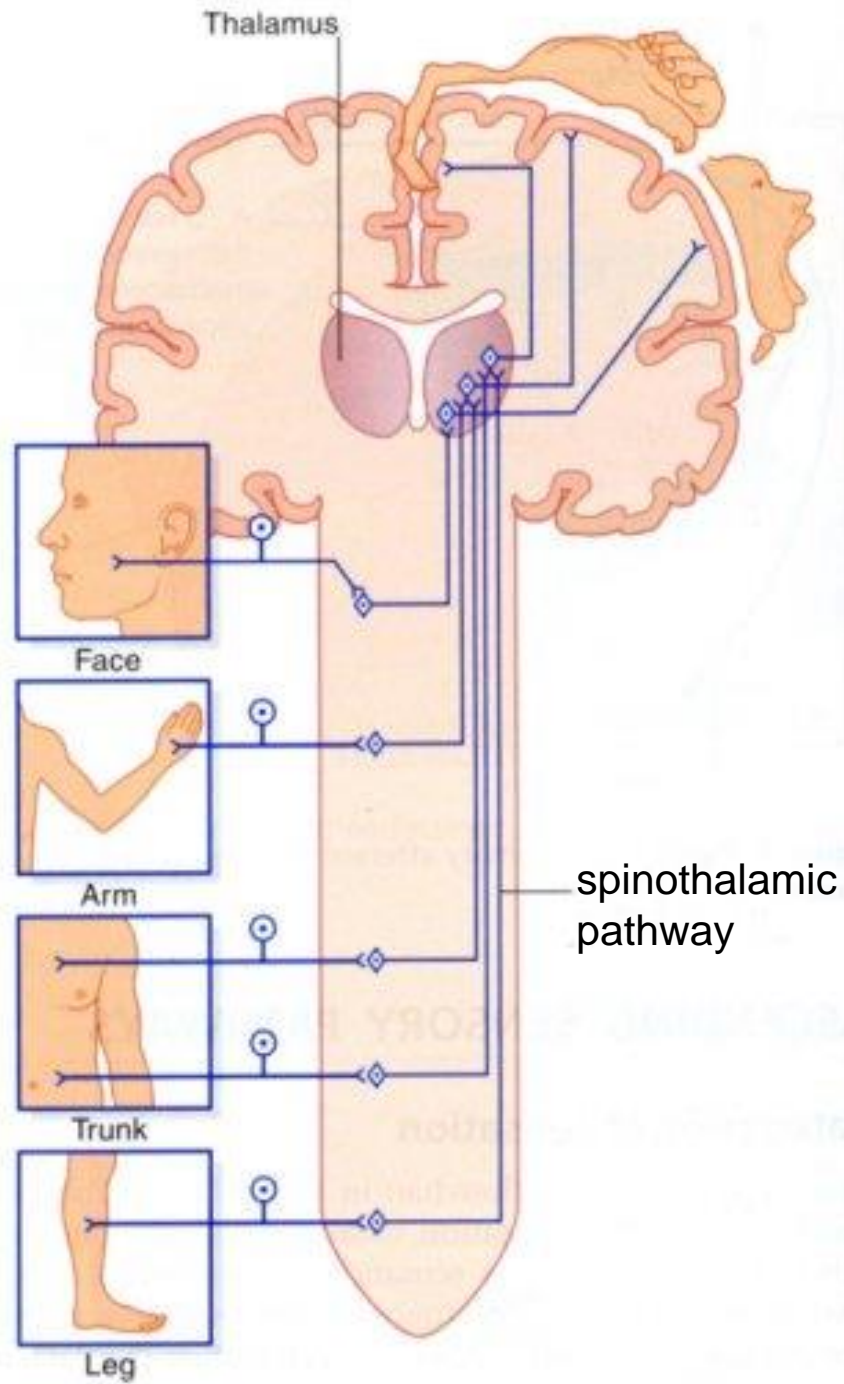
# Ataxia and Gait Disturbances-2

- **Motor Ataxia:** caused by cerebellar disorders
  - Intact sensory receptors and afferent pathways
  - Integration of proprioception is faulty
  - Midline cerebellar lesions cause truncal ataxia
    - Lateral cerebellar lesions cause limb ataxia
- **Features of Cerebellar ataxia**
  - Clumsy movements
  - Incoordination of the limbs
  - Reeling gait (unsteadiness, and irregularity of steps; often with a tendency to fall to one or other side, forward or backward)
  - Alcoholic intoxication produces similar effects!

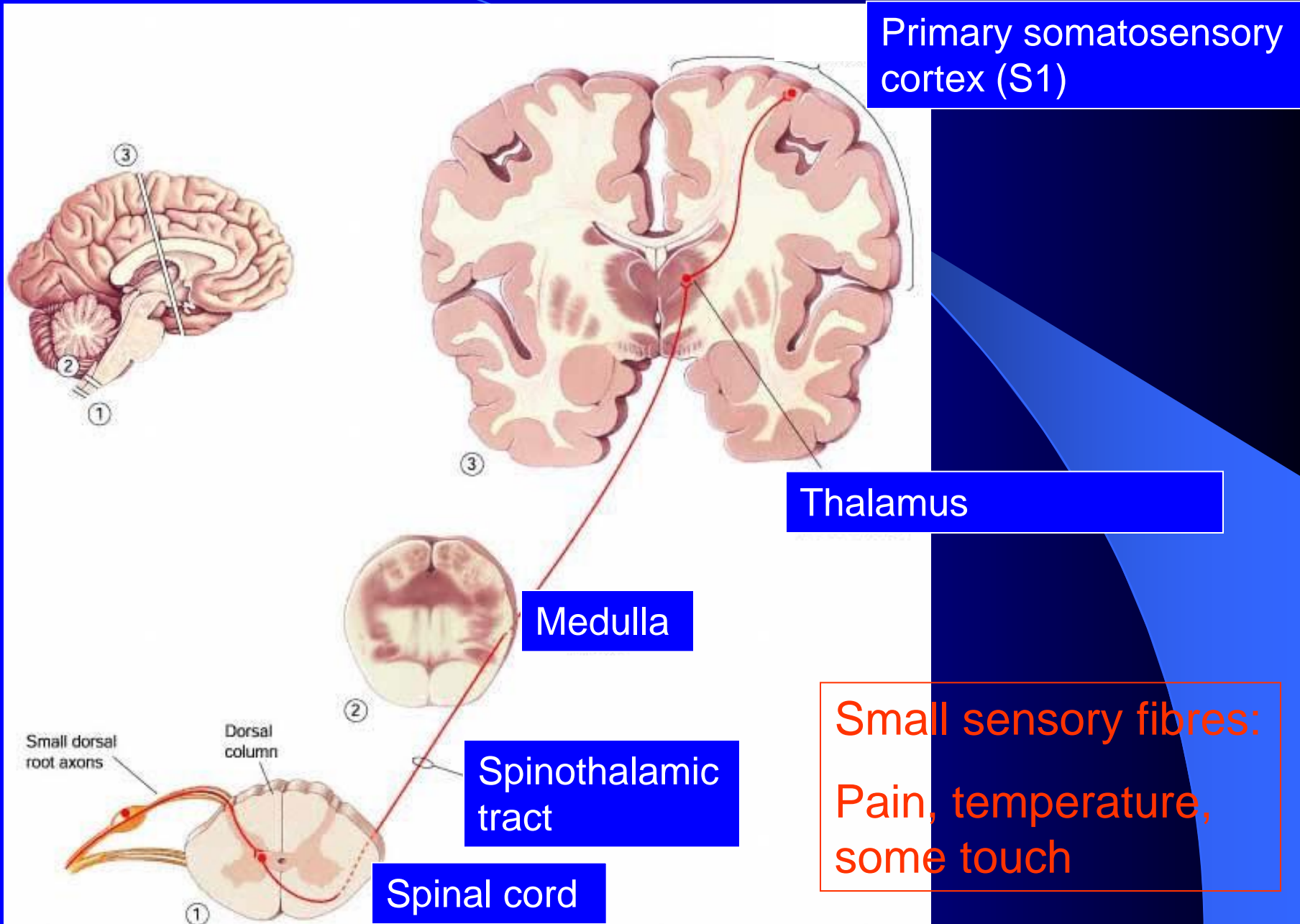
# Spinothalamic pathway

- Carries pain, temperature, touch and pressure signals
- 1<sup>st</sup> neuron enters spinal cord through dorsal root
- 2<sup>nd</sup> neuron crosses over in spinal cord; ascends to thalamus
- 3<sup>rd</sup> neuron projects from thalamus to somatosensory cortex



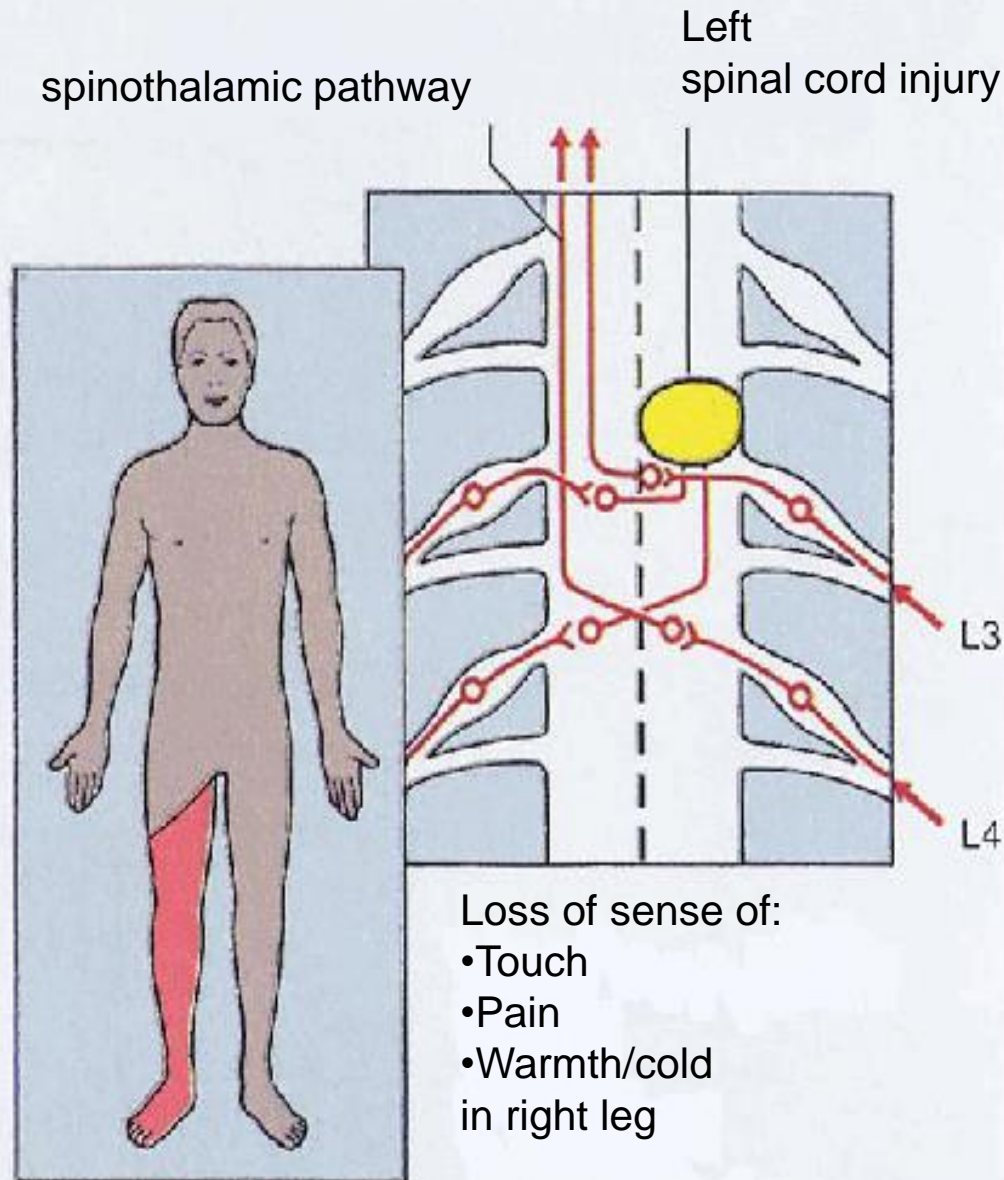


# Spinothalamic Pathway



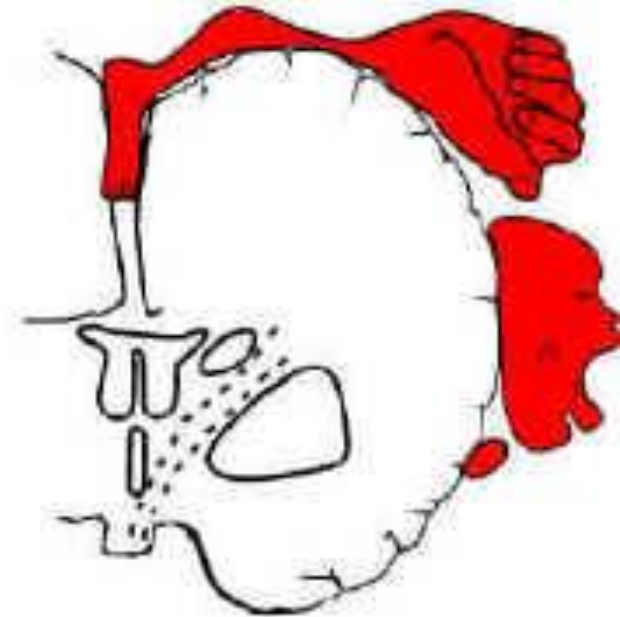
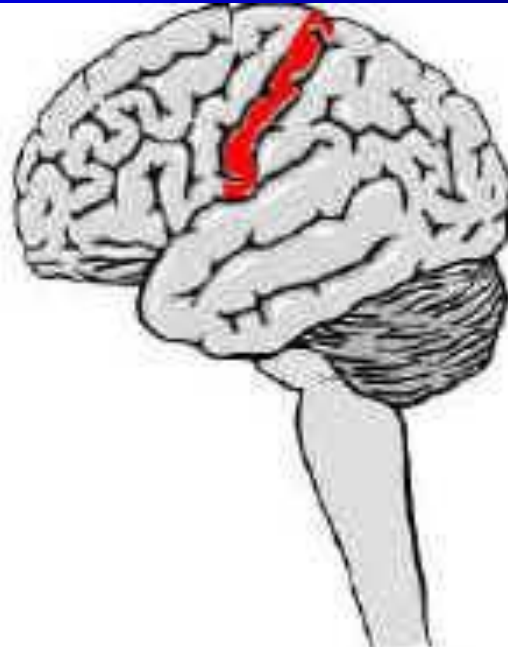
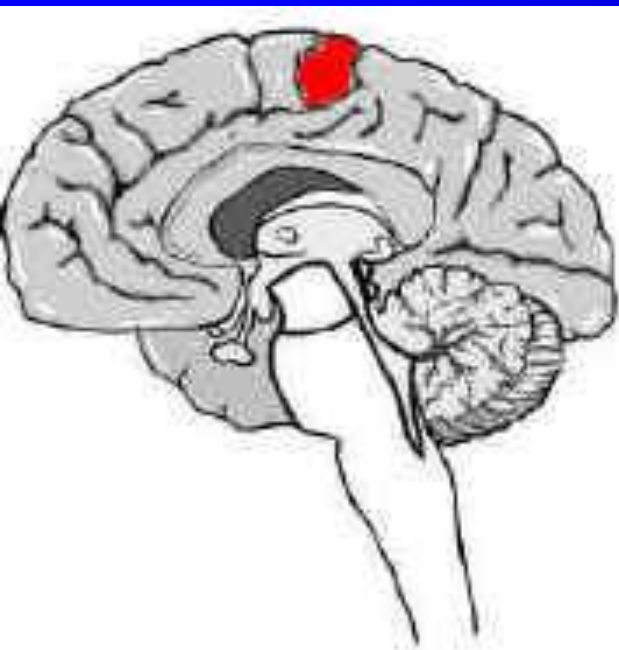


# Spinothalamic damage



## 4. Somatosensory cortex

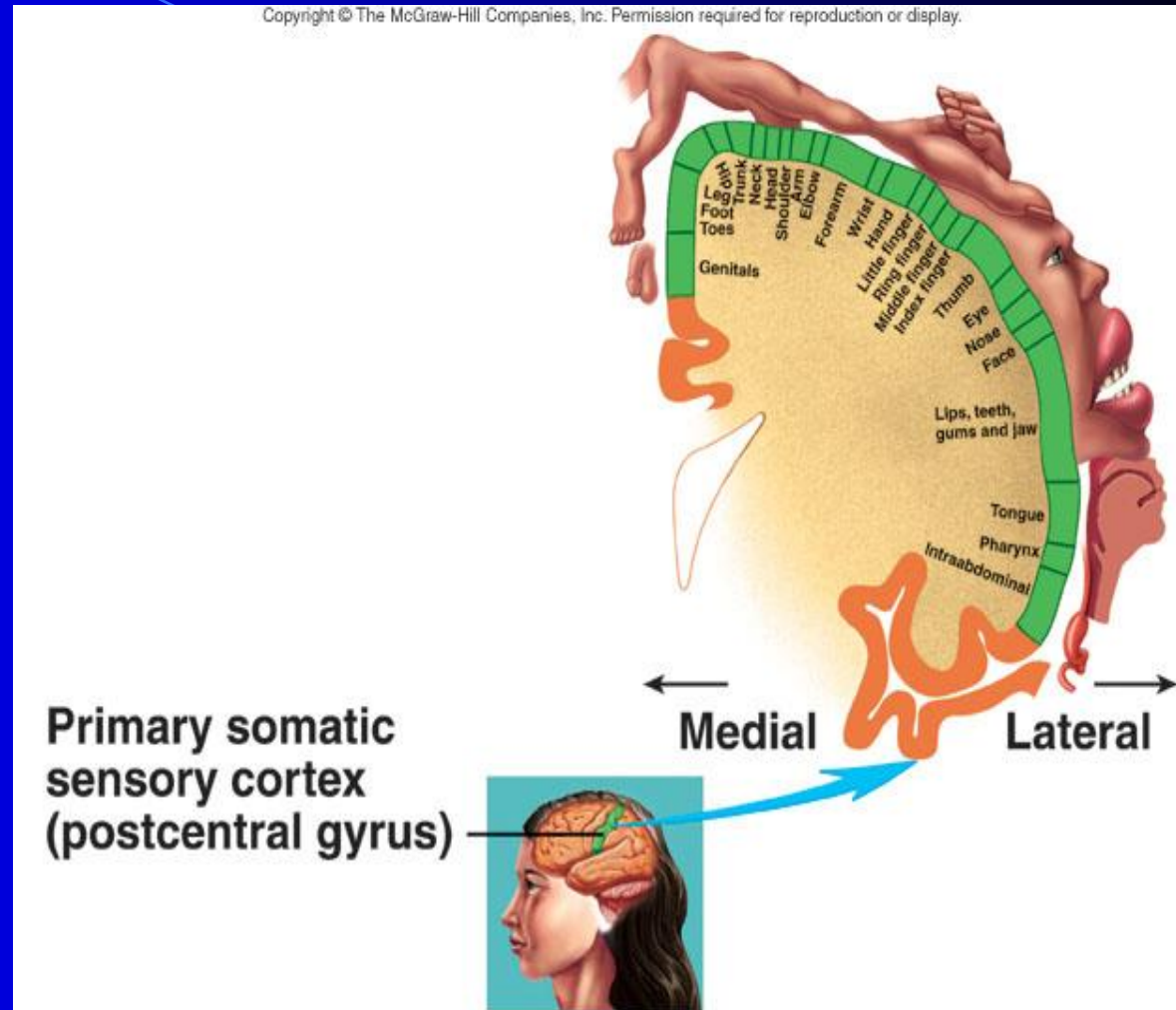
Located in the postcentral gyrus of the human cerebral cortex.



# Spatial orientation of signals.

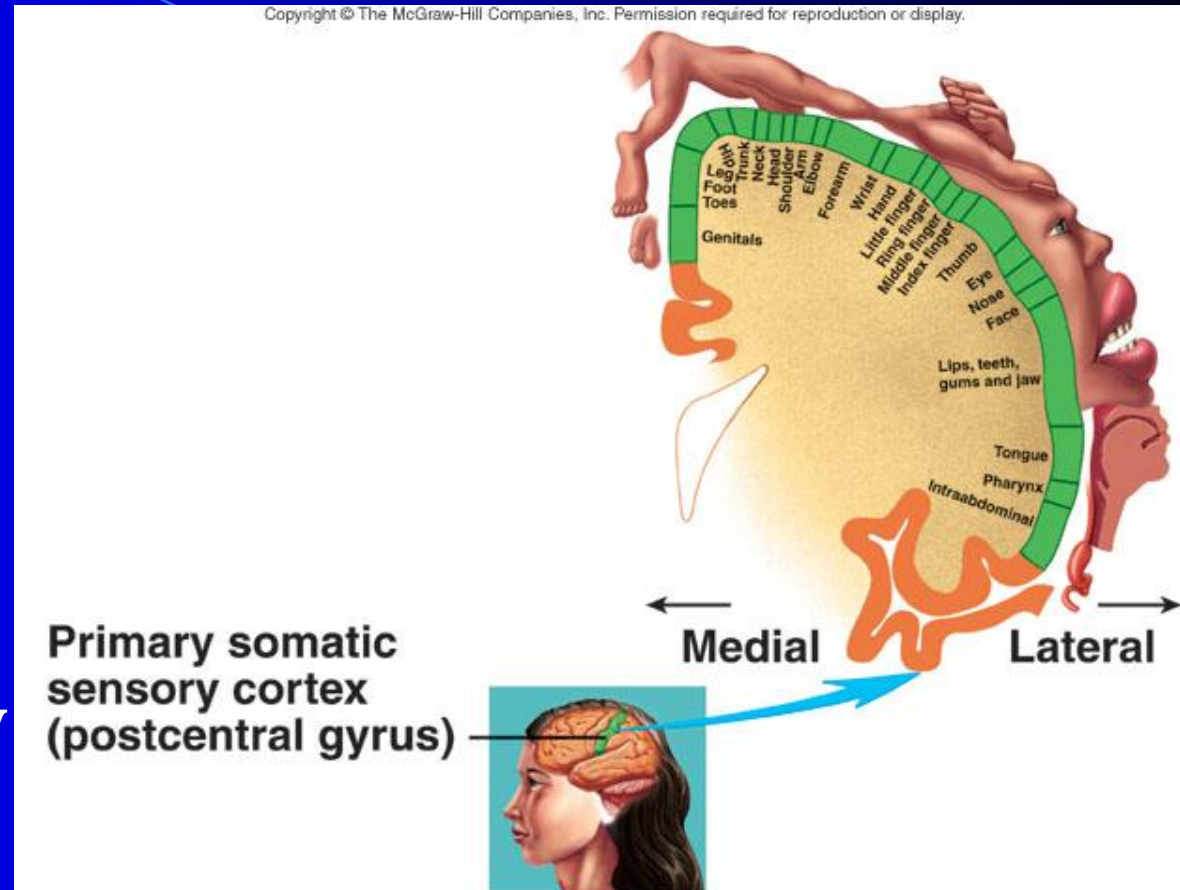
1) Each side of the cortex receives sensory information exclusively from the opposite side of the body

(the exception: the same side of the face).



## Spatial orientation of signals.

2) The lips, face and thumb are represented by large areas in the somatic cortex, whereas the trunk and lower part of the body, relatively small area.



3) The head in the most lateral portion, and the lower body is presented medially