Physiology of Proprioception in Balance

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NeuroPsychiatry Block

Somatic Sensations:

I. General Organization, the Tactile and Position Senses

Chapter 48

(Guyton & Hall)

Objectives

By the end of this lecture students are expected to:

- Identify the major sensory receptors & pathways
- Describe the components, processes and functions of the sensory pathways
- Appreciate the dorsal column system in **conscious proprioception**
- Describe the spinocerebellar tract pathway in **unconscious proprioception**
- Differentiate between sensory and motor **ataxia**

What Are Somatic Receptors?

- **Somatic receptors** are sensory receptors that respond to a stimulus in the external environment of **the body/organism**

- 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 the surface of the body
   - Monitor changes in the external environment
2. **Interoceptors:** concerned with the internal environment (visceral)
3. **Proprioceptors:** concerned with one`s own body position
   - Are those relating to the physical state of the body, including **joint position, and sate of tendons and muscles.**

Classification of Sensory Receptors-2

B. Based on their adequate stimulus

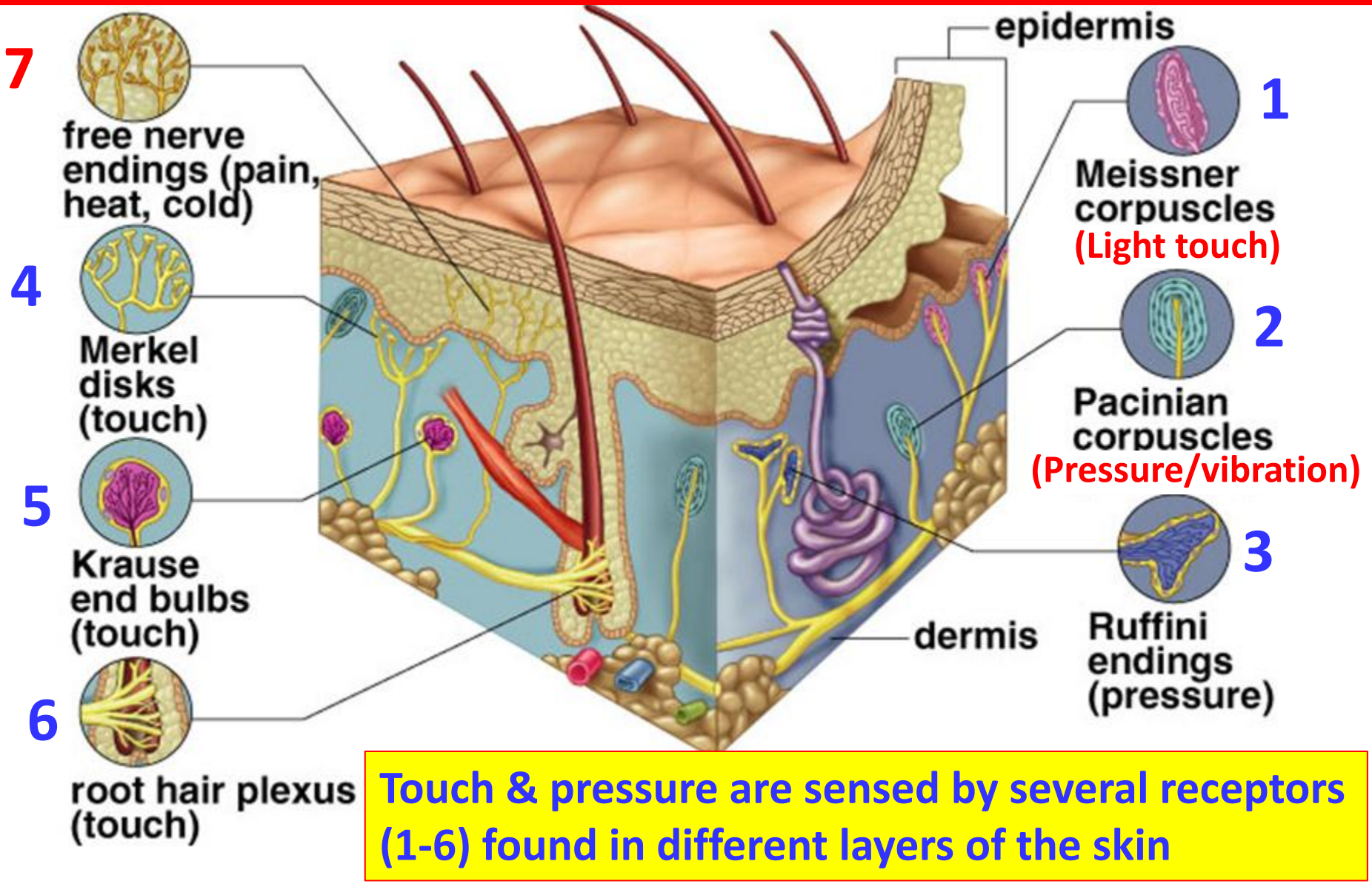
- Mechanoreceptors
- Thermoreceptors (cold & heat)
- Chemoreceptors (e.g. taste receptors)
- Photoreceptors (in the retina).
- Nociceptors (pain receptors)

Classification of Sensory Receptors-3

C. Based on their speed of adaptation

- **Slowly adapting (SA):** fire as long as the stimulus is there **(tonic receptors)**
  - Nociceptors and proprioceptors show no or very little adaptation
- **Rabidly adapting (RA):** fire upon stimulus and cease firing when the stimulus remains constant **(phasic receptors).**
  - Getting used to the bad smell in a room
  - Being aware of a ring or a watch only when putting them on or taking them off (onset and offset).

Cutaneous Receptors & Sense Organs-1



Touch & pressure are sensed by several receptors (1-6) found in different layers of the skin

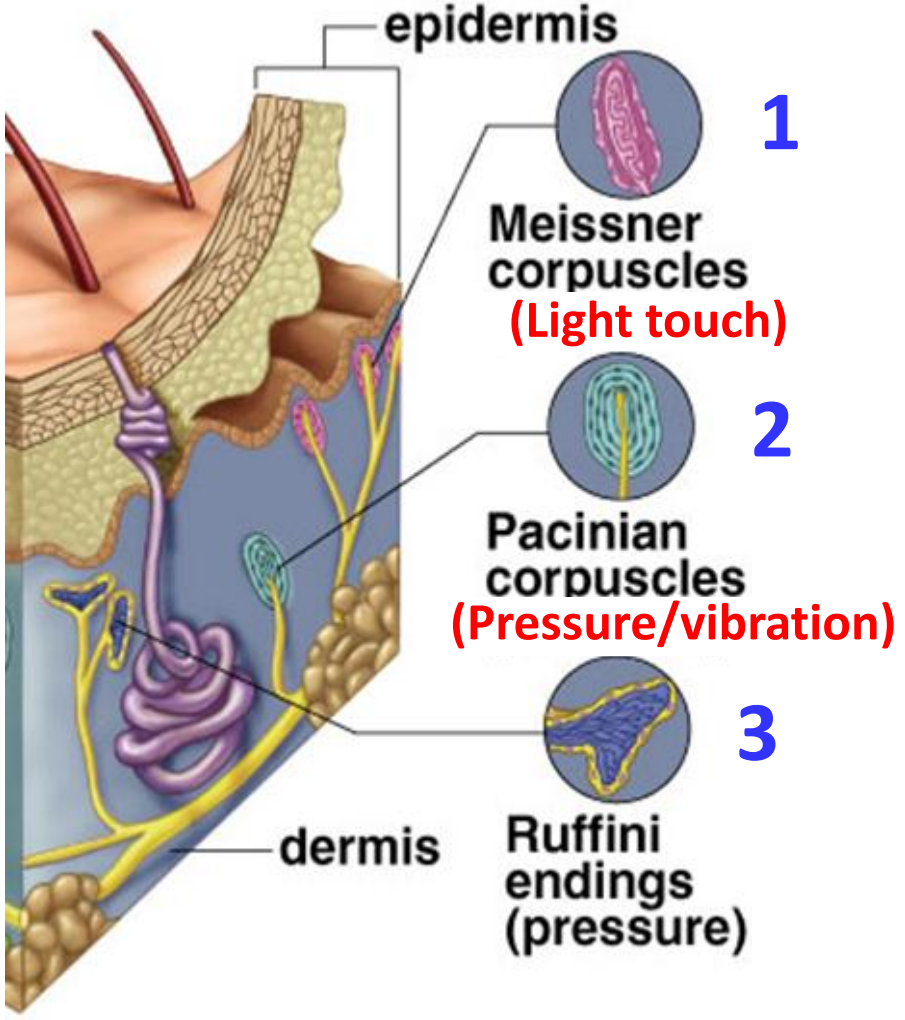
Cutaneous Receptors & Sense Organs-2

1 Meissner`s corpuscles:

- Are dendrites encapsulated by connective tissue in the epidermis (egg-shaped)
- Detect **light touch** and help identify objects by touch when **eyes are closed**

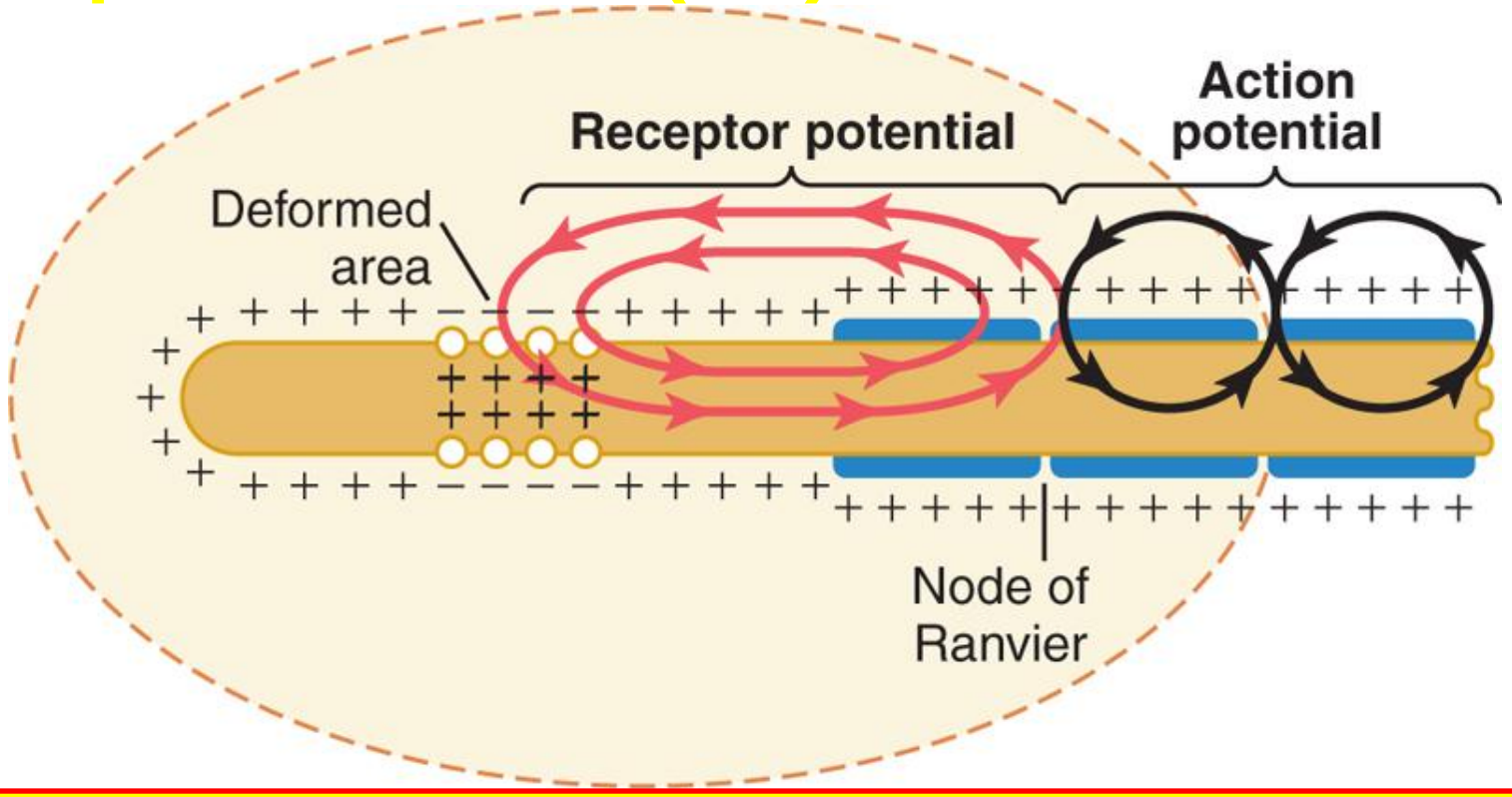
2 Pacinian corpuscles:

- Consist of dendritic endings deep in the dermis (onion-shaped)
- Detect **heavy pressure** and **vibration**



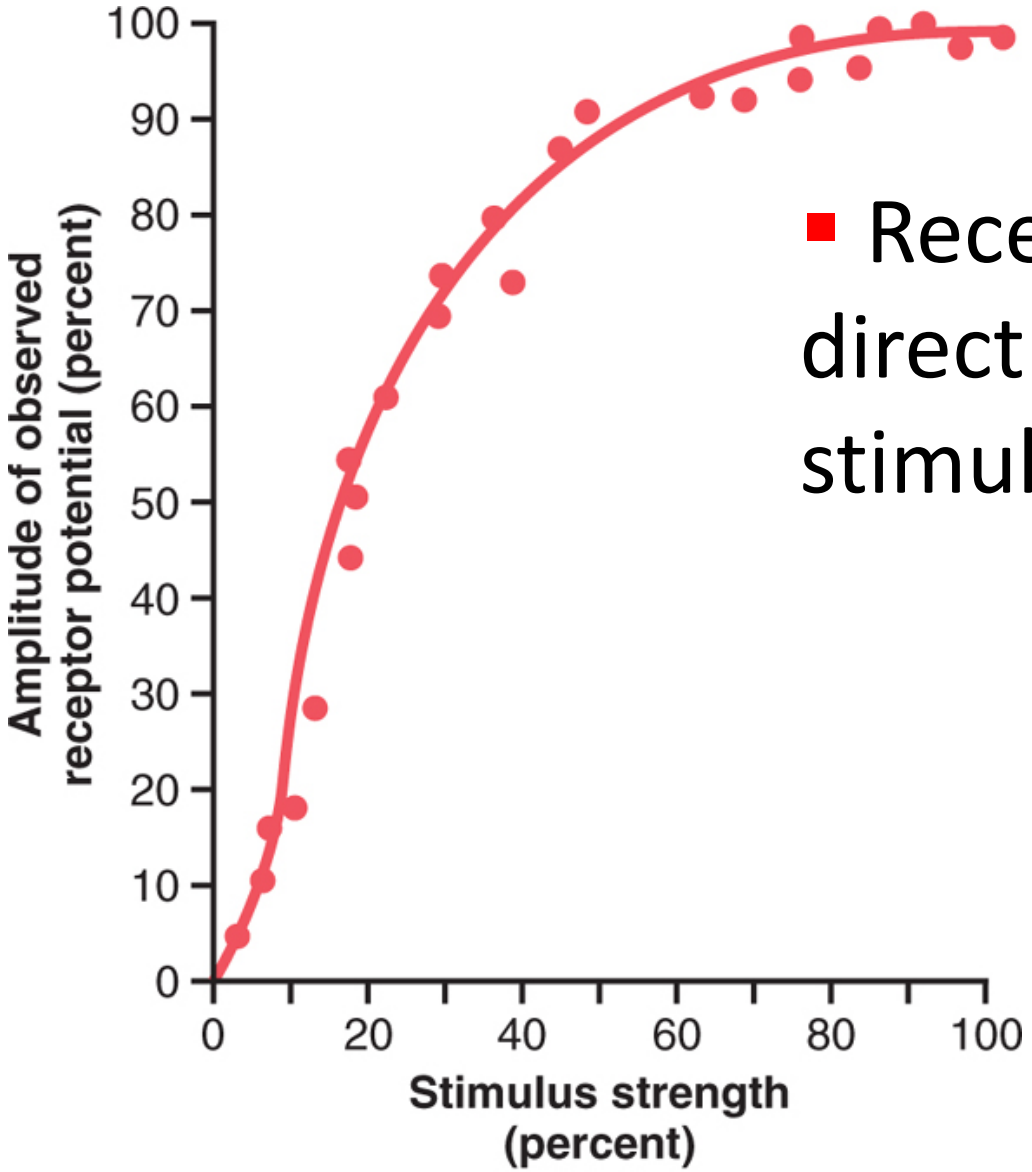
✓ **Objective: Identify the major sensory receptors & pathways**

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
- RP induces a local circuit of current flow that spreads along nerve fiber and generates **APs** when threshold is reached.

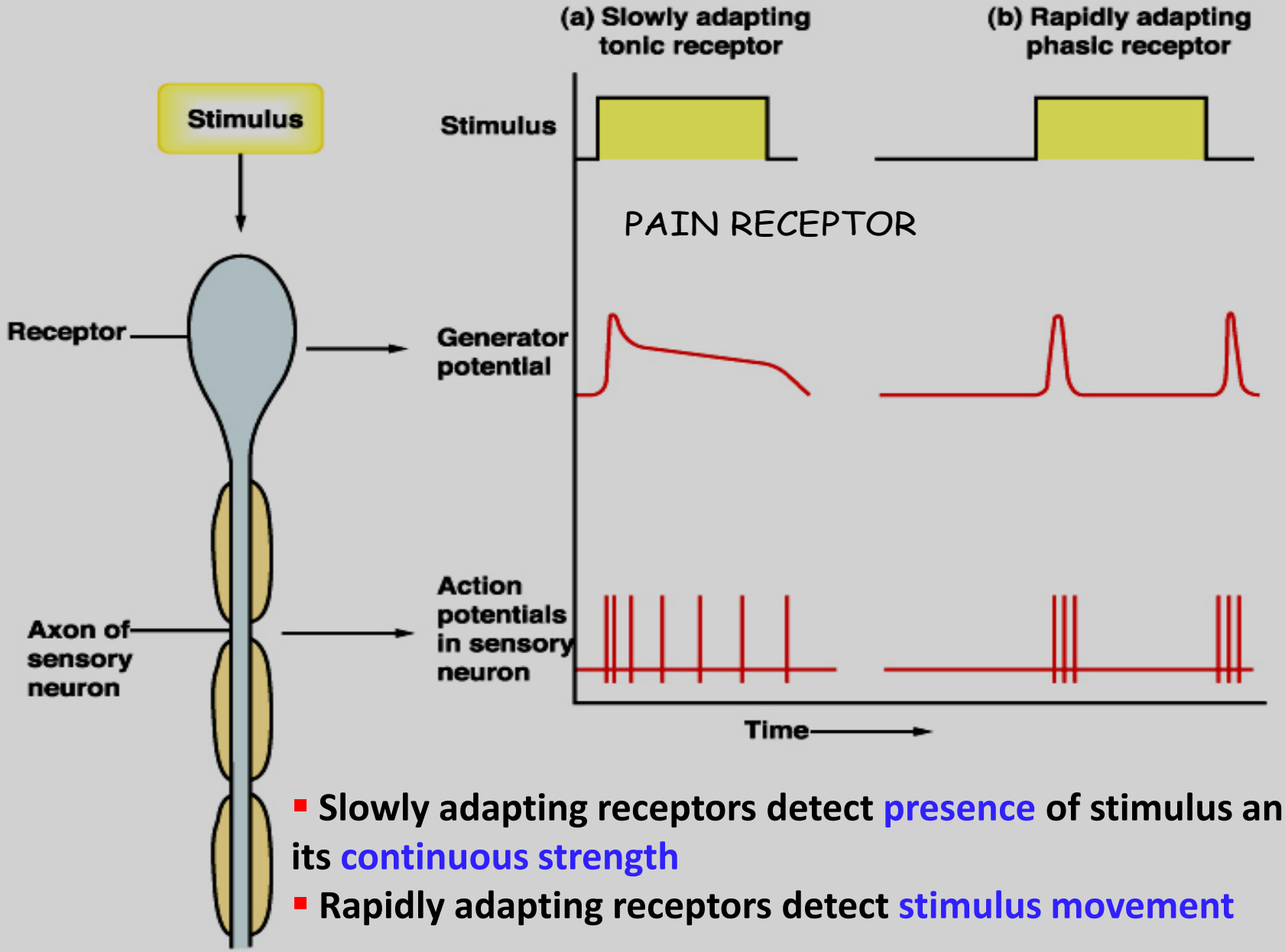
Relation Between Stimulus Strength & Receptor Potential Amplitude



Hall: Guyton and Hall Textbook of Medical Physiology, 12th Edition

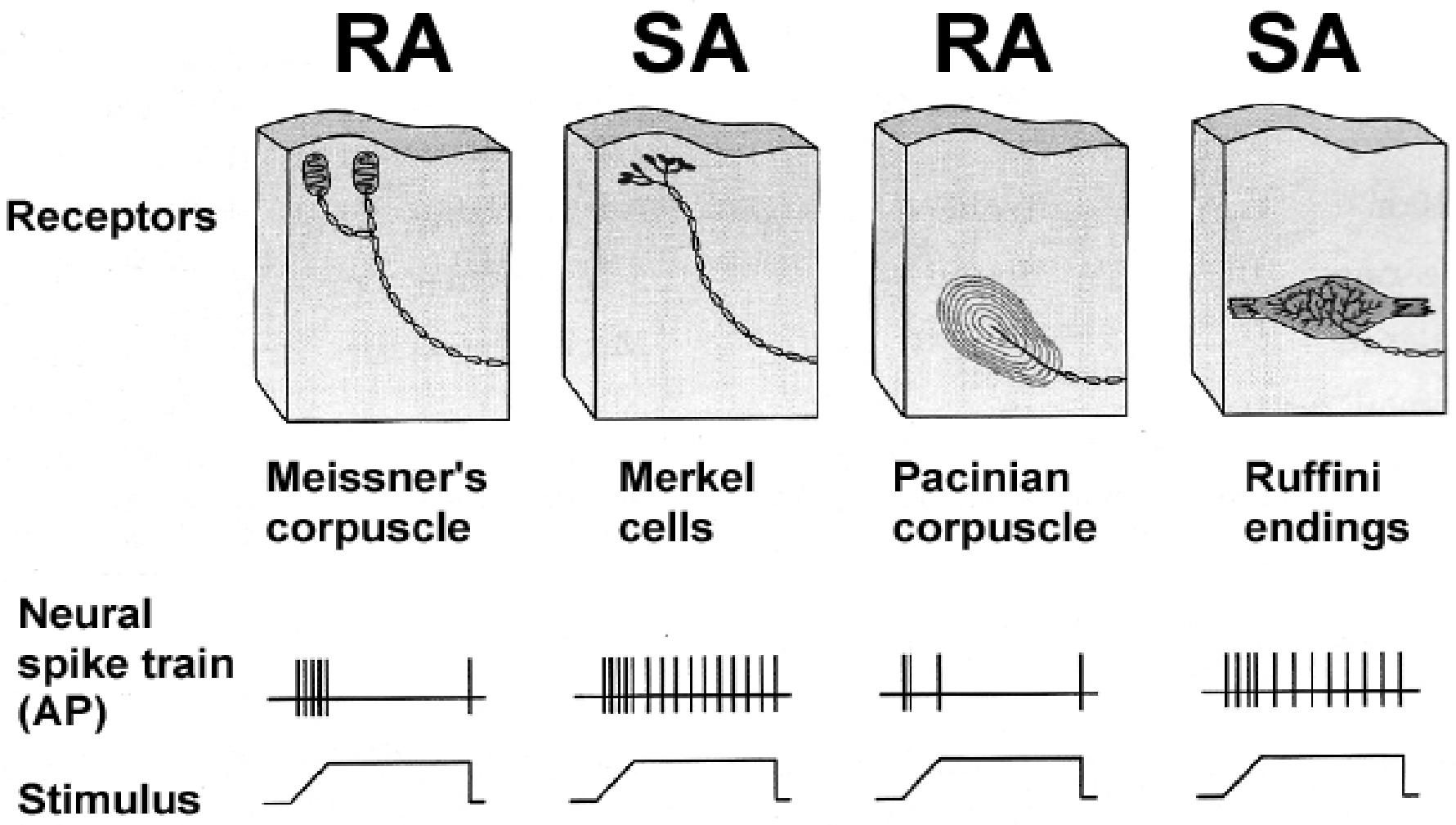
- Receptor potential is directly related to stimulus strength

Generation of a Receptor Potential



- Slowly adapting receptors detect presence of stimulus and its continuous strength
- Rapidly adapting receptors detect stimulus movement

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**).

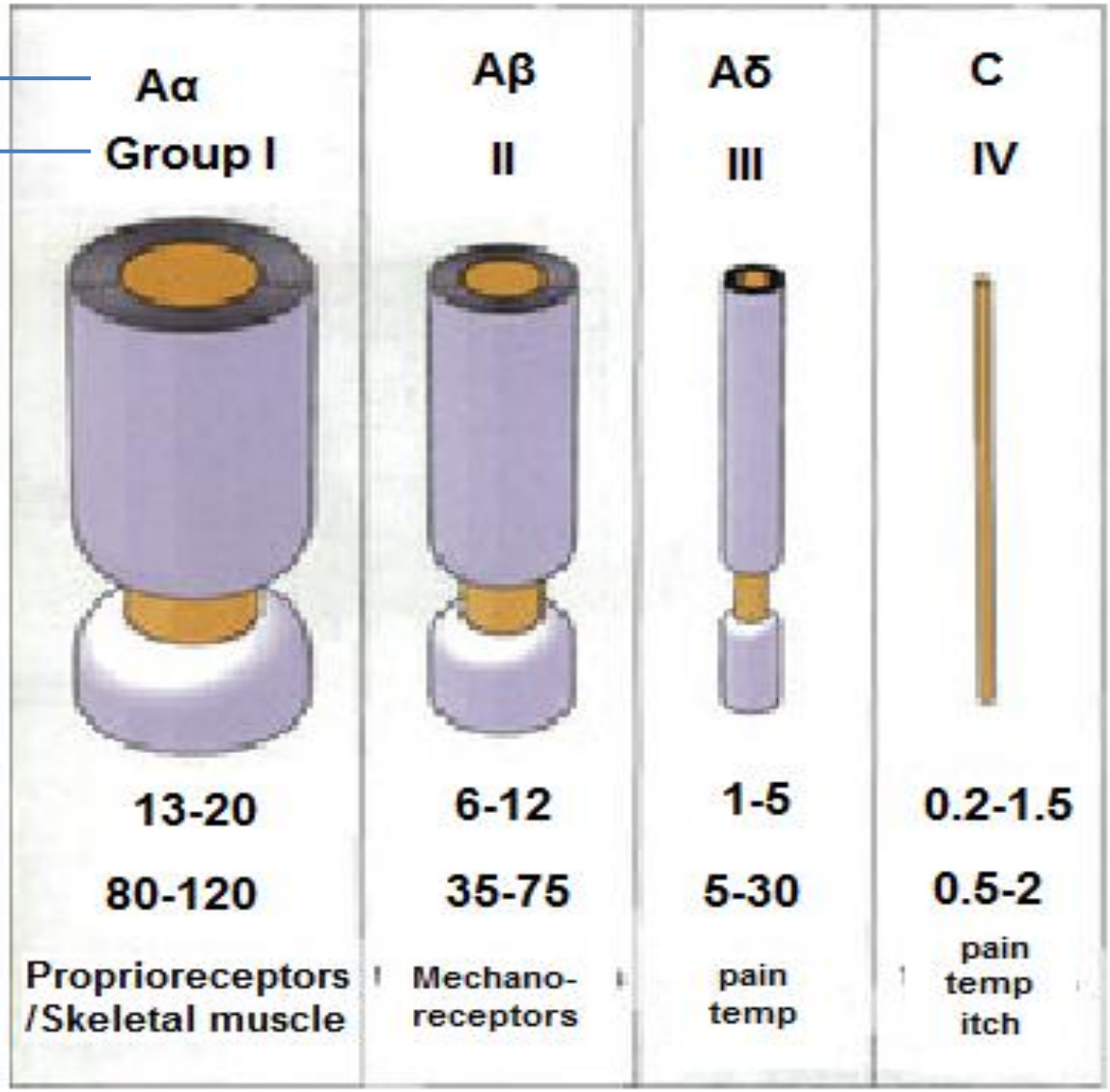
Classification of Nerve fibers

Skin & other tissue ←

Skeletal muscle tissue ←

Types of nerve fibers:

- **Myelinated (A-fiber)**
  - **Aα** (thickly myelinated)
  - **Aβ** (intermediate m.)
  - **Aδ** (thinly myelinated)
- **Unmyelinated (C-fiber)**



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 course touch (**Pain lecture**).
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 **d**orsal **s**pino-**c**erebellar **t**ract (d**SCT**)
- The **v**entral **s**pino-**c**erebellar **t**ract (v**SCT**)

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 muscle 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

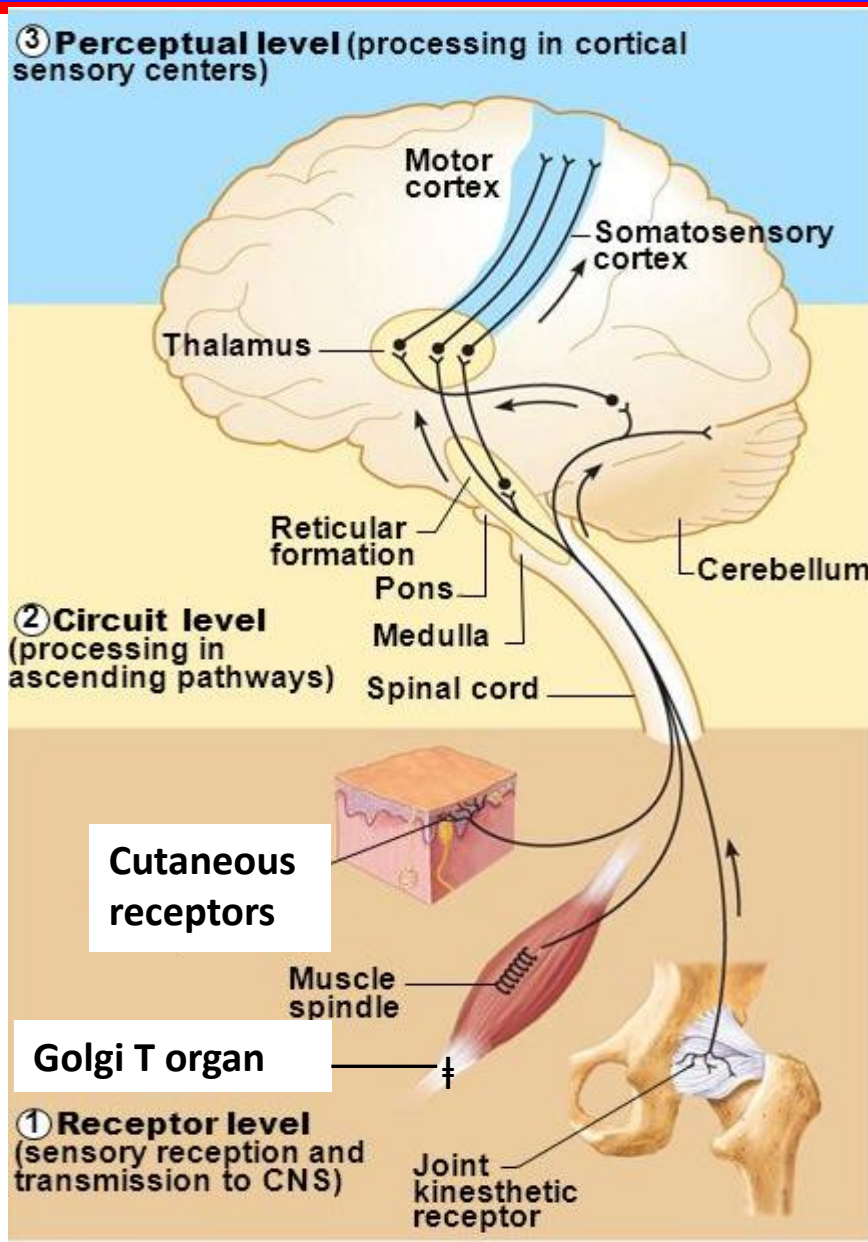
2 Golgi tendon organs

* 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 angle and movement of the joints.

Cutaneous & deep receptors also contribute to proprioception



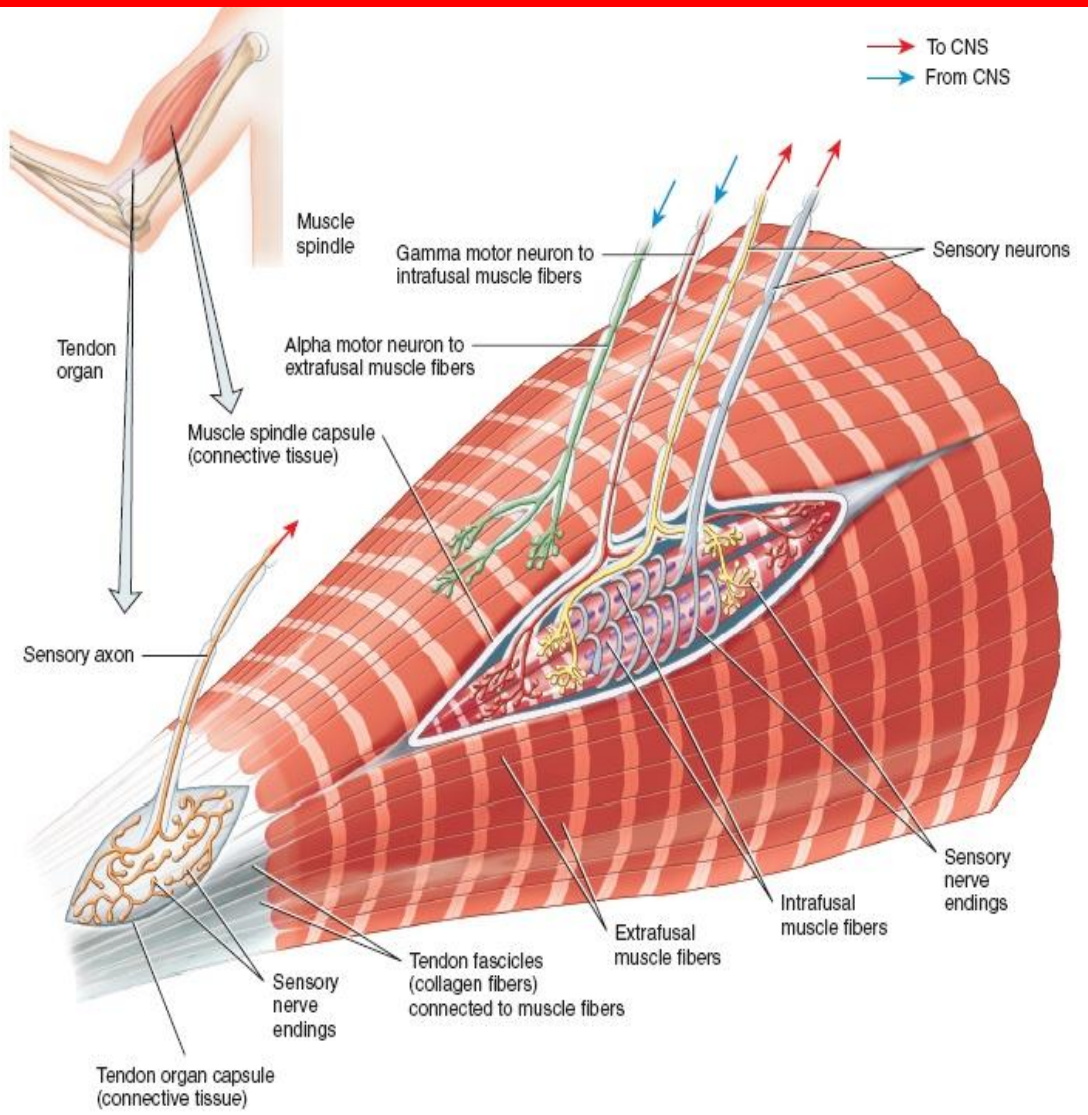
Muscle Spindles & Golgi Tendon Organs

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 organs

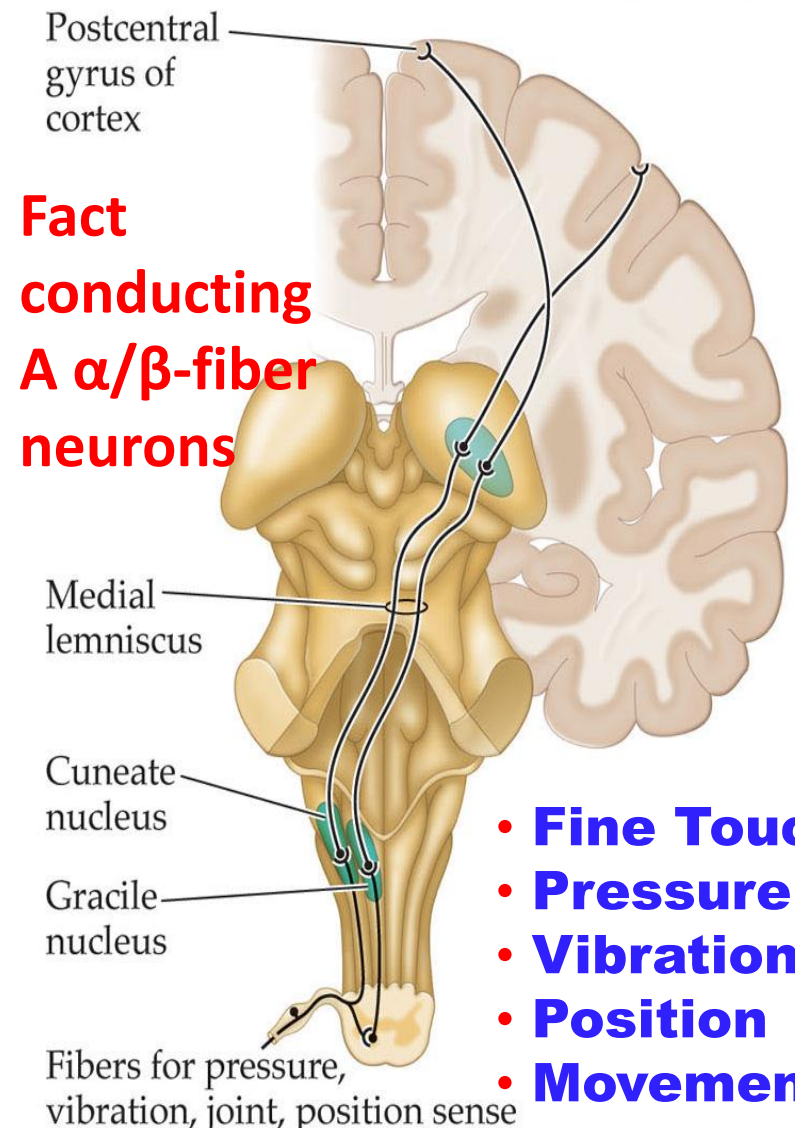
- They detect changes in **muscle tension**



✓ **See the lecture on deep reflexes**

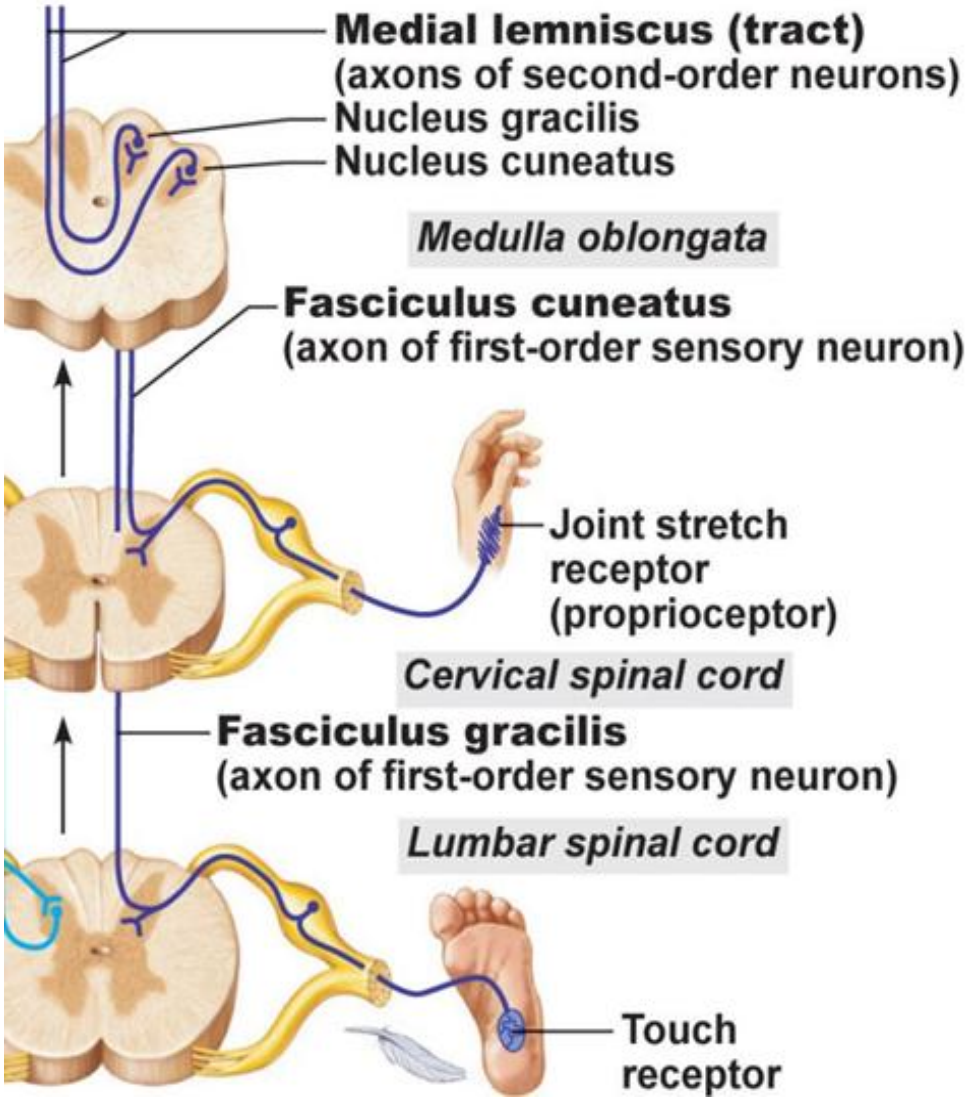
Dorsal Column–Medial Lemniscal System

✓ **Objective: Appreciate the dorsal column system in conscious proprioception**



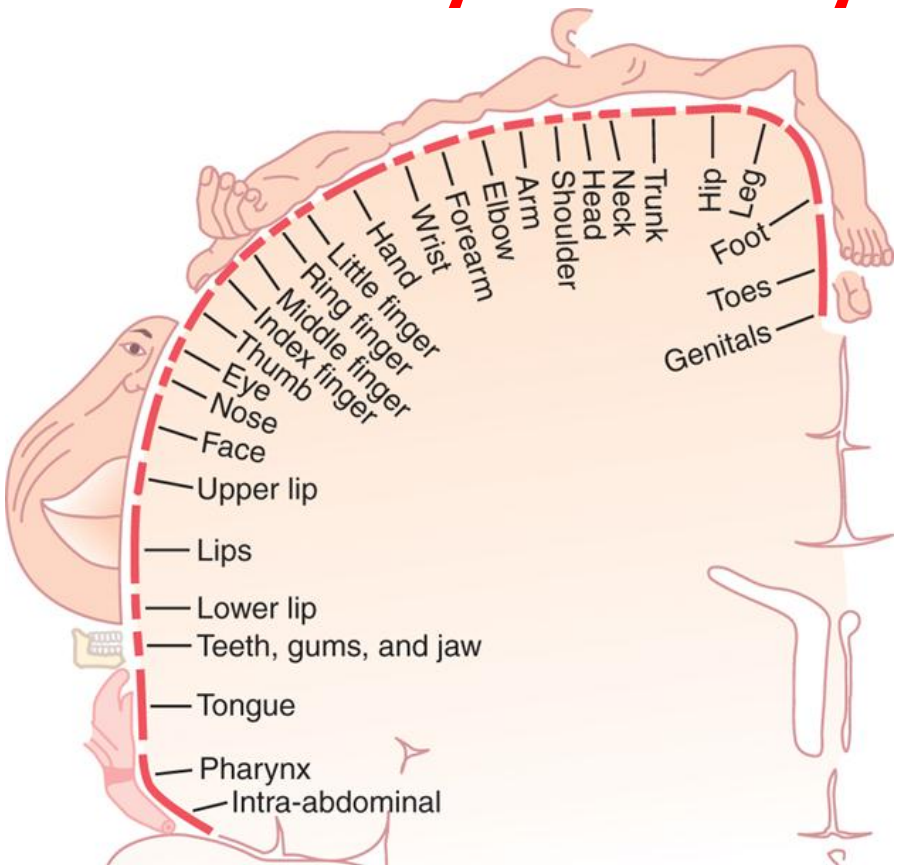
Fact conducting A α/β-fiber neurons

- **Fine Touch**
- **Pressure**
- **Vibration**
- **Position**
- **Movement**

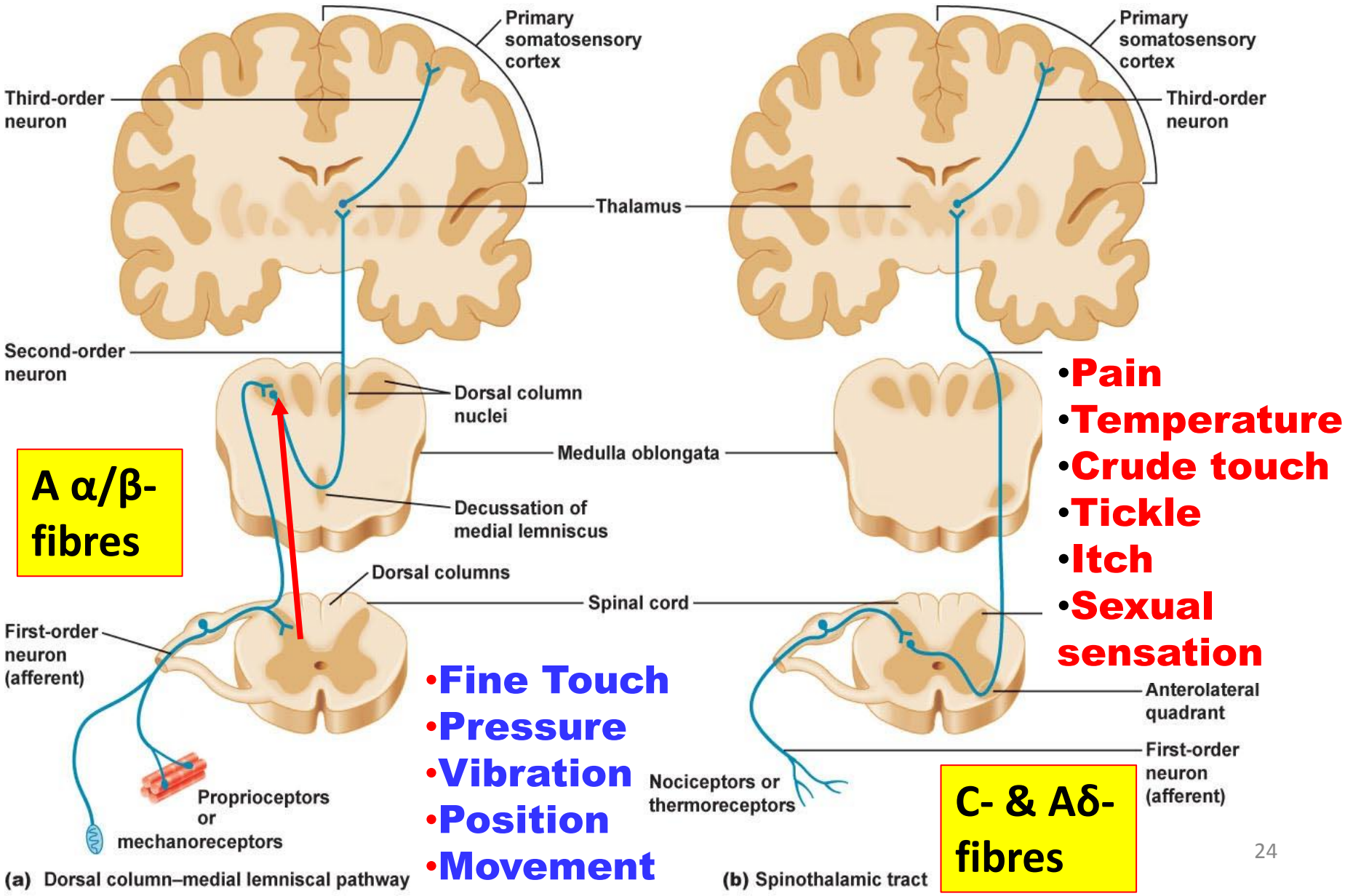


Sensory Homunculus (Little Man)

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



Nociceptive vs Non-nociceptive Pathways



A α/β-fibres

- **Fine Touch**
- **Pressure**
- **Vibration**
- **Position**
- **Movement**

- **Pain**
- **Temperature**
- **Crude touch**
- **Tickle**
- **Itch**
- **Sexual sensation**

C- & Aδ-fibres

The Dorsal & Ventral Spinocerebellar Tracts

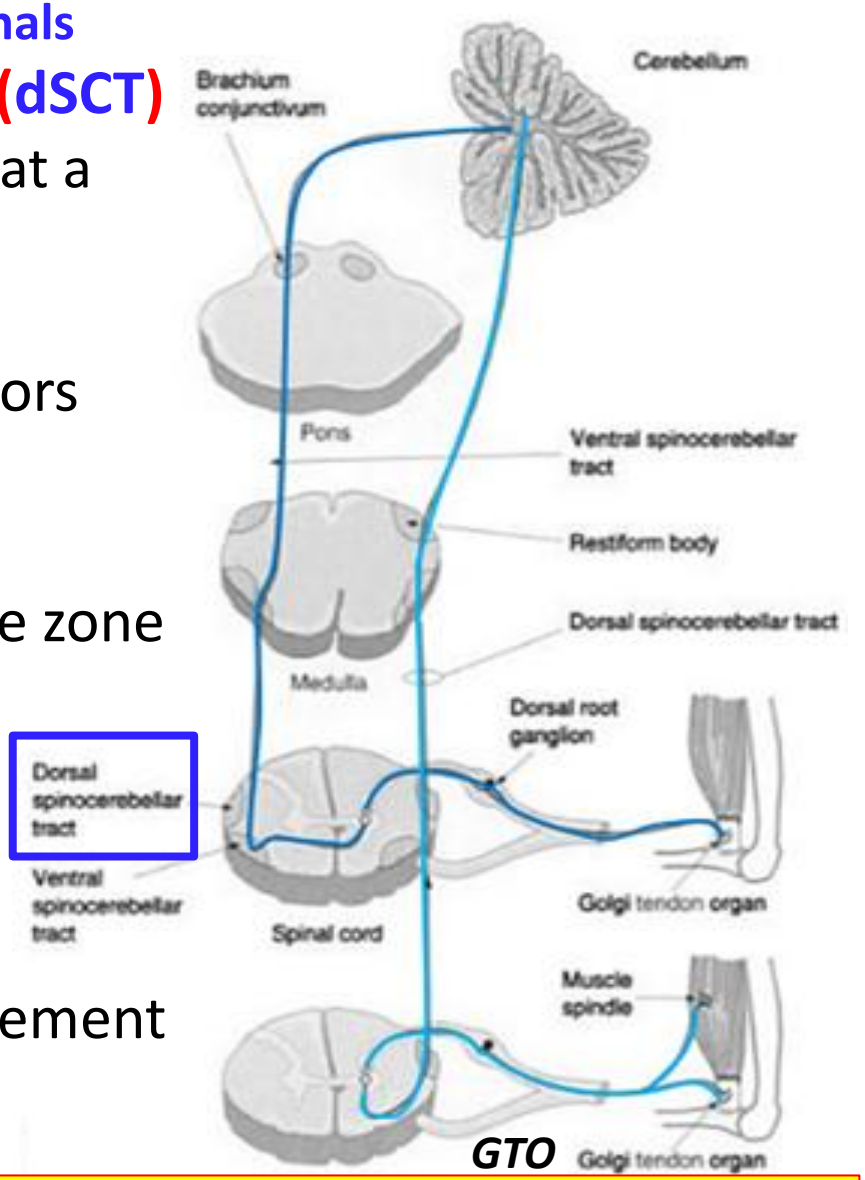
They carry subconscious proprioception signals

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 of body parts & their movement
- Forces acting on the body surfaces



✓ **Objective: Describe the spinocerebellar tract pathway in unconscious proprioception**

The Dorsal & Ventral Spinocerebellar Tracts

❷ 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)
- 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.

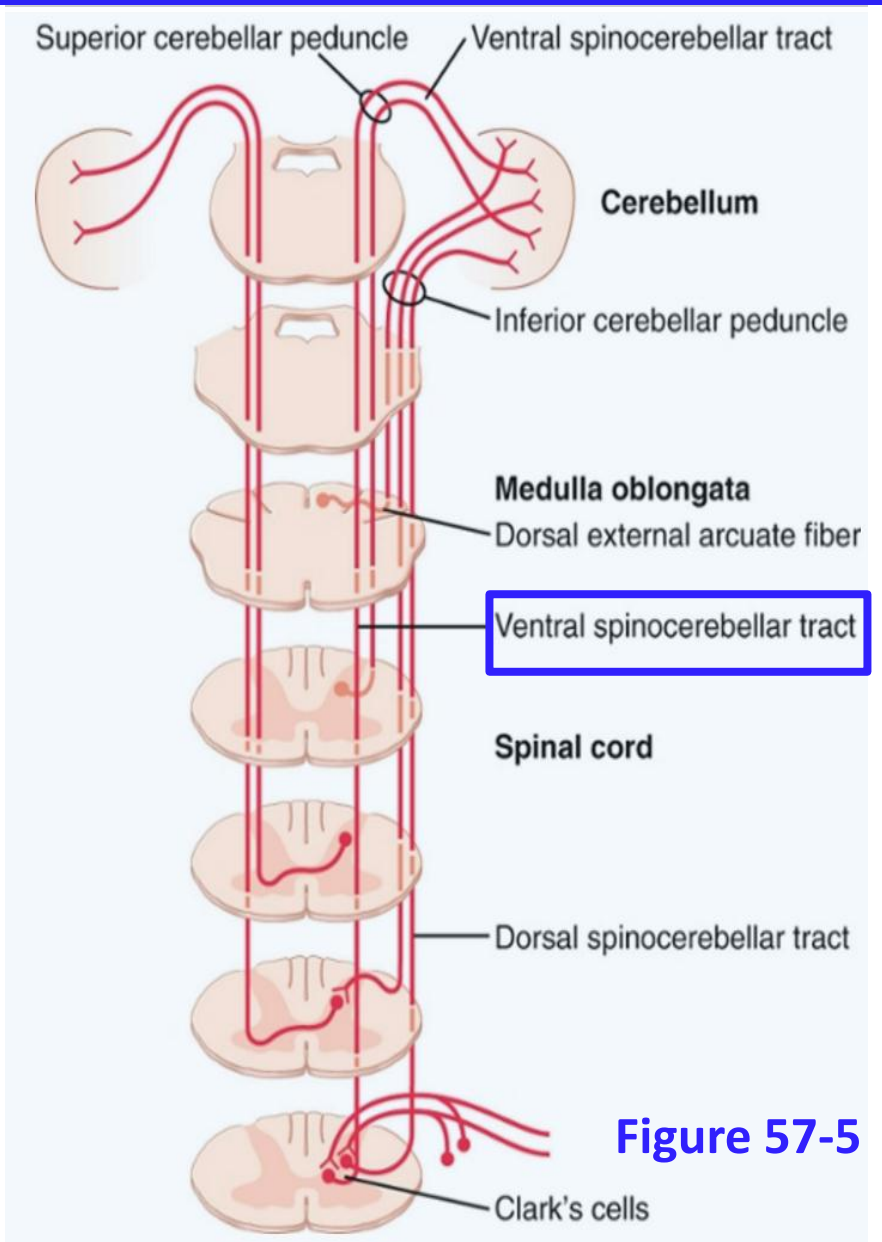


Figure 57-5

Proprioception Disorders

Balance problems: Too much consumption of vitamin B6 (pyridoxine).

- **Position agnosia:** inability to identify the location and position of an extremity without looking at them
- They have difficulties with all motor tasks including walking, eating, dressing, etc (**ataxia and gait disturbances**).
- They must use their vision to watch each body part to make it move in the right direction.

Clinical test: proprioception can be tested in several ways:

- Having the patient close their eyes and saying if their fingers are up or down.
- Finger to nose (alcohol test)

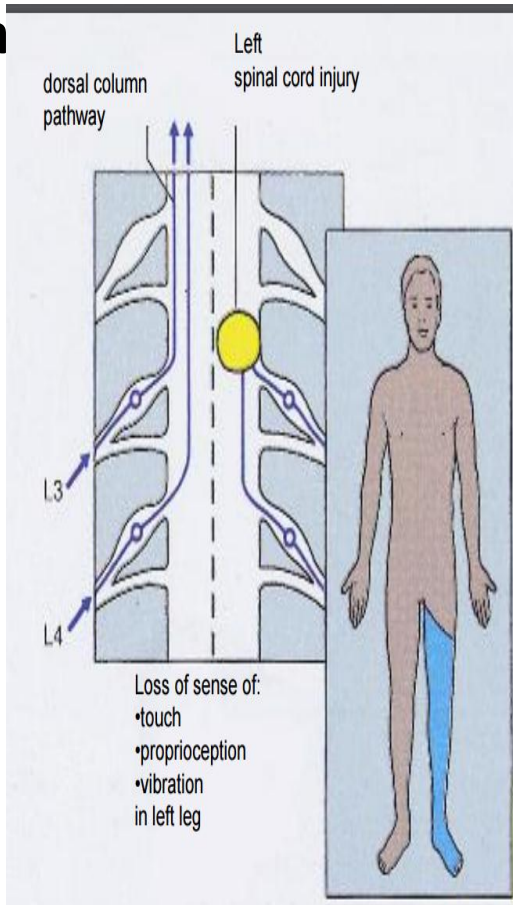
Ataxia and Gait Disturbances-1

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: ❶ **Sensory ataxia** ❷ **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** (+ Romerg`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!

Brown-Séquard syndrome

- Is an incomplete spinal cord lesion
- Hemisection injury often in cervical region
- May be caused by **trauma**, tumor, multiple sclerosis …

Ipsilateral loss

- Fine touch, Vibration, Proprioception (injury to dorsal Column)
- Leg ataxia (injury to dorsal spinocerebellar tract)
- Patients also suffer from ipsilateral **upper motor neuron paralysis** (see lecture of Upper motor lesion):

Contralateral Loss:

- Loss of pain and temp (injury of spinothalamic tract, STT)
- Loss of crude touch and pressure (injury to STT)
- Minor contralateral muscle weakness (V. corticospinal tract)
- Leg ataxia (injury to V. spinocerebellar)

Some Neurological Tests

Several neurological tests can be used to examine the integrity of DCML system including:

- **Two-point discrimination** test (using a compass with points separated by 2-60 mm), is a measure of **tactile acuity** (ability to resolve fine spatial details of an object with the sense of touch).
- **Pallesthesia:** ability to feel mechanical vibration (elevation of threshold for vibratory stimuli may be an indication of damage in the DCML system)
- **Stereognosis:** ability to identify objects with eyes closed.
  - **Tactile agnosia:** inability to identify an object by touch


Thank You
Any Questions
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