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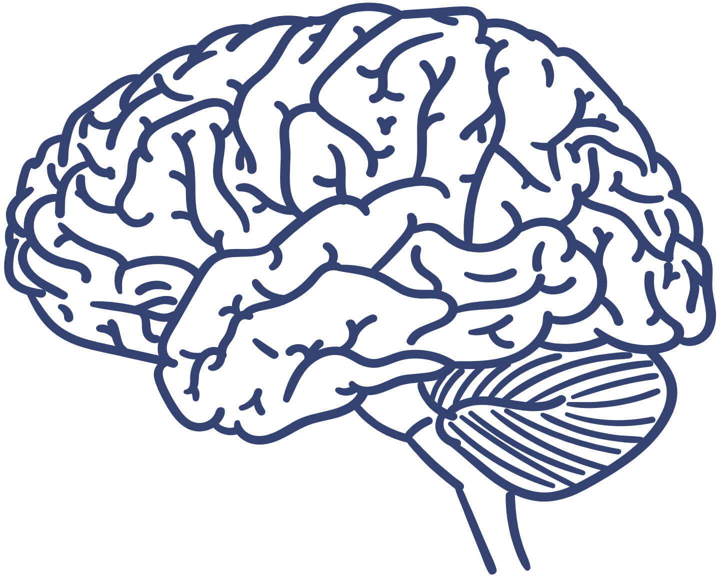

Physiology of the proprioceptors in Balance

Color Index:

- Main text
- Important
- Girls Slides
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Editing File

Objectives:

By the end of this lecture students are expected to :

1. Identify the major sensory receptors & pathways
2. Describe the components, processes and functions of the sensory pathways
3. Appreciate the dorsal column system in conscious proprioception (Anatomy & Functions)
4. Describe the spinocerebellar tract pathway in unconscious proprioception from muscles, tendons, and joints
5. Differentiate between sensory and motor ataxia

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. Based on their **location** (sherrington 1906):

Exteroceptors (Usually on skin): concerned with the external environment.
- Found on the surface of the body
- E.g. touch and temperature receptors

Interoceptors: concerned with the internal environment.
- e.g. chemoreceptors ,osmoreceptors

Proprioceptors: concerned with position of the body in the Space.
- Are found in joint, tendons and muscles.

Classification of sensory receptors cont…

2 Based on the Adequate **Stimuli:**

Adequate stimulus is the particular form of energy to which the receptors is most sensitive

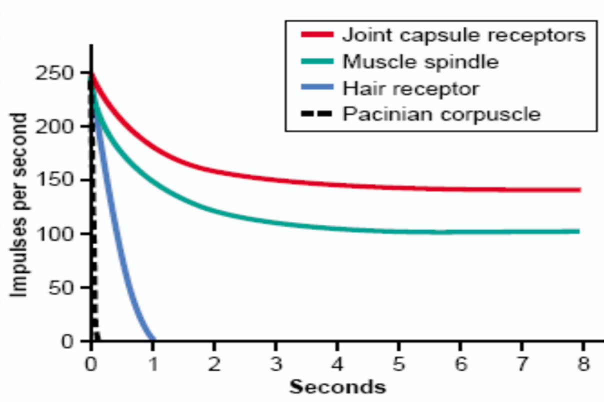
Receptors respond to different stimuli but adequate stimuli is what stimulate them the most, like light for rods and cones. (eye can detect touch, but it's more sensitive to light)

1. **Mechanoreceptors** :which detect mechanical compression or stretching of the receptor or of tissues adjacent to the receptor. e.g proprioceptors
2. **Thermoreceptors**: which detect changes in temperature, some receptors detecting cold and others warmth.
3. **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.
   e.g chemo R in carotid bodies
4. **Electromagnetic receptors:** which detect light on the retina of the eye eg rods and cones.
5. **Nociceptors (pain receptors):** which detect damage occurring in the tissues, whether physical damage or chemical damage
   e.g free nerve endings

Classification of sensory receptors cont...

3 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.



like wearing glasses, you don't feel it after a while due to adaptation of touch receptors in that area

Accordingly receptors can be classified Into:	
Rabidly adapting (RA) or phasic receptors:	**Slowly adapting** (SA) or tonic receptors:
❖ e.g meissner's corpuscles (touch), ❖ pacinian corpuscles (vibration).	❖ Muscle spindle, joint receptors, baroreceptors, Merkel cells and Ruffini endings ,macula in vestibular apparatus ❖ Pain receptors do not adapt at all. or very slow adapt ❖ pain receptors don't adapt so you can remove your hands from the painful stimuli (non adapting receptors)

Mechanisms by which Receptors adapt

Is different for each type of receptor.

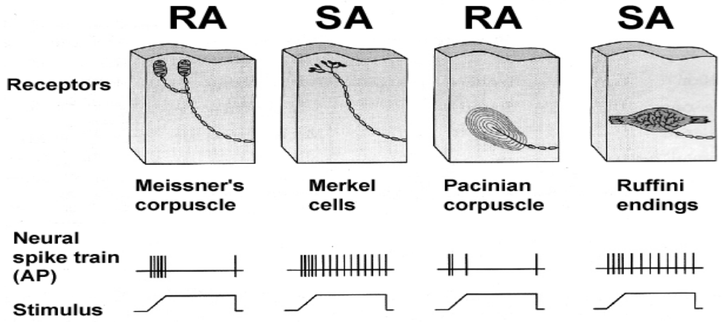
1. **In the eye**
   the rods and cones adapt by changing the concentrations of their light-sensitive chemicals.

2. **Pacinian corpuscle**
   - The Pacinian corpuscle is a viscoelastic structure so that after stimulation within few hundredths of a second, the fluid within the corpuscle redistributes, so that the receptor potential is no longer elicited.
   - The second mechanism of adaptation of the Pacinian corpuscle, but a much slower one, results from accommodation, which occurs in the nerve fiber itself. no Na influx
   - This probably results from progressive "inactivation" of the sodium channels in the nerve fiber membrane.

- Examples of RA and SA Receptors:

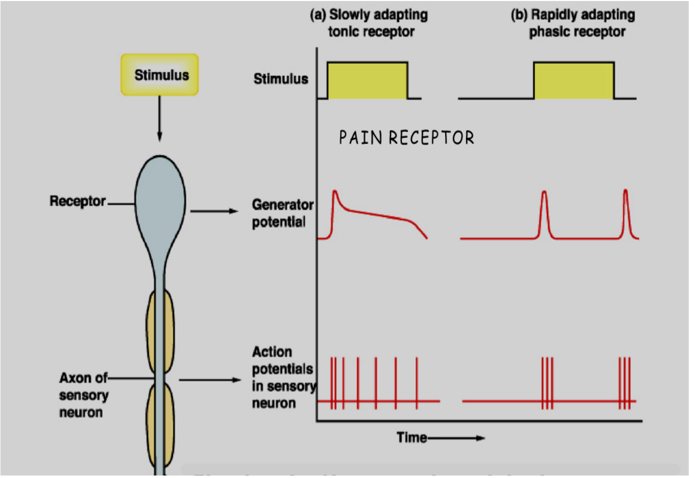
Muscle spindles & nociceptors are other examples of SA receptors.

*SA = Slowly adaptive
*RA = Rapidly adaptive



Generation of a Receptor Potential

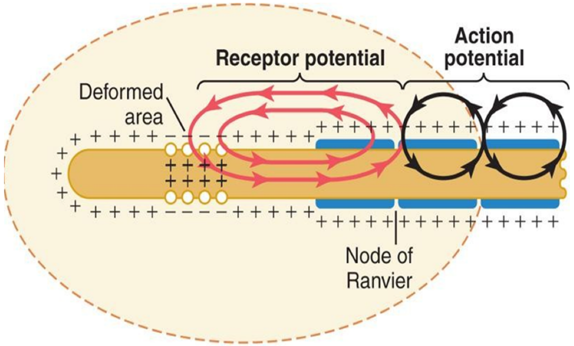
لو ماغيرت قوة ال stimulus يصير adaptation



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

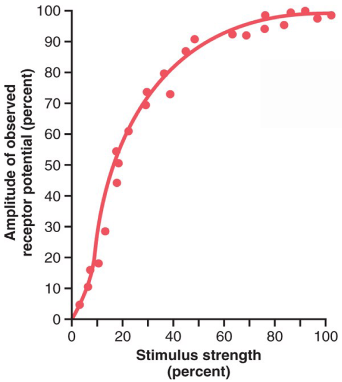
- **Activation of Sensory Receptors: Generation of Receptor Potential (RP)**

- 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



if u increase stimulus strength:
1- Generator potential-> increased **amplitude**
2- Action potential-> increased **frequency**

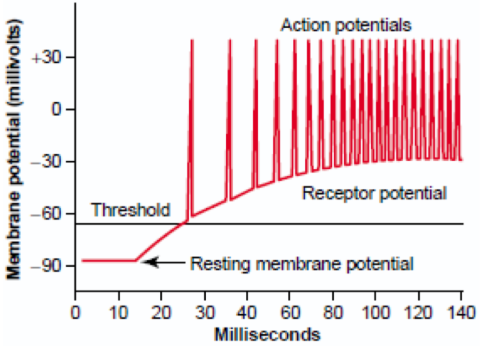
Relation Between Stimulus Strength & Receptor Potential Amplitude



- Receptor potential is directly related to stimulus strength

Transduction of Sensory Stimuli into Nerve Impulses

- Local Electrical Currents at Nerve Endings produce Receptor Potentials
- When the receptor potential rises above the threshold then action potentials occurs



The difference between generator potential and Action potential

Receptor or Generator potential	Action potential
- In the receptor	- In the sensory nerve fiber
- Graded	- Not Graded
- Doesn't obey all or none role	- Obeys all or none role
- Can be summated	- Not summated
- Unpropagated	- propagated

Stimulus Features That Are Mediated by Sensory Receptors

Sensory receptors mediate 4 features of a stimulus:
"MILD"

Modality

It 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 Signal amplitude or 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

Myelinated (A- fiber)

- **Aα** (thickly myelinated)
- **Aβ** (intermediate m.)
- **Aδ** (thinly myelinated)

Unmyelinated (C-fibers)

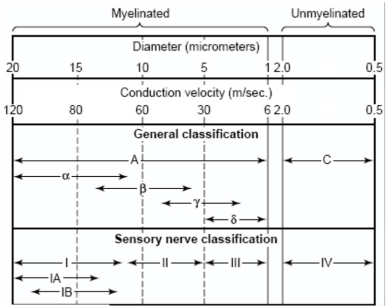


TABLE 4-1 Types of mammalian nerve fibers.

Fiber Type	Function	Fiber Diameter (μm)	Conduction Velocity (m/s)	Spike Duration (ms)	Absolute Refractory Period (ms)
Aα	Proprioception; somatic motor	12–20	70–120		
Aβ	Touch, pressure	5–12	30–70	0.4–0.5	0.4–1
Aγ	Motor to muscle spindles	3–6	15–30		
Aδ	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	Aα
Ib	Golgi tendon organ	Aα
II	Muscle spindle, flower-spray ending; touch, pressure	Aβ
III	Pain and cold receptors; some touch receptors	Aδ
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 pathways:

1 **Spinothalamic pathway**

Carries signals of pain, temperature. Crude pressure, and crude touch

2 **Dorsal column pathway**

Carries signals of fine touch, pressure, vibration and proprioception.

3 **Posterior (dorsal) spinocerebellar pathway**

Carry subconscious proprioception

4 **Anterior (ventral) spinocerebellar pathway**

Carry subconscious proprioception

What is proprioception?

- ❖ Proprioception is a term 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 and rate of movements.

Static
Conscious perception of the orientation of the different parts of the body with respect to one another

Proprioception can be divided into

Dynamic
Rate of movement sense (also called kinesthesia)

Types of Proprioception

1

Conscious proprioception

It reaches the level of sensory cerebral cortex (cerebrum) via the dorsal column-medial lemniscus pathway.
end in somatosensory area 1

2

Unconscious proprioception

Is communicated to the cerebellum primarily via:
- ❖ The dorsal spinocerebellar tract (dSCT).
- ❖ The ventral spinocerebellar tract (vSCT).

These are main ascending sensory pathways for proprioception.

Role of Proprioception:

- ❖ Proprioception informs us about:

1. The location of a body part in relation to other parts.
2. The rate of movement of a body part when it is moving.
3. The degree to which our muscle are being contracted or stretched.
4. The amount of tension created in our tendons.
5. The head orientation in relation to the ground and in response to movement.

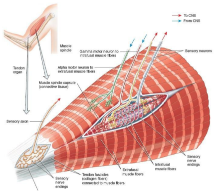
- ❖ Proprioceptive information is carried from periphery to the CNS by proprioceptors and other somatic receptors.

Types of Proprioceptors and functions

1

Joint Kinesthetic Receptors

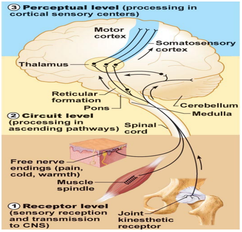
- Are mechanoreceptors in the joint capsules
- they detect angle and movement of the joints



2

Golgi tendon organs

- Detect tension of a muscle on its tendon
- Provide information about the strength of contraction & tension
- Detect changes in muscle tension



3

Muscle spindles

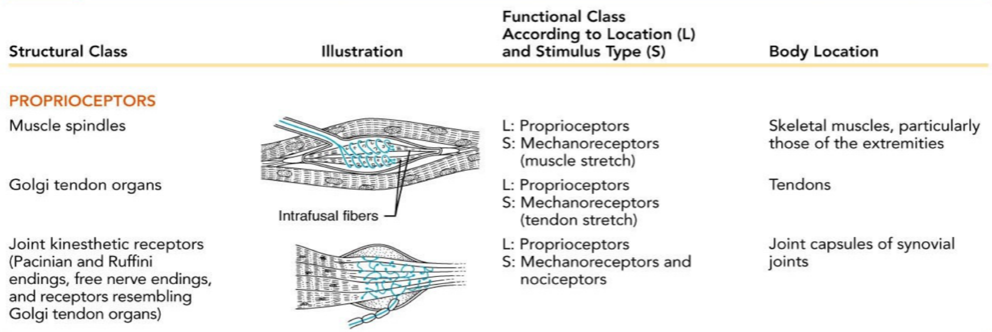
- Detect how much a muscle is stretched
- They detect changes in the length of muscle
- They convey length information to the CNS via group I and II afferent neurons
- This information is important for determining the position of body part

4

Multiple different types of receptors help to determine joint angulation:

- In the fingers, where skin receptors are much as half of position recognition is believed to be detected through the skin receptors
- In midranges of motion, the muscle spindles are the most important receptor
- At the extremes of joint angulation , Pacinian corpuscles, Ruffini's endings, and Golgi tendon receptors
- The Pacinian corpuscles and muscle spindles are the receptors most responsible for detecting rate of movement

❖ Cutaneous & deep receptors also contribute to proprioception



Structural Class	Illustration	Functional Class According to Location (L) and Stimulus Type (S)	Body Location
PROPRIOCEPTORS			
Muscle spindles	Intrafusal fibers	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 (Pacinian and Ruffini endings, free nerve endings, and receptors resembling Golgi tendon organs)		L: Proprioceptors S: Mechanoreceptors and nociceptors	Joint capsules of synovial joints

Female slides

Sensory Pathways:

- Sensory system allow us to detect, analyze and respond to our environment
- Ascending Pathway
- 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 multi neuron pathways connecting the CNS to the PNS . At some point most pathways crossover (decussate), Ascending (sensory) Pathways :-

Dorsal column pathway	Posterior and anterior spinocerebellar pathways	Spinothalamic 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 (postcentral gyrus).	carry subconscious proprioception. Dorsal gray horn- to lateral column- to medulla oblongata- to pons – to cerebellum.	carries signals of pain, temperature, deep pressure, and course touch. From posterior gray horn decussate into lateral and anterior funiculi up to the thalamus to primary somatosensory cortex (postcentral gyrus).

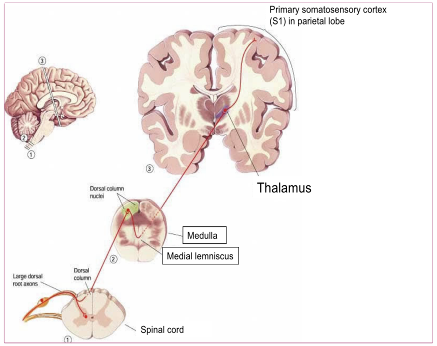
-Stereognosis :is the ability to perceive and recognize the form of an object in the absence of visual and auditory information
-Vibration is examined by using tuning fork

Dorsal Column–Medial Lemniscal System:

- Carries fine touch, position, pressure, vibration, two point discrimination, conscious proprioception signals and stereognosis.
- 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 pressure).
- Afferent sensory fibers **Aα and** aβ type. very fast velocity 30-70 m/s.
- 3 neuron system, decussates at the level of medulla:

-Two-point discrimination : is the ability to discern that two nearby objects touching the skin are truly two distinct points, not one
- in the tongue and fingers the sense of two point discrimination is better than the back because :
1/ there are more sensory receptors in the tongue and fingers . 2/they are represented by larger areas in the somatic cortex

Dorsal column pathway



1st Neuron*

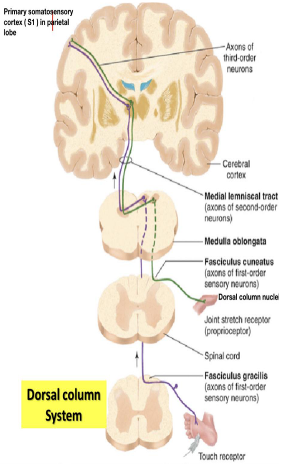
Enters spinal cord through dorsal root; ascends to medulla (brainstem).

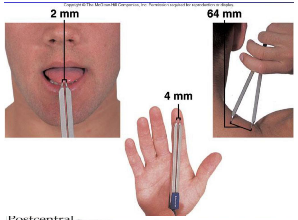
2st Neuron *

Crosses over in medulla; ascends to thalamus.

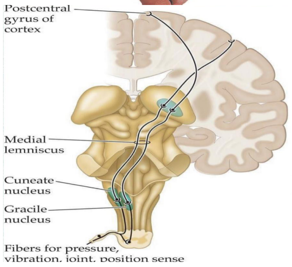
3st Neuron*

Projects to somatosensory cortex.

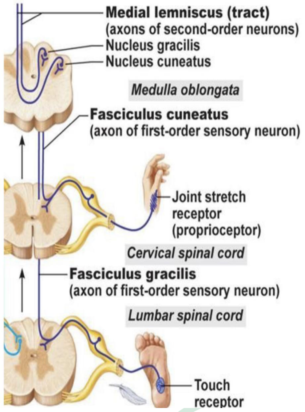




<— Two-point Discrimination



<—Fast conducting **Aα and** aβ fiber neurons



Dorsal Column–Medial Lemniscal System:

A modification of clinical applications from females doctor

Clinical application of physiology of proprioception

Damage to the dorsal column-medial lemniscus pathway clinical aspect;

below the crossing point of its fibers results in loss of vibration and joint sense (proprioception) on the same side of the body as the lesion.

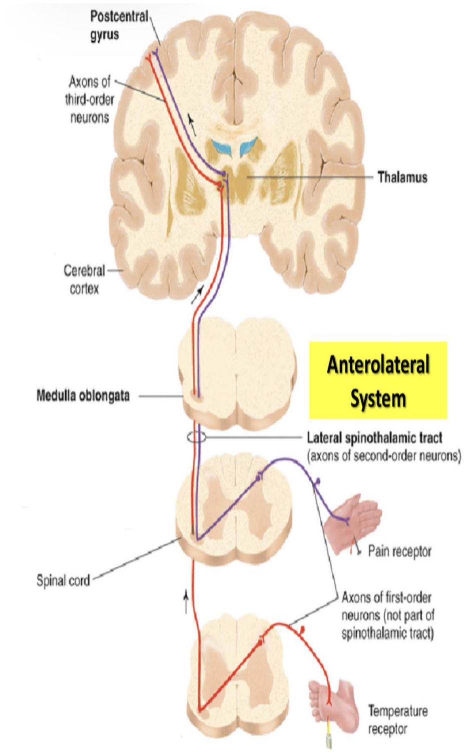
Damage above the crossing point result a loss of vibration and joint sense on the opposite side of the body to the lesion

Damage to the spinothalamic tract within the spinal cord, as seen in Brown Squared syndrome, results in contralateral loss of pain and temperature whilst vibration and proprioception, transmitted via the dorsal columns, will be affected ipsilaterally

Anterolateral system:

Ventral & lateral spinothalamic tracts

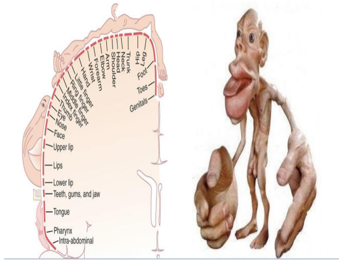
- Pain.
- Thermal sensations (warmth & cold).
- Crude touch and pressure sensations capable only of crude localizing ability on the surface of the body.
- Tickle and itch sensations.
- Sexual sensations.
- Carries pain & temperature (lat.ap.th)
- Crude touch & pressure (vent.sp.th).
- Afferent sensory fibers aδ (myelinated) fast pain.
- C fibers (unmyelinated) slow pain.
- Relatively slow velocity aδ-6-30m/s, C-0.5-2m/s.
- 3 neuron system (see the diagram)
- Decussates at level of spinal cord



Anterolateral system:

Sensory Homunculus (little Man)

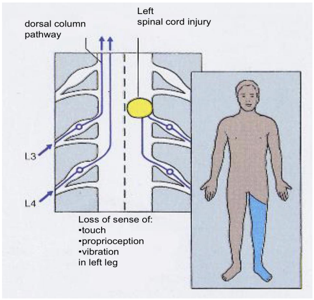
- ❖ Body is represented upside-down, with large representation of hands & lips.
- ❖ The extent of representation is proportional to the density of sensory receptors



Dorsal column damage

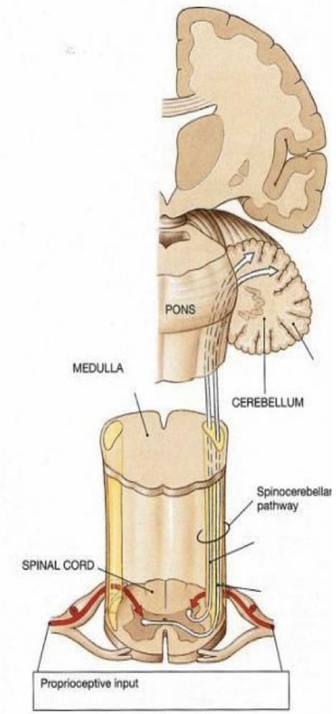
- ❖ Sensory ataxia
- ❖ Visual clues help movement.
- ❖ Patient staggers: cannot perceive position or movement of legs.

Positive Romberg test; the test depends on the integrity of proprioception from the joints of the legs. -the damage is in the same side at the level of spinal cord (picture) but if the damage above the medulla it will be on the opposite side



Spinocerebellar pathway

- Carries unconscious proprioception signals
- Receptors in muscles & joints

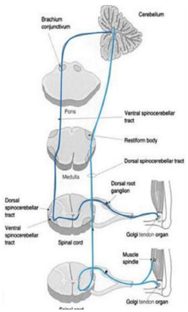
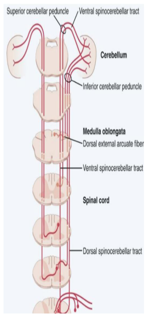


1st Neuron*	enters spinal cord through dorsal root
2st Neuron*	ascends to cerebellum
3st Neuron*	No 3rd neuron to cortex, hence unconscious

Spinocerebellar tract damage

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

Spinocerebellar pathway

The dorsal & ventral spinocerebellar tracts	
They carry subconscious proprioception signals	
1- The dorsal spinocerebellar tract (dSCT)	**2- The ventral spinocerebellar tract (vSCT)**
❖ 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  	❖ Carry some signals from the 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 the cerebellum through superior cerebellar peduncle and terminate on both sides of cerebellum 
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	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 to PNS) and not due to muscle weakness (called also incoordination)

Types of ataxia:

1. Sensory ataxia
2. Motor ataxia

Pathophysiology

❖ Result from any condition that affects the central and peripheral nervous system

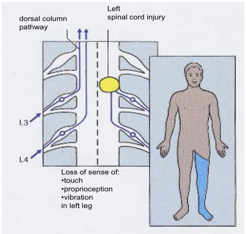
Pathophysiology of sensory ataxia

❖ **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 the thalamus & sensory cortex**

Romberg's test: ask the patient to close the eyes while standing with feet together.
The affected patient becomes unstable (Positive Romberg's test)

Ataxia and Gait Disturbances-2

Motor ataxia	Sensory 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 ❖ Even with the eyes open the ataxia is present (Main difference) ❖ Thalamic infarcts may cause contralateral ataxia with sensory loss ❖ N.B cerebellar ataxia will discussed later with cerebellum lecture	❖ Failure of proprioceptive information to CNS ❖ May be due to disorders of spinal cord or peripheral nerves ❖ Can be compensated for by visual inputs

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!

TEST YOURSELF !

1\ Which of the following receptors is considered a interoceptor ?

A)Joints

B)Temperature

C)Touch

D)Osmoreceptors

2\ .... is the stimulus feature that is encoded by action potential frequency.

A)Location

B)Duration

C)Modality

D)Intensity

3\ The Dorsal Column is responsible for all the following EXCEPT:

A)Discrimination

B) Crude touch

C)Vibration

D)Proprioception

answer key:
1: D
2: D
3 :B

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Khalid Alanezi
sami Mandoorah
Abdullah alzamil
Mohammed Alqutub
Mohammed Bin Manee

Salmam Althunayan
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Special Thanks to Physiology **Team441**
Team logo and design was done by **Rafan Alhazzani**
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PHYSIOLOGY
CNS BLOCK
TEAM 443