Physiology Team 439

MED439
KING SAUD UNIVERSITY

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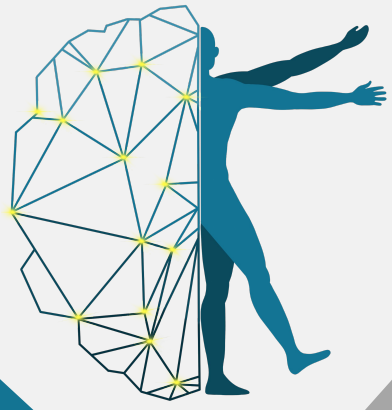


Proprioceptive pathways

Objectives:

- 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

Color index:

- Important.
- Girls slide only.
- Boys slide only.
- Dr's note.
- Extra information.

Editing File

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

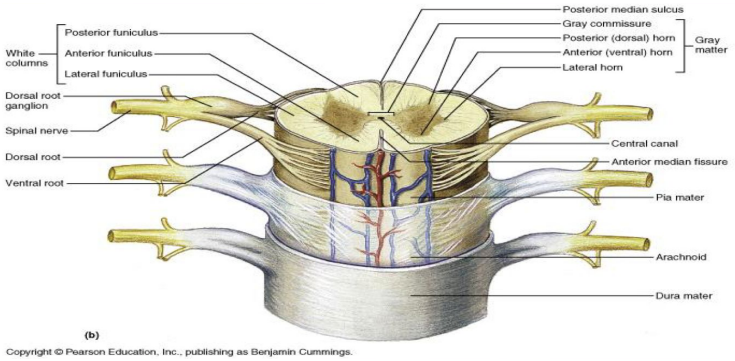
The nervous system outside of the brain and spinal cord
Consists of:
31 Spinal nerves
Carry info to and from the spinal cord 12 Cranial nerves
Carry info to and from the brain

- Spinal cord

- A Cross-section view of spinal cord- wider laterally 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.



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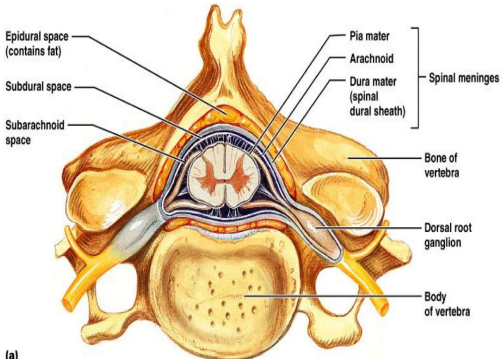
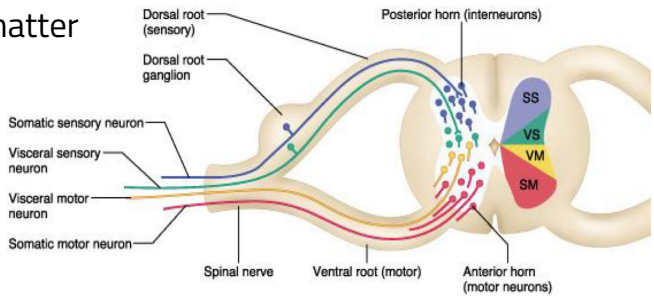


Spinal cord organization *

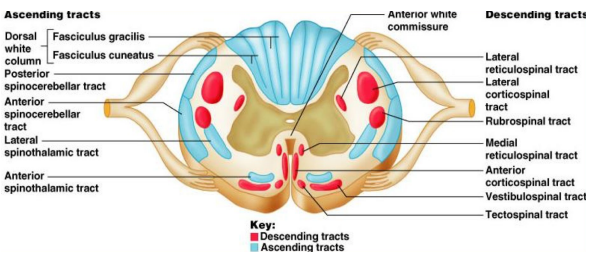
- Dorsal half – sensory roots and ganglia
- Ventral half – motor roots
- Dorsal and ventral roots fuse laterally to form spinal nerves

- Four zones are evident within the gray matter
  - somatic sensory (SS)
  - visceral sensory (VS)
  - visceral motor (VM)
  - 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



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 — concerned with the external environment.
- Found on the surface of the body
- E.g. touch and temperature receptors

Usually on skin

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.

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

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

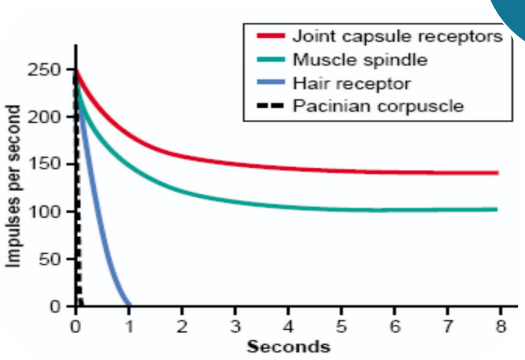
4. **Electromagnetic receptors:** which detect light on the retina of the eye eg rods and cones.

5. **Nociceptors (pain receptors):** which detect damage occurring in the tissues, whether physical damage or chemical damage
e.g free nerve endings

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. - Pain receptors do not adapt at all. 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.

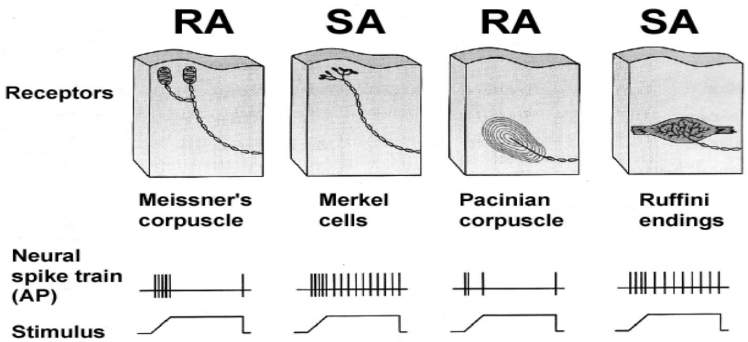
2

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:

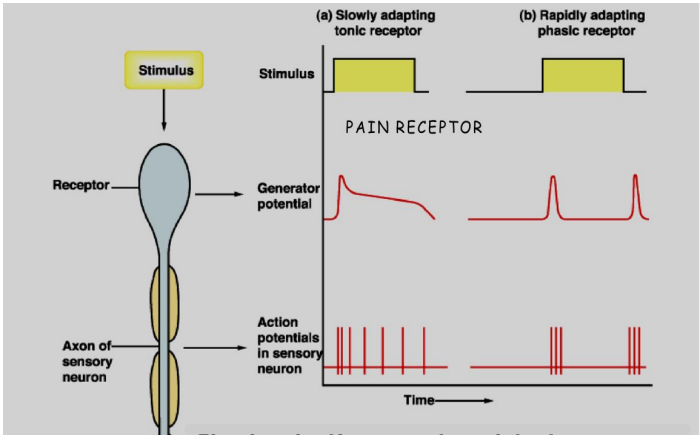
Muscle spindles & nociceptors are other examples of SA receptors.



Generation of a Receptor Potential

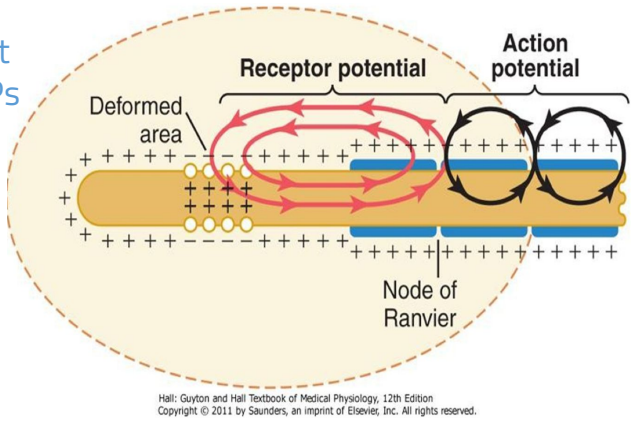
لو ماغيرت قوة ال stimulus يصير adaptation

- 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)

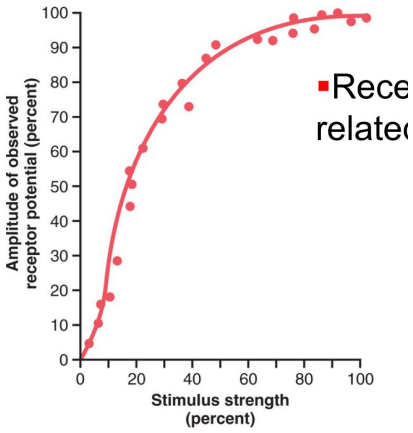
- Stimuli (mechanical, thermal, chemical) cause deformation in the sensory receptors
- This causes influx of positive ions and generation of RP
- RP induces a local circuit of current flow that spreads along nerve fiber and generates APs when threshold is reached



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

Relation Between Stimulus Strength & Receptor Potential Amplitude

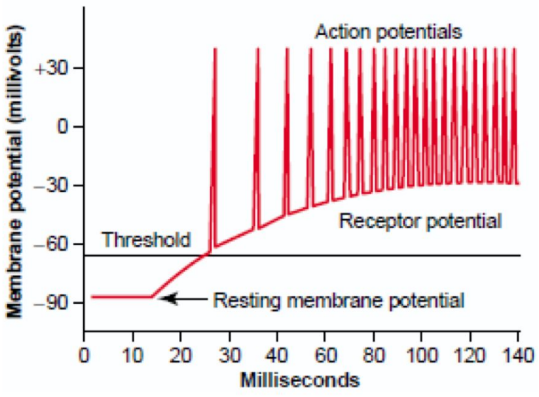
- Receptor potential is directly related to stimulus strength



Transduction of Sensory Stimuli into Nerve Impulses*

Boys slides only

- 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 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)

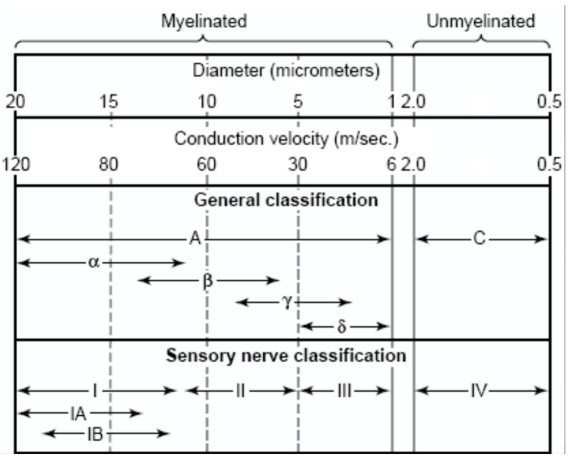


TABLE 4-1 Types of mammalian nerve fibers.

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.,

1. **Spinothalamic pathway**
   Carries signals of pain, temperature. Crude pressure, and crude touch & deep pressure

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 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.
- It is the awareness of body position and of movements of body parts

Proprioception can be divided into

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

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.

2 Unconscious proprioception

Is communicated to the cerebellum primarily via:

- The dorsal spino-cerebellar tarct (dSCT).
- The ventral spino-cerebellar tract (vSCT).

These are main ascending sensory pathways for proprioception.

Role of Proprioception:

- Proprioception informs us about:

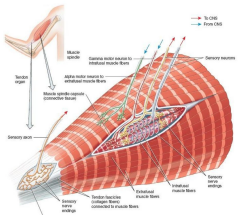
1. The location of a body part in relation to other parts.
2. The rate of movement of a body part when it is moving.
3. The degree to which our muscle are being contracted or stretched.
4. The amount of tension created in our tendons.
5. The head orientation in relation to the ground and in response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

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

Types of Proprioceptors:

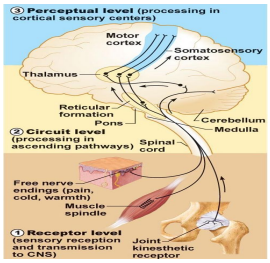
1 Joint Kinesthetic Receptors

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



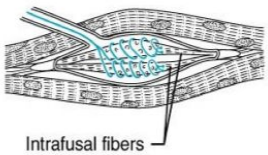
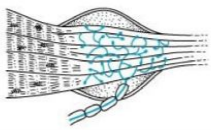
2 Golgi tendon organs

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

Structural Class	Illustration	Functional Class According to Location (L) and Stimulus Type (S)	Body Location
PROPRIOCEPTORS			
Muscle spindles		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

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:

- 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

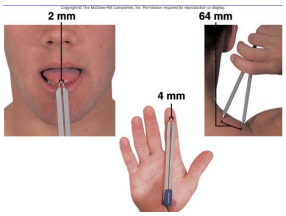
These are known as sensory and motor pathways consisting of multineuron pathways connecting the CNS to the PNS . At some point most pathways crossover (decussate)
Ascending (sensory) Pathways : -

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 (post central 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 steregnosis.
- 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 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

1st Neuron*

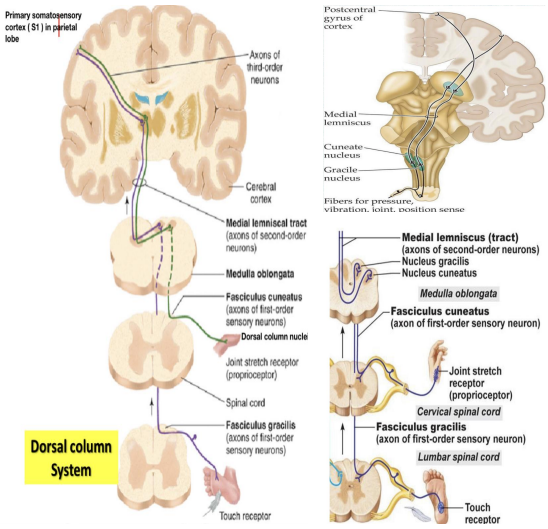
Enters spinal cord through dorsal root; ascends to medulla (brainstem).

2st Neuron*

Crosses over in medulla; ascends to thalamus.

3st Neuron*

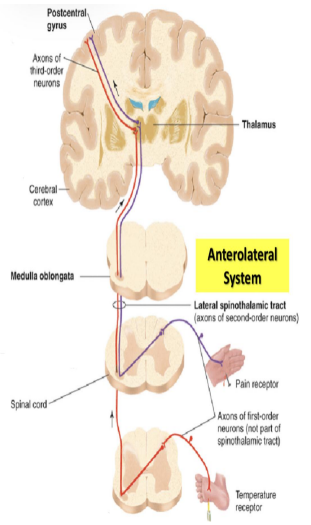
Projects to somatosensory cortex.



Anterolateral system:

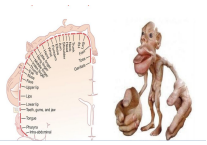
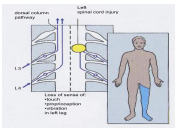
ventral & lateral spinothalamic tracts

- 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



Sensory pathways: 3 neurons*

- **1st Neuron*** — Enters spinal cord from periphery
- **2st Neuron*** — Crosses over (decussates), ascends in spinal cord to thalamus
- **3st Neuron*** — Projects to somatosensory cortex

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	 

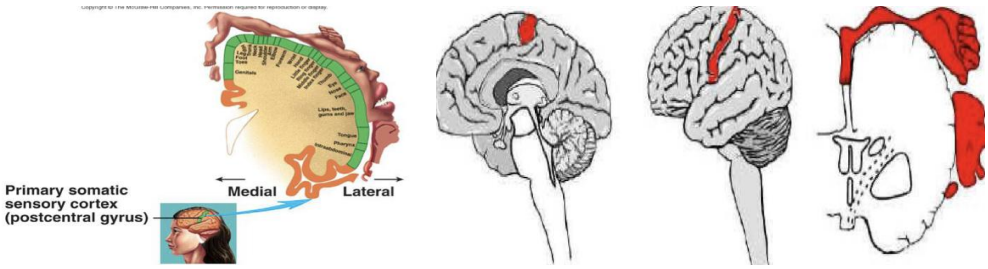
Somatosensory cortex*

- ❖ 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)

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.



Spinocerebellar pathway

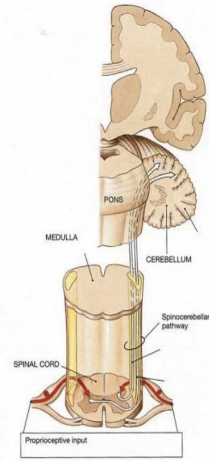
*Girls slides

- 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*

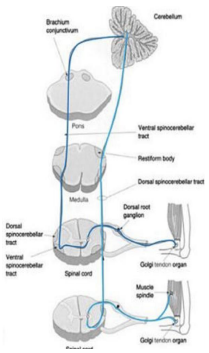
- Cerebellar ataxia
- Clumsy movements
- Incoordination of the limbs (intention tremor)
- Wide-based, reeling gait (ataxia)
- Alcoholic intoxication produces similar effects!

The dorsal & ventral spinocerebellar tracts * Extra

They carry subconscious proprioception signals

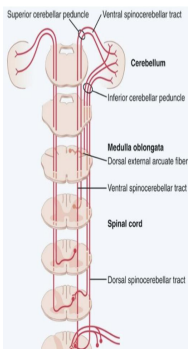
1- The dorsal spinocerebellar tract (dSCT)

- 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



2- The ventral spinocerebellar tract (vSCT)

- 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*

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 or 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)

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

Sensory ataxia*

- 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!

MCQ & SAQ:

Q1: Which one of the following lesion will cause motor ataxia ?

A. Afferent fibers
B. Free nerve endings
C. Cerebellum
D. None of the above

Q2: Which one of the following is true about spinocerebellar tract damage?

A. Patient has static tremor
B. Patient has intention tremor
C. Blindness
D. All of the above

Q3: Which one is a rapid adapting receptor?

A. Merkel's disc
B. Krause's end bulbs
C. Meissner's corpuscles (touch)
D. None of the above

Q4: The spinocerebellar pathway has how many neurons

A. 1
B. 2
C. 3
D. 4

Q5: A patient went to a neurologist and when the doctor asked him to close his eyes while he's standing, he was falling down and he couldn't localize his position in a balance what could be his diagnosis ?

A. Cerebellar ataxia
B. Motor ataxia
C. Vestibular ataxia
D. Sensory ataxia

Q6: What type of receptors are located in carotid bodies?

A. Thermoreceptors
B. Mechanoreceptors
C. Chemoreceptors
D. Nociceptors

answer key:
1: C
2: B
3: C
4: B
5: D
6: C

1- Name 3 lesions that would cause sensory ataxia

2- What are the three types of proprioceptors?

3- What is the difference between conscious and unconscious pathway?

4- Mention three signals that are carried by the dorsal column pathway

A1: 1-Peripheral Nervous system "PNS" Lesion 2-Dorsal Column Lesion 3-Lesion to the Thalamus & Sensory Cortex

A2: 1- Muscle spindles 2- Golgi tendon organs 3-Joint kinesthetic receptors

A3: -Conscious: reaches the cerebral cortex
-Unconscious: Doesn't reach the cerebral cortex

A4: Carries fine touch, position, pressure, vibration, two point discrimination, conscious proprioception signals and steregnosis.

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