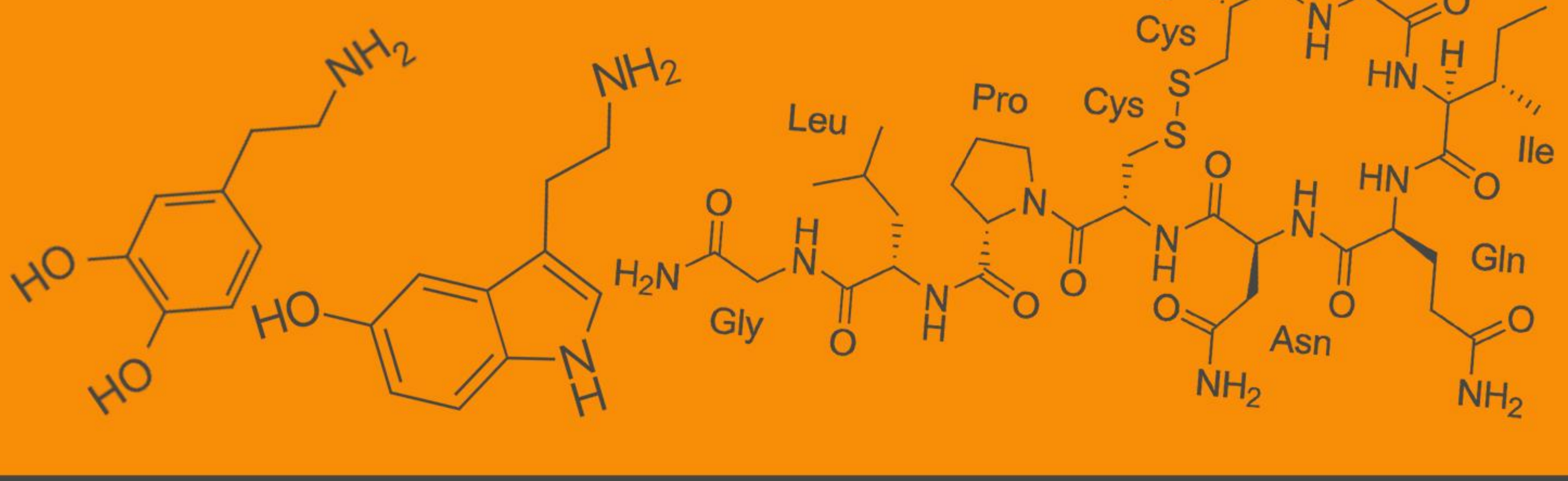
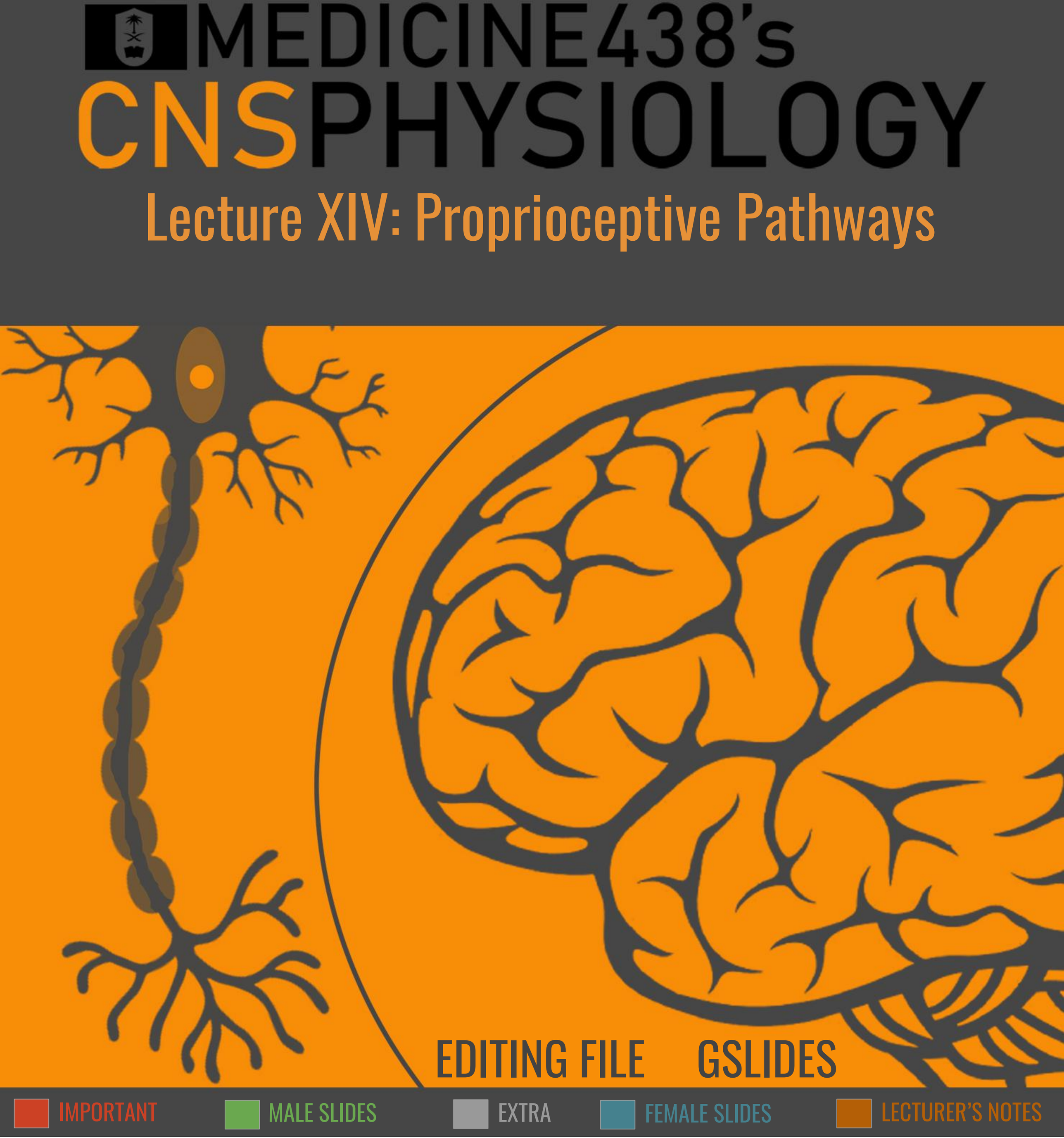


MEDICINE438's CNS PHYSIOLOGY

Lecture XIV: Proprioceptive Pathways



EDITING FILE GSLIDES

IMPORTANT MALE SLIDES EXTRA FEMALE SLIDES LECTURER'S NOTES

1 PROPRIOCEPTIVE PATHWAYS

Lecture Fourteen

OBJECTIVES

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

BOX 14-1: NEUROSCIENCE: EXPLORING THE BRAIN

Sensations can generally be divided into special and somatic, the term somatic sensation encompasses all sensations that are not seeing, hearing, smelling, tasting, and balance, which are special sensations.

- The somatic sensory system is unique is that its receptors are distributed throughout, unlike special sensations which are mainly in the head. It includes many sensations such as touch, temperature, body position, and pain. Clearly the view that we possess only five senses is too narrow.

- **Somatic Receptors** are specialized structures present in the peripheral terminations of the Afferent fibers.
- Receptors are detectors & **transducers** which transduce different forms of energy into Action potential which can conducted through the afferent fibers.
- They are found in many parts of the body, including :-
  - The skin (cutaneous receptors).
  - Skeletal muscles.
  - Bones & joints (proprioceptors)
- **They different from specific receptors which mediate the special senses, such as vision, taste, smell and equilibrium.**

Classification of Receptors

It's based on a lot of different factors :-

A. Based on their location (sherrington 1906):-

1. **Exteroceptors**: concerned with **external** environment, so they are found on the body surface, such as **touch & temperature receptors**.
2. **Interoceptors**: concerned with **internal** environment, such as **Chemoreceptors & Osmoreceptors**.
3. **Proprioceptors**: concerned with position of the body in the space, found in joints, tendons & muscles.

B. Based on the 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.

1. **Slowly adapting "SA" (or tonic receptors):**
   - Includes Muscle Spindles, Joint receptors, Baroreceptors.
   - Also Pain receptors which DON'T adapt at all.
2. **Rapidly adapting "RA" (or phasic receptors):**
   - Meissner's corpuscles (touch)
   - Pacinian corpuscles (vibration).

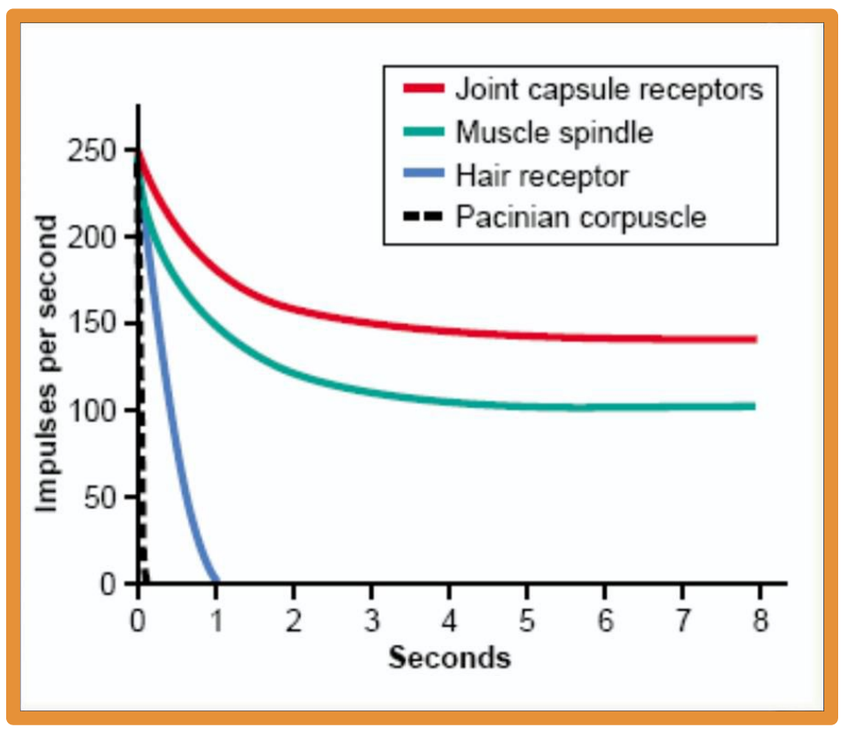


Figure 14-1

BOX 14-2: CLINICAL RELEVANCE

MECHANISMS OF SLOW ADAPTATION BY PAIN RECEPTORS

- Nociceptors can be stimulated by bending or chemical compression by a painful stimulus, also, it can be activated by chemicals secreted by damaged cells.
- Let us suppose there was an injury causing damage to underlying cells can trigger release of many chemicals that are released in response to damage, they are called Damage Associated Molecular Patterns or DAMPS.
- Injured cells release many DAMPs, like lactic acid for instance after a hypoxic injury, which can produce hydrogen ions, hydrogen ions can bind to ion channels and open them to activate nociceptors. This is the reason for the sensation of pain in hypoxic injuries, furthermore, injured cells release proteases from their disrupted lysosomes, these proteases can activate extracellular kininogen to form bradykinin, bradykinin can also open ion channels of nociceptors thus eliciting the sensation of pain. One more example is histamine release by mast cells in response to an allergen, histamine can bind to ion channels on nociceptors to cause pain sensation. In short, the mechanisms of pain are diverse and renewing, with many mediators activating the receptors. Hence why adaptation is difficult, since there is really more than one way to activate pain receptors.

C- Based on the Adequate Stimuli

Adequate stimuli *is the particular form of energy to which the receptor is most sensitive.*

Thermoreceptors
Detect changes in temperature, some receptors detecting cold and others warmth.

Mechanoreceptors
Detect mechanical compression or stretching of the receptor, or the tissues adjacent to it.
Such as :
Proprioceptors

Nociceptors
Aka (pain receptors) detect damage occurring in the tissues, whether physical damage or chemical damage.
Such as:
Free nerve endings[1]

Chemoreceptors
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.
Such as:
Chemoreceptors in the carotid body

Electromagnetic receptors
Detect light on the retina of the eye .
Such as :
Rods & Cones

The Mechanisms Of Receptor Adaptation (only in male slides)

- Is different for each type of receptor.
- In the eye, the rods and cones adapt by changing the concentrations of their light sensitive chemicals .
- The pacinian corpuscle is a viscoelastic structure so that after stimulation within a 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, from progressive “inactivation” of the sodium channels in the nerve fiber membrane.

FOOTNOTES

1. Most of sensory receptors are really only ending of neurons wrapped in layers of connective tissue, such as pacinian capsule, which is made of onion-shaped connective tissue arrangement structured around a nerve ending. Free nerve endings however are free dendrites that are not encapsulated in connective tissue layers, instead they extend into the epithelium of the epidermis of the skin and sense mechanical and chemical stimuli of pain.

Generation of Receptor Potential:-

1. Stimuli (mechanical, thermal or chemical) causes a deformity in the receptor.
2. That causes an influx of positive ions & generates **Receptor potential**.
3. The Receptor potential causes a local circuit of current flow that spreads through the nerve fiber and **generates action potentials when the threshold is reached.**

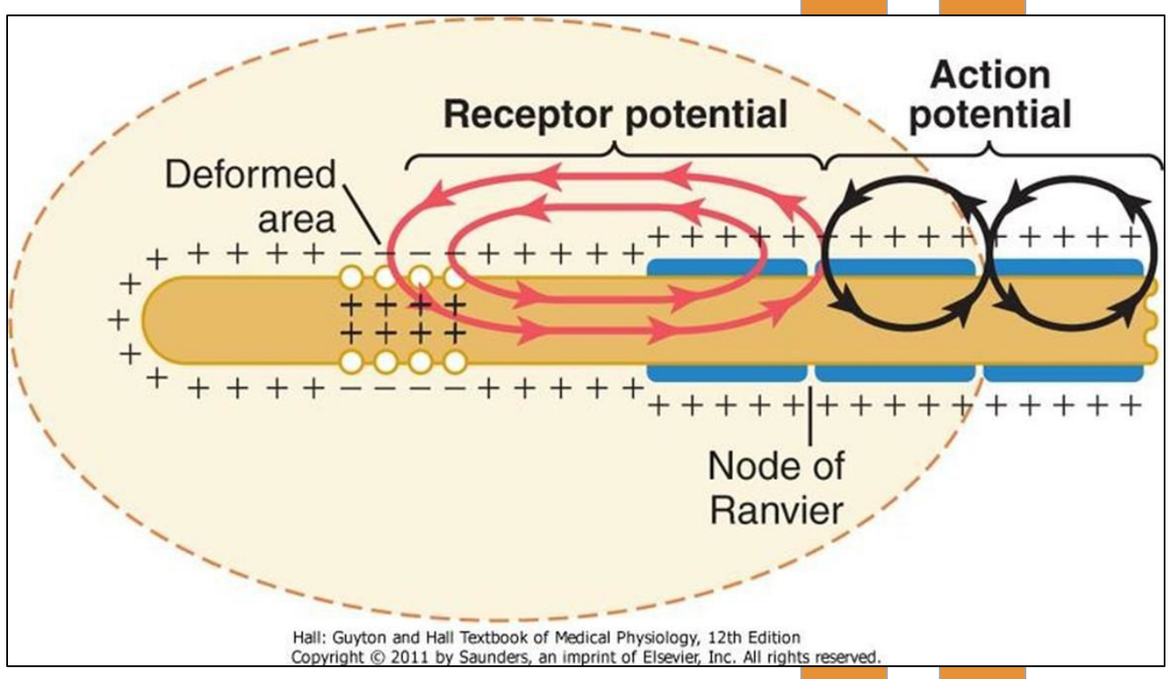


Figure 14-2

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

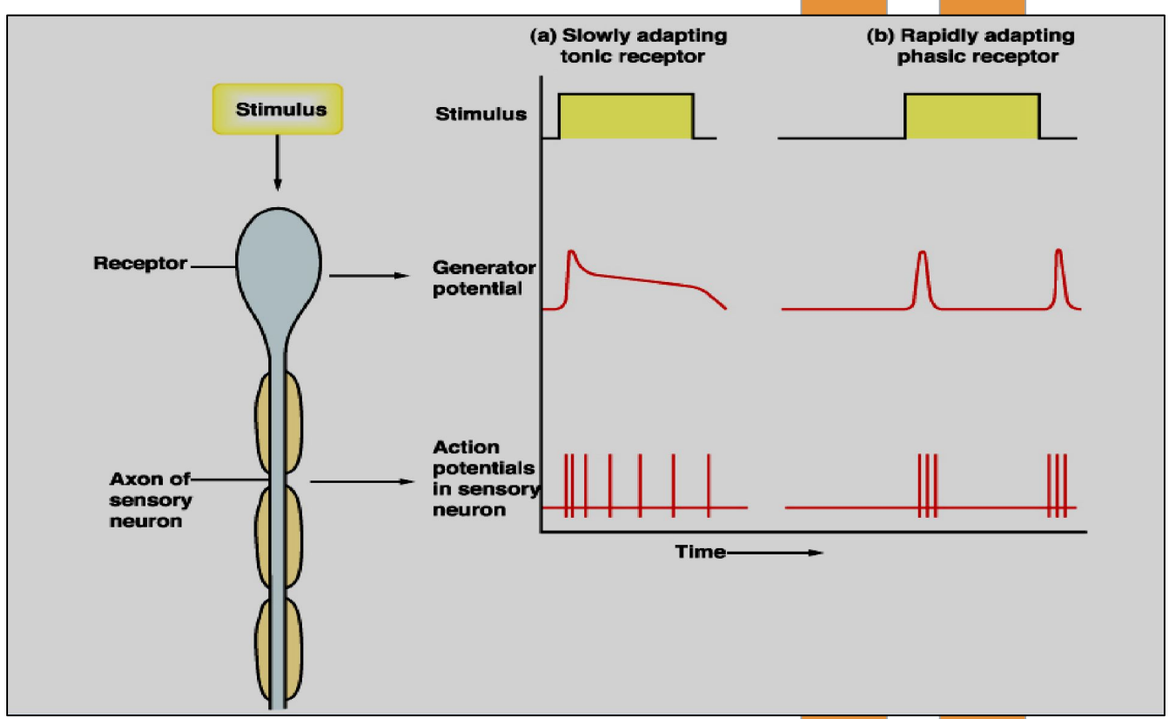


Figure 14-3

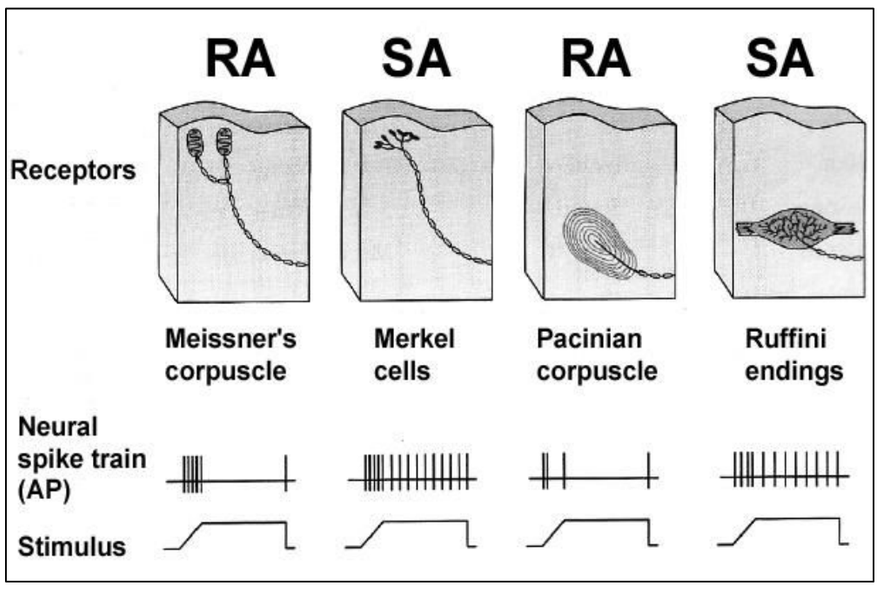


Figure 14-4

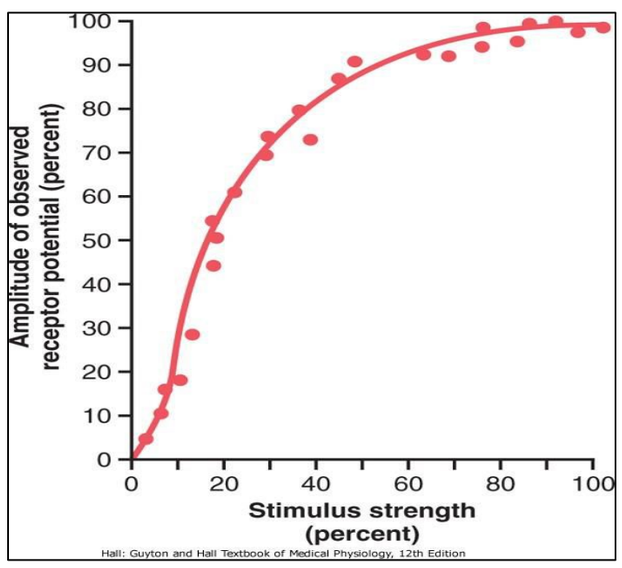


Figure 14-5:**Receptor potential is directly related to stimulus strength.**

Receptor potentials are present regardless if the threshold is reached for the action potential to generate to deliver the impulses to their respective processing areas.

Generation of Receptor Potential:-

- Myelinated (A-fiber):-
- Aα (thickly myelinated)
- Aβ (intermediate myelinated)
- Aδ (thinly myelinated)

- Unmyelinated (C-fiber)

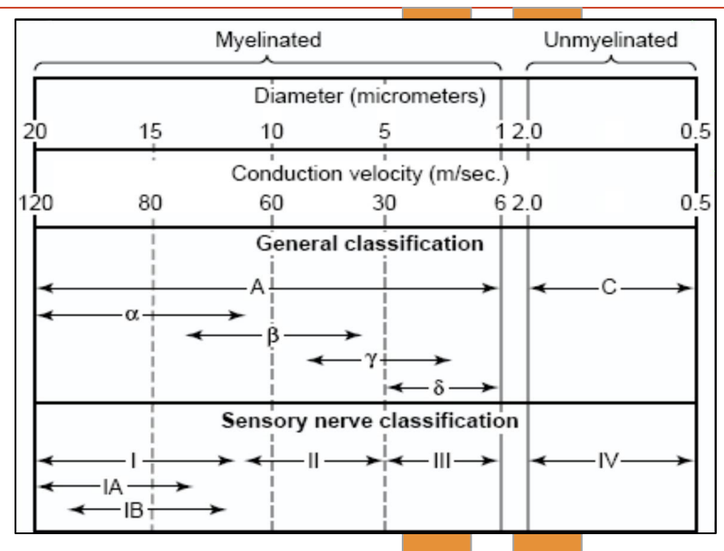


Figure 14-6

4 PROPRIOCEPTIVE PATHWAYS

Lecture Fourteen

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

Stimulus Features Mediated By Receptors "MILD"

Modality:
It's what we perceive after the stimulus stimulates the receptors, such as vision, taste, hearing. The main modalities also have some submodalities such as: Taste→sweet, sour, salty. Temperature →hot, cord.

Intensity:
Dependending on the stimulus strength, and is encoded by Action potential frequency.

Location:
The site or space of the body where the stimulus originated from.

Duration:
The time between the onset & the offset of the stimulus, which could be affected by the receptor adaptation.

Ascending Sensory Tracts

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.
4. Anterior (ventral) Spinocerebellar Pathway.

} Subconscious Proprioception

What Is Proprioception?

- Derived from the latin word "proprius" which means "one's own" or "individual".
- Defined as : "It is the sense of one's own body position" or " It is the awareness of body position and of movements of body parts "
- Also known as proprioceptive or position sense.
- 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 (kinesthesia)** : rate of movement sense.

The Types Proprioception

	Conscious Proprioception	Unconscious Proprioception
communication	Reaches the level of the sensory cerebral cortex (cerebrum)	Communicates primarily with the cerebellum
Conducted Through	Dorsal column & Medial lemniscus	Dorsal/ventral spinocerebellar tract

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:-**
   - Detected how long is the muscle stretched, so it detects the changes in the muscle length.
   - 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:**
   - Detect tension of a muscle on its Tendon.
   - Provide information about the strength of contraction & tension.
3. **Joint Kinesthetic Receptors:**
   - Mechanoreceptors found in the joint capsule.
   - Detect the angle and movement of the joint.

- Cutaneous & deep receptors also contribute to proprioception.

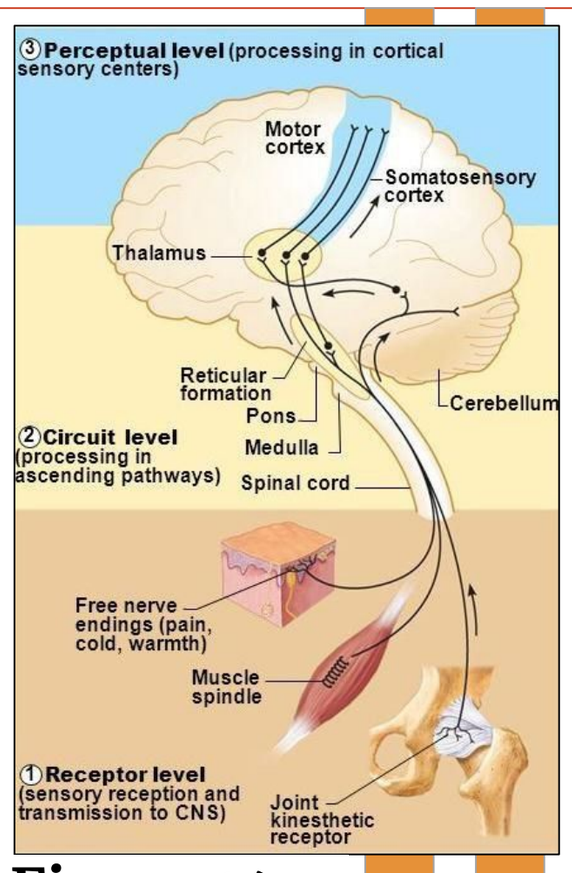


Figure 14-7

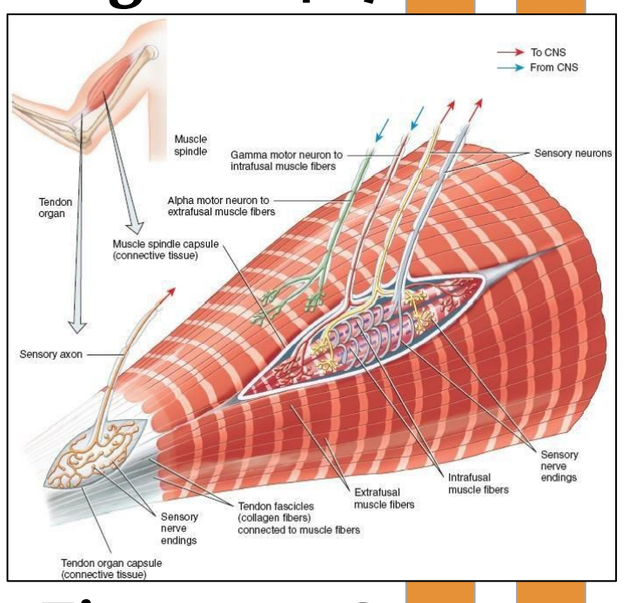


Figure 14-8

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

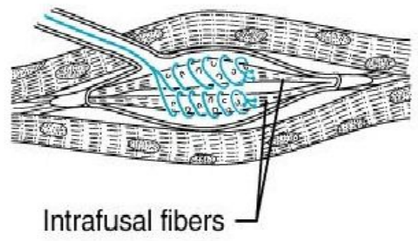
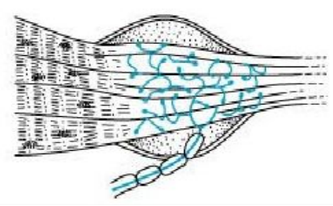
Structural Class	Illustration	Functional Class According to Location (L) and Stimulus Type (S)	Body Location
PROPRIOCEPTORS			
Muscle spindles		L: Proprioceptors S: Mechanoreceptors (muscle stretch)	Skeletal muscles, particularly those of the extremities
Golgi tendon organs		L: Proprioceptors S: Mechanoreceptors (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

Figure 14-9

Dorsal Column–Medial Lemniscal System

- Touch sensations requiring a high degree of localization and high intensity of discrimination (also known as "fine touch").
- Rapidly repetitive sensation such as vibration.
- Joint Position sensations (Proprioception).
- Pressure sensations characterized by high intensity discrimination (also known as "fine pressure").
- Two point discrimination & Stereognosis (perceive and recognize the form of an object in the absence of visual and auditory information).
- They use fast conducting A α/β-fiber neurons.

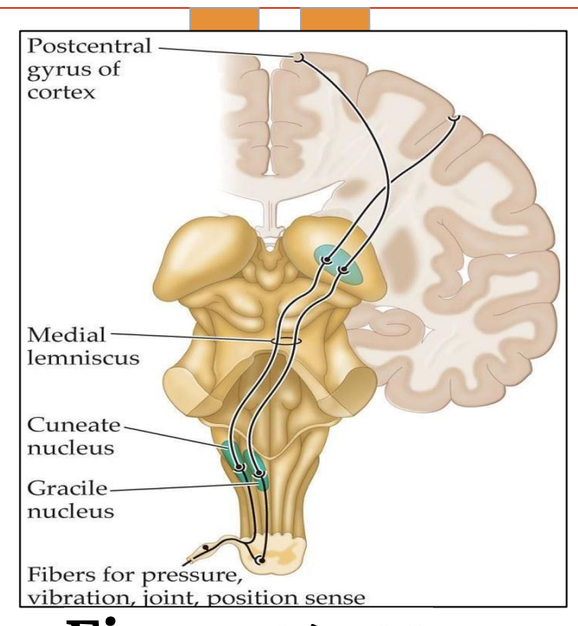


Figure 14-10

Anterolateral System

- **Consists of the Spinothalamic Tracts.**
- Sensation of pain.
- Thermal sensations (warmth or cold).
- Crude touch and pressure sensations capable only of crude localizing ability on the surface of the body.
- Tickle & itch sensations.
- Sexual sensations.

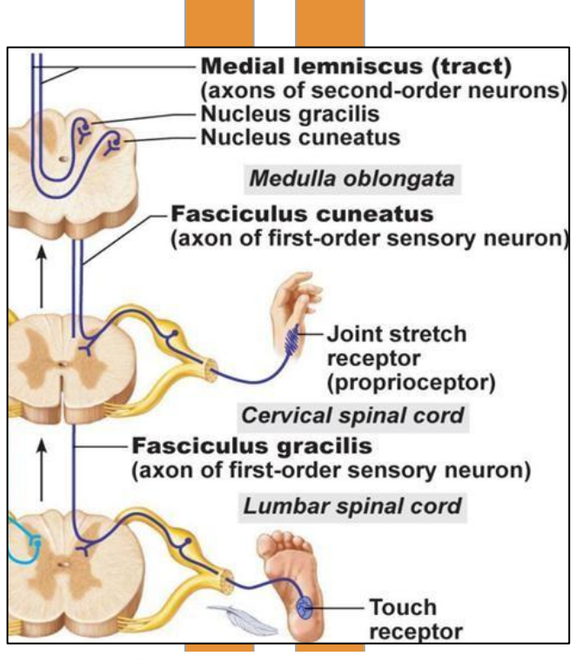


Figure 14-11

Dorsal column system

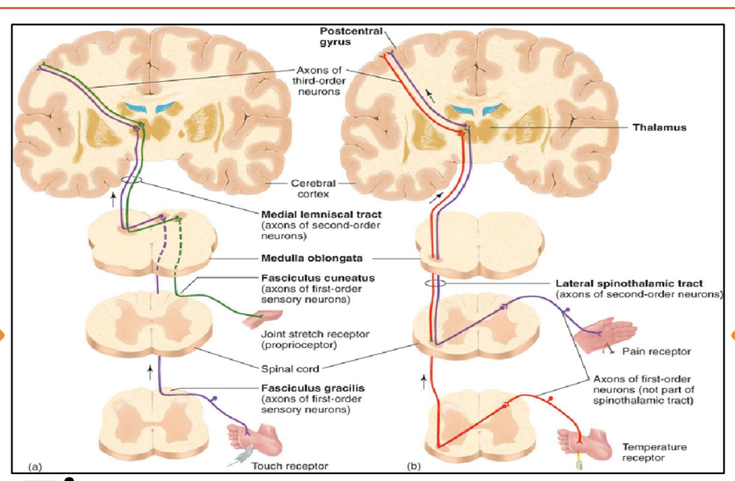


Figure 14-12

Anterolateral System

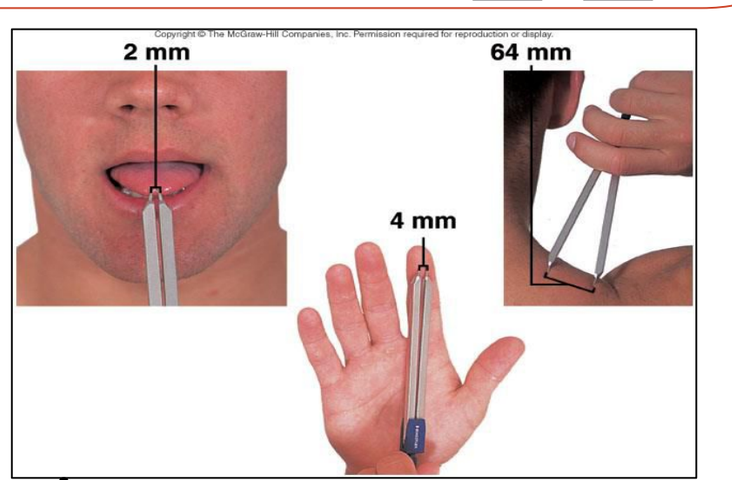


Figure 14-13: two point discrimination

Sensory Homunculus

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

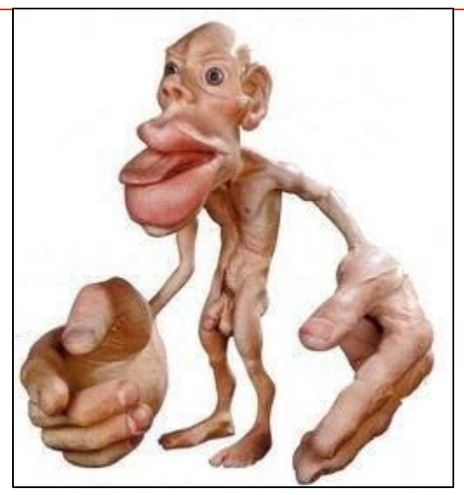


Figure 14-14

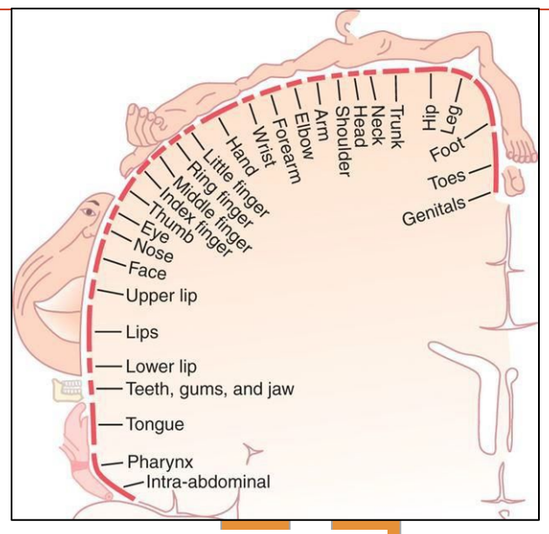


Figure 14-15

Dorsal Column Damage:

It cause "sensory ataxia", the patient will stagger because he can't perceive the position or movement of his legs , the can walk because they use their vision to help coordinate their movement, that's why it's more severe in dark conditions.
The patient will be positive to Romberg[1] test which depends on the integrity of proprioception from the joints of the legs.

Figure 14-16

Dorsal & Ventral Spinocerebellar Tracts

Dorsal Spinocerebellar Tract (dSCT)	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 golgi tendon organs, skin receptors & joint receptors.** • Enter cerebellum through inferior cerebellar peduncle • Terminate in vermis & intermediate zone. • **It's function is to inform the cerebellum about:-** • Muscle length and contraction. • Degree of tension on tendons. • Position and rate of movement of the parts of body. • Forces acting on the body surfaces.	• 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. • **It's function is to inform the cerebellum about:-** • Which motor signals have arrived to the spinal cord.

FOOTNOTES

1. Maintaining balance depends on input from vision, proprioception and vestibular system. The body requires at least two of these inputs to maintain balance. In Romberg's test the patient is asked to close their eyes, thereby taking the visual aspect. As a result, any imbalance will be a result of either vestibular or proprioceptive impairment.

Ataxia and Gait Disturbances :-

Ataxia

It's the inability coordinate voluntary movements due to nerve damage, Not muscular weakness.

Divided into :-

1- Sensory Ataxia:

Failure of proprioceptive information to the CNS.

It's pathophysiology (causes) include:

- **Peripheral Nervous System"PNS" Lesion**: injury to sensory receptors and Afferent.
- **Dorsal Column Lesion**: Loss of proprioception, vibration and fine touch sensations, worse in dark conditions as mentioned before.
- **Lesion to the Thalamus & Sensory Cortex.**

➢ **Patients are positive to Romberg's test, which consists of asking the patient closing their eyes while standing with their two feet together, if the patient staggers or becomes unstable that means the test is positive.**

(male slides only but still important)

2-Motor Ataxia:

- **It's caused by Cerebellar disorders:-**

- Intact sensory receptors & afferent pathways, but the integration and processing of sensory information is faulty.

- **Can be divided into:-**

- **Midline cerebellar lesions**: (BOX 14-3) causes truncal (in the trunk) ataxia.
- **Lateral cerebellar lesions**: causes limb ataxia.

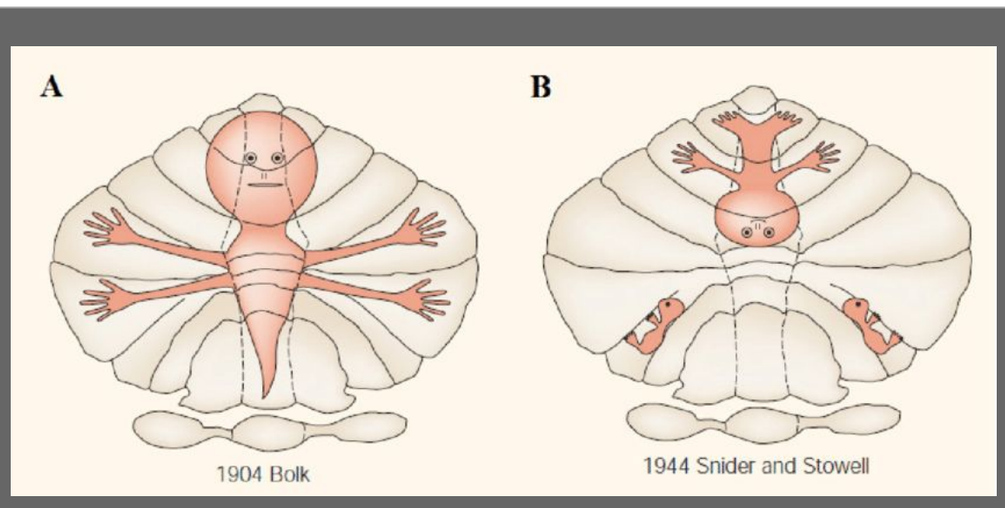
- **Features (presentation) of cerebellar ataxia:-**

- Clumsy movements.
- Incoordination of the limbs(intention tremor).
- **Reeling gait** :unsteadiness and irregularity of steps often with a tendency to fall to one or other side, forward or backward.

➢ **Alcoholic intoxication**(polite way to say drunk) **produces similar effects.**

BOX 14-3: GUYTON AND HALL

- Signals from dorsal spinocerebellar tracts reach the vermis and paravermis (intermediate zone of cerebellum), these zones have topological representation of trunk and limbs, meaning that the cerebellum computes different signals from vestibular system for head position, as well as from the trunk via the vermis (trunk representation), and paravermis (limb representation).
- Consequently, if there is a mismatch between trunk, limb and head positions, the cerebellum sends corrective signals from its vermis to correct trunk position, and from its paravermis to correct limb position. Head position is corrected first from signals that pass from vestibule and semicircular canals directly into the vestibular nuclei then the medial longitudinal fasciculus.
- Therefore, a lesion in the vermis causes truncal ataxia, and a lesion in the paravermis causes limbic ataxia.



QUIZ

MEDICINE438's
CNSPHYSIOLOGY

1. Fibers that are responsible for Conscious Proprioception terminate at:

A) Cerebellum
B) Sensory Cortex
C) Spinal Cord

2. Which of the following mediate Unconscious Proprioception?

A) Spinocerebellar Tracts
B) Medial Lemniscus
C) Dorsal Column

3. Rods & Cones are an example for?

A) Chemoreceptors
B) Electromagnetic Receptors
C) Bipolar Receptors

4. Which of the following lesions will cause Motor Ataxia?

A) Afferent fibers
B) Free nerve endings
C) Cerebellum

Short Answer Questions "SAQ" :-

1. Name 3 Lesions that would cause sensory Ataxia.

2. What does a Muscle spindle detect ?

3. Give 2 examples of rapidly adapting receptors.

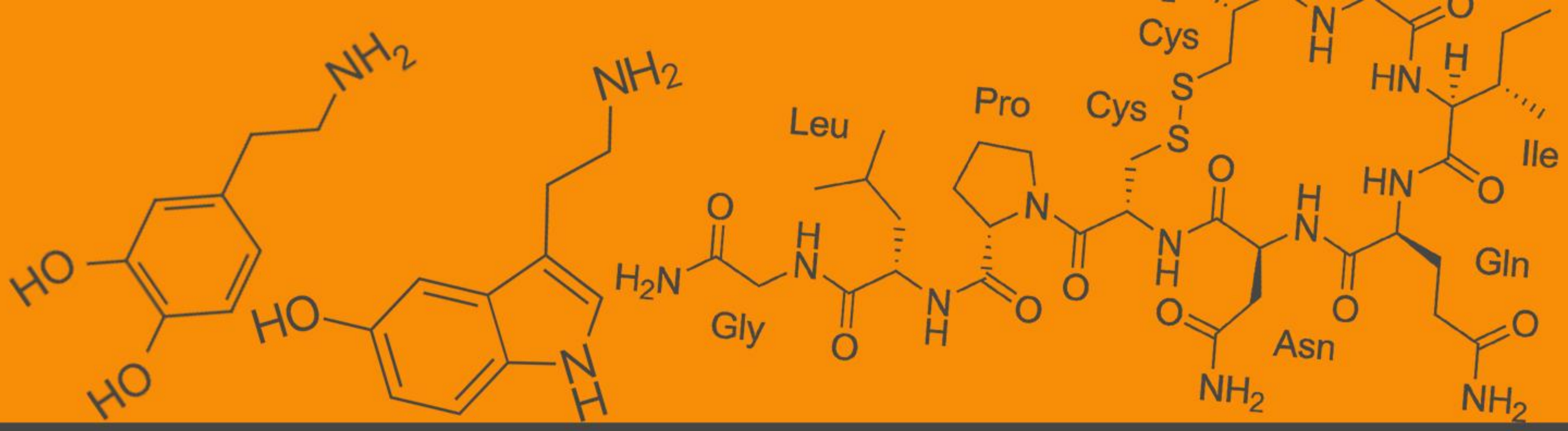
ANSWER KEY for SAQ:

1) Mind map page 8.

2) The length of the muscle.

3) Pacinian corpuscle & meissner's corpuscle.

ANSWER KEY for MCQs: B, A, B, C



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