PHYSIOLOGY OF THE PROPRIOCEPTORS IN BALANCE & ITS PATHWAYS

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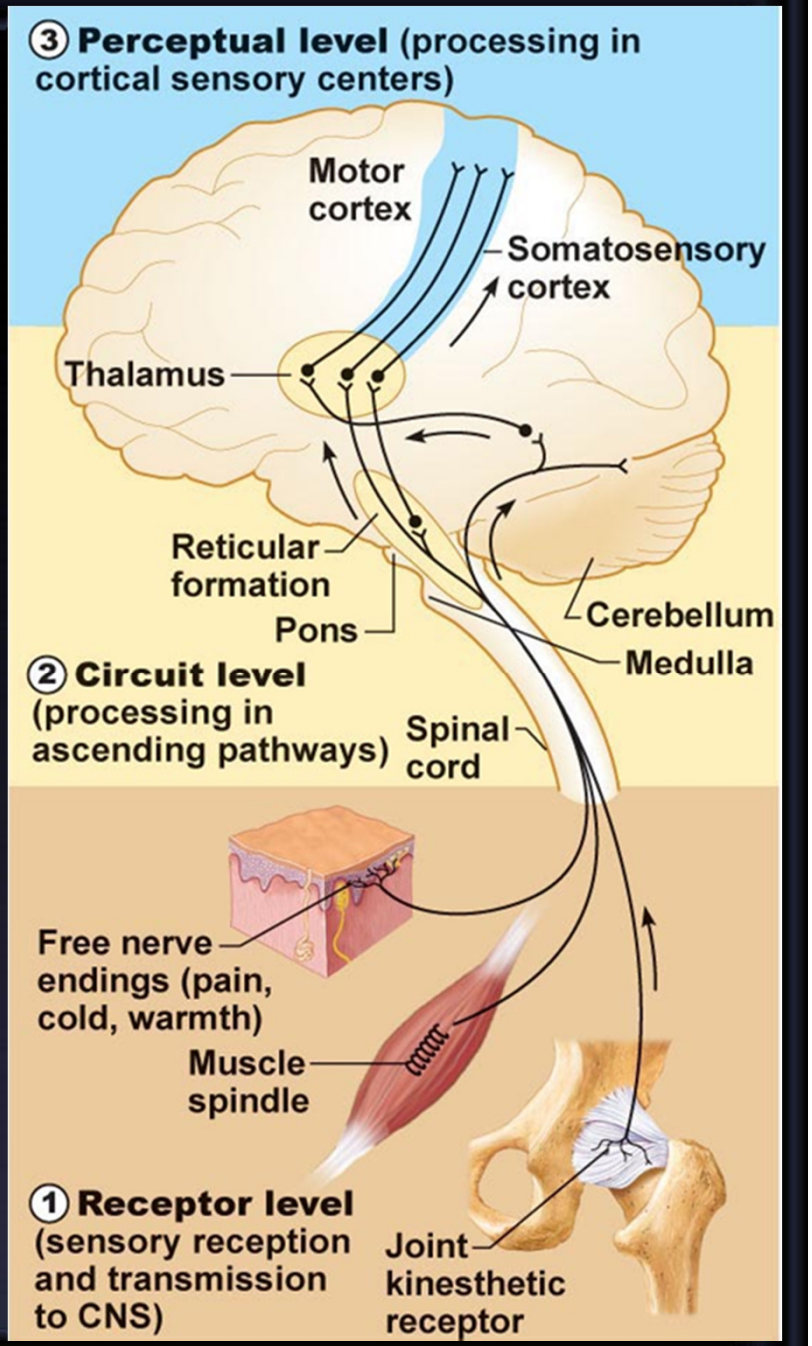


OBJECTIVES

At the end of this lecture you should be able to:

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

PROPRIOCEPTION

Latin proprius, meaning "one's own", "individual" and perception, is the sense of the relative position of neighbouring parts of the body and strength of effort being employed in movement.

exteroception, by which one perceives the outside world

interoception, by which one perceives pain, hunger, etc., and the movement of internal organs.

MECHANORECEPTORS: which detect mechanical compression or stretching of the receptor or of tissues adjacent to the receptor

PROPRIOCEPTORS

- **Proprioceptors include the muscle spindles, Golgi tendon organs, and joint receptors.**
- **These provide a sense of body position and allow fine control of skeletal movements**

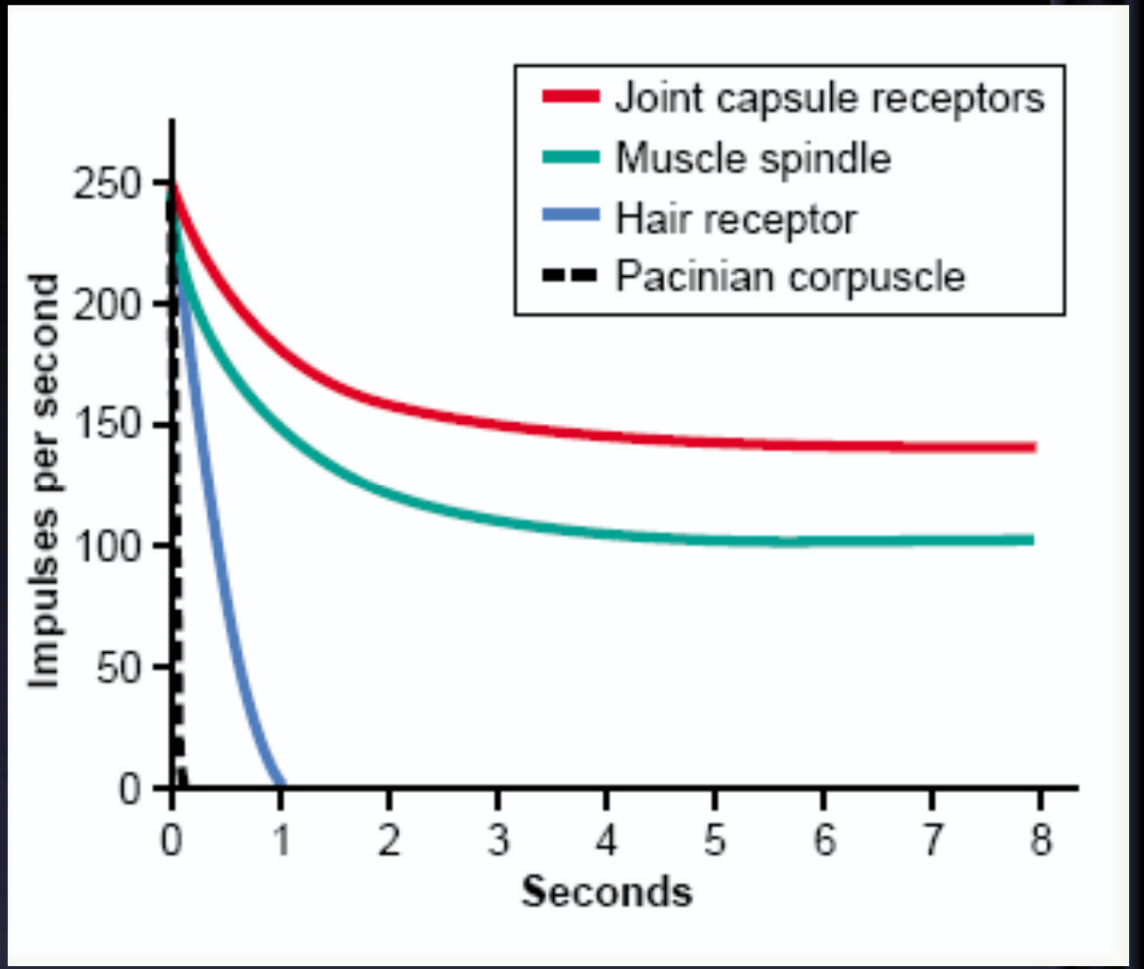
(1) Static position sense: which means conscious perception of the orientation of the different parts of the body with respect to one another, and
(2) Rate of movement sense: also called kinesthesia or dynamic proprioception

STRUCTURES CONCERNED WITH PROPRIOCEPTION

- Proprioceptors
- Brain Stem (Cortico,Rubro,Vestibulo,Retculo,Olivo,Tectospinal)
- vestibular system (apparatus, nuclei etc)
- Ascending Tracts
- Visual system
- Cerebellum (flocculonodular→dynamic equilibrium, Uvula → Static equilibrium)
- Cerebral cortex (primary cortical center for equilibrium located in the parietal lobe deep in the sylvian fissure)

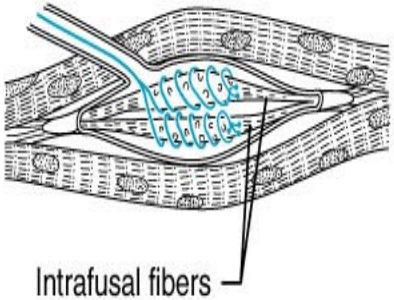
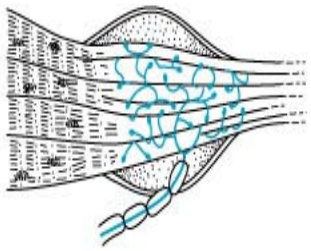
Adaptation of Receptors

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.



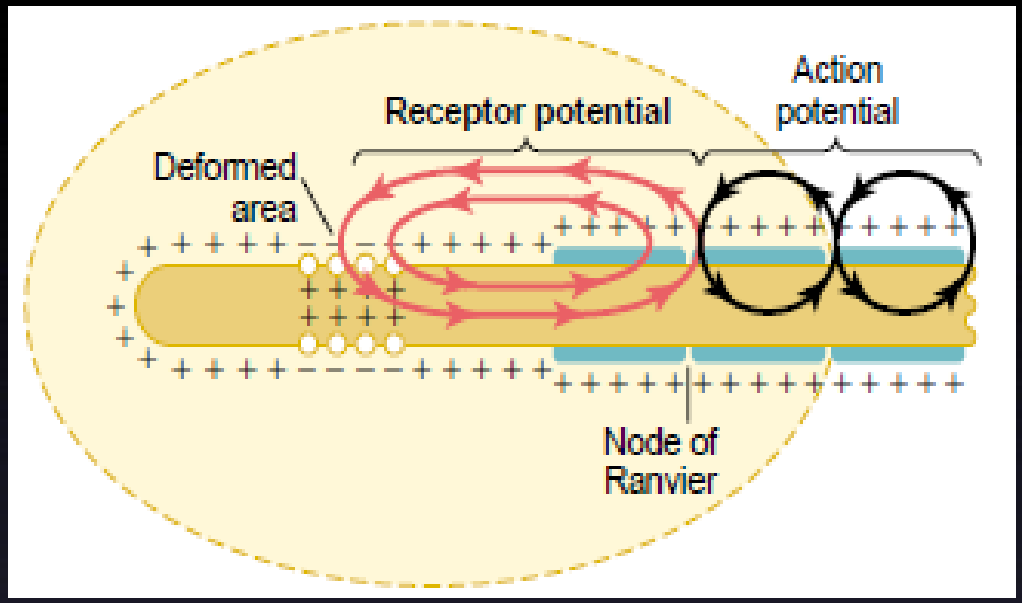
TABLE

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

Receptor Potential of the Pacinian Corpuscle

For joint position and vibration sensation (Also Ruffini's Endings)



- The receptor potential produced by compression induces a local circuit of current flow that spreads along nerve fiber.
- The frequency of repetitive action potentials transmitted from sensory receptors increases approximately in proportion to the increase in receptor potential

Three Types of Proprioceptors

- **Muscle spindles** – measure the changing length of a muscle
  - –Imbedded in the perimysium between muscle fascicles
- **Golgi tendon organs** – located near the muscle-tendon junction
  - Monitor tension within tendons & reflex provides a negative feedback (inverse stretch reflex) mechanism that prevents the development of too much tension on the muscle
- **Joint kinesthetic receptors**
  - –Sensory nerve endings within the joint capsules

Types of proprioception

1- Conscious proprioception reach the level of cerebral cortex sensory area via dorsal column tract.

2- Subconscious proprioception reach the level of cerebellum via spinocerebellar tracts

Where is the location of these tracts?

Structure of Proprioceptors

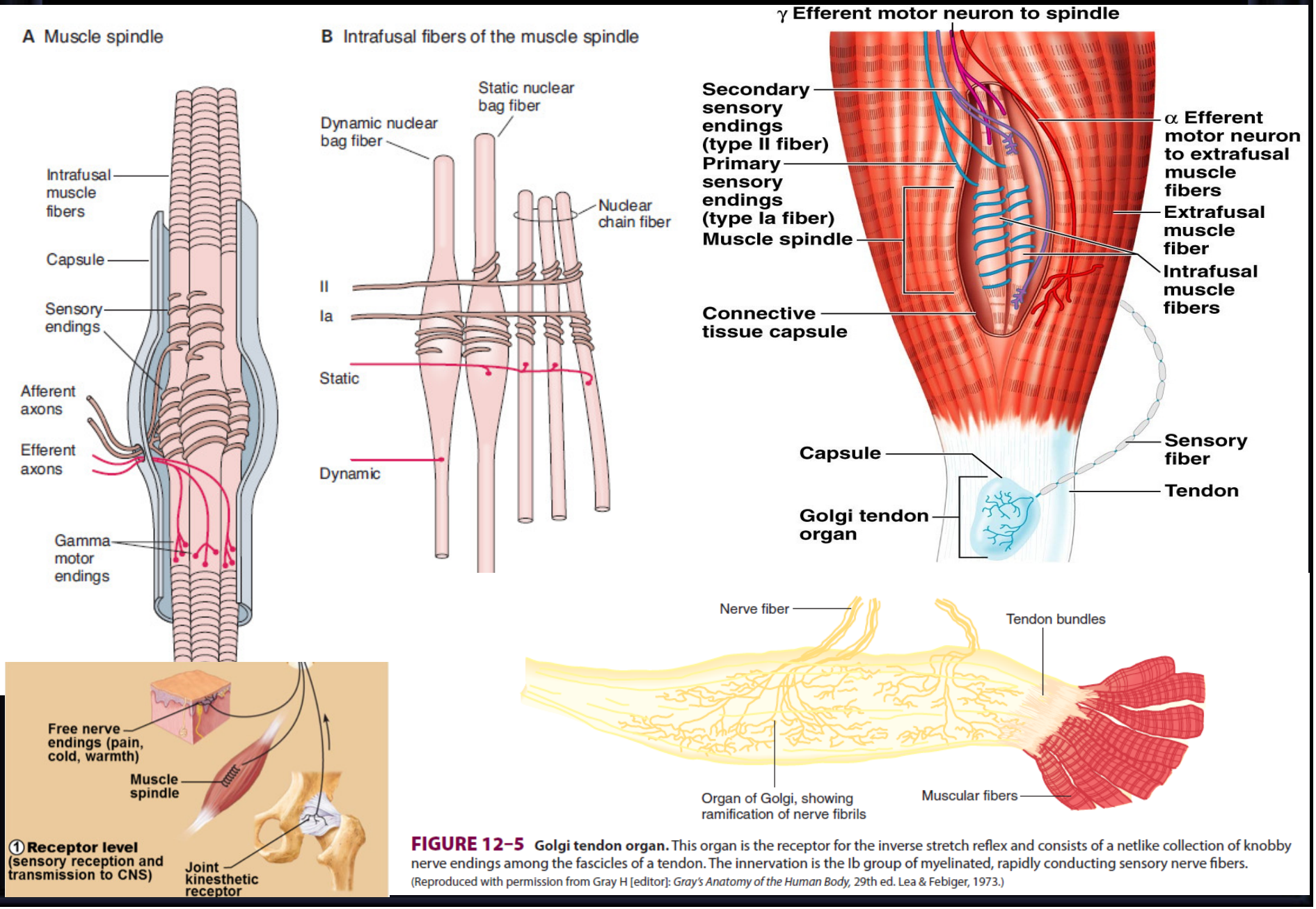


FIGURE 12–5 **Golgi tendon organ.** This organ is the receptor for the inverse stretch reflex and consists of a netlike collection of knobby nerve endings among the fascicles of a tendon. The innervation is the Ib group of myelinated, rapidly conducting sensory nerve fibers.
(Reproduced with permission from Gray H [editor]: *Gray's Anatomy of the Human Body,* 29th ed. Lea & Febiger, 1973.)

NERVE FIBERS CLASSIFICATION

- **Type A**
  - **Alpha**
  - **Beta**
  - **Gamma**
  - **Delta**
- **Type C**

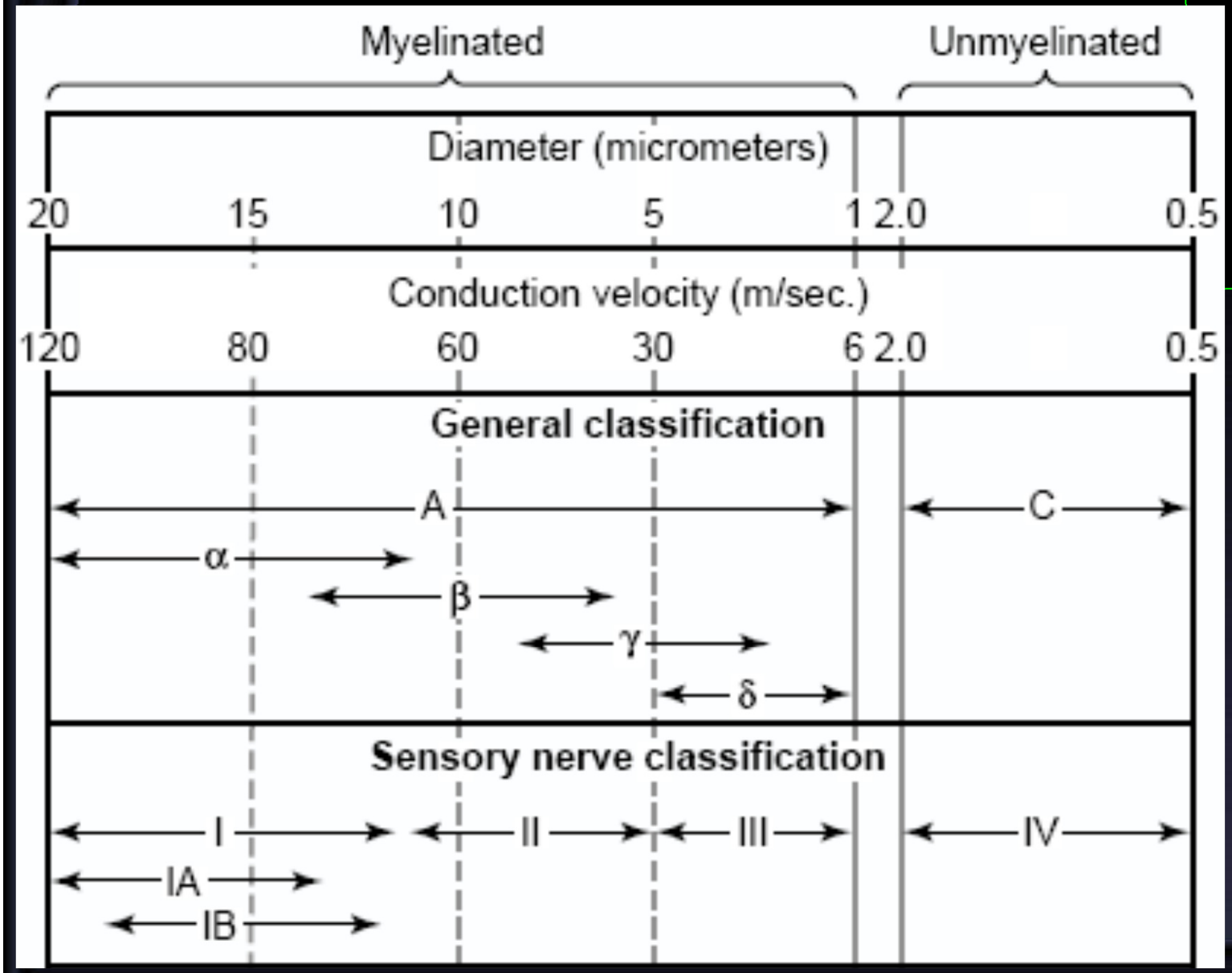


TABLE 4–1 Types of mammalian nerve fibers.

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

SPINAL CORD TRACTS

Sensory information from receptors throughout most of the body is relayed to the brain by means of ascending tracts of fibers that conduct impulses up the spinal cord.

When the brain directs motor activities, these directions are in the form of nerve impulses that travel down the spinal cord in descending tracts of fibers.

Ascending Tracts (Sensory)

Descending Tracts (Motor)

SENSORY TRACTS

- **DORSAL COLUMN SYSTEM**
- **ANTEROLATERAL SYSTEM**

Each system carries different types of sensations which are known as MODALITIES like pain, temperature, fine touch, crude touch, vibration, proprioception etc

1. Dorsal column pathway- carries signal of fine touch, pressure, vibration , stereognsis and proprioception,

2. Spinothalamic pathway- carries signals of pain, temperature, deep pressure, and course touch.

3,4- Posterior and anterior spinocerebellar pathways- carry subsconcious proprioception. Dorsal gray horn- to lateral column- to medulla oblongata- to pons – to cerebellum.

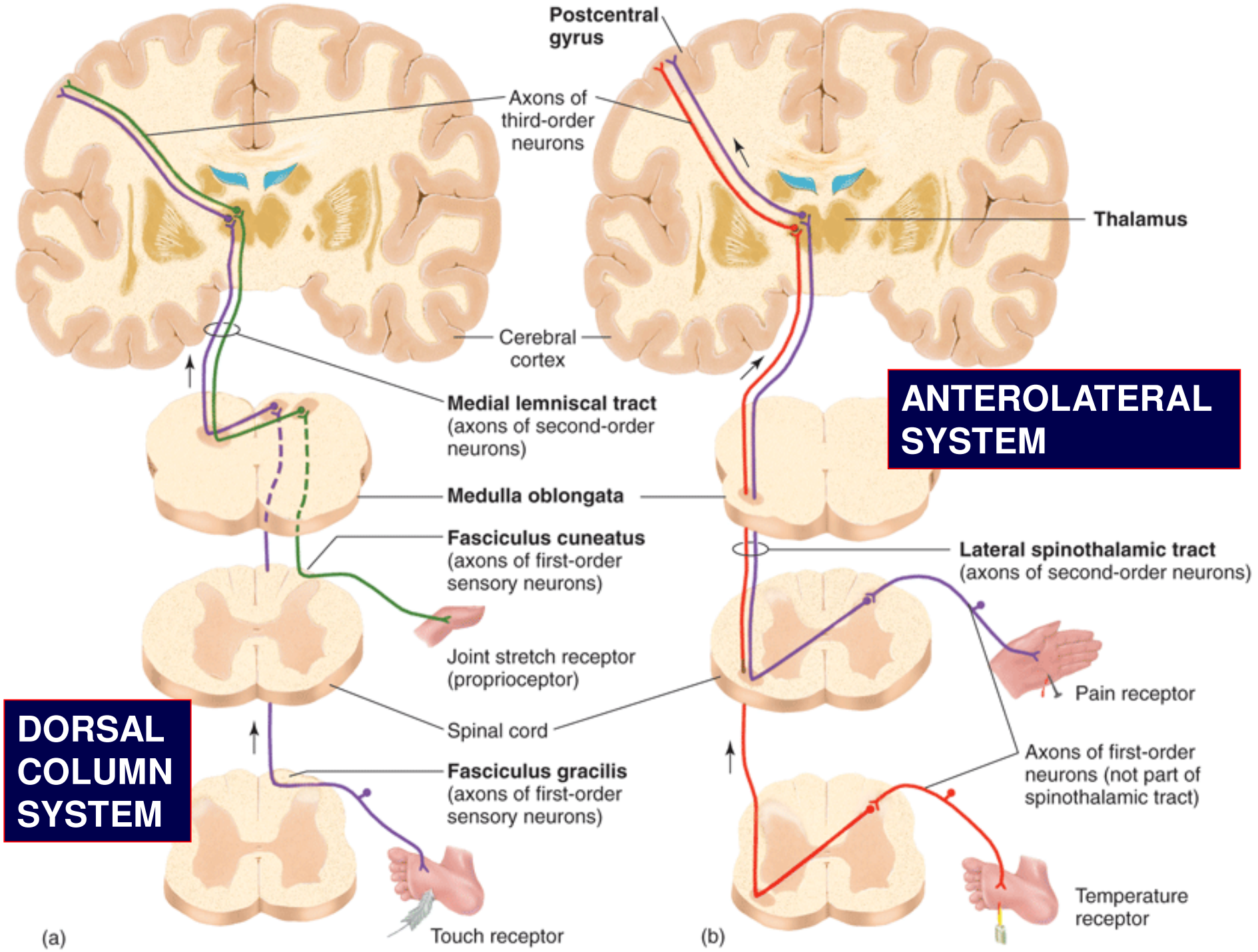
DORSAL COLUMN MEDIAL LEMNISCAL SYSTEM

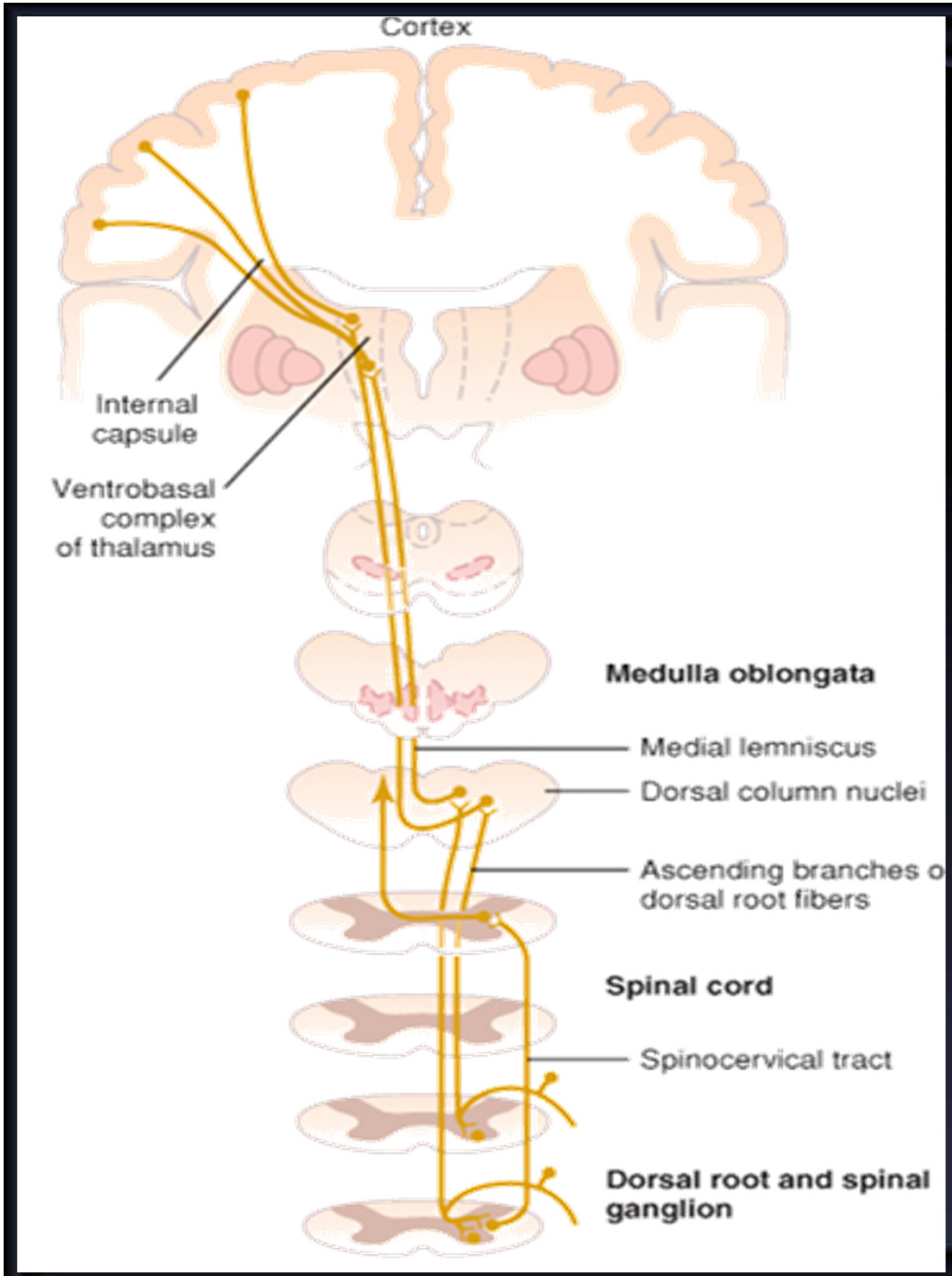
1. Touch sensations requiring a high degree of localization of the stimulus
2. Touch sensations requiring transmission of fine gradations of intensity
3. Phasic sensations like vibratory sensations
4. Sensations that signal movement against skin
5. Joints Position sensations (Proprioception)
6. Pressure sensations requiring fine degrees of judgment of intensity
7. Strereognosis

ANTEROLATERAL SYSTEM

Ventral & lateral spinothalamic tracts

1. **Pain**
2. **Thermal sensations, (warmth & cold)**
3. **Crude touch and pressure sensations capable only of crude localizing ability on the surface of the body**
4. **Tickle and itch sensations**
5. **Sexual sensations**

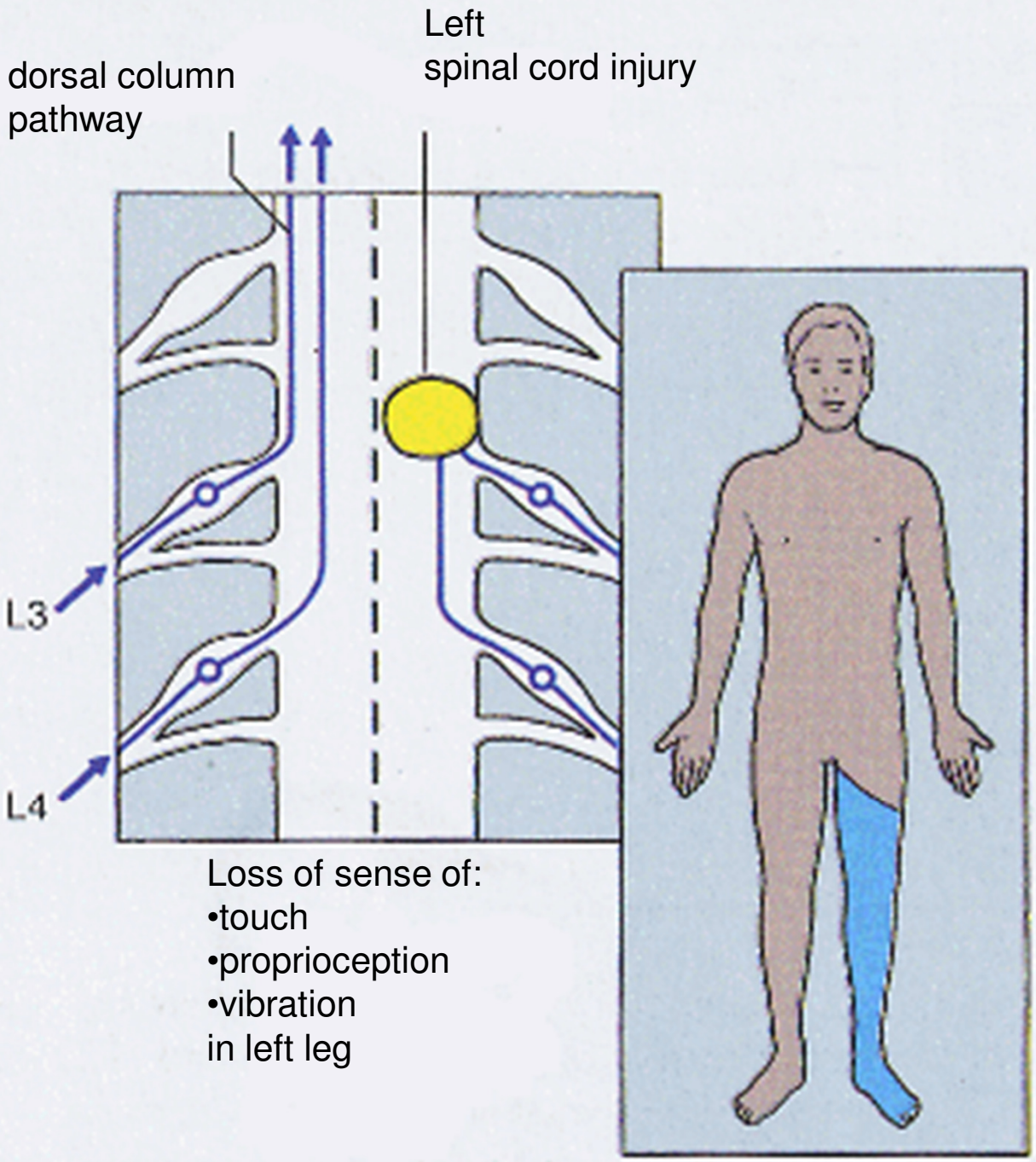

Postcentral gyrus
Axons of third-order neurons
Thalamus
Cerebral cortex
Medial lemniscal tract (axons of second-order neurons)
ANTEROLATERAL SYSTEM
Medulla oblongata
Fasciculus cuneatus (axons of first-order sensory neurons)
Lateral spinothalamic tract (axons of second-order neurons)
Joint stretch receptor (proprioceptor)
Pain receptor
DORSAL COLUMN SYSTEM
Spinal cord
Axons of first-order neurons (not part of spinothalamic tract)
Fasciculus gracilis (axons of first-order sensory neurons)
Temperature receptor
Touch receptor
(a)
(b)



PROPRIOCEPTION FROM HEAD

In this pathway through the brain stem, each medial lemniscus is joined by additional fibers from the sensory nuclei of the trigeminal nerve; these fibers subserve the same sensory functions for the head that the dorsal column fibers subserve for the body.

Dorsal column damage

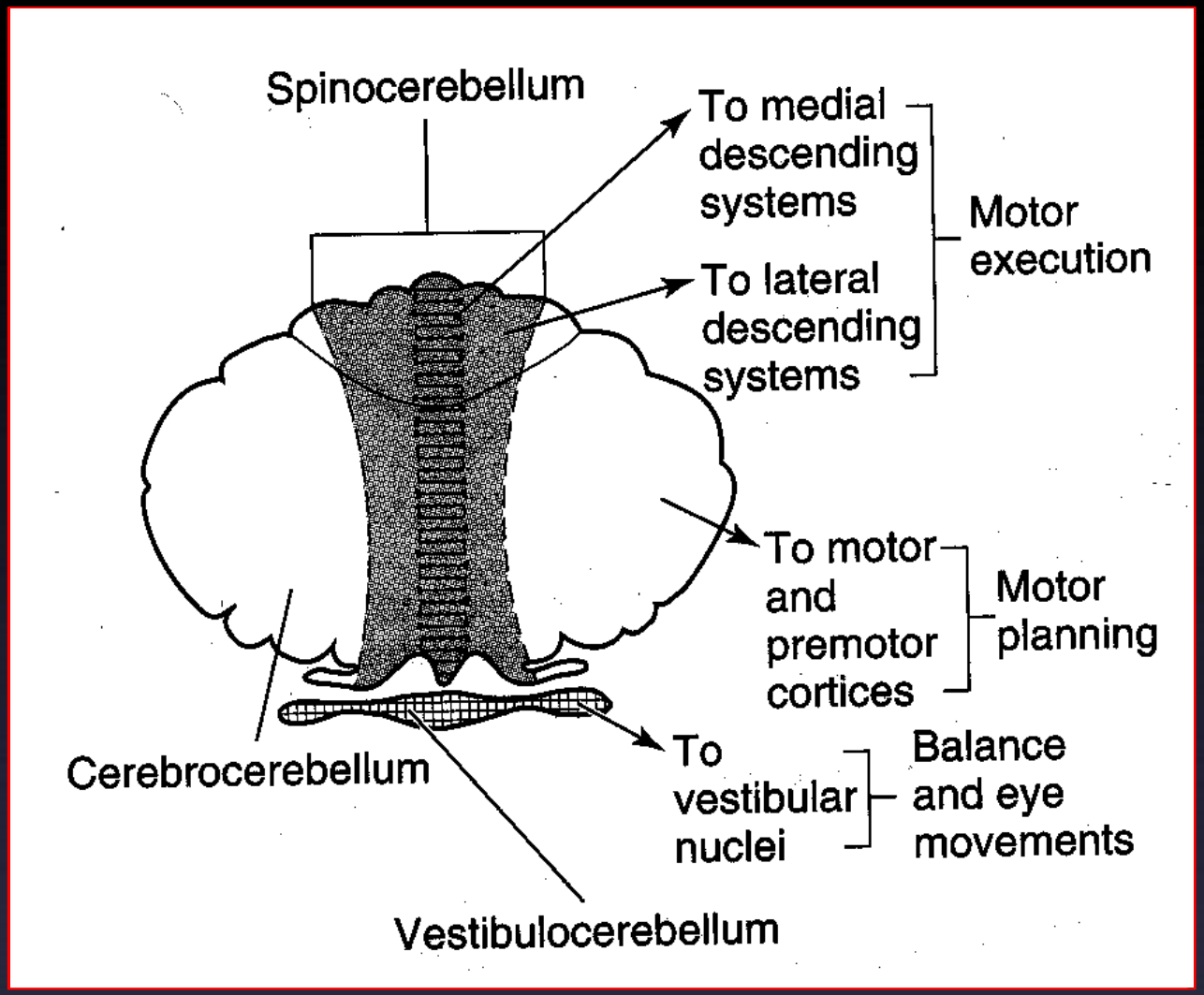


Dorsal column damage

- **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.

FUNCTIONAL DIVISION OF CEREBELLUM



Role of Cerebellum in Proprioception

Vestibulocerebellum— In Association with the Brain Stem and Spinal Cord Control Equilibrium and Postural Movements

during performance of rapid motions specially with changes in direction controlling balance between agonist and antagonist muscle contractions of the spine, hips, and shoulders during rapid changes in body positions as required by the vestibular apparatus

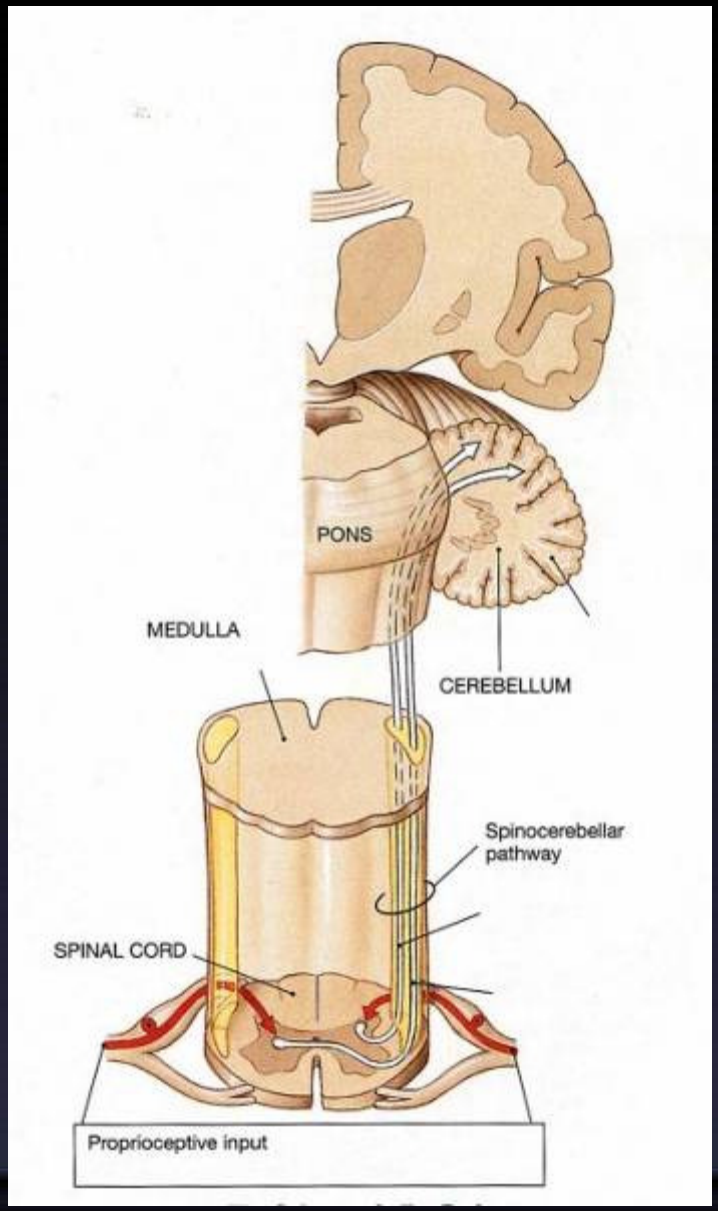
Spinocerebellum— Feedback Control of Distal Limb Movements by Way of the Intermediate Cerebellar Cortex and the Interposed Nucleus

feedback information from the peripheral parts of the body, especially from the distal proprioceptors of the limbs, telling the cerebellum what *actual movements* result.

Cerebrocerebellum— Function of the Large Lateral Zone of the Cerebellar Hemisphere to Plan, Sequence, and Time Complex Movements

Spinocerebellar pathway

- Carries subconscious proprioception signals
- Receptors in muscles & joints
- 1st neuron: enters spinal cord through dorsal root
- 2nd neuron: ascends to cerebellum
- No 3rd neuron to cortex



Spinocerebellar tract damage

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

Ataxia and Gait Disturbances

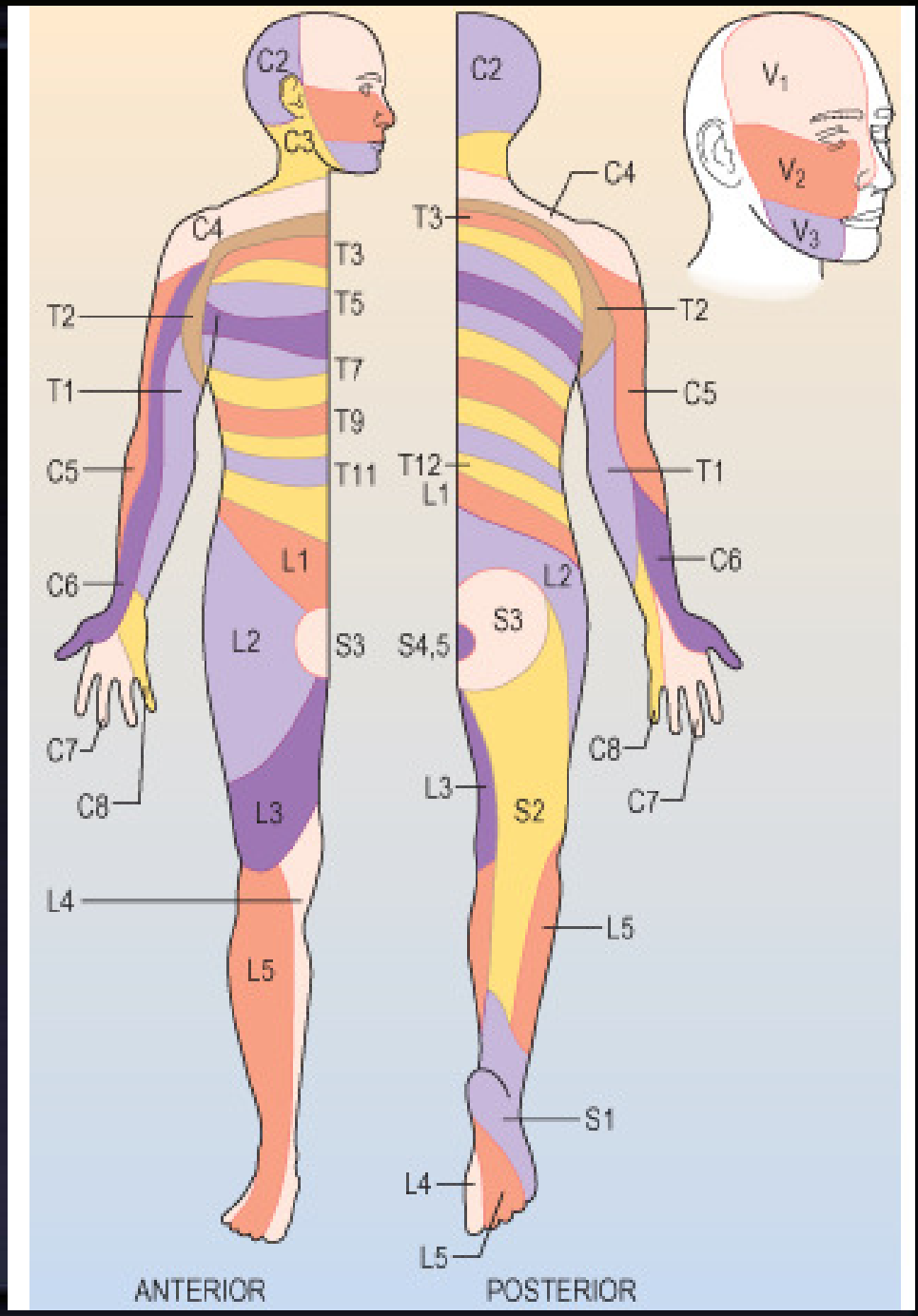
- **Pathophysiology**
  - **Result from any condition that affects the central and peripheral nervous systems**
  - **Ataxia: Types**
    - **Motor ataxia**
    - **Sensory ataxia**

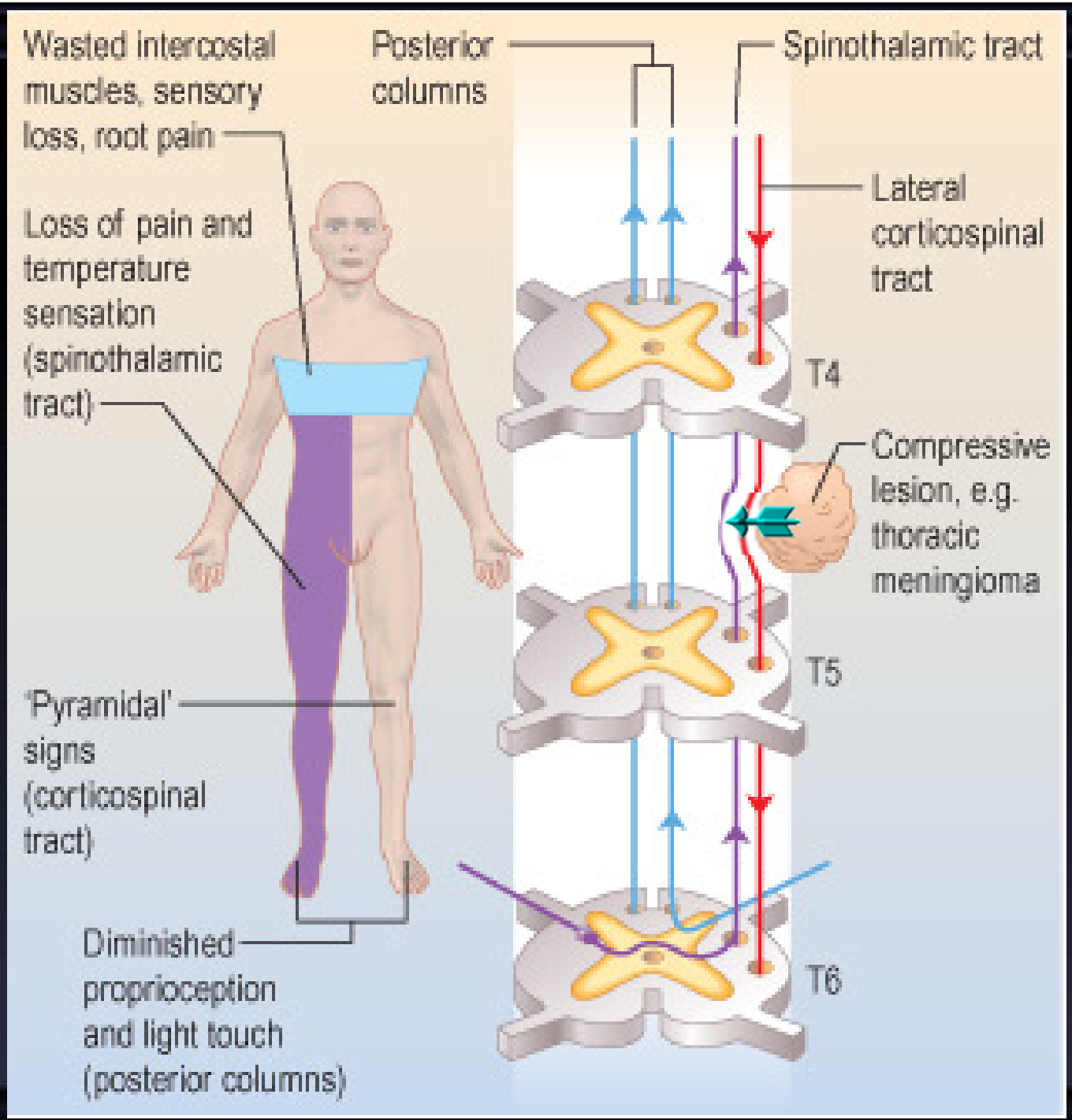
Ataxia and Gait Disturbances

- **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 contralateral ataxia with sensory loss**

Dermatomes

Dermatome is area on skin supplied by a single spinal nerve




Wasted intercostal muscles, sensory loss, root pain
Posterior columns
Spinothalamic tract
Lateral corticospinal tract
Loss of pain and temperature sensation (spinothalamic tract)
T4
Compressive lesion, e.g. thoracic meningioma
T5
'Pyramidal' signs (corticospinal tract)
Diminished proprioception and light touch (posterior columns)
T6

Brown Sequard syndrome

HEMISECTION OF SPINAL CORD

Ipsilateral Loss:

- Fine touch, Vibration, Proprioception (Dorsal Column)
- Leg Ataxia (Dorsal Spinocerebellar)
- Spastic Paresis below lesion (Lat Corticospinal)
- Flaccid Paralysis (Vent horn destruction)
- Dermatomal Anesthesia (Dorsal Horn destruction)

Contralateral Loss:

- Loss of pain and temp (lat Spinothalamic)
- Loss of crude touch and Pressure (Vent Spinothalamic)
- Minor Contralat Muscle Weakness (Vent Corticospinal)
- Leg Ataxia (Vent Spinocerebellar)

SENSORY ATAXIA

• Peripheral sensory lesions (e.g. polyneuropathy) cause ataxia because there is loss of the sense of joint position - proprioception. Broad-based, high-stepping, stamping gait develops.

• This ataxia is made worse by removal of additional sensory input (e.g. vision) and is worse in the dark. First described in sensory ataxia of tabes dorsalis, this is the basis of……..Romberg's test. Ask the patient to close the eyes while standing: observe whether the patient becomes unstable (and prevent falling).