PERIPHERAL NERVOUS SYSTEM

- **The PNS includes all nervous structures - the peripheral ganglia, spinal nerves, cranial nerves and the autonomic nerves, located out of the brain and the spinal cord.**
- **The PNS functions to provide communication between the sensory receptor organ and the CNS (sensory) and from the CNS and the effector organs (motor).**
- **Peripheral nerves are myelinated.**
- **It is divided into motor (efferent) and sensory (afferent) subsystems.**
- **The motor peripheral nerves that supply to skeletal muscles are referred to as *somatic motor nerves***
- **The motor peripheral nerves that supply the cardiac and smooth muscles and exocrine glands are referred to as *autonomic nerves*.**

- The afferent (sensory) system consists of two divisions: ***Somatic*** and ***visceral.***
- Somatic sensory nerves carry impulses from all sensory systems including **mechanoreceptors, chemoreceptors, thermoreceptors, nociceptors.**
- photoreceptors (eye), auditory receptors (ear) and stretch receptors (skeletal muscles), whereas the visceral sensory nerves carry visceral sensations from the chest and abdomen.

Cranial Nerves

Cranial nerve	*Name*	*Nature*	*Function*	*Distribution*
1	Olfactory	Sensory	Smell	From nose
2	Optic	Sensory	Vision	From eye
3	Oculomotor	Motor	Eye movement, pupil constriction, lens shape	To muscles of eye ball
4	Trochlear	Motor	Eye movement	To muscles of eye ball
5	Trigeminal	Mixed	Sensory information from face, mouth; motor control for chewing	From and to face, teeth, lip
6	Abducens	Motor	Eye movement	To muscles of eye ball
7	Facial	Mixed	Taste sensation, motor signals for tear, salivary glands, facial expression	From taste buds, to sali va face
8	Auditory (vestibulocochl ear)	Sensory	Hearing and equilibrium	From ear
9	Glossopharyng eal	Mixed	Sensory from mouth, baro- and chemoreceptors of blood vessels, motor for swallowing, parotid salivary gland secretion	From and to pharynx, from Salivary glands
10	Vagus	Mixed	Sensory and motor to many internal organs, muscles, glands	From and to visceral orga
11	Spinal accessory	Motor	Muscles of mouth, some muscles in neck and shoulder	To shoulder and neck mus
12	Hypoglossal	Motor	Movement of tongue	To tongue

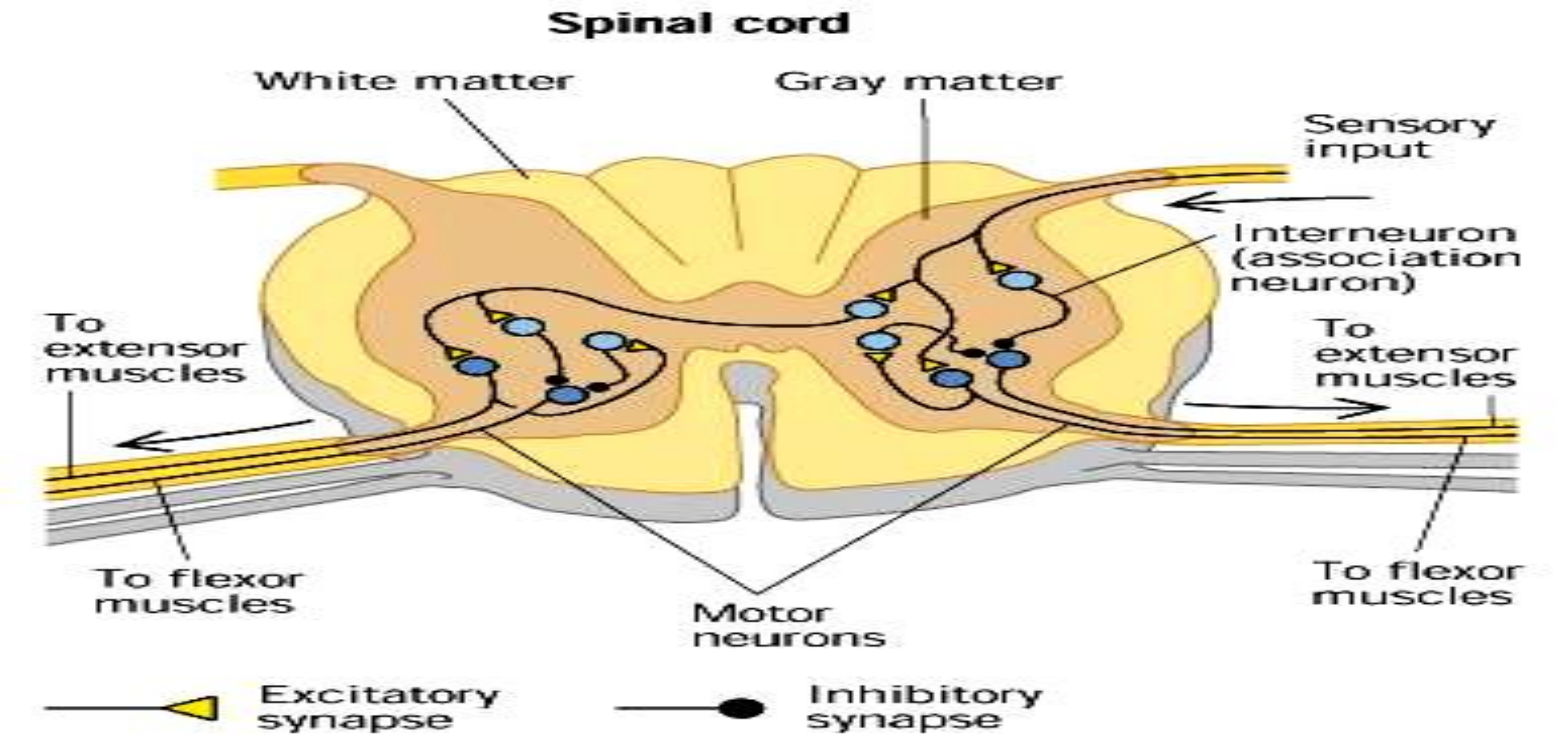
STRUCTURE OF SPINAL CORD:

Spinal cord is a caudal extension of the medulla oblongata present throughout the length of the vertebral canal.

•Each spinal segment provides a pair of spinal nerves that are formed by the fusion of *dorsal root* (sensory) fibres and the *ventral root* (motor) fibres.

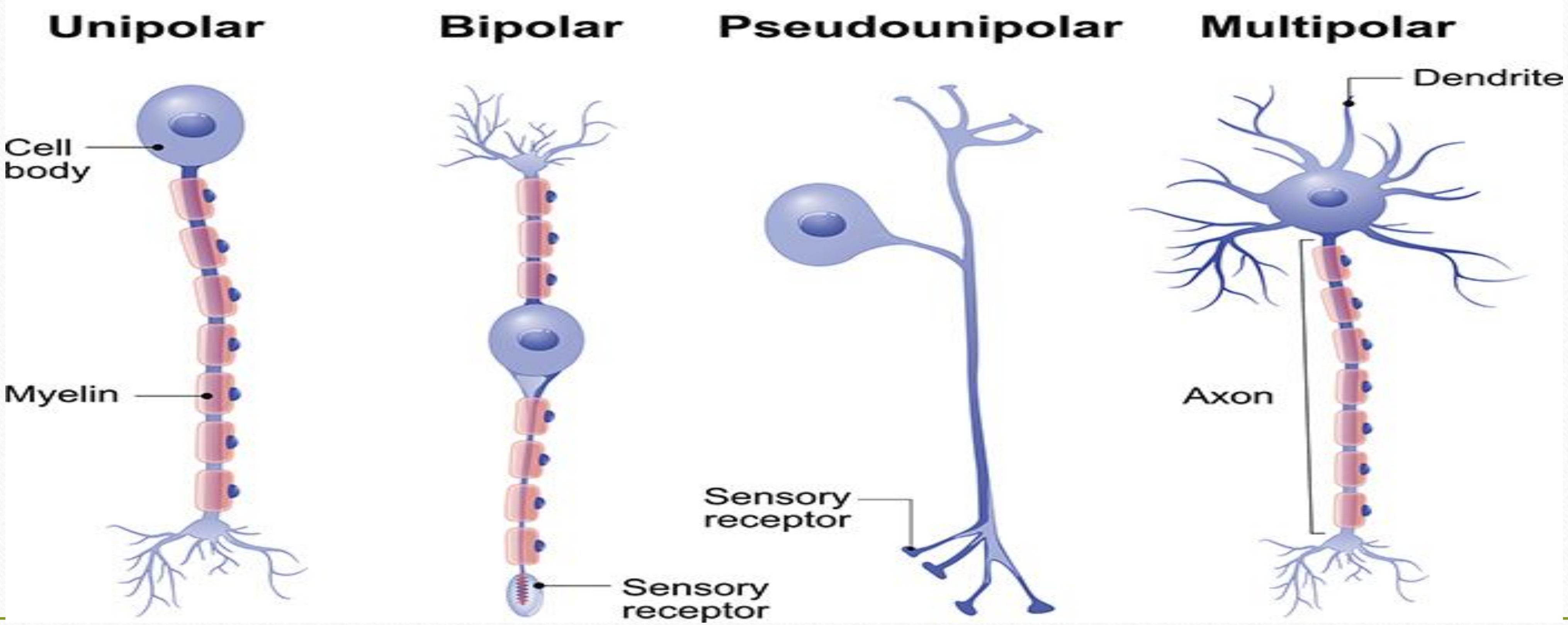
•The number of spinal segments (dogs) is: 8 cervical (C1-8), 13 thoracic (T1-13), 7 lumbar (L1-7), 3 sacral (S1-3) and variable number of caudal segments.

•At the centre of the cord, the cellular components form an `H' shaped column known as the *gray matter*. It is surrounded by *white matter* which represents bundles of nerve fibres or *tracts*


Spinal cord
White matter
Gray matter
Sensory input
Interneuron (association neuron)
To extensor muscles
To extensor muscles
To flexor muscles
Motor neurons
To flexor muscles
Excitatory synapse
Inhibitory synapse

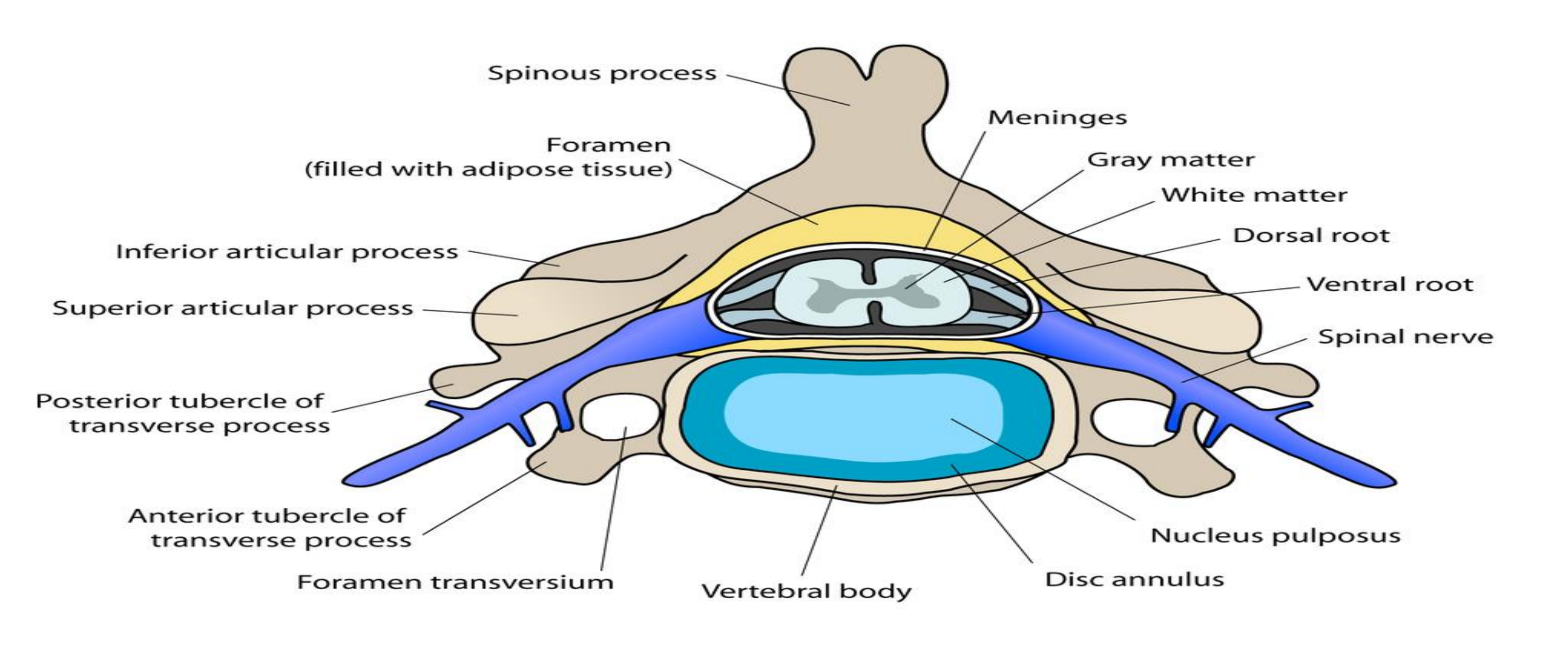
- The neurons of the gray matter of CNS aggregate together to form ***nuclei*****.**
- **The sensory nuclei occupy the dorsal and the lateral columns of the spinal gray matter**
- **The motor nuclei are located in the ventral motor columns of the spinal gray matter.**
- Sensory signals enter the cord through the dorsal root fibres. After entering the cord, the primary afferent fibre synapses with second order neurons which may be an interneuron, an ascending neuron or a descending neuron.
- The neurotransmitters released at the primary afferent fibre terminals in the spinal cord are **glutamate and aspartate (excitatory) or GABA (inhibitory)**. Substance P is also coreleased with these neurotransmitters to modulate their effect.
- The gray matter of spinal cord has cell bodies (soma), dendrites and axon terminals of the nerves.

Types of Neurons



Spinal nerves

- The ventral branches from the **last three cervical and the first one or two thoracic nerves** form a network, the left and the right **brachial plexus,** which supply to the respective forelimbs.
- The ventral branches of the last 3 to 5 lumbar and first 2 to 3 sacral nerves unite to form the right and left **lumbo-sacral plexus**, supplying to the respective hind limbs.


Spinous process
Meninges
Foramen
(filled with adipose tissue)
Gray matter
White matter
Dorsal root
Inferior articular process
Ventral root
Superior articular process
Spinal nerve
Posterior tubercle of
transverse process
Anterior tubercle of
transverse process
Nucleus pulposus
Foramen transversium
Vertebral body
Disc annulus

- The cervical nerves are the spinal nerves from the cervical vertebrae in the cervical segment of the spinal cord. Although there are seven cervical vertebrae (C1-C7), there are eight cervical nerves C1–C8. C1–C7 emerge above their corresponding vertebrae, while C8 emerges below the C7 vertebra.
- Everywhere else in the spine, the nerve emerges below the vertebra with the same name.

SENSORY SYSTEM

Classification Of Receptors

- Based on physiologic type, somatic receptors can be classified into
- **Mechanoreceptors**– detect mechanical stimulus
- **Tactile receptors** – detect touch, pressure, vibrations, tickle sensations
- **Proprioceptors**–involved in detection of posture (body position) and movement; located in muscle, tendon, joints and vestibular organ.
- **Thermoreceptors** – detect heat and cold
- **Pain receptors** – detect damage to tissues
- **Electromagnetic receptors:** detect light – rods and cones

- **Chemoreceptors**: Receptors in taste bud (taste), olfactory epithelium (smell), medulla, carotid and aortic bodies (detect blood O_2 and CO_2), osmotic receptors in hypothalamus,
- **Magnetoreceptors**: detect magnetic field; many birds, some species of fish, whales are able to perceive earth's magnetic field which helps these species to navigate through long distances; however, no specific sensory cell that detect magnetic field has been detected so far.

- Based on origin of stimuli, somatic receptors can be classified into
- **Exteroreceptors:** Detect stimuli arising from outside the body or from the surface of body
- **Proprioceptors:** includes position sense receptors located in muscle, tendons, joints and equilibrium receptors located in vestibular organ
- **Visceral receptors –** detect stimuli arising from viscera – GI tract, heart, blood vessels, bladder etc
- **Deep sensory receptors –** detect stimuli from deep tissues like muscle, bone, deep pressure, vibration etc

Stimulus	Receptor	Location	Structure	Mechanism
Gravity	Statoconia	Outer Chamber of ear	Otolith and Cilia	Cilia deformation
Motion	Cupula	Semi-circular canal	Cilia and cupula	Cilia deformation
Hearing	Organ of corti	Cochlea of ear	Cilia with basilar and tectorial membrane	Cilia deformation
Taste	Taste bud chemo-sensitive receptors	Mouth	Chemo-receptors	Sites on membrane where chemicals bind, open Na+ channels
Smell	Olfactory receptors	Nasal epithelium	Chemo-receptors	Sites on membrane where chemicals bind, open Na+ channels
Vision	Rods and cones	Retina	Photo-sensitive pigments in retina of eye	Light-chemical reactions close ion channels
Temp	Heat/cold receptors	Skin, hypo-thalamus	Free nerve processes	Temperature opens or closes ion channels
Blood Pressure	Baro-receptors	Carotid bodies, aortic arch, artery walls	Free nerve processes	Stretch of artery wall deforms membrane
Muscle Stretch	Stretch (spindle) receptors	Inside muscle	Spinal nerve processes around spindle	Spindle stretch deforms membrane
Touch	Free nerve endings, Meissners corpuscles Merkel cells	Skin surface	Nerve processes in elastic corpuscle	Pressure change deforms membrane
Vibration	Pacinian corpuscles	Deep in skin	As above	As above
Pain	Nociceptor	Distributed except in brain and lungs	Free nerve endings	Chemicals, Pressure Temperature

a) Mechanoreceptors: They respond to displacement of tissue.

(i) Tactile Receptors:

- Touch, pressure and vibrations are tactile sensation and they are detected by

a) *Free nerve endings* in most areas of the skin and many tissues; detect touch and pressure

b) **Meissner's corpuscle:** are encapsulated nerve endings and they have greater sensitivity to tactile sensation; present in non hairy parts of the skin – lips, finger tips etc

c) ***Merkel's discs*****:** slow-adapting receptors of touch; present in higher numbers in non hairy parts of skin and in less numbers in hairy parts of skin

d) **Hair end organs:** located at the base of the hairs, detects hair movement

e) **Ruffini's end organs:** encapsulated endings located in deep layers of skin and in internal organs and they are slowly adapting

f) **Pacinian corpuscles**: located below the skin and in deep tissues, stimulated by local compression of tissues; they are rapidly adapting

Proprioceptors - Position Senses:

- Proprioception, also known as kinesthetic sense, is the *awareness of body position in relation to environment and movement of body parts*
- It includes two types of sensations –

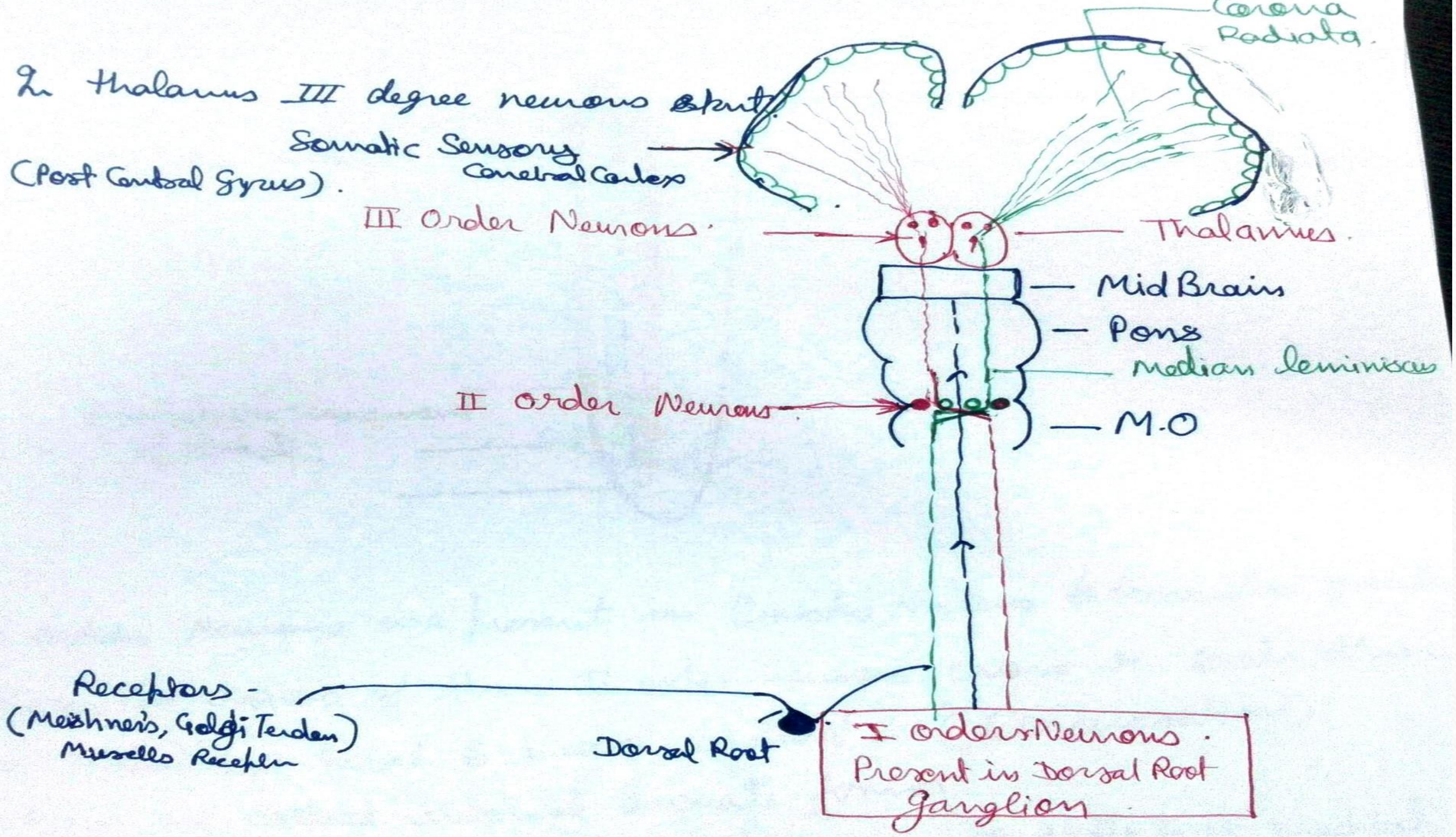
1) ***static position sense*** that involves perception of orientation of different parts of the body with respect to one another
2) ***kinesthesia*** or rate of movement sense or *dynamic position sense*

- There are two types of proprioceptors –
- One type is associated with skeletal muscles and includes **muscle spindle and Golgi tendon organs** and they detect muscle length and rate of change in muscle length
- The second type includes mechanoreceptors found in **connective tissues, ligaments** and receptors located in and around joints that detect orientation (includes skin tactile receptors, pacinian corpuscles, Ruffini's endings) i.e. angle and movement of joints

Nociceptors - Pain receptors

- Pain occurs whenever any tissue is damaged and it causes the individual to react to remove the pain stimulus.
- Pain receptors are free nerve endings.
- They are located in skin, in many internal organs like periosteum, arterial walls, joint surfaces, meanings of brain etc.
- The pain receptors are stimulated by mechanical, thermal and chemical stimuli.
- **Chemicals that stimulate pain: bradykinin, serotonin, histamine, potassium, acids, PGs etc.**
- Thermal nociceptors are stimulated by temperature above 45°C and extreme cold;
- Mechanical nociceptors are stimulated by pinching, squeezing and extreme pressure
- Pain receptors do not adapt and sometimes increases in sensitivity to pain (*hyperalgesia)*

- In thalamus III degree neurons start



(Travel of Ascending tract)(Dorsal system).

Types of Ascending Spinal Tracts

Directly concerned with Sensation

- Dorsal Column Pathway
- Spinothalamic Tract
- Spinocervical Tract
- Trigeminal Tract

Not concerned with Conscious Sensation

- Dorsal Spinocerebellar tract
- VentralSpinocerebellar tract
- Spinoreticuar tract
- Spinotectal tract

Dorsal Column Pathway (Medial Lemniscal system)

Carries sensation of cutaneous touch and joint muscle and tendon sensations

- Large primary fibers enter the Dorsal Column & travel up or down
- One group of fibres leaves the column and make synapse with spinocerebellar tract
- Other group of fibres leaves the column with 2nd order neurons
- 2nd order neurons runs in Dorsal Column via medial leminiscus
- Contralateral thalamus

The Dorsal Column (Touch, pressure, proprioception and vibration)

The fibers run in the dorsalspinal cord between the dorsal horn and mid line.
These fibers run directly without any secondary neurons.

↓

Fibers from lumbar and lower thorasic enter and run in fasciculus gracilis. While Fibers from mid thorasic and cervical enter and run in fasciculus cuneatus

↓

Fibers terminate in grailus and cuneatus nucleus epsilaterally then cross in opposite direction and run through the medulla pons and midbrain in the medial leminiscus.

↓

Fibers carrying touch and pressure from head and neck end on the ventroposteriomedial thalamic nuclei
Fibers carrying touch and pressure from trunk and limbs, end on the ventroposteriolateral thalamic nuclei

↓

Fibers from thalamic map project to primary somatsensory cortex

Spinothalamic Tract (Ventrolateral System)

Important pain pathway by central pathway

touch and pressure sensations by dorsal column pathway

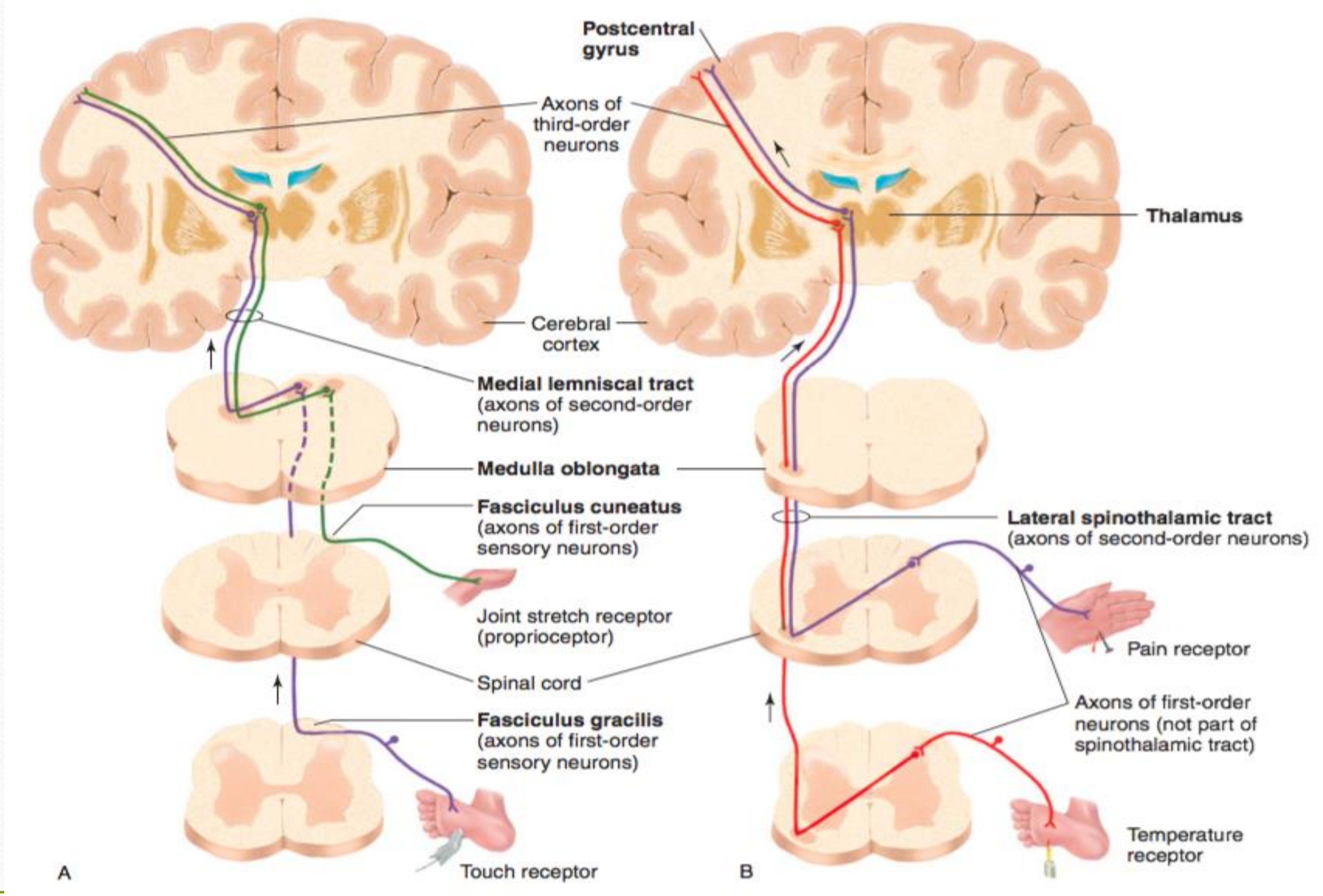
- Large primary fibers enter the Dorsal Column & travel up or down
- 2nd order neurons cross the midline and enter the ventrolateral quadrant, here these ascend the medulla
- Lastly ends in thallamus

The spinalothalamic tract carries information about pain temperature and some extent touch.

Unlike the dorsal column system, axons from spinothalamic tract immediately decussate then ascend to the thalamus without synapsing in the brain system.

The tract itself lies lateral and ventral to the ventral horn and comprises the ventrolateral portion of the medulla.

Then it goes to thalamus.


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

Spinocervical Tract

Neurons are excited by cutaneous stimuli

- Large primary fibers enter @ upper thoracic and lower cervical level
- The tracts terminates epsilaterally in the lateral cervical nucleus
- Nucleus sends axons that crosses @ ant. Commissure and passes through med. leminiscus
- Lastly ends in thallamus

Trigeminal Tract

Neurons are excited from facial cutaneous stimuli

- Large primary fibers enter the spinal cord @ upper thorasic and lower cervical level
- The tracts terminates trigeminal nucleus in medulla

ASCENDING TRACTS		
TRACTS		**FUNCTION**
Spinothalamic	**Lateral Spinothalamic**	Pain & temperature
	Anterior Spinothalamic	Light (crude) touch pressure
Dorsal Column System	**Fasciculus Gracilis**	Fine touch, proprioception, two-point discrimination
	Fasciculus Cuneatus	
Spinocerebellar Tracts	**Anterior/Ventral Spinocerebellar**	Movement and position mechanisms
	Post./Dorsal Spinocerebellar	
Spinotectal Tract		Afferent information for spinovisual reflexes and brings about mov't of the eyes and head toward the source of the stimulation
Spinoreticular Tract		Deep and chronic pain
Spino-olivary Tract		Conveys information to the cerebellum from cutaneous and proprioceptive organs

Dorsal Spinocerebellar Tract (DSCT)

Ascending tract not concerned with Conscious Sensation

- Arise in dorsomedial gray matter in the thorasic and lumbar SC
- Tract goes to cerebellum through Restiform body
- This pathway is concerned with adjustment and coordination of epsilaeral limbs

Ventral Spinocerebellar Tract (VSCT)

Ascending tract not concerned with Conscious Sensation

- Arise in ventrolateral to DSCT cell bodies in gray matter in the thorasic and lumbar SC
- The fibers cross to opposite side
- Tract goes to cerebellum through superior cerebellar peduncle
- This pathway is concerned with adjustment and coordination of hind limbs

Spinoreticular connections

Ascending tract not concerned with Conscious Sensation

- The fibers run in ventrolateral funiculus at all levels
- The fibers end epsilaterallly in medullary reticular formation and bilaterally in pontine reticular formation
- This pathway is concerned with control of general level activity of cerebral activity

Spinotectal tract

Ascending tract not concerned with Conscious Sensation

- Arise in dorsal horn of gray matter in the SC
- The fibers cross to opposite side in ventral white commissure and finally ascend in lateral funiculus with lateral spinothalamic tract fibers
- Tract ends in the colliculi of the tectum
- This pathway is concerned with adjustment and coordination of movement with the visual and acoustic stimuli

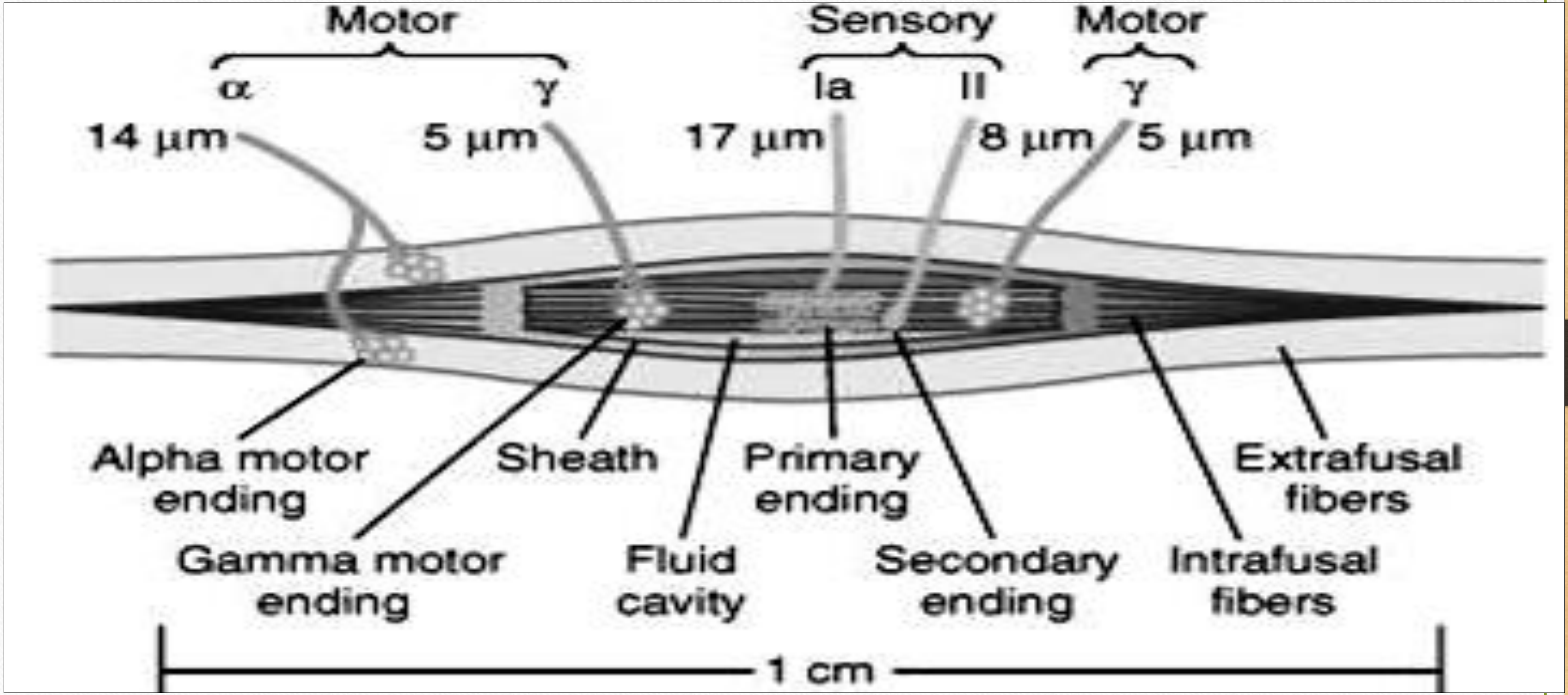
Descending tract	Location in Spinal Cord	Function
Corticospinal Tracts (Pyramidal Tract) 1. Anterior corticospinal tract 2. Lateral corticospinal tract	Anterior column of white matter. Lateral column of white matter	Control skilled voluntary movements
Extrapyramidal tracts 1. Tectospinal tract	Anterior column of white matter.	Spinovisual reflexes (controls movement of head, neck in response to visual stimuli).
2. Vestibulospinal tract	Anterior column of white matter.	Equilibrium reflexes (unconscious maintenance of posture and balance)
3. Olivospinal tract	Lateral column of white matter	Not known
4. Rubrospinal tract	Lateral column of white matter	Facilitatory influence on flexor muscles.

- ***Upper motor neurons*** are those that arise from brain and modify the activity of lower motor neurons. The upper motor neurons control the muscle tone and locomotion in animals through descending efferent fibre tracts to spinal cord.
- The motor neurons that innervate the skeletal muscles are called **lower motor neurons**. They arise from spinal cord and brainstem e.g**. α- and γ motor neurons of spinal cord**.
- The α- lower motor neuron is called **final common pathway** because it is this neuron that receives commands from different regions of brain, different segments of spinal cord and from interneurons and they are integrated for final passage to skeletal muscles.
- A motor unit consists of an α-lower motor neuron and all the skeletal muscle fibres innervated by this fibre.
- The spinal motor neurons are located at the ventral gray horn and are called ventral motor neurons. They project their axons into the peripheral nervous system.

- There are of two types of ventral horn motor neurons
- Alpha or somatic motor neurons -->supply to skeletal muscles.
- Gamma motor or intrafusal neurons -->supply to muscle spindles.
- **Interneurons**
- These neurons are present in all areas of the gray matter of spinal cord – the dorsal, ventral and intermediate horns. They are more numerous than sensory and motor neurons of the spinal cord.
- *Functionally the interneurons* are either:
  - Excitatory inter neurons- cause depolarization effects in the postsynaptic neurons.
  - Inhibitory inter neurons-cause hyperpolarization effects at the postsynaptic points.
- These two types of inter neurons are involved in most of the spinal cord reflexes, except the myotatic reflex. They coordinate the sensory activities with the motor activities at the cord level.
- The ***Renshaw cells*** are inhibitory interneurons of the ventral horn motor neuronal pool.
- ***Propriospinal fibres*** are those that run from one segment of the spinal cord to another. They include both ascending and descending fibres and they participate in the multisegmental spinal cord reflexes.

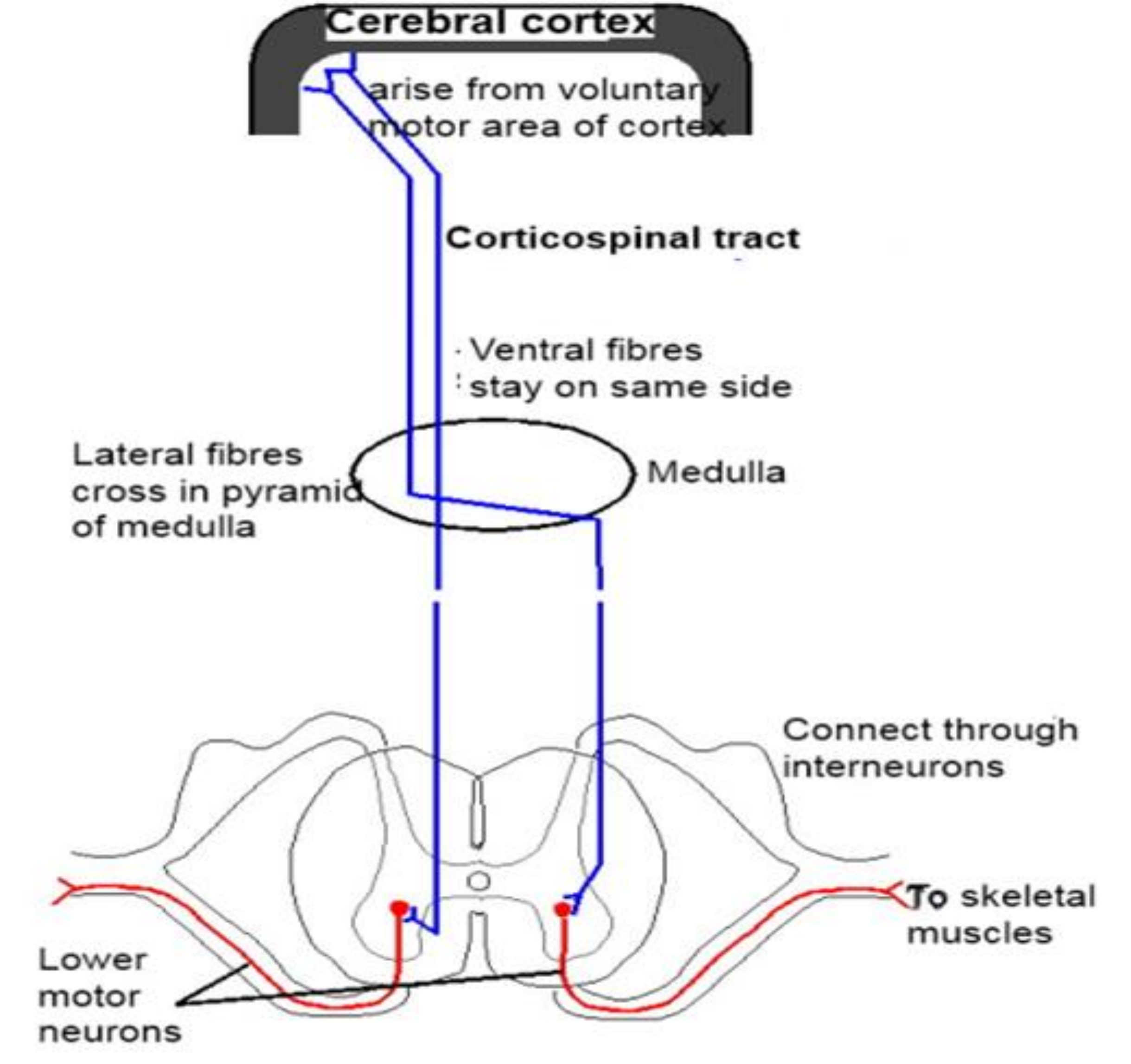
Sensory Receptors of Muscle and their Role in Muscle Contraction

- To provide feedback information, muscles and tendons have two types of sensory receptors
  - **Muscle spindle**
  - **Golgi tendon organs**
- These receptors transmit their impulses not only to spinal cord but also to cerebellum and cerebral cortex.


Motor
α
γ
14 μm
5 μm
Sensory
Ia
II
17 μm
8 μm
Motor
γ
5 μm
Alpha motor ending
Gamma motor ending
Sheath
Fluid cavity
Primary ending
Secondary ending
Extrafusal fibers
Intrafusal fibers
1 cm

Receptor Function of Muscle Spindle

- The receptor organs of the skeletal muscle are encapsulated within the belly of the skeletal muscles and are called as the ***muscle spindle organs***, they are excitable by simple stretch in the skeletal muscles.
- Muscle spindle organs are complex receptor organs made of specialised striated muscle called the ***intrafusal muscle fibres***; they are present within a connective tissue capsule, which are attached to the surrounding skeletal muscles.
- The muscle fibres of the skeletal muscle, which produce the physical shortening of the muscle, are referred to as ***extrafusal muscle fibres*** that are innervated by **a-motor neurons.**
- The intrafusal muscle fibres have contractile proteins at their polar ends but none in their middle, equatorial region. Therefore, their polar ends can contract but the central (equatorial) region cannot.
- Sensory (afferent) nerve arises from this equatorial region and it carries impulses from the muscle spindle to the CNS by way of peripheral nerves.
- The contractile end regions of the intrafusal muscle fibres are innervated by small-diameter myelinated motor fibres called *g-motor nerve fibres* arising from g-motor neurons of the ventral horn of the spinal cord.
- The extrafusal fibres are innervated by ***a-motor neurons.***

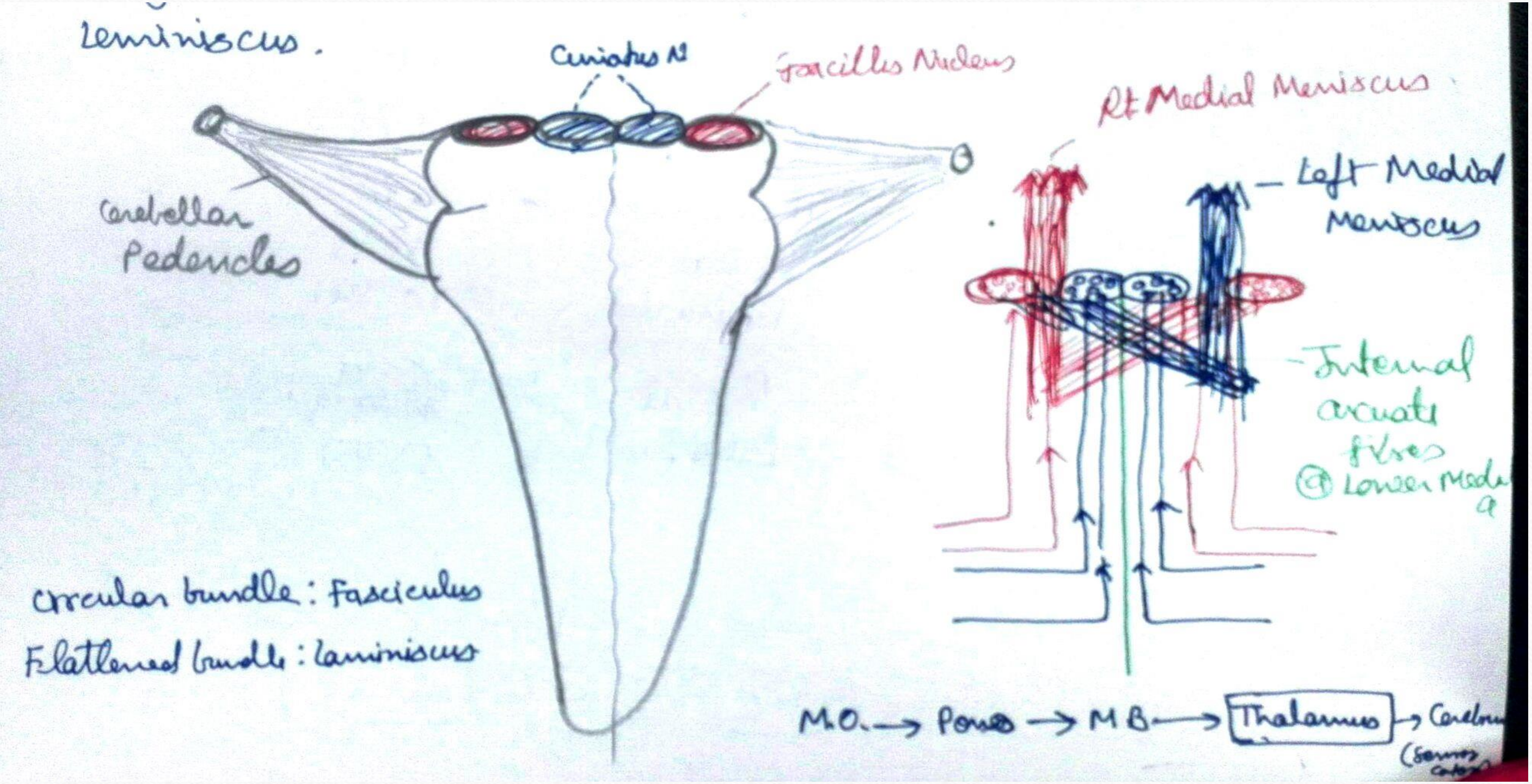

Cerebral cortex
arise from voluntary motor area of cortex
Corticospinal tract
Ventral fibres stay on same side
Lateral fibres cross in pyramid of medulla
Medulla
Connect through interneurons
To skeletal muscles
Lower motor neurons

Spinal animal

- **Spinal animal** is prepared either by transecting at the spinomedullary junction or by ligating both carotid arteries and the mid-vertebral artery to arrest the brain activities.
- ***Spinal shock*:**
- Transection of the spinal cord at the level of the spinomedullary junction abolishes all the visceral reflexes caudal to that point (cardiovascular, respiratory and acid-base balance). This state is called as ***spinal shock.***
- The duration of spinal shock varies with level of spinal cord transection, age of the animal. Within a period of about 30 minutes to 2 hours (frog and chicken) and after many months in higher animals, many reflexes return - myotatic, inverse myotatic, crossed extensor and scratch reflex and extensor thrust reflexes are re-established.
- The spinal shock is due to the removal of excitatory influences of the brain on the motor neurons of the spinal cord. On removal of the higher brain excitation, Renshaw cells become hyperactive, and inhibit the spinal motor neurons.

Decerebrate animal

- It is prepared by transecting the brainstem at the level of the midbrain between rostral and caudal colliculi and it causes **hyper excitability of the gamma motor** neurons of the segmental myotatic reflex and produces a pronounced rigidity of the antigravity muscles (extensors). All the four limbs are extended and the head and tail are elevated. This is called ***decerebrate rigidity.***
- Decerebrate rigidity is due to enhanced reticulospinal and vestibulespinal excitatory influence upon the gamma motor neurons following complete removal of the inhibitory influence of the ponitine reticular formation. Hence, it is also called as ***gamma rigidity.*** The animal assumes a hobbyhorse–like posture and often stands rigidly in a fixed position.



Leminiscus.
Cuniatus N
Gracillis Nucleus
Rt Medial Meniscus
Left Medial Meniscus
Cerebellar Peduncles
Internal arcuate fibres @ Lower Medu
Circular bundle : Fasciculus
Flattened bundle : Laminiscus
M.O. → Pons → M B → Thalamus → Cerebru