ANATOMY OF SPINAL CORD

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OBJECTIVES

At the end of the lecture, students should be able to:

- **Describe the external anatomy of the spinal cord.**
- **Describe the internal anatomy of the spinal cord.**
- **Describe the spinal nerves: formation, branches & distribution via plexuses.**
- **Define Dermatome and describe its significance.**
- **Describe the meninges of the spinal cord.**
- **Define a reflex and reflex arc, and describe the components of the reflex arc.**

REVIEW

FUNCTIONS

The nervous system has 3 functions:

- **Collection of Sensory Input**

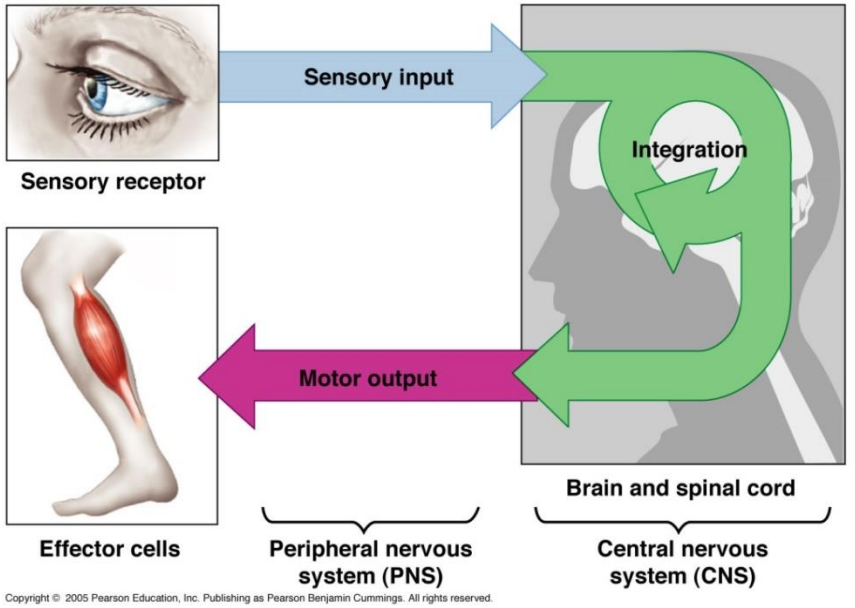
  Identifies changes occurring inside and outside the body by using sensory receptors. These changes are called stimuli

- **Integration**

  Processes, analyses & interprets these changes and makes decisions

- **Motor Output**

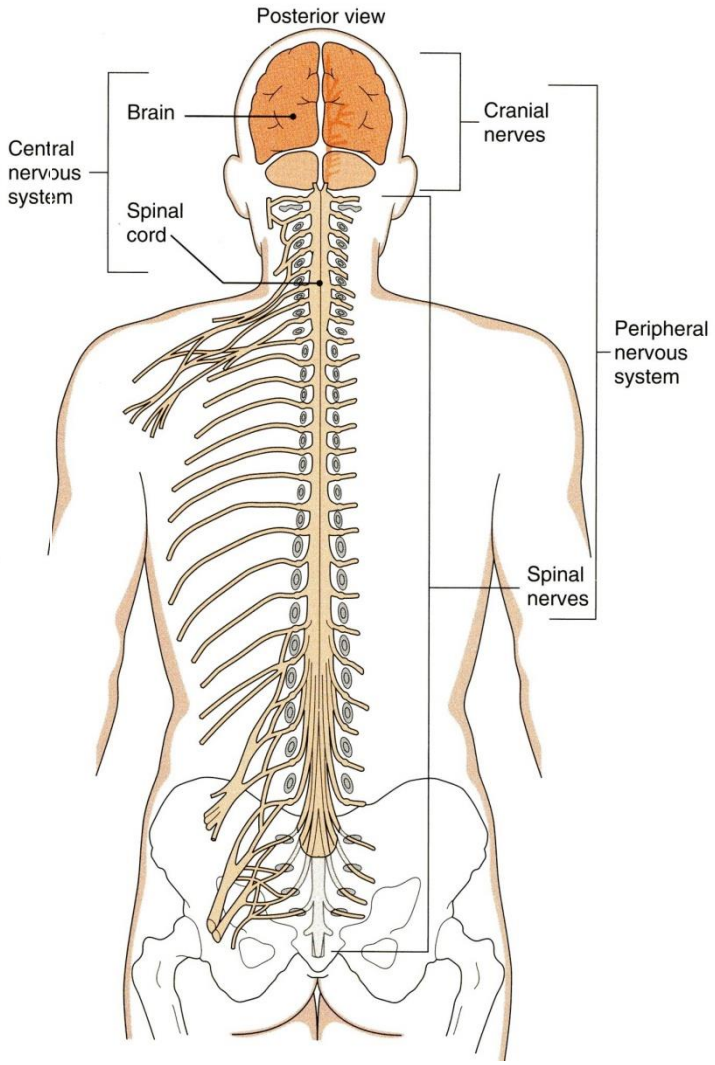
  It then effects a response by activating muscles or glands (effectors) via motor output



ORGANIZATION

STRUCTURAL

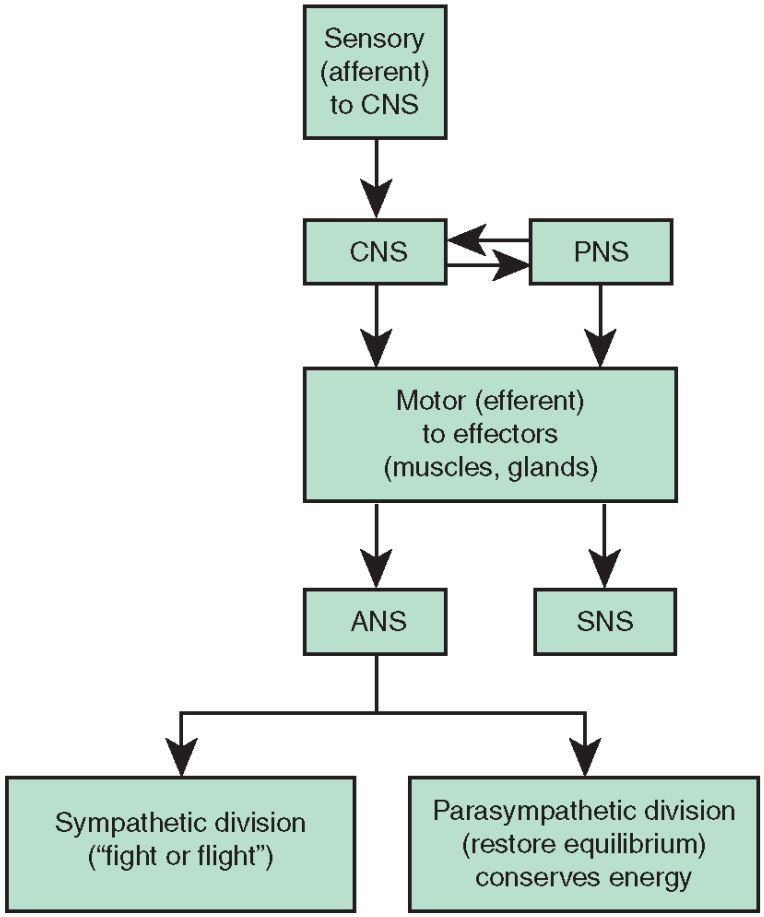
- Central Nervous System (CNS)
  - Brain & Spinal Cord
- Peripheral Nervous System (PNS)
  - Nerves & Ganglia
    - Cranial nerves
    - Spinal nerves



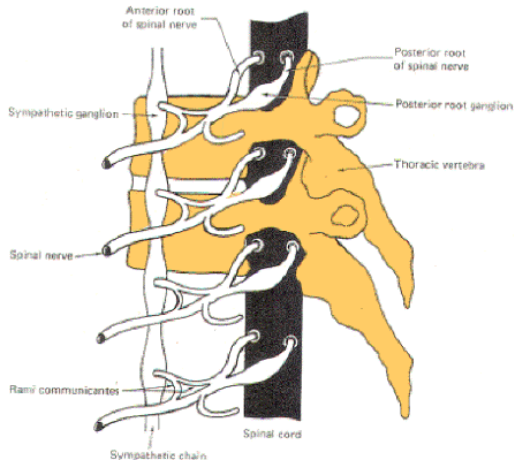
ORGANIZATION

FUNCTIONAL

- Sensory Division (Afferent)
- Motor Division (Efferent)
  - Autonomic
  - Somatic

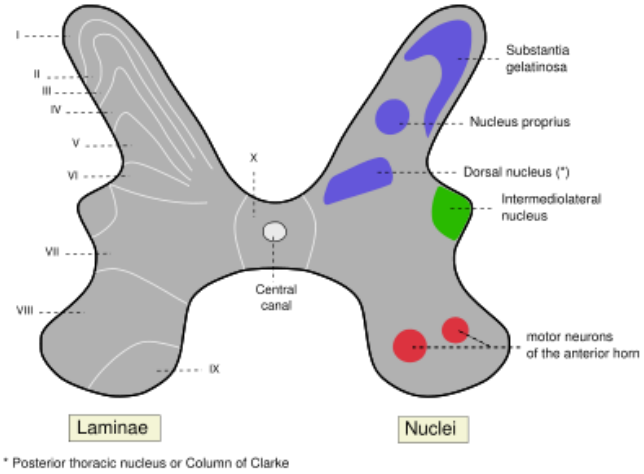


CNS = Central nervous system
PNS = Peripheral nervous system
ANS = Autonomic nervous system
SNS = Somatic nervous system



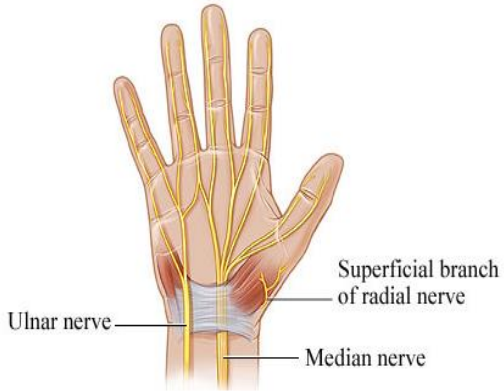
Ganglion

A group of neurons outside the CNS



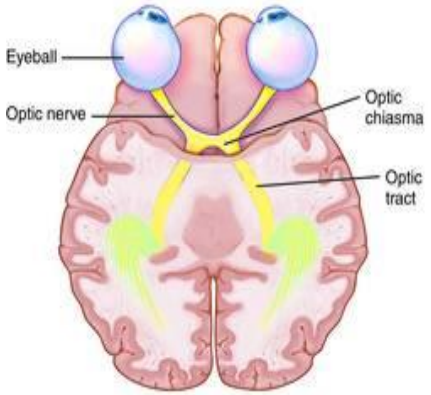
Nucleus

A group of neurons within the CNS



Nerve

A group of nerve fibers (axons) outside the CNS



Tract

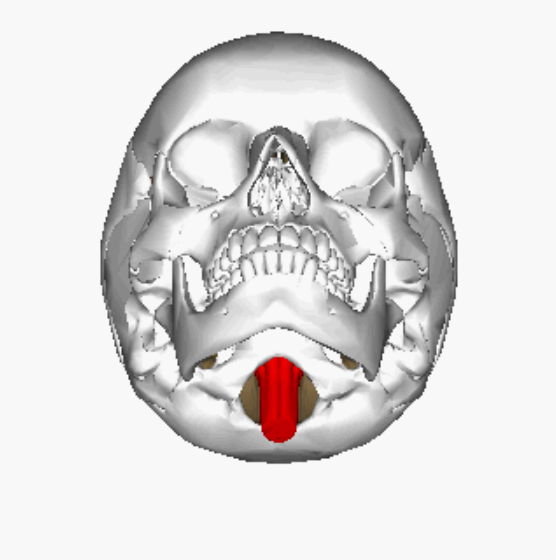
A group of nerve fibers (axons) within the CNS

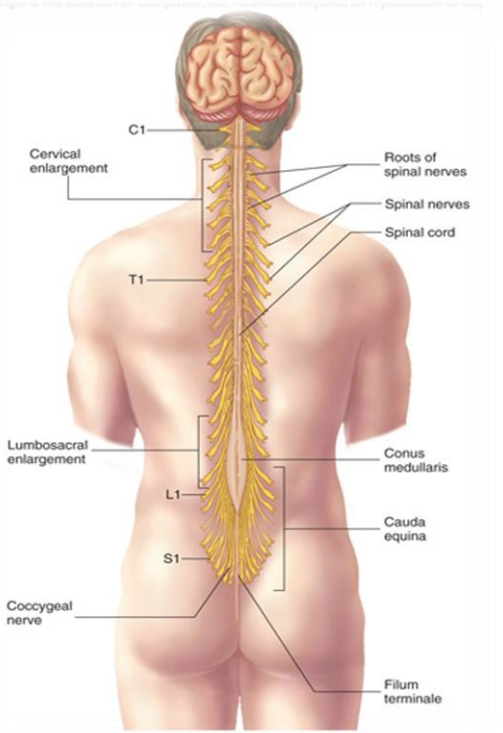
SPINAL CORD

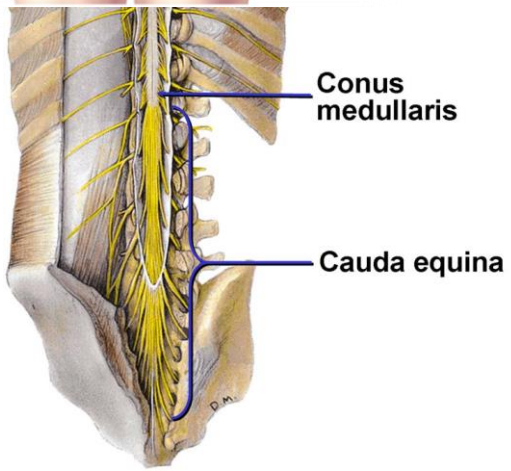
- The main pathway for information connecting the brain and peripheral nervous system.
- It is elongated, cylindrical, suspended in the vertebral canal and protected by vertebrae
- Surrounded by the meninges and cerebrospinal fluid (CSF).
- The primary function of spinal cord is a transmission of neural signals between the brain and the rest of the body.
  - Sensory
  - Motor
  - Local reflexes

SPINAL CORD

- Extends from *foramen magnum* to *2nd lumbar vertebra.*
- Continuous above with the ***medulla oblongata***.
- The tapered inferior end forms ***conus medullaris***.
- It is connected to the coccyx by a non-neuronal cord called ***Filum Terminale.***

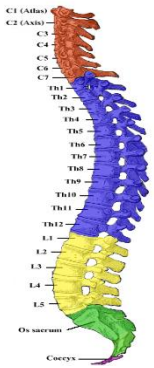




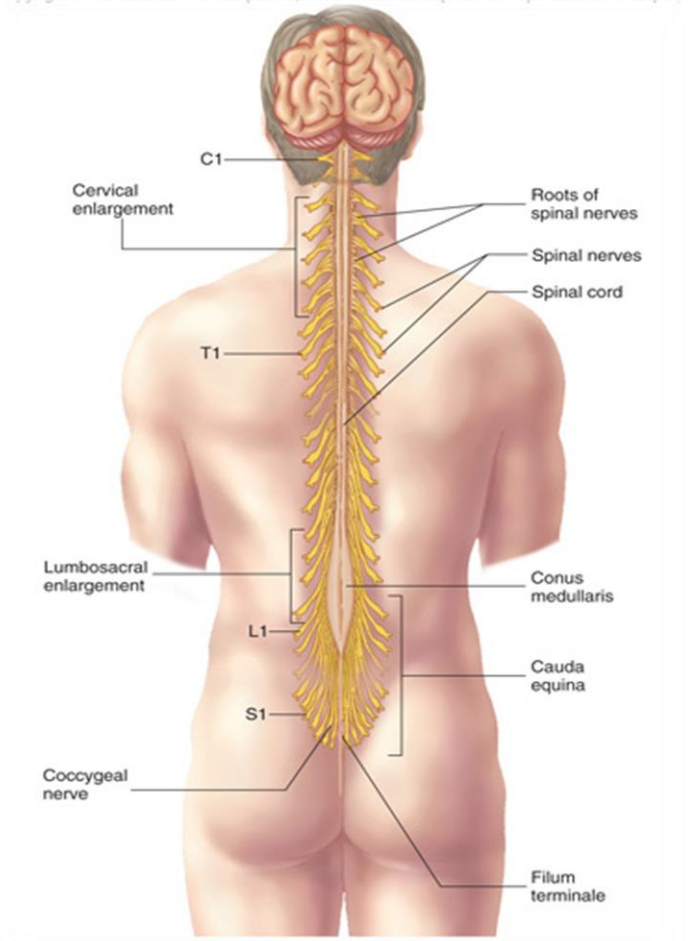


SPINAL CORD

- Gives rise to 31 pairs of spinal nerves
- The bundle of spinal nerves extending inferiorly from *lumbosacral enlargement* and *conus medullaris* surround the *filum terminale* and form *cauda equina*
- Segmented
  - 8 Cervical
  - 12 Thoracic
  - 5 Lumbar
  - 5 Sacral
  - 1 Coccygeal

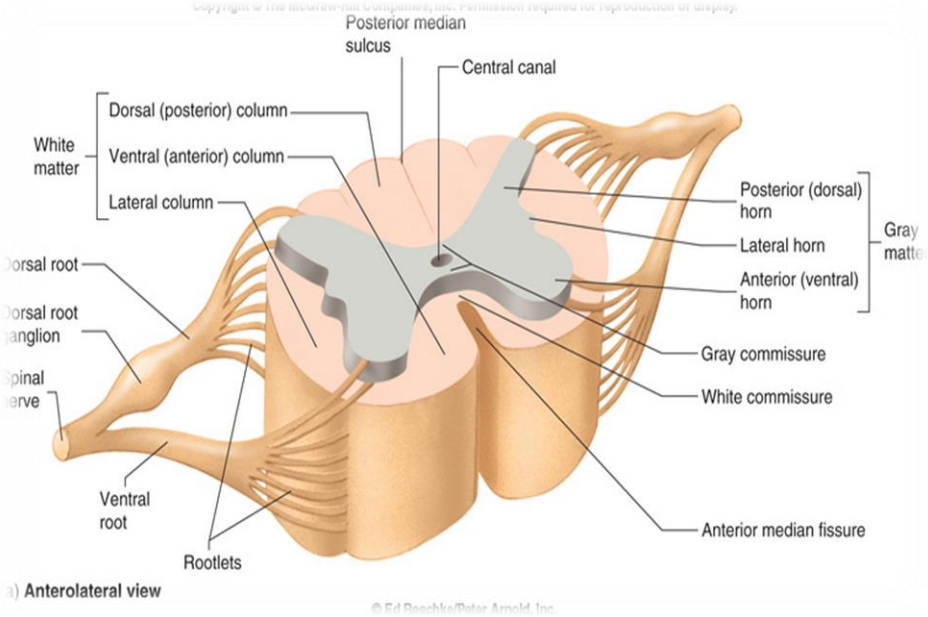


- Has two enlargements:
  - Cervical Enlargement: supplies upper limbs.
  - Lumbosacral Enlargement: supplies lower limbs.



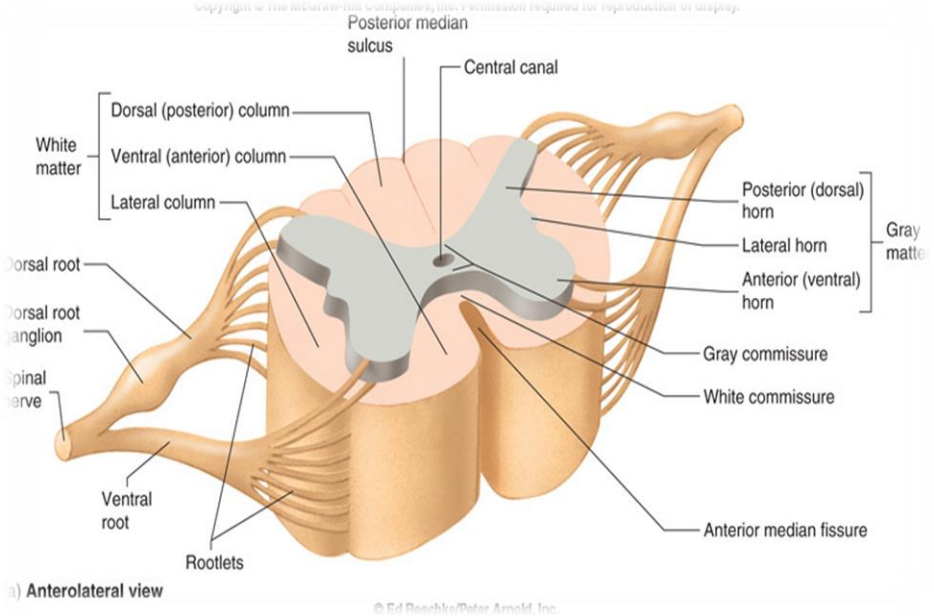
CROSS SECTION OF SPINAL CORD

- The spinal cord is incompletely divided into two equal parts, anteriorly by a short, shallow median fissure and posteriorly by a deep narrow septum, the posterior median sulcus.
- Composed of grey matter in the center surrounded by white matter supported by neuroglia.
- Commissures: connections between left and right halves
  - Gray with central canal in the center.
  - White.
- Roots: spinal nerves arise as rootlets then combine to form roots
  - Dorsal (posterior) root has a ganglion
  - Ventral (anterior)
  - Two roots merge laterally and form the spinal nerve



GREY MATTER

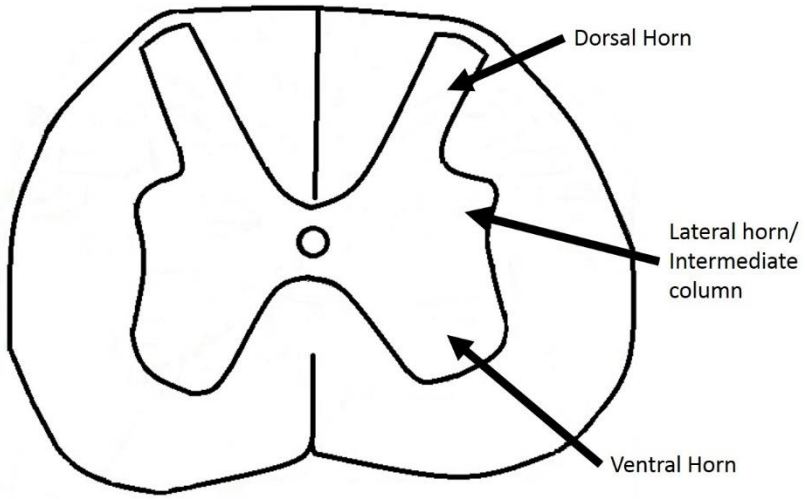
- The arrangement of grey matter in the spinal cord resembles the shape of the letter H.
- Having:
  - two posterior
  - two anterior
  - two lateral horns/columns.
- Consists of:
  - nerve cell bodies and their processes
  - neuroglia
  - blood vessels



GREY MATTER

- **The nerve cells are multipolar, and are of three main categories:**

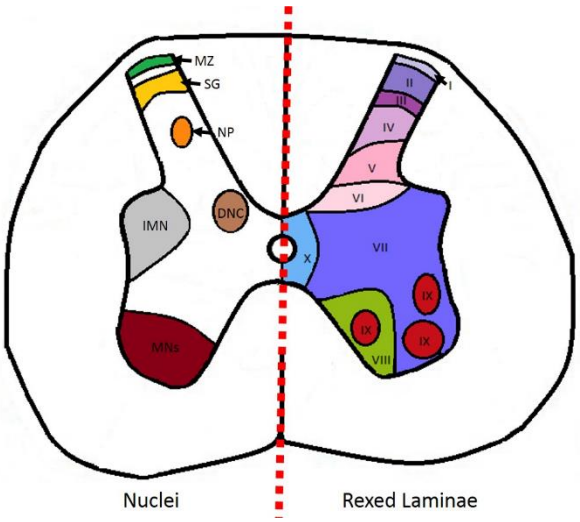
- **Sensory neurons (Tract cells)**
  - **receive impulses from the periphery of the body and whose axons constitute the ascending fasciculi of the white matter.**
  - **located in the dorsal horns.**
- **Lower motor neurons**
  - **transmit impulses to the skeletal muscles.**
  - **located in the ventral horns**
    - **similar neurons in the lateral horn are the preganglionic neurons of the autonomic system.**
- **Interneurons (connector neurons)**
  - **linking sensory and motor neurons, at the same or different levels, which form spinal reflex arcs.**

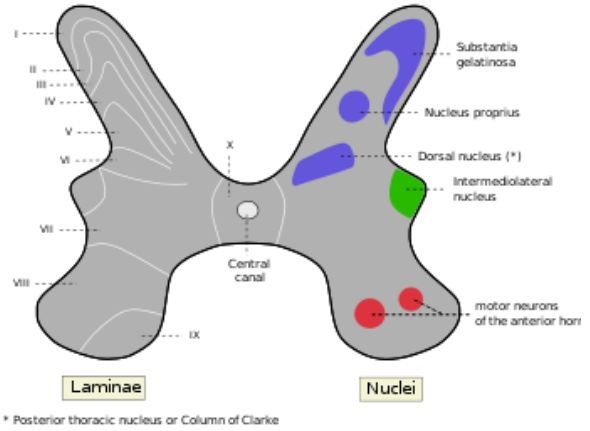


SPINAL CORD NUCLEI

The main groups of neuron cell bodies in the spinal cord are the:

- **Marginal Zone (MZ)(Posterior Marginalis)**
  - located at the tip of the dorsal horn.
  - important for relaying pain and temperature sensation to the brain.
- **Substantia Gelatinosa (SG)**
  - located at the top of the dorsal horn.
  - Composed of large neurons.
  - Extends throughout the length of spinal cord.
  - important for relaying pain, temperature and light touch sensation to the brain.
- **Nucleus Proprius (NP)**
  - located in the neck of the dorsal horn.
  - Composed of large neurons.
  - Extends throughout the length of spinal cord.
  - relays mechanical and temperature sensation to the brain.
- **Dorsal Nucleus of Clarke (DNC)**
  - the most dorso-medial nuclei.
  - Composed mostly of large neurons
  - Extends from C8 to L3-4 segments
  - relays unconscious proprioceptive information to the brain.
  - Only found in spinal segments C8 to L3.

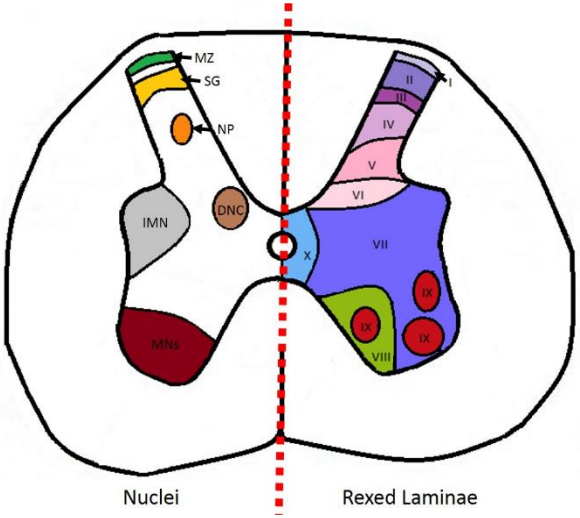




SPINAL CORD NUCLEI

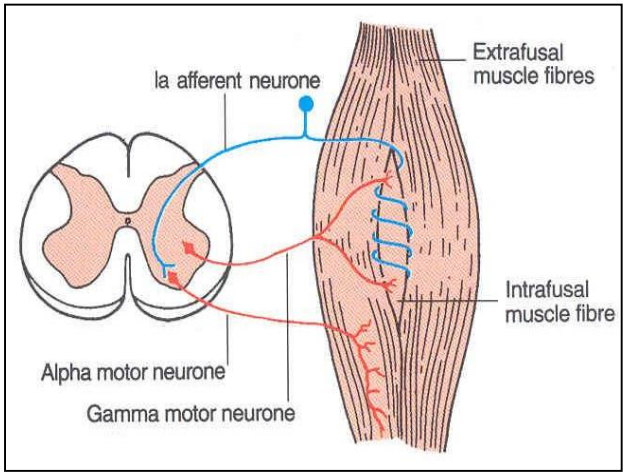
Interomediolateral Nucleus (IMN)

- located in the intermediate column and lateral horn.
- relays sensory information from viscera to the brain, and autonomic signals from the brain to the visceral organs.
- Extends from T1 to L2-3 segments:
  - Give rise to preganglionic sympathetic fibers
- Extends from S2-4 segments:
  - Give rise to preganglionic parasympathetic fibers



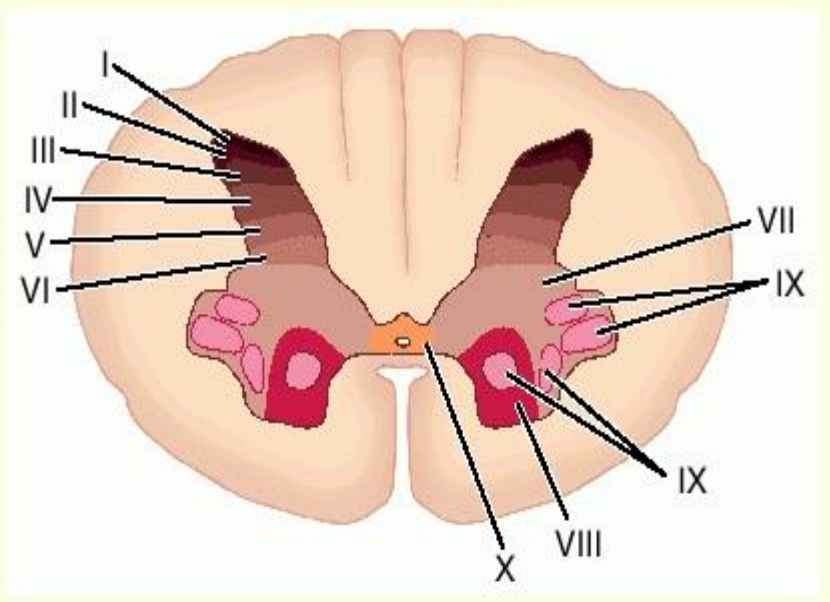
Lateral Motor Neurons and Medial Motor Neurons (MNs)

- located in the ventral horn.
- Composed of motor neurons that innervate visceral and skeletal muscles.
- Are of Two types:
  - Large multipolar cells
    - Whose axons pass out in the ventral roots of spinal nerves as alpha efferents which innervate extrafusal muscle fibers of skeletal muscles.
  - Less numerous smaller multipolar cells
    - Whose axons pass out in the ventral roots of spinal nerves as gamma efferents which innervate intrafusal muscle fibers of neuromuscular spindles



NEURONAL ARCHITECTURE OF SPINAL GREY MATTER

- Cells of the same type are clustered into groups, which occur in long columns
- In transverse section, these columns appear as layers, especially within the dorsal horn
- These layers are called the laminae of Rexed that are numbered by Roman numerals, starting from the tip of the dorsal horn and moving ventrally into the ventral horn.
- The Rexed laminae comprise a system of ten layers of grey matter (I-X), identified in the early 1950s by *Swedish neuroscientist*.



REXED LAMINAE

Lamina I

- tip of the dorsal horn
- cells respond to noxious or thermal stimuli
- sends information to the brain by the contralateral spinothalamic tract
- corresponds to the marginal zone

Lamina II

- Involved in sensation of noxious and non-noxious stimuli, and modulating sensory input to contribute to the brain's interpretation of incoming signals as painful, or not.
- Sends information to Lamina III and IV
- Corresponds to substantia gelatinosa.

Lamina III

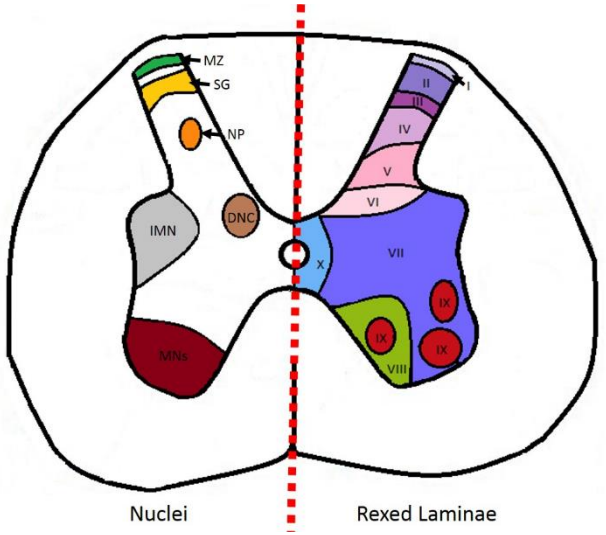
- Involved in proprioception and sensation of light touch.
- Cells in this layer connects with cells in layers IV, V and VI.
- Partially corresponds to nucleus proprius

Lamina IV

- Involved in non-noxious sensory information relay and processing.
- Cells connect with those in lamina II
- Partially corresponds to nucleus proprius

Lamina V

- Relays sensory, including nociceptive (potentially painful), information to the brain via the contralateral and spinothalamic tracts
- Receives descending information from the brain via the corticospinal and rubrospinal tracts.



REXED LAMINAE

Lamina VI

- Contains many small interneurons involved in spinal reflexes
- Receives sensory information from muscle spindles (involved in proprioception).
- Sends information to the brain via ipsilateral spinocerebellar pathways

Lamina VII

- Large, heterogenous zone that varies through the length of the spinal cord.
- Receives information from Lamina II to VI, and from viscera
- Relays motor information to the viscera
- Gives rise to cells involved in the autonomic system.
- Dorsal nucleus of Clarke is part of Lamina VII

Lamina VIII

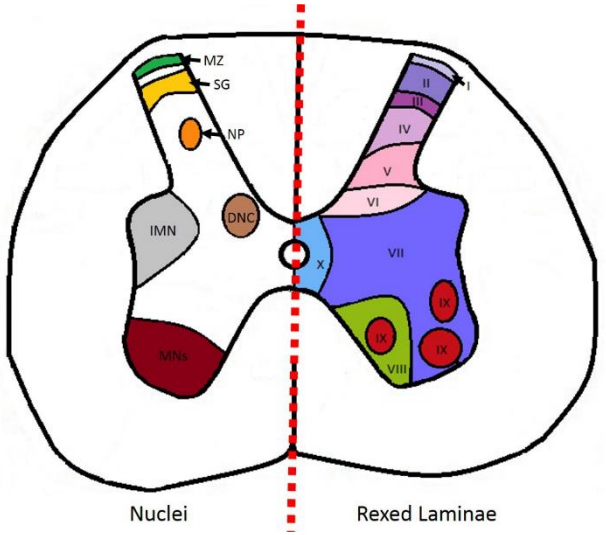
- Varies depending on spinal cord level, but is most prominent in cervical and lumbar enlargements.
- Cells are involved in modulating motor output to skeletal muscle.

Lamina IX

- Size and shape varies between spinal cord levels.
- Distinct groups of motor neurons that innervate skeletal muscle.

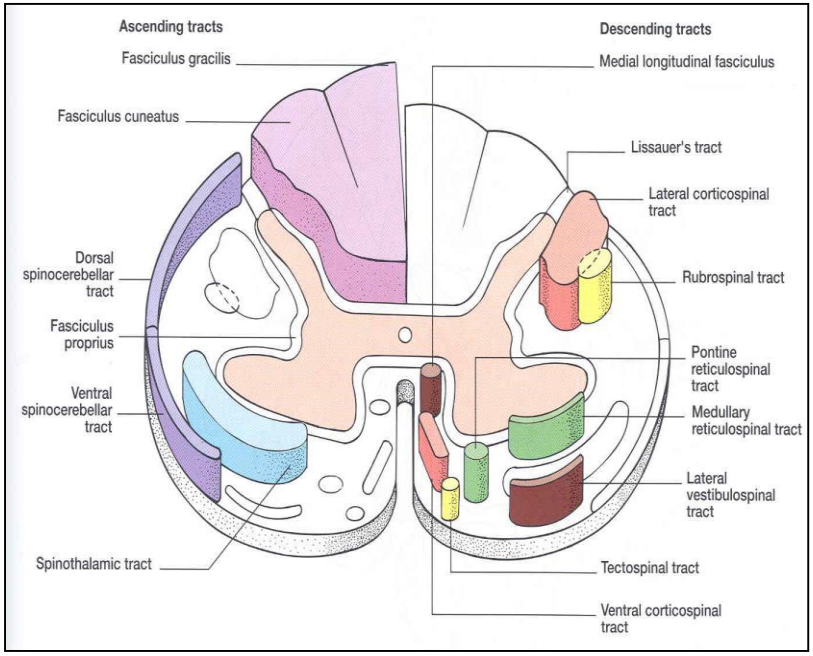
Lamina X

- Surrounds the central canal – the grey commissure.
- Axons decussate (cross over) from one side of the spinal cord to the other.

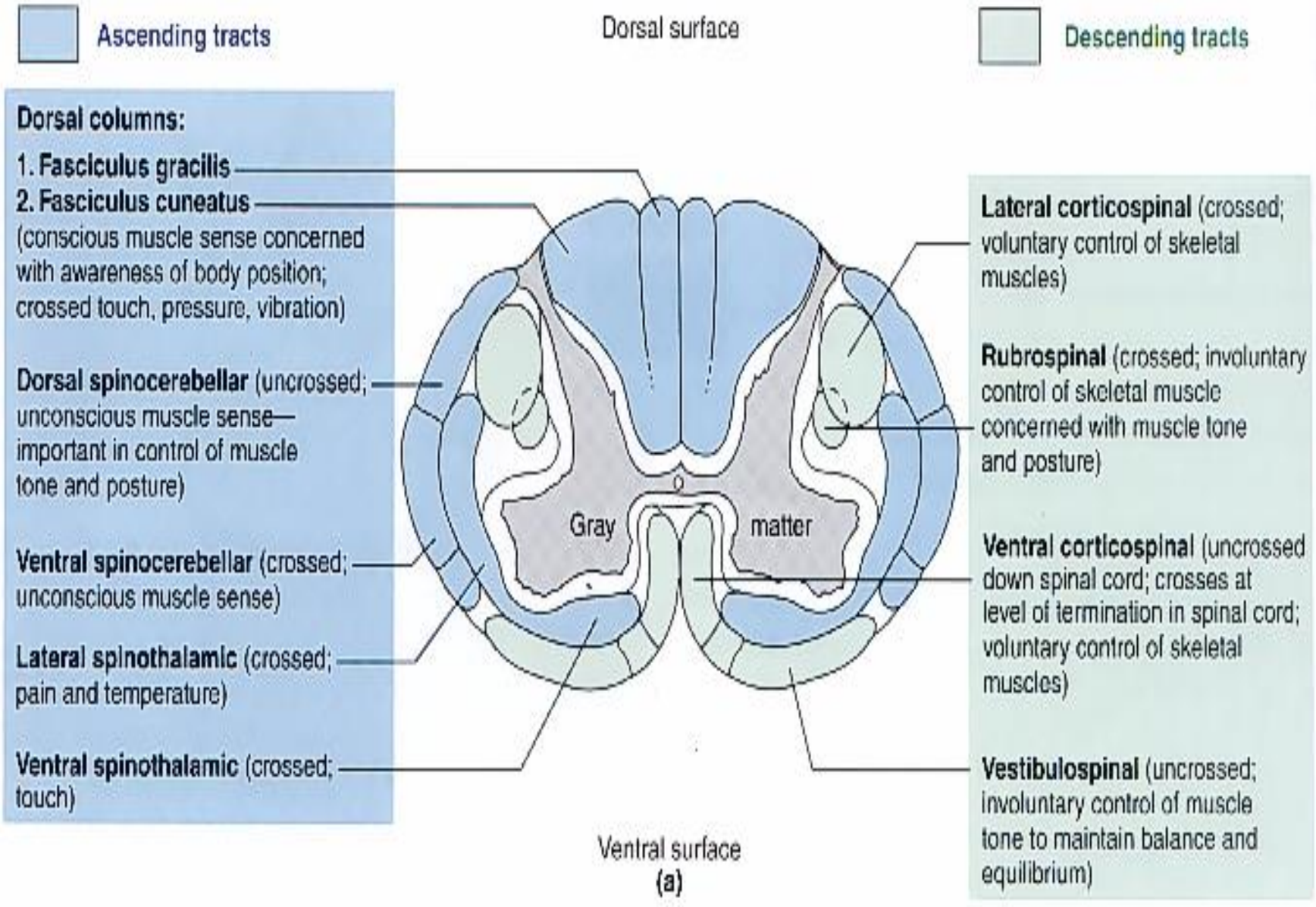


WHITE MATTER

- Consists of mixture of **nerve fibers**, **neuroglia** and **blood vessels.**
- White color is due to high proportion of **myelinated nerve fibers**
- The white matter of the spinal cord is arranged in columns/funiculi; ***anterior, posterior and lateral.***
- The nerve fibers are arranged as bundles, running vertically through the cord.
- A group of nerve fibers (axons) that share a common origin, termination and function form a **tract** or **fasciculus**
- These tracts are formed by **sensory nerve fibers ascending to the brain**, **motor nerve fibers descending from the brain** and **fibers of connector neurons.**
- Tracts are often named according to their points of origin and destination, e.g. ***spinothalamic***, ***corticospinal***.



Depending on their function, the spinal tracts are divided into ascending and descending tracts

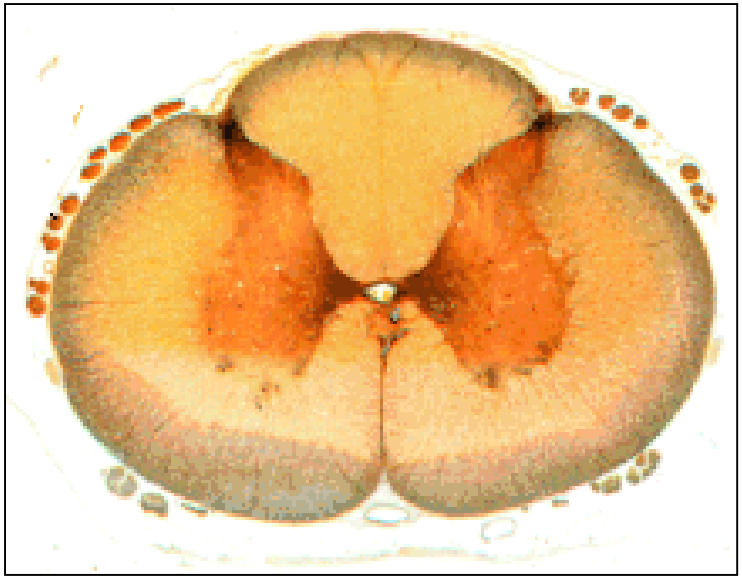

Ascending tracts
Dorsal surface
Descending tracts
Dorsal columns:
1. Fasciculus gracilis
2. Fasciculus cuneatus
(conscious muscle sense concerned with awareness of body position; crossed touch, pressure, vibration)
Dorsal spinocerebellar (uncrossed; unconscious muscle sense—important in control of muscle tone and posture)
Ventral spinocerebellar (crossed; unconscious muscle sense)
Lateral spinothalamic (crossed; pain and temperature)
Ventral spinothalamic (crossed; touch)
Gray
matter
Lateral corticospinal (crossed; voluntary control of skeletal muscles)
Rubrospinal (crossed; involuntary control of skeletal muscle concerned with muscle tone and posture)
Ventral corticospinal (uncrossed down spinal cord; crosses at level of termination in spinal cord; voluntary control of skeletal muscles)
Vestibulospinal (uncrossed; involuntary control of muscle tone to maintain balance and equilibrium)
Ventral surface
(a)

COMMISSURES OF THE SPINAL CORD

- **Grey Commissure:**
  - Transverse bridge of grey matter connecting the anterior and posterior gray horns on each side
  - Is pierced by the central canal that divides it into anterior and posterior parts
- **White Commissure:**
  - Lies ventral to the gray commissure
  - Mainly contains decussating nerve fibers

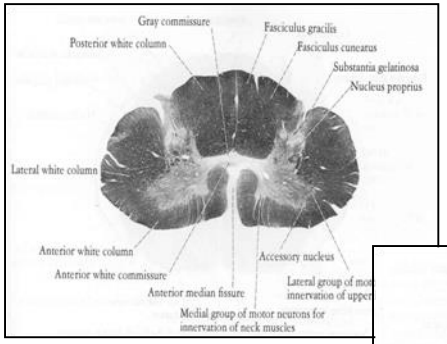
CENTRAL CANAL

- The cerebrospinal-filled space that runs longitudinally through the entire length of the spinal cord.
- Lined by ependyma (ciliated columnar epithelium)
- Continuous with the ventricular system of the brain
- Superiorly opens into the 4th ventricle
- Inferiorly in the conus medullaris, it expands into the fusiform terminal ventricle and terminates below at the root of filum terminale

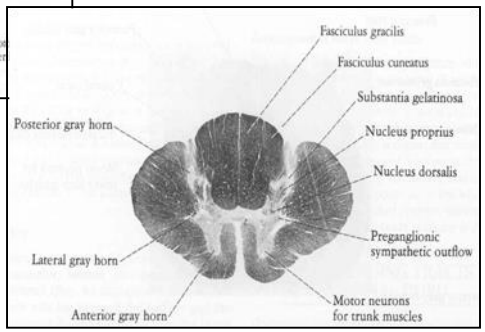


REGIONAL DIFFERENCES

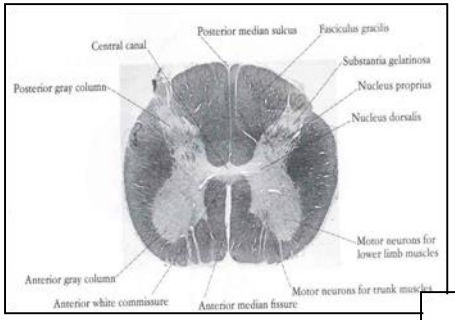
- Although the general pattern of gray matter is the same throughout spinal cord, regional differences are apparent in transverse sections
- The amount of white matter increases in a caudal-to-cranial direction because fibers are added to ascending tracts and fibers leave descending tracts
- The gray matter is in increased volume in cervical & lumbosacral enlargements for innervation of upper & lower limbs
- The lateral horn is characteristics of thoracic and upper lumbar segments



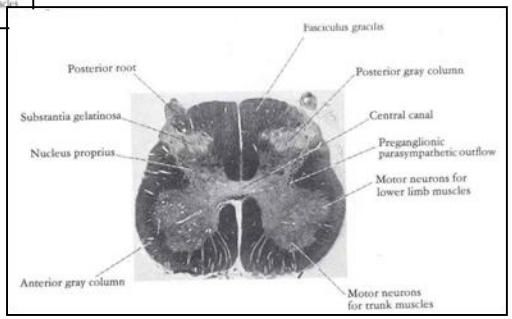
Cervical



Thoracic



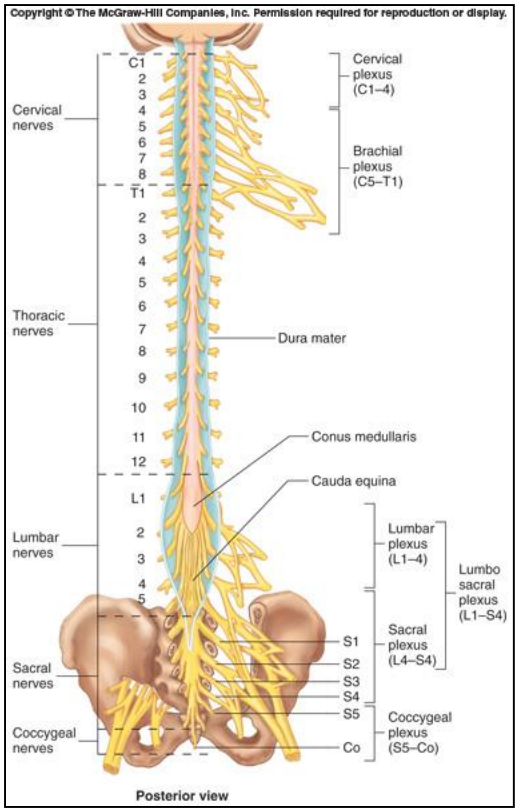
Lumbar

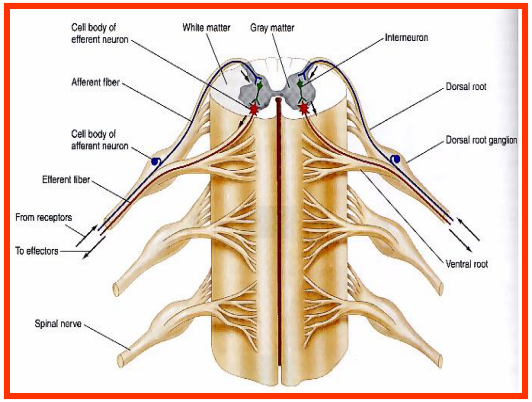


Sacral

SPINAL NERVES

- Thirty-one pairs of spinal nerves
- First pair exit vertebral column between skull and atlas, last four pairs exit via the sacral foramina and others exit through intervertebral foramina
- Eight pair cervical, twelve pair thoracic, five pair lumbar, five pair sacral, one pair coccygeal
- Each spinal nerve arises as rootlets which then combine to form dorsal (posterior) & ventral (anterior) roots.
- Two roots merge laterally and form the spinal nerve.
- Dorsal (posterior) root has a ganglion (dorsal root/sensory ganglion) that contains the cell bodies of the sensory neurons
- Each spinal nerve then divides into a smaller dorsal and a larger ventral ramus



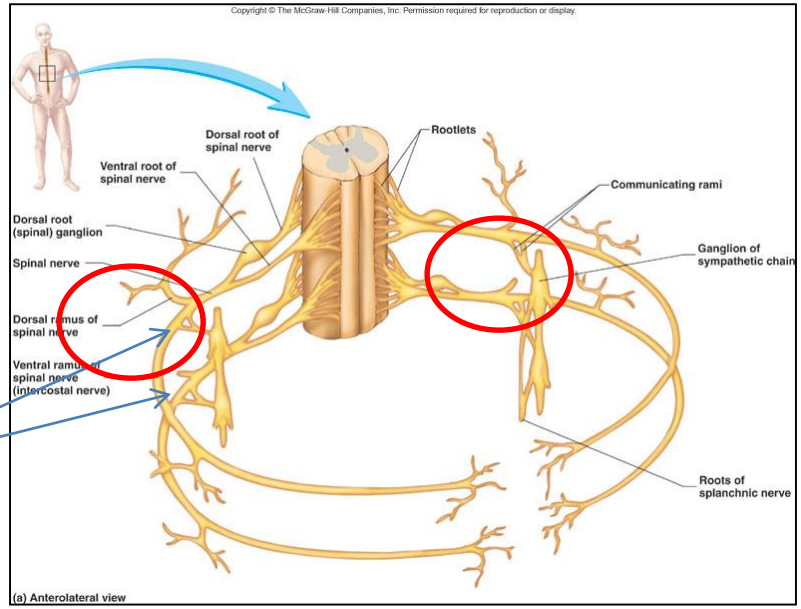


BRANCHES OF SPINAL NERVES

- **Dorsal Ramus:** innervate deep muscles of the trunk responsible for movements of the vertebral column and skin near the midline of the back.
- **Ventral Ramus:** what they innervate depends upon which part of the spinal cord is considered.
  - **Thoracic region:** form **intercostal nerves** that innervate the intercostal muscles and the skin over the thorax
  - **Remaining spinal nerve ventral rami (roots of the plexus):** form five plexuses (intermingling of nerves).

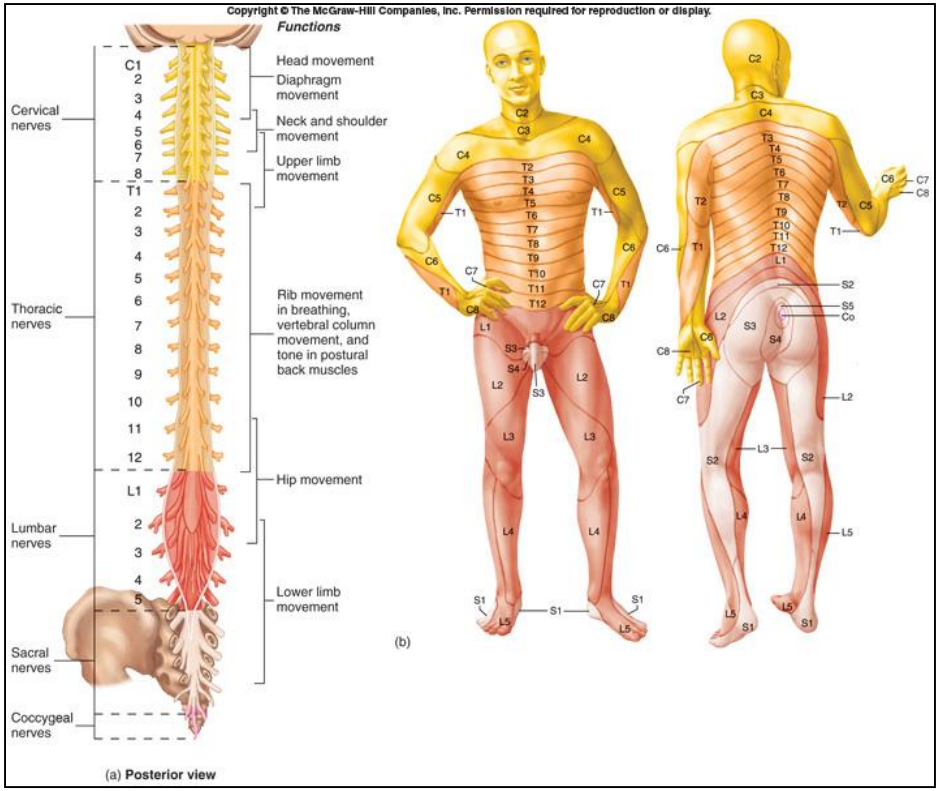
- Ventral rami of C1-C4= **cervical plexus**
- Ventral rami of C5-T1= **brachial plexus**
- Ventral rami of L1-L5= **lumbar plexus**
- Ventral rami of L4-S4= **sacral plexus**
- Ventral rami of S4 & S5= **coccygeal plexus**

- **Communicating Rami:** communicate with sympathetic chain of ganglia.



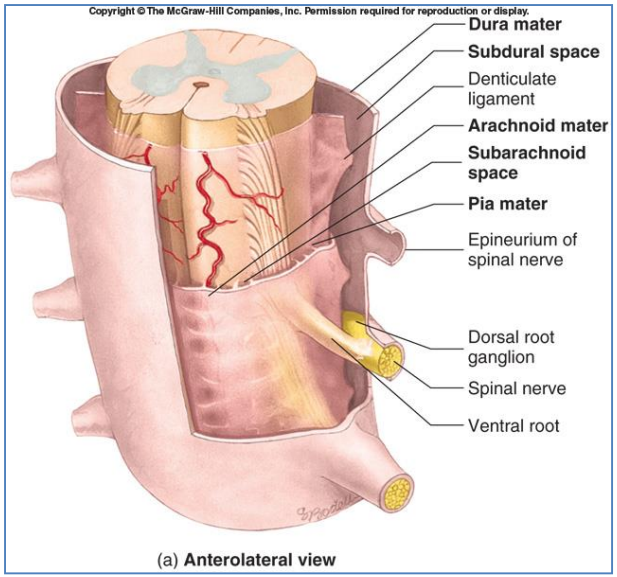
DERMATOMES

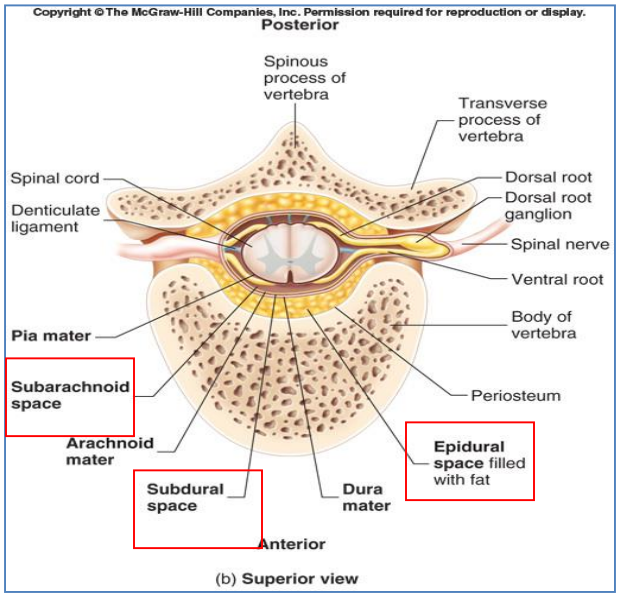
- Dermatome is a segment of skin supplied by one spinal nerve
- Cutaneous areas supplied by adjacent spinal nerves overlap.
- There is therefore little or sensory loss after interruption of a single spinal nerve or dorsal root



SPINAL MENINGES

- **Connective tissue membranes surrounding spinal cord and brain**
  - **Dura mater**: continuous with epineurium of the spinal nerves
  - **Arachnoid mater**: thin and wispy
  - **Pia mater**: bound tightly to surface of brain and spinal cord.
    - Forms the **filum terminale**, which anchors spinal cord to coccyx and the denticulate ligaments that attach the spinal cord to the dura mater
- **Spaces**
  - **Epidural**: Contains blood vessels, connective tissue and fat.
  - **Subdural**: Contains serous fluid
  - **Subarachnoid**: Contains CSF and blood vessels within web-like strands of arachnoid tissue

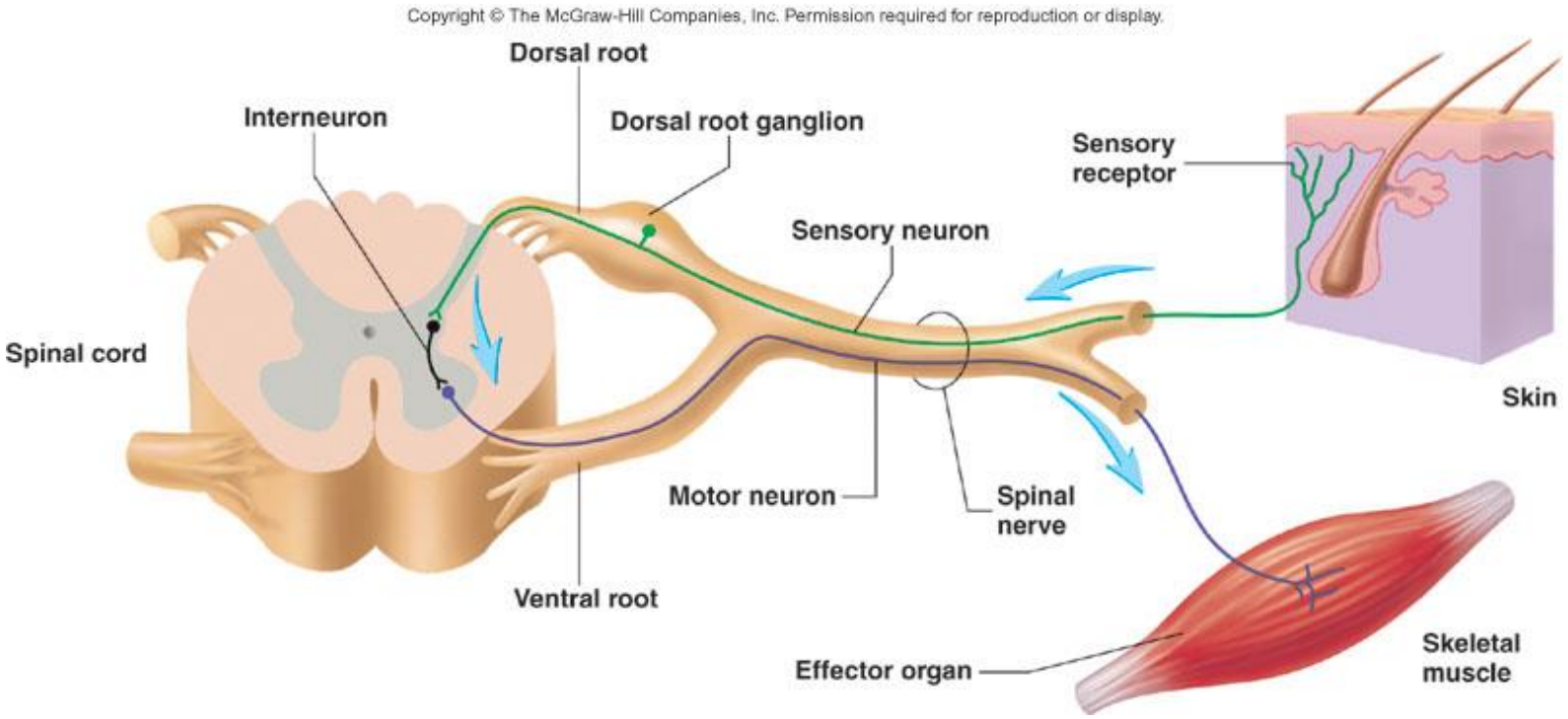




REFLEX & REFLEX ARC

A reflex is a rapid, involuntary, stereotyped pattern of response brought by a sensory stimulus

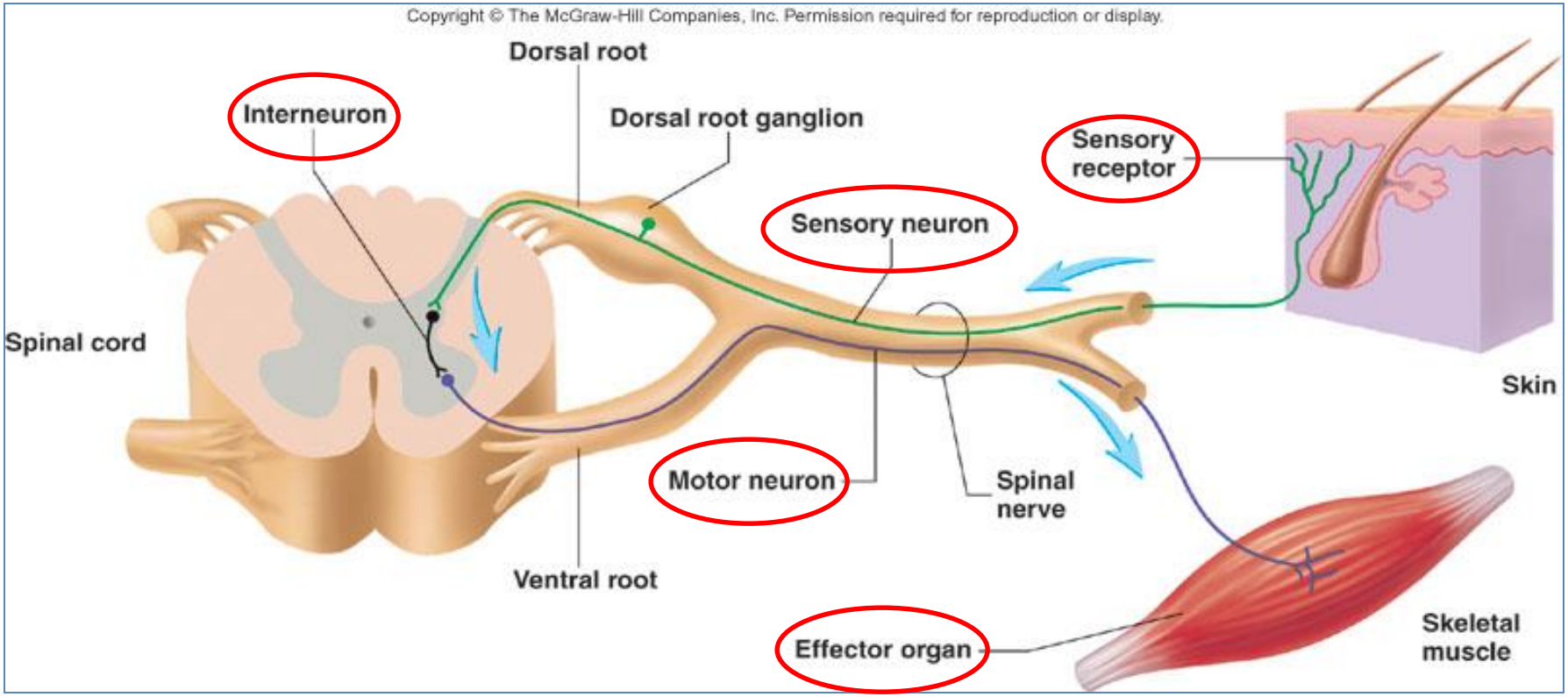
A neural pathway mediating the reflex actions is called reflex arc.



COMPONENTS OF A REFLEX ARC

Action potentials produced in

Sensory receptor → **Sensory neuron** → **Interneuron** → **Motor neuron** → **Effector organ** which responds with a **reflex**



CLINICAL SIGNIFICANCES

- Spinal cord injuries can be caused by trauma to the spinal column (stretching, bruising, applying pressure, severing).
- Usually, victims of spinal cord injuries will suffer loss of feeling in certain parts of their body.
- In milder cases, a victim might only suffer loss of hand or foot function.
- More severe injuries may result in paraplegia, tetraplegia (also known as quadriplegia), or full body paralysis below the site of injury to the spinal cord.
- Spinal shock and neurogenic shock can occur from a spinal injury.
- Spinal shock is usually temporary, lasting only for 24–48 hours, and is a temporary absence of sensory and motor functions.
- Neurogenic shock lasts for weeks and can lead to a loss of muscle tone due to disuse of the muscles below the injured site.

QUESTIONS!