



MED437  
KING SAUD UNIVERSITY



# Anatomy of the Spinal Cord

Lecture (2)

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هذا العمل مبني بشكل أساسي على عمل دفعة ٤٣٦ مع المراجعة والتدقيق وإضافة الملاحظات ولا يعني عن المصدر الأساسي للمذاكرة

- **Important**
- **Doctors Notes**
- Notes/Extra explanation

{وَمَنْ يَتَوَكَّلْ عَلَى اللَّهِ فَهُوَ حَسْبُهُ}

# Objectives

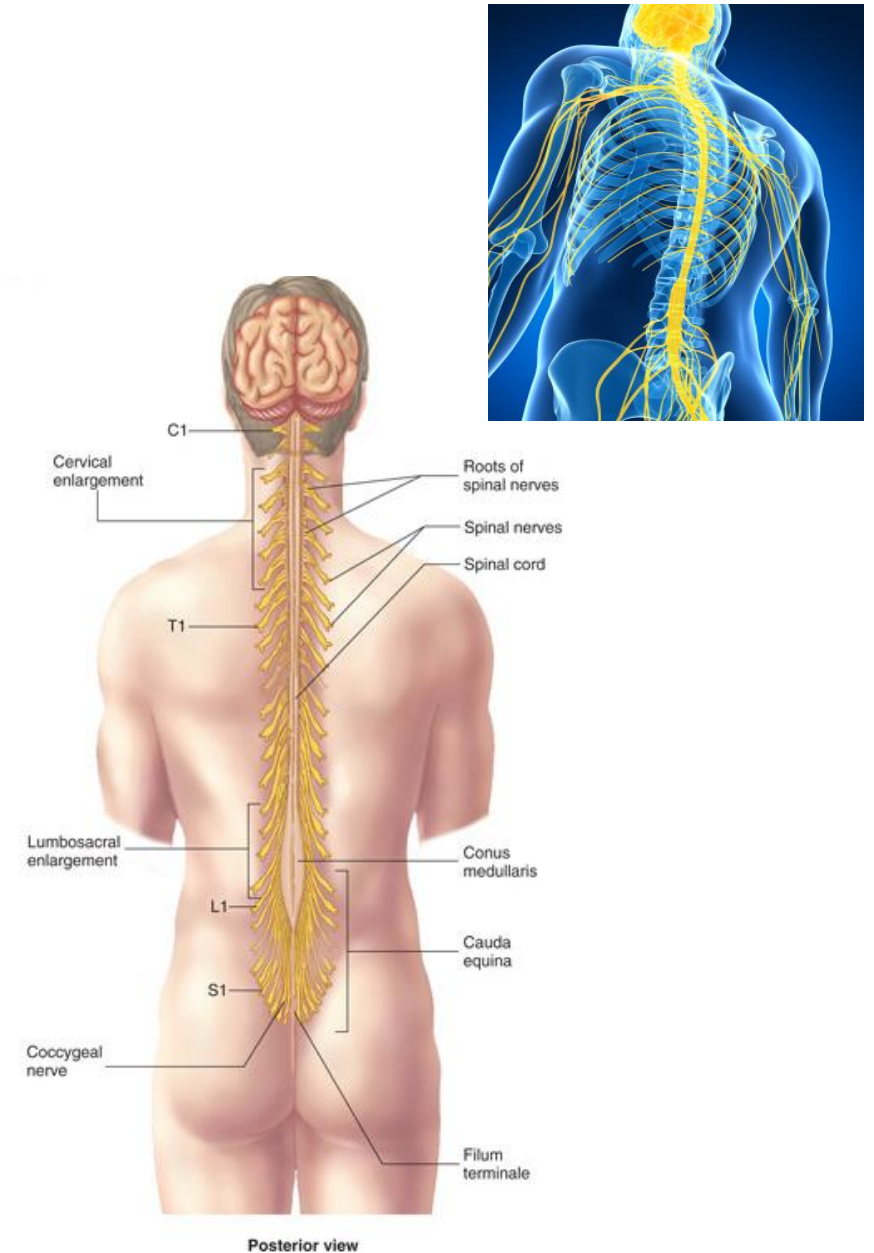
**At the end of the lecture, the students should be able to:**

- ✓ Describe the external anatomy of the spinal cord.
- ✓ Describe the internal anatomy of the spinal cord.
- ✓ Describe the spinal nerves: formation, branches and 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.

The first 4 slides of the boys lecture were not included since they are a review of the first lecture.

# Spinal Cord

- The main pathway for information connecting the brain and peripheral nervous system.
- An *elongated*, almost *cylindrical* structure, about the thickness of the little finger.
- It is suspended in the **vertebral canal** & surrounded by the **meninges** and **cerebrospinal fluid (CSF)**.
- In adults, its Length is approximately 45 cm.
- 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

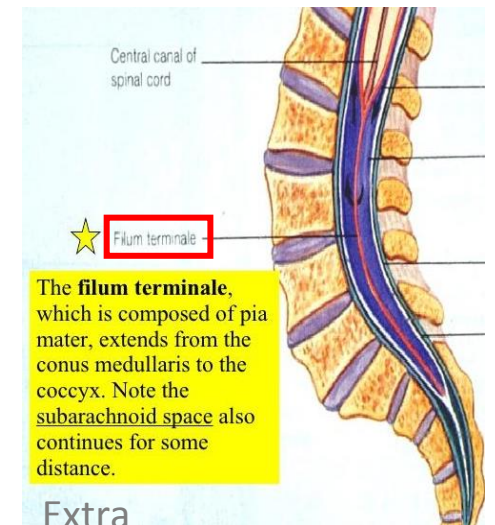
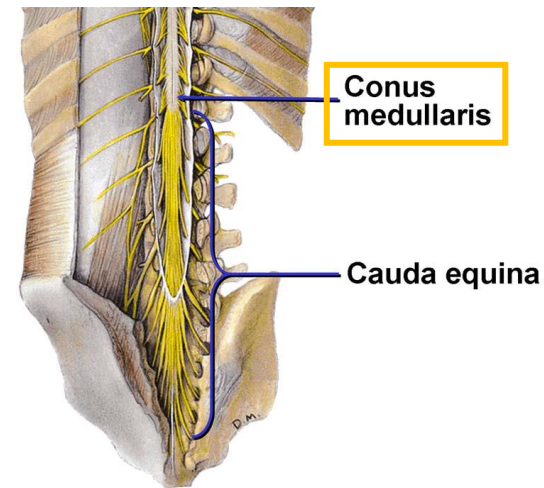
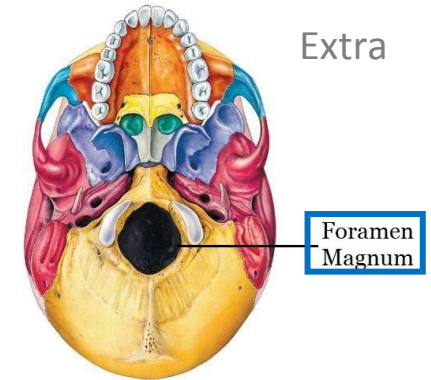
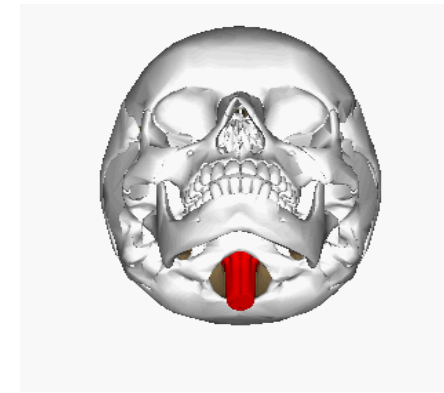


# Spinal Cord

- Extends from **foramen magnum** to **L1-L2** (**intervertebral disc**). (boys slides: until second lumbar vertebra L2)
- In children it extends to L3 because their vertebral column is smaller/shorter.
- Continuous above with the **medulla oblongata**.
- The tapered inferior end forms **conus medullaris\***, which is connected to the coccyx by a non-neuronal cord called **filum terminale** (its not considered a part of the spinal cord.).
- Gives rise to **31 pairs** of spinal nerves.

\*cone like (مخروطي)

(its enlarged because it supplies the lower limbs and it is the place anesthetics are injected during child birth).

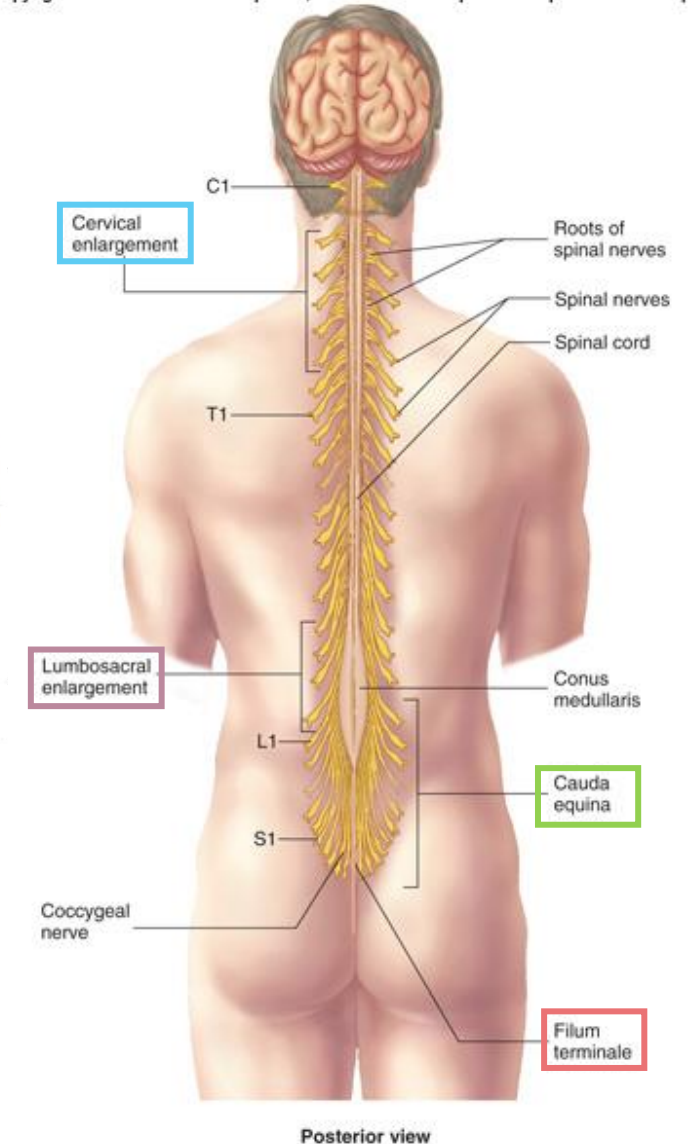
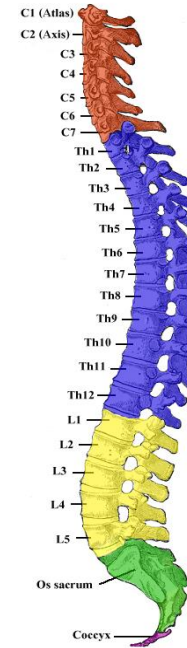


# Spinal Cord



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- The spinal cord is a **Segmented** structure, has
  - **8 Cervical**
  - **12 Thoracic**
  - **5 Lumbar**
  - **5 Sacral**
  - **1 Coccygeal** segments
- Not uniform in diameter, (not the same diameter throughout)
- Has **two enlargements**:
  - **Cervical enlargement**: supplies upper limbs
  - **Lumbosacral enlargement**: supplies lower limbs
- The bundle of spinal nerves extending inferiorly from lumbosacral enlargement and conus medullaris surround the filum terminale and form cauda equina (because of its resemblance to a horse's tail)



*\*Recall:*

End of spinal cord: conus medullaris.

End of spinal nerves: cauda equina.

# Spinal Cord Cross Section

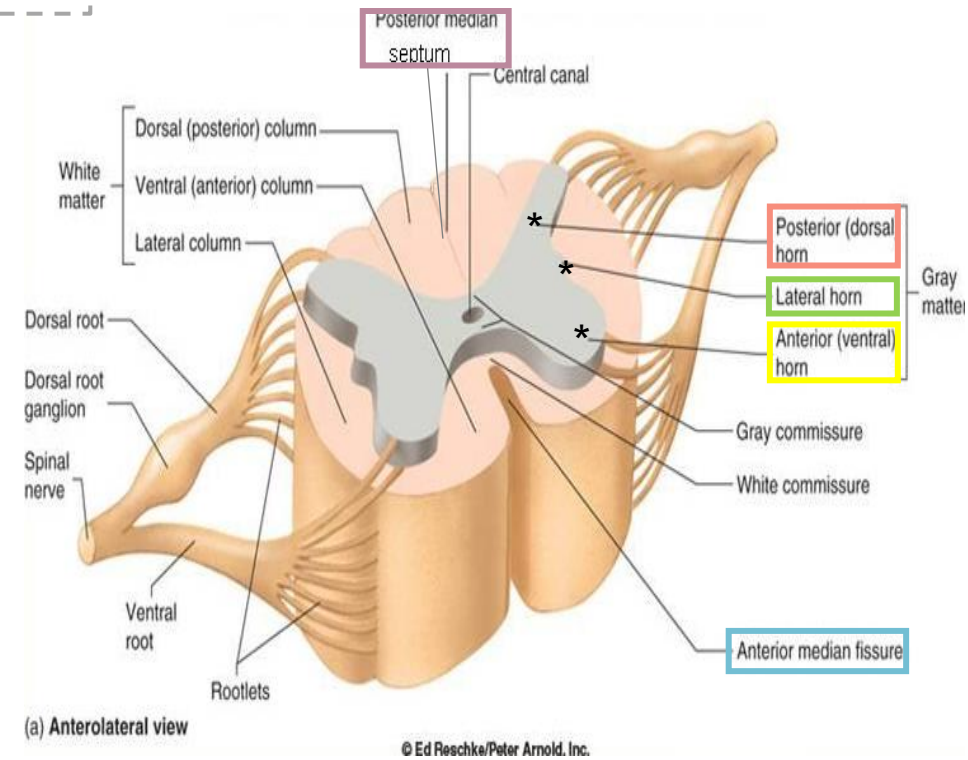
You can know the orientation by:

- 1- dorsal root ganglion
- 2- anterior median fissure

Fissure > sulcus

Ventral = Anterior  
Dorsal = Posterior

- The spinal cord is incompletely divided into two equal parts,
  - *anteriorly* by a short, shallow **median fissure** (thicker) and
  - *posteriorly* by a deep narrow septum, the posterior **median septum (sulcus)**.
- Composed of grey matter in the centre surrounded by white matter supported by neuroglia.\*
- The arrangement of grey matter resembles the shape of the letter **H**, having two posterior, two anterior and two lateral horns/columns. (not all grey matter has lateral horns)
- Commissures: connections between left and right halves
  - Gray with central canal in the center
  - White (both will be discussed later)
- Roots: spinal nerves arise as rootlets then combine to form roots: **Dorsal** (posterior) root has a **ganglion** and **Ventral** (anterior). Two roots merge laterally and form the spinal nerve.



\*Don't be confused:

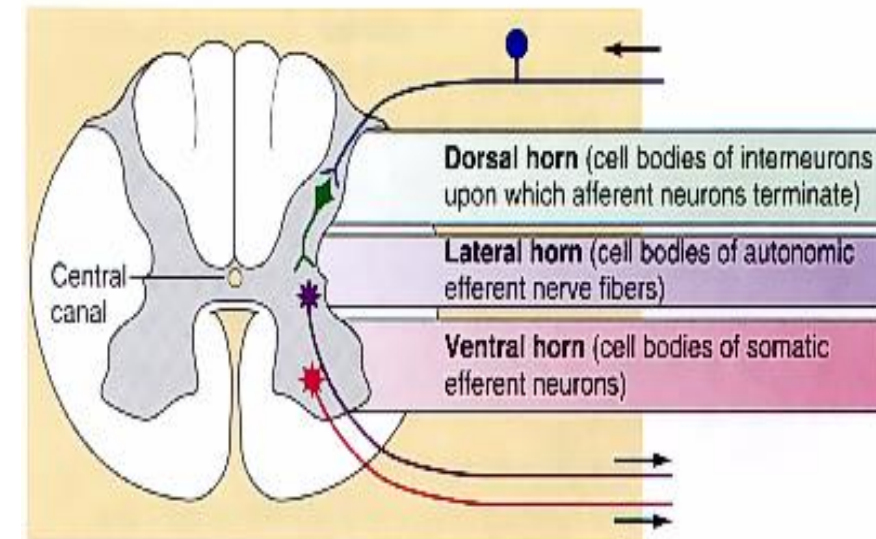
	The brain	Spinal cord
Cortex "outer layer"	Gray matter	White matter
Medulla "inner layer"	White matter	Gray matter

# Grey Matter



- Consists of (1) nerve cell bodies and their processes, (2) neuroglia, and (3) blood vessels
- The nerve cells are multipolar and are of **three** main categories:
  - 1. Sensory neurons** (Tract cells), which receive impulses from the periphery of the body and whose axons constitute the ascending fasciculi of the white matter, are located in the **Dorsal horns**.
  - 2. Lower motor neurons**, which transmit impulses to the skeletal muscles, are located in the **ventral horns** (similar neurons in the **lateral horn** are the preganglionic neurons of the autonomic system)
  - 3. Interneurons** (connector neurons): linking sensory and motor neurons, at the same or different levels, which form spinal reflex arcs. (only in spinal cord not brain)

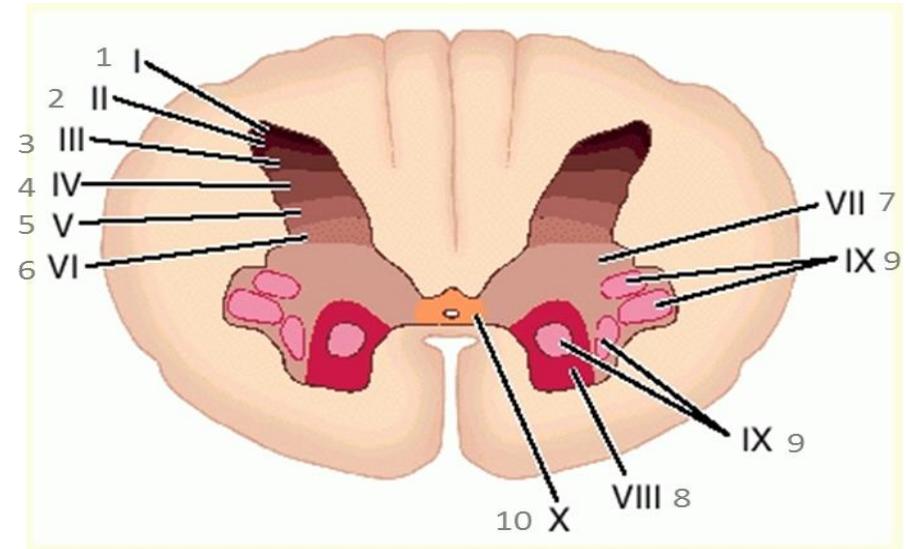
Ventral = Anterior  
Dorsal = Posterior



# Spinal Grey Matter Neuronal Architecture

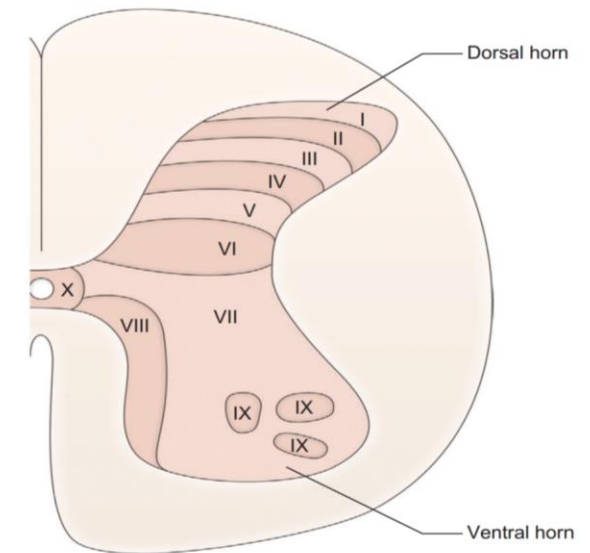
Dorsal horn: 1 → 7  
 Ventral horn: 8, 9  
 Central horn: 10

- 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 consecutively 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 a Swedish neuroscientist.



1 = I	11 = XI
2 = II	12 = XII
3 = III	13 = XIII
4 = IV	14 = XIV
5 = V	15 = XV
6 = VI	16 = XVI
7 = VII	17 = XVII
8 = VIII	18 = XVIII
9 = IX	19 = XIX
10 = X	20 = XX

Extra



Extr

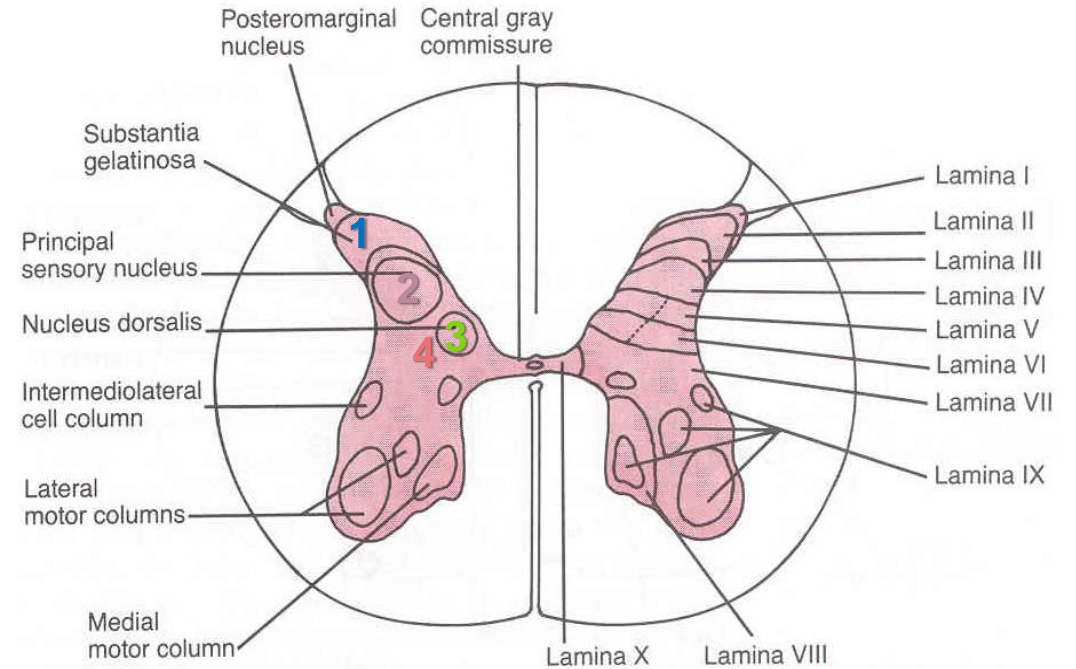
Figure 8.10 Lamination of spinal grey matter (Rexed's laminae).



# Dorsal Horn Nerve Cell Groups

5 main groups

1. Substantia gelatinosa
2. Nucleus proprius
3. Nucleus dorsalis (Clark's column, nucleus thoracis)
4. Visceral afferent nucleus
5. Marginal zone (posterior marginals)\*



\* Only in boys slides

# Dorsal Horn Nerve Cell Groups

The doctor said: you should know the correspondence of each lamina.  
For example, lamina 2 corresponds to substantia gelatinosa

## Marginal zone (posterior marginals)

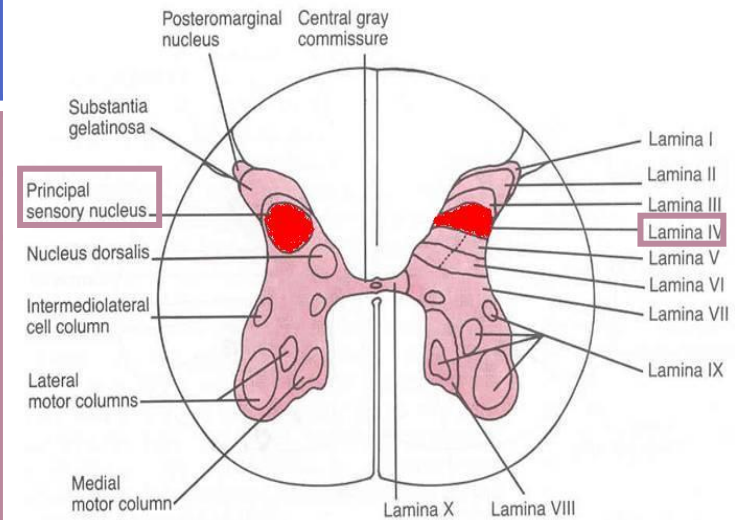
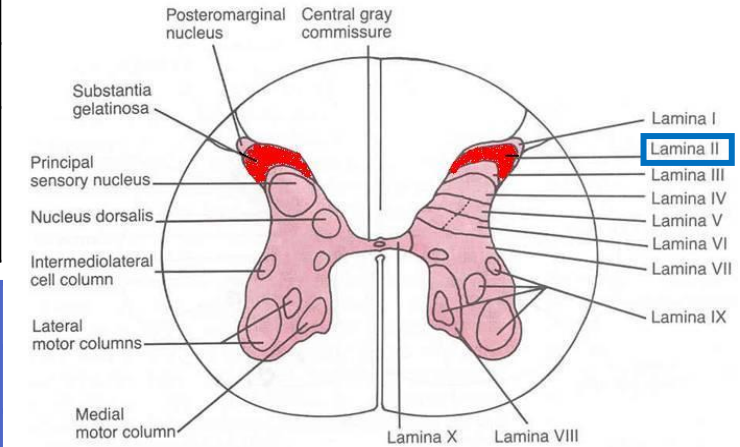
Rexed Laminae	Location	Composed of	Extends	Afferents
I (1)	At the tip of dorsal horn	-	-	Important for relaying pain and temperature sensation to the brain.

## Substantia Gelatinosa

Rexed Laminae	Location	Composed of	Extends	Afferents
II (2)	<b>apex</b> of the posterior/dorsal horn	<u>large</u> neurons	<b>throughout</b> the length of spinal cord	<u>dorsal</u> root fibers concerned with <b>pain, temperature</b> and crude <b>touch</b>

## Nucleus Proprius

Rexed Laminae	Location	Composed of	Extends	Afferents
IV (4)	<b>anterior</b> to substantia gelatinosa/ located in the neck of dorsal horn	<u>large</u> neurons	<b>throughout</b> the length of spinal cord	<u>dorsal</u> root fibers concerned with <b>fine touch (senses of position &amp; movement (proprioception) and two point discrimination &amp; vibration) *</b>



\*There is variation in this point between boys and girls slides, This is the correct information according to **Snell's Clinical Neuroanatomy**

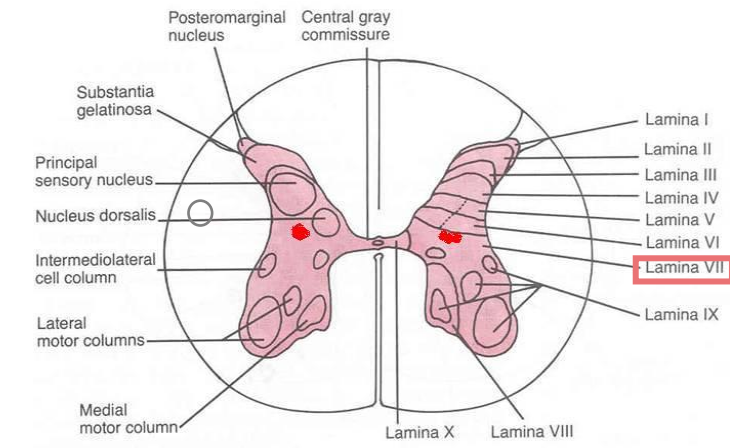
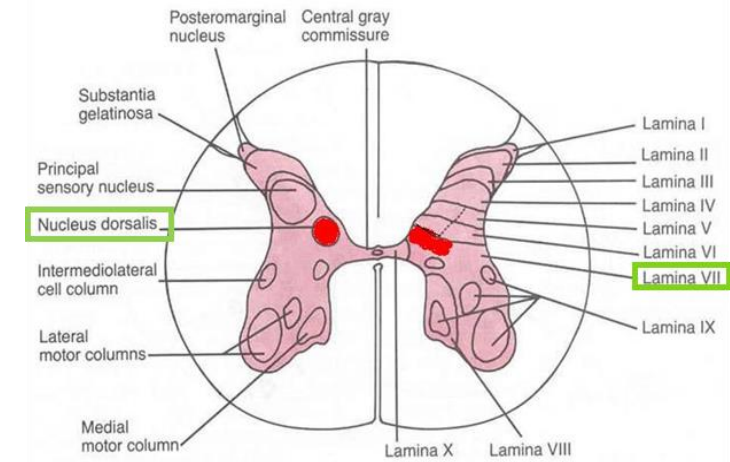
# Dorsal Horn Nerve Cell Groups

Nucleus Dorsalis (Clark's column, Nucleus thoracis)				
<i>Rexed Laminae</i>	<i>Location</i>	<i>Composed of</i>	<i>Extends</i>	<i>Afferents</i>
VII (7)	<b>base</b> of dorsal horn/ the most dorso-medial nuclei	mostly <u>large</u> neurons	from <b>C8</b> to <b>L3-4</b> segments	<u>dorsal</u> root fibers concerned with information from <b>muscle spindles</b> and <b>tendon organs.</b>

\*Associated with **proprioceptive endings**

\*Relays unconscious proprioceptive information to brain

Visceral Afferent Nucleus				
<i>Rexed Laminae</i>	<i>Location</i>	<i>Composed of</i>	<i>Extends</i>	<i>Afferents</i>
VII (7)	<b>lateral</b> to nucleus dorsalis	mostly of <u>medium</u> size neurons	from <b>T1</b> to <b>L3</b> segments	Visceral afferents



# Rexed laminae

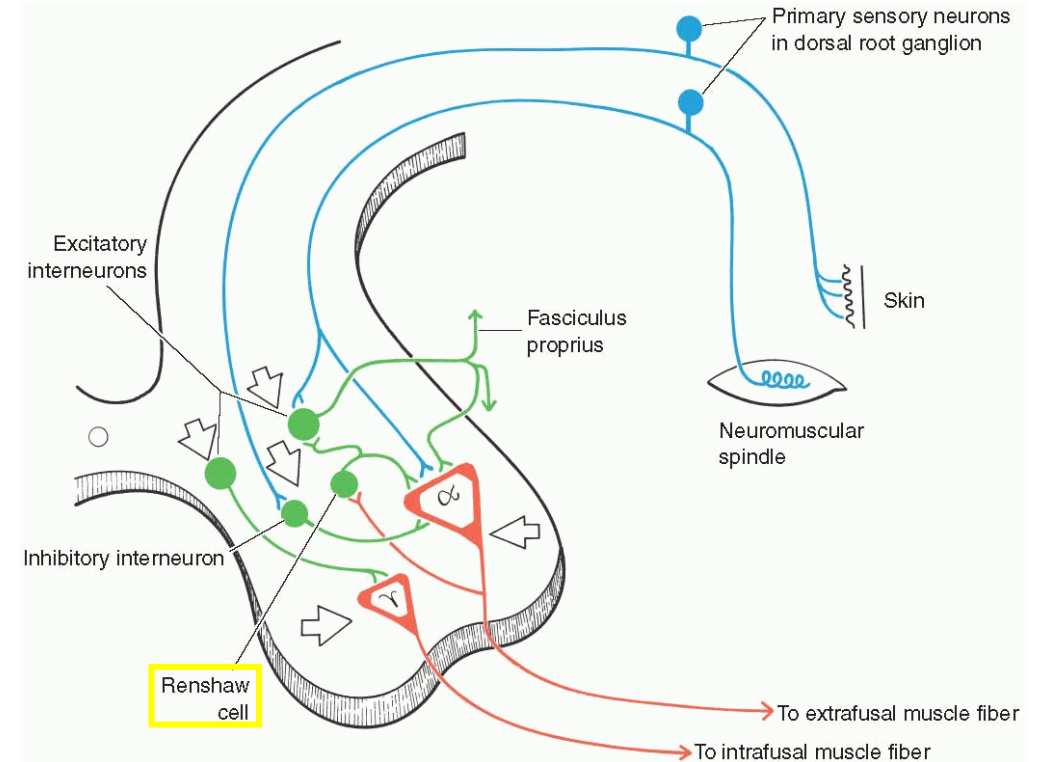
\*The doctor noted that we only required to know the location of each nucleus in previous slide in which lamina

- **Lamina I:**
  - o tip of the dorsal horn
  - o cells respond to noxious or thermal stimuli
  - o sends information to the brain by the contralateral spinothalamic tract
  - o corresponds to the marginal zone
- **Lamina II:**
  - o 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.
  - o Sends information to Lamina III and IV
  - o Corresponds to substantia gelatinosa.
- **Lamina III:**
  - o Involved in proprioception and sensation of light touch.
  - o Cells in this layer connects with cells in layers IV, V and VI.
  - o Partially corresponds to nucleus proprius
- **Lamina IV:**
  - o Involved in non-noxious sensory information relay and processing.
  - o Cells connect with those in lamina II
  - o Partially corresponds to nucleus proprius
- **Lamina V:**
  - o Relays sensory, including nociceptive (potentially painful), information to the brain via the contralateral and spinothalamic tracts
  - o Receives descending information from the brain via the corticospinal and rubrospinal tracts.
- **Lamina VI:**
  - o Contains many small interneurons involved in spinal reflexes
  - o Receives sensory information from muscle spindles (involved in proprioception).
  - o Sends information to the brain via ipsilateral spinocerebellar pathways
- **Lamina VII:**
  - o Large, heterogenous zone that varies through the length of the spinal cord.
  - o Receives information from Lamina II to VI, and from viscera
  - o Relays motor information to the viscera
  - o Gives rise to cells involved in the autonomic system.
  - o Dorsal nucleus of Clarke is part of Lamina VII
- **Lamina VIII:**
  - o Varies depending on spinal cord level, but is most prominent in cervical and lumbar enlargements.
  - o Cells are involved in modulating motor output to skeletal muscle.
- **Lamina IX:**
  - o Size and shape varies between spinal cord levels.
  - o Distinct groups of motor neurons that innervate skeletal muscle.
- **Lamina X:**
  - o Surrounds the central canal – the grey commissure.
  - o Axons decussate (cross over) from one side of the spinal cord to the other.

# Ventral Horn Nerve Cell Groups

The ventral horns contain:

1. **Motor neurons**, also called lower motor neurons (the upper motor neurons are in the brain).
2. **Interneurons**, the (Renshaw cells), whose branched axons form **inhibitory** synaptic junctions on motor neurons



# Ventral Horn

## 1. Motor Neurons

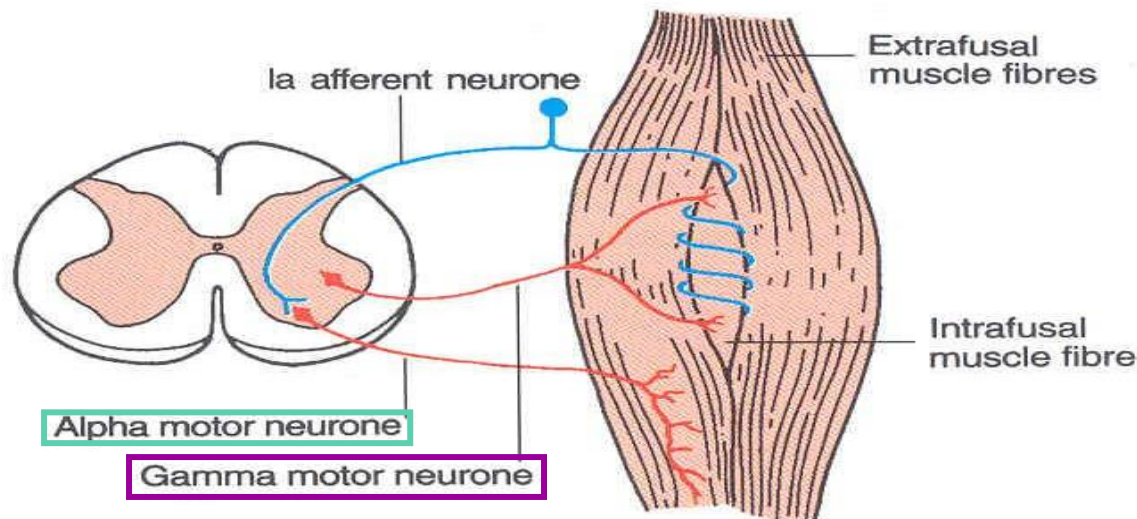
There are **two** types of **motor** neurons in ventral horn:

- **Large** multipolar cells

- **Numerous**
- Axons pass out in the ventral roots of spinal nerves as **alpha** efferents
- Innervate **extrafusal muscle fibers**

- **Smaller** multipolar cells

- **Less numerous**
- Axons pass out in the ventral roots of spinal nerves as **gamma** efferents
- Innervate **intrafusal muscle fibers** of neuromuscular spindles



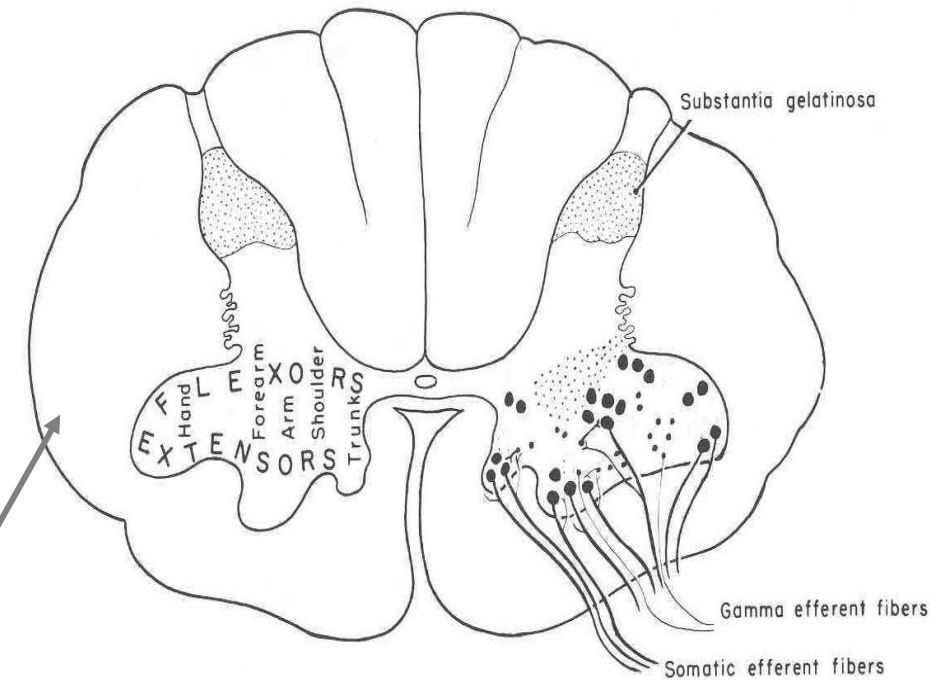
Both alpha and gamma motor neurons are under the influence of *descending pathways* (*upper motor neurons*) from brain.

# Ventral Horn

## 1. Motor Neurons

In the the ventral horn motor neurons are organized in **3 groups**:

Medial	Central	Lateral
present in <b>most segments</b>	present in some segments: <b>cervical</b> (phrenic C3-5, spinal accessory C1-6) and <b>lumbosacral (L2-S1)</b>	present in cervical and lumbosacral segments
Innervate muscles of <b>Neck and Trunk</b> (including intercostal and abdominal muscles)	smallest	innervates muscles of the <b>Limbs</b>



Neurons supplying **flexor** muscles are located **dorsal** to neurons for extensor muscles.

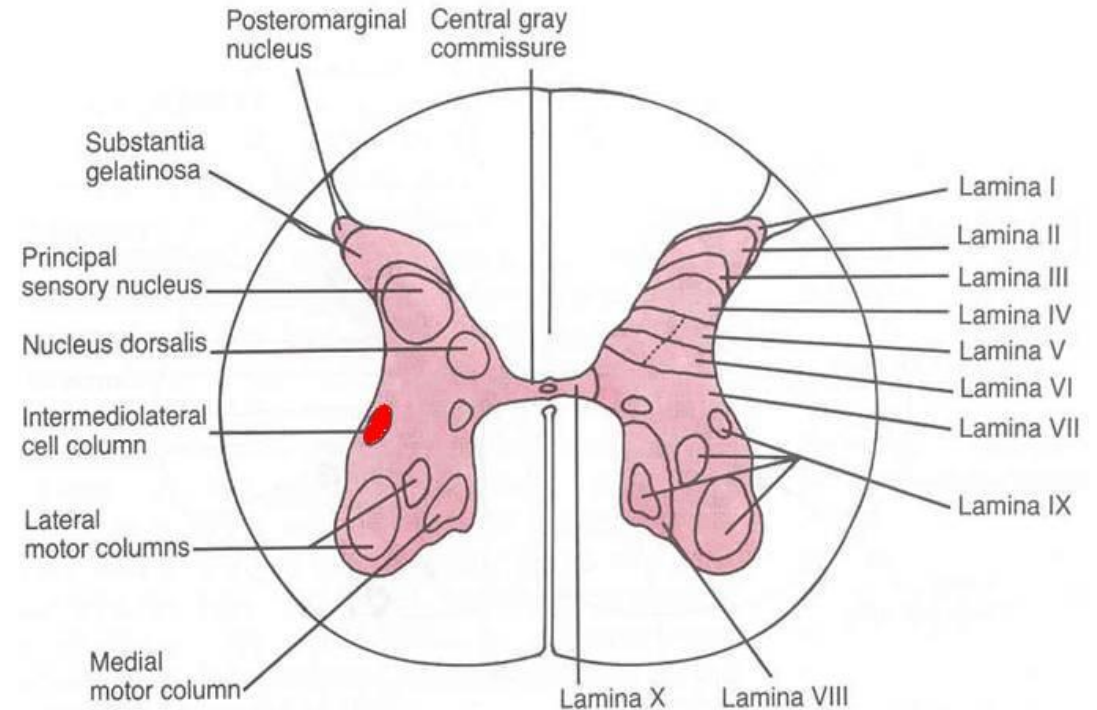
# Lateral Horn Nerve Cell Groups

Small column composed of small neurons extend from:

- **T1 to L2-3** segments, give rise to pre-ganglionic **sympathetic fibers** (thoracolumbar).
- **S2-4** segments, give rise to preganglionic **parasympathetic fibers** (craniosacral).

## Intermediolateral 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.



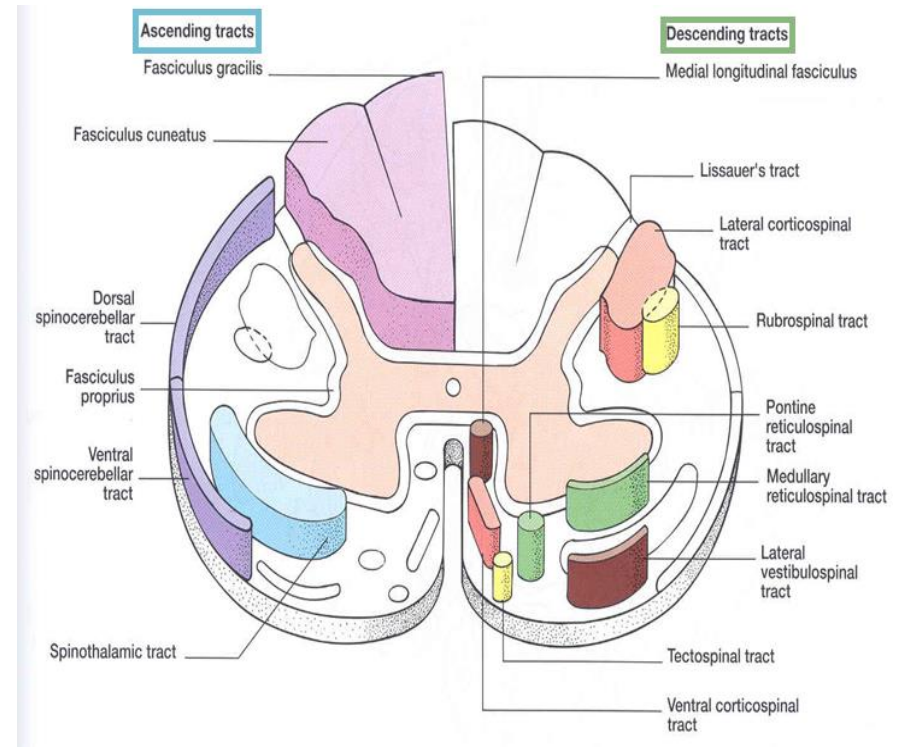


# White Matter



09:14

- Consists of mixture of nerve fibers, neuroglia and blood vessels.
- White color is due to high proportion of **myelinated nerve fibers**.
- 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 (1) sensory nerve fibers ascending to the brain, (2) motor nerve fibers descending from the brain and (3) fibers of connector neurons.
- Depending on their function, the spinal tracts are divided into **ascending** and **descending** tracts.
- Tracts are often named according to their points of **origin** and destination, e.g. spinothalamic, corticospinal.



Funiculi: a bodily structure suggesting a cord; especially : a bundle of nerve fibers

Fasciculus: a small or slender bundle (as of nerve fibers)



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;

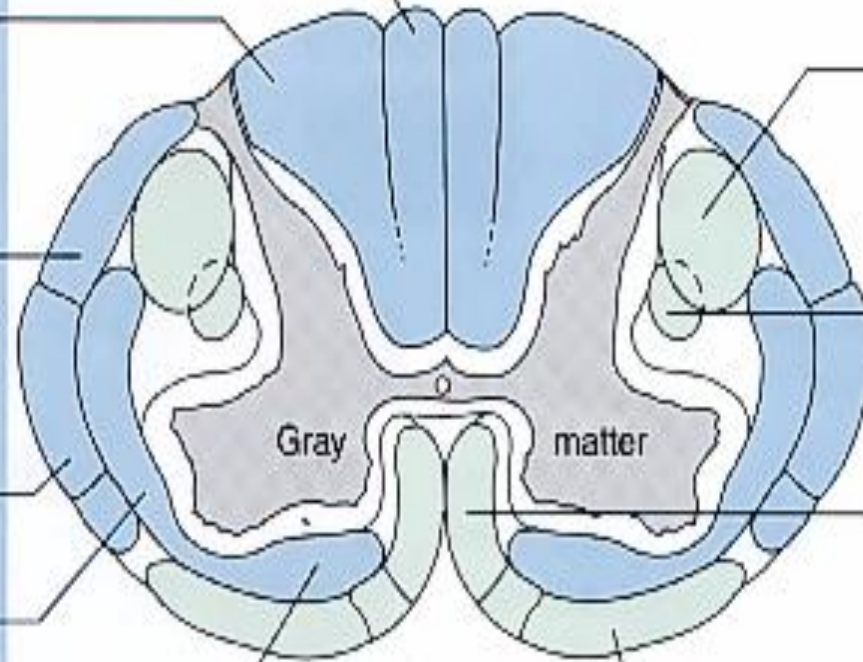
unconscious muscle sense)

**Lateral spinothalamic** (crossed;

pain and temperature)

**Ventral spinothalamic** (crossed;

touch)



**Lateral corticospinal** (crossed; voluntary control of skeletal muscles)

**Rubrospinal** (crossed; involuntary control of skeletal muscle concerned with muscle tone and posture)

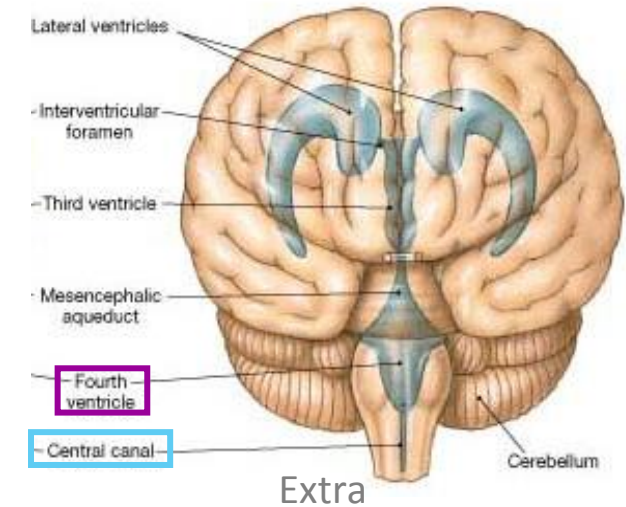
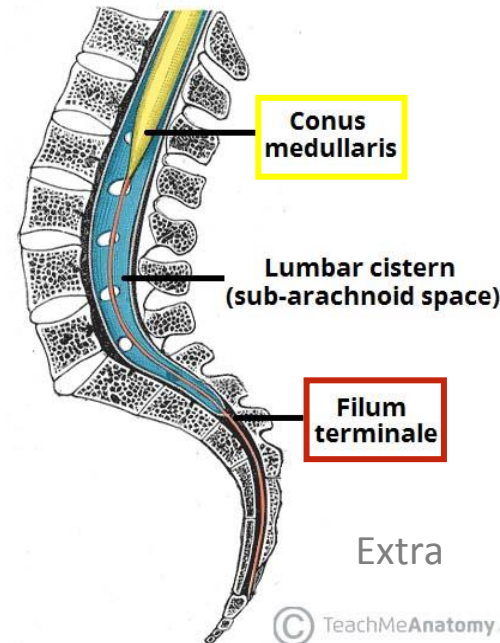
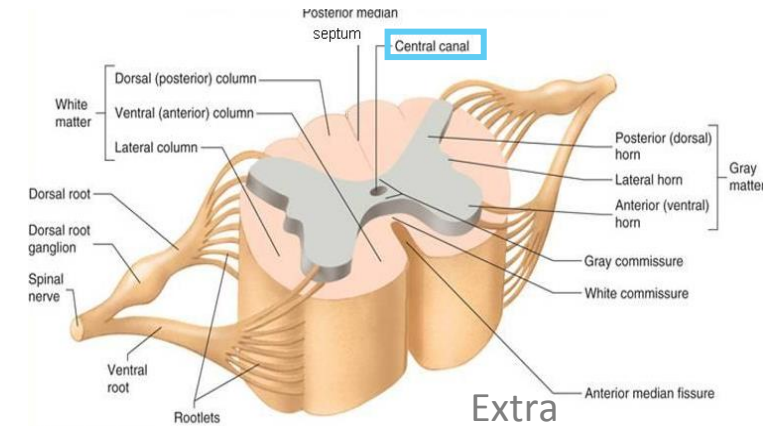
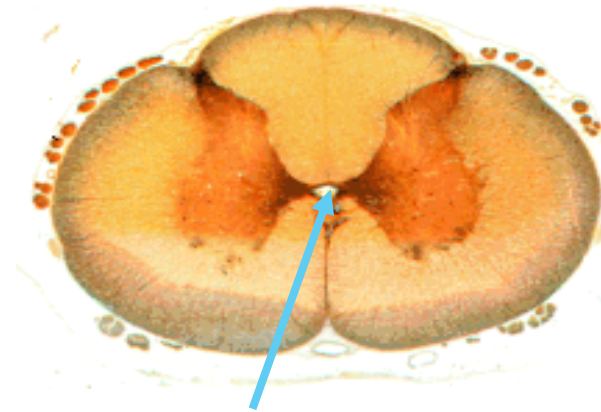
**Ventral corticospinal** (uncrossed down spinal cord; crosses at level of termination in spinal cord; voluntary control of skeletal muscles)

**Vestibulospinal** (uncrossed; involuntary control of muscle tone to maintain balance and equilibrium)

Ventral surface  
**(a)**

# Central Canal

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



# Spinal Cord Commissures

## Grey commissure:

- A 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:

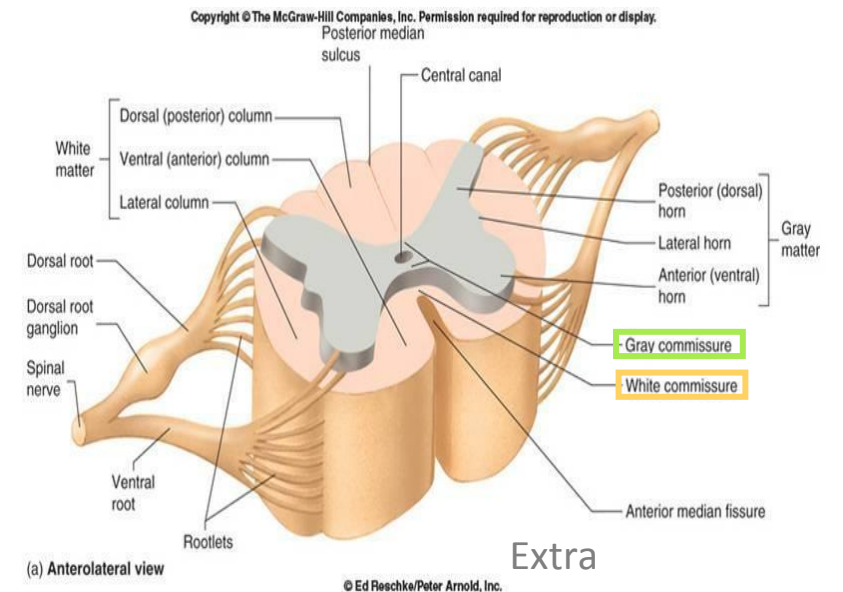
- Lies ventral (anterior) to the gray commissure
- Mainly contains decussating\* nerve fibers

\*decussating: (متقاطع) cross or intersect each other to form an X



White commissure

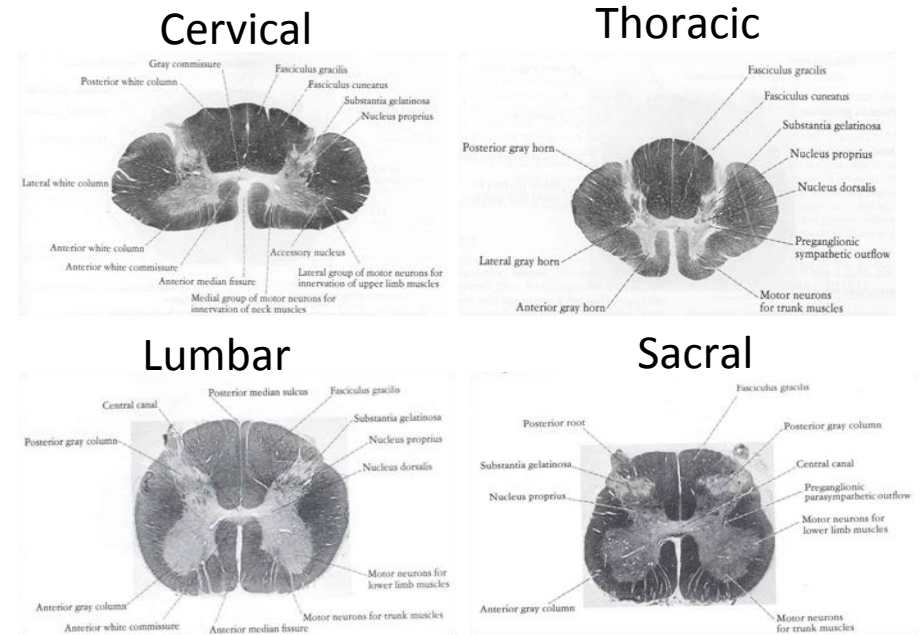
Grey commissure



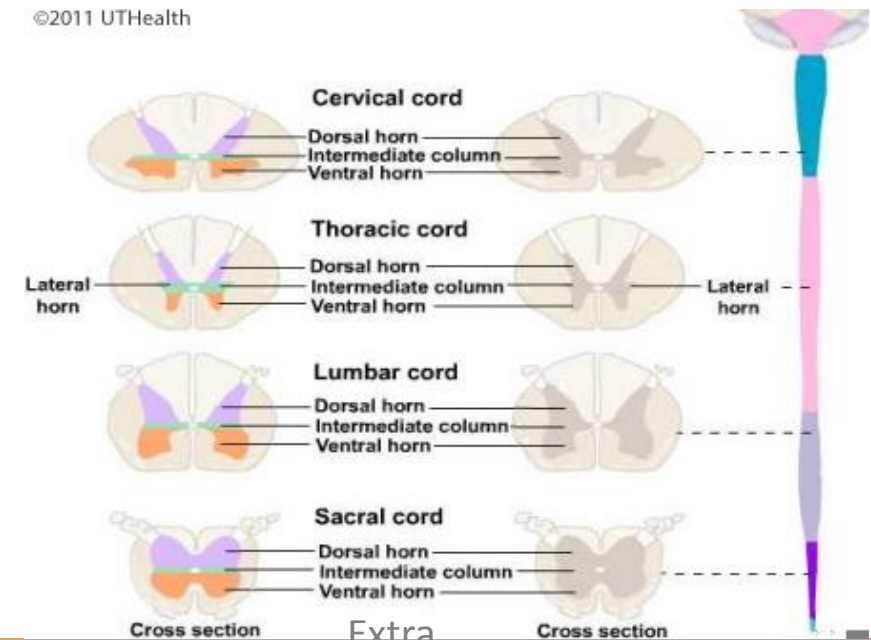
# Spinal Cord

## 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
- The **gray matter** is increased in volume in cervical & lumbosacral enlargements for innervation of upper & lower limbs
- The **lateral horn** is characteristics of thoracic and upper lumbar segments



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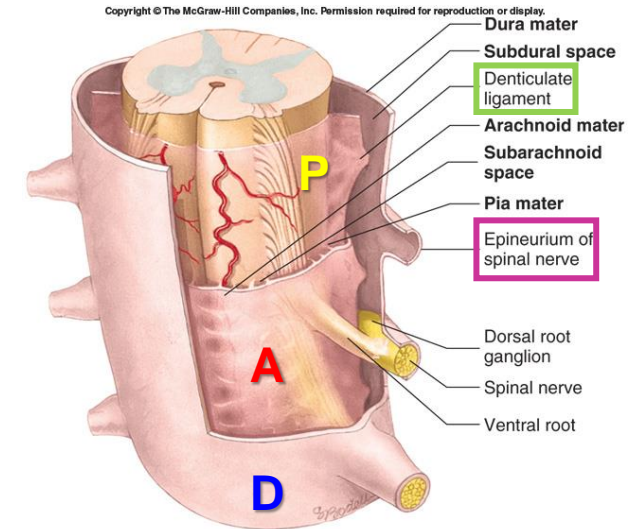
Extra

# Spinal Meninges



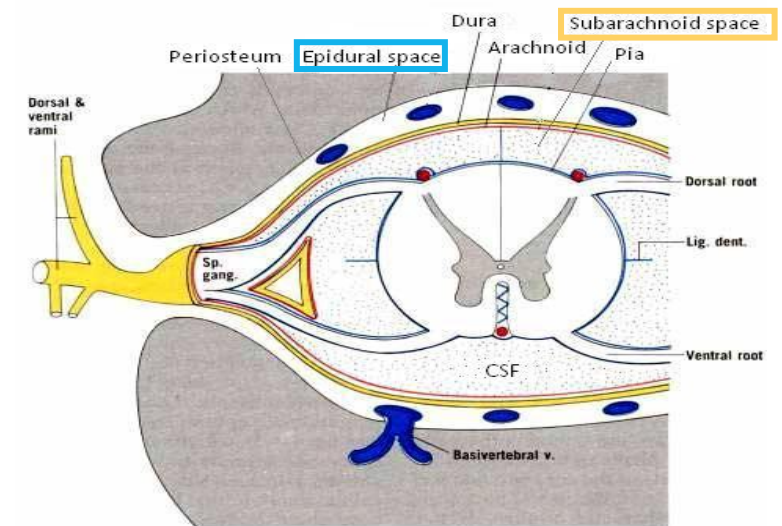
07:07

- Three connective tissue membranes\* surround spinal cord and brain:
  - **Dura mater**: tough outer layer, continuous with epineurium of the spinal nerves
  - **Arachnoid mater**: thin and wispy membrane deeper to dura mater
  - **Pia mater**: delicate membrane bound tightly to surface of brain and spinal cord and carries blood vessels. 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, areolar connective tissue and fat. (between dura and bone: skull/vertebra)
  - **Subdural**: a potential cavity between the dura and arachnoid mater, contains a small volume of serous fluid.
  - **Subarachnoid**: Contains cerebrospinal fluid (CSF) and blood vessels within web-like strands of arachnoid tissue. (between arachnoid and pia mater) CSF can be collected from this space for diagnostic purposes.



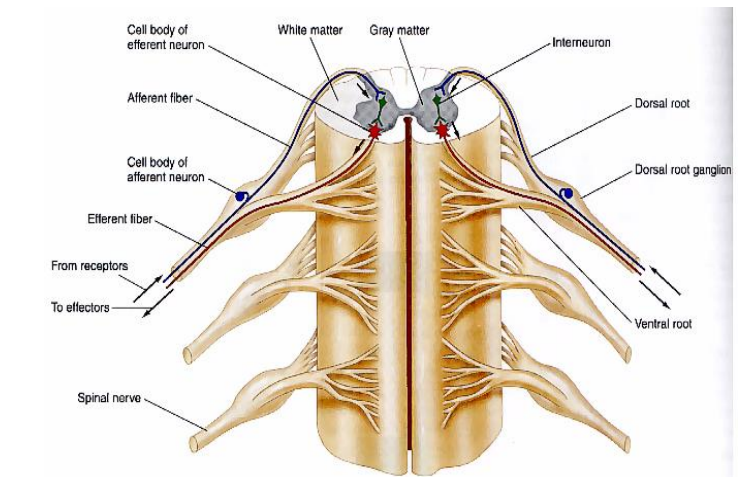
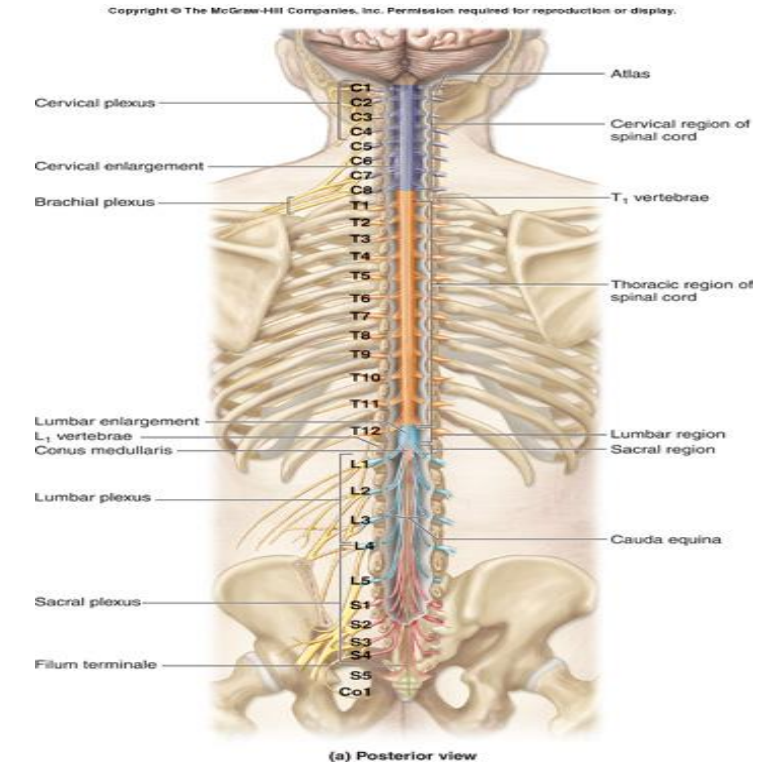
(a) Anterolateral view

Dura → Outside  
 Pia → Iinside



# Spinal Nerves

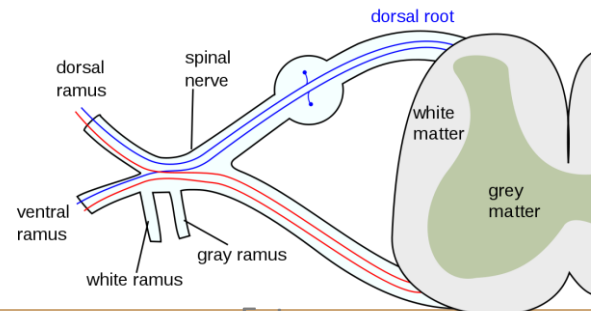
- **Thirty-one pairs** of spinal nerves.
- First pair exit vertebral column between skull and atlas, last four pair exit via the sacral foramina and others exit through intervertebral foramina
- **Eight pair cervical, twelve pair thoracic, five pair lumbar, five pair sacral, one pair coccygeal**
- Each spinal nerve arises as rootlets which then combine to form dorsal (posterior) **purely sensory** & ventral (anterior) **purely motor 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 **MIXED smaller dorsal** and a **larger ventral Ramus**



Rootlet → Root → Spinal Nerve → Rami

Dorsal		Ventral	
Purely	Purely	Purely	Purely
Sensory	Sensory	Motor	Motor

Dorsal		Ventral	
Mixed			



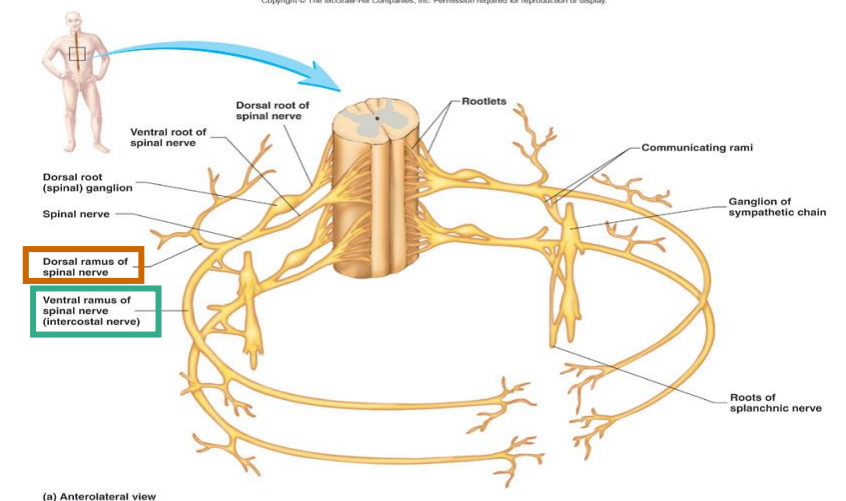
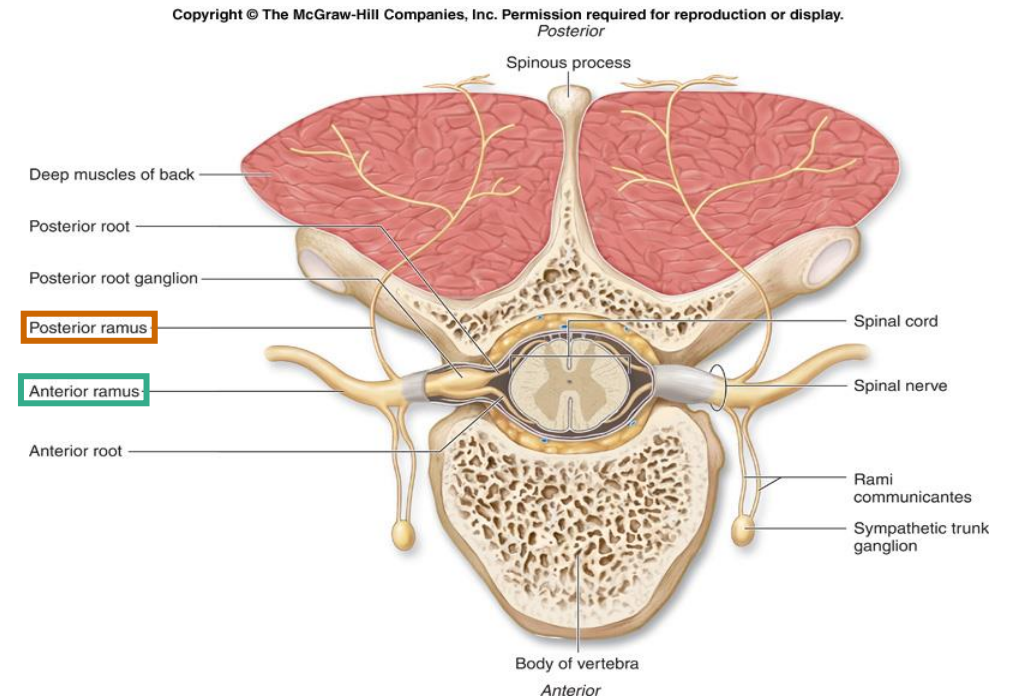
Extra ventral root

# Spinal Nerves Branches

Ventral = Anterior  
Dorsal = Posterior

- **Dorsal Rami** innervate:
  - Deep muscles of the trunk responsible for movements of the vertebral column
  - Skin near the midline of the back.
- **Ventral Rami**:
  - In the thoracic region form **intercostal nerves** that innervate the intercostal muscles and the skin over the thorax
  - Remaining ventral rami form **five plexuses** \*: (intermingling of nerves)
    - C1 - C4= **Cervical plexus**
    - C5 - T1= **Brachial plexus**
    - L1 - L4= **Lumbar plexus**
    - L4 - S4= **Sacral plexus**
    - S5 & Co= **Coccygeal plexus**\*\*

*\*see the next slide*

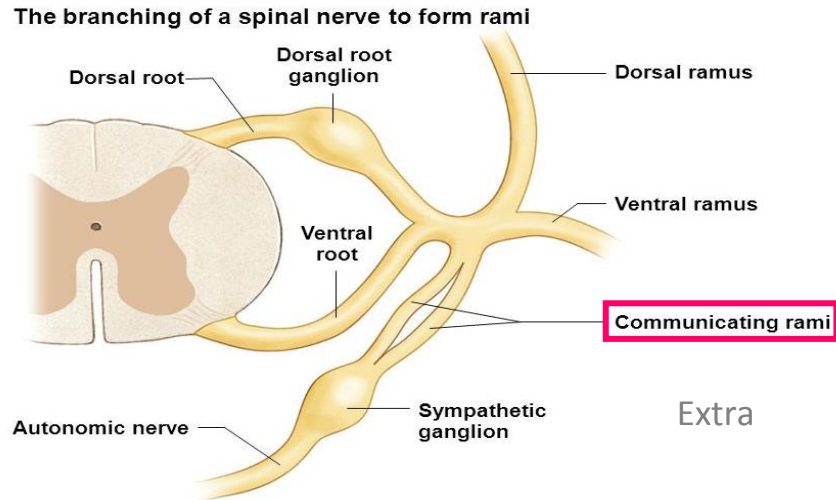


(a) Anterolateral view

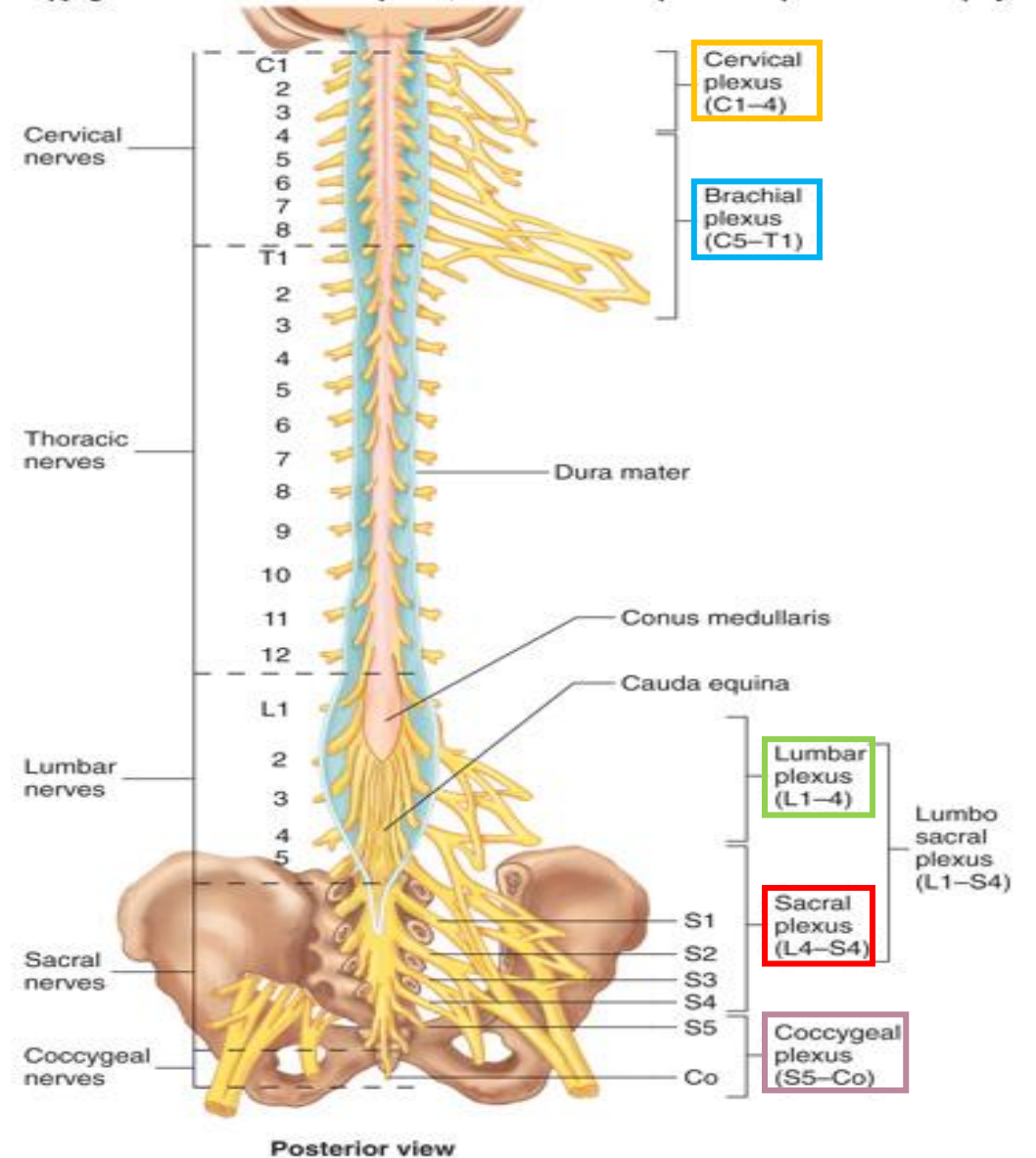


# Spinal Nerves Branches

The spinal nerves are connected to sympathetic chain of ganglia by communicating rami.

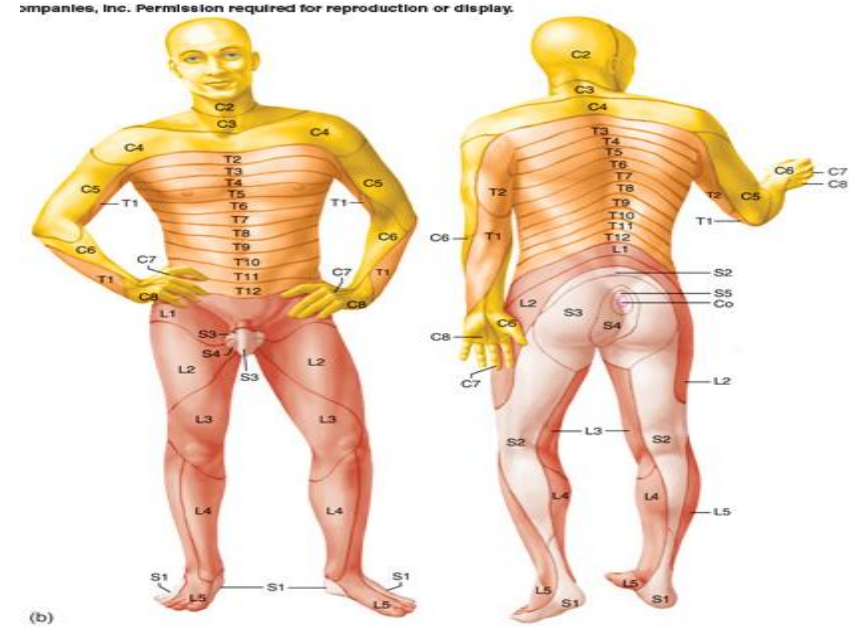


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# Dermatomes

- 'Dermatome' is a **segment** of skin supplied by a specific segment of the spinal cord (**segmental spinal nerve**), i.e, one nerve.
- Cutaneous areas supplied by adjacent spinal nerves overlap. There is therefore little or no sensory loss after interruption of a single spinal nerve or dorsal root

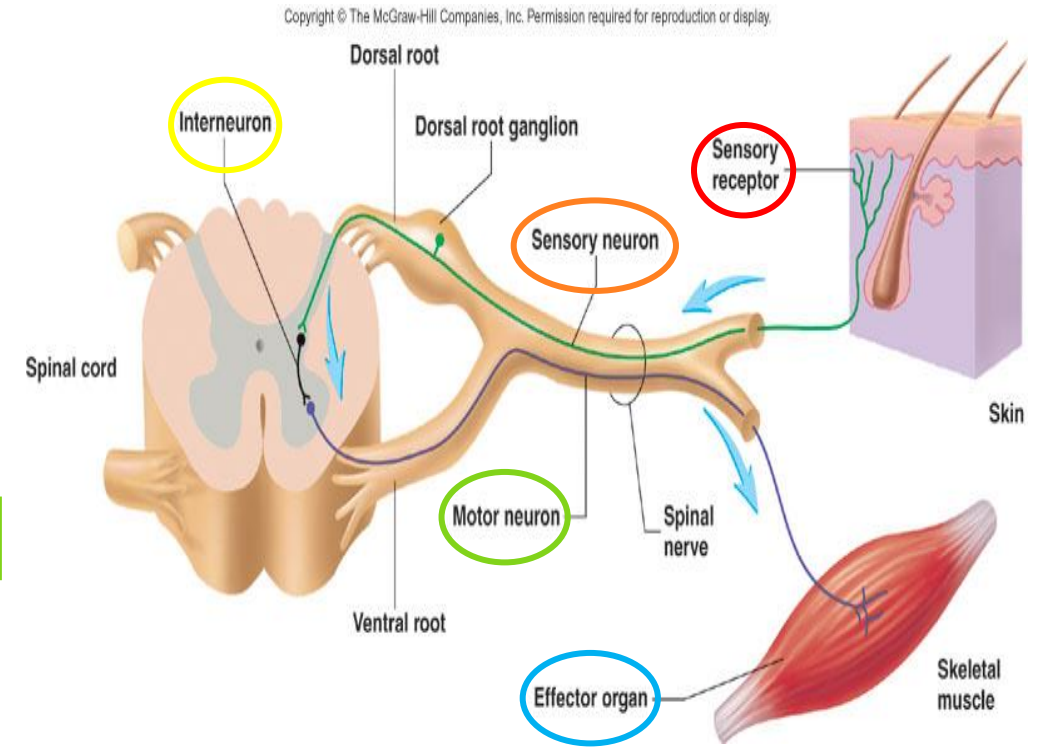
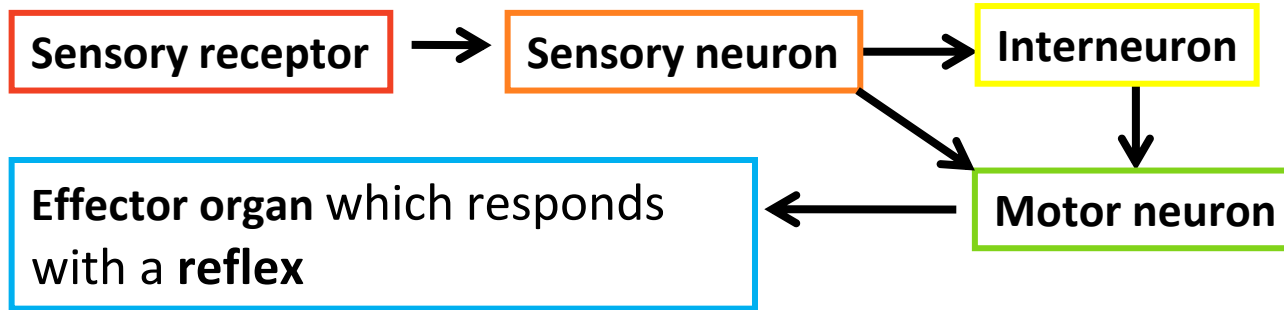


## Reflex & Reflex Arc

- A reflex is a rapid, involuntary, predictable, stereotyped pattern of response brought by a **sensory stimulus**.
- The neural pathway mediating the reflex actions is called **reflex arc**.

# Components of a Reflex Arc

Action potentials produced in



## Variety of Reflexes

*Only on the girls' slides*

- Some integrated within spinal cord; some within brain
- Some involve excitatory neurons yielding a response; some involve inhibitory neurons that prevent an action
- Higher brain centers can influence, suppress, or exaggerate reflex responses

# 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.



# MCQs

1. The tapered inferior end of the spinal cord forms:

- A- filum terminale
- B- conus medullaris
- C- cauda equina
- D- denticulate ligaments

Answer: B

2. Filum terminale is formed from:

- A- dura mater
- B- arachnoid mater
- C- pia mater
- D- spinal nerves

Answer: C

3. If a cross section of the spinal cord is taken from C8 which of the following nerve cell group will be missing?

- A- Substantia gelatinosa
- B- Nucleus proprius
- C- Nucleus dorsalis
- D- Visceral afferent nucleus

Answer: D

4. Renshaw cells are present in which horn?

- A- Lateral
- B- Ventral
- C- Dorsal

Answer: B

5. Dorsal root fibers concerned with information from muscle spindles are found in which laminae?

- A- II
- B- IV
- C- VI
- D- VII

Answer: D

6. In which segment of the spinal chord can we find lateral horn:

- A- cervical
- B- thoracic
- C- coccygeal

Answer: B

7. A plexus is made of:

- A- dorsal root
- B- dorsal rami
- C- ventral root
- D- ventral rami

Answer: D

8. Which of the following is continuous with epineurium of the spinal nerves?

- A- dura mater
- B- arachnoid mater
- C- pia mater

Answer: A

# MCQs

9. : the **Brachial** plexus is from ... to ... :

A- C1-C4

B- C5-T1

C- L5-Co

D- S4-L5

Answer: B

10. The spinal cord has:

A- 30 pairs of spinal nerves

B- 30 spinal nerves

C- 31 pairs of spinal nerves

D- 31 spinal nerves

Answer: C

# SAQ

**Q1: Mention the location of Nucleus Dorsalis in the spinal cord ?**

**Answer:**

from **C8** to **L3-4** segments in the base of the dorsal horn.

**Q2: Define Reflex Arc .**

**Answer:**

It's is a rapid, involuntary, predictable, stereotyped pattern of response brought by a **sensory stimulus**.



Good luck  
Special thank for team436 ❤️

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- References:
  1. Girls' & Boys' Slides
  2. Greys Anatomy for Students
  3. TeachMeAnatomy.com

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