



**Anatomy Team**  
**MED 439**

Revised & Approved



**MED439**  
KING SAUD UNIVERSITY

# Anatomy of the Spinal Cord

CNS Block

Don't forget to check the [Editing File](#)

Color index:

Content  
Male slides  
Female slides  
Important  
Doctors notes

Extra information, explanation

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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.

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
- It is elongated, cylindrical, it is suspended in the **vertebral canal** and protected by vertebrae
- Surrounded by the **meninges** and **cerebrospinal fluid** (CSF)
- In adults, its length is approximately 45cm

## Function & protection

- The primary function of spinal cord is a transmission of neural signals between the brain and the (PNS) then to the rest of the body by:
  1. Sensory
  2. Motor
  3. Local reflexes

**Note:** One of the characteristics of the spinal cord is the "local reflex mechanism" which enables it to make "decisions" without the intervention of higher centers.

## Features

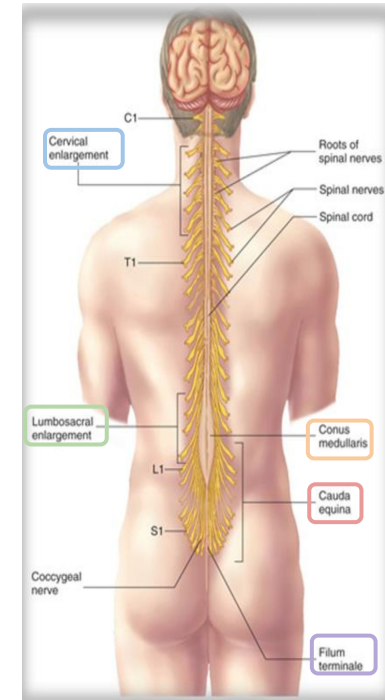
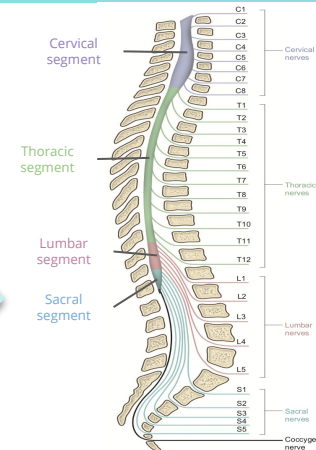
- Gives rise to 31 pair of spinal nerves:
  - 8 Cervical, 12 thoracic, 5 Lumbar, 5 Sacral, 1 coccygeal
  - **Spinal cord has two enlargements:**
    1. **Cervical enlargement:** supplies upper limbs.
    2. **Lumbosacral enlargement:** supplies lower limbs.

**Note:** we have these enlargements to satisfy the huge needs in the upper and lower limbs.

End of spinal cord : **conus medullaris**.  
End of spinal nerves : **cauda equina**

## Shape & Pathway

- extends from foramen magnum to 2nd lumbar (L1-L2) vertebra. (In children it extends to L3).
- 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**.
- The bundle of spinal nerves extending inferiorly from lumbosacral enlargement and conus medullaris surround the filum terminale and form **cauda equina**.



# Cross section of the spinal cord

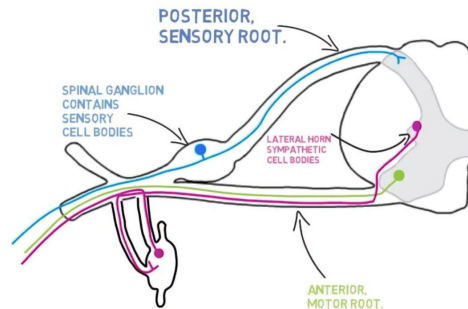
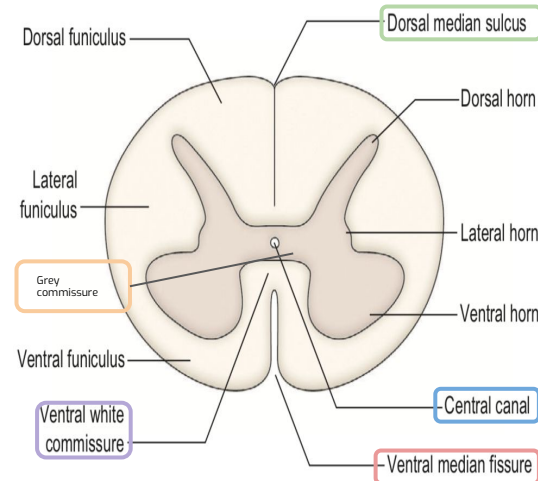
- The spinal cord is Incompletely divided into two equal parts:
- Anteriorly by a short, shallow **median fissure**. (Deeper)
- Posteriorly by a deep narrow septum, the **posterior median septum./ posterior median sulcus** (Thinner than the fissure)
- Composed of grey matter in the centre surrounded by white matter (unlike the brain), and supported by neuroglia.

1

## Central canal

3

- A cerebrospinal-filled space that runs longitudinally through the entire length of the spinal cord.
- Lined by **ependymal** (ciliated columnar epithelium) **Note: the ependymal lining increases CSF's motility**
- 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**.



## Roots

Spinal nerves arise rootlets then combine to form roots.

- Dorsal ( posterior ) root has a ganglion
- Ventral ( anterior )
- Two roots merge laterally

2

## Commissures:

Connections between left and right halves.

### Grey commissure:

1. A Transverse bridge of grey matter connecting the anterior and posterior gray horns on each side
2. Is pierced by the **central canal** that divides it into anterior and posterior part.

### White commissure:

1. Lies ventral to the gray commissure.
2. Mainly contains **decussating nerve fibers**.

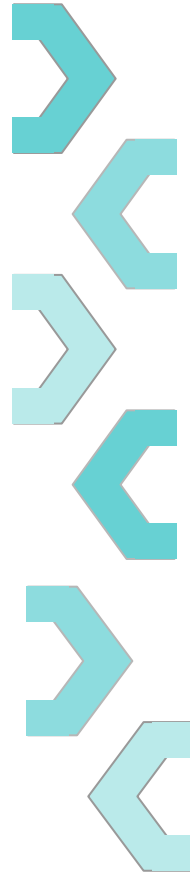
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# Neuronal architecture of spinal grey matter (Rexed laminae)

In transverse section, these columns appear as layers, especially within the dorsal horn

It is an **alternative** to spinal cord nuclei where cells were grouped according to their structure and function, rather than solely on location.

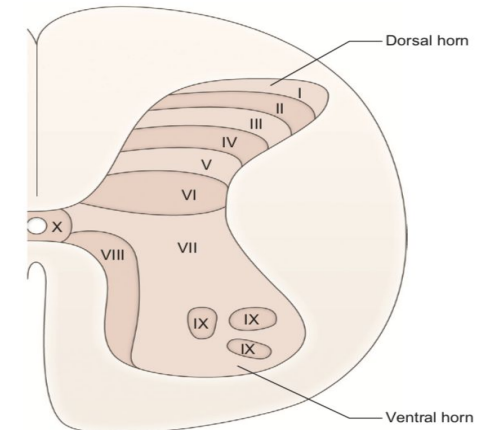
Identified in the early 1950s by Swedish neuroscientist.



Cells of the same type are clustered into groups, which occur in **long columns**.

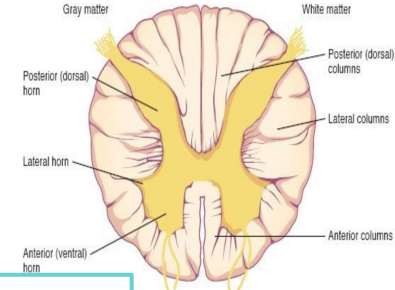
These layers are called the **laminae of Rexed** that are numbered by Roman numerals, starting from the tip of the dorsal horn and moving ventrally into the ventral horn.

The rexed laminae comprise a system of ten layers of grey matter (I-X)



# Grey matter

- The arrangement of grey matter resembles the shape of letter **H**.
- Having: 2 posterior horns, 2 anterior horns and two lateral horns/columns
- Consists of : **nerve cell bodies** and their processes , neuroglia , and blood vessels.



## Nerve cells are multipolar. They have 3 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, are located in the **Dorsal horns**.

**Lower motor neurons:** transmit impulses to the skeletal muscles. Its located in the ventral horn  
**Note:** 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.(local reflex)

## Arrangement of the nerve cell group

Some involve excitatory neurons yielding a response; some involve inhibitory neurons that prevent an action

### Dorsal horn

1. **Marginal zone (laminae I)**
2. **Substantia Gelatinosa (laminae II)**
3. **Nucleus Proprius (laminae IV)**
4. **Nucleus dorsalis( Clarke's column, nucleus thoracis) (laminae VII)**
5. **Visceral afferent nucleus** (lateral to the nucleus dorsalis and composed mostly of medium sized neurons). Extends from T1-L3

### Ventral horn

1. Motor neurons, also called lower motor neurons (**laminae VIII & IX**)
2. Interneurons, the Renshaw cells, whose branched axons form inhibitory synaptic junctions on motor neurons.

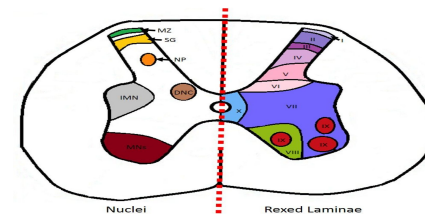
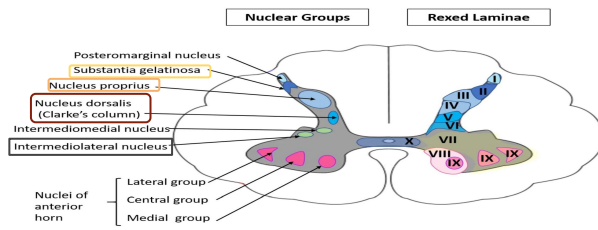
### Lateral horn

- Small column composed of small neurons extend from:
  1. **T1 - L2,3 segments:** give rise to preganglionic sympathetic fibers.
  2. **S2 - S4 segments:** give rise to preganglionic parasympathetic fibers.
- **Intermediolateral nucleus:** Located in the intermediate column & lateral horn. Relays sensory information from the visceral organs to the brain, and autonomic signals from the brain to the visceral organs. (**laminae VII**)

# Spinal cord nuclei

The prominent nuclei (groups of neuron cell bodies) in the spinal cord are the following:

Name	Location	Function and features
<b>Marginal zone (MZ)</b> <small>*Male slides only</small>	At the tip of the dorsal horn (Laminae I)	Important for relaying <b>pain and temperature</b> sensation to the brain.
<b>Substantia gelatinosa (SG)</b>	At the apex of the dorsal horn (Laminae II)	It is important for relaying <b>pain, temperature and light touch sensation</b> to the brain. It is composed of large neurons and <b>found throughout the length of spinal cord.</b>
<b>Nucleus proprius (NP)</b>	In the neck of the dorsal horn (anterior to Substantia gelatinosa) (Laminae IV) in male slides (Laminae III) in female slides	Concerned with <b>senses of position &amp; movement &amp; 1/2 of crude touch</b> . Also composed of large neurons and <b>found throughout the length of spinal cord</b>
<b>Dorsal nucleus of Clarke (Nucleus Dorsalis)</b>  <small>*Male slides only</small>	Most dorso-medial nuclei (Laminae VII)	Dorsal root fibers concerned with information from muscle spindles and tendon organs) (relays unconscious proprioceptive information to the brain). Only found in spinal segments <b>C8 to L3.</b>
<b>Intermediolateral nucleus</b>  <small>*Male slides only</small>	Located in the intermediate column and lateral horn, (Laminae VII)	Relays sensory information from viscera to the brain, and autonomic signals from the brain to the visceral organs.
<b>Lateral motor neurons and medial motor neurons</b>  <small>*Girls slides only</small>	Ventral horn (Laminae VIII & IX)	Composed of motor neurons that innervate visceral and skeletal muscle
<b>Visceral afferent nucleus</b>	Located lateral to nucleus dorsalis (Laminae VII)	Composed mostly of medium sized neurons. Extends from T1 - L3 segments. Afferents: Visceral afferents



# Nerve Cell Groups in Ventral & Lateral Horns

## Ventral Horn

A. **Motor neurons** also called "lower motor neurons". It has two types:

1- Large multipolar cells: Numerous, Axons pass out in the ventral roots of spinal nerves as **alpha** efferents and **Innervate extrafusal muscle** fibers.

2- Smaller multipolar cells: Less numerous, Axons pass out in the ventral roots of spinal nerves as **gamma** efferents and **Innervate intrafusal muscle** fibers of neuromuscular spindles \*Girls slides only

B. **Interneurons: "Renshaw cells"** whose branched axons form **Inhibitory** synaptic junctions on motor neurons. **Used in spinal reflex**

C. **Excitatory interneurons**

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

A. Motor neurons are organized in 3 groups:

**1- Medial:** present in most segments Innervate muscles of Neck and Trunk (including intercostal and abdominal muscles)

**2- Central:** smallest, present in some segments: cervical (phrenic C3-5, spinal accessory C1-6) and lumbosacral (L2-S1)

**3- Lateral:** present in cervical and lumbosacral segments innervates muscles of the Limbs

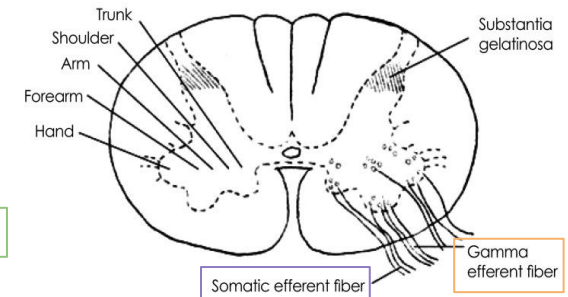
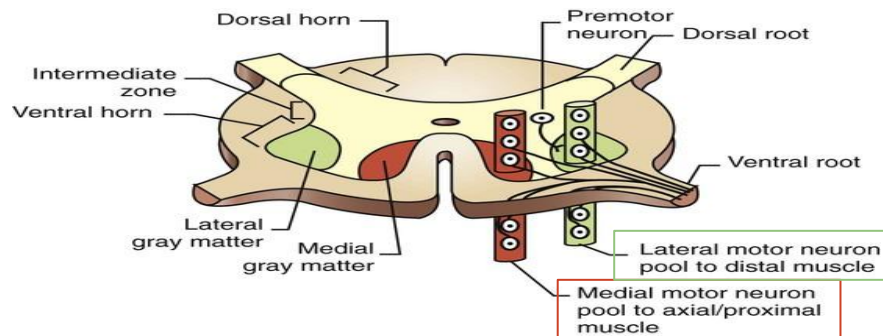
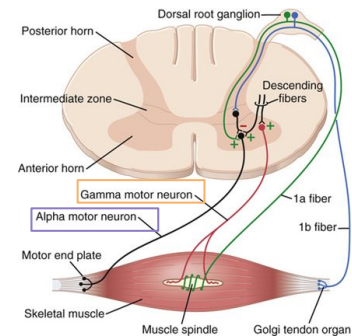
## Lateral Horn

A. Small column composed of small neurons extend from:

B. **T1 to L2-3** segments, give rise to preganglionic **Sympathetic fibers**  
(Thoracolumbar outflow)

C. **S2-4** segments, give rise to preganglionic **Parasympathetic**  
(cranial nerve nuclei & cells of the lateral horn of the spinal cord)

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





# White matter

01

Consists of mixture of nerve fibers, neuroglia and blood vessels. White color is due to high proportion of myelinated nerve fibers. (Has no cell bodies)

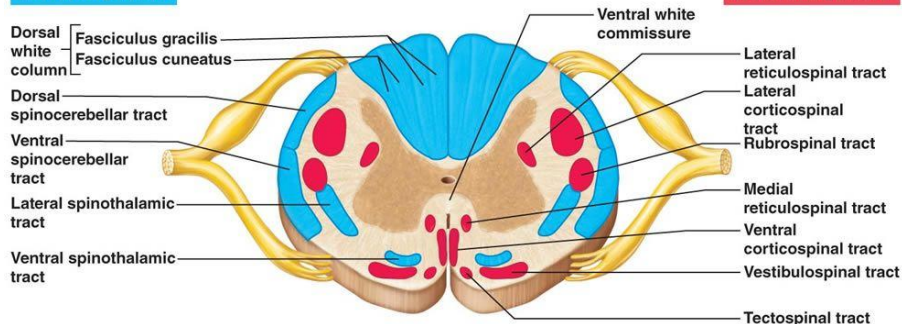
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Arranged in columns/funiculi; anterior, posterior and lateral.

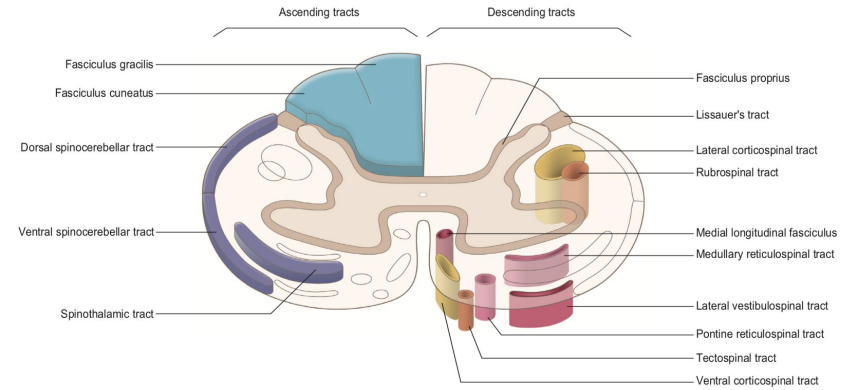
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The nerve fibers are arranged as bundles, running vertically through the cord. A group of nerve fibers (axons) that share a common **origin**, **termination** and **function** form a tract or fasciculus

Ascending tracts



Descending tracts



04

Tracts are often named according to their points of origin and destination, e.g. spinothalamic, corticospinal.

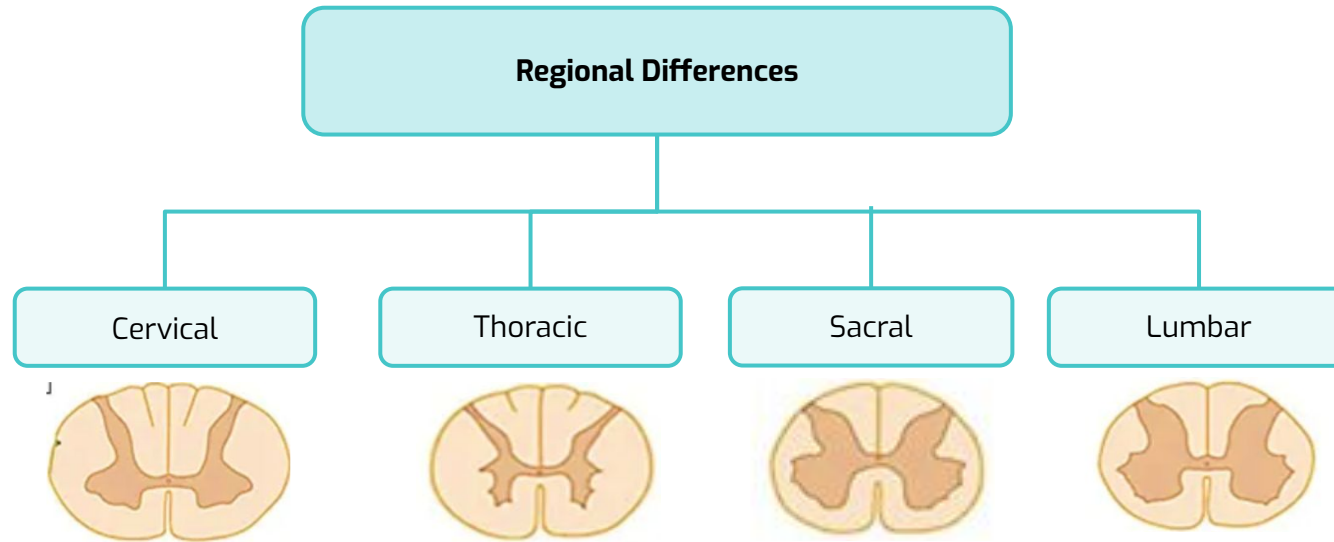
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Depending on their function, the spinal tracts are divided into Ascending and Descending tracts

06

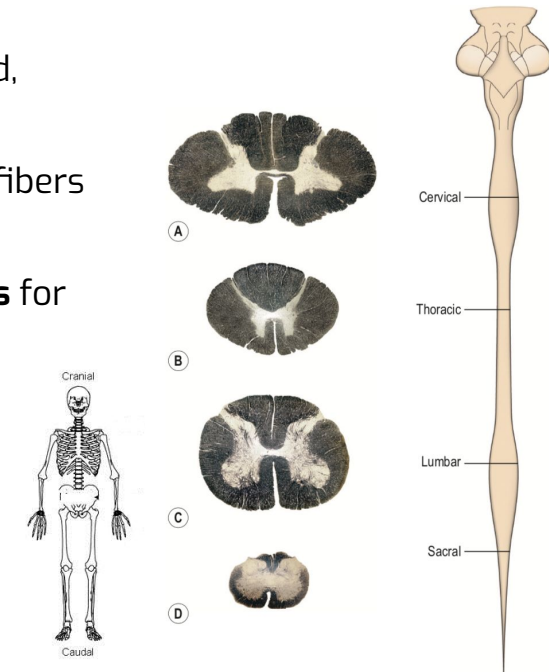
These tracts are formed by sensory nerve fibers ascending to the brain, motor nerve fibers descending from the brain and fibers of connector neurons.

# White matter cont.



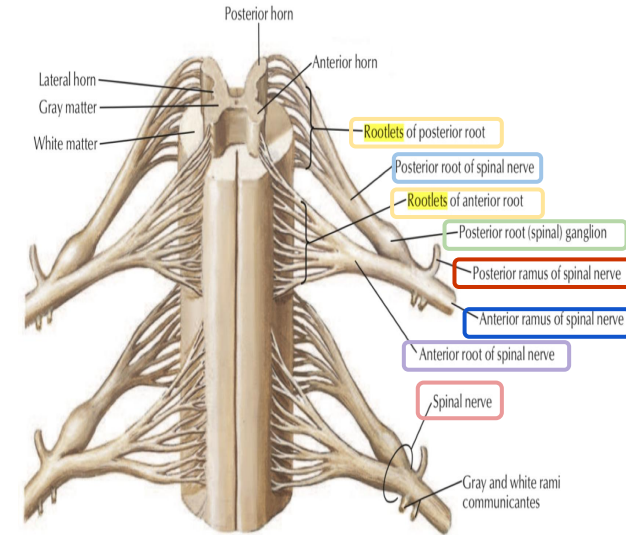
- ❖ Although the general pattern of gray matter is the same throughout spinal cord, regional differences are apparent in transverse sections
- ❖ The **amount of white matter** increases in a caudal-to-cranial direction because fibers are added to ascending tracts (going up)
- ❖ The **gray matter** is increased in volume in **cervical & lumbosacral enlargements** for innervation of upper & lower limbs
- ❖ The **lateral horn** is characteristics of **thoracic and upper lumbar segment**.
- ❖ **In the lateral horn we can find the cell bodies of preganglionic sympathetic motor neurons.**

كأنه مصعد في عمارة كل ما طلعت فوق زاد عدد الركاب (signals)، عشان كذا نحتاج وايت ماتر أكثر كل ما طلعتنا فوق



# 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 pairs cervical, twelve pairs thoracic, five pairs lumbar, five pairs sacral and one pair coccygeal**
- Each **spinal nerve** arises as **rootlets** which then combine to form **dorsal (posterior) purely sensory root** & **ventral (anterior) purely motor Root**.
- 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 ramus** and a **larger ventral Ramus**



## Branches of spinal nerve:

<p><b>Dorsal Rami</b></p>	<p>Innervate: <b>Deep muscles</b> of the trunk responsible for movements of the vertebral column, Skin near the midline of the back.</p> <p><b>Note: the dorsal ramus is slightly smaller compared the ventral. Why? Due to the small number of muscles which are located in the back thus less supply is needed compared to the ventral.</b></p>	
<p><b>Ventral Rami</b></p>	<p>In the thoracic region form <b>Intercostal nerves</b> that innervate the intercostal muscles and the skin over the thorax. <b>What they innervate depends upon which part of spinal cord is considered</b></p> <p>Remaining ventral rami form <b>five plexuses:</b></p> <ul style="list-style-type: none"> <li>• C1 - C4: <b>Cervical</b> plexus</li> <li>• C5 - T1: <b>Brachial</b> plexus. <b>Note: supply muscles of the upper limb</b></li> <li>• L1 - L4: <b>Lumbar</b> plexus. <b>Note: supply muscles of the lower limb</b></li> <li>• L4 - S4: <b>Sacral</b> plexus</li> <li>• S5 &amp; Co: <b>Coccygeal</b> plexus</li> </ul>	
<p><b>communicating rami</b></p>	<p>The <b>spinal nerves</b> are connected to <b>sympathetic chain of ganglia</b> by <b>communicating rami</b></p>	

# Reflex and Reflex Arc

## Reflex & Reflex Arc

A reflex is a rapid, involuntary, predictable response brought by a **sensory stimulus**

The neural pathway mediating the reflex actions is called **reflex arc**.

Starting from here...in girls slides only

### Components of a Reflex Arc

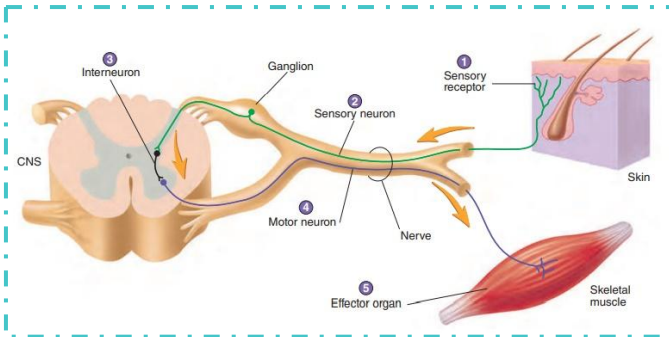
Action potential produced in sensory receptor then go to sensory neuron will go to interneuron or to motor neuron → Effector organ which responds with a reflex

### Variety of Reflexes

Some integrated within spinal cord; some within brain

Some involve excitatory neurons yielding a response; some involve inhibitory neurons that prevent an action

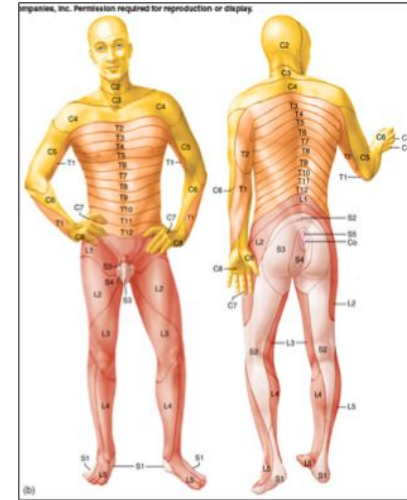
Higher brain centers can influence, suppress, or exaggerate reflex responses



# Dermatome

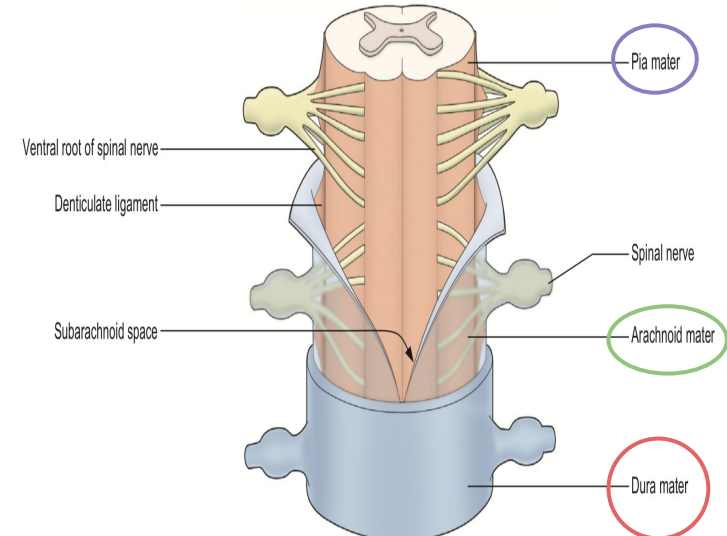
**Dermatome** is a **segment** of skin supplied by a (**spinal nerve**) specific segment of the spinal cord (**segmental spinal nerve**)

- 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
- Each of these spinal nerves relay sensation from a particular region of skin to the brain.
- The nerves from the upper cervical spine supply the skin of the neck.  
**C5 to T1** nerves supply the **arms**.  
**T2 to L2** nerves supply the **chest and abdomen**.  
**L3 to S1** nerves supply the **skin of the legs**.
- **S1-C1** nerves go to the **groin**.
- Testing of dermatomes is part of the neurological examination looking for sensation changes within a specific dermatome that may help in determining the pathological disc level.



# 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.
- ( note: the boy's doctor hinted about this part to be potential SAQ or MCQ questions )



# Spinal Nerve Injury

**The spinal cord injury** is the damage to the spinal cord that causes temporary or permanent changes in the functions.

**Symptoms** may include loss of muscle function, sensation, or autonomic function.

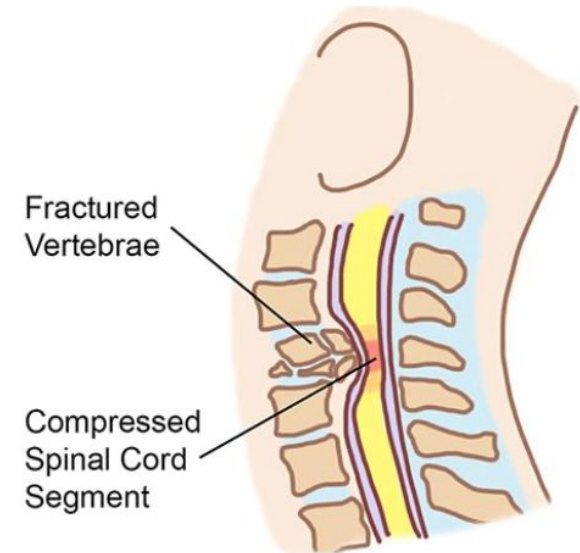
Injury can occur at any level of the spinal cord and can be complete injury with a total loss of sensation and muscle function, or it can be incomplete injury.

Depending on the location and the severity of damage, the symptoms could include numbness, paralysis or incontinence.

Long term outcomes ranges widely from full recovery to permanent quadriplegia or paraplegia.

**Complications** can include muscle atrophy, pressure sores, infections, and breathing problems.

\*Male slides only



# MCQ

**Q1: Renshaw cells are present in which Horn?**

**A: Lateral                      B: Ventral                      C: Dorsal                      D: Medial**

**Q2: The tapered inferior end of the spinal cord forms:**

**A: Conus medullaris                      B: Filum terminale                      C: Cauda equina                      D: Foramen Magnum**

**Q3: Substantia gelatinosa is found in which horn?**

**A: Dorsal horn                      B: Lateral horn                      C: Ventral horn                      D: Anterior**

**Q4: Only found in spinal segments C8 to L3**

**A: Nucleus proprius                      B: Marginal zone                      C: Intermediolateral Nucleus                      D: Dorsal nucleus of clark**

**Q5: The spinal cord has:**

**A: 33 pairs of spinal nerves                      B: 31 spinal nerves                      C: 33 Spinal nerve                      D: 31 Pairs of spinal nerve**

**Q6: The nerve cells are ..... And are of ..... Main categories:**

**A: Multipolar-THREE                      B: Unipolar-THREE                      C: Multipolar-FOUR                      D: Unipolar-FOUR**

Answer key:  
1 (B) , 2 (A) , 3 (A) , 4 (D) , 5 (D) , 6 (A)

# MCQ

**Q7: The grey commissure is divided into anterior and posterior part by the**

**A: Central Canal**

**B: Anterior Median Fissure**

**C: Posterior Median Sulcus**

**D: White Commissure**

**Q8: What region of spinal cord has a largest amount of white matter?**

**A: Cervical region**

**B: Thoracic region**

**C: Lumbar region**

**D: Sacral region**

**Q9: Group of nerve fibers share the same origin, Termination, and function are:**

**A: Neuron**

**B: Laminae**

**C: Fasciculus**

**D: Neuroglia**

**Q10: Central canal lined by:**

**A: Mesothelium**

**B: Ependyma**

**C: Simple squamous epithelium**

**D: Nonkeratinized stratified squamous epithelium**

**Q11: Non-neural cord connect spinal cord to the coccyx:**

**A: Cauda equina**

**B: Conus medullaris**

**C: Foramen magnum**

**D: Filum terminale**

**Q12: Spinal cord injury could cause change in the function:**

**A: Permanent only**

**B: Temporary only**

**C: Permanent or Temporary**

**D: None**

Answer key:  
7(A) , 8(A) , 9(C) , 10(B) , 11(D) , 12(C)



Q1: What is a Dermatome?

Q2: Define Reflex arc?

Q3: What is Rexed laminae?

Q4: Enumerate lower motor neuron type and the type of muscle fiber that is innervated?

## Answers

1 : Segment of skin supplied by one spinal nerve.

2 : A reflex is a rapid, involuntary, predictable response brought by a sensory stimulus

3 : It is an alternative to spinal cord nuclei where cells were grouped according to their structure and function, rather than solely on location.

4: - large multipolar cells: Numerous , Axons pass out in the ventral roots of spinal nerves as alpha efferents and Innervate extrafusal muscle fibers.

-smaller multipolar cells: Less numerous ,Axons pass out in the ventral roots of spinal nerves as gamma efferents and Innervate intrafusal muscle fibers of neuromuscular spindles.

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## A special thanks to Mohamed Alquhidan

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