

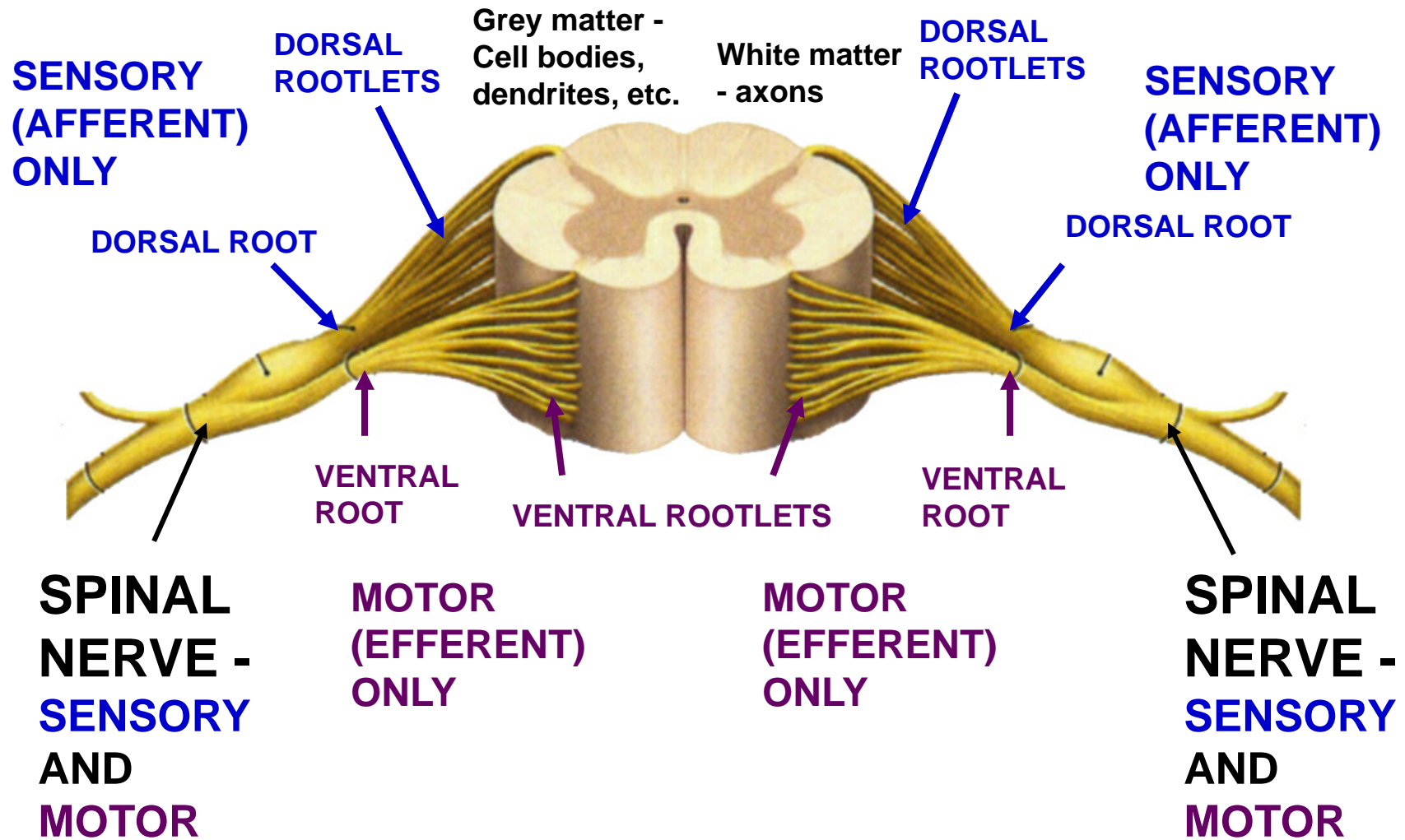
# **SPINAL CORD AND EXTREMITY INNERVATION: CLINICAL ANATOMY**

## **CLINICAL - USING REFLEXES TO DIAGNOSE SPINAL NERVE DAMAGE AND ANATOMY OF CLINICAL PROCEDURES**

### **OUTLINE**

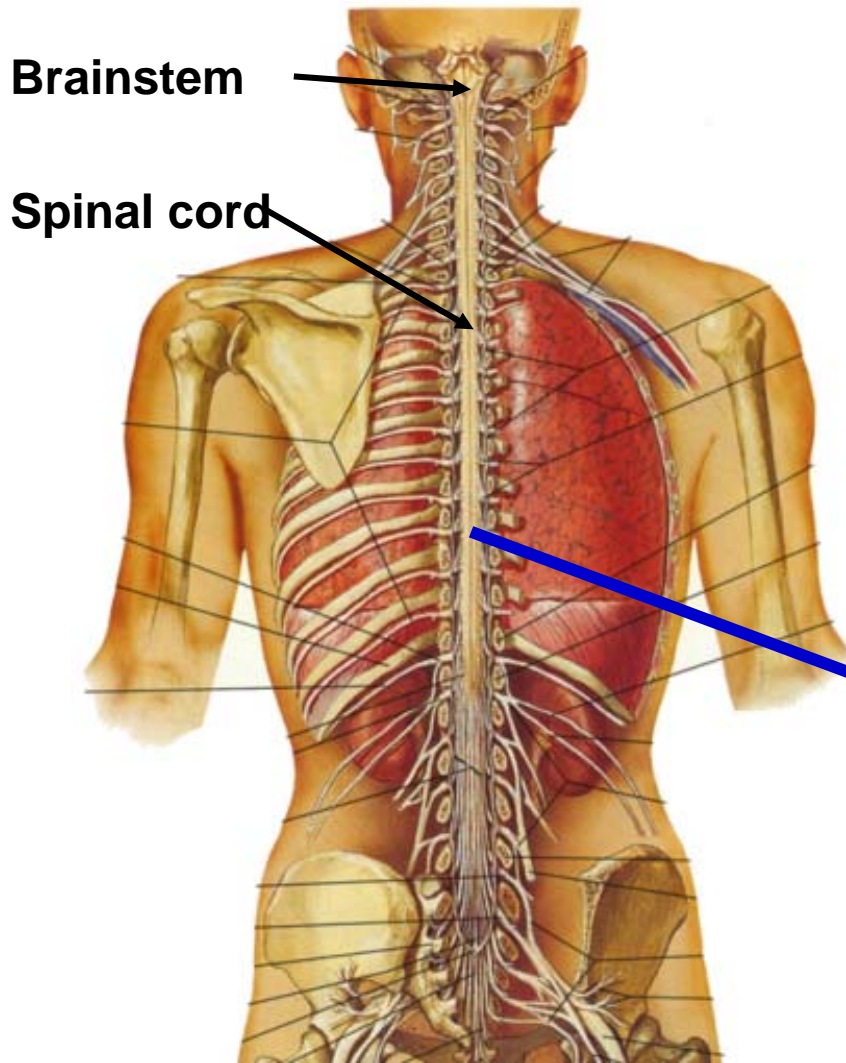
- I. SPINAL NERVES - DERMATOMES AND PLEXUSES**
- II. REFLEXES CAN BE USED TO IDENTIFY SPINAL LEVELS OF NERVE DAMAGE**
- III. LOCATION OF SPINAL CORD IN VERTEBRAL CANAL**
- IV. MENINGES OF SPINAL CORD - EPIDURAL ANESTHESIA**
- V. CEREBROSPINAL FLUID (CSF) AND LUMBAR PUNCTURE (SPINAL TAP)**

# I. FORMATION OF SPINAL NERVE



- Dorsal Rootlets unite to form Dorsal Roots; contain sensory afferent) axons
- Ventral rootlets unite to form Ventral Roots; contain motor (efferent) axons
- Dorsal and Ventral roots form a Spinal Nerve; contains sensory and motor axons

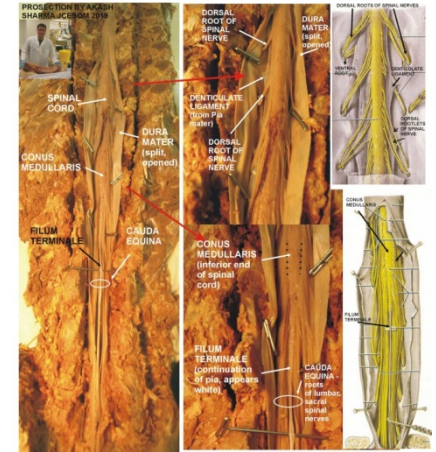
# SPINAL NERVES ARISE AS A SERIES



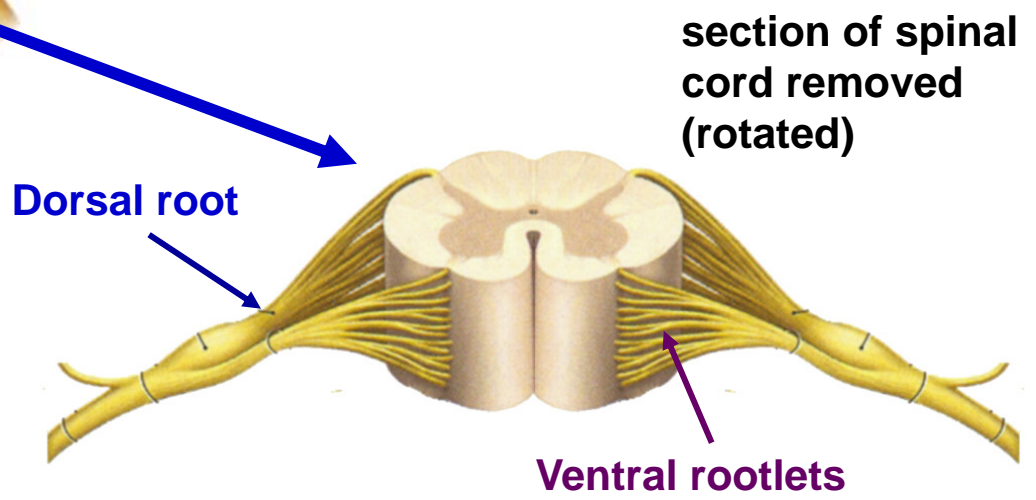
Spinal cord is located within vertebral canal and is continuous with the brain via the brainstem

Spinal nerves arise as a series and exit vertebral column (via openings called Intervertebral foramina)

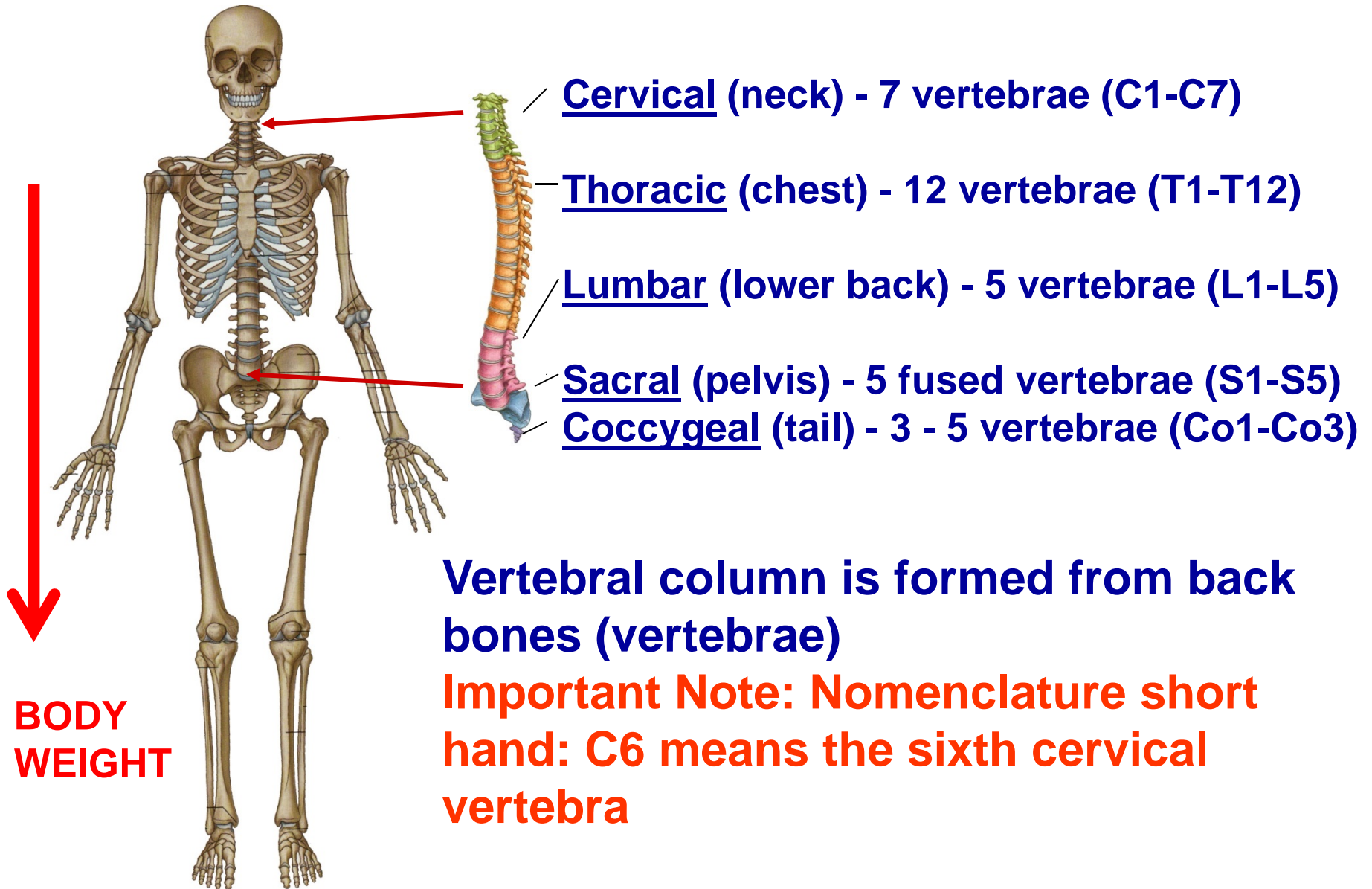
SPINAL CORD



PROSECTION 44



# NOMENCLATURE (NAMING) OF SPINAL NERVES - NAMED FOR REGIONS OF VERTEBRAL COLUMN





# SPINAL NERVES AND VERTEBRAL LEVELS

## LEVELS OF VERTEBRAE

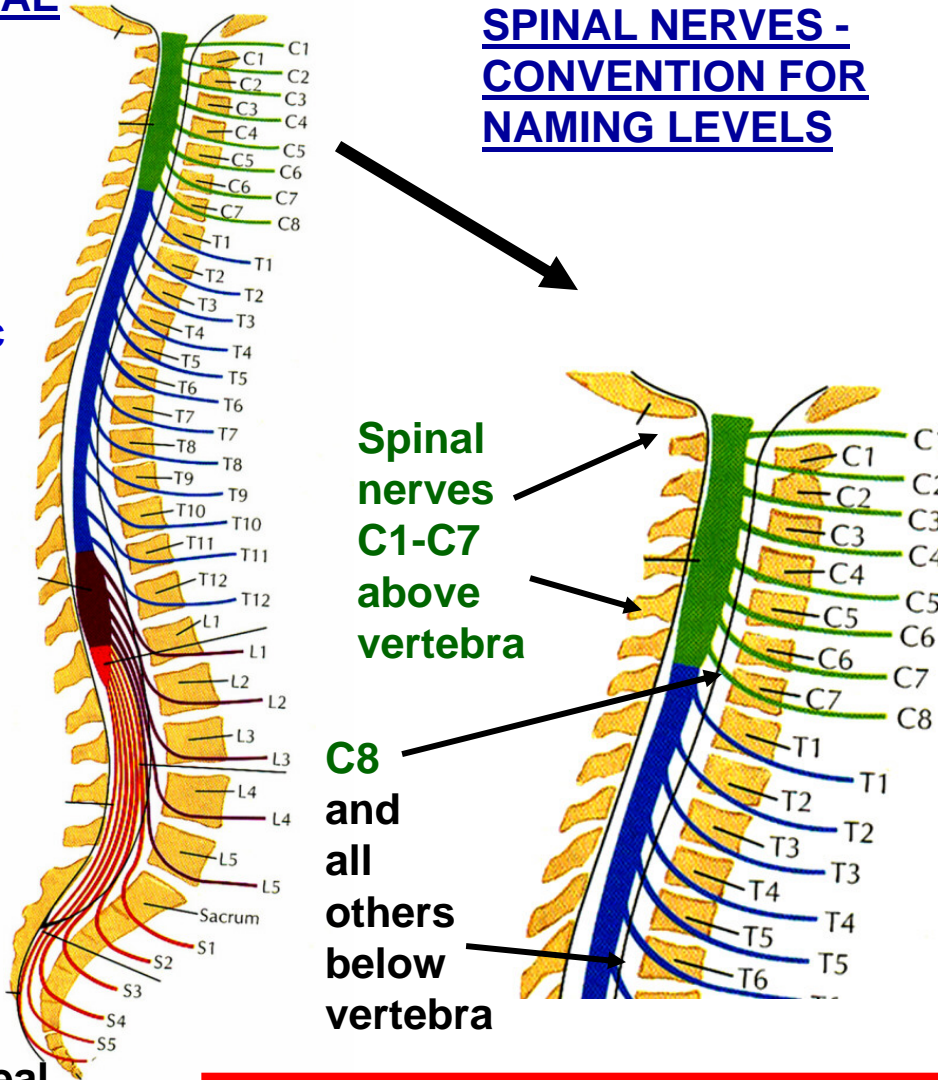
**Cervical (C1-C8)**

**Thoracic (T1-T12)**

**Lumbar (L1-L5)**

**Sacral (S1-S5)**

**Coccygeal (Co1)**



## SPINAL NERVES - CONVENTION FOR NAMING LEVELS

2. Spinal nerves - arise from/project to spinal cord; there are 31 spinal nerves (8 cervical, 12 thoracic, 5 lumbar, 5 sacral and 1 coccygeal).

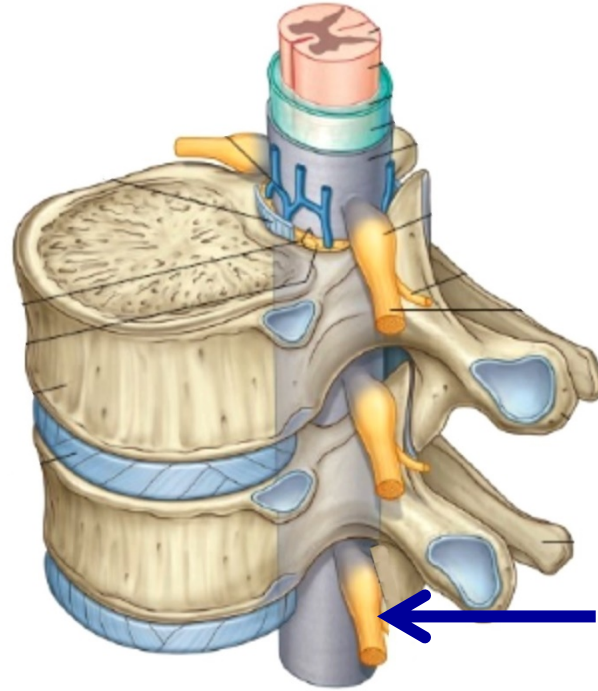
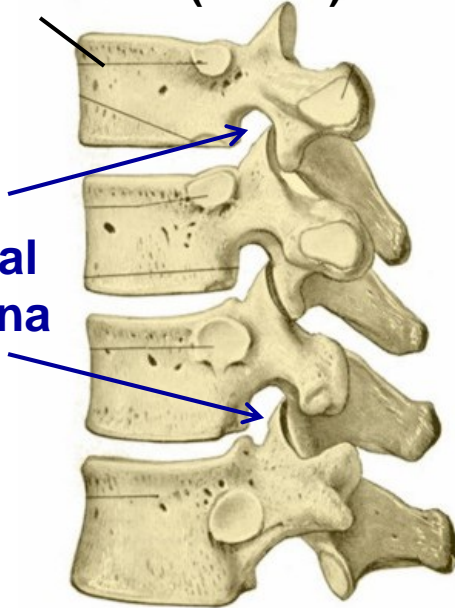
**Clinically Important for Identifying Level of Nerve compression - Cervical spinal nerves 1-7 (C1-C7) exit above corresponding vertebrae; Spinal nerve C8 exits below vertebra C7; All other spinal nerves exit below corresponding vertebrae. \*\***

**REMEMBER = C1-C7 ABOVE; ALL OTHERS BELOW**

# 'TYPICAL' SPINAL NERVE

Vertebra - side (lateral) view

Inter-vertebral Foramina



- Spinal nerves exit vertebral canal at openings between vertebra called Intervertebral Foramina (singular is Foramen)

Spinal nerve passing through Intervertebral Foramen

Dorsal root ganglion

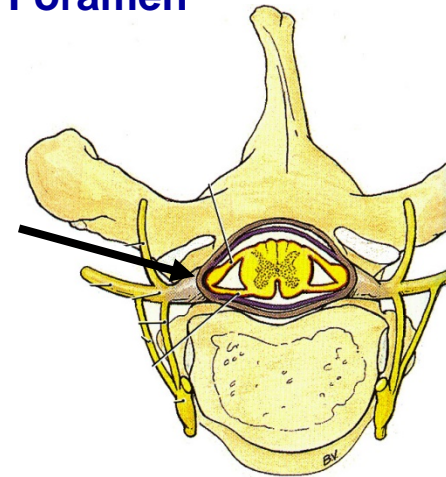
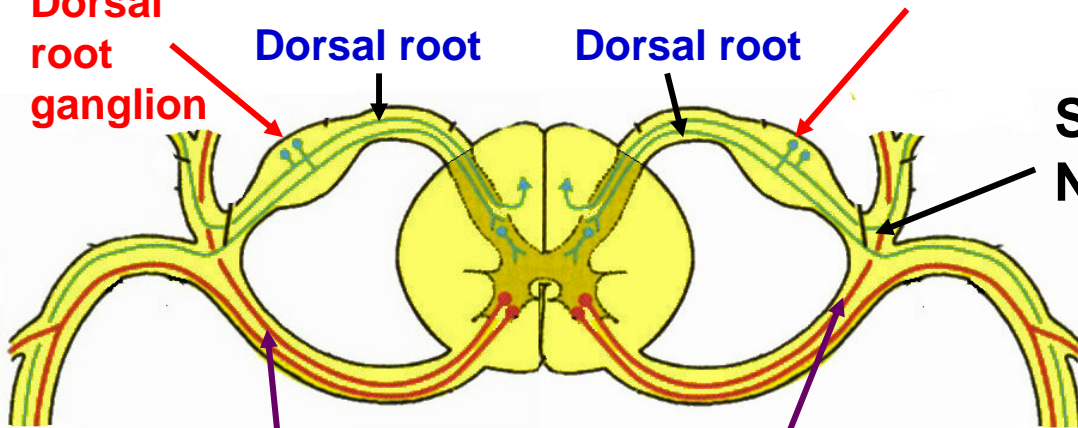
Dorsal root

Dorsal root

SPINAL NERVE

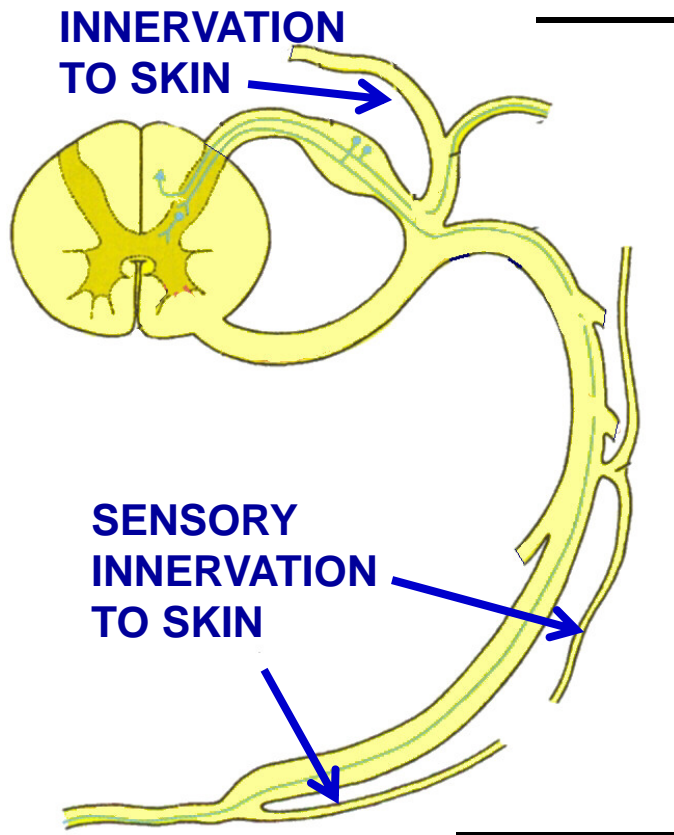
Ventral root

Ventral root



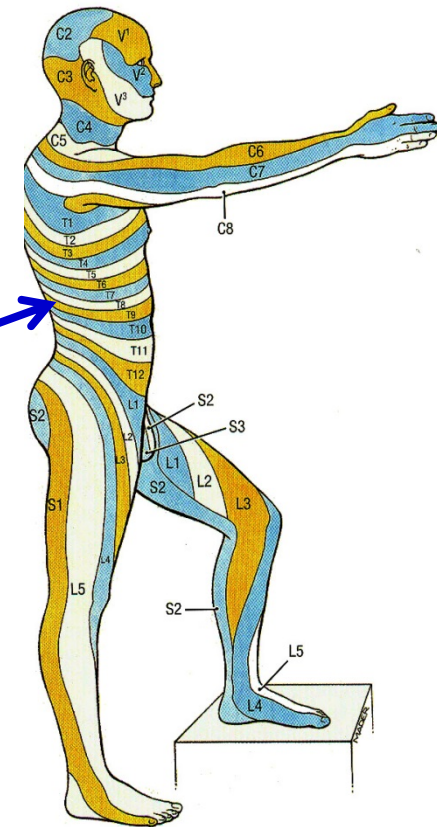
# DERMATOME - area of skin innervated by a single SPINAL NERVE

Sensory neurons in a single spinal nerve innervate a discrete area of the body



## DERMATOME MAP

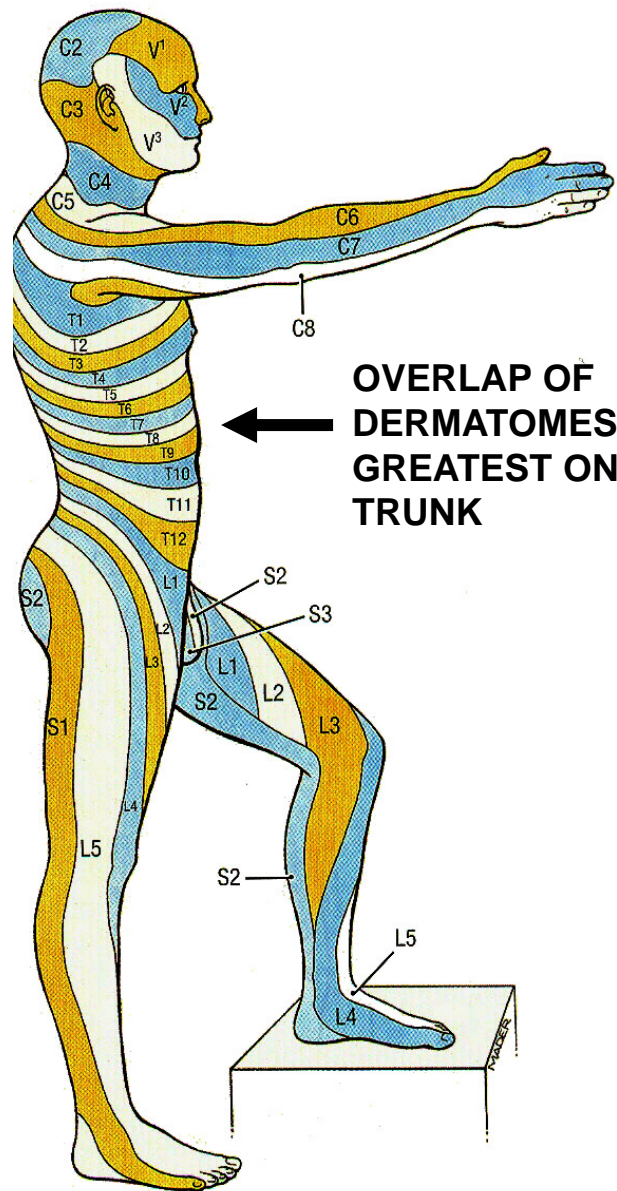
Dermatome - is area of skin innervated by a single spinal nerve



1. Structure - sensory axons from each spinal nerve end up innervating strips of skin on body called dermatomes; regions from different spinal nerves form a continuous series (look like stripes)



# DERMATOME - CLINICAL TESTING FOR DAMAGE



**1. Structure - AREAS OF SKIN INNERVATED** by different spinal nerves form a continuous series; in thorax dermatome map looks like stripes; more complex in extremities.

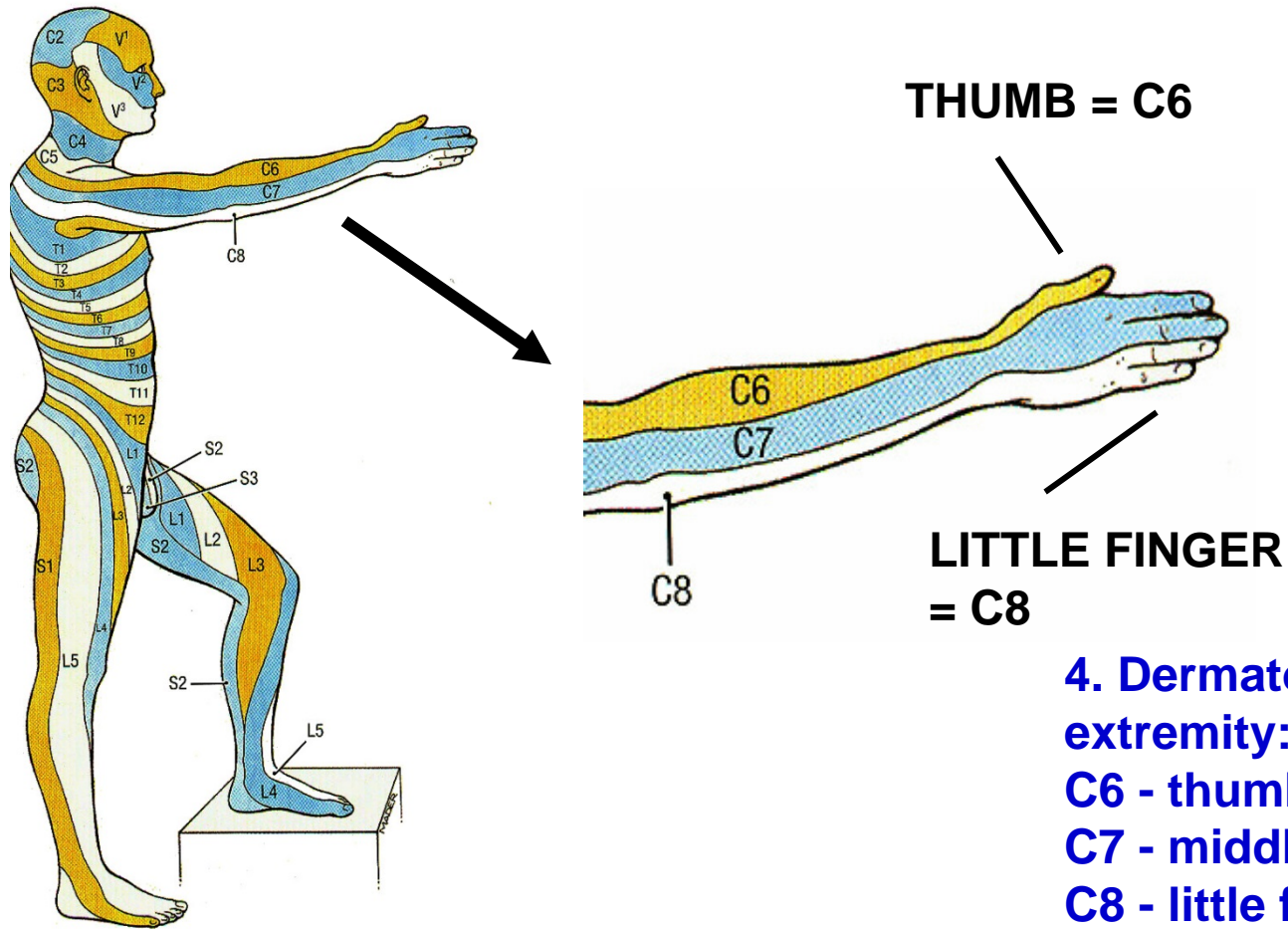
**2. Overlap** - there is some overlap between adjacent dermatomes; overlap is greater on trunk than on extremities

**3. Clinical testing - damage** to a single spinal nerve or single dorsal root can produce **pain or anesthesia** in its dermatome; physician can test for damage to a specific spinal nerve by **lightly touch (pin prick) area of skin** in dermatome.

(Note: because of overlap of dermatomes in region of trunk, damage to a single spinal nerve will not produce loss of sensation (anesthesia); loss of sensation on skin of trunk will occur if two or more adjacent dorsal roots or spinal nerves are damaged.

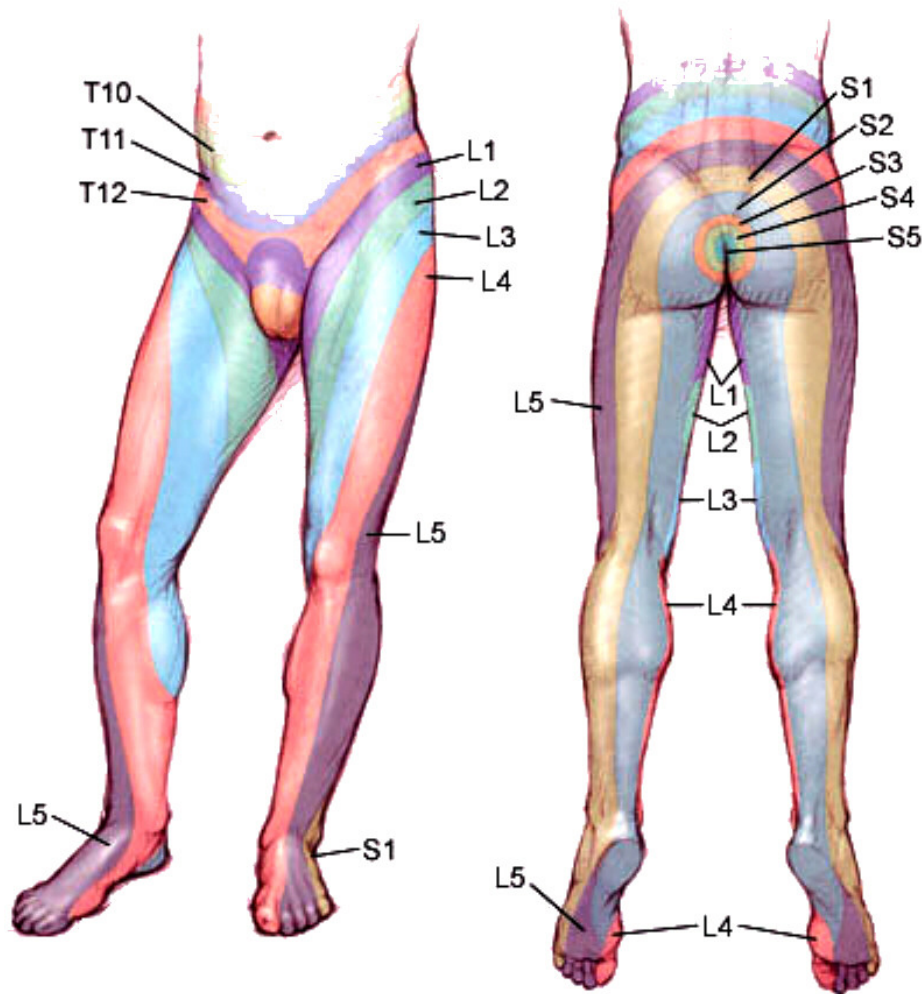


# DERMATOMES OF UPPER EXTREMITY - HAND



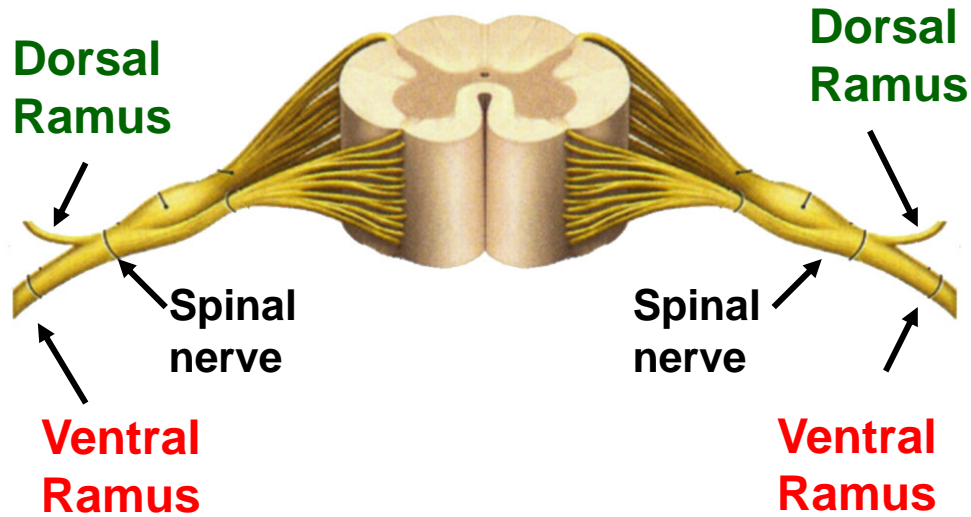
4. Dermatomes of upper extremity: Important
- C6 - thumb
  - C7 - middle finger
  - C8 - little finger

# DERMATOMES OF LOWER EXTREMITY - FOOT



**Important  
Dermatomes of  
Lower Extremity**  
L1 - region of  
Inguinal Ligament  
(anterior to hip)  
L4 – Big Toe  
S1 – Little Toe

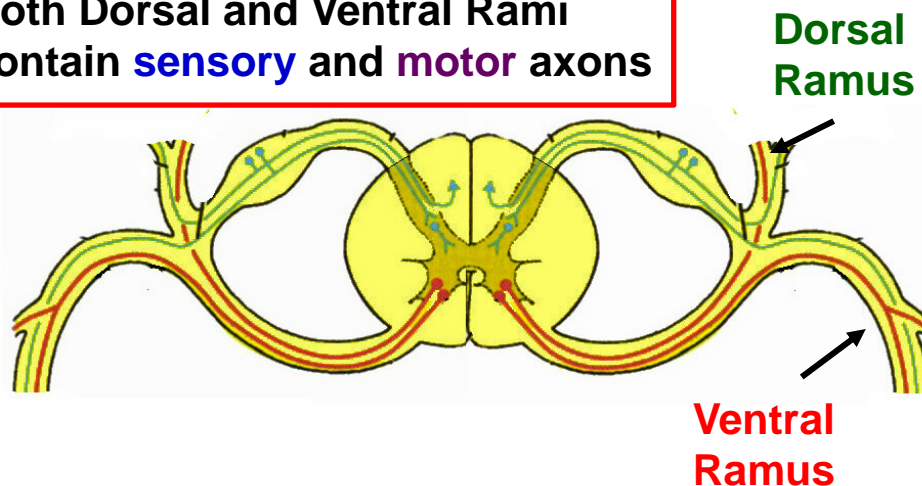
# DORSAL AND VENTRAL RAMI OF SPINAL NERVES



Spinal nerves divide into Dorsal and Ventral Rami immediately after they leave the intervertebral foramen. Dorsal Rami are much smaller.

1. **Dorsal Ramus** (also called Dorsal Primary Ramus) - contains **sensory** and **motor** axons to region of back; sensory to skin of back and posterior neck, motor axons to deep muscles of back and neck.

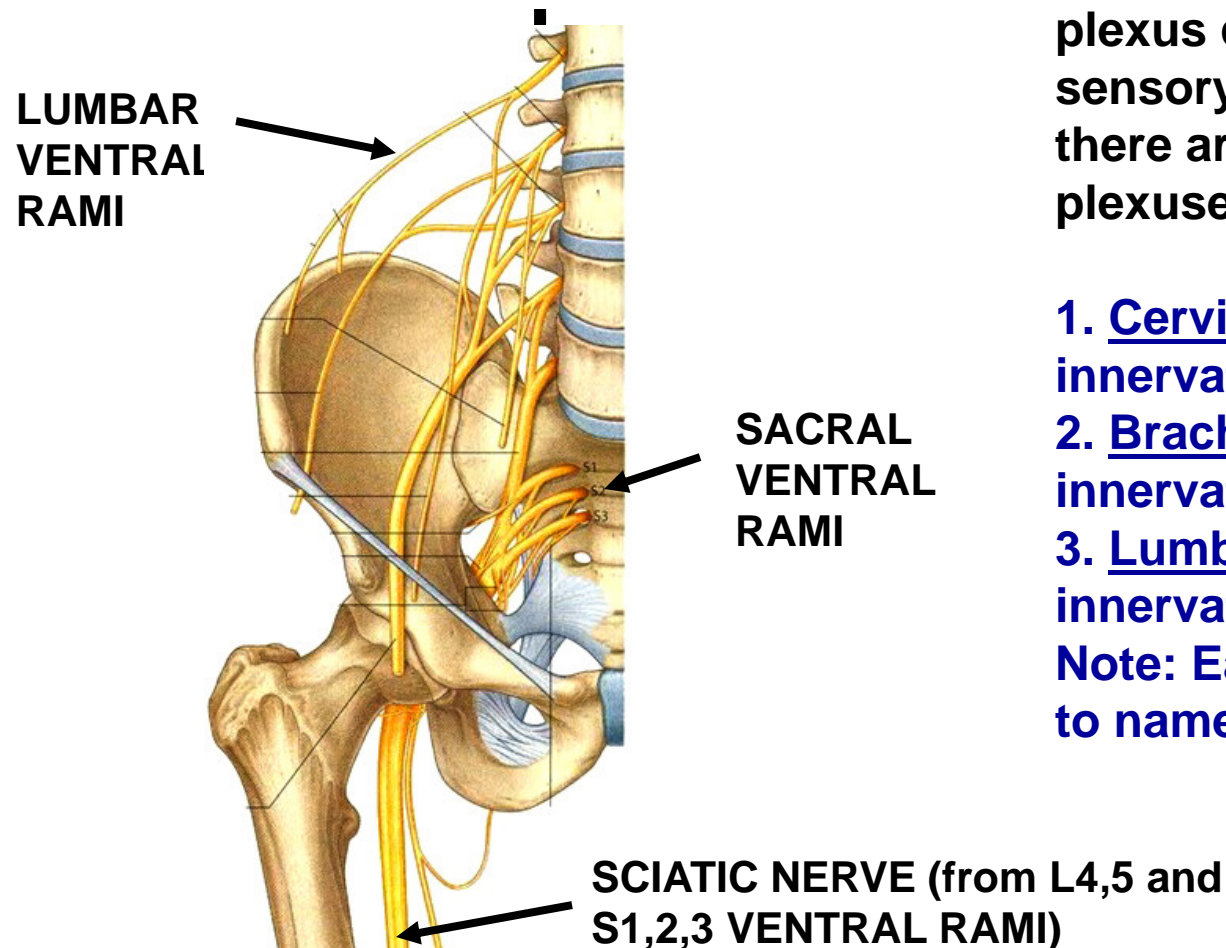
Both Dorsal and Ventral Rami contain **sensory** and **motor** axons



2. **Ventral Ramus** (also called Ventral Primary Ramus) - **sensory** and **motor** axons to other parts of body; sensory to skin of extremities (arm, leg) and anterior and lateral regions of trunk; motor to muscles of extremities and anterior and lateral regions of trunk.

# PLEXUS - forms from ventral rami of spinal nerves

## Lumbosacral Plexus



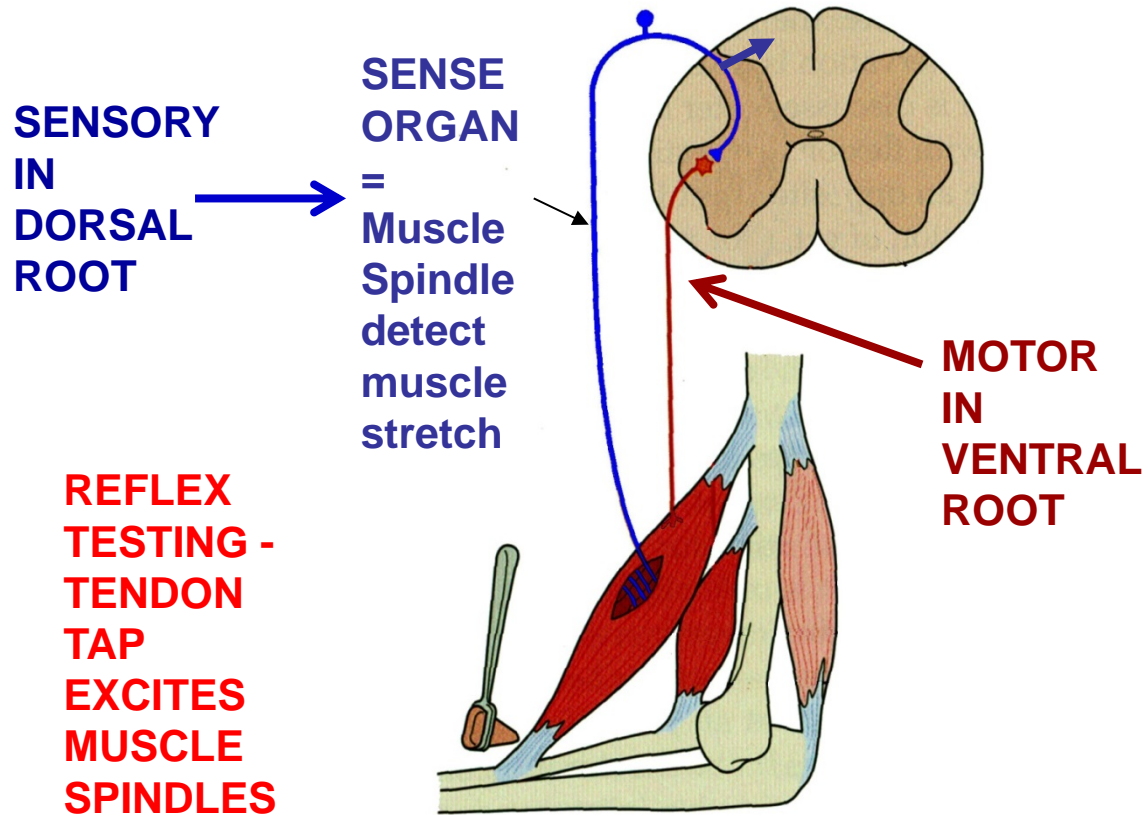
D. Plexus - **ventral rami of spinal nerves** interconnect in complex patterns; each plexus contains both sensory and motor axons; there are three major plexuses:

1. Cervical Plexus - innervates neck
  2. Brachial Plexus - innervates upper extremity
  3. Lumbosacral Plexus - innervates lower extremity
- Note: Each plexus gives rise to named nerves.



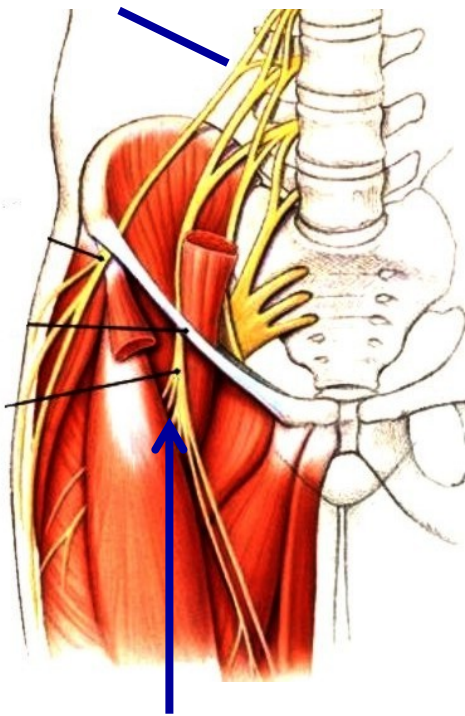
## II. REFLEXES CAN BE USED TO IDENTIFY LEVELS OF SPINAL NERVE DAMAGE

**STRETCH (DEEP TENDON) REFLEXES** - tapping on the tendon of a muscle causes the muscle to contract  
– **CLINICALLY IMPORTANT**



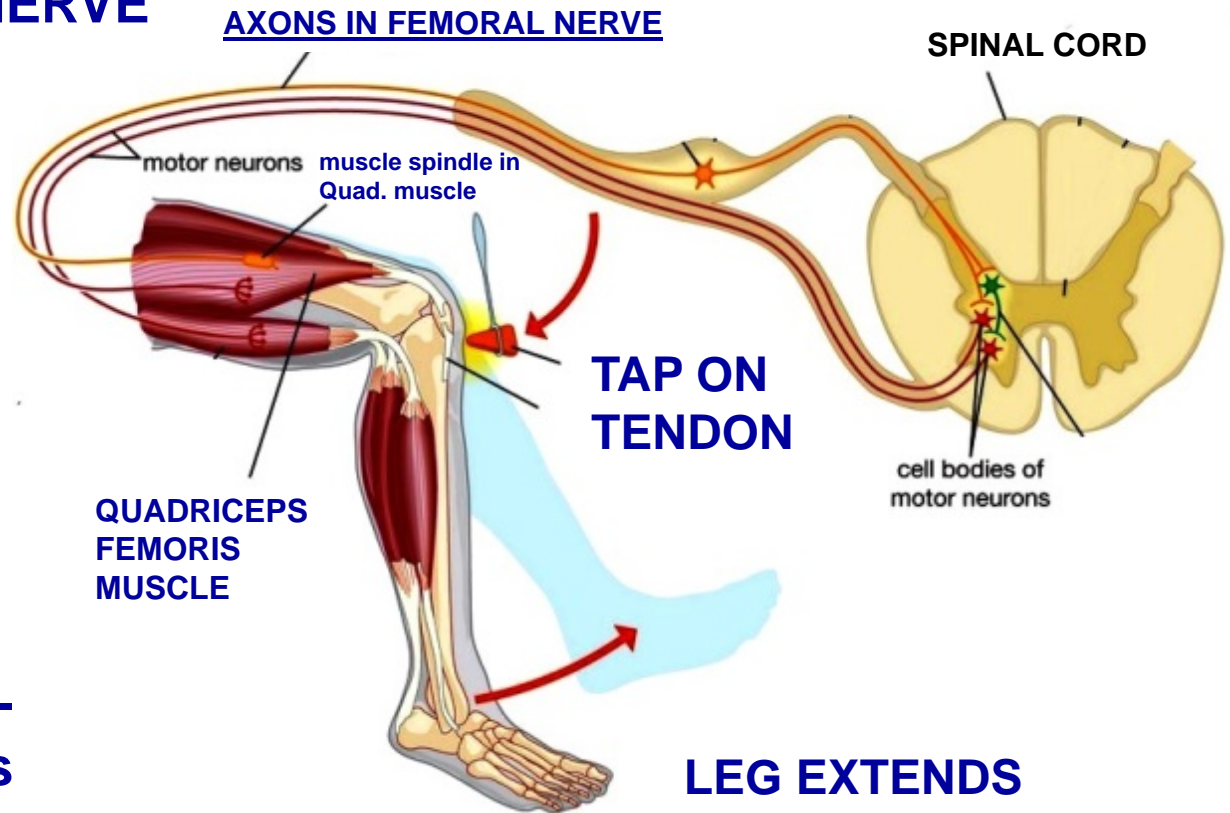
## II. REFLEXES CAN BE USED TO IDENTIFY LEVELS OF SPINAL NERVE DAMAGE

Lumbosacral Plexus

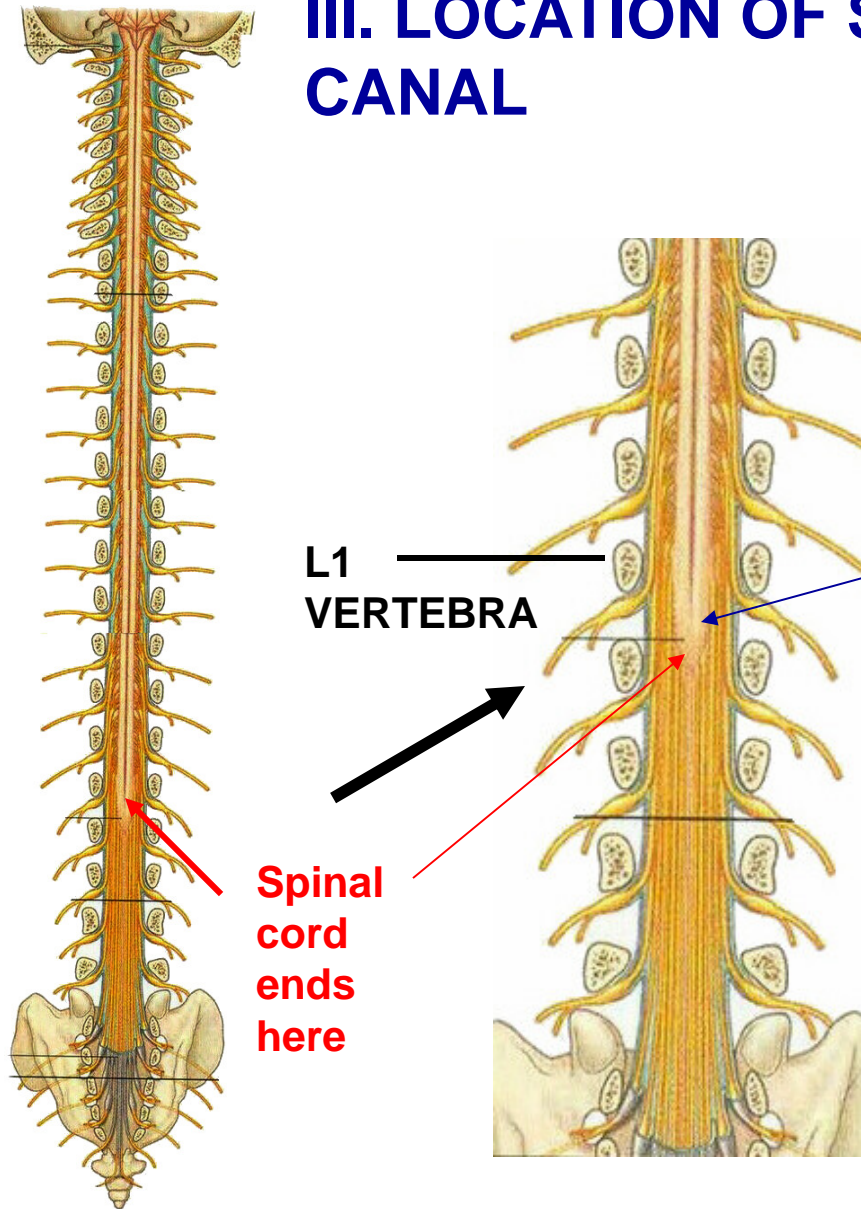


Femoral Nerve (L234) - innervates Quadriceps Femoris muscle

QUADRICEPS FEMORIS STRETCH REFLEX (KNEE JERK REFLEX) TESTS FUNCTION OF FEMORAL NERVE



### III. LOCATION OF SPINAL CORD IN VERTEBRAL CANAL



L1  
VERTEBRA

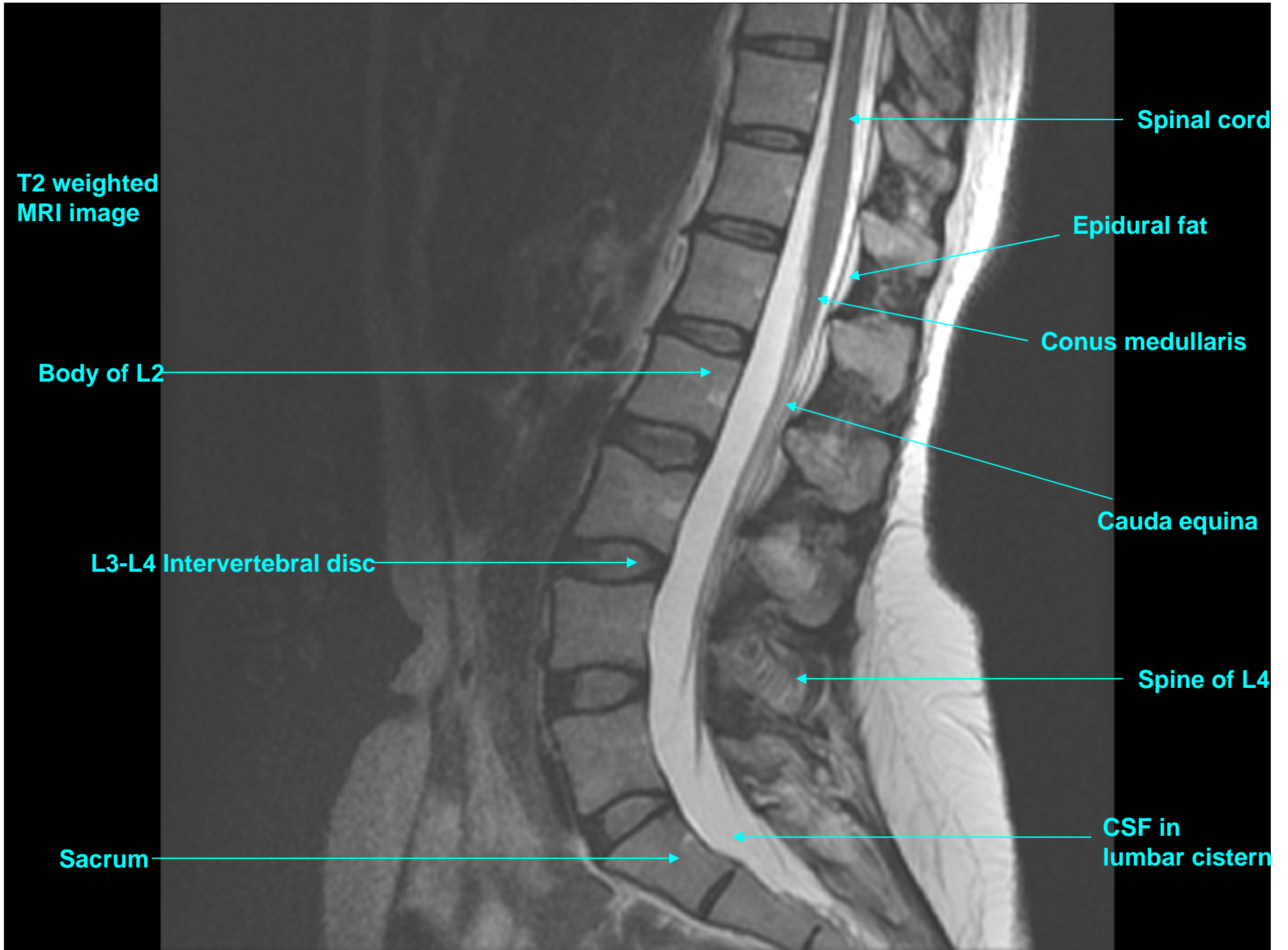
Conus  
medullaris

Spinal  
cord  
ends  
here

- spinal column (vertebra) increases greatly in length in development; spinal cord only has small increase in size; in adult, vertebral canal is much longer than spinal cord.

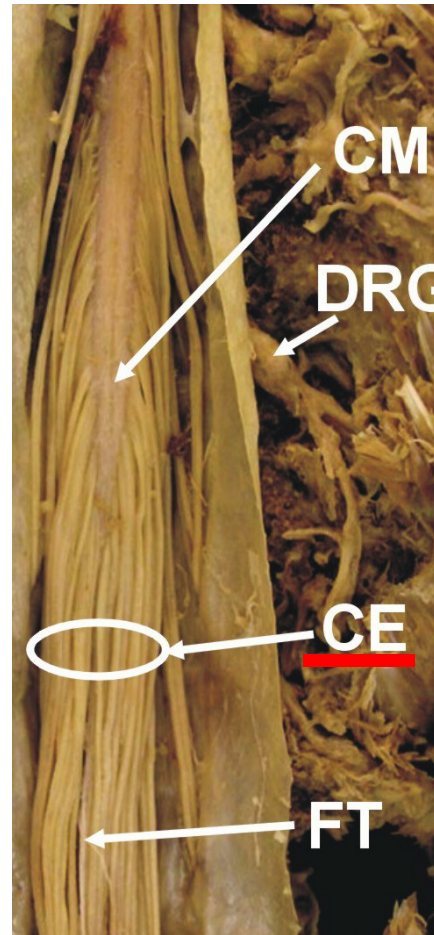
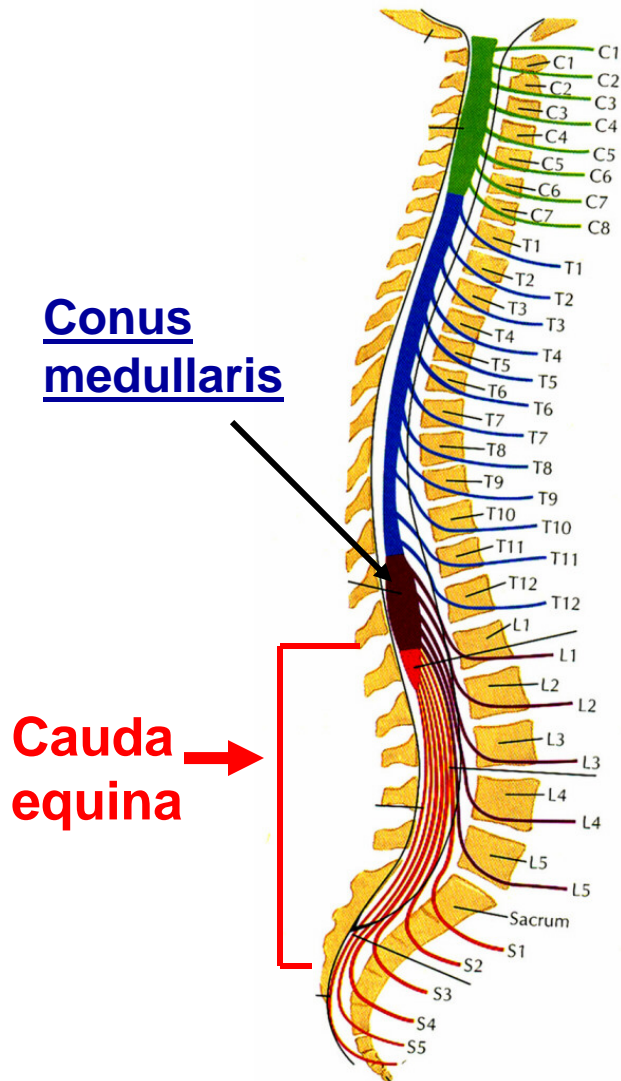
A. Conus medullaris - is inferior (caudal) end of spinal cord

1. In newborn, conus medullaris is located at vertebral level L3
2. In adult, conus medullaris is located at vertebral level L1.





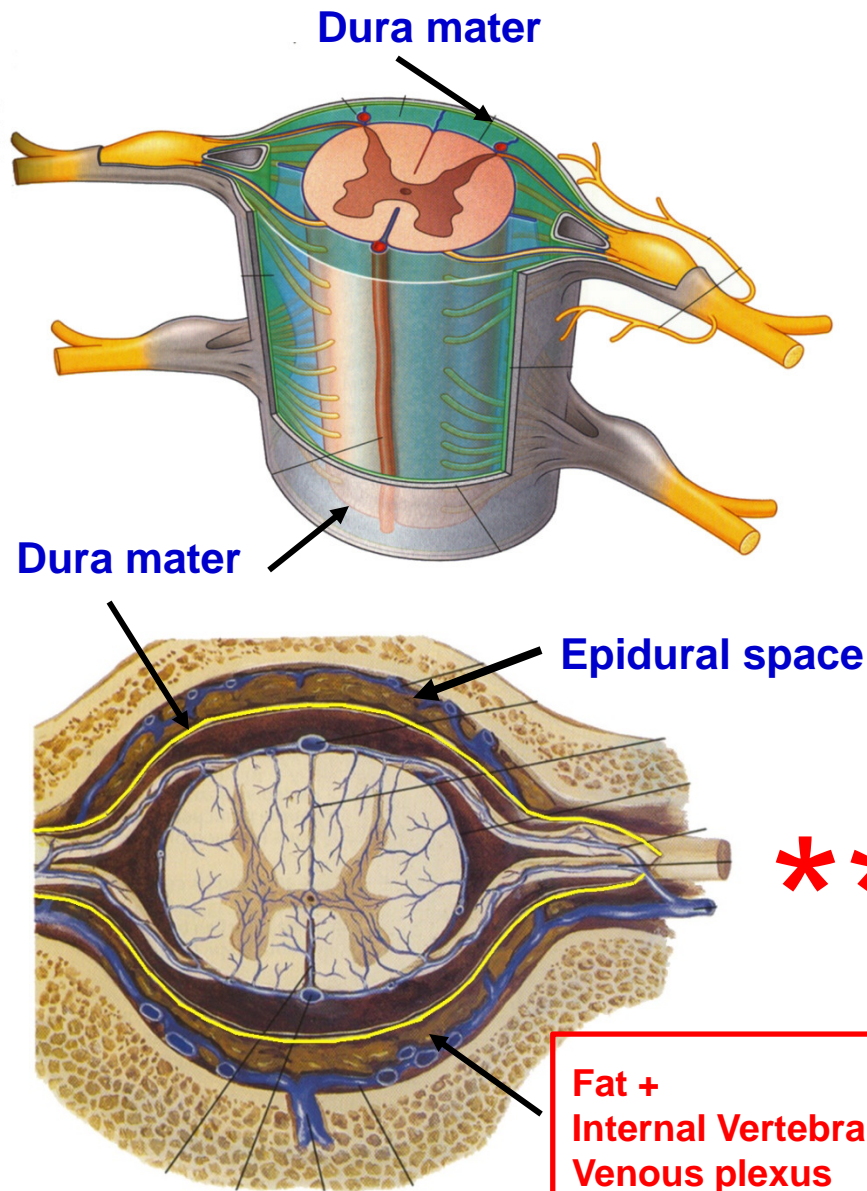
# CONUS MEDULLARIS AND CAUDA EQUINA



prosection view

B. **Cauda equina** (is Latin for Horse's tail) - as vertebral column grows longer, **lower dorsal and ventral rootlets** also grow longer so they pass through correct intervertebral foramina; these rootlets extend inferior to conus medullaris at lower lumbar, sacral and coccygeal levels and are collectively called the Cauda Equina.

## IV. MENINGES - connective tissue layers surround, protect spinal cord



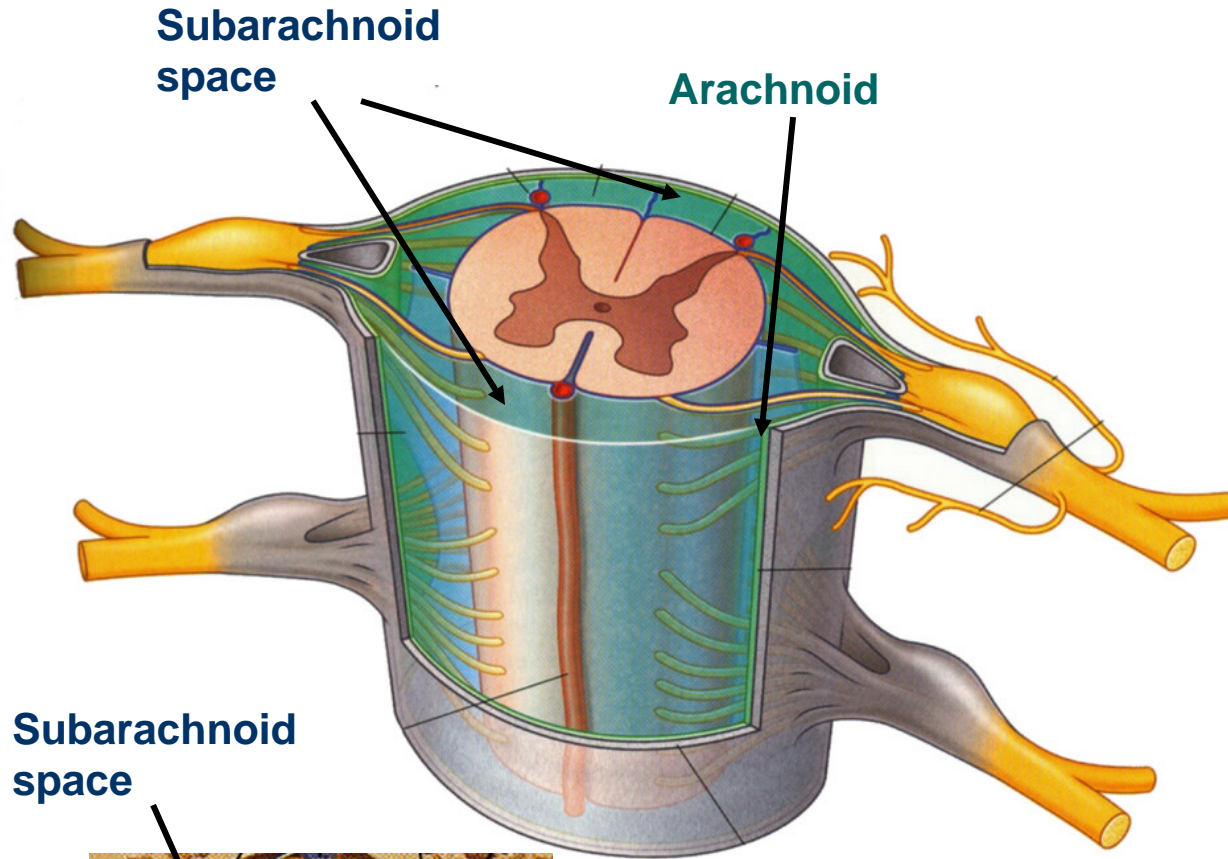
described as three layers.

A. Dura mater (Latin for tough mother) - tough outer layer that forms sac that completely surrounds spinal cord in vertebral canal; below level L1 in adult (L3 in newborn), Dural sac surrounds cauda equina; dural sac ends inferiorly at level S2.

1. Epidural space - dural sac is separated from inner side of vertebral canal by space (Epidural space) containing fat and loose connective tissue; also contains Internal Vertebral Venous plexus.

**Epidural Anesthesia - can block conduction in spinal nerves by anesthetic injection into epidural space; effect is by diffusion**

# MENINGES - ARACHNOID AND SUBARACHNOID SPACE



Subarachnoid space

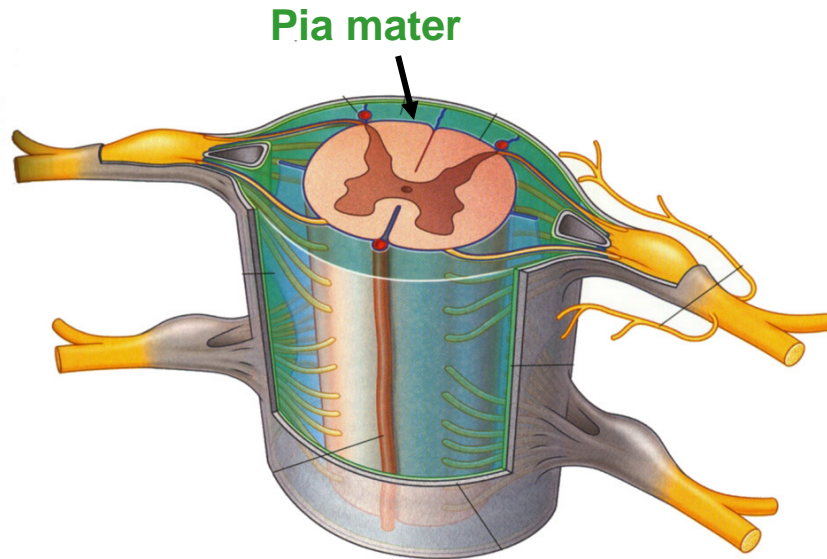


fine strands extend from arachnoid to pia - broken in prosections

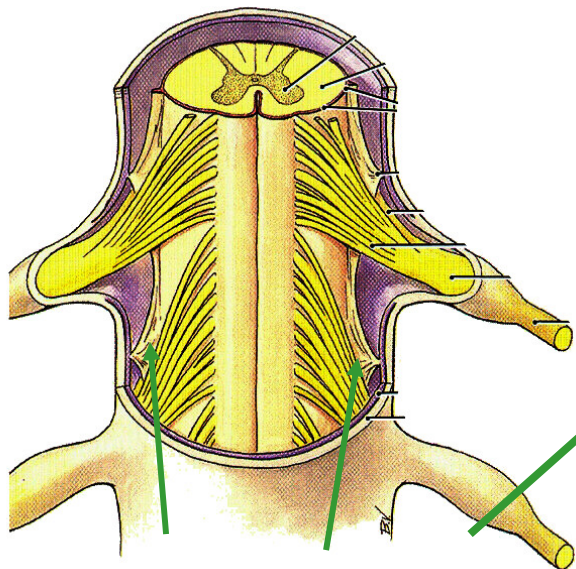
B. Arachnoid (Latin for spider like) - middle layer of meninges; **attached to inner side of dura** but has fine strands that extend to pia mater (like spider's web).  
2. Subarachnoid space - found between arachnoid and pia; contains Cerebrospinal fluid.



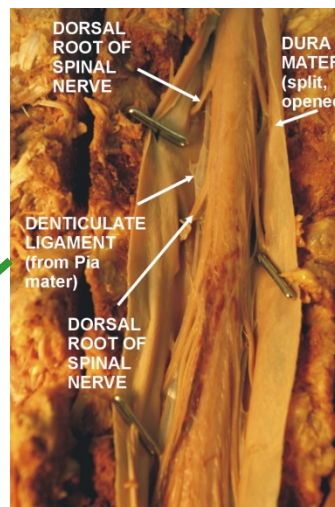
# MENINGES OF SPINAL CORD - PIA MATER



Spinal Cord  
Prosection 44



Denticulate Ligaments



C. **Pia mater** (Latin for tender mother) - thin layer that is adherent to surface of spinal cord; contains blood vessels supplying cord.

1. **Denticulate Ligaments** (Latin tooth like) - **projections of pia** on each side of cord that extend to arachnoid **to inner side of Dura**; 21 pairs of denticulate ligaments stabilize spinal cord

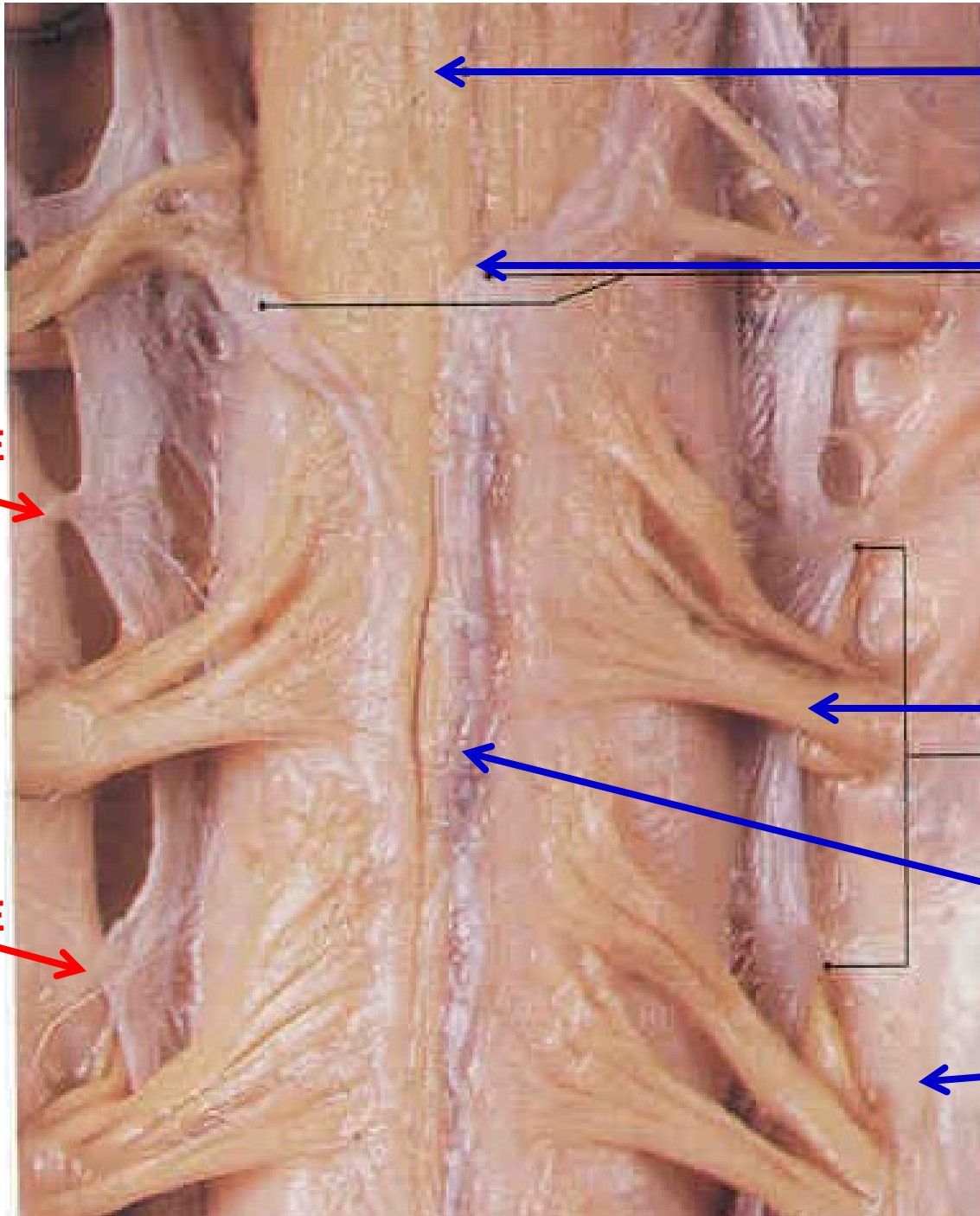
**Note: Denticulate ligaments are used as landmarks in neurosurgery; dorsal rootlets travel dorsal to denticulate ligaments; ventral rootlets are ventral to denticulate ligaments; can cut dorsal rootlets (dorsal rhizotomy) to relieve chronic pain using denticulate ligaments as guide.**



**ORIENT:  
PHOTO  
OF  
RECENTLY  
DISSECTED  
SPINAL  
CORD**

**DENTICULATE  
LIGAMENT** →

**DENTICULATE  
LIGAMENT** →



**← SPINAL CORD**

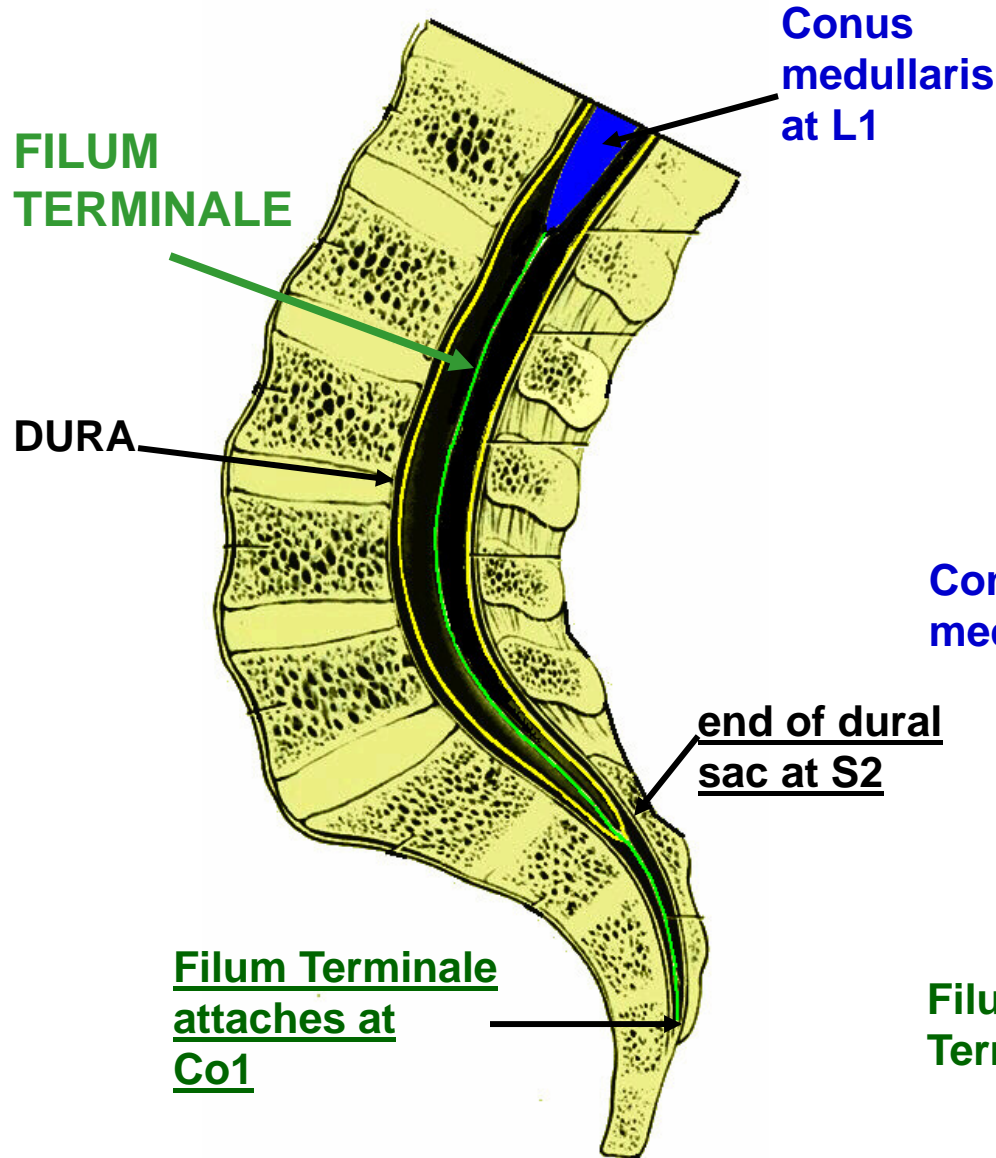
**← PIA MATER**

**← VENTRAL  
ROOT**

**← BLOOD  
VESSEL**

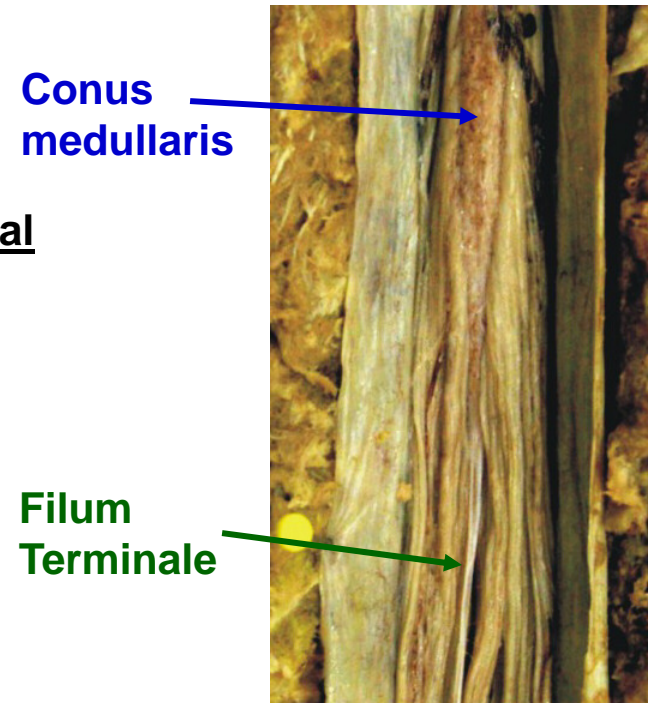
**← DURA MATER**

View of lower vertebral canal with spinal nerves of cauda equina removed

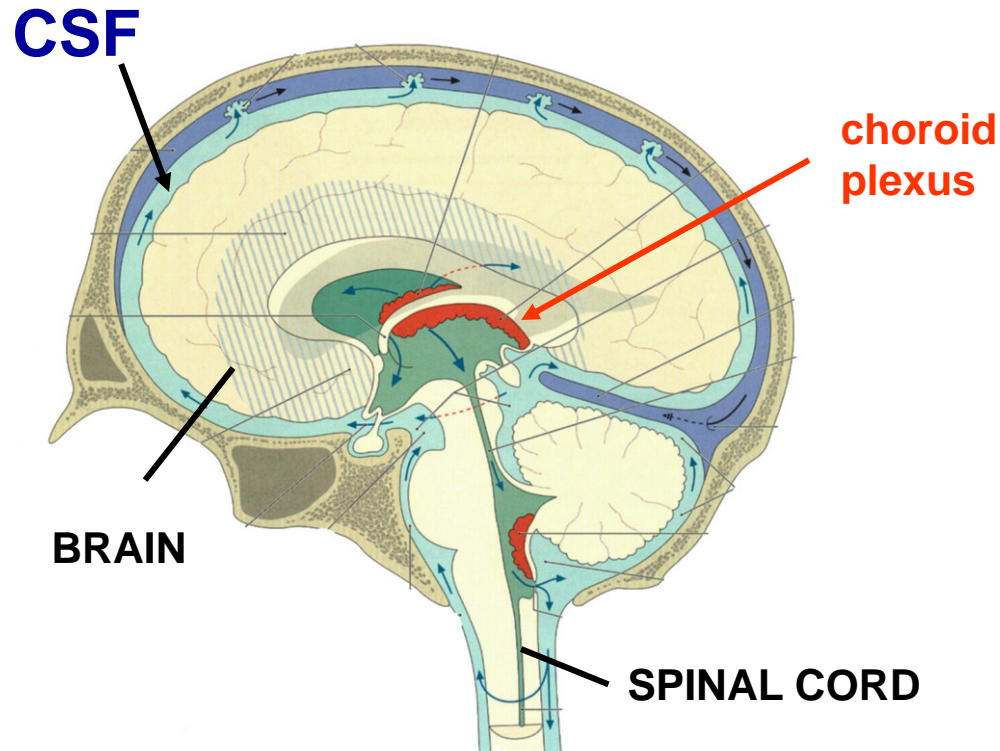


## FILUM TERMINALE

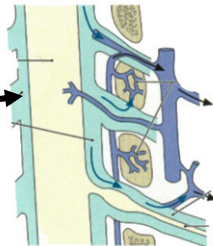
2. **Filum Terminale - pia** extends as a thin strand below conus medullaris; strand traverses dural sac, pierces dural sac at S2 and continues inferiorly to attach at first coccygeal vertebra (**Co1**).



# V. CEREBROSPINAL FLUID (CSF) AND SPINAL TAP



CSF in subarachnoid space around spinal cord

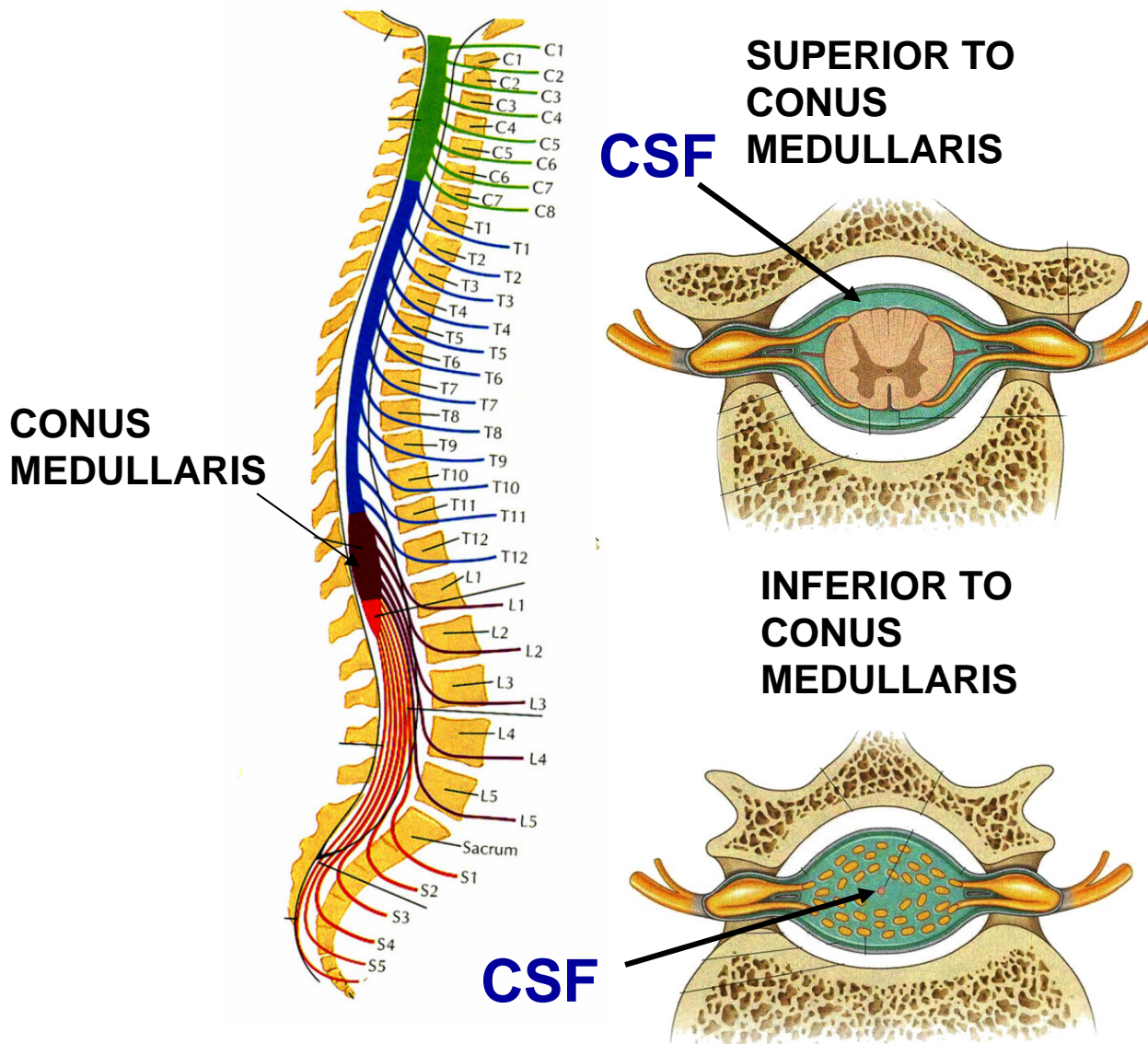


- CSF is clear, acellular fluid contained in subarachnoid space; surrounds and protects spinal cord; produced within choroid plexuses (mostly in brain)

1. Changes in CSF can indicate disease processes - excessive CSF production (or decreased reabsorption) produces increased pressure (hydrocephalus); also blood cells in CSF can indicate infection or hemorrhage.



# SAMPLING CEREBROSPINAL FLUID (CSF): 'SPINAL TAP'



Sample CSF by inserting a needle between vertebra into subarachnoid space; needle must be below (inferior to) conus medullaris

## a. Level of Lumbar Puncture

i. **Adult** - between **L3-L4** or **L4-L5** (spinal cord extends to **L1**)

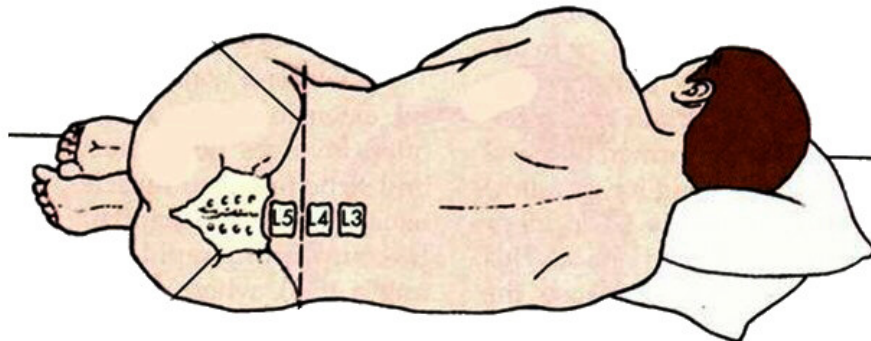
ii. **Children** - \* **must be done at L4-L5** (spinal cord at birth extends to **L3**)



## CEREBROSPINAL FLUID (CSF) AND SPINAL TAP



LUMBAR PUNCTURE =  
RACHIOCENTESIS (pronounce rack-e-o)



PALPATE ILIAC CREST TO LOCATE SPINE OF L4

2. Lumbar Puncture  
(Spinal Tap) - CSF is  
sampled by **inserting  
needle into Subarachnoid  
space**; is performed with  
vertebral column flexed  
and patient sitting or  
lying on side (lateral  
decubitus position).

### **REMEMBER:**

1) **Spinal cord ends**  
**(Conus medullaris)**

L1 - Adult

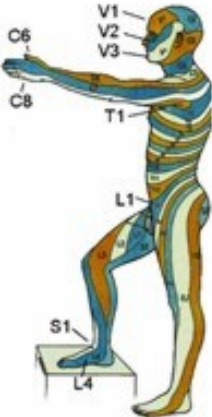
L3 - Child

2) **Dural Sac ends** S2

3) **Filum terminale ends**  
**and attaches - Co1**

# SUMMARY CHART 1

## SUMMARY CHART: CLINICAL ANATOMY OF SPINAL NERVES

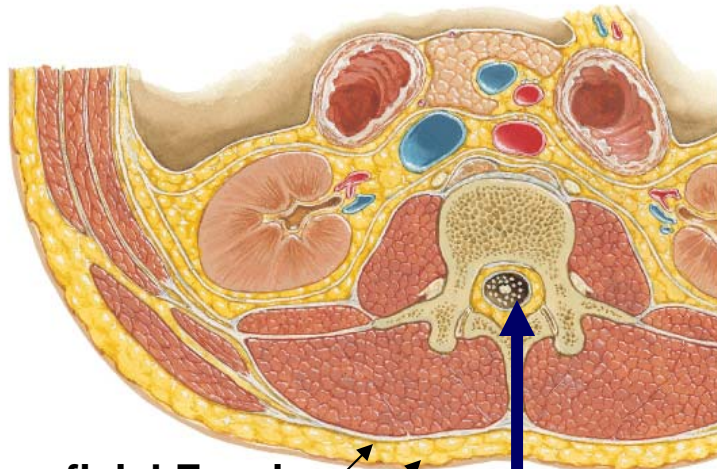
Syndrome/ Procedure	Anatomy	Structures	Clinical, ID Features on CT
<b>Nerve Compression</b>	<b>Convention:</b> Cervical spinal nerves <b>C1-C7 exit Above</b> corresponding vertebrae; <b>C8 exits below C7 and All other spinal nerves exit Below corresponding vertebrae</b>	Dermatomes - area of distribution of single nerve root to skin; Reference list: learn when discussed in lecture Head - Cranial nerve V [V1 - Face (above eyes *) V2 - Face (below eyes*) V3- Face (below mouth)*] C5 - Shoulder C6 - Thumb C8 - Little finger L4 - Big toe S1 - Little toe	Symptoms of compression of <u>nerve S-</u> Paresthesia, pain, sensory loss, <u>hyporeflexia</u> , muscle weakness    <b>Note:</b> overlap of dermatomes in region of trunk: sensory loss in trunk only with Two Thoracic spinal roots
<b>Lumbar Puncture</b>	Inferior end of Spinal Cord = Conus medullaris	Conus medullaris at 1. In <b>Newborn</b> , vertebral level L3 2. In <b>Adult</b> , conus at vertebral level L1	<b>Lumbar Puncture</b> done below Conus Medullaris (region of Cauda Equina); Level: 1. <b>Children - L4-L5</b> 2. <b>Adult - L3-L4 or L4-L5</b>
<b>Epidural Anesthesia</b>	Epidural Space (outside Dura) Dura is separated from inner side of vertebral canal; Note: in Skull, there is no epidural space	Contains: <b>Internal Vertebral Venous plexus</b> - inside vertebral canal in Epidural Space;	Anesthetic injected into Epidural space can safely produce local block of spinal nerves (spread by diffusion).

# SUMMARY CHART 2

## REVIEW STRETCH REFLEX AND CLINICAL DIAGNOSIS OF LESIONS TO SPINAL NERVES

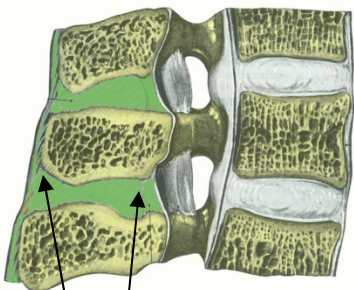
REFLEX	STIMULUS/SENSE ORGANS	RESPONSE	CLINICAL/ABNORMAL RESPONSES
Stretch (Myotatic, Deep Tendon) Reflex	Rapid Stretch of muscle (test: tap on muscle tendon) Excites Muscle Spindle sensory neurons (NOT Golgi Tendon Organ)	Stretched muscle contracts rapidly (monosynaptic connection); also excite synergist and Inhibit antagonist	<u>Clinical Diagnosis</u> - tap to single muscle tendon can be used to test innervation of muscle (Ex. Tap to Quadriceps Tendon (knee jerk reflex tests Femoral Nerve (L2/3/4)) <u>Hyporeflexia</u> - decrease in stretch reflexes occurs in Spinal Nerve compression, Lower <u>Motoneuron</u> Diseases, Muscle atrophy etc. <u>Hyperreflexia</u> - (increase) - <u>Note: characteristic of CNS NOT peripheral nerve damage</u> - Upper Motor Neuron lesions (ex. damage Corticospinal tract); note: <u>Clonus</u> = hyperreflexia - repetitive contractions to single stimulus]

# REFERENCE SLIDE: SEQUENCE OF STRUCTURES IN LUMBAR PUNCTURE

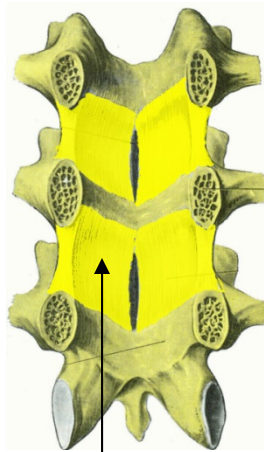


ii. Superficial Fascia  
i Skin

path of needle  
between vertebrae



iii. Supraspinous and  
iv. Interspinous ligaments



v. Ligamentum flavum

b. Structures that needle passes through in lumbar puncture in midline to enter Subarachnoid space - superficial to deep

i. Skin

ii. Superficial Fascia

iii. Supraspinous ligament

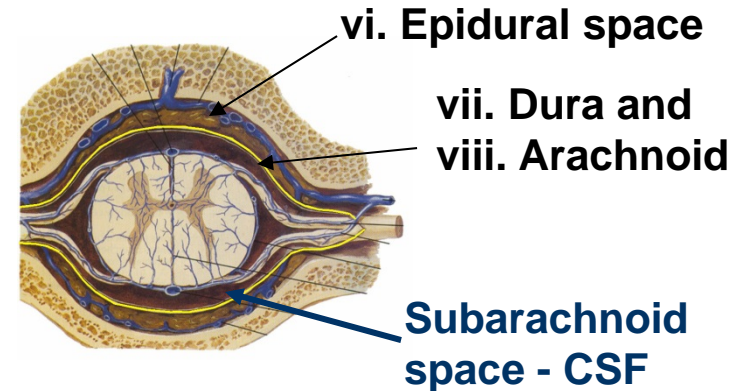
iv. Interspinous ligament

v. Ligamentum flavum (sudden yield, first 'pop') \*\*

vi. Epidural space (connective tissue and fat)

vii. Dura mater (sudden yield, second 'pop') \*\*

viii. Arachnoid



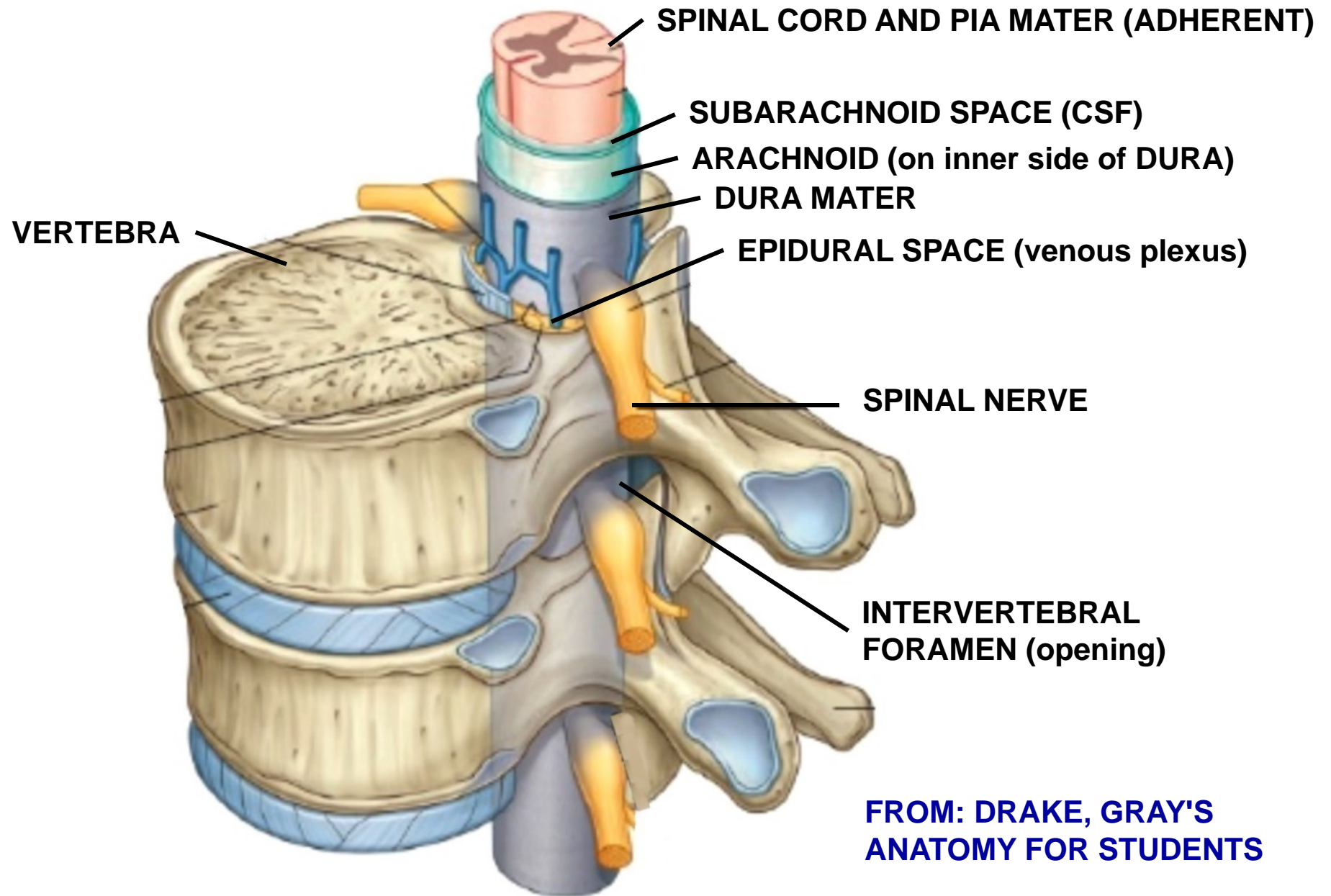
vi. Epidural space

vii. Dura and  
viii. Arachnoid

Subarachnoid  
space - CSF

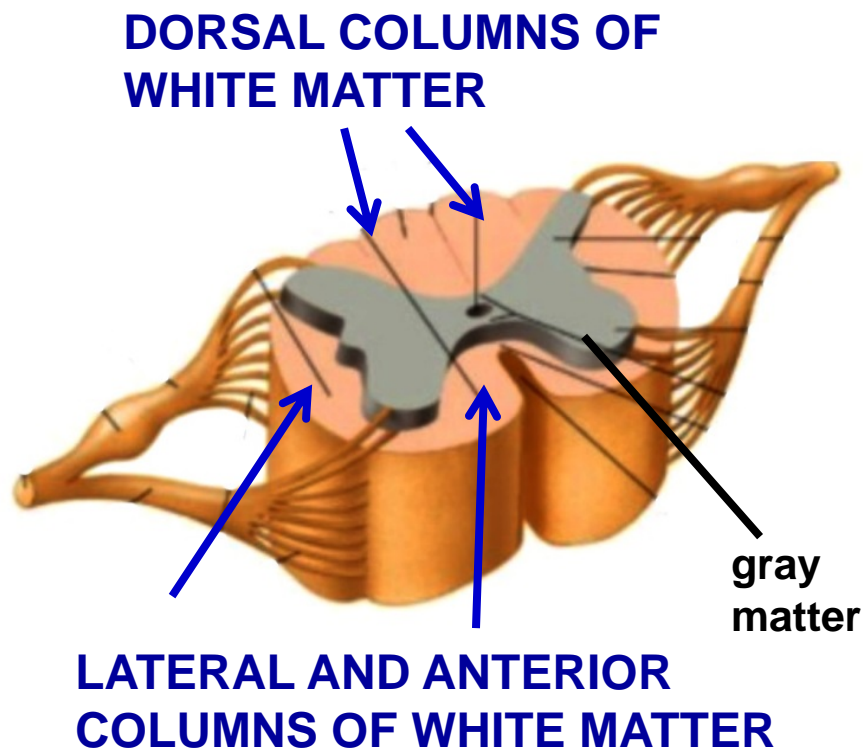


## SUMMARY DIAGRAM: SPINAL CORD, MENINGES IN VERTEBRAL CANAL



## SOME USEFUL TERMINOLOGY - applicable to terms used in clinical courses

- Spinal cord has central gray matter and surround white matter (axons)
- White matter is described as **Dorsal, Lateral and Ventral Columns**.
- White matter contains ascending and descending tracts.



**DORSAL COLUMNS - SENSORY**  
contains axon branches of sensory neurons that carry fine/discriminative touch, conscious proprioception, and vibration

**LATERAL AND ANTERIOR COLUMNS OF WHITE MATTER -**  
contains (in part) 1) **Spinothalamic tracts** (SENSORY) of neurons that receive sensory inputs about crude touch, pain and temperature  
2) **CORTICOSPINAL TRACTS - MOTOR** - voluntary motor control

**Note: STROKE = "Cerebrovascular accident" - INTERRUPT OR BLOCK BLOOD FLOW to brain (either block or rupture vessel, i.e. bleed)**

# **MAJOR POINTS: CLINICALLY IMPORTANT: REVIEW CLINICAL PROCEDURES**

1- **EPIDURAL ANESTHESIA** - put needle in **EPIDURAL SPACE** = space surrounding SPINAL CORD, INSIDE VERTEBRAL CANAL **contains NO MAJOR NEURONAL STRUCTURES; ONLY FAT, INTERNAL VERTEBRAL VENOUS PLEXUS** (net work of veins); ALL MAJOR NEURONAL STRUCTURES ARE INSIDE DURA (DURAL SAC);

2- **LUMBAR PUNCTURE** - sampling of Cerebrospinal fluid (CSF) - needle inserted between vertebrae into **SUBARACHNOID SPACE** (deep to DURA and ARACHNOID, which adheres to inner side of DURA) **INFERIOR to SPINAL CORD**; **SPINAL CORD ends** inferiorly at vertebral level **L1 in ADULT, L3 in newborn children**  
**INSERT NEEDLE at L3-L4 or L4-L5 in ADULT; must be L4-L5 in newborn children.**