

**TERRI SCHIAVO CT OF HER BRAIN**

# OVERVIEW OF NERVOUS SYSTEM

## OUTLINE OF LECTURE

I. INTRODUCTION/DIVISIONS OF NERVOUS SYSTEM

II. TERMINOLOGY OF NERVOUS SYSTEM

III. SPINAL NERVES AND DERMATOMES - nerve compression

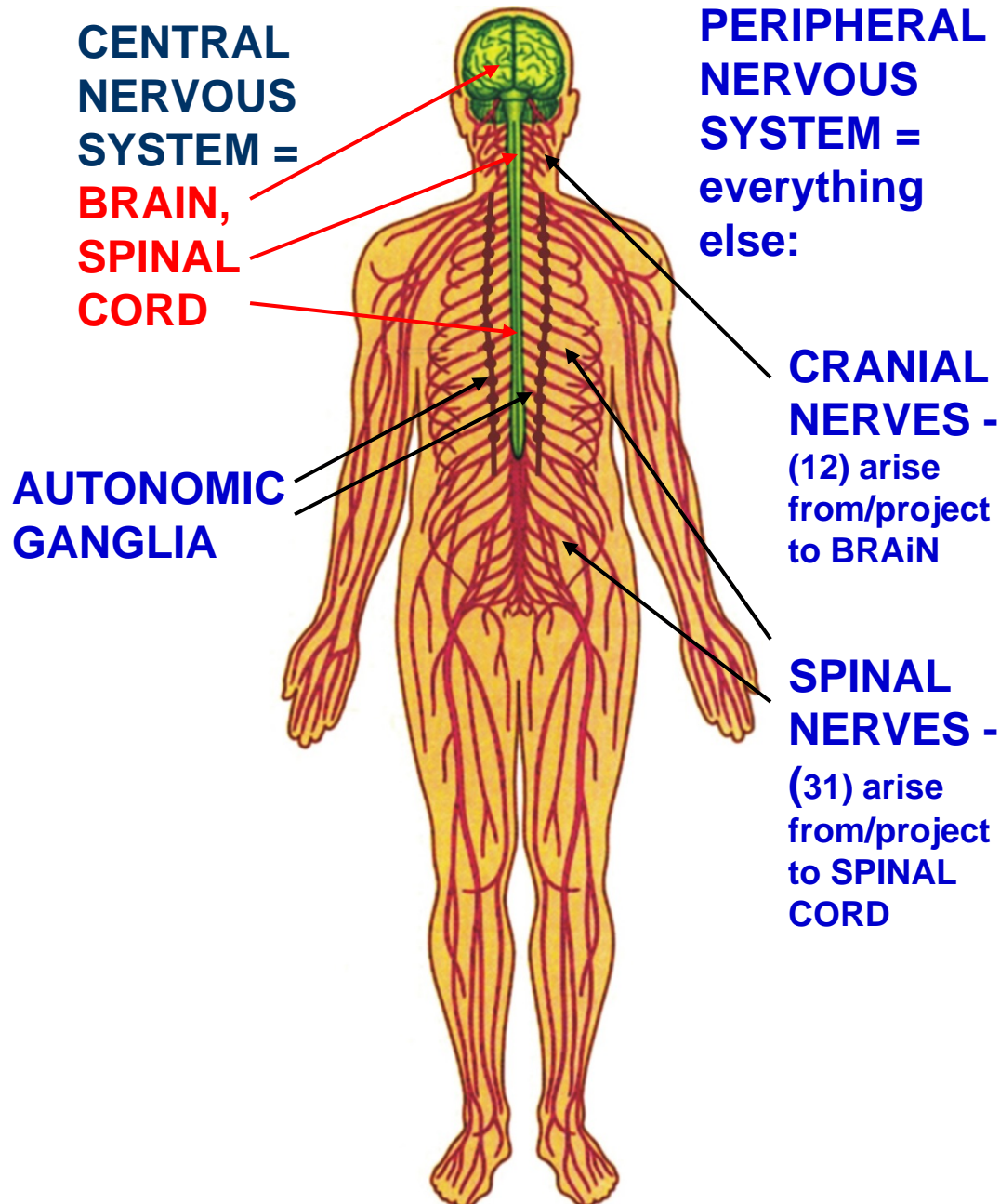
IV. LOCATION OF SPINAL CORD IN VERTEBRAL CANAL - changes in development

V. MENINGES OF SPINAL CORD

VI. CEREBROSPINAL FLUID (CSF) AND SPINAL 'TAP' = Lumbar puncture

Nervous system is the most complex and layered system in human body; required for human consciousness and behavior; **irreversible cessation of function of nervous system is legal definition of death**

# MAJOR DIVISIONS OF NERVOUS SYSTEM



**CENTRAL NERVOUS SYSTEM = BRAIN, SPINAL CORD**

**PERIPHERAL NERVOUS SYSTEM = everything else:**

**CRANIAL NERVES - (12) arise from/project to BRAIN**

**SPINAL NERVES - (31) arise from/project to SPINAL CORD**

**AUTONOMIC GANGLIA**

**A. CENTRAL NERVOUS SYSTEM (CNS) - definition is precise; consists of **BRAIN (contained in cranial cavity)** and **SPINAL CORD (contained in vertebral canal)**.**

**B. PERIPHERAL NERVOUS SYSTEM (PNS) = EVERYTHING ELSE INCLUDING:**

- 1) NERVES - CRANIAL NERVES, SPINAL NERVES that carry signals to and from the CNS;**
- 2) GANGLIA (collections of nerve cell bodies) including GANGLIA OF AUTONOMIC NERVOUS SYSTEM**
- 3) SENSE ORGANS (eye, inner ear, etc.)**

**SOMATIC NERVOUS SYSTEM -**  
voluntary, conscious precise sensation

**SOMATIC EFFERENTS -**  
 motor axons to skeletal muscles

ex. muscles of hand



**SOMATIC AFFERENTS -**  
 sensory axons to skin ; also joints, body position

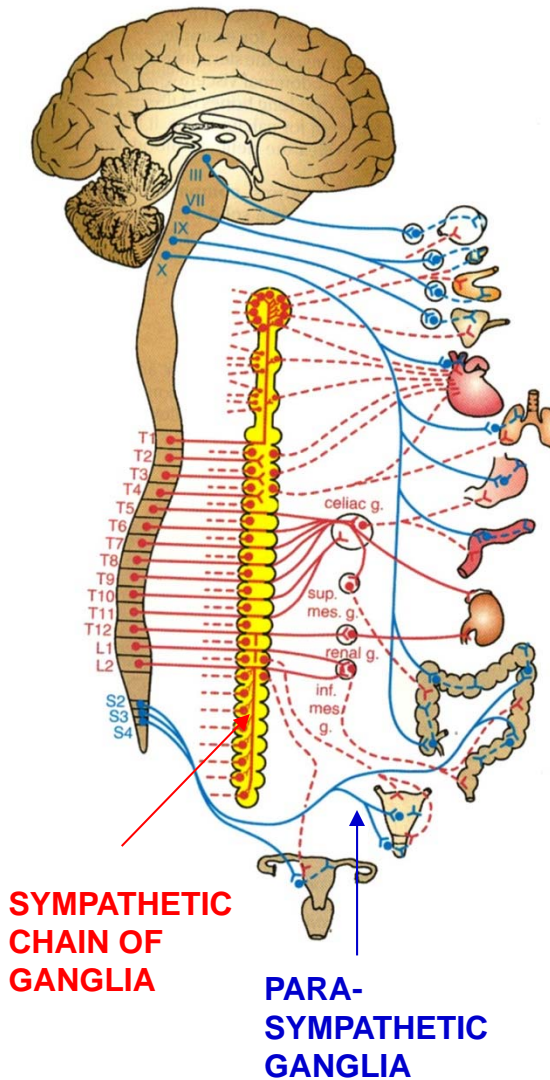
ex. skin of hand



**AUTONOMIC = VISCERAL NERVOUS SYSTEM -**  
involuntary, imprecise sensation, localization of pain

**VISCERAL EFFERENTS -**  
 (parasympathetic and sympathetic) - control smooth and cardiac muscle, glands and internal organs;

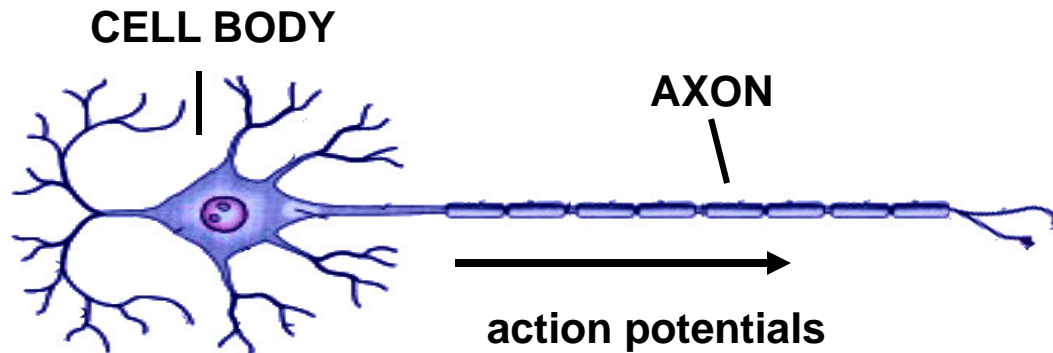
**VISCERAL AFFERENTS -** course with efferents - sensory neurons that innervate internal organs, blood vessels; only provide **imprecise localization of sensation** and dull sense of pressure, pain, etc.



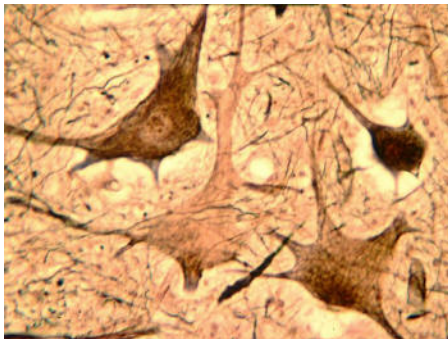
**SYMPATHETIC CHAIN OF GANGLIA**

**PARASYMPATHETIC GANGLIA**

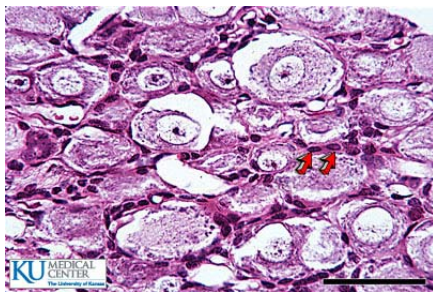
# TERMINOLOGY OF GROUPS OF CELL BODIES AND AXONS



NUCLEI - in CNS

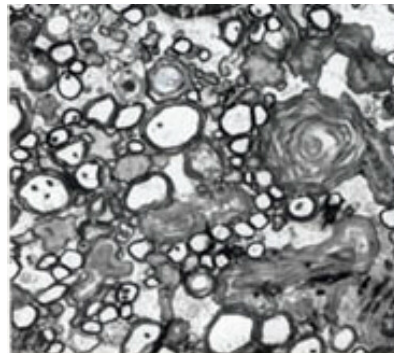


GANGLIA - in PNS

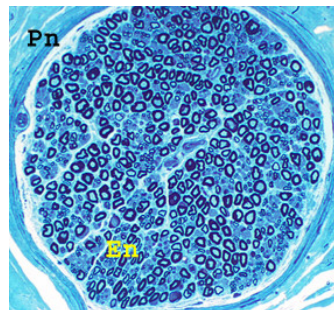


ex. Dorsal Root Ganglion

TRACTS - in CNS



NERVES - in PNS



## D. Terminology

1. **Nuclei** = Groups of nerve cell bodies in Central Nervous system (CNS); Grey matter.

2. **Ganglia** = Groups of nerve cell bodies in Peripheral Nervous system (PNS)

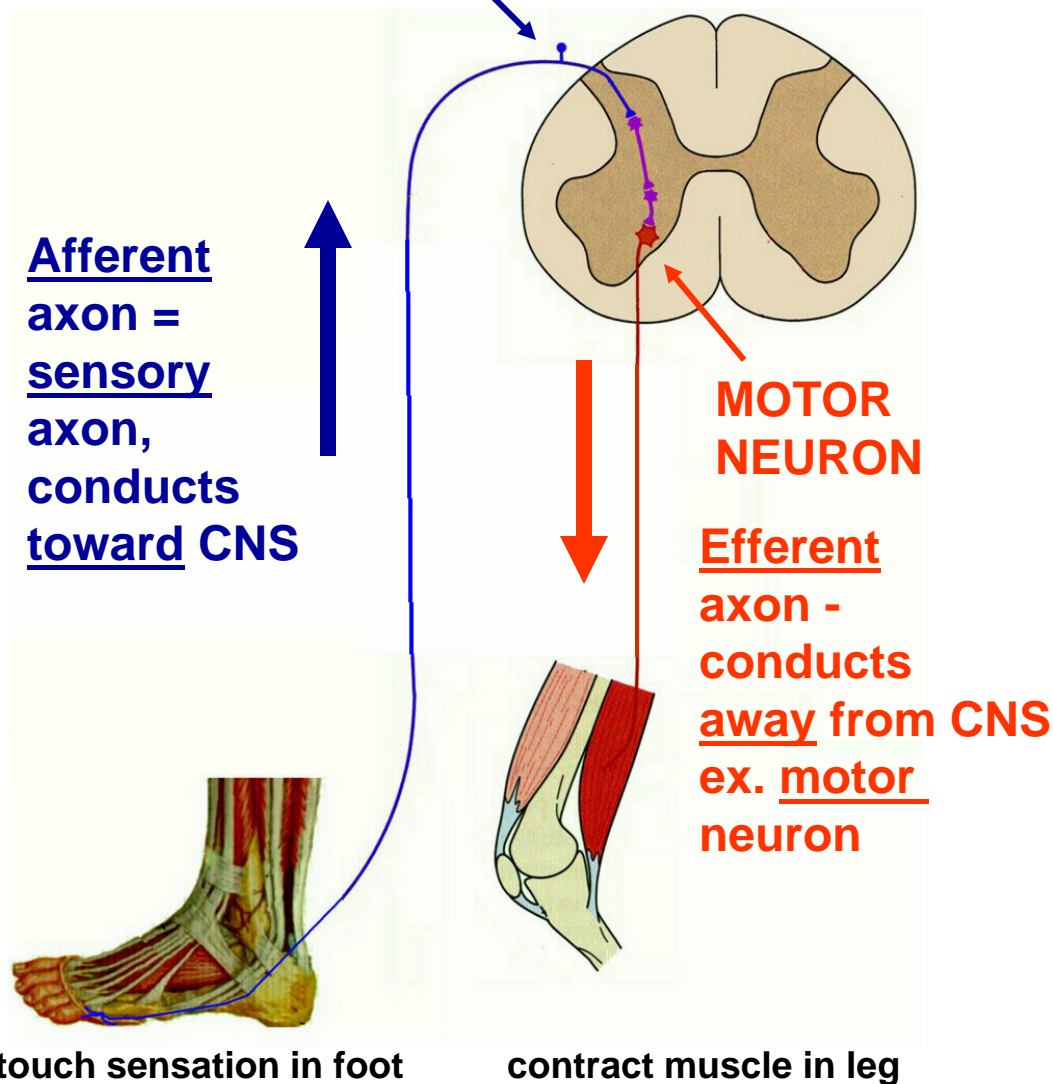
3. **Tract or Columns** - Groups of axons in CNS; White matter.

4. **Nerves** = Groups of axons in PNS.

# TERMINOLOGY: AXONS IN PERIPHERAL NERVES

## SENSORY NEURON

View of Spinal Cord in Horizontal Section  
CNS

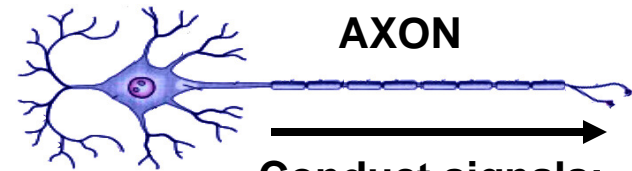


Afferent axon = sensory axon, conducts toward CNS

**MOTOR NEURON**

Efferent axon - conducts away from CNS ex. motor neuron

NEURON = nerve cell



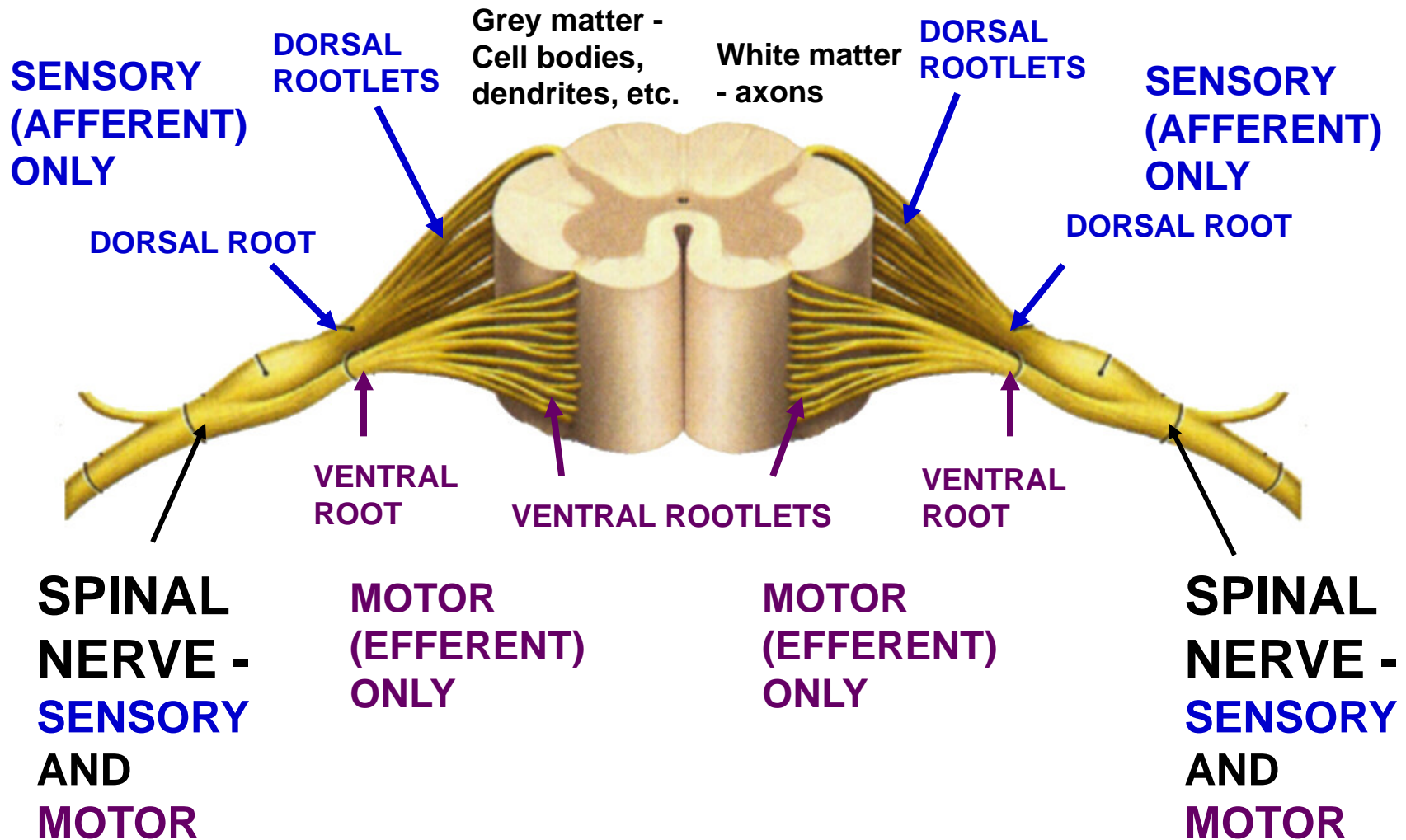
AXON

Conduct signals: action potentials

**a. Afferent axons** (also called **sensory axons** or just afferents) - axons of **sensory neurons** that conduct signals **toward CNS** (ex. sensory neurons signaling touch, taste, pain, etc.)

**b. Efferent axons** - axons of neurons that conduct signals **away from CNS**; most efferent axons are **motor axons** that cause contractions of muscles; **OTHER EFFERENT AXONS ARE AUTONOMIC**; more complicated.

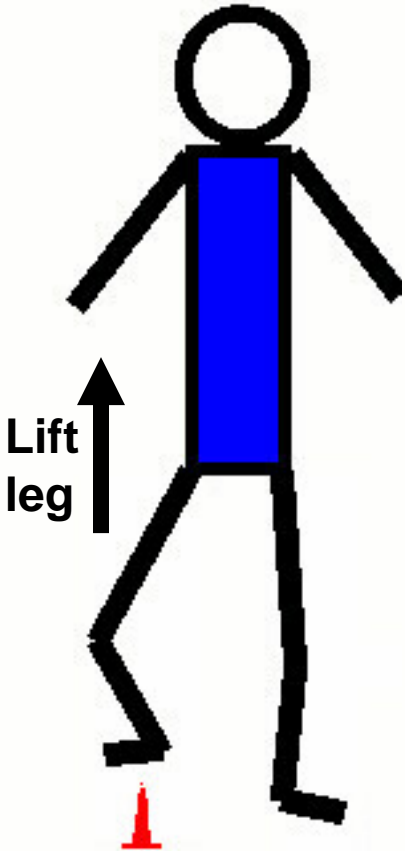
## FORMATION OF SPINAL NERVE



- 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 unite to form a Spinal Nerve; contains sensory and motor axons

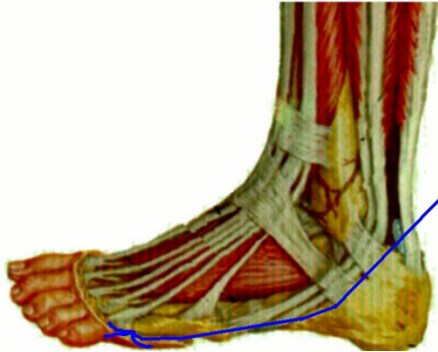
**REFLEX = STEREOTYPED MOTOR RESPONSE TO A SPECIFIC SENSORY STIMULUS**

**Example: FLEXOR REFLEX –**  
**SENSORY STIMULUS - Stepping on nail**  
**causes pain**  
**MOTOR RESPONSE - Lift leg**



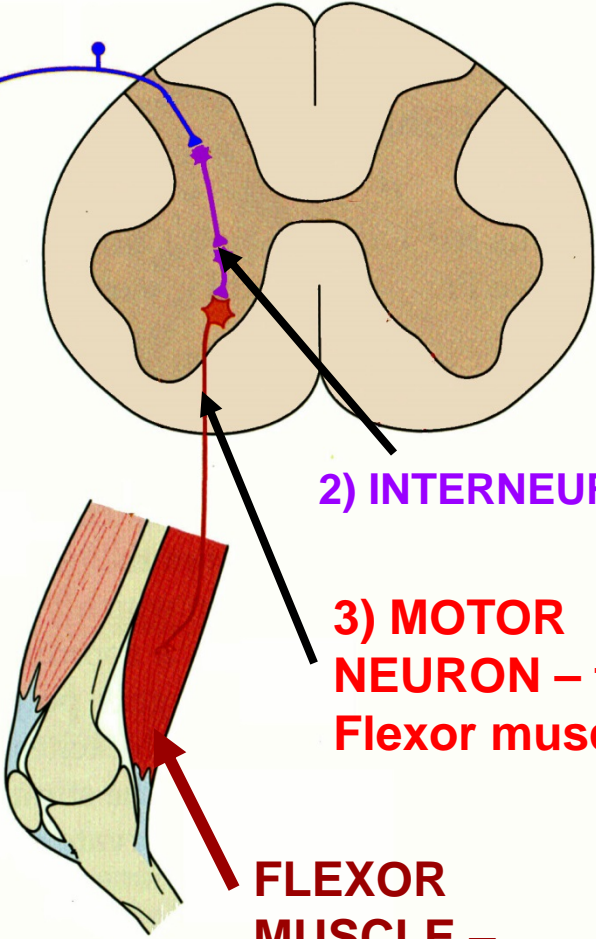
Lift leg

Step on nail



1) **SENSORY NEURON – cutaneous afferent in sole of foot (A delta)**

Knee Joint



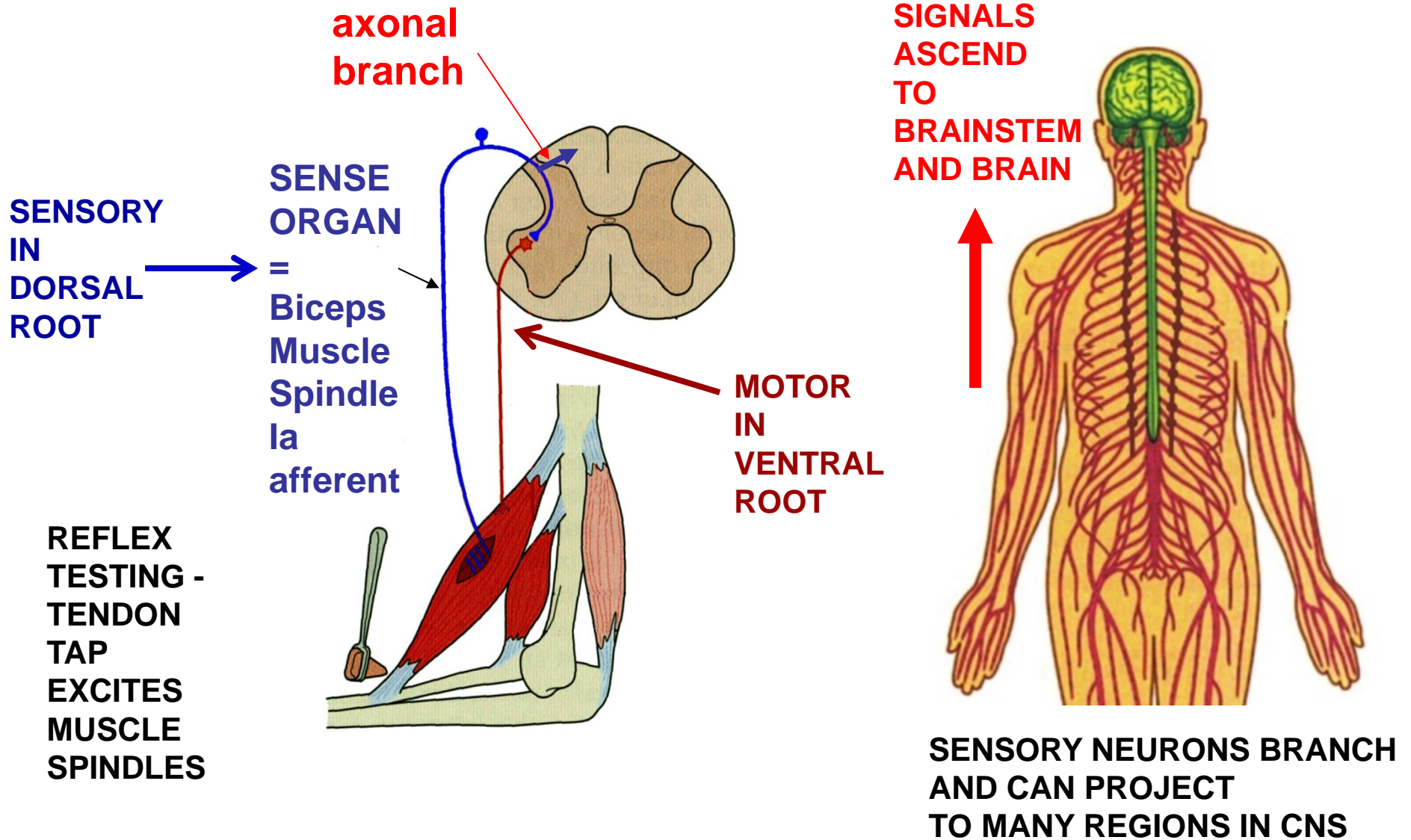
2) **INTERNEURON(S)**

3) **MOTOR NEURON – to Flexor muscle**

**FLEXOR MUSCLE – Hamstring flexes knee**

**REFLEXES CAN BE USED TO TEST NERVOUS SYSTEM FUNCTION, LOCATE SITE OF LESION**

**STRETCH (DEEP TENDON) REFLEXES - tapping on the tendon of a muscle stretches the muscle and causes it to reflexively contract.**





**STRETCH (DEEP TENDON) REFLEXES - ELICIT BY TAPPING ON MUSCLE TENDON - CAUSES MUSCLES TO CONTRACT**

**NORMAL PATIENT**



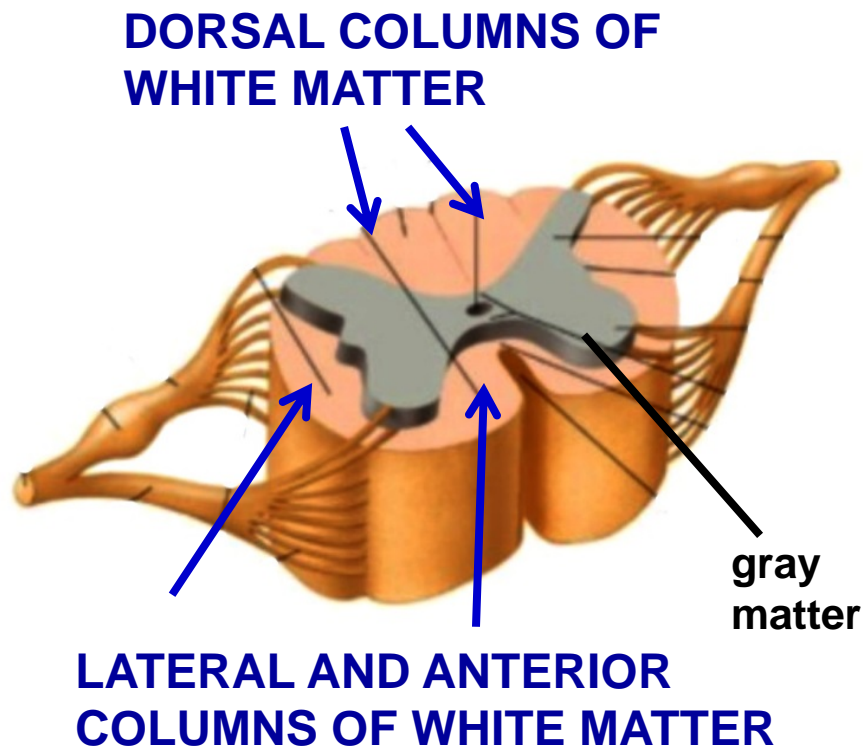
**STRETCH (DEEP TENDON) REFLEXES - ELICIT BY TAPPING ON MUSCLE TENDON - CAUSES MUSCLES TO CONTRACT**

**ABNORMAL - CHILD WITH CNS LESION (STROKE) - REFLEXES HYPERACTIVE ON RIGHT SIDE**



## ORIENTATION: applicable to terms used in ICS course

- 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 -

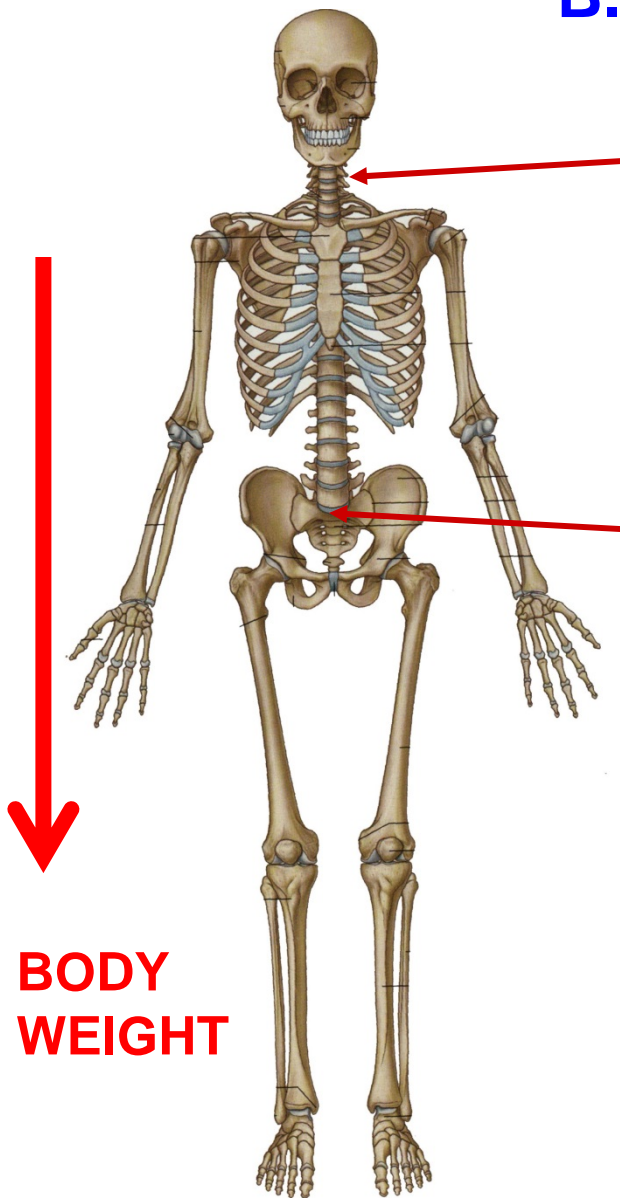
contains axon branches of sensory neurons that carry fine/discriminative touch, conscious proprioception, and vibration

### LATERAL AND ANTERIOR COLUMNS OF WHITE MATTER -

contains (in part) **Spinothalamic tracts** of neurons that receive sensory inputs about crude touch, pain and temperature

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

## B. REGIONS OF VERTEBRAL COLUMN



- Structure of vertebrae differ in different regions
- Some cervical vertebrae are uniquely identifiable (ex. C1, C2 and C7)

**Important Note: Nomenclature short hand: C6 means the sixth cervical vertebra**

# SPINAL NERVES AND VERTEBRAL LEVELS

## LEVELS

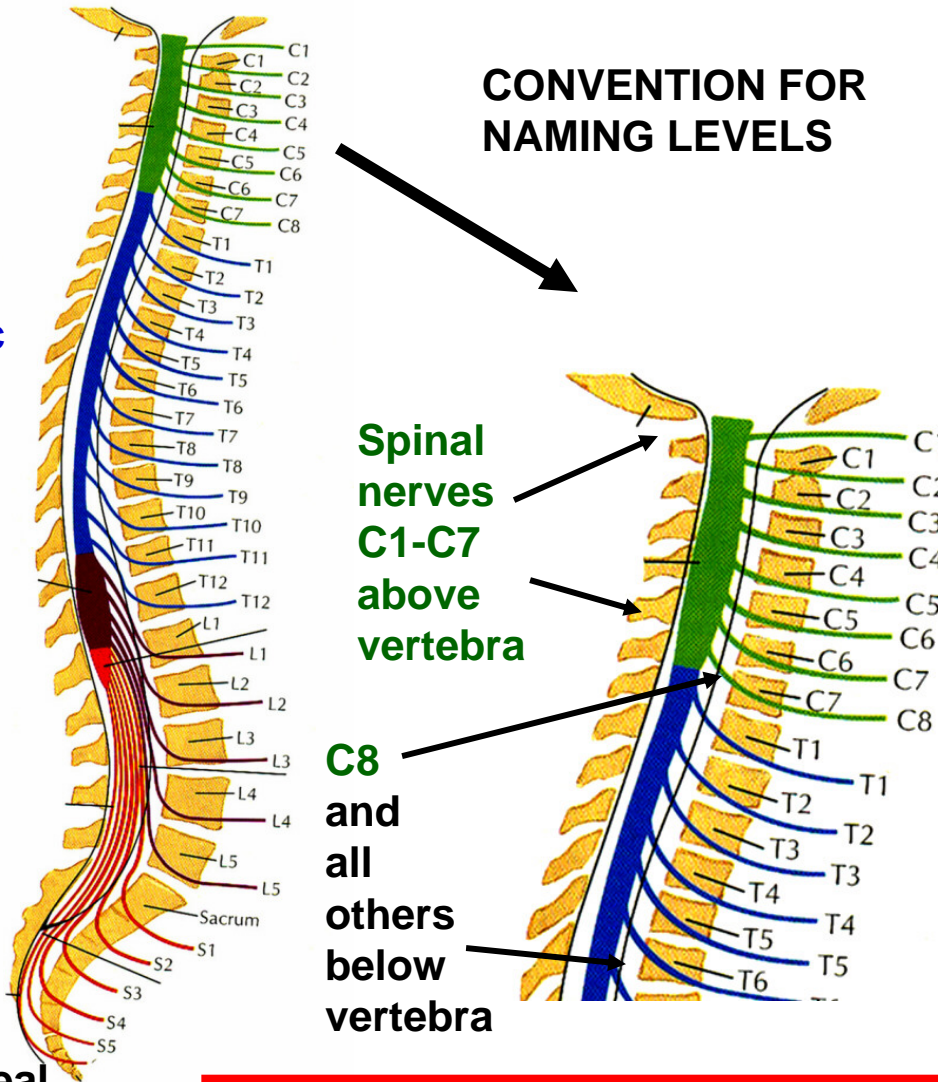
Cervical  
(C1-C8)

Thoracic  
(T1-T12)

Lumbar  
(L1-L5)

Sacral  
(S1-S5)

Coccygeal  
(Co1)

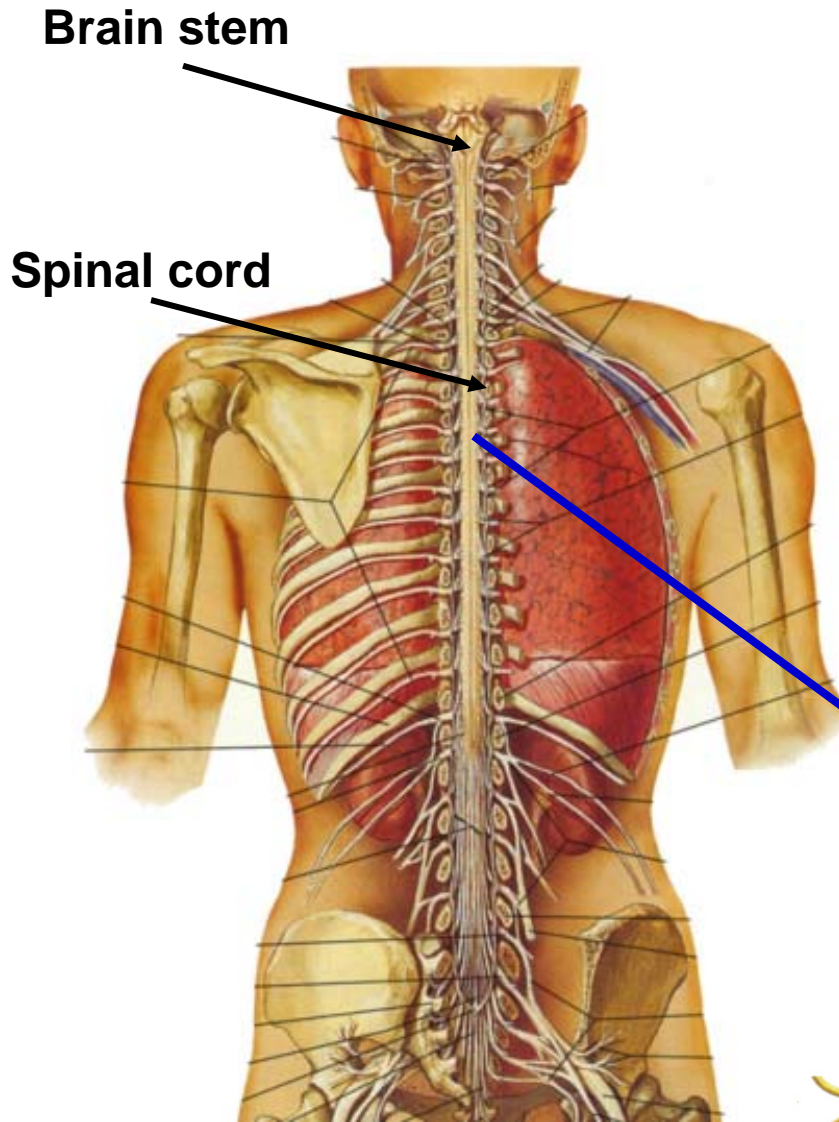


2. Spinal nerves - arise from/project to spinal cord; there are 31 spinal nerves (8 cervical, 12 thoracic, 5 lumbar, 5 sacral and 1 coccygeal).

**Clinically Important Note:** 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**

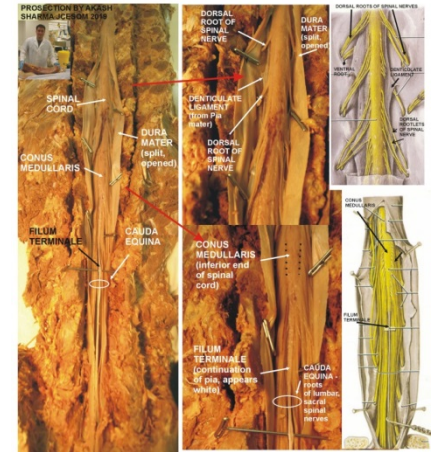
### III. SPINAL NERVES AND DERMATOMES



Spinal cord is located within vertebral canal and is continuous with the brain at the medulla oblongata (inferior part of brain stem)

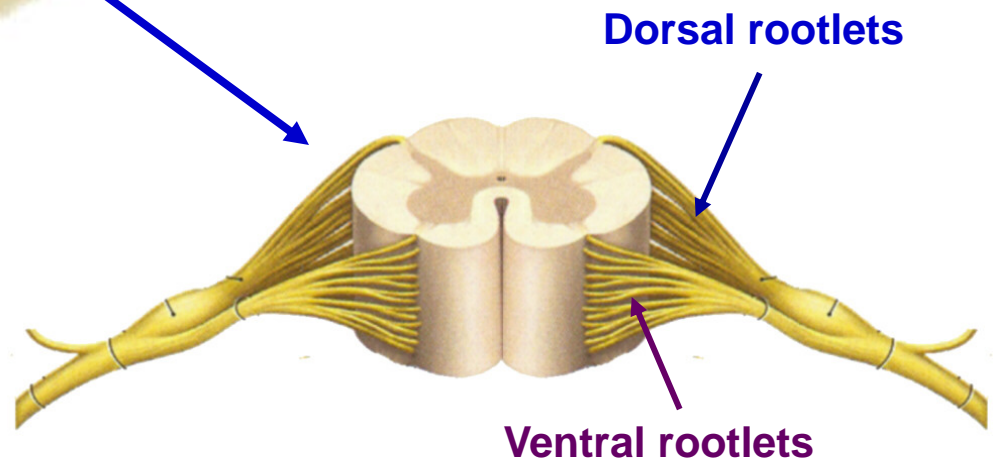
**Dorsal** and **ventral rootlets** that form spinal nerves attach to the spinal cord along its length.

SPINAL CORD

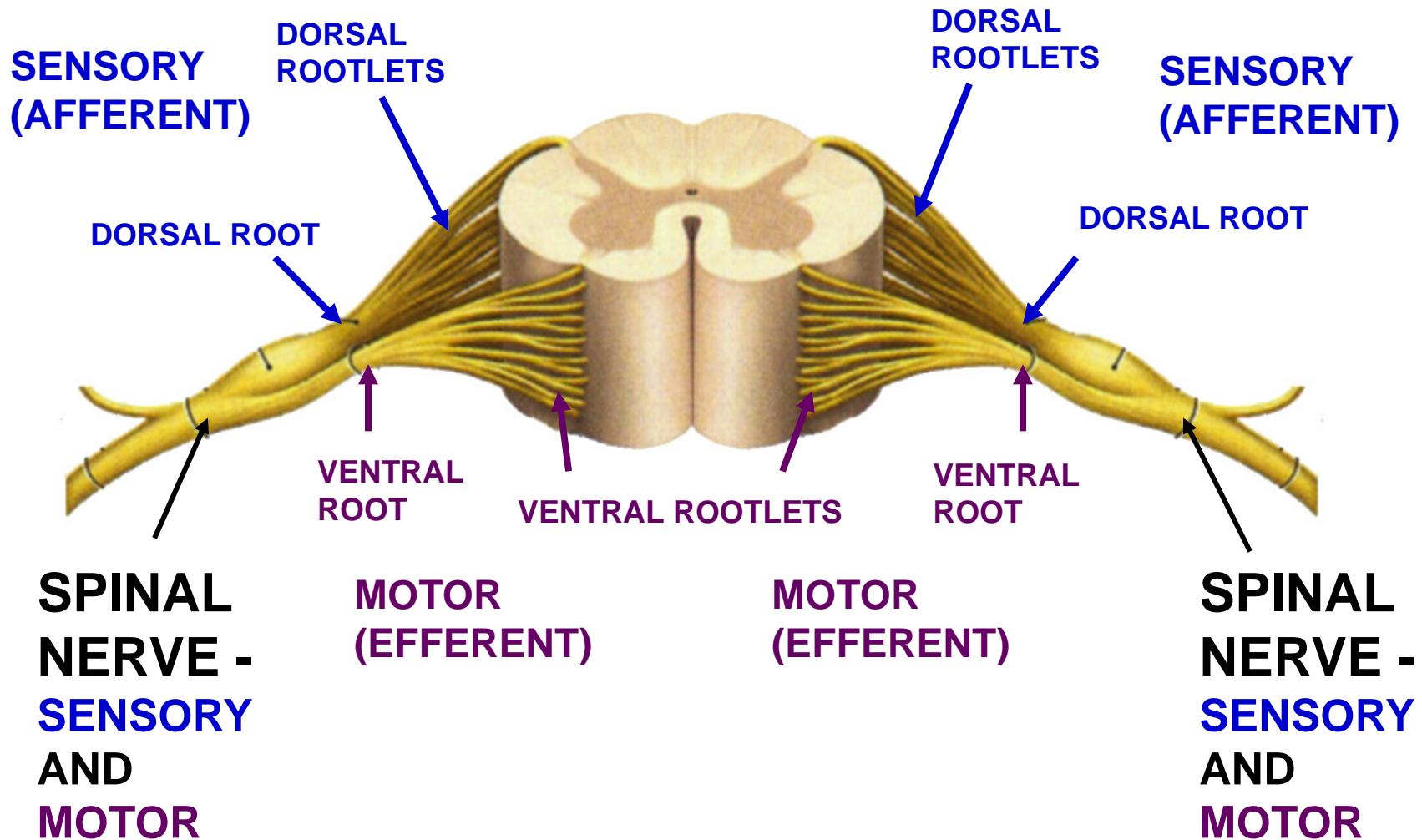


SEE ON PROSECTIONS 44, 43

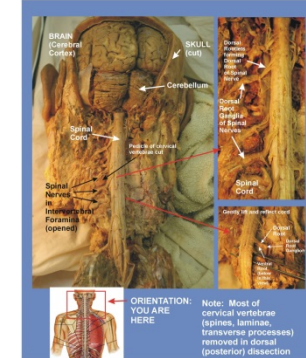
section of spinal cord removed (rotated)



## FORMATION OF SPINAL NERVE



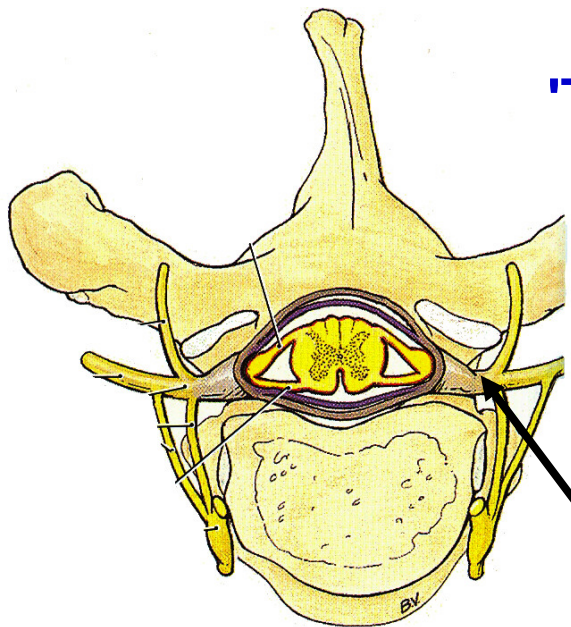
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SEE PROSECTION 43  
Dorsal Root Ganglia

## 'TYPICAL' SPINAL NERVE

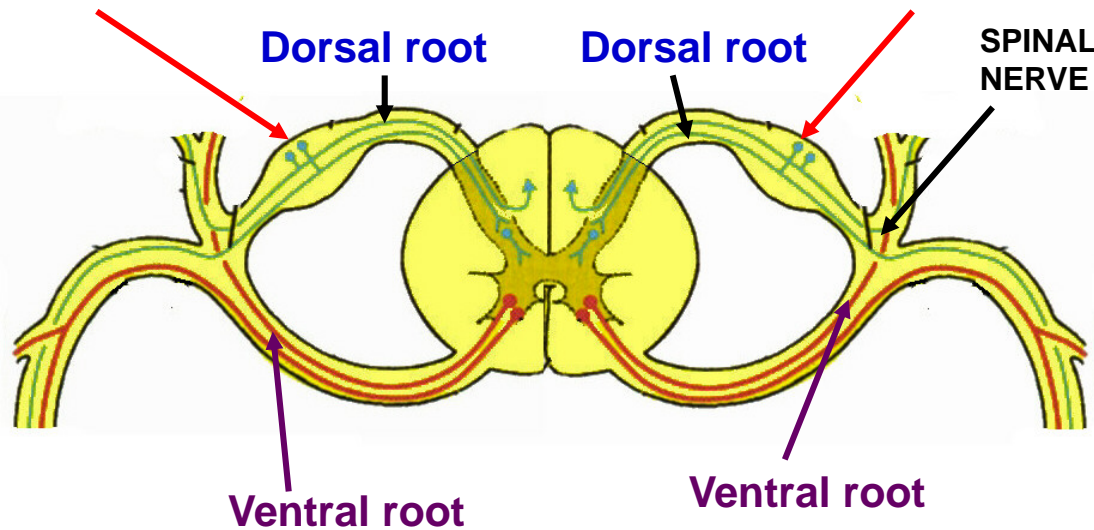
- formed at intervertebral foramen where spinal nerve exits vertebral canal; spinal nerves contain both sensory and motor axons



SPINAL NERVE

Dorsal root ganglion

Dorsal root ganglion



### A. Components and Structures

1. **Dorsal root** of spinal nerve - forms from series of dorsal rootlets; contains afferent (sensory) axons.

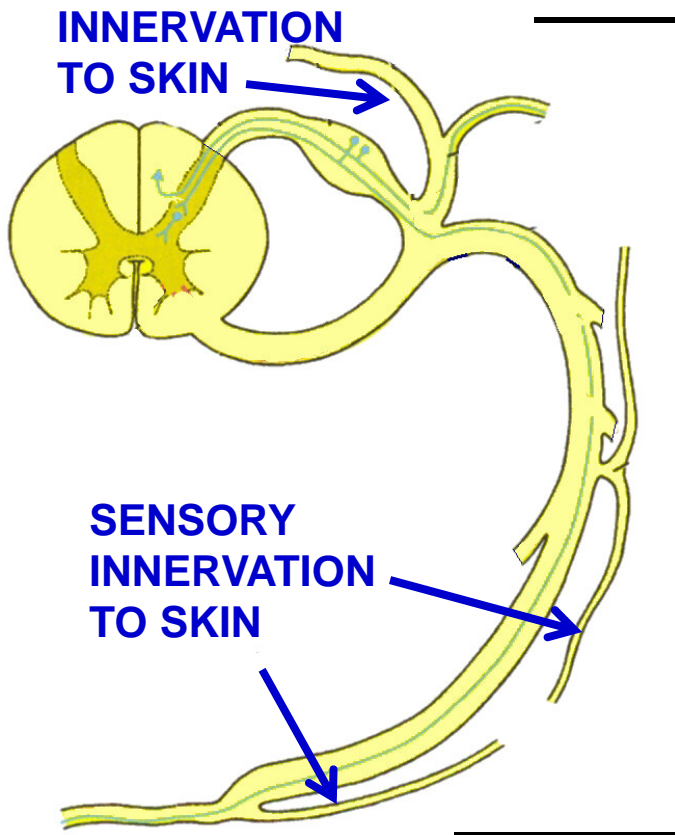
2. **Dorsal root ganglion** - cell bodies of all sensory neurons (somatic and visceral) are located at dorsal root ganglia; look like swellings attached to dorsal root.

3. **Ventral root** of spinal nerve - forms from ventral rootlets; contains efferent (motor) axons

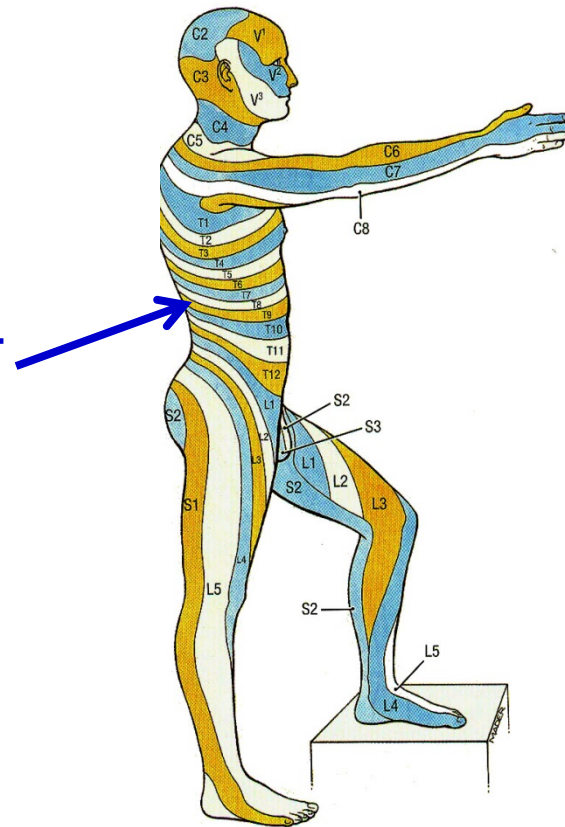


# DERMATOME = area of skin innervated by a single spinal nerve

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

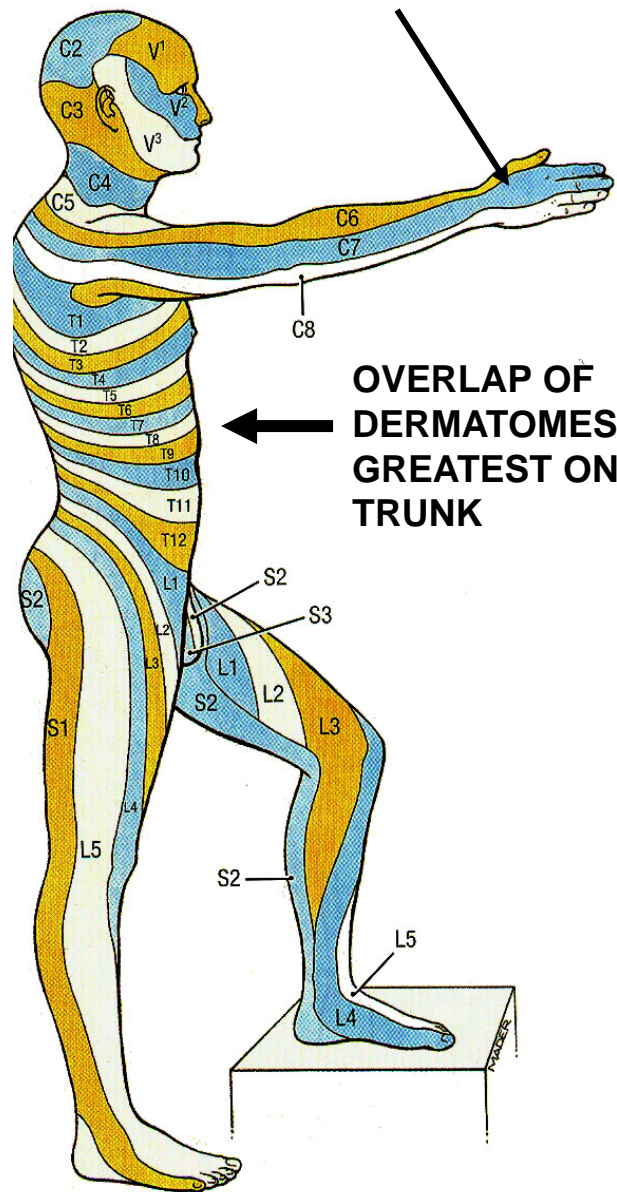


Dermatome - is area of skin innervated by a single spinal nerve



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 = area of skin innervated by a single spinal nerve



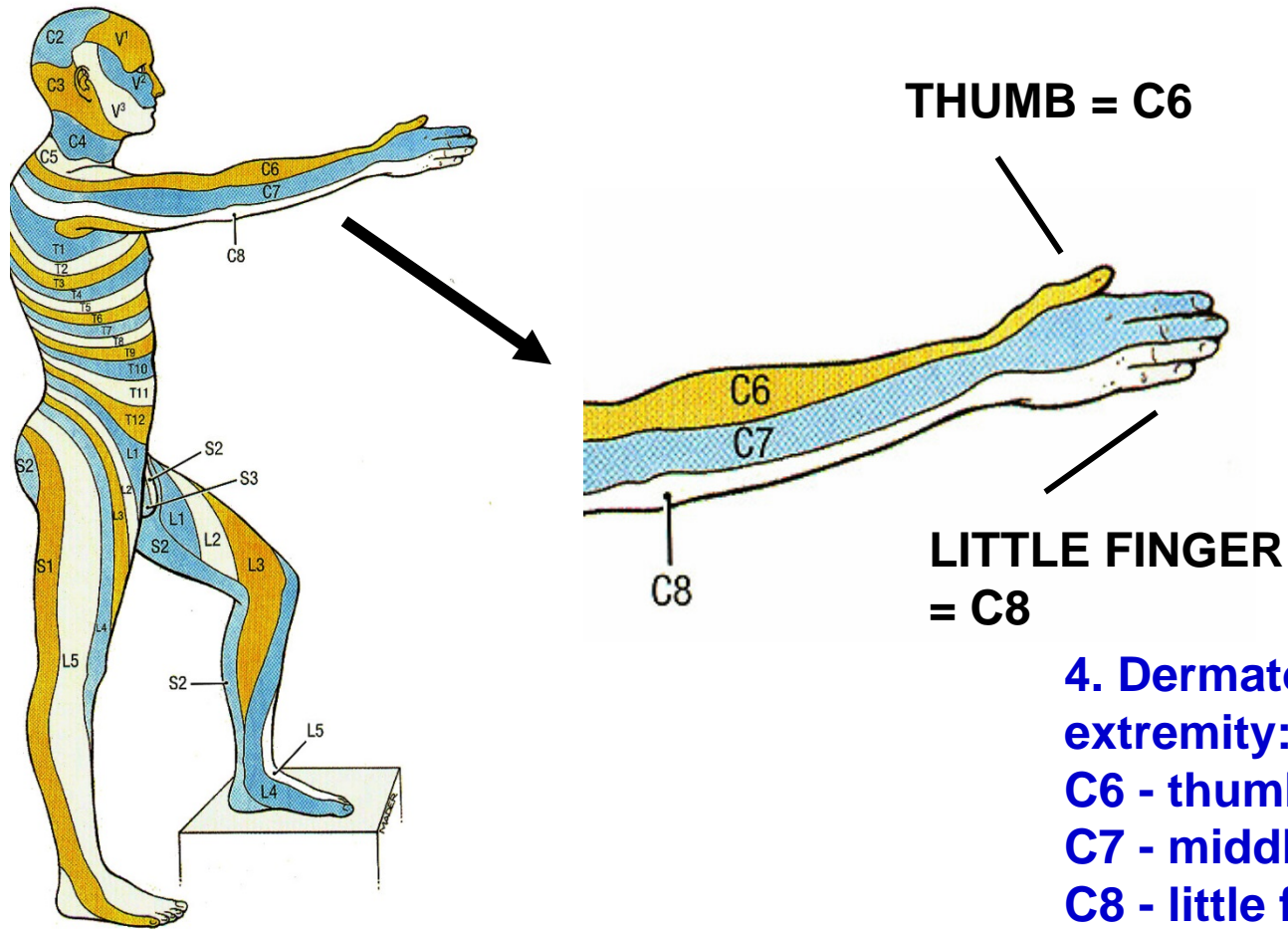
**1. Structure - AREAS OF SKIN INNERVATED** by different spinal nerves form a continuous series; in thorax dermatome map looks like stripes; more complex in extremities.

**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

**Questions: What is the level of a herniated disc that would produce numbness of thumb? Little finger?**

# SPINAL NERVES AND VERTEBRAL LEVELS

## LEVELS

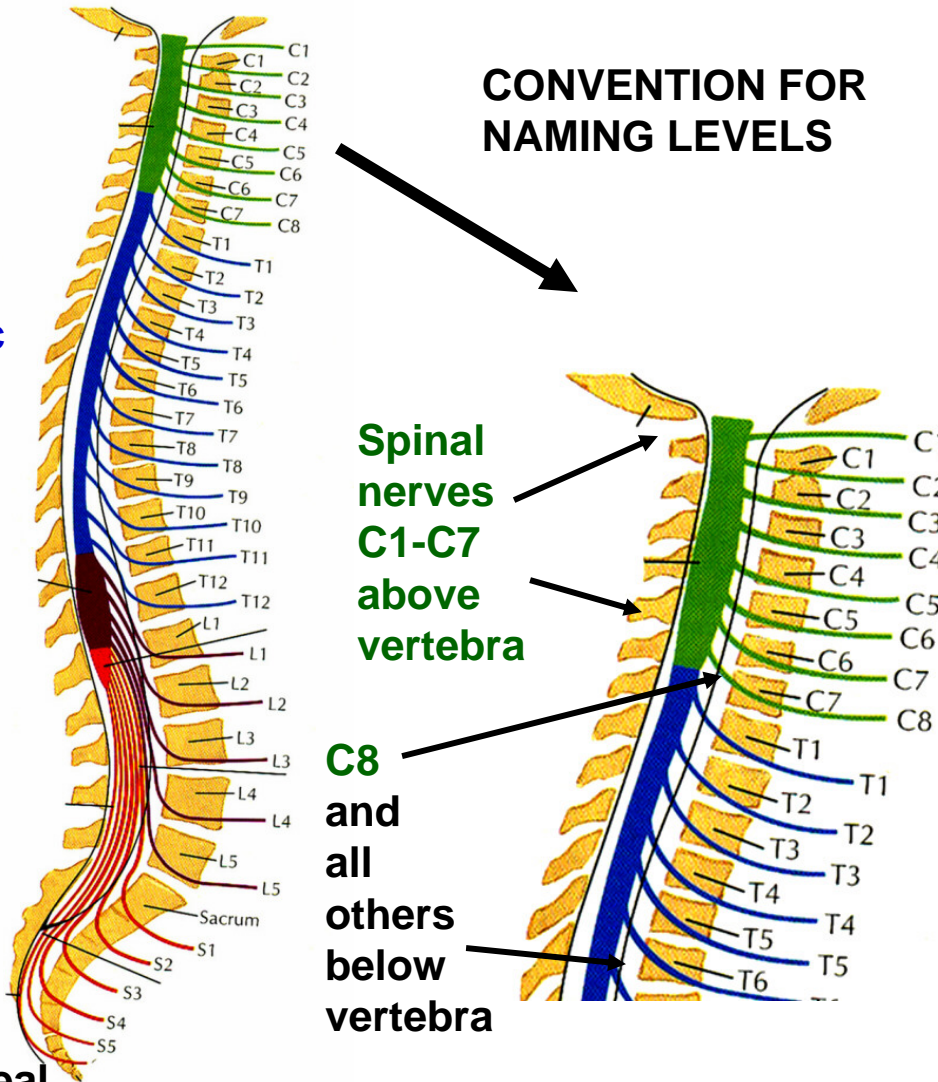
Cervical  
(C1-C8)

Thoracic  
(T1-T12)

Lumbar  
(L1-L5)

Sacral  
(S1-S5)

Coccygeal  
(Co1)



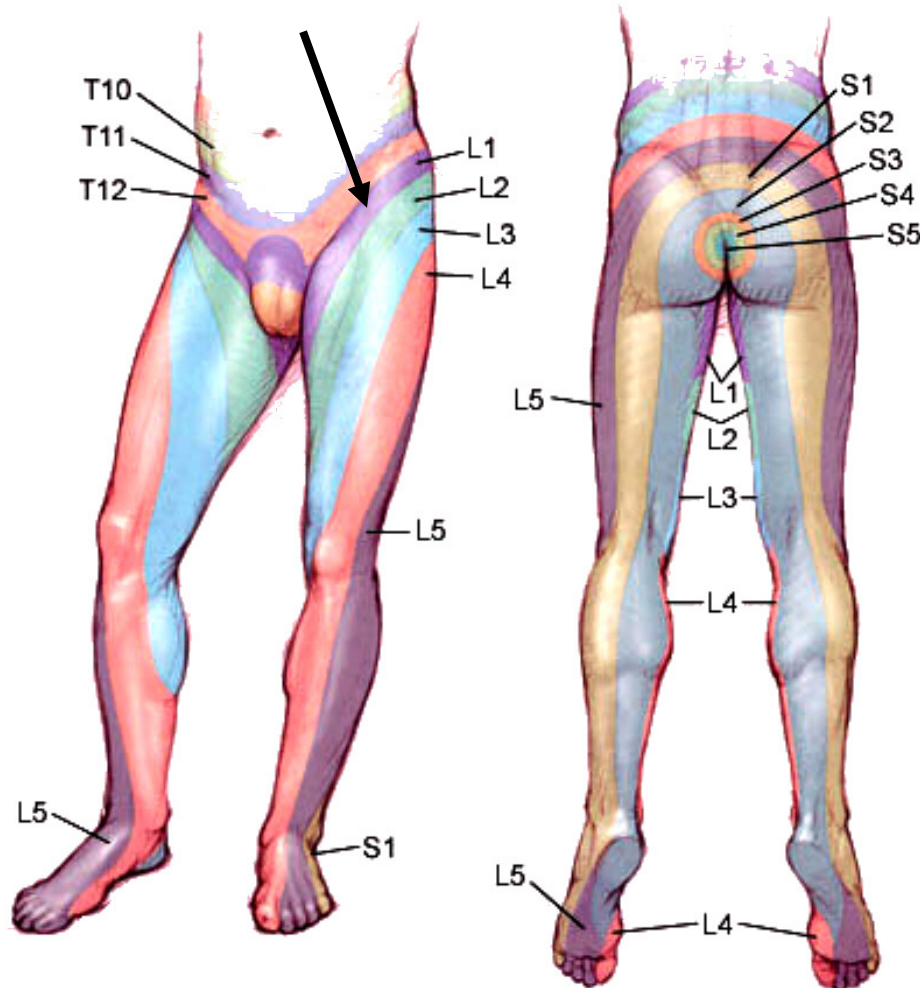
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# DERMATOMES OF LOWER EXTREMITY - FOOT

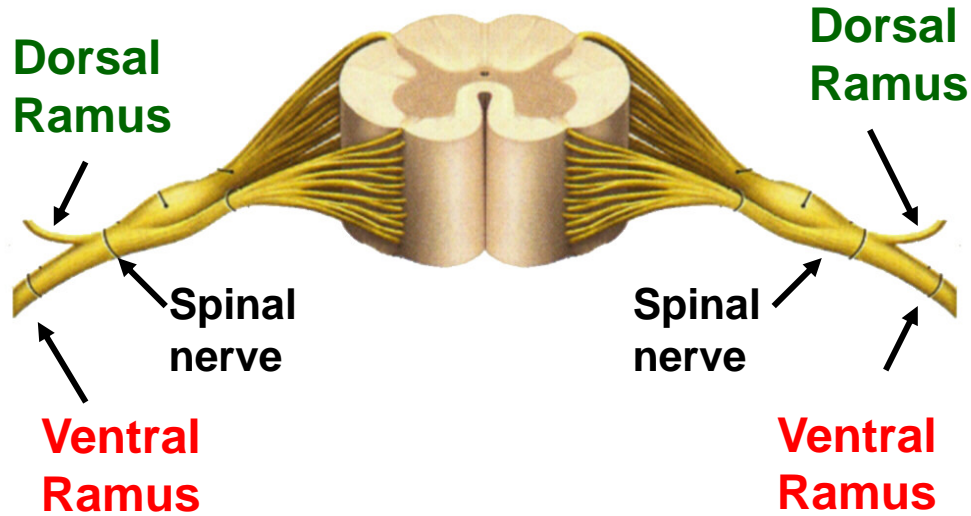
## SKIN OVERLYING INGUINAL LIGAMENT



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

**Questions: What is the level of a herniated disc that would produce numbness of the big toe? Numbness of skin overlying the inguinal ligament?**

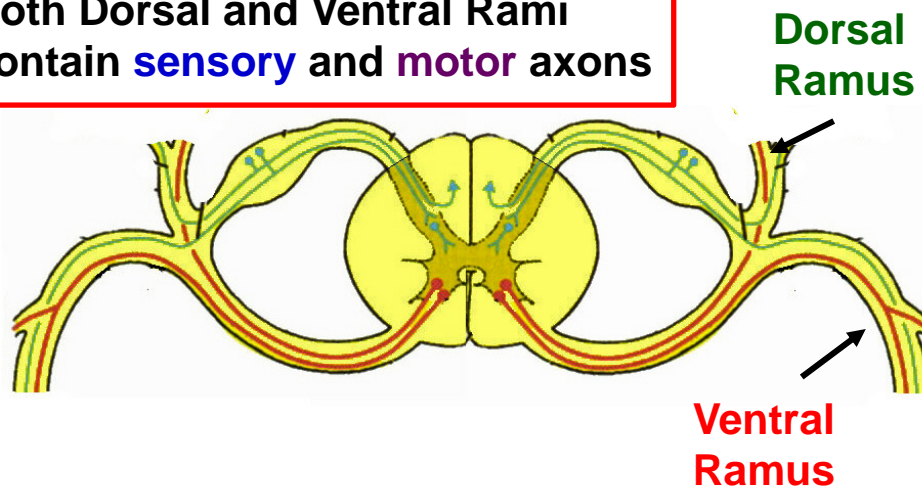
# DORSAL AND VENTRAL RAMI OF SPINAL NERVES



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.

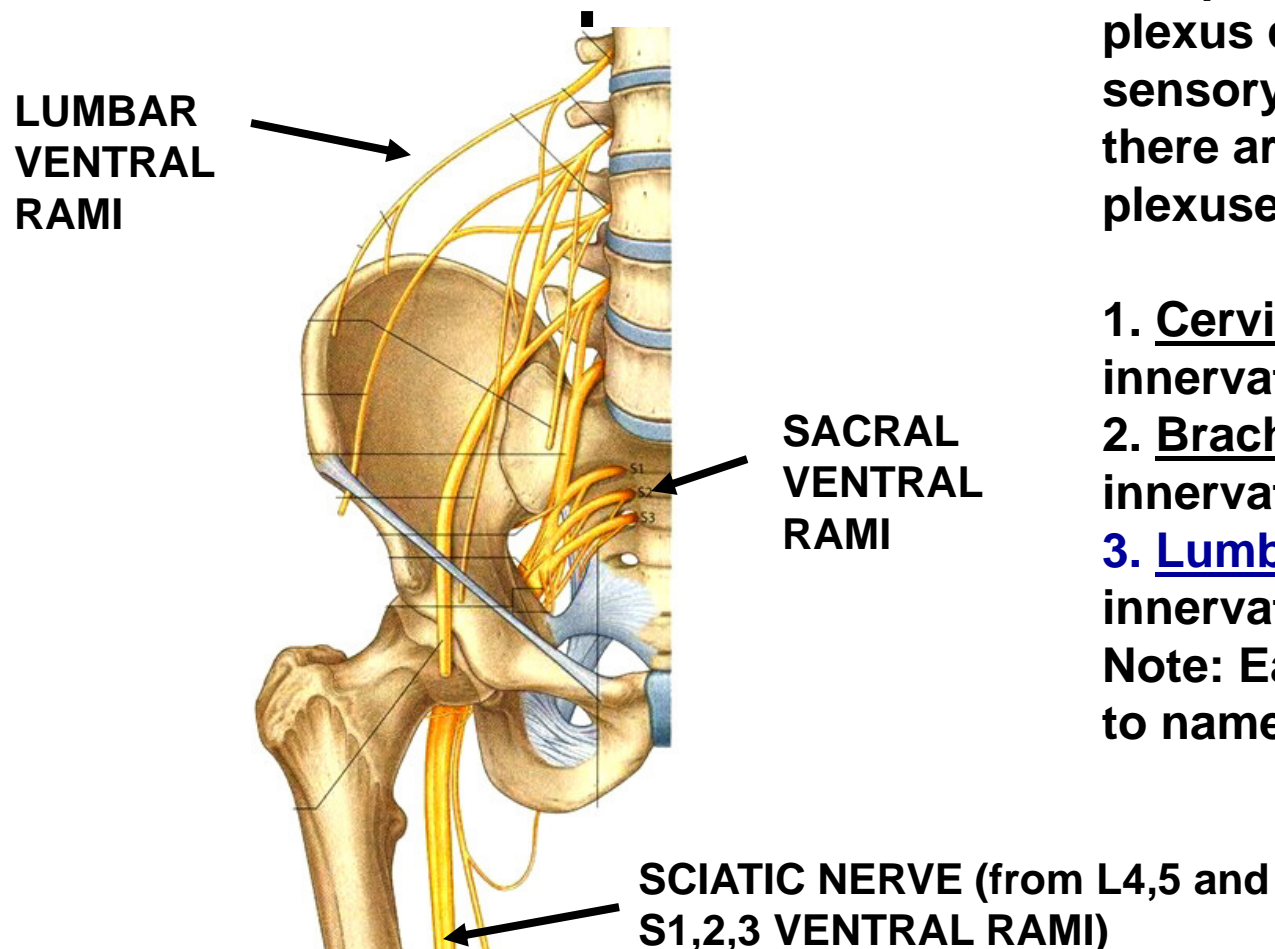
Both Dorsal and Ventral Rami contain **sensory** and **motor** axons



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:

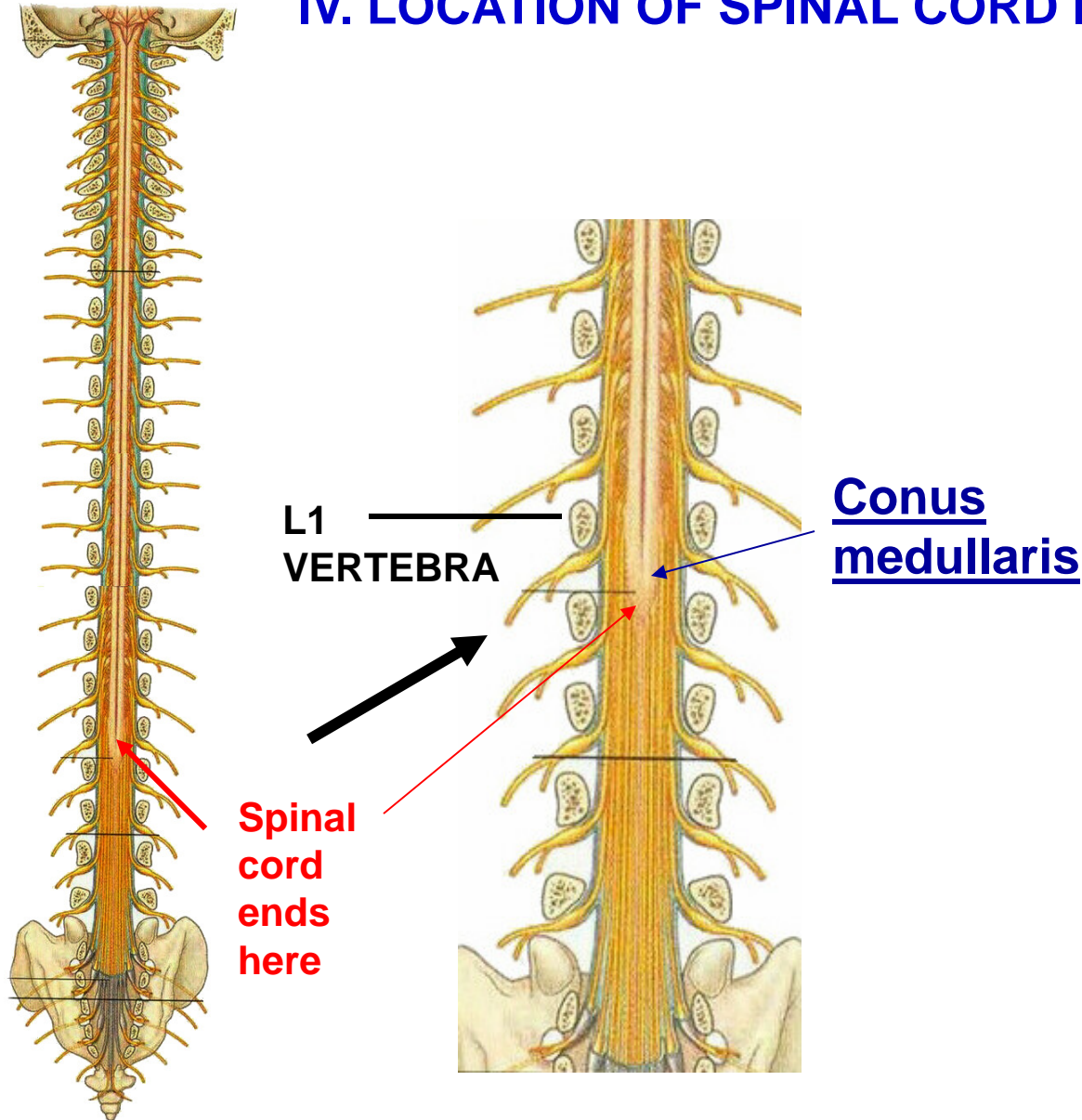
1. Cervical Plexus - innervates neck

2. Brachial Plexus - innervates upper extremity

3. Lumbosacral Plexus - innervates **lower extremity**

Note: Each plexus gives rise to named nerves.

## IV. LOCATION OF SPINAL CORD IN VERTEBRAL CANAL

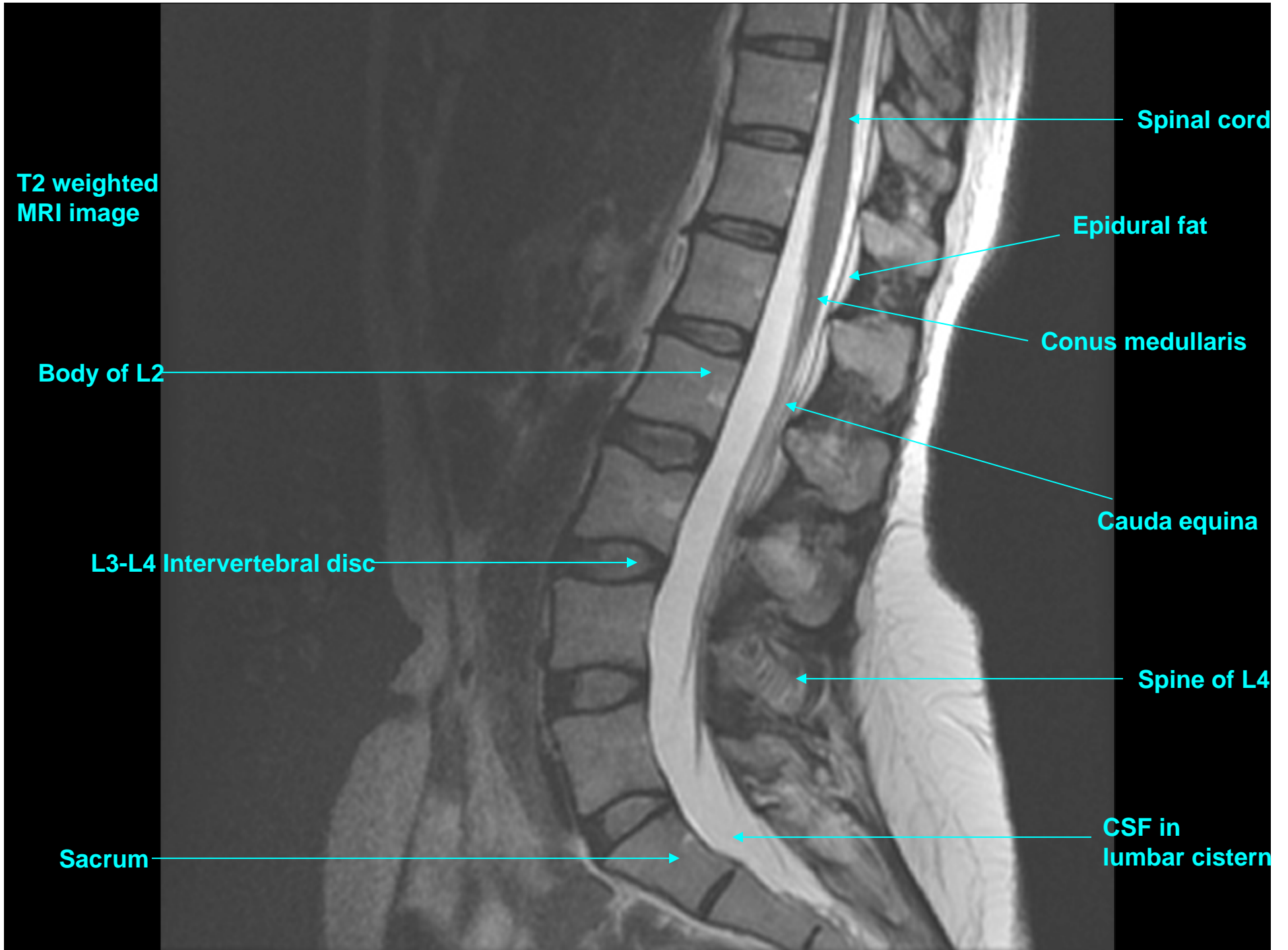


- spinal column (vertebra) increases greatly in length in development; spinal cord only has small increase in size; in adult, vertebral canal is much longer than spinal cord.

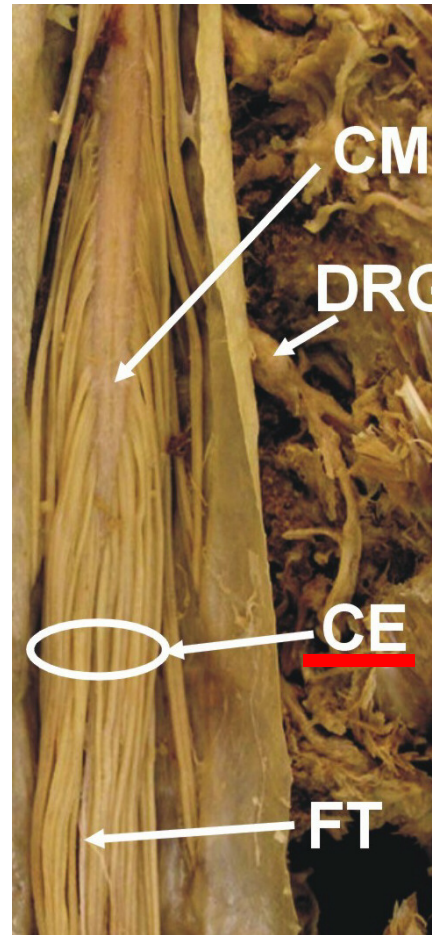
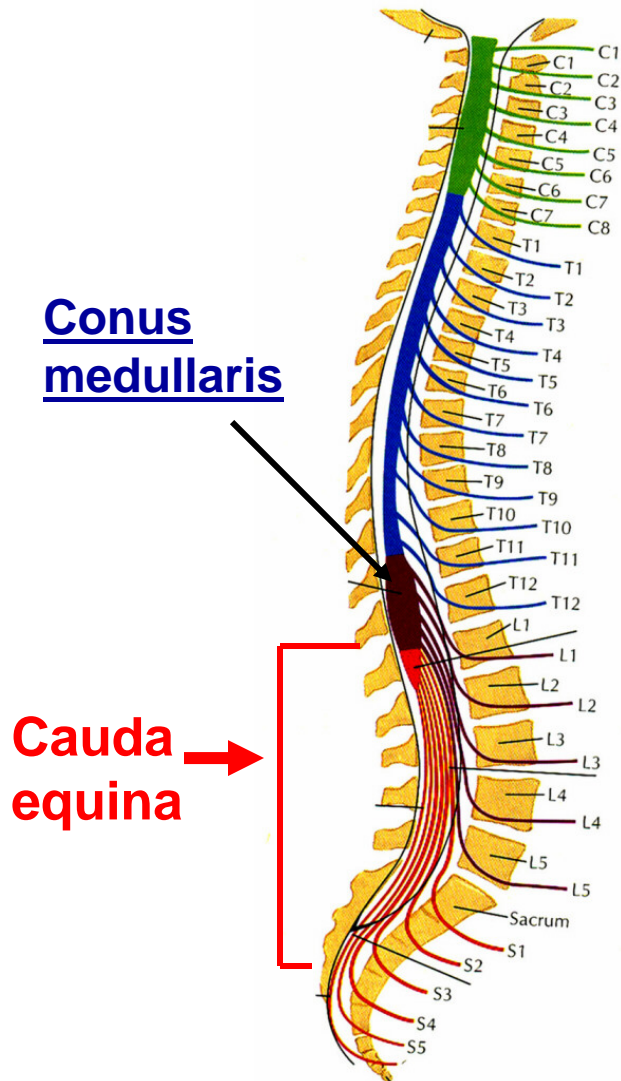
A. Conus medullaris - is inferior (caudal) end of spinal cord

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





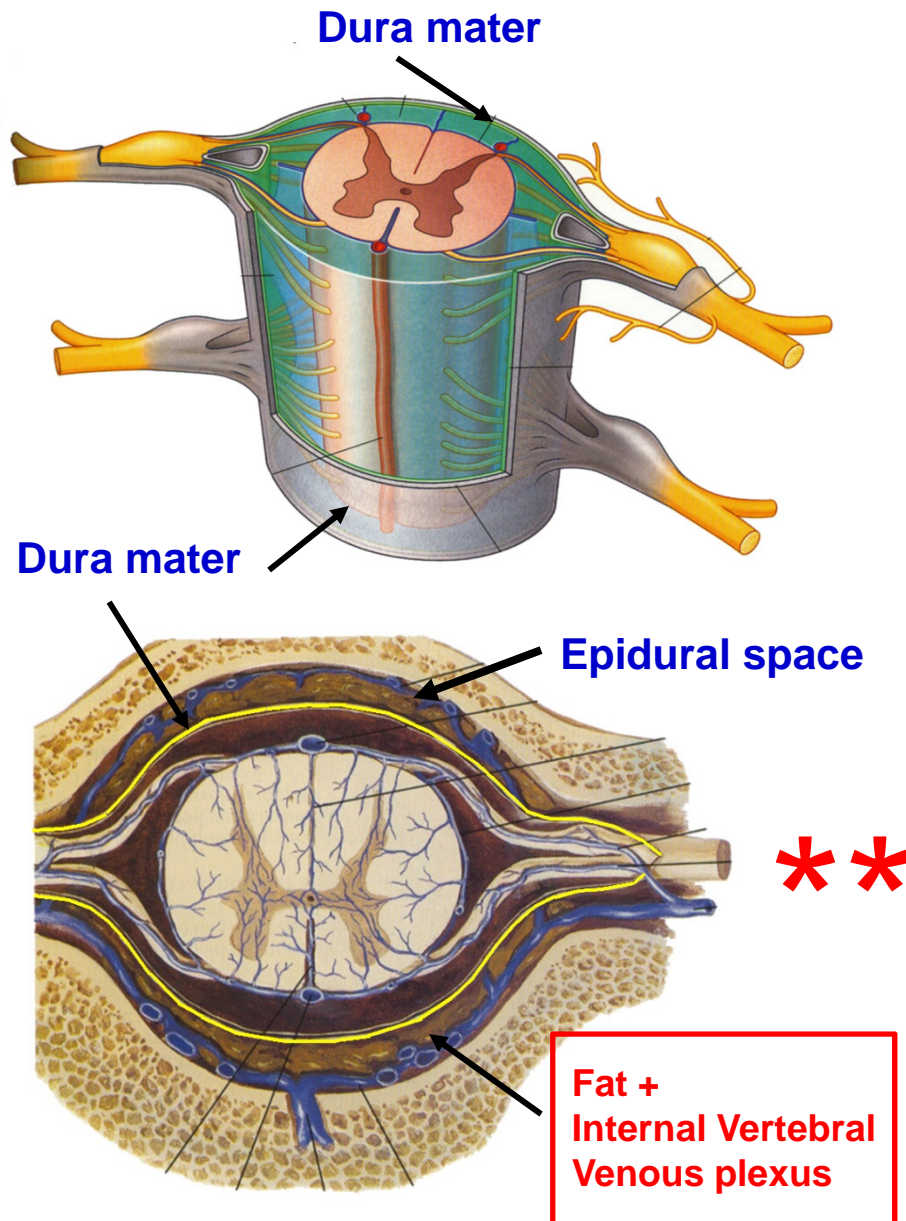
## CAUDA EQUINA



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.

## V. MENINGES - connective tissue layers surround and protect spinal cord



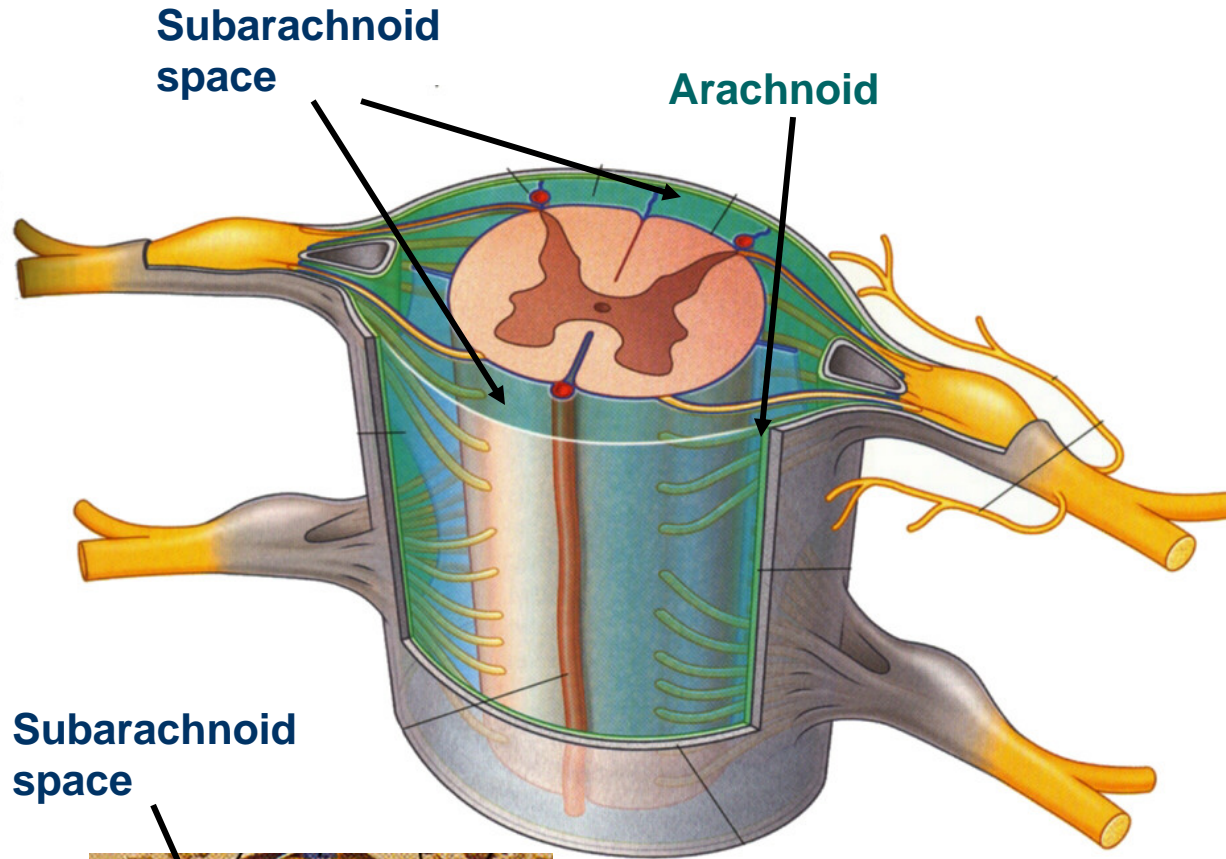
described as three layers.

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 OF SPINAL CORD



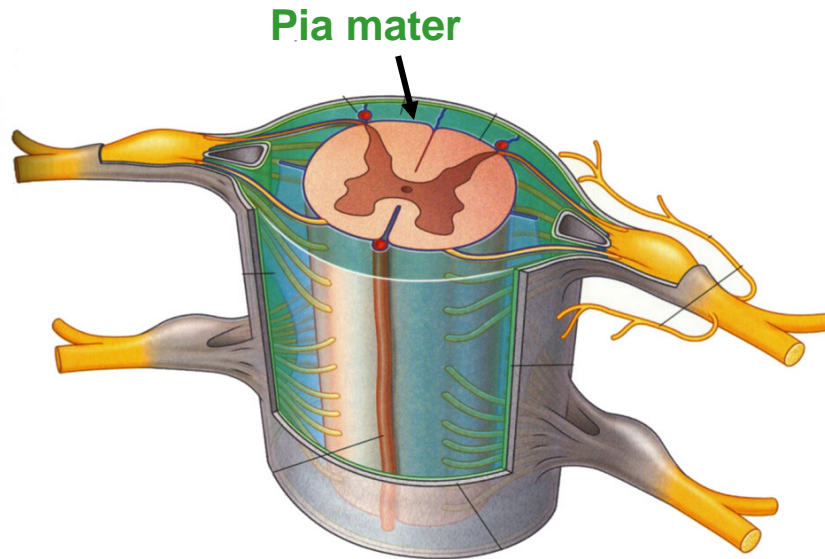
Subarachnoid space



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.

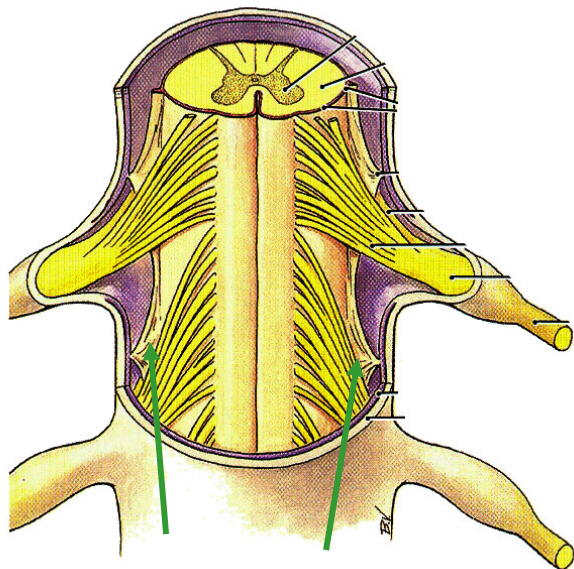
# MENINGES OF SPINAL CORD



Pia mater

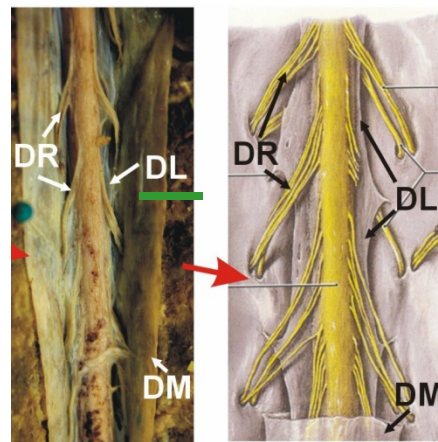
C. **Pia mater** (Latin for tender mother) - thin layer that is adherent to surface of spinal cord; contains blood vessels supplying cord.

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

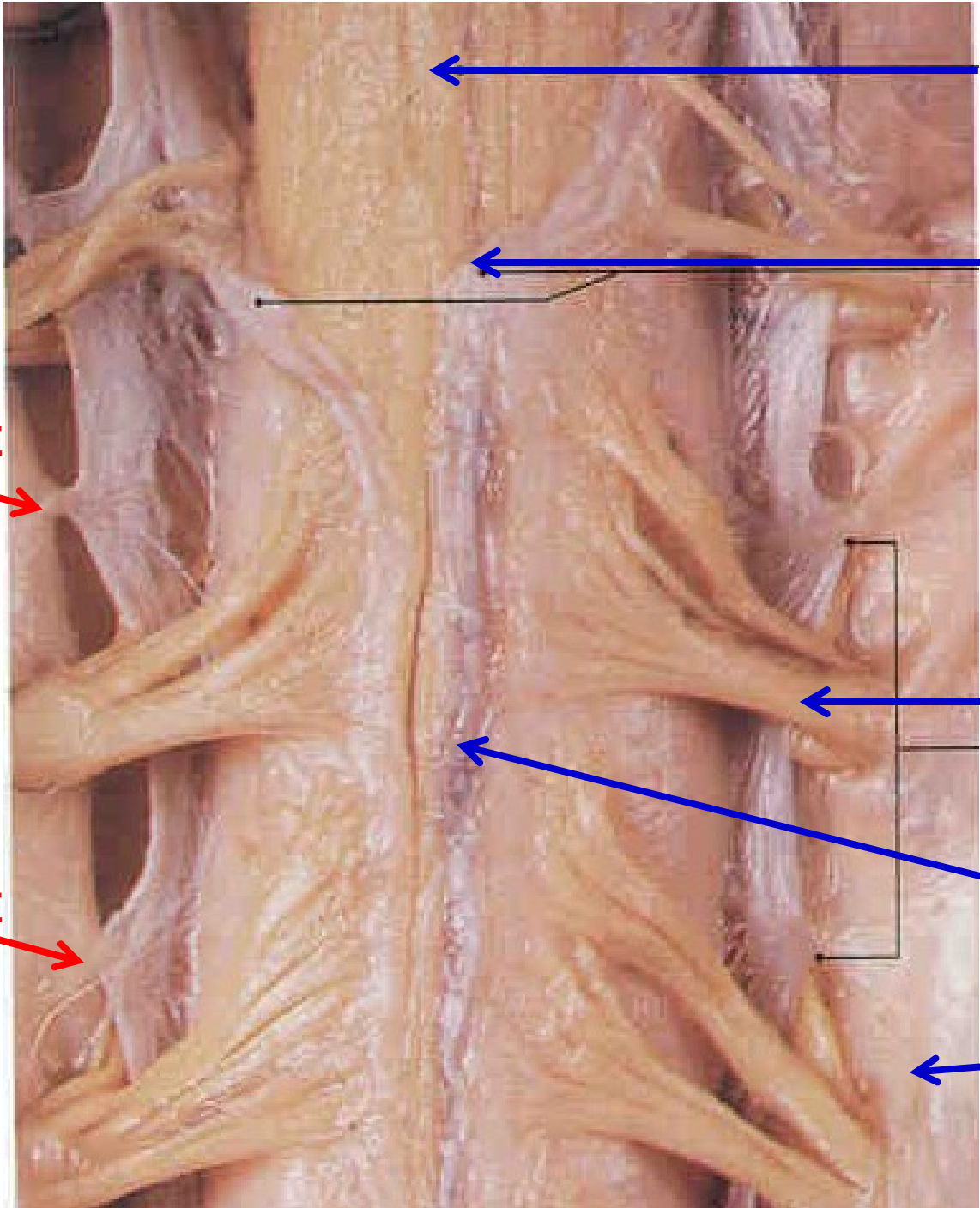


Denticulate Ligaments

see Spinal Cord Prosections



**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.**



**SPINAL CORD**

**PIA MATER**

**DENTICULATE  
LIGAMENT**

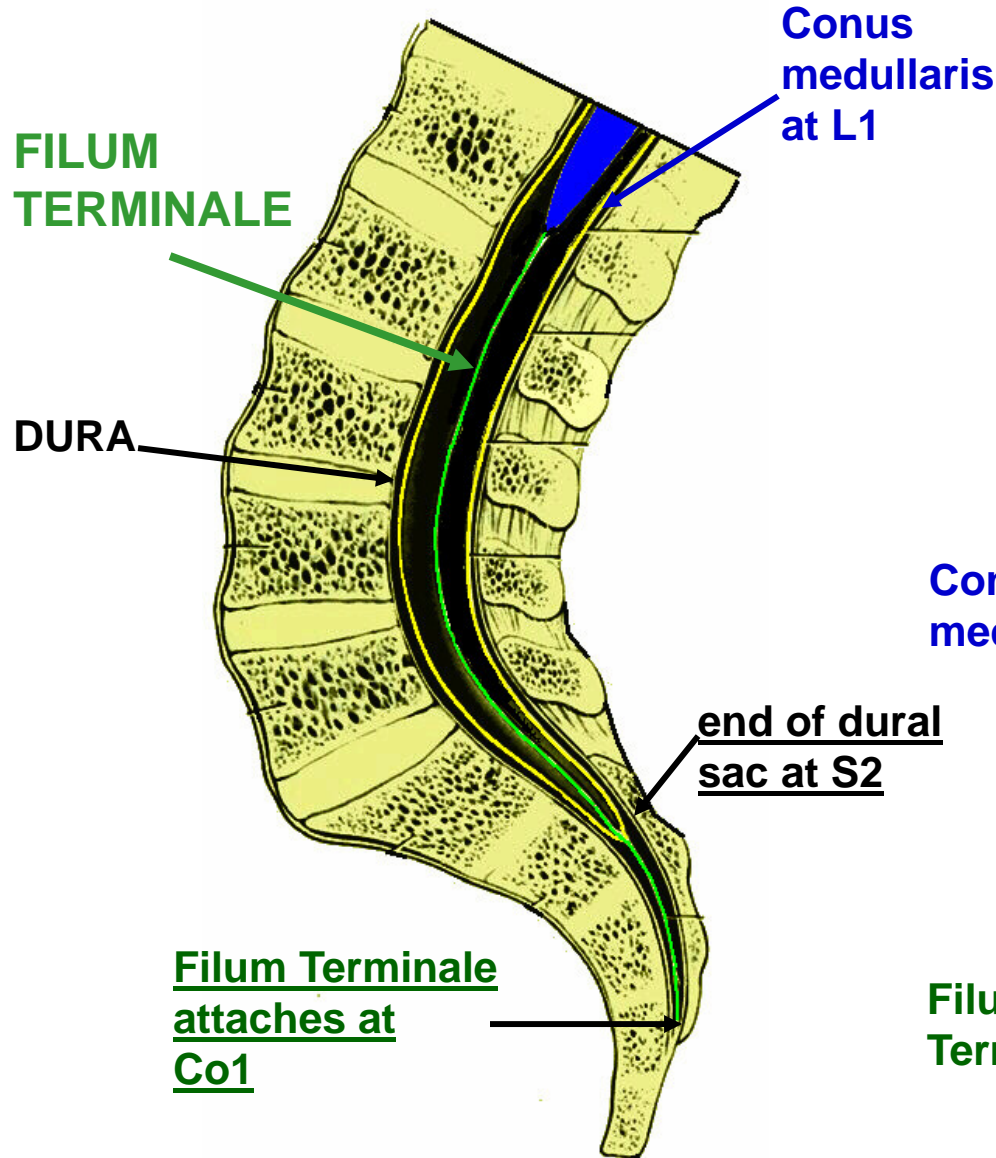
**VENTRAL  
ROOT**

**DENTICULATE  
LIGAMENT**

**BLOOD  
VESSEL**

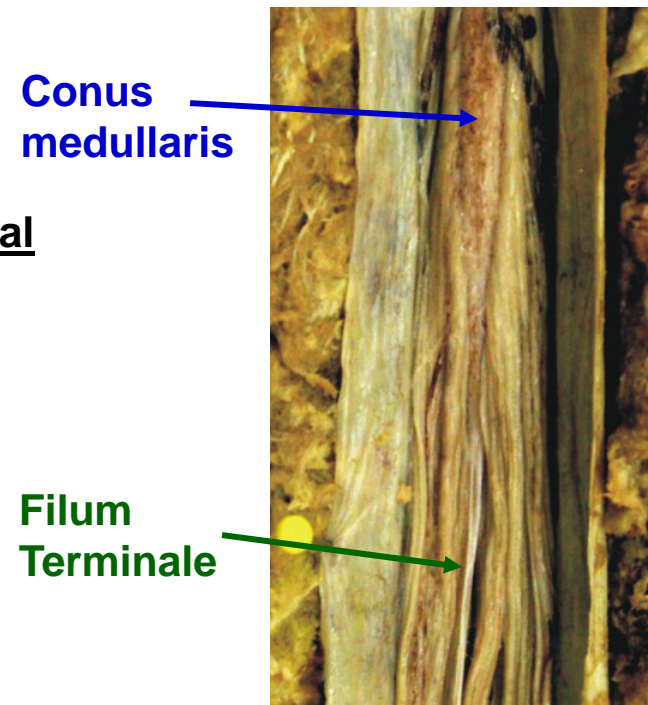
**DURA MATER**

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

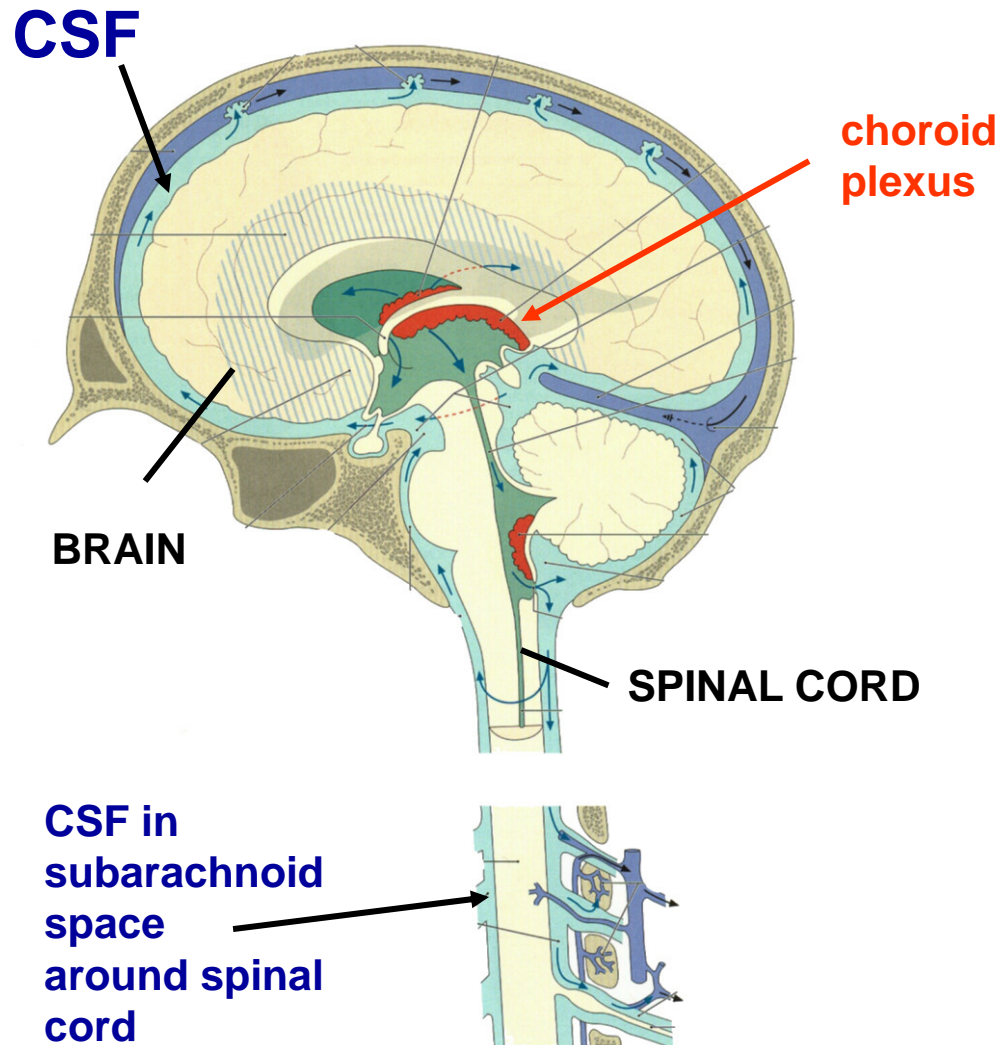


## FILUM TERMINALE

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).



## VI. CEREBROSPINAL FLUID (CSF) AND SPINAL TAP

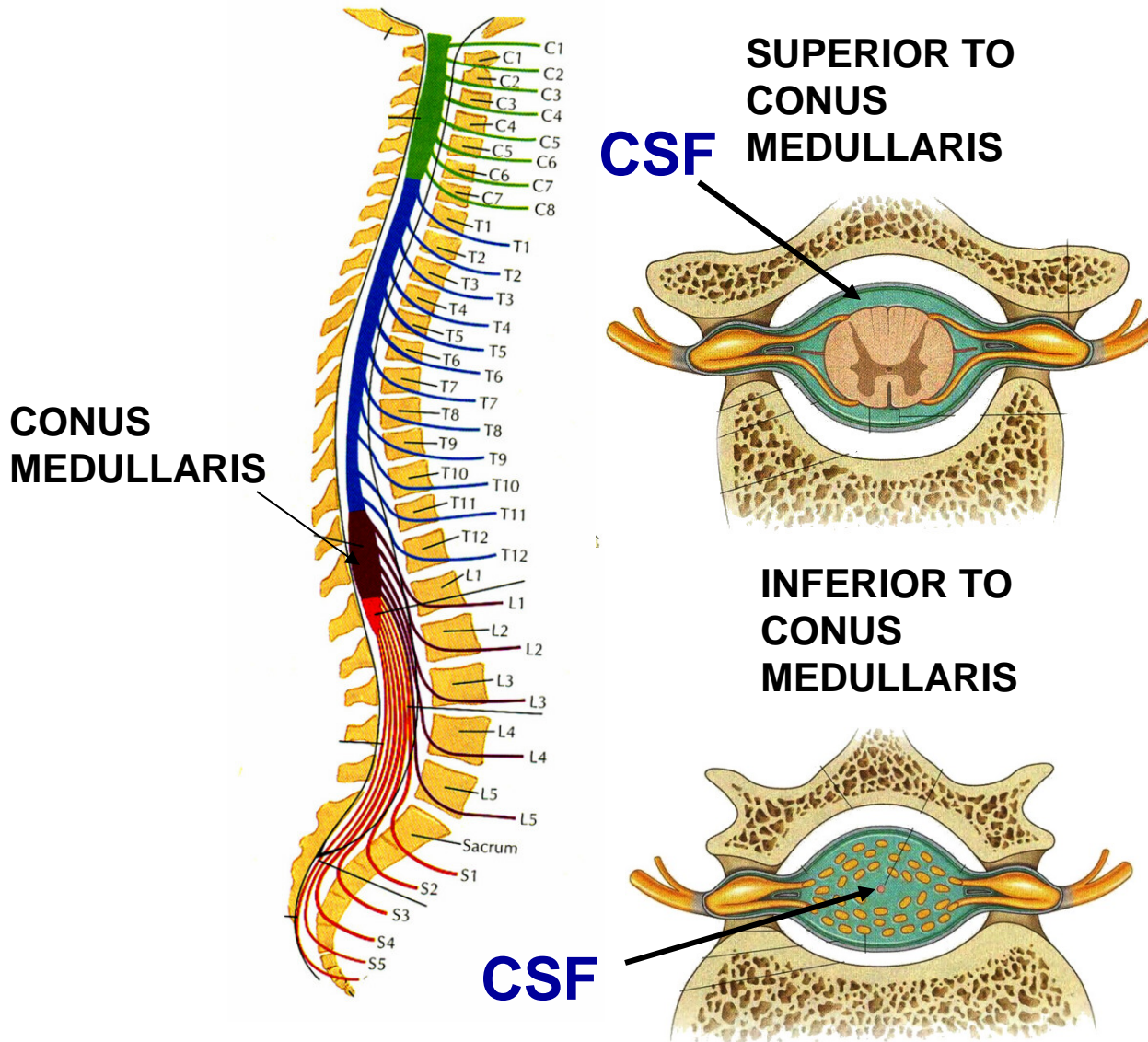


- **CSF** is clear, acellular fluid contained in subarachnoid space; surrounds and protects spinal cord; produced within choroid plexuses (mostly in brain)

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

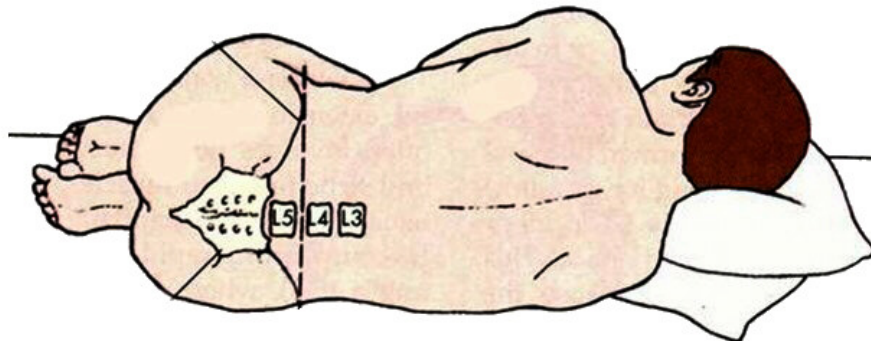
i. **Adult** - between **L3-L4** or **L4-L5** (spinal cord extends to **L1**)

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)**

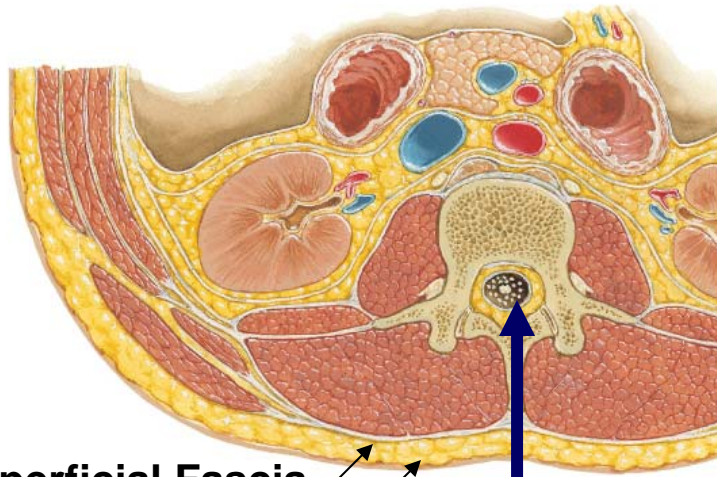
L1 - Adult

L3 - Child

2) **Dural Sac ends S2**

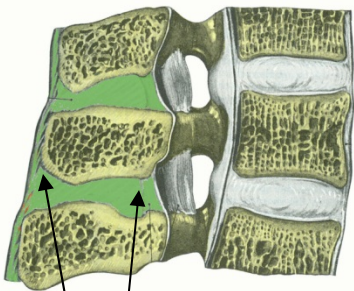
3) **Filum terminale ends and attaches - Co1**

# CEREBROSPINAL FLUID (CSF) AND SPINAL TAP

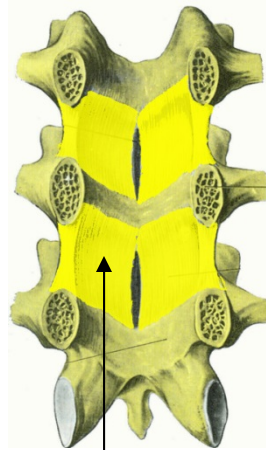


ii. Superficial Fascia  
i Skin

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

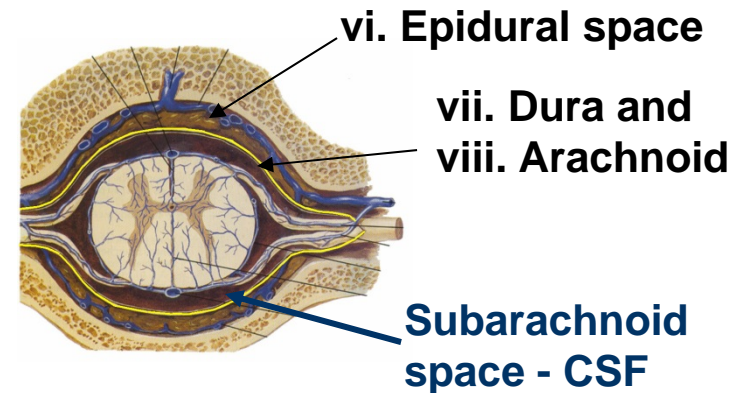
iv. Interspinous ligament

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