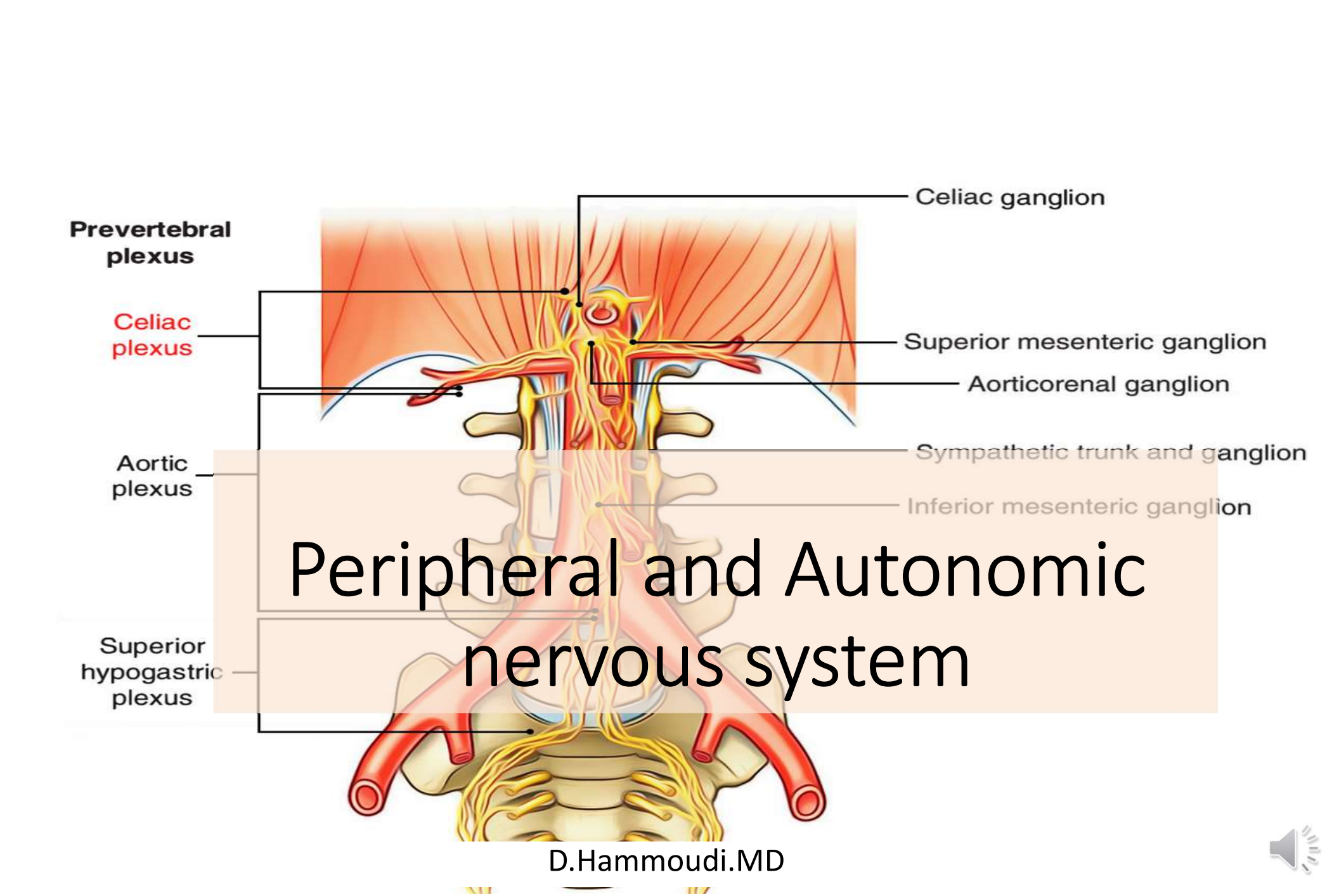
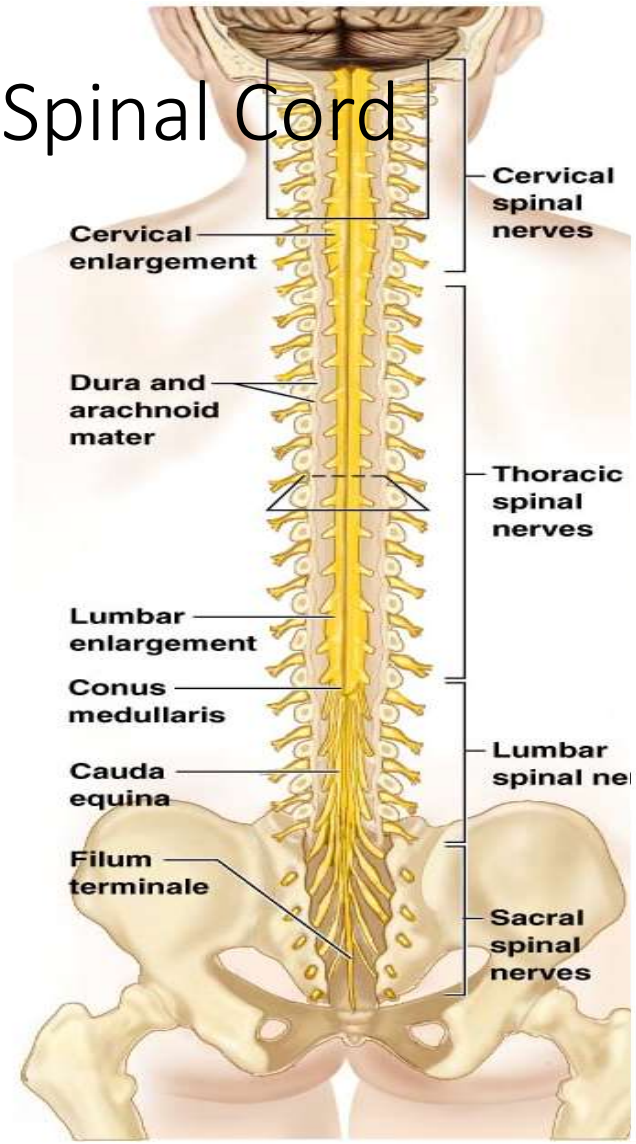


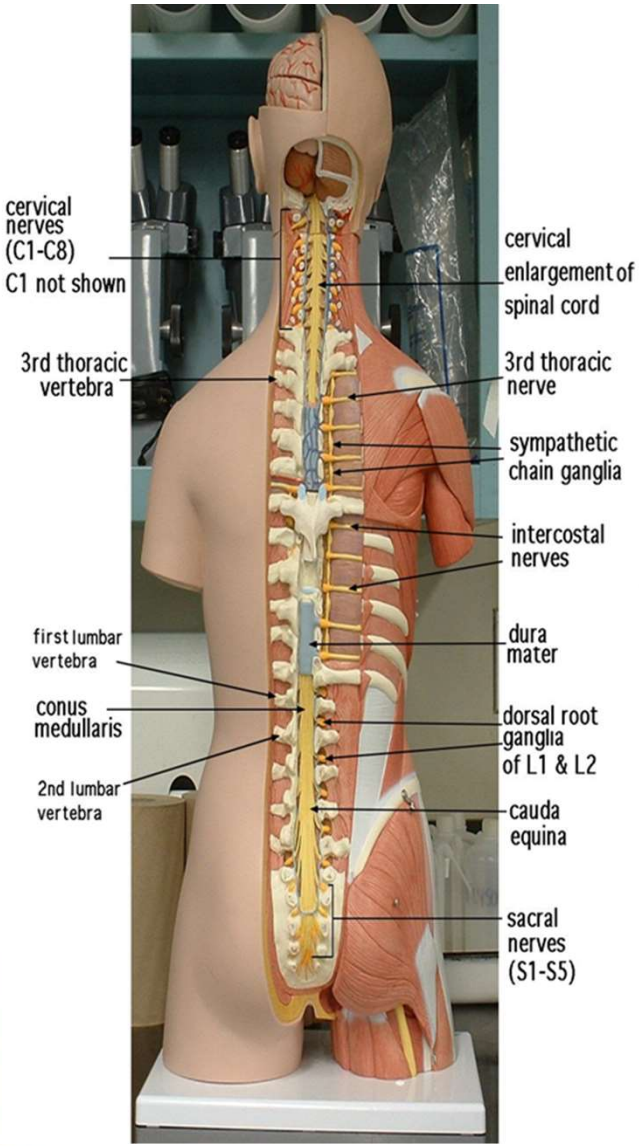
Peripheral and Autonomic nervous system

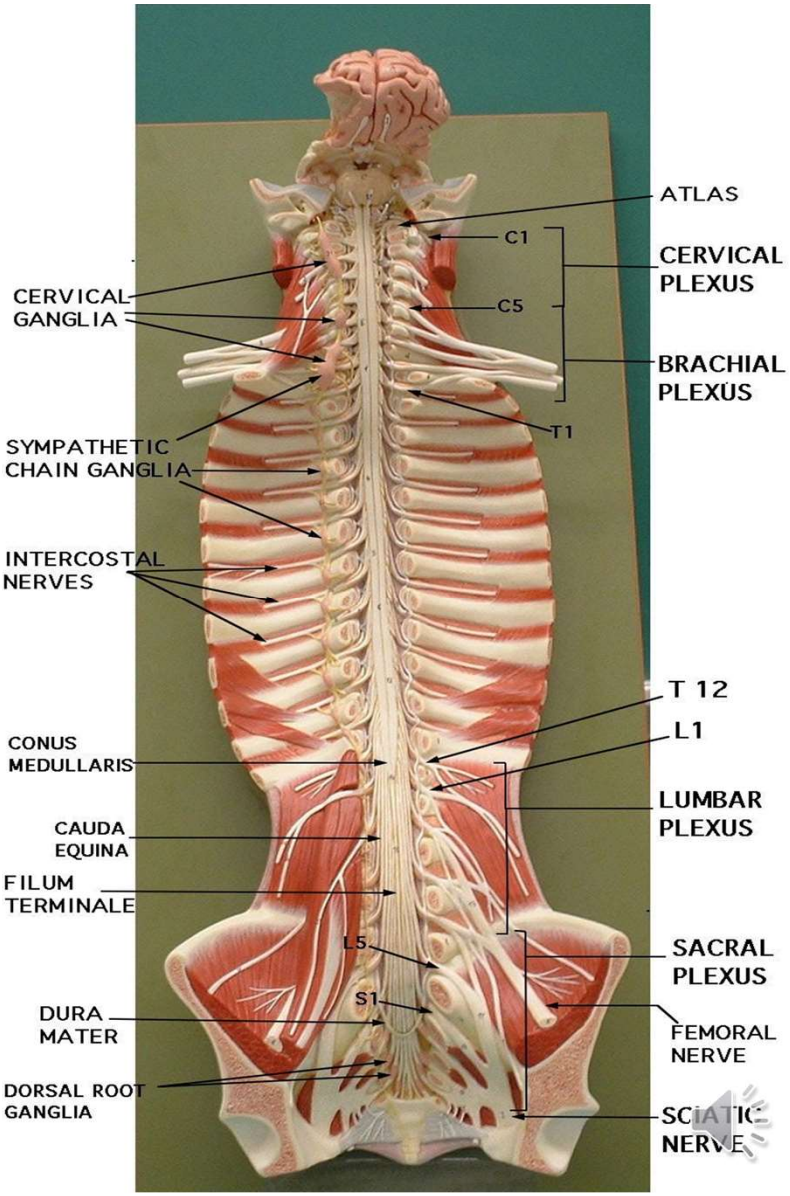
D.Hammoudi.MD

Spinal Cord



(a)





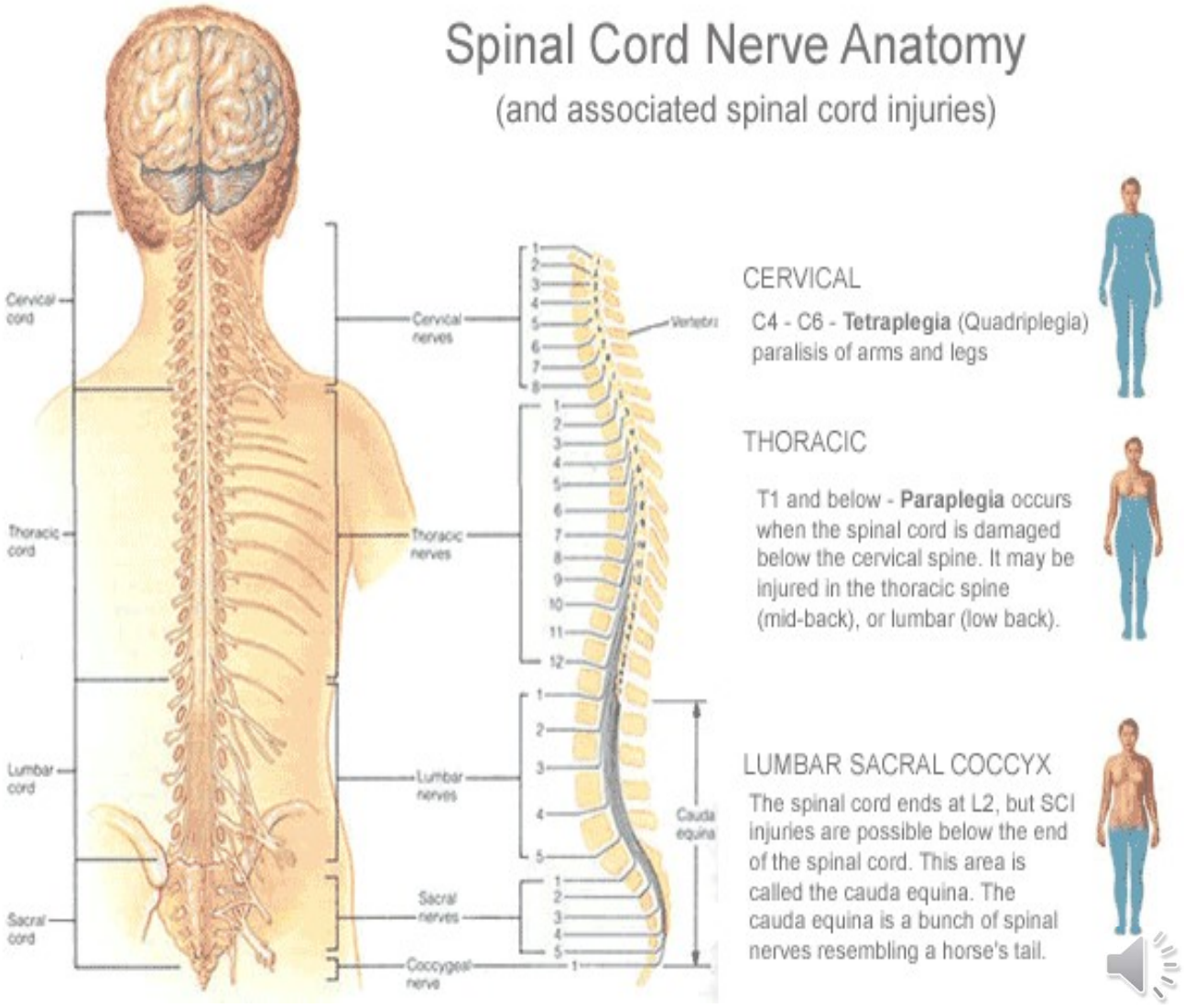
There are 31 spinal cord segments:

- 8 cervical segments
- 12 thoracic segments
- 5 lumbar segments
- 5 sacral segments
- 1 coccygeal segment

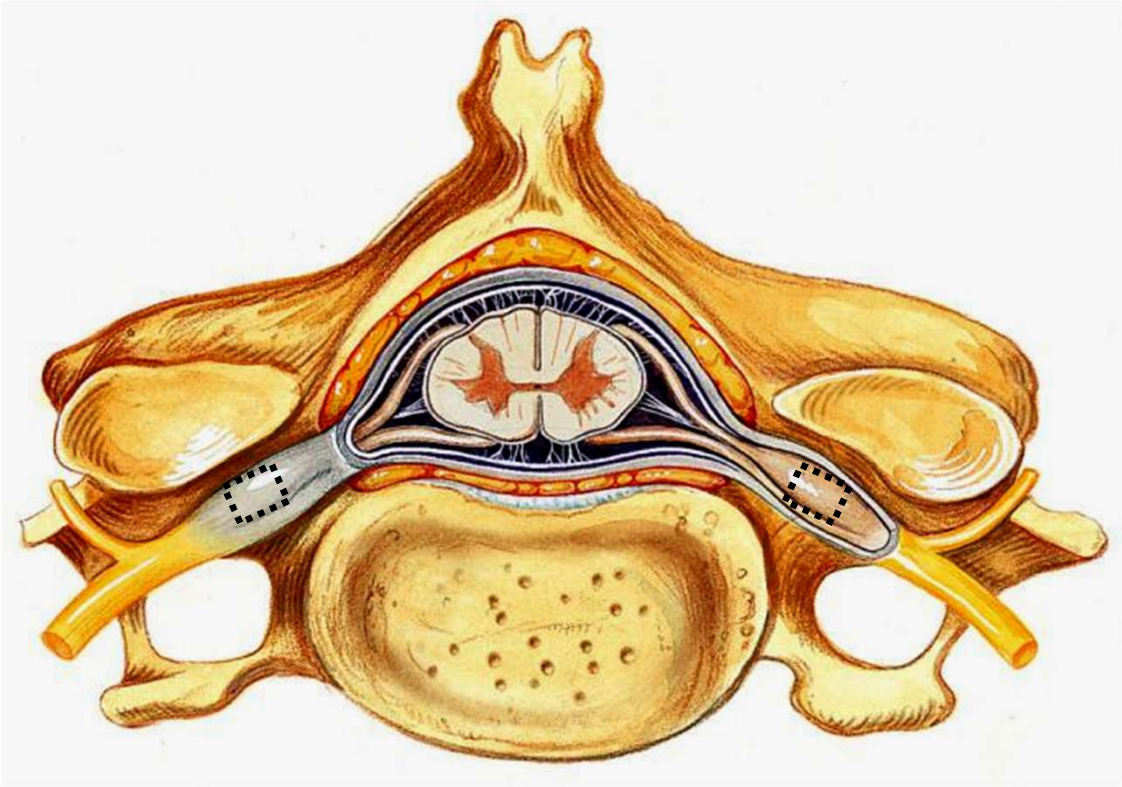
There are two regions where the spinal cord enlarges:

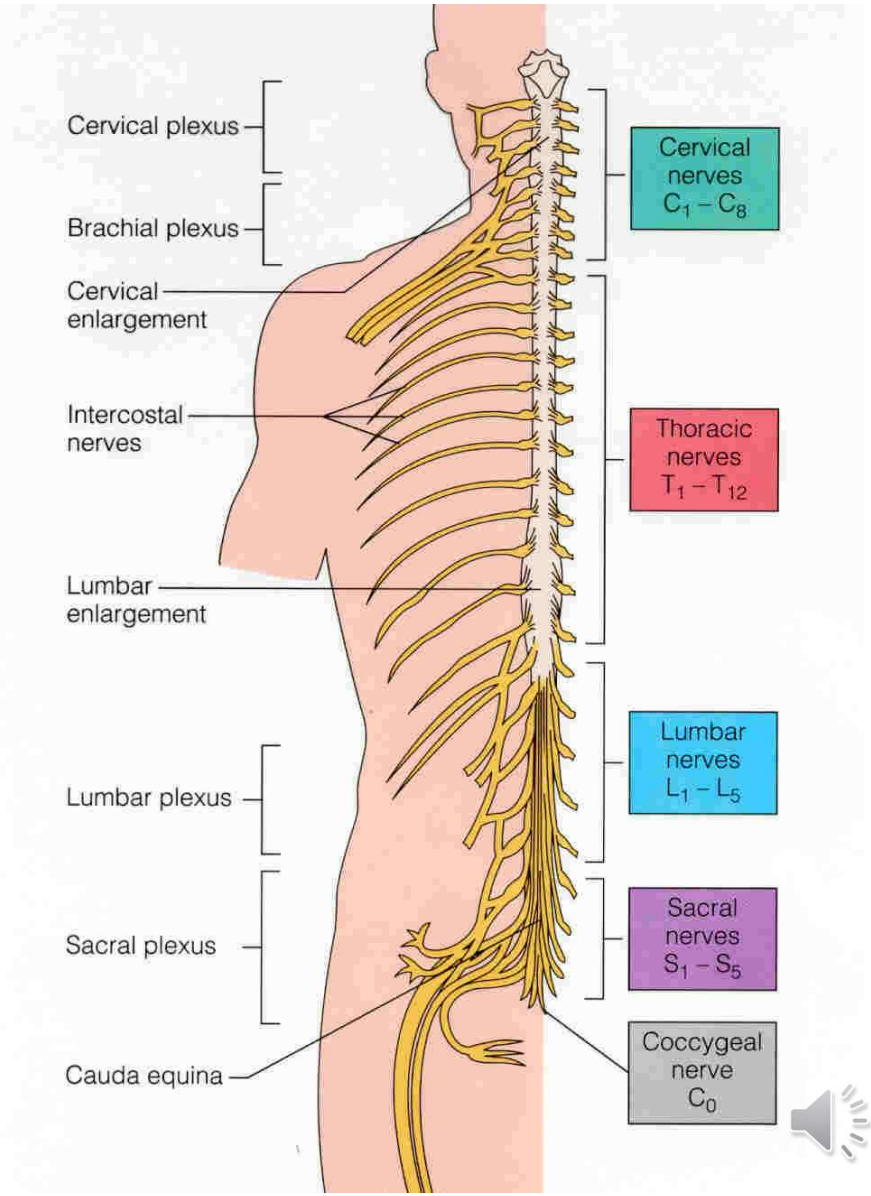
- **Cervical enlargement** - corresponds roughly to the brachial plexus nerves, which innervate the upper limb. It includes spinal cord segments from about C4 to T1. The vertebral levels of the enlargement are roughly the same (C4 to T1).

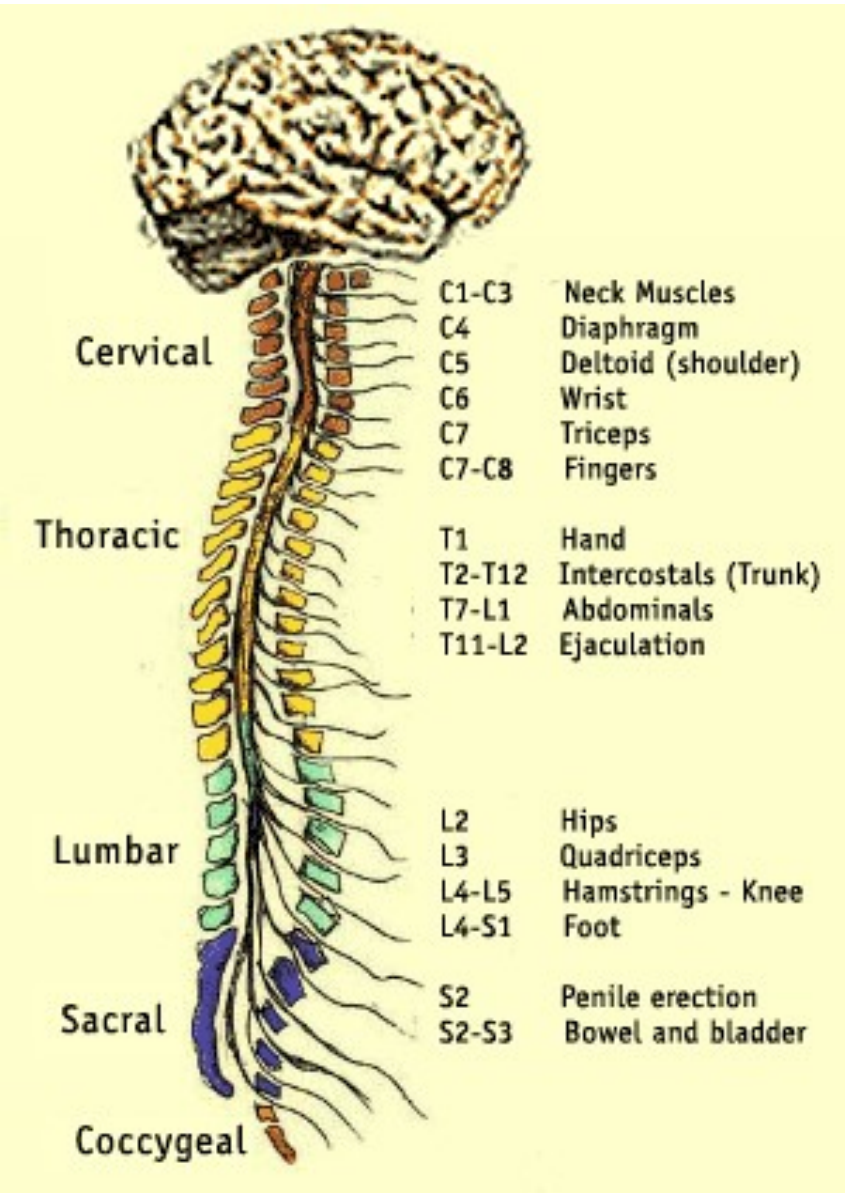
- **Lumbosacral enlargement** - corresponds to the lumbosacral plexus nerves, which innervate the lower limb. It comprises the spinal cord segments from L2 to S3, and is found about the vertebral levels of T9 to T12.

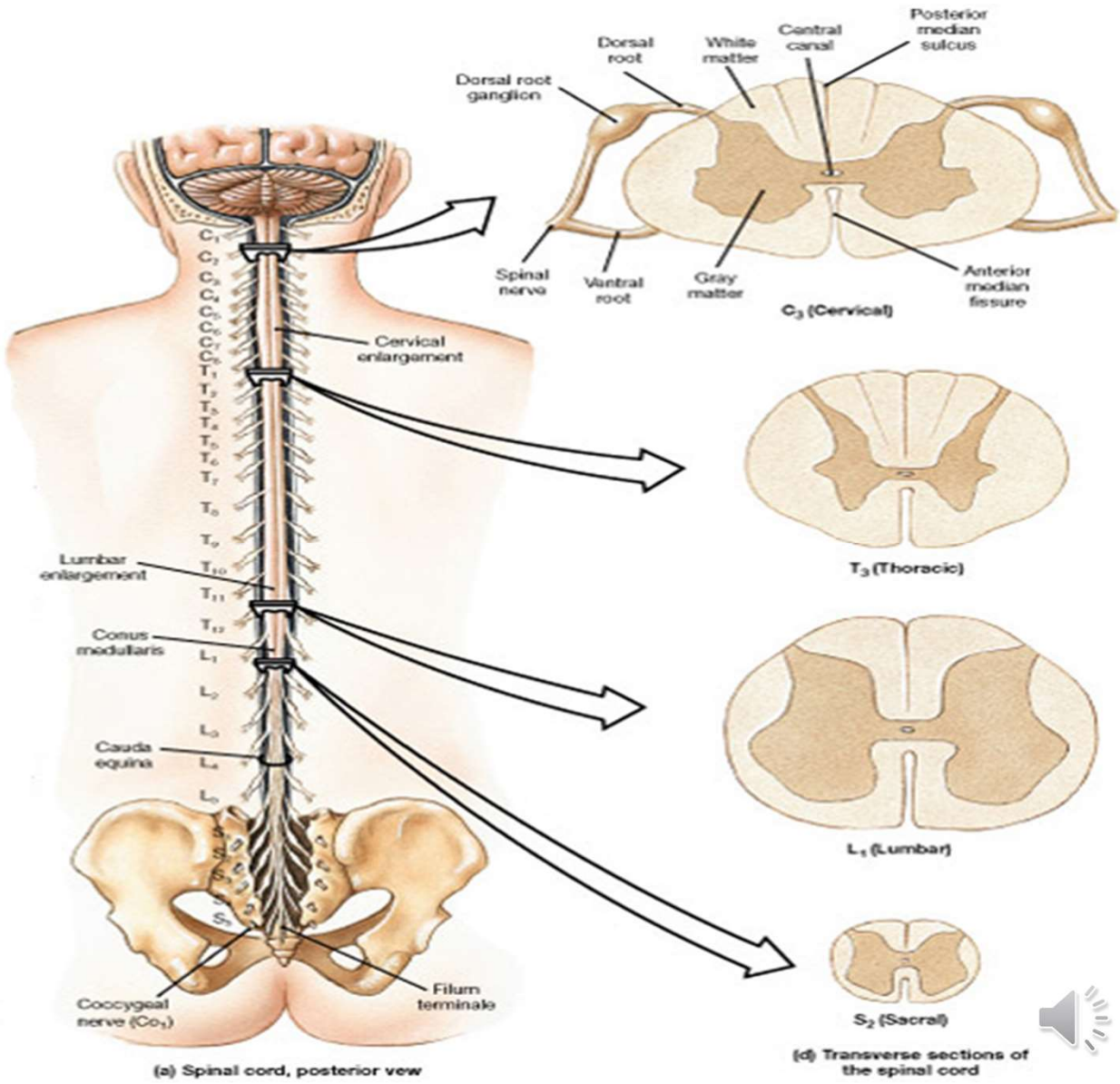


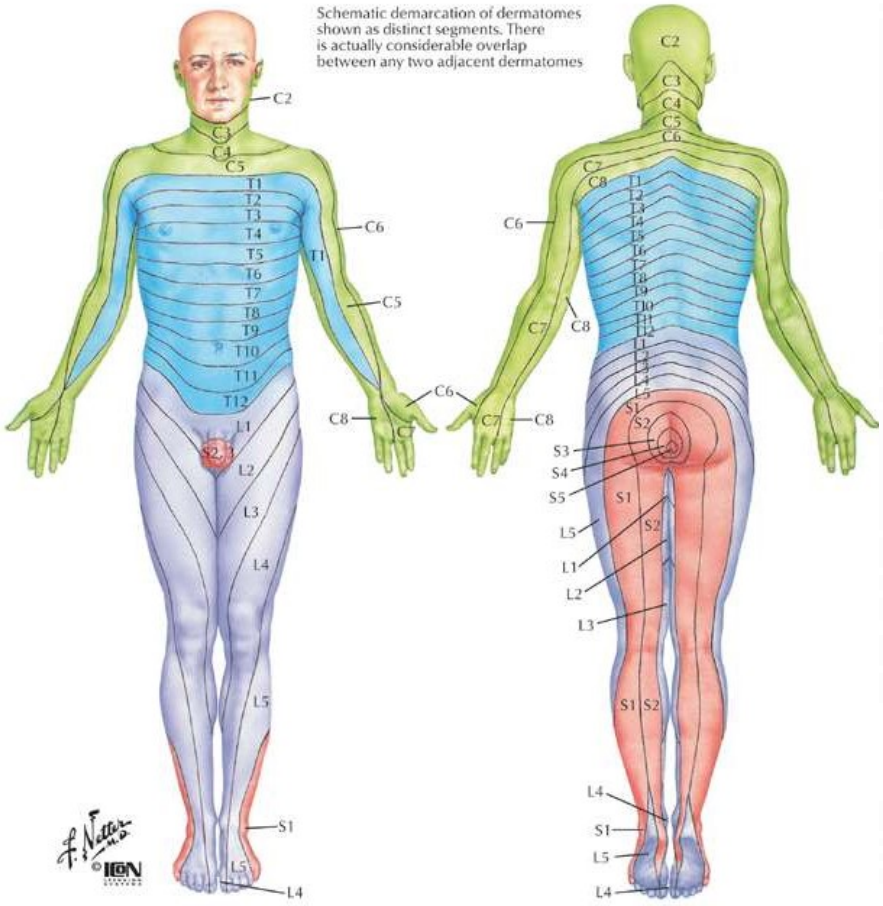
There are 31 pairs of spinal nerves





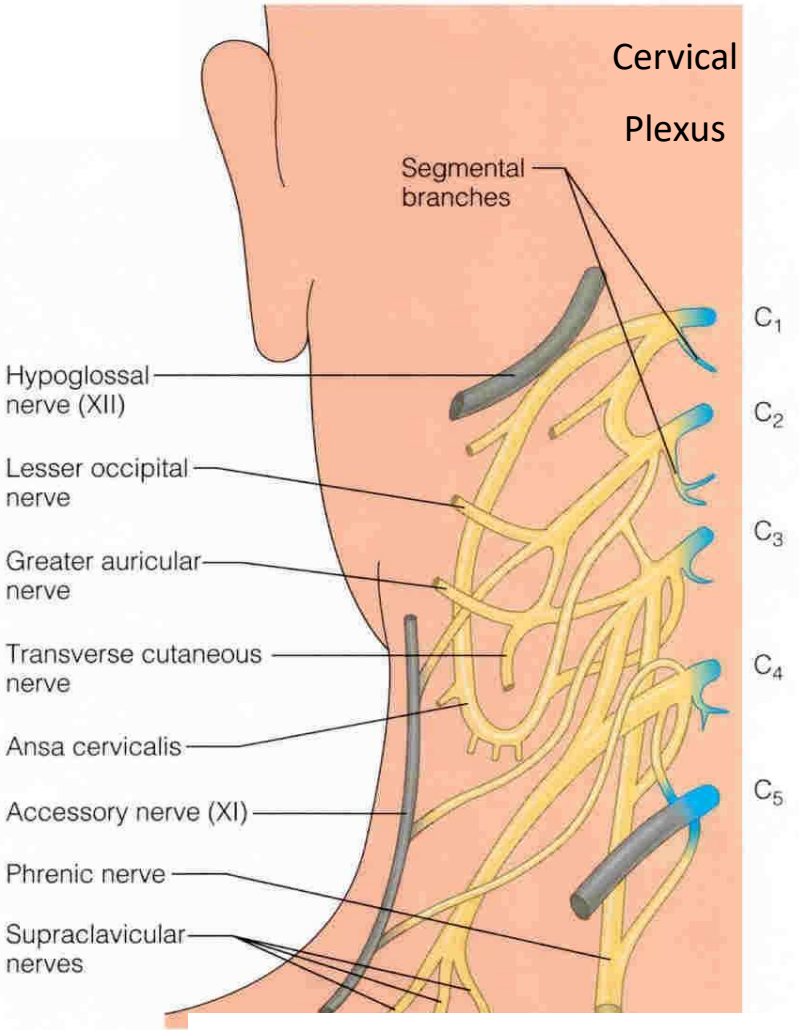

Cervical
C1-C3 Neck Muscles
C4 Diaphragm
C5 Deltoid (shoulder)
C6 Wrist
C7 Triceps
C7-C8 Fingers
Thoracic
T1 Hand
T2-T12 Intercostals (Trunk)
T7-L1 Abdominals
T11-L2 Ejaculation
Lumbar
L2 Hips
L3 Quadriceps
L4-L5 Hamstrings - Knee
L4-S1 Foot
Sacral
S2 Penile erection
S2-S3 Bowel and bladder
Coccygeal


Cervical enlargement
Lumbar enlargement
Conus medullaris
Cauda equina
Filum terminale
Coccygeal nerve (Co1)
(a) Spinal cord, posterior vew
Dorsal root ganglion
Dorsal root
White matter
Central canal
Posterior median sulcus
Spinal nerve
Ventral root
Gray matter
Anterior median fissure
C3 (Cervical)
T3 (Thoracic)
L1 (Lumbar)
S2 (Sacral)
(d) Transverse sections of the spinal cord



Levels of principal dermatomes

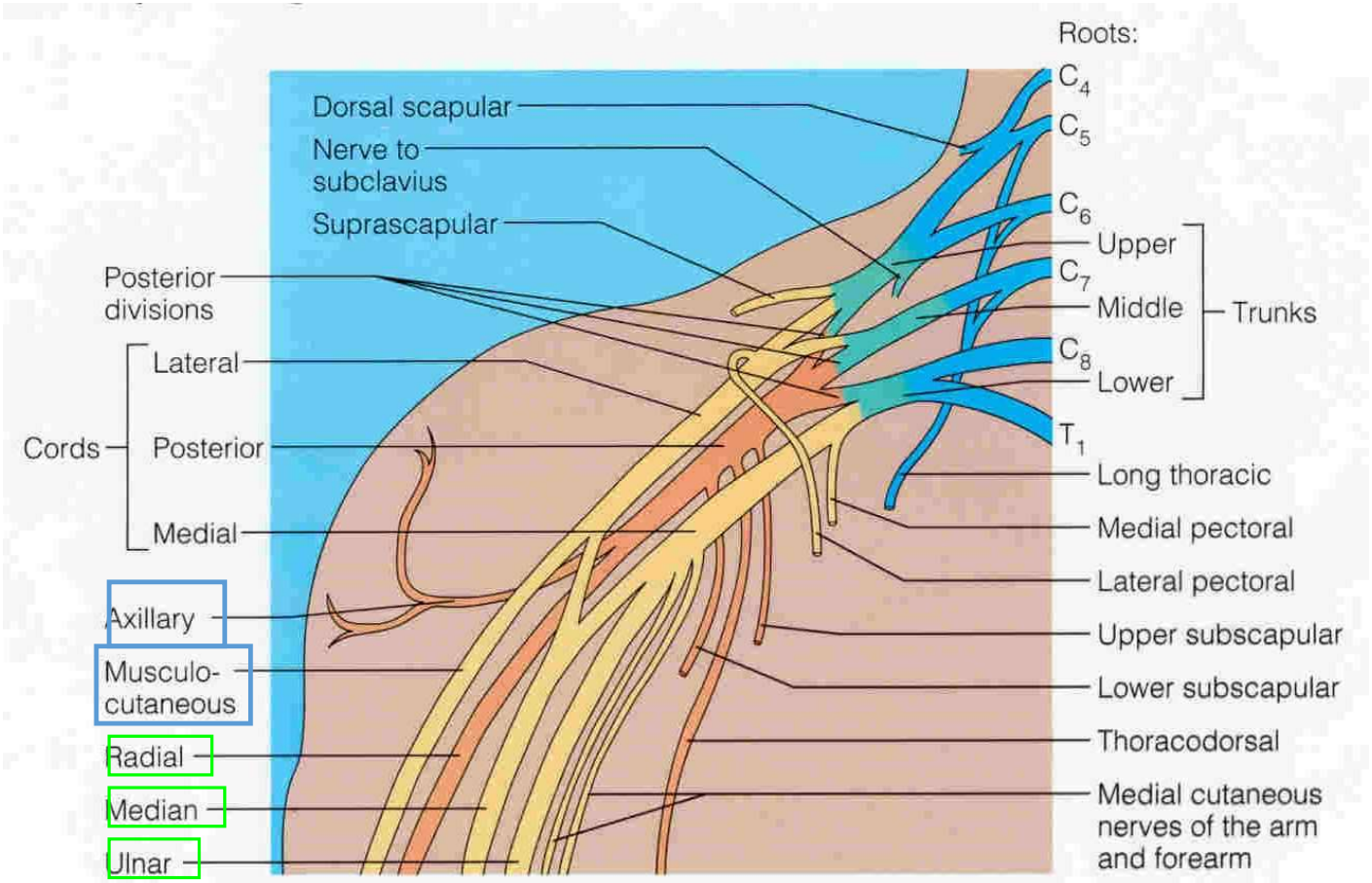
C5	Clavicles
C5, 6, 7	Lateral parts of upper limbs
C8, T1	Medial sides of upper limbs
C6	Thumb
C6, 7, 8	Hand
C8	Ring and little fingers
T4	Level of nipples
T10	Level of umbilicus
T12	Inguinal or groin regions
L1, 2, 3, 4	Anterior and inner surfaces of lower limbs
L4, 5, S1	Foot
L4	Medial side of great toe
S1, 2, L5	Posterior and outer surfaces of lower limbs
S1	Lateral margin of foot and little toe
S2, 3, 4	Perineum

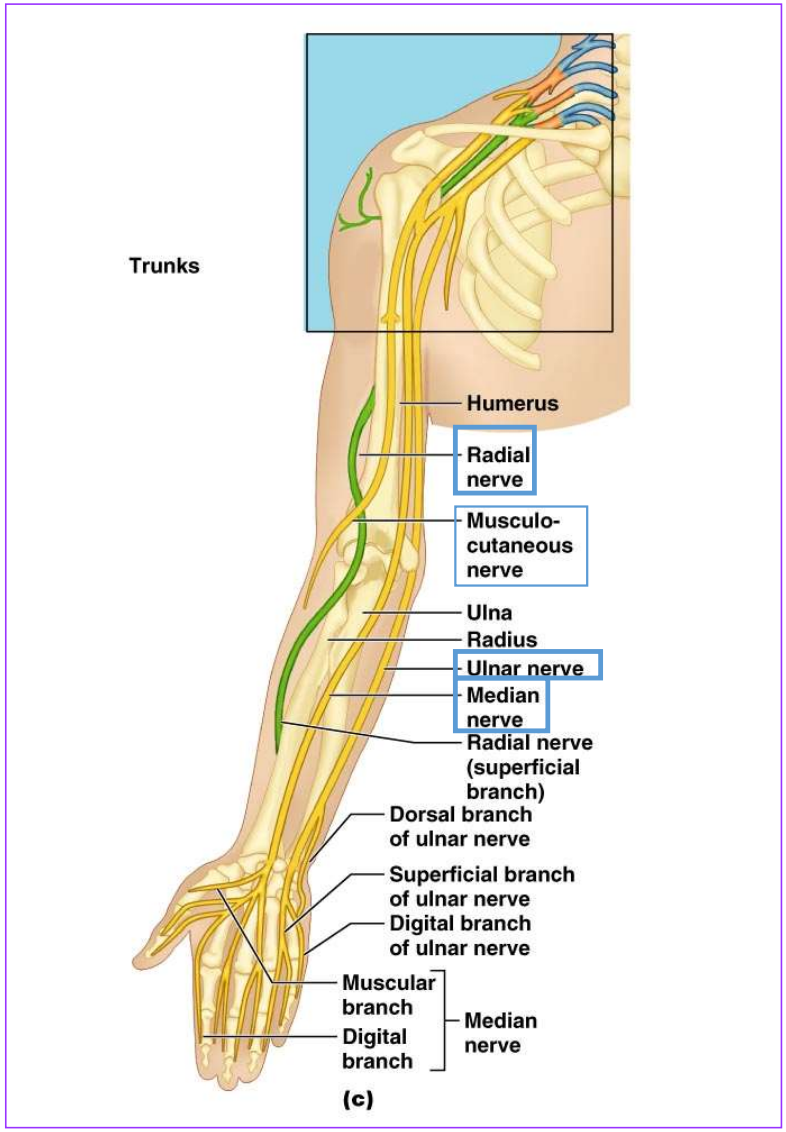


The phrenic nerve innervates the respiratory diaphragm

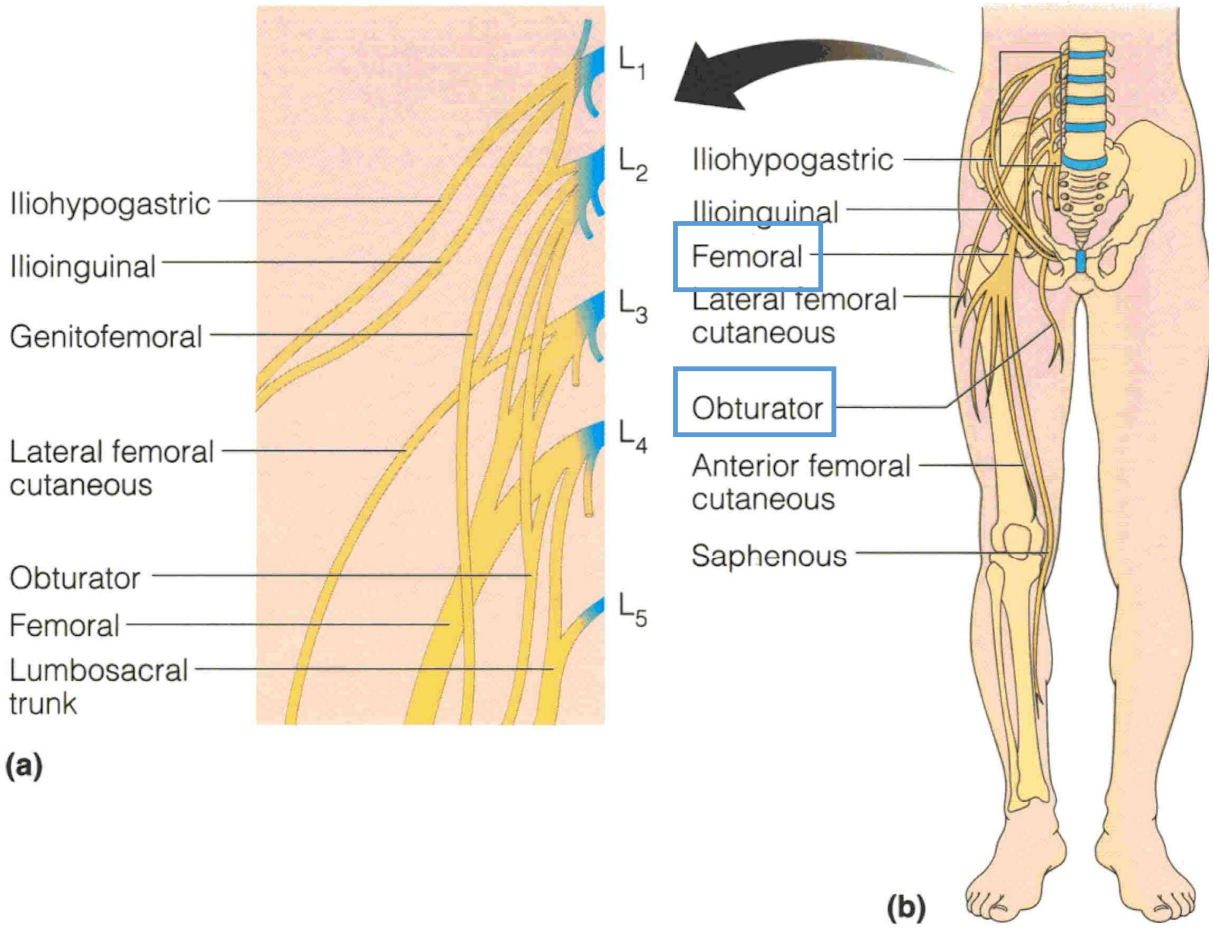
" $C_{3,4,5}$ keeps the diaphragm alive!

Brachial Plexus

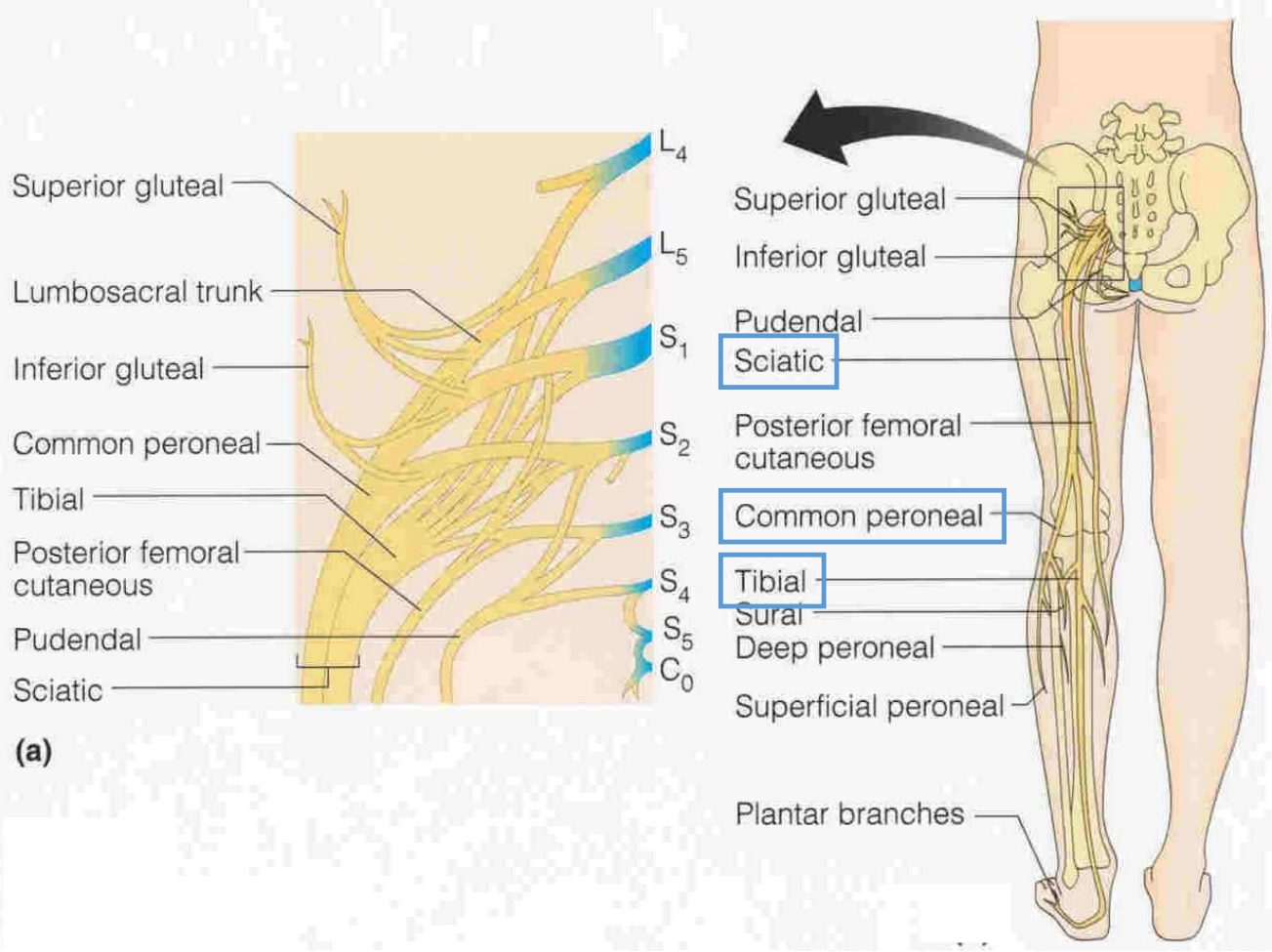



Trunks
Humerus
Radial nerve
Musculo-cutaneous nerve
Ulna
Radius
Ulnar nerve
Median nerve
Radial nerve (superficial branch)
Dorsal branch of ulnar nerve
Superficial branch of ulnar nerve
Digital branch of ulnar nerve
Muscular branch
Digital branch
Median nerve
(c)

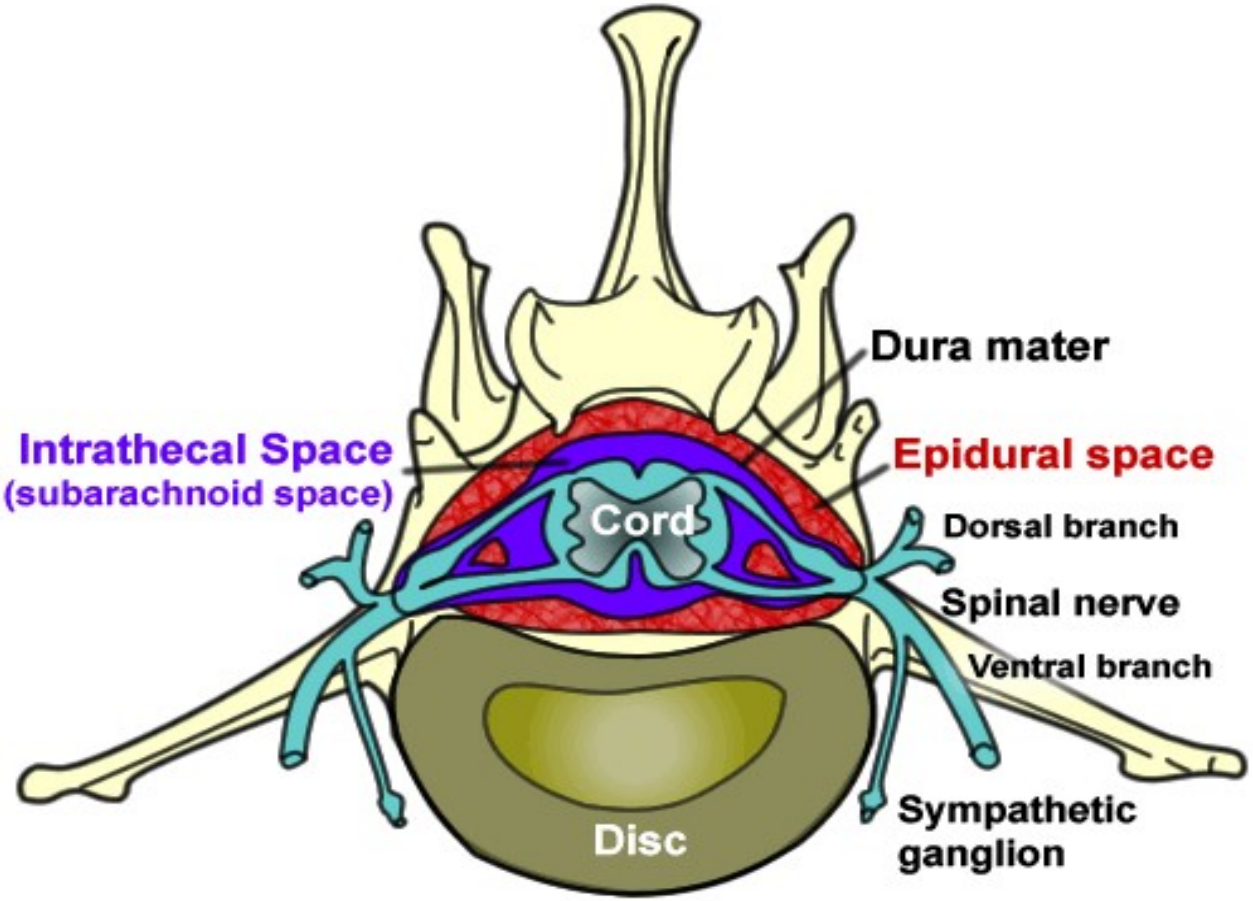
Lumbar Plexus

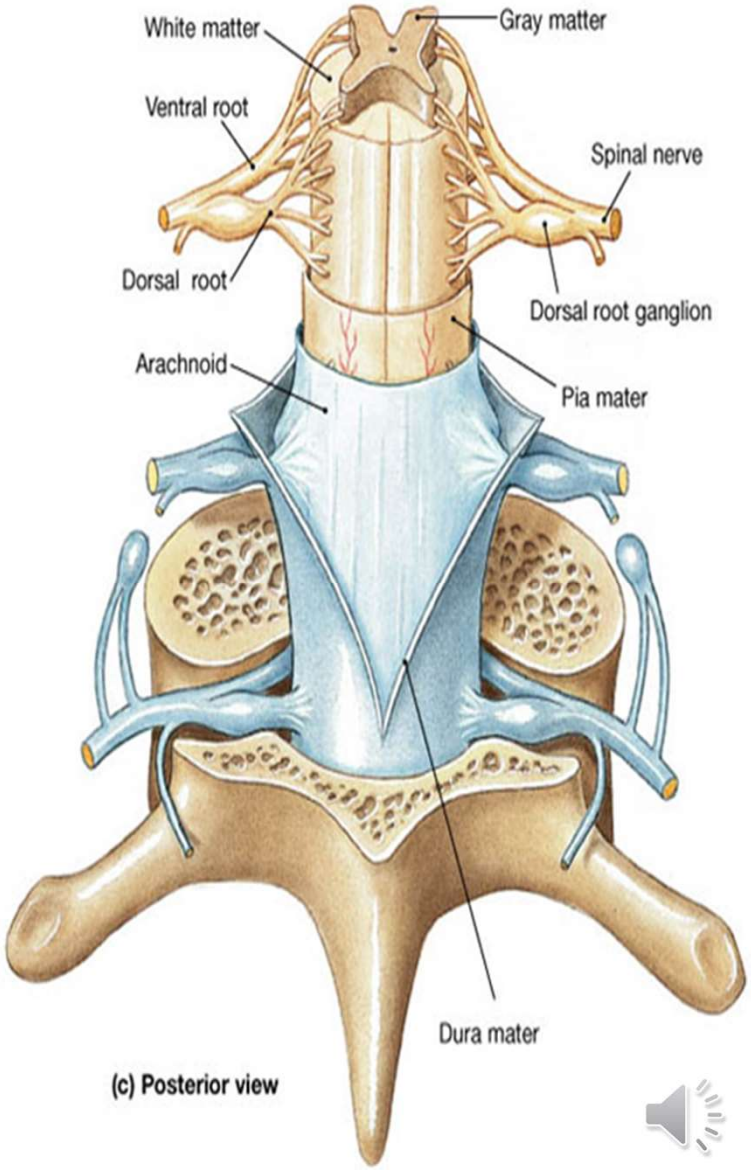


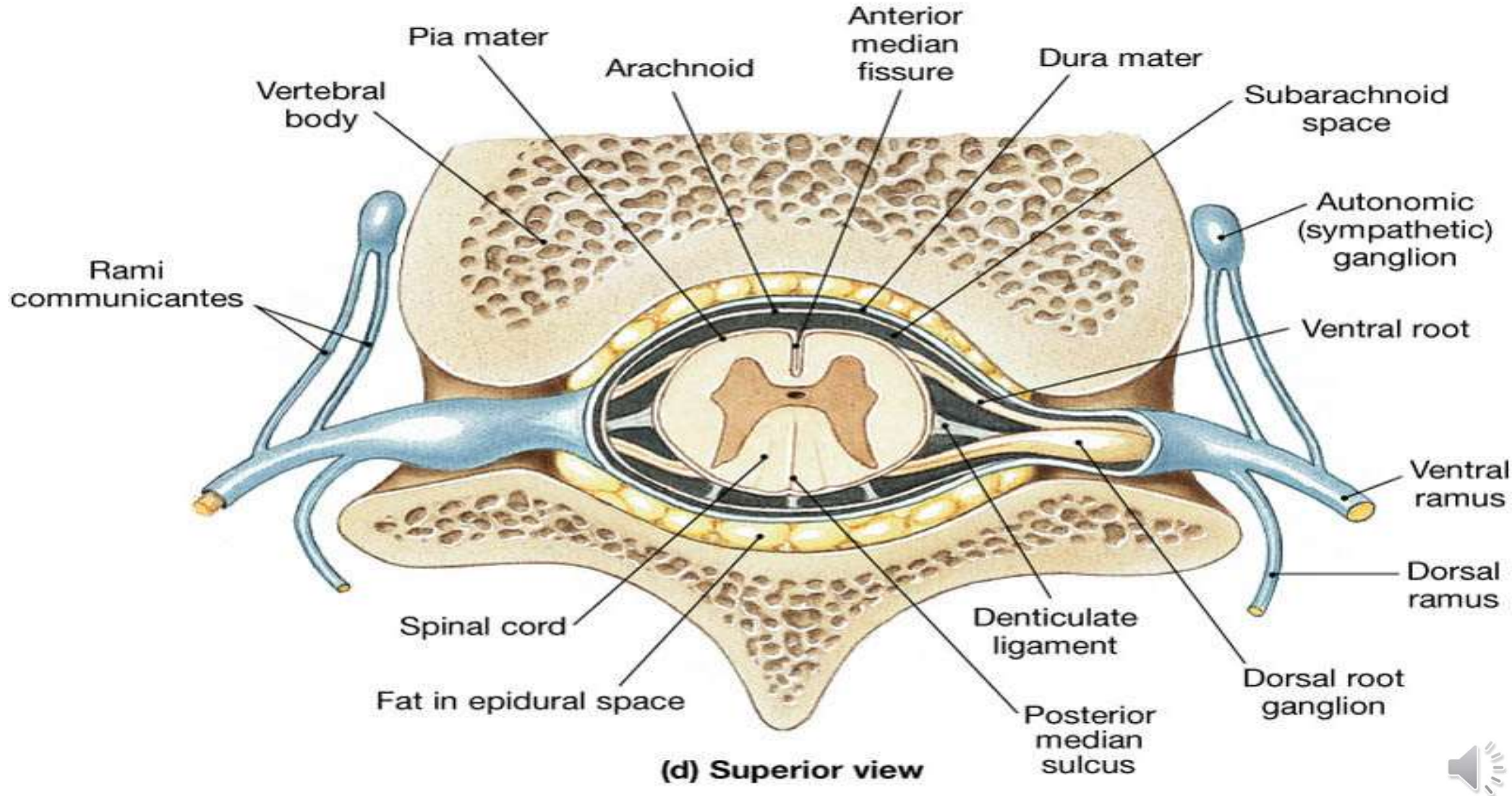
Sacral Plexus



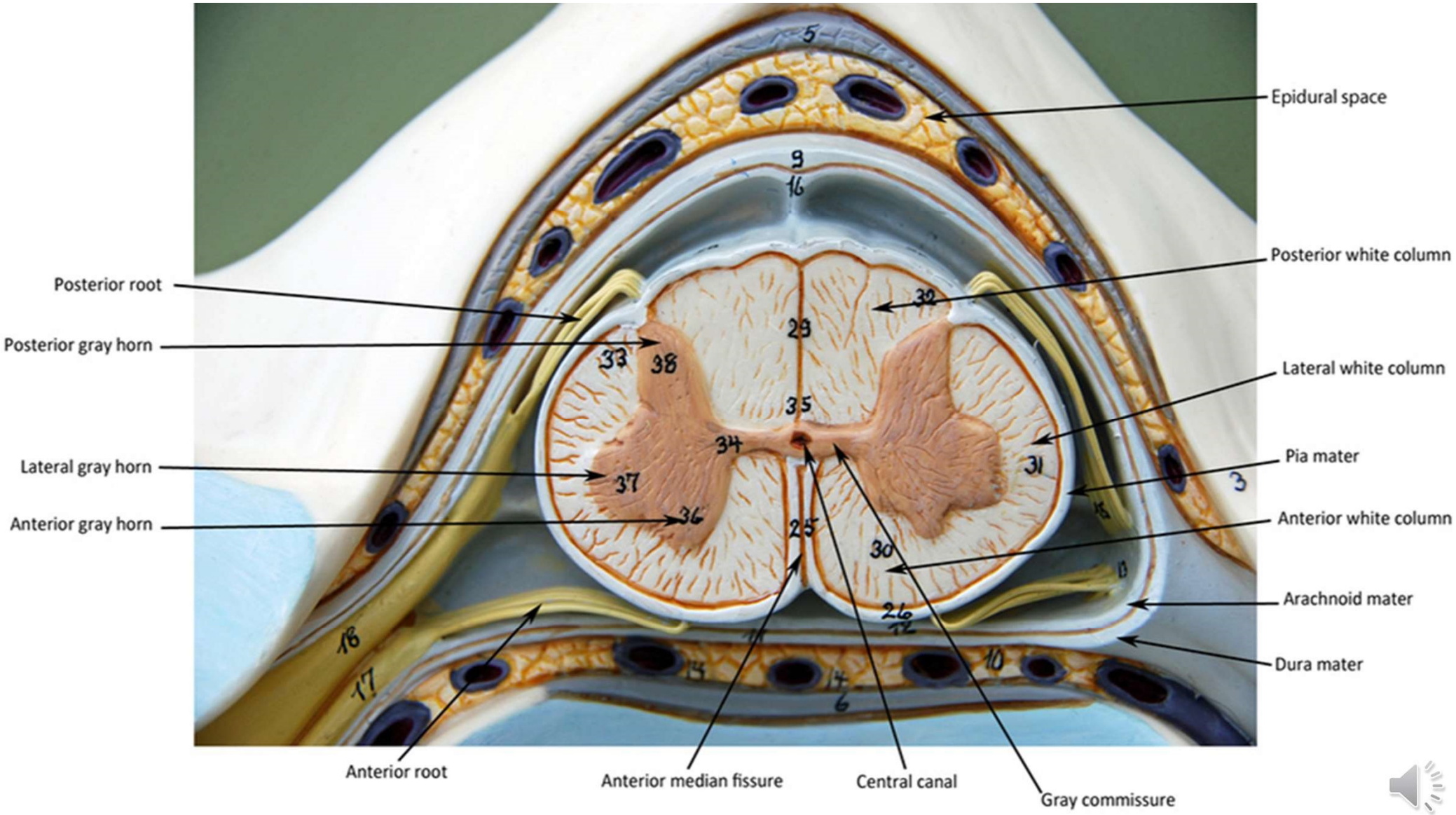
SPINAL CORD ANATOMY



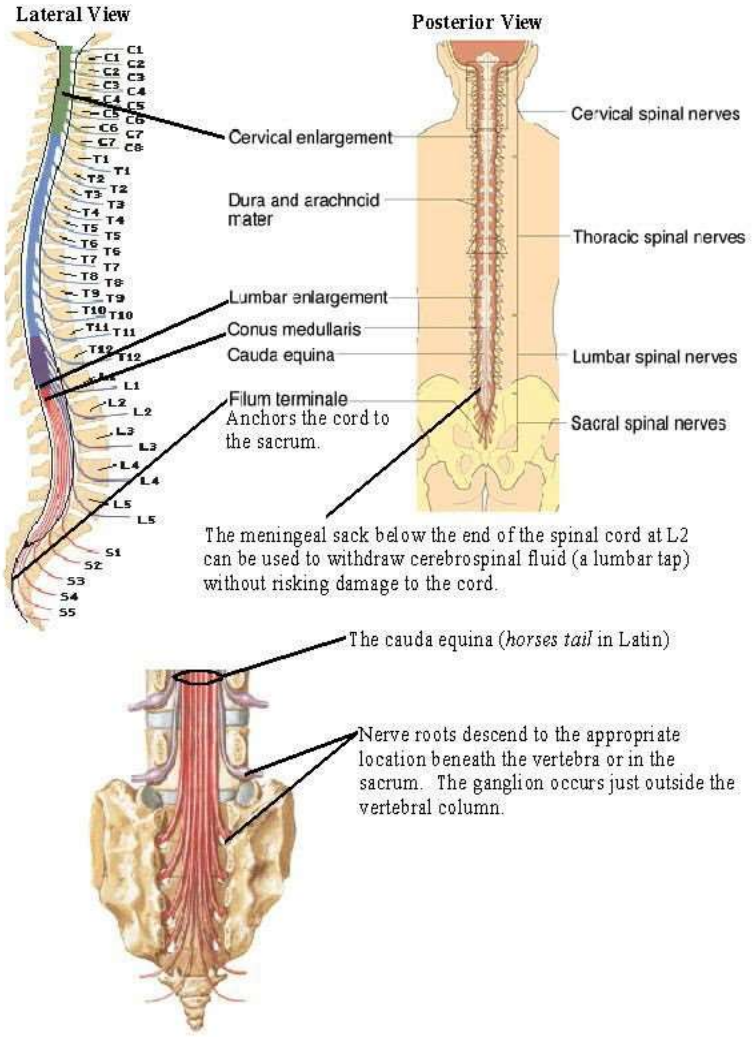




(d) Superior view


Epidural space
Posterior white column
Posterior root
Posterior gray horn
Lateral white column
Lateral gray horn
Pia mater
Anterior gray horn
Anterior white column
Arachnoid mater
Dura mater
Anterior root
Anterior median fissure
Central canal
Gray commissure

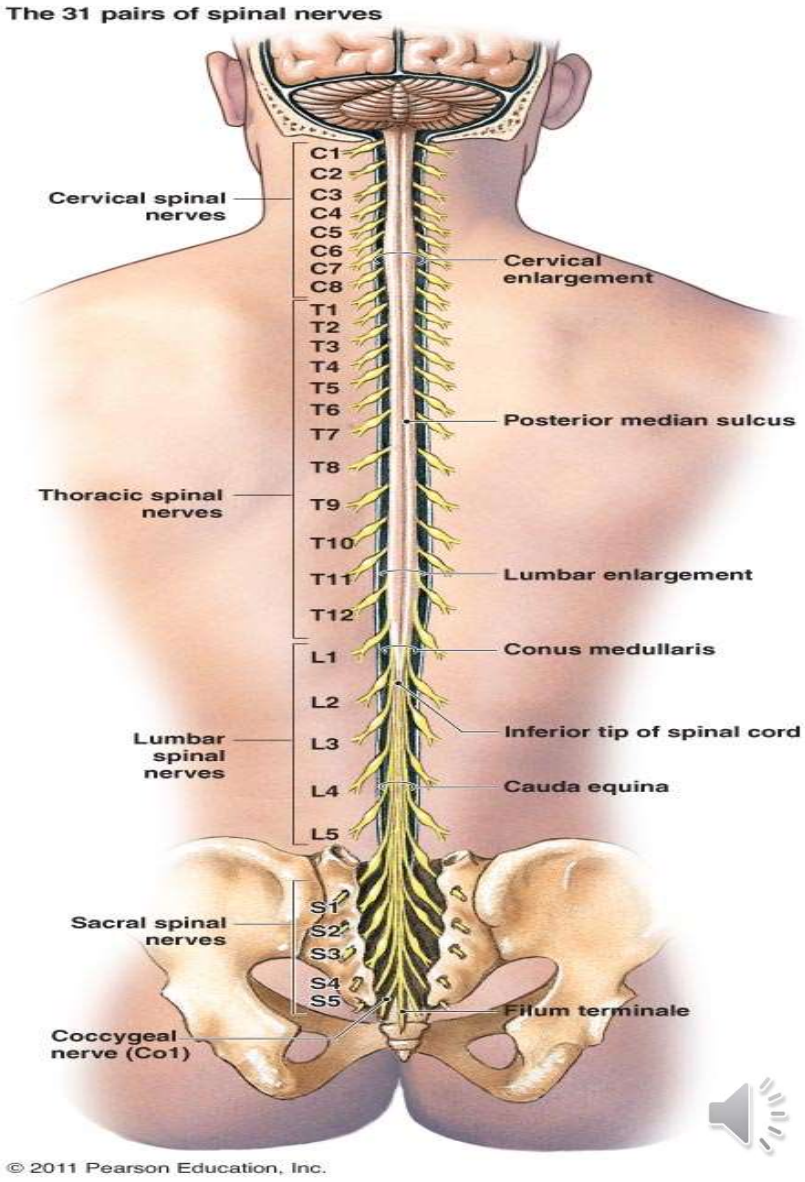
The Spinal Cord and Spinal Nerves



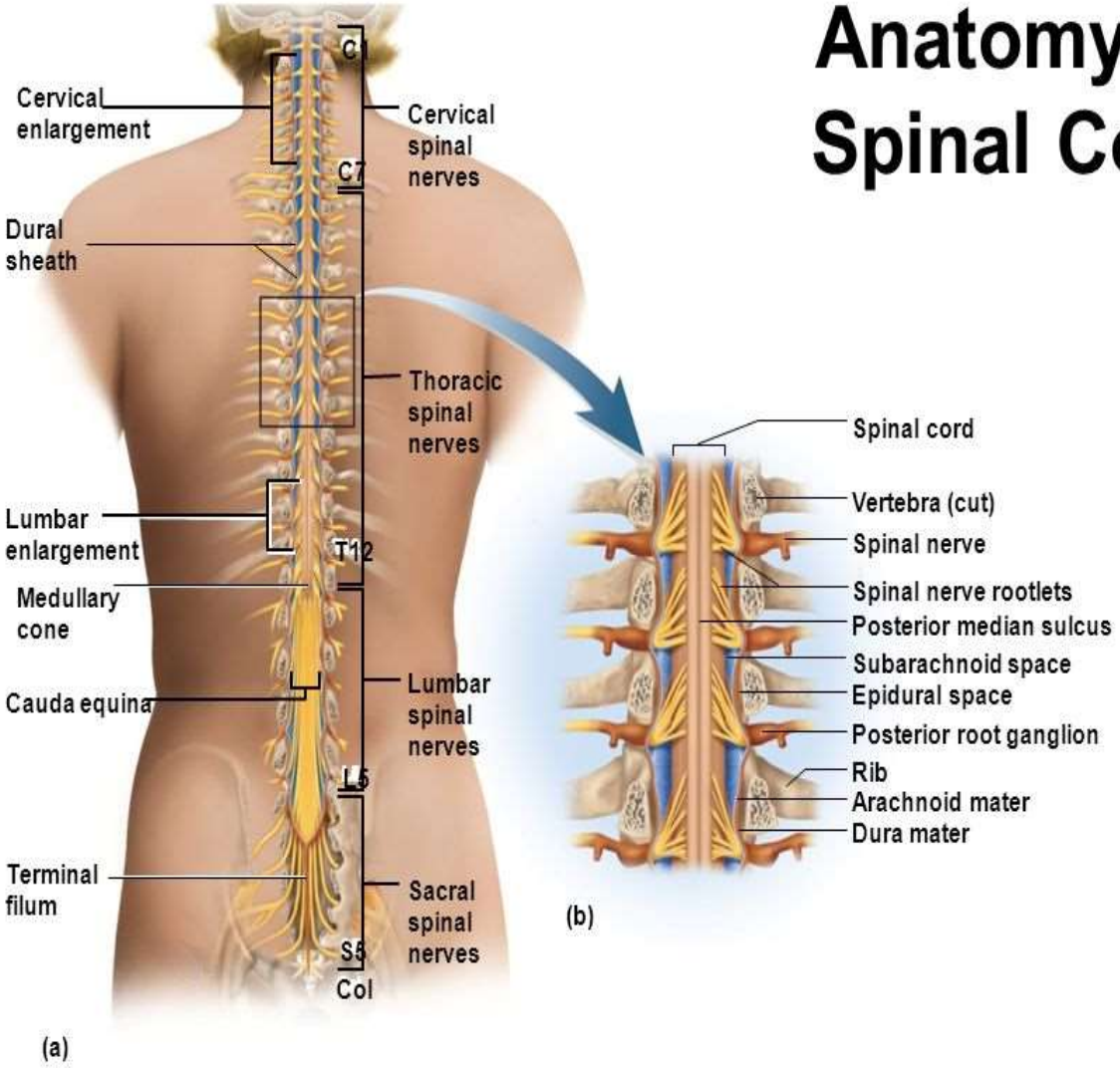
Conus medullaris – terminal portion of the spinal cord

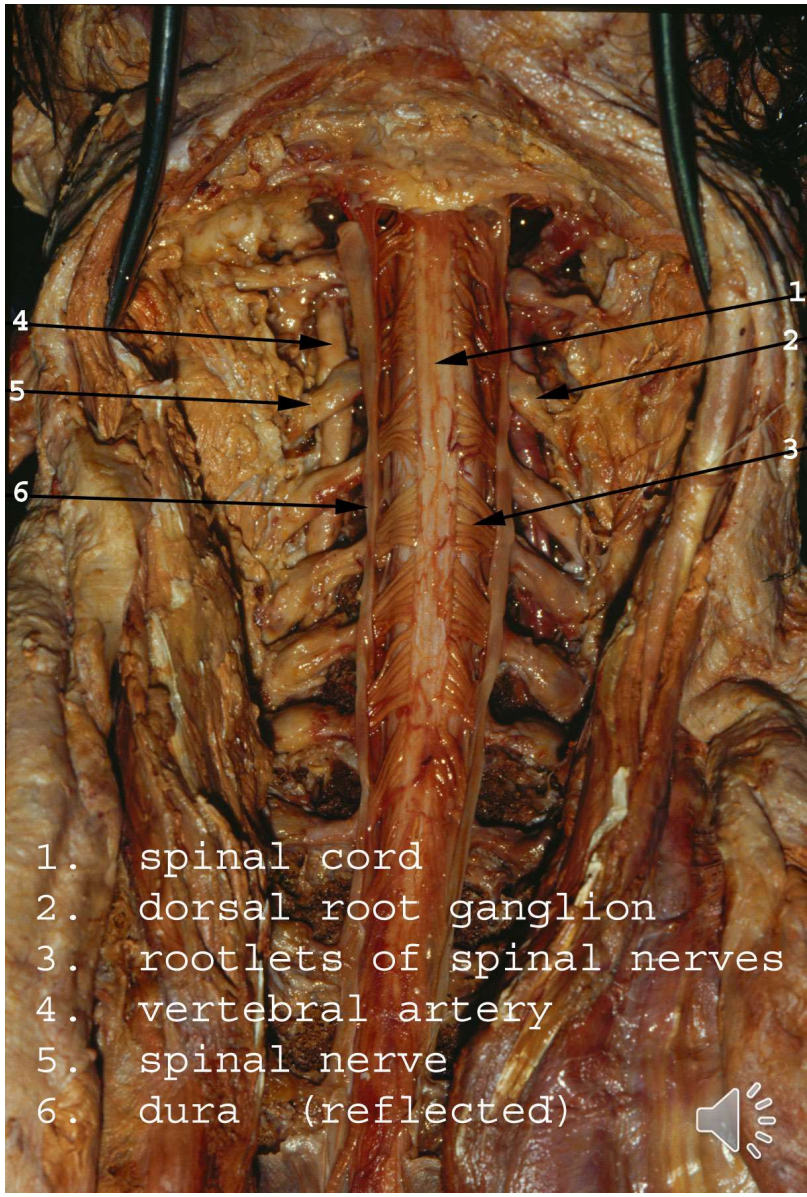
Filum terminale – fibrous extension of the pia mater; anchors the spinal cord to the coccyx

Denticulate ligaments – delicate shelves of pia mater; attach the spinal cord to the vertebrae



Anatomy of Spinal Cord





ganglion - a collection of cell bodies located outside the Central Nervous System. The spinal ganglia or dorsal root ganglia contain the cell bodies of sensory neurons entering the cord at that region.

nerve - a group of fibers (axons) *outside* the CNS. The spinal nerves contain the fibers of the sensory and motor neurons. A nerve does not contain cell bodies. They are located in the ganglion (sensory) or in the gray matter (motor).

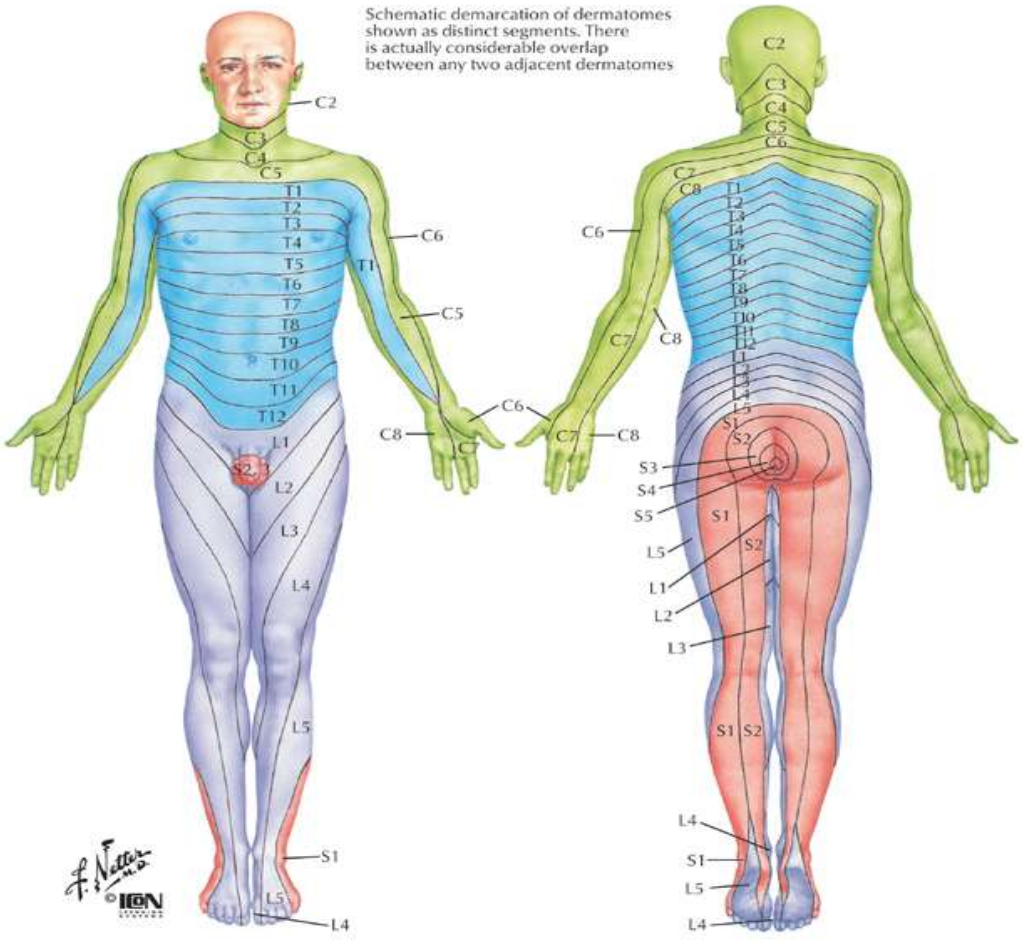
tract - a group of fibers *inside* the CNS. The spinal tracts carry information up or down the spinal cord, to or from the brain. Tracts within the brain carry information from one place to another within the brain. Tracts are always part of white matter.

gray matter - an area of unmyelinated neurons where cell bodies and synapses occur. In the spinal cord the synapses between sensory and motor and interneurons occurs in the gray matter. The cell bodies of the interneurons and motor neurons also are found in the gray matter.

white matter - an area of myelinated fiber tracts. Myelination in the CNS differs from that in nerves.

The **dermatomes** are somatic or musculocutaneous areas served by fibers from specific spinal nerves.

Referred pain is caused when the sensory fibers from an internal organ enter the spinal cord in the same root as fibers from a dermatome. The brain is poor at interpreting visceral pain and instead interprets it as pain from the somatic area of



Levels of principal dermatomes

C5	Clavicles
C5, 6, 7	Lateral parts of upper limbs
C8, T1	Medial sides of upper limbs
C6	Thumb
C6, 7, 8	Hand
C8	Ring and little fingers
T4	Level of nipples
T10	Level of umbilicus
T12	Inguinal or groin regions
L1, 2, 3, 4	Anterior and inner surfaces of lower limbs
L4, 5, S1	Foot
L4	Medial side of great toe
S1, 2, L5	Posterior and outer surfaces of lower limb
S1	Lateral margin of foot and little toe
S2, 3, 4	Perineum

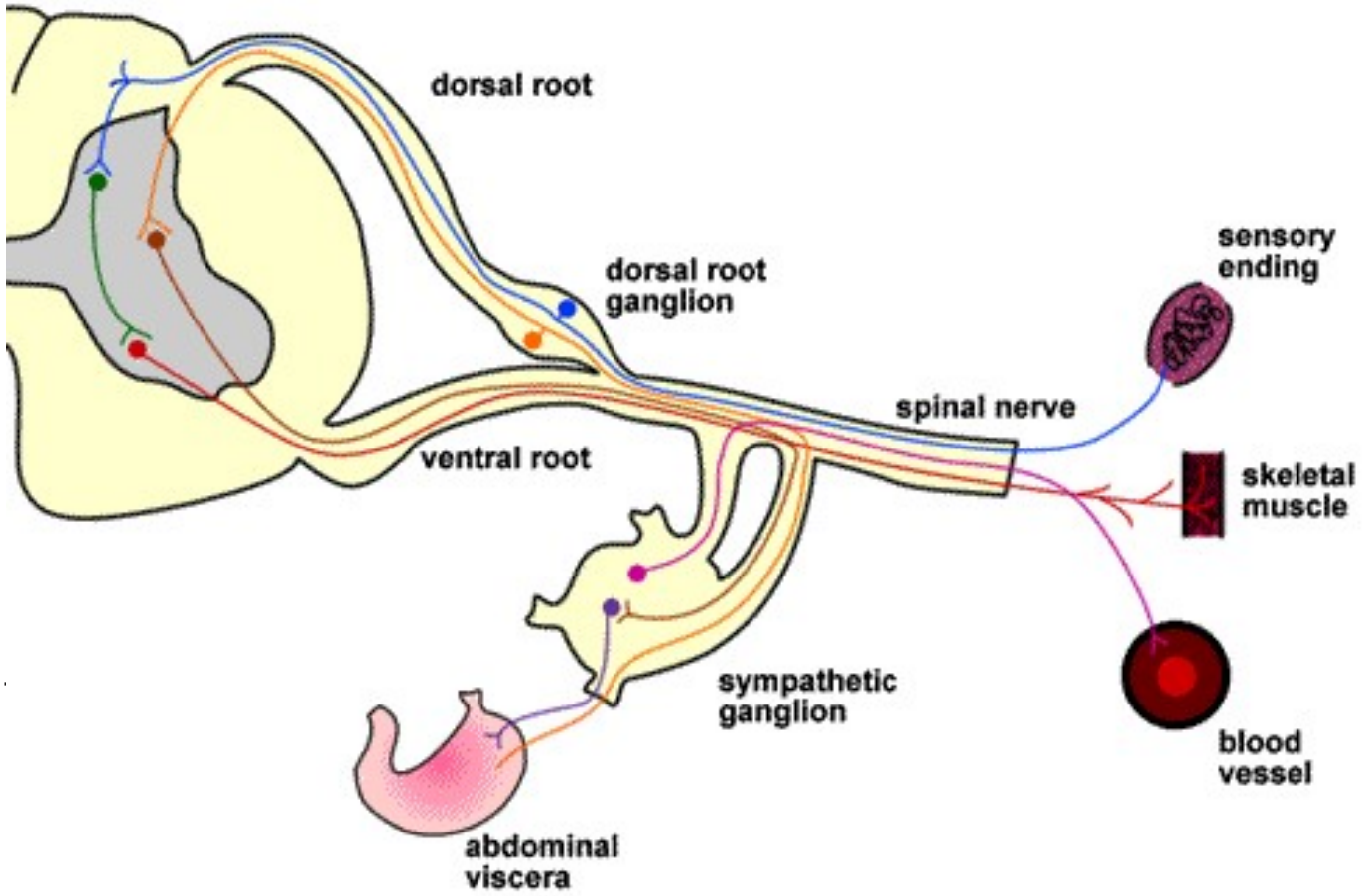
Cervical Plexus - the **phrenic nerve** travels through the thorax to innervate the diaphragm.

Brachial Plexus -
Axillary nerve - innervates the deltoid muscle and shoulder, along with the posterior aspect of the upper arm.
Musculocutaneous nerve - innervates anterior skin of upper arm and elbow flexors. **Radial nerve** - innervates dorsal aspect of the arm and extensors of the elbow, wrist, and fingers, abduction of thumb.
Median nerve - innervates the middle elbow, wrist and finger flexors, adducts the thumb.
Ulnar nerve - innervates the medial aspect wrist and finger flexors.

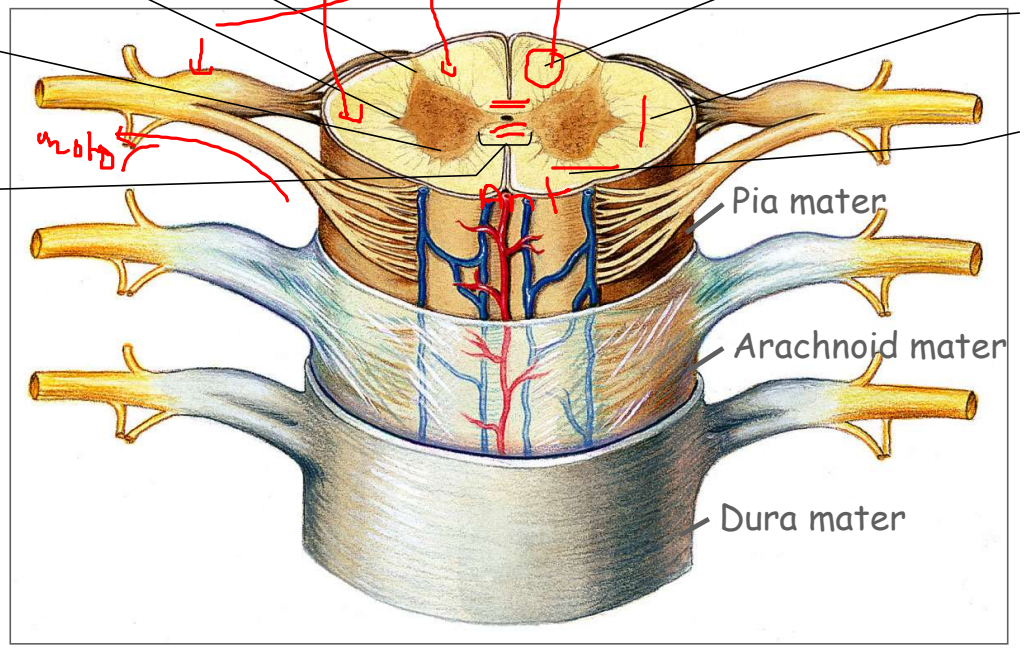
Celiac plexus or the solar plexus: under the **aortic hiatus** of the diaphragm along with ganglia connected with the roots of the **celiac trunk** and **superior mesenteric artery**. Ganglia related to the celiac plexus consist of two celiac ganglia, a single superior mesenteric ganglion, and two aorti-corenal ganglia.

Lumbar Plexus
genitofemoral - to the **external** genitalia
obturator - to the adductor muscles

Sacral Plexus –
contains fibers from the ventral rami of $L_4 – S_4$.
The sciatic nerve is a major nerve of this plexus.


dorsal root
dorsal root ganglion
sensory ending
spinal nerve
ventral root
skeletal muscle
sympathetic ganglion
blood vessel
abdominal viscera

Spinal Cord Anatomy



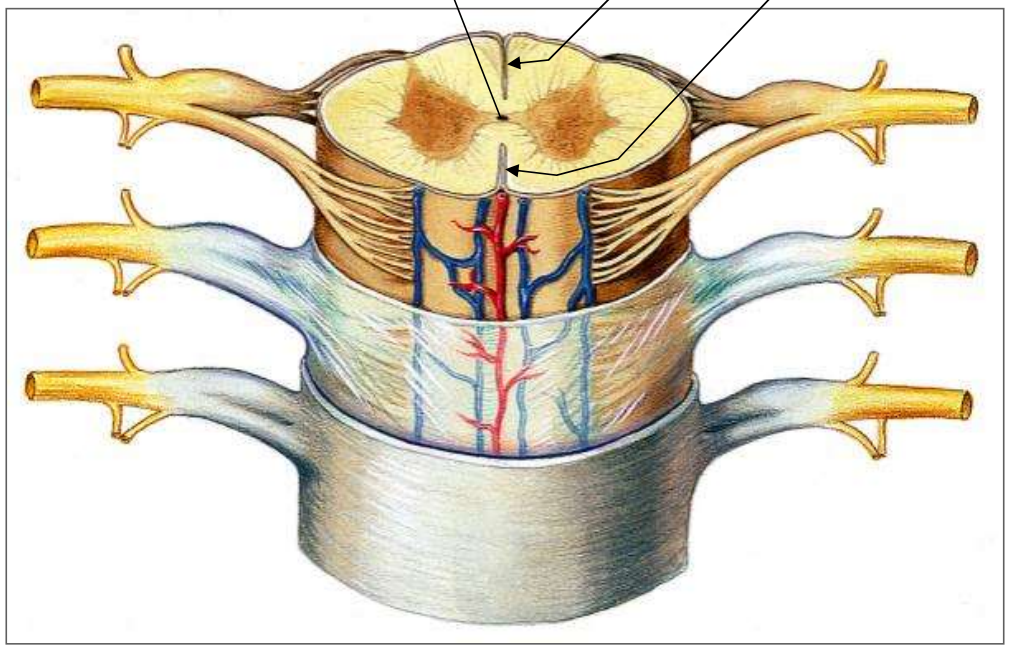
a funiculus:
posterior funiculus
lateral funiculus
anterior funiculus
interconnected by the white commissure
The axons within each funiculus are organized into tracts.

Dermatomes → SKIN
Myotomes → skeletal Muscle
Sclerotomes → Bones Ligaments

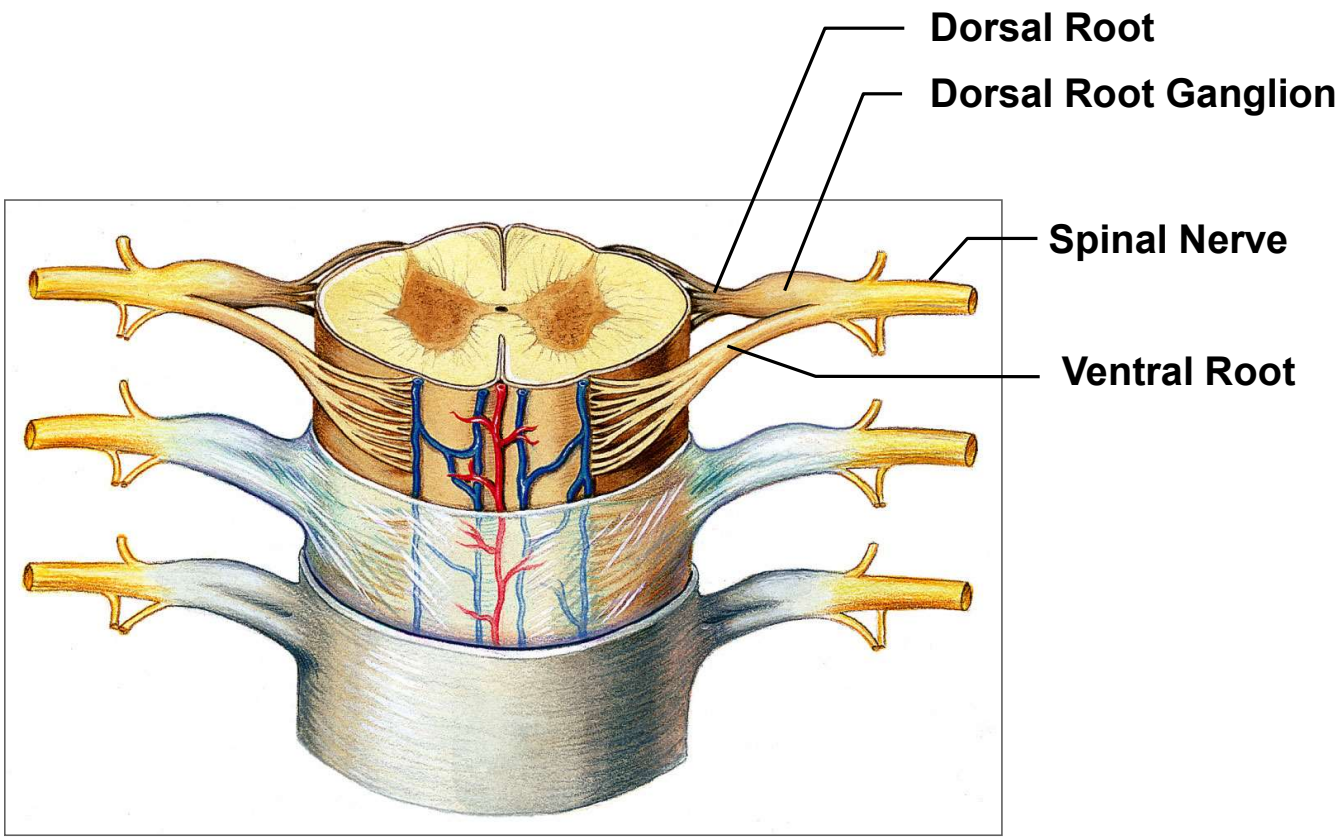
Gray matter = Inside, cell bodies & unmyelinated fiber tracts

White matter = Outside, myelinated fiber tracts

Spinal Cord Anatomy



Spinal Cord / Spinal Nerve Anatomy



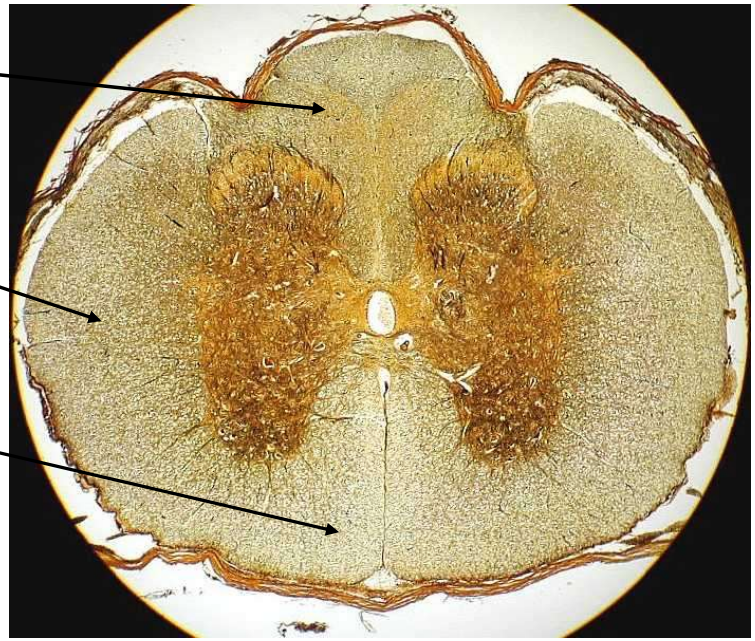
White Matter – Funiculis = Bundle of Nerve Fibers or Tracts

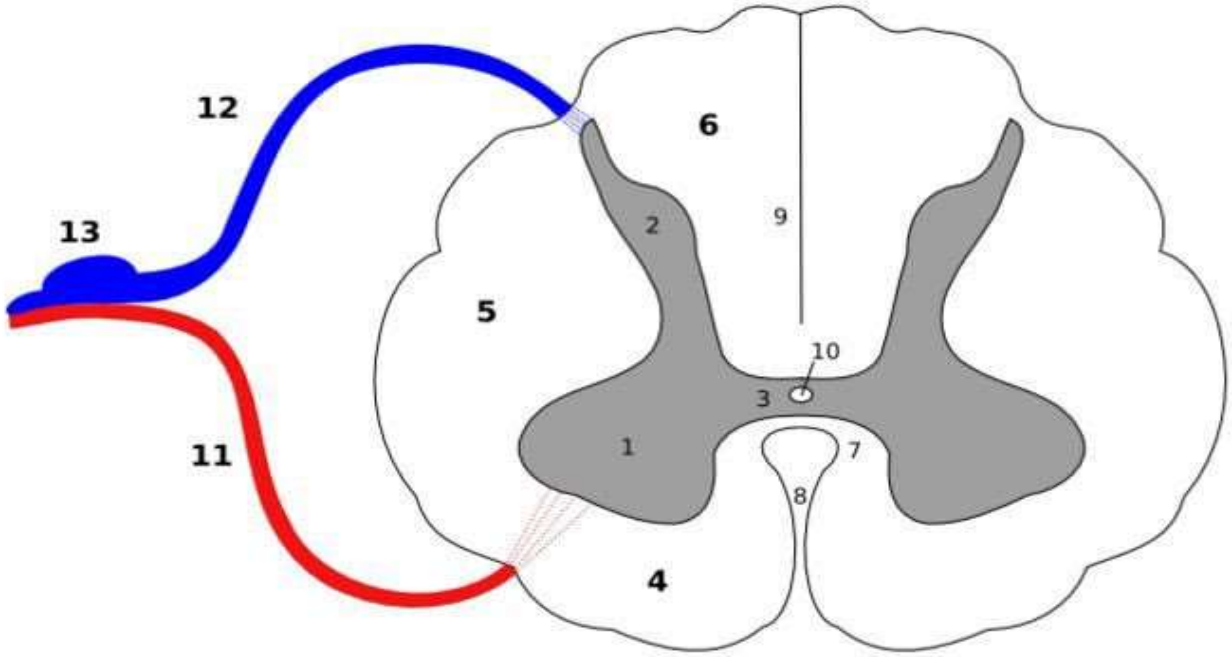
- fiber tracts for transmission of information
- ascending (sensory) tracts → Thalamus → Cortex
- descending (motor) tracts → Brain → P

Posterior funiculus

Lateral funiculus

Anterior funiculus



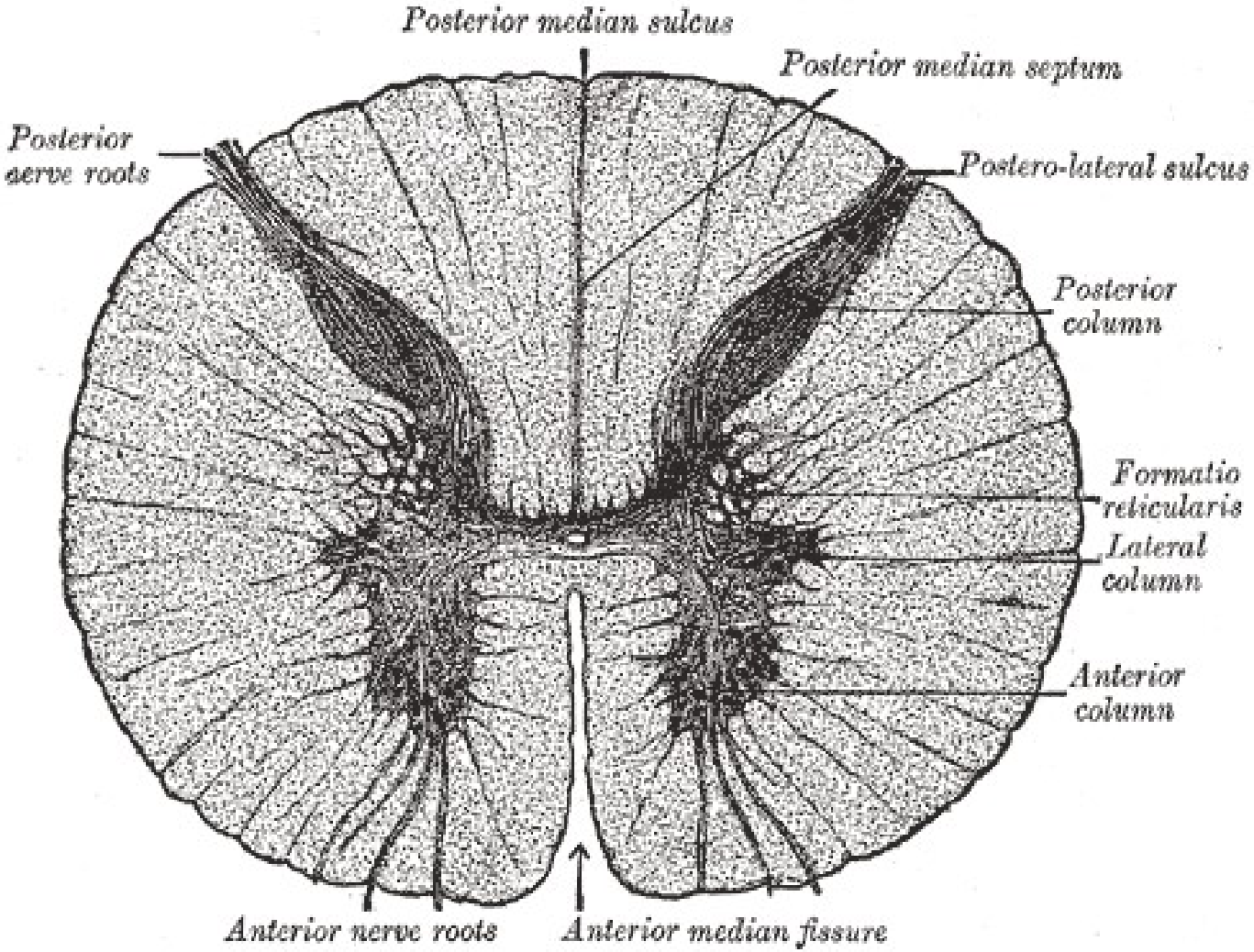


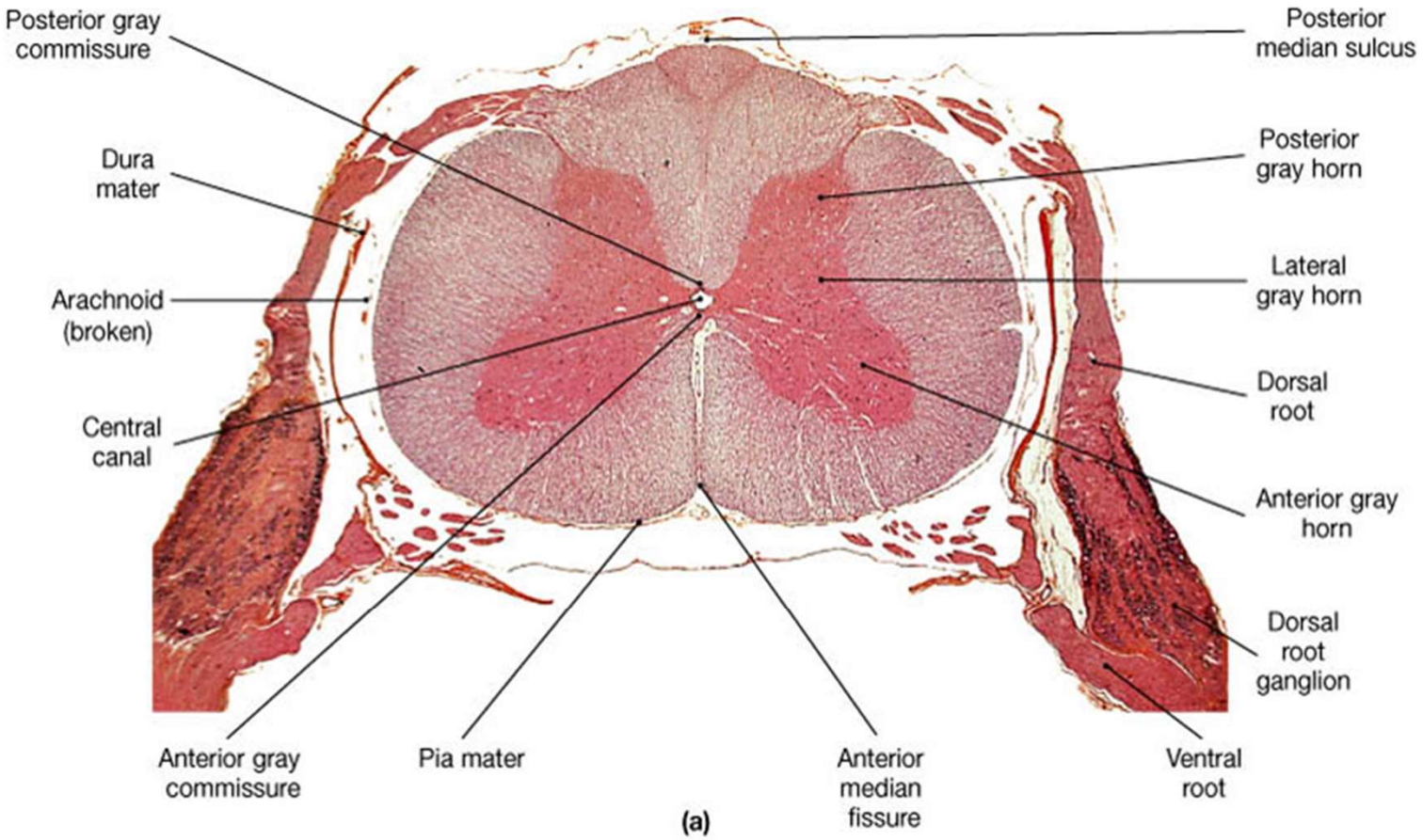
Substantia grisea

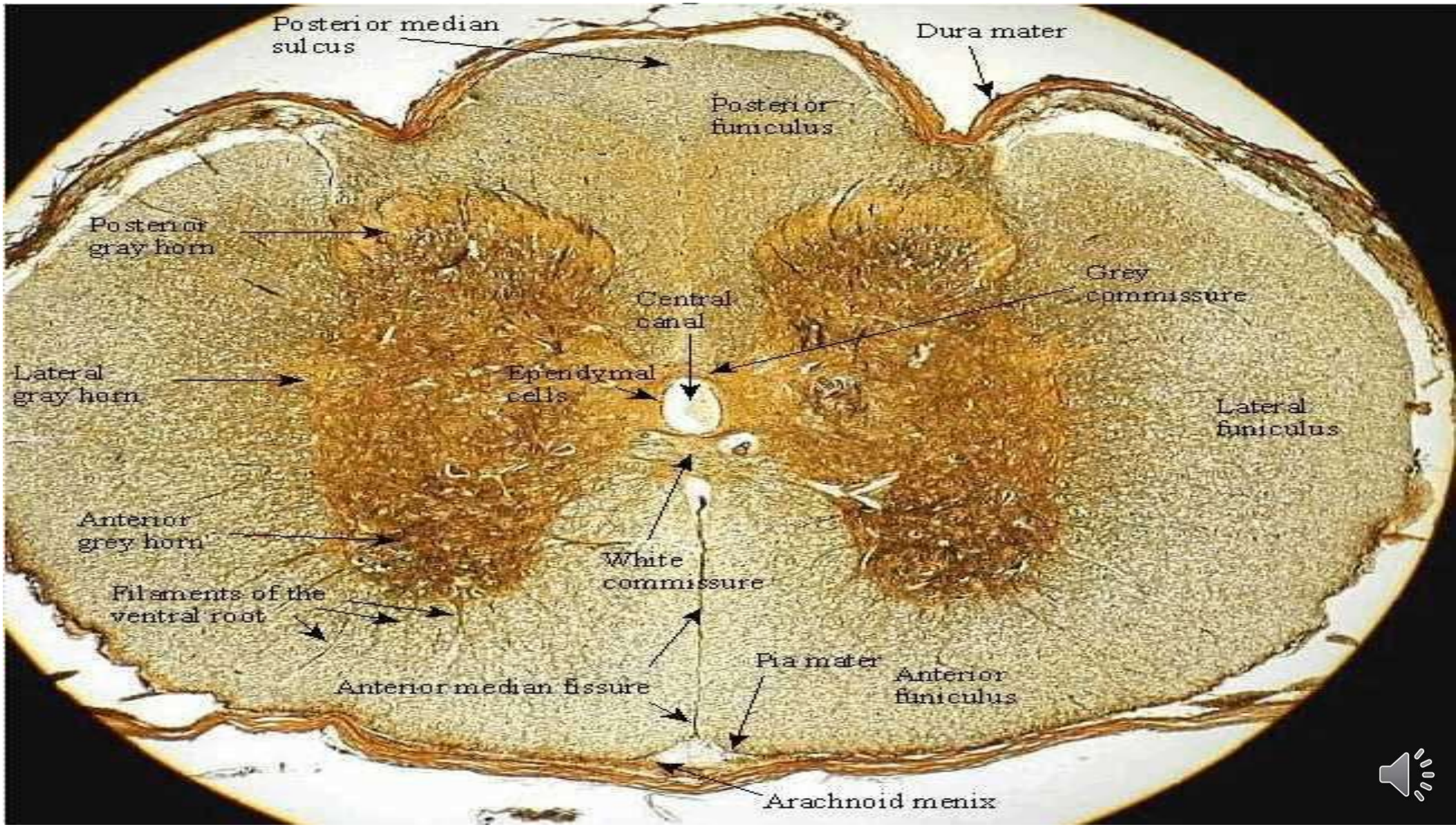
1. Cornu anterius
2. Cornu posterius
3. Commisura grisea

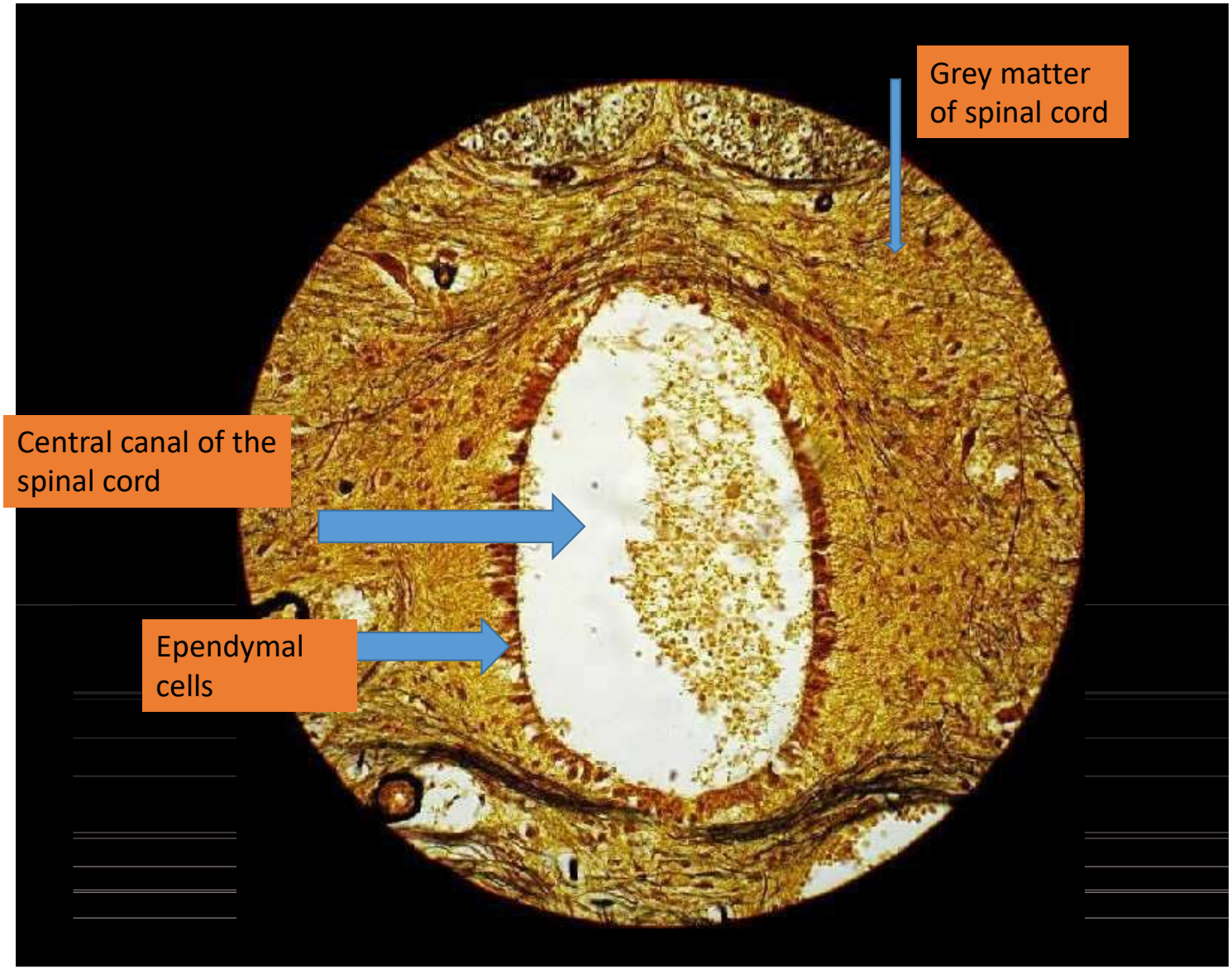
Substantia alba

4. Funiculus anterior
5. Funiculus lateralis
6. Funiculus posterior
7. Commisura alba anterior
8. Fissura mediana anterior
9. Sulcus medianus posterior
10. Canalis centralis
11. Radix anterior
12. Radix posterior
13. Ganglion sensorium nervi spinalis

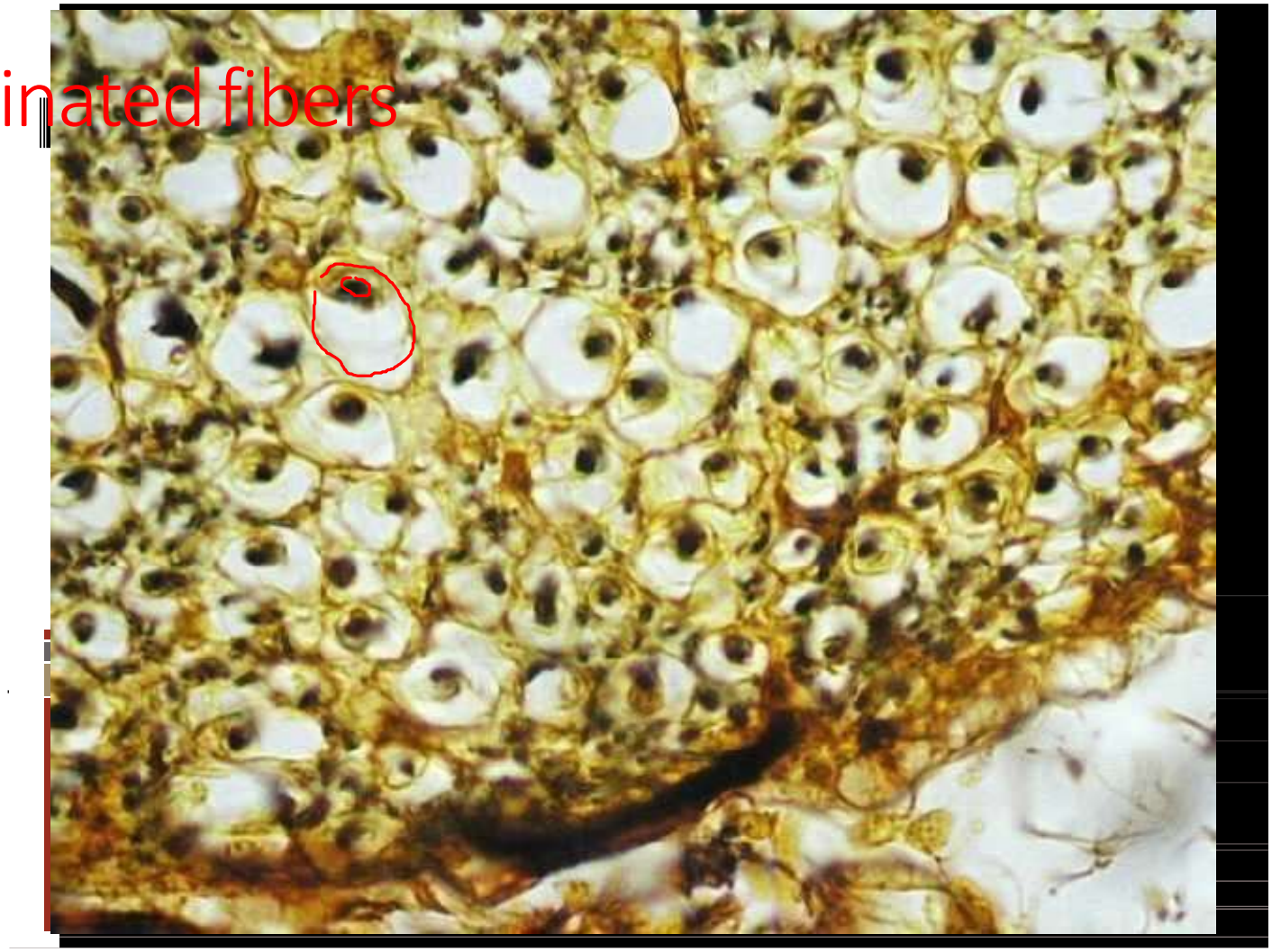

Posterior median sulcus
Posterior median septum
Posterior nerve roots
Postero-lateral sulcus
Posterior column
Formatio reticularis
Lateral column
Anterior column
Anterior nerve roots
Anterior median fissure


Posterior gray commissure
Posterior median sulcus
Dura mater
Posterior gray horn
Arachnoid (broken)
Lateral gray horn
Central canal
Dorsal root
Anterior gray horn
Dorsal root ganglion
Anterior gray commissure
Pia mater
Anterior median fissure
Ventral root
(a)

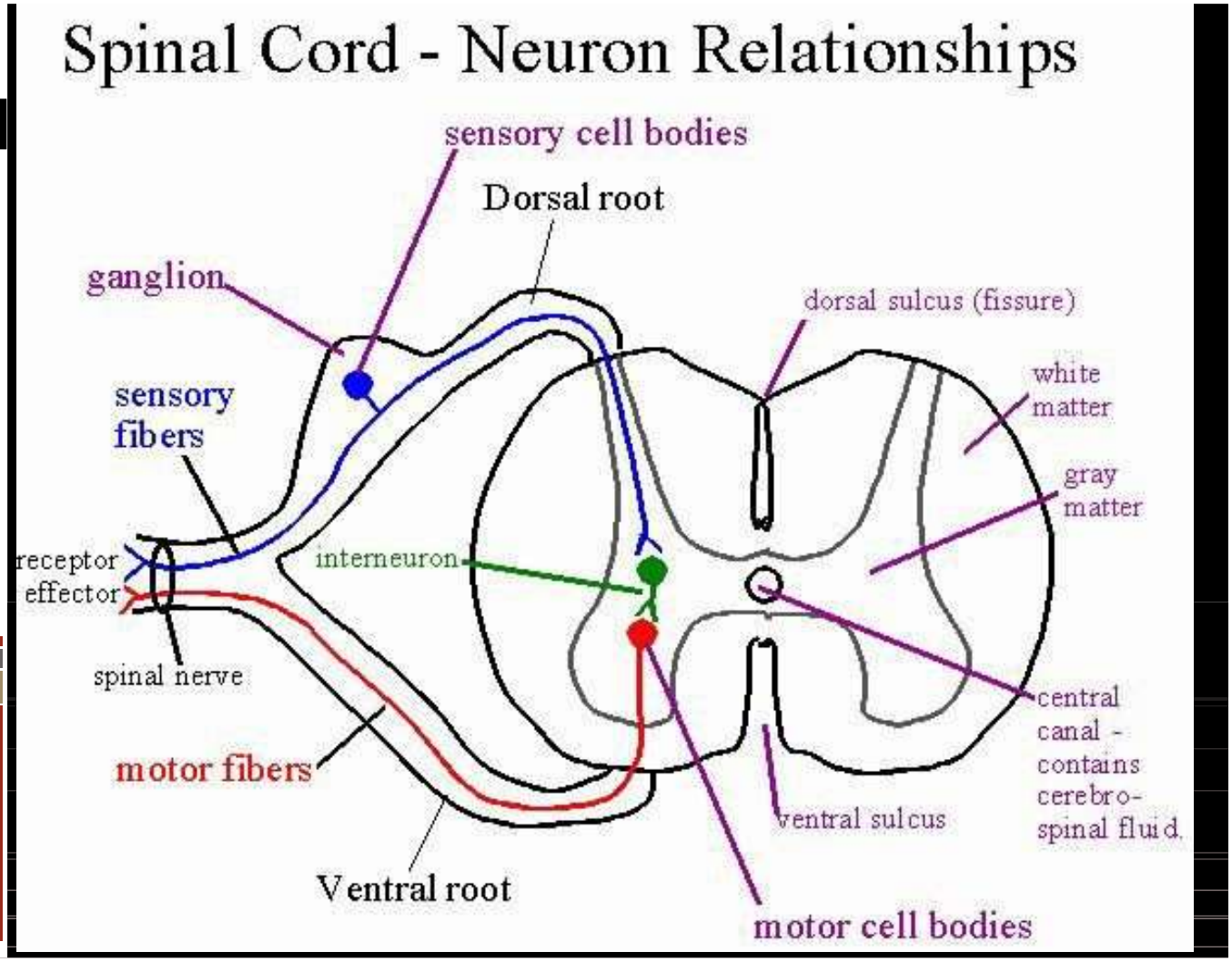

Posterior median sulcus
Dura mater
Posterior funiculus
Posterior gray horn
Grey commissure
Central canal
Lateral gray horn
Ependymal cells
Lateral funiculus
Anterior grey horn
White commissure
Filaments of the ventral root
Pia mater
Anterior funiculus
Anterior median fissure
Arachnoid menix

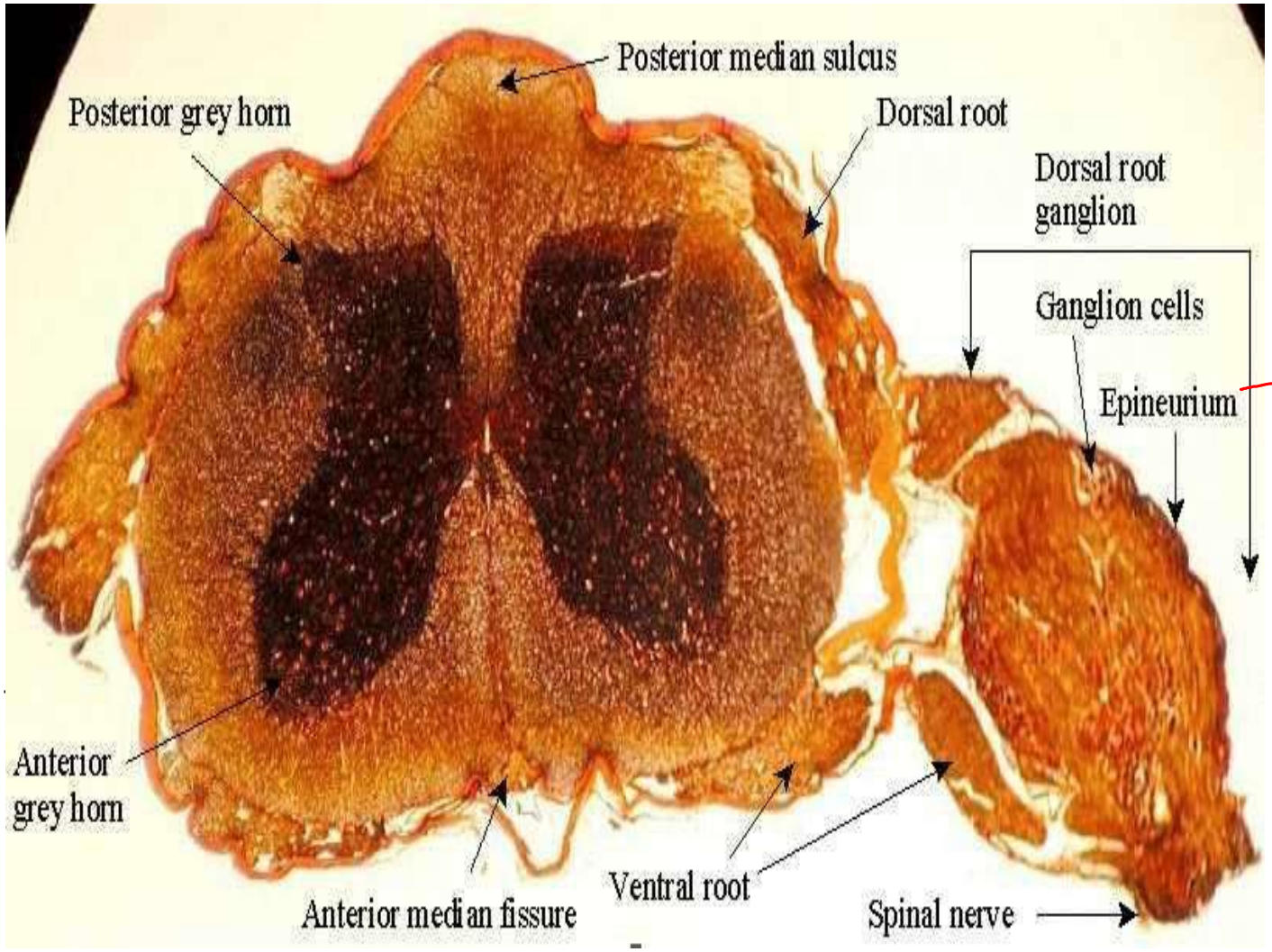

Grey matter of spinal cord
Central canal of the spinal cord
Ependymal cells

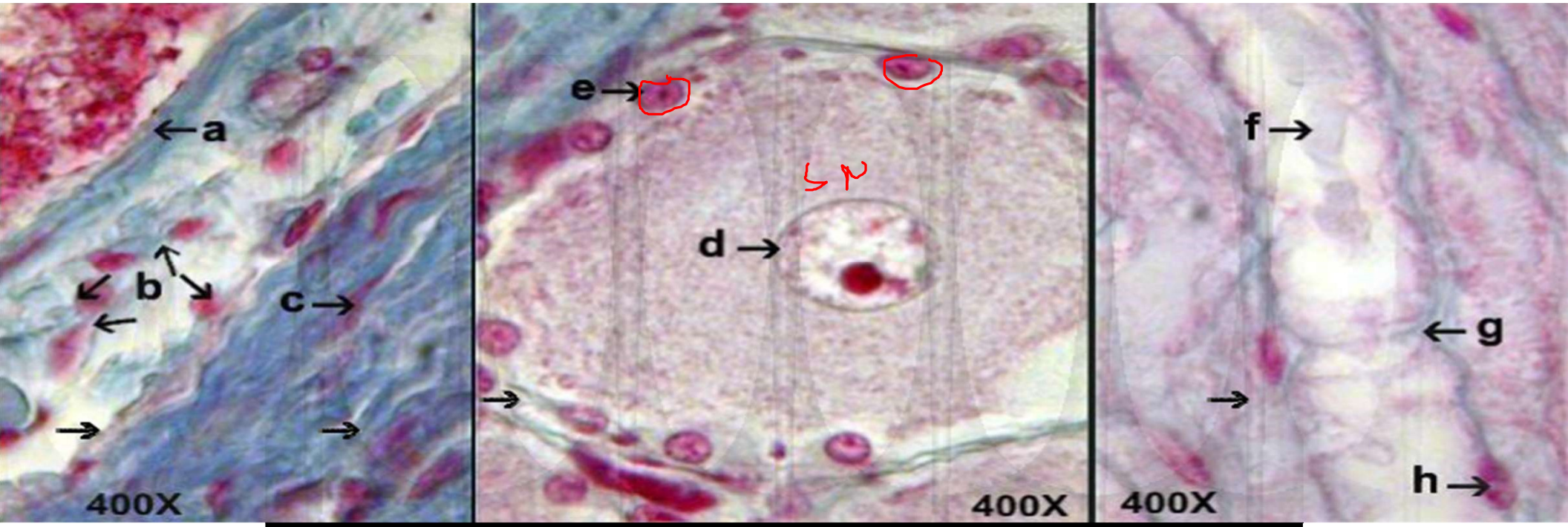
Myelinated fibers



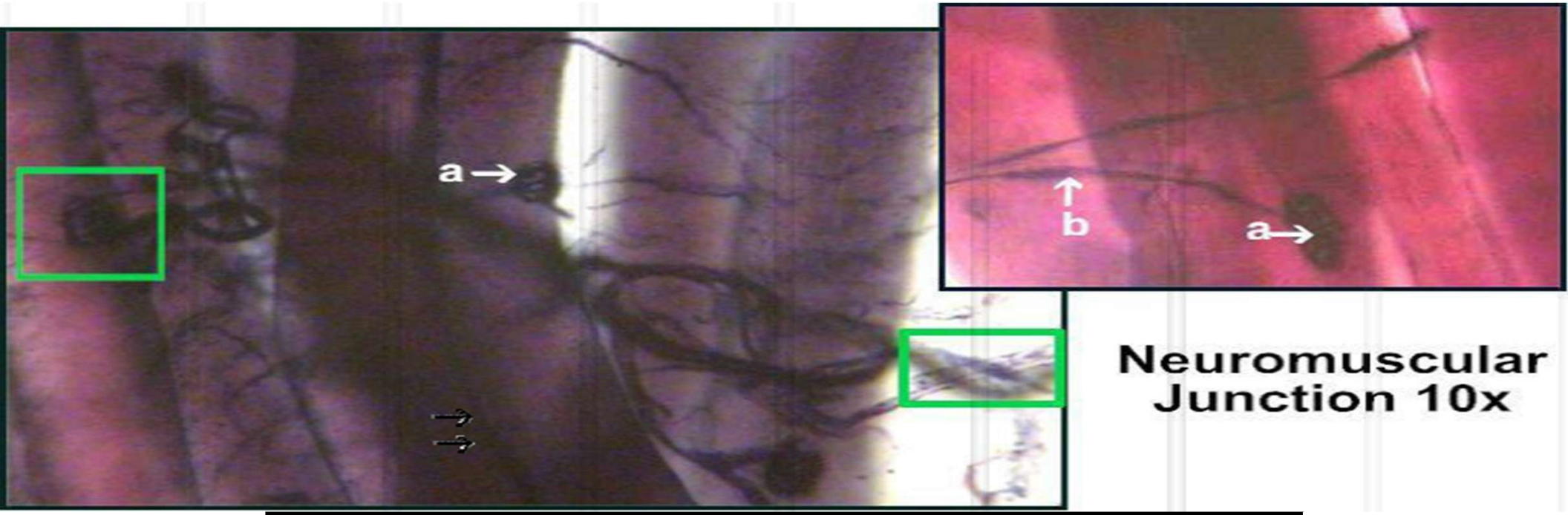
Spinal Cord - Neuron Relationships




Posterior median sulcus
Posterior grey horn
Dorsal root
Dorsal root ganglion
Ganglion cells
Epineurium
Anterior grey horn
Anterior median fissure
Ventral root
Spinal nerve



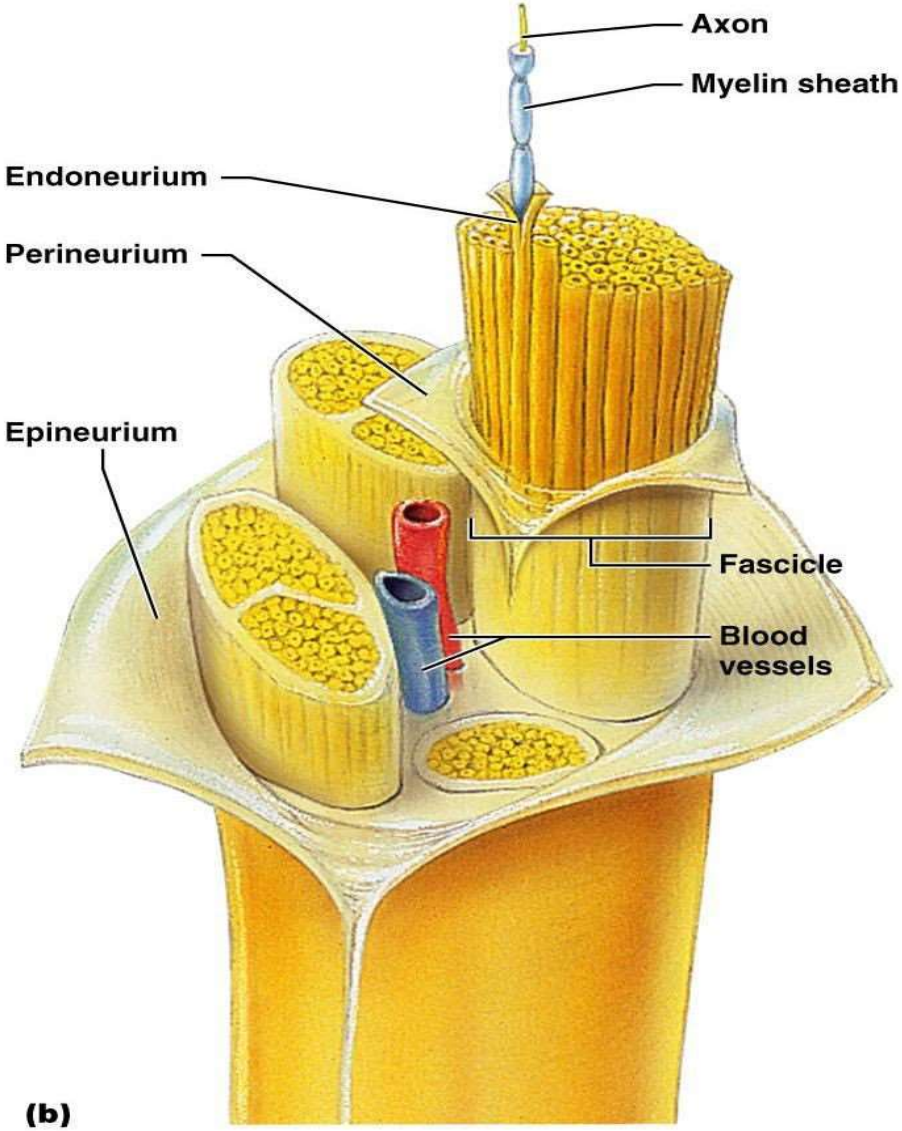
a Pia mater b Subarachnoid space filled with cerebral spinal fluid, wastes and various cells. c Fibrocyte mixed in the blue collagen fibers of the dura mater. d Nucleus & nucleolus of unipolar neuron e Nucleus of one of many tiny satellite cells surrounding the large unipolar neuron. f Myelinated axon g Node of Ranvier h Nucleus of white Schwann cell

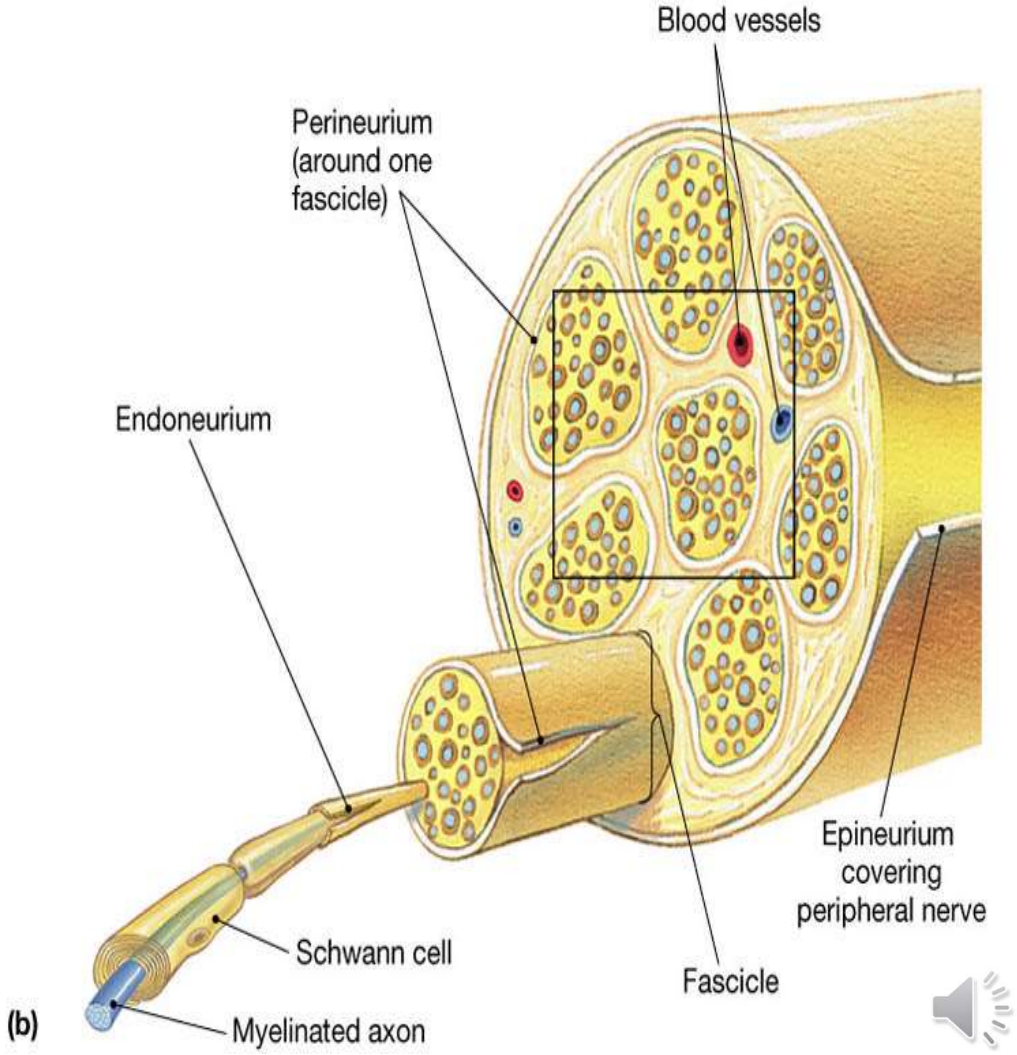


a Synaptic bulbs over the motor end plate - neuromuscular junction

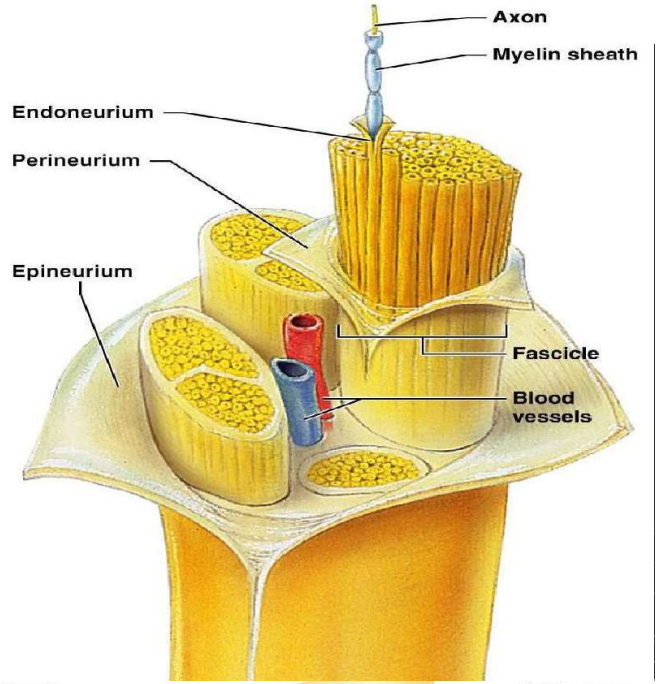
b Neuron axon terminal - black fibers

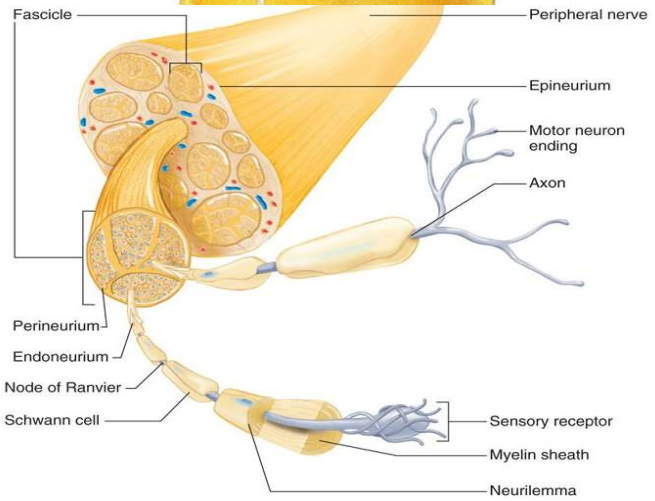
Structure of a Nerve



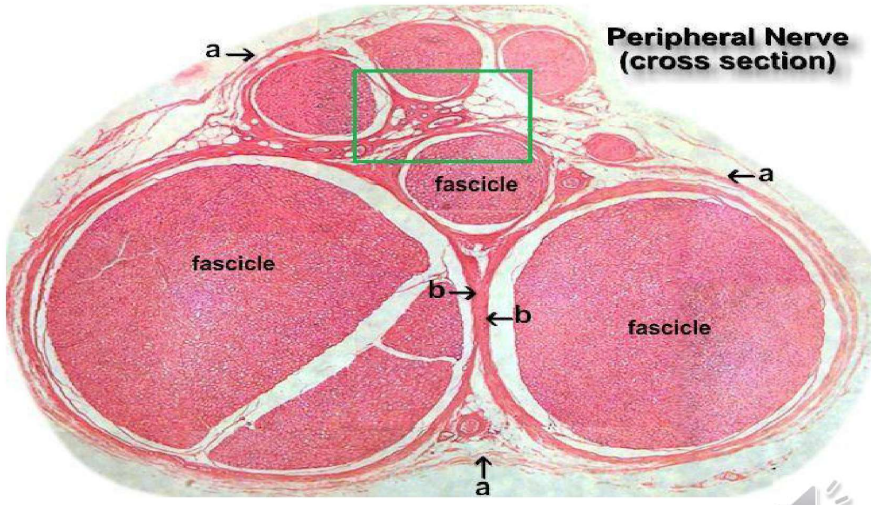


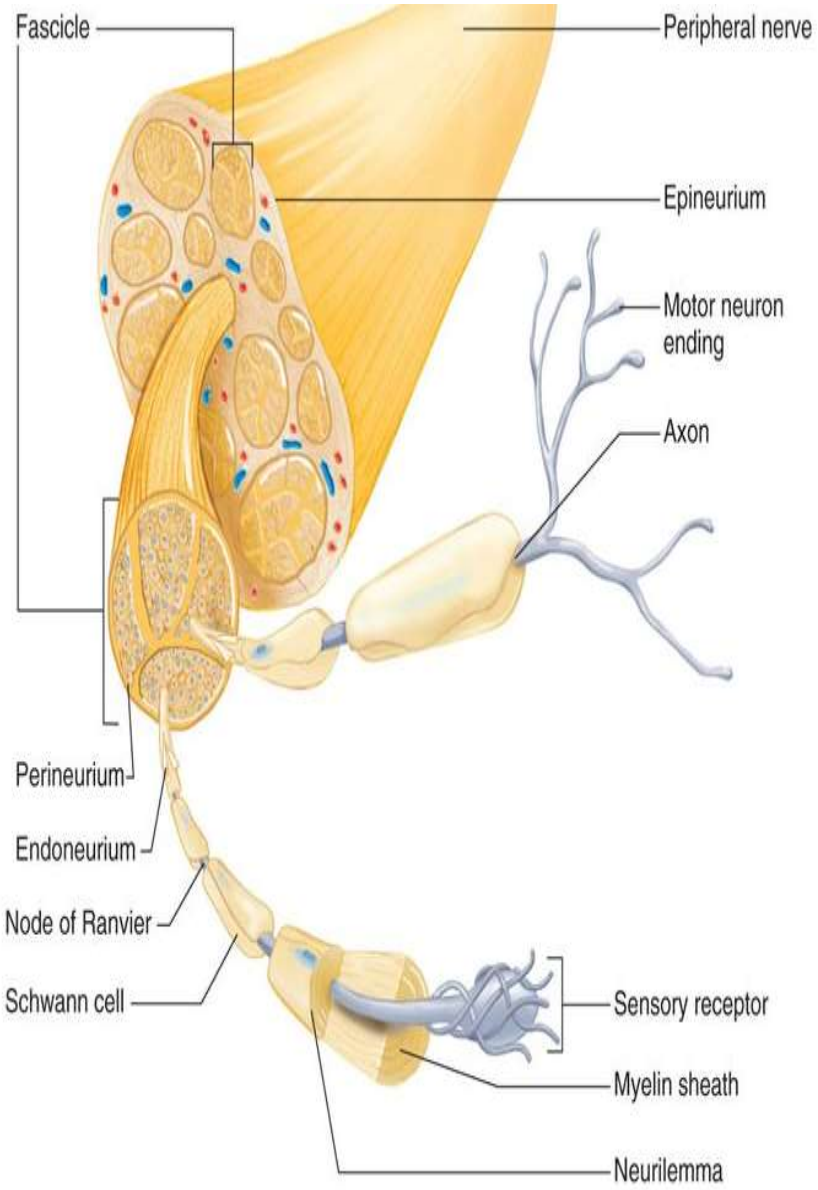
Structure of a Nerve





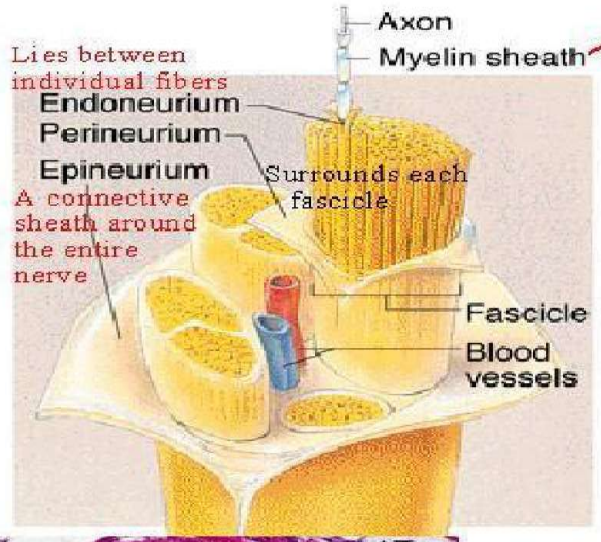
- Nerve – cordlike organ of the PNS consisting of peripheral axons enclosed by connective tissue
- Connective tissue coverings include:
  - Endoneurium – loose connective tissue that surrounds axons
  - Perineurium – coarse connective tissue that bundles fibers into fascicles
  - Epineurium – tough fibrous sheath around a nerve



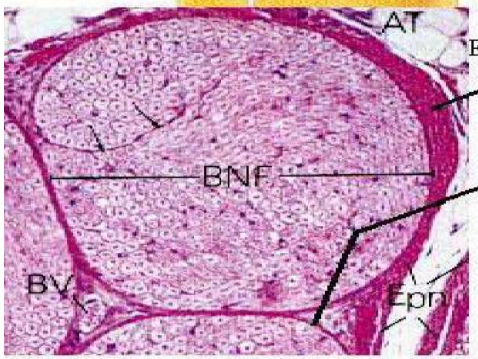


Structure of a Nerve

Consists of a continuous series of Schwann cells wrapped around the fiber.



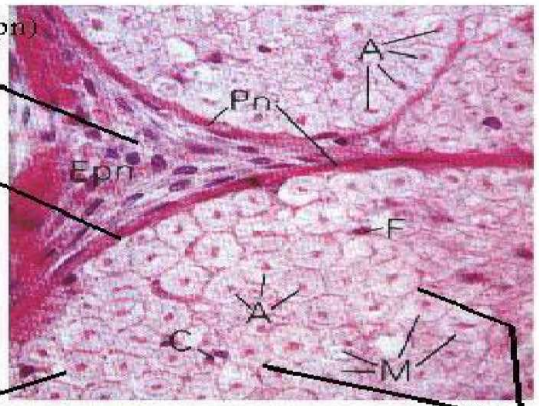
A nerve is a group of axons (nerve fibers) outside the CNS. These fibers are bundled together with connective layers. Many of the fibers are myelinated, which means they have a covering made from successive wrappings of Schwann cells.



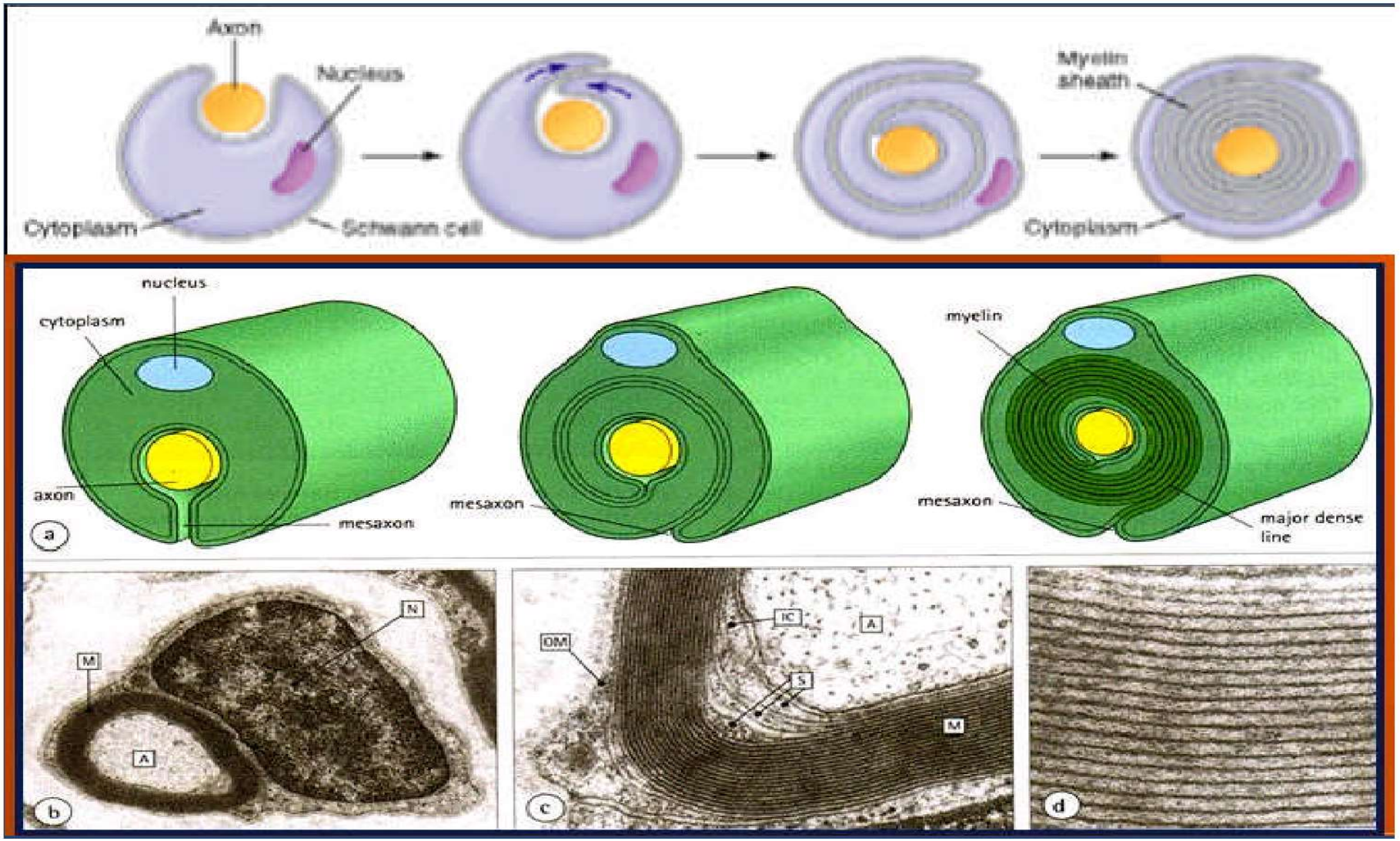
BV=blood vessel, BNF=fascicle, A=axons, F=a fibroblast, C=capillary.

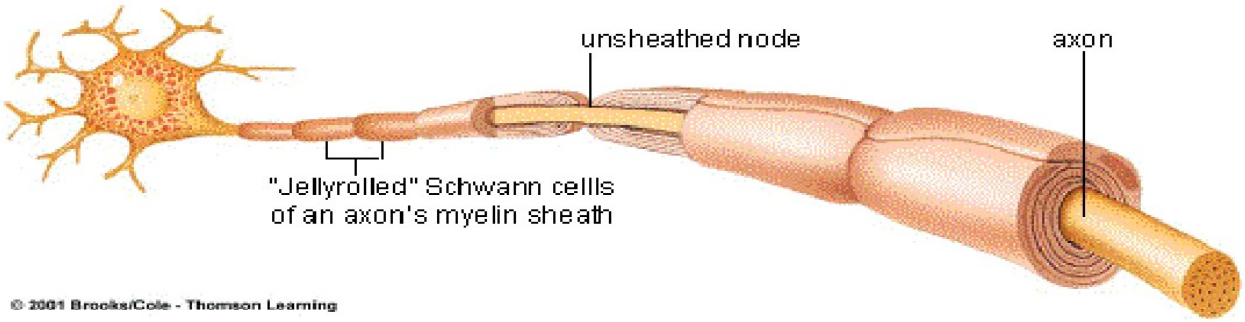
Epineurium (Epn)

Perineurium (Pn)



M = the myelin sheath, composed of wrappings of a Schwann cell. The outer membrane or layer of the myelin sheath is called the neurilemma.


Axon
Nucleus
Cytoplasm
Schwann cell
Myelin sheath
Cytoplasm
nucleus
cytoplasm
axon
mesaxon
a
mesaxon
myelin
mesaxon
major dense line
N
M
A
b
OM
IC
A
S
M
c
d

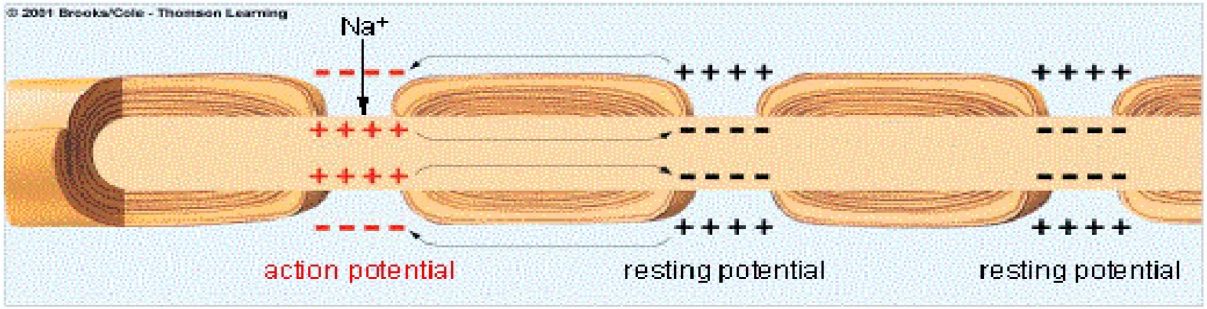


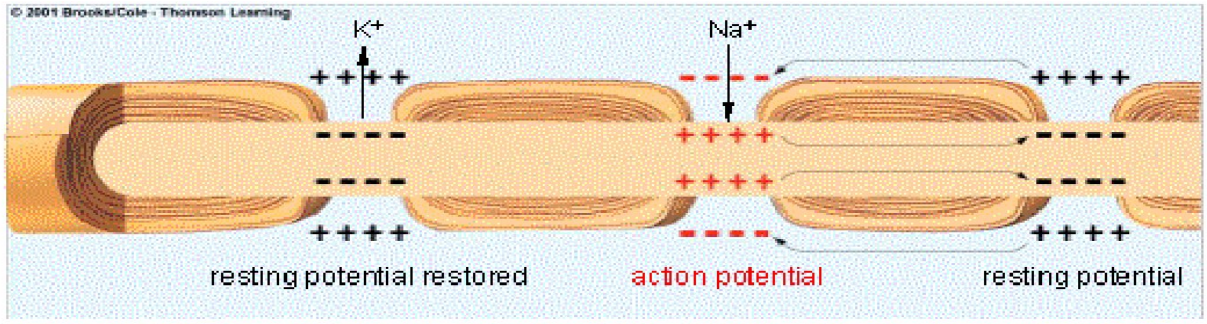
Myelin Sheath

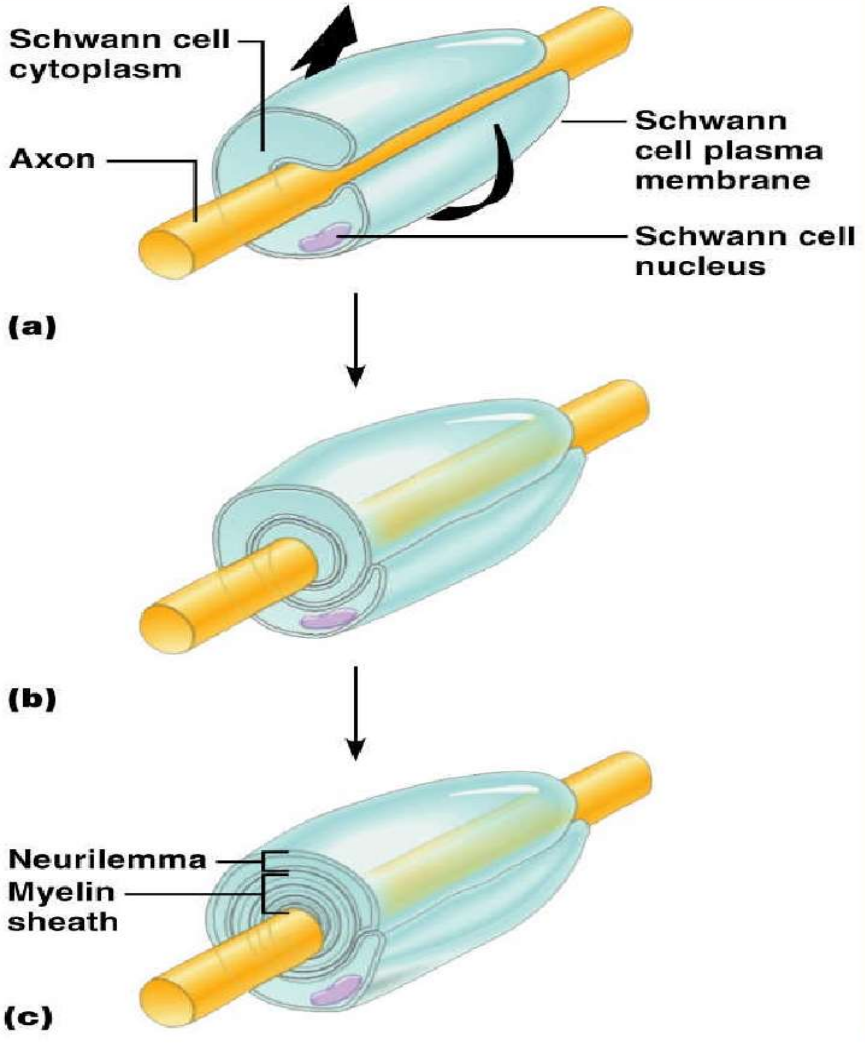
A series of Schwann cells

Sheath blocks ion movements

Action potential must "jump" from node to node

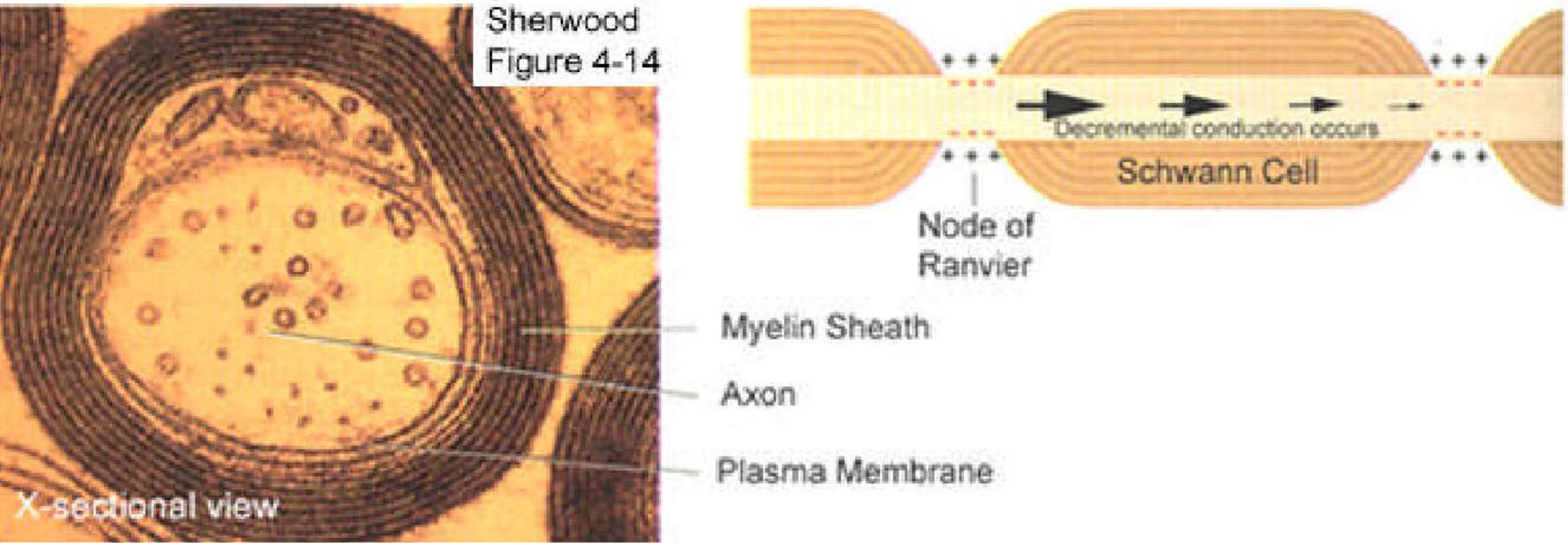


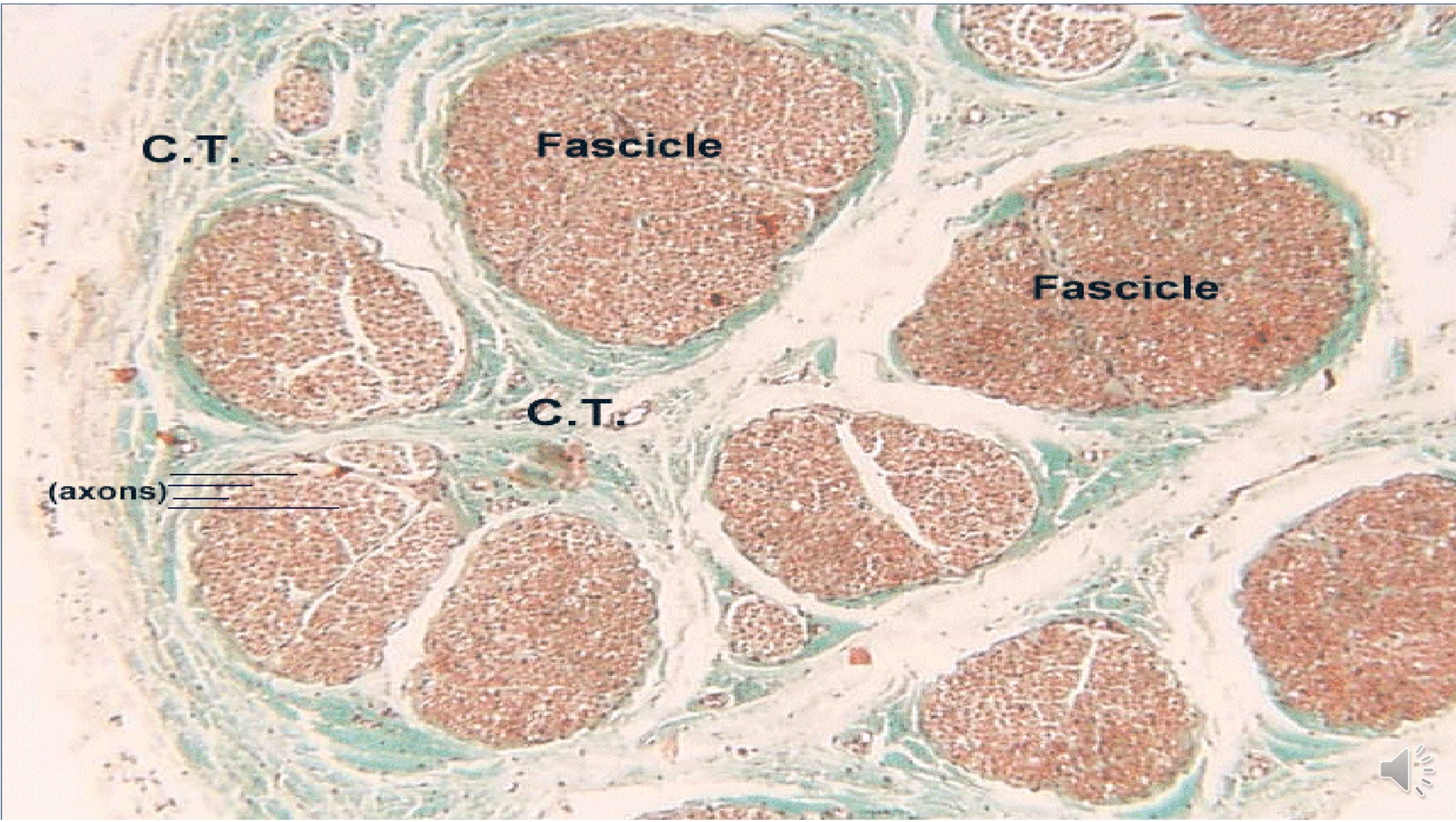


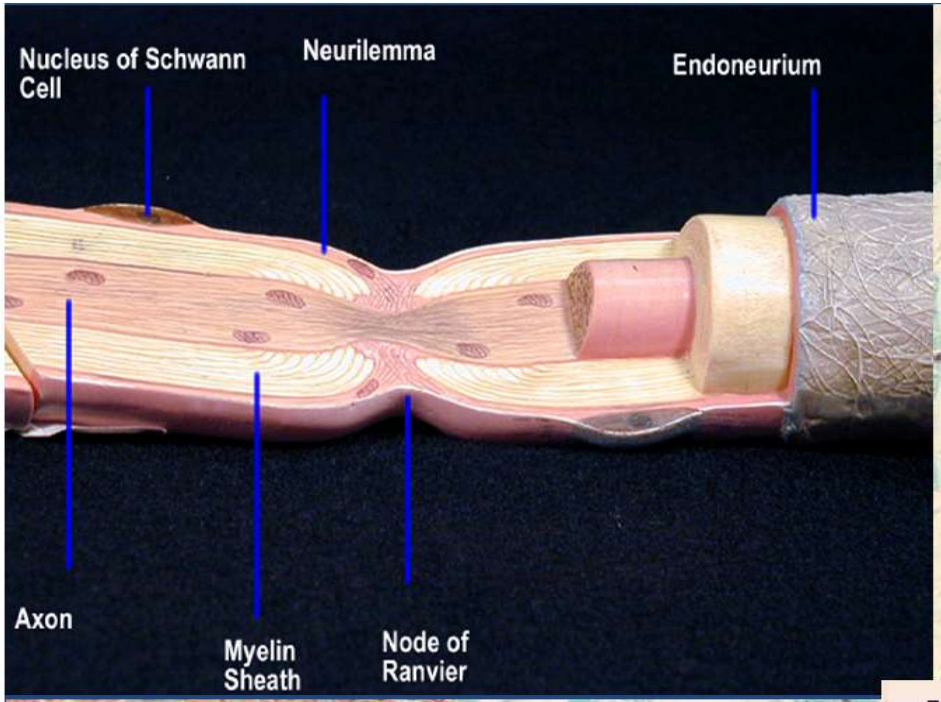


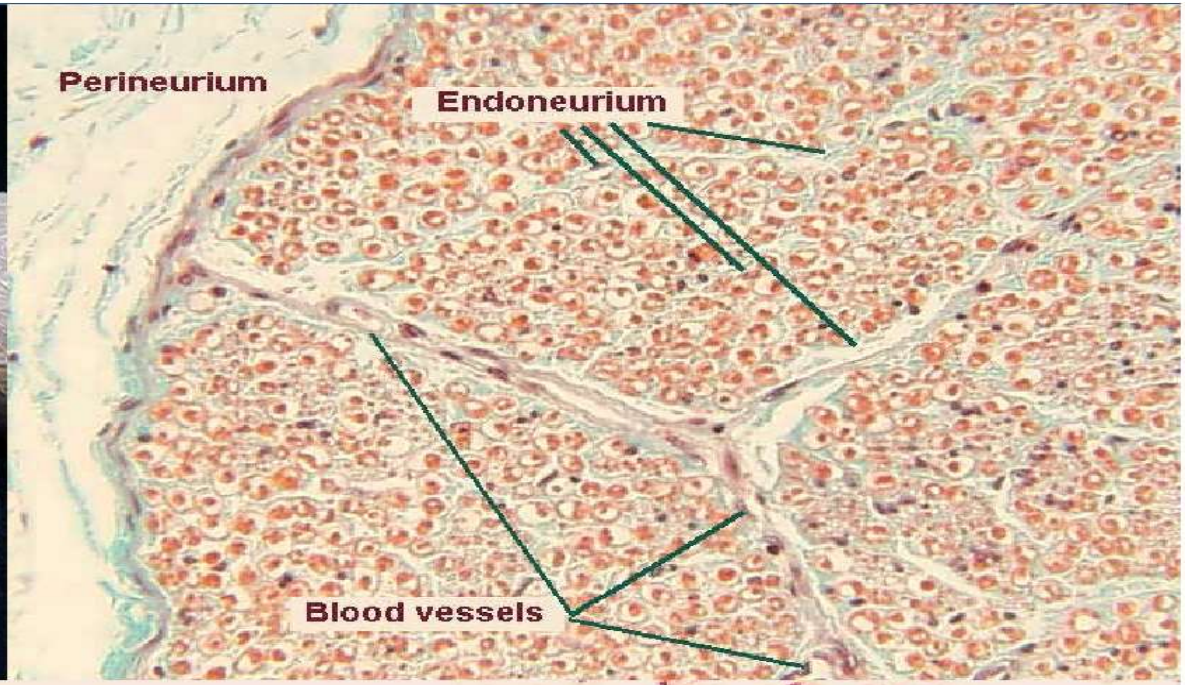
The outer nucleated cytoplasmic layer of the neurolemmocyte, which encloses the myelin sheath, is called the neurolemma (sheath of Schwann). A neurolemma is found only around the axons in the PNS. When an axon is injured, the neurolemma aids in the regeneration by forming a regeneration tube that guides and stimulates regrowth of the axon. At intervals along an axon, the myelin sheath has gaps called neurofibral nodes (nodes of Ranvier).

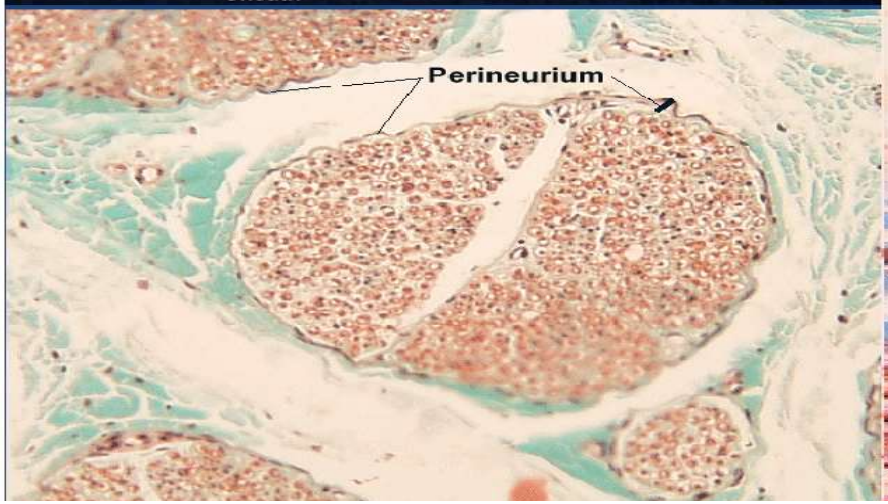
Action Potential Leaps From Node of Ranvier to Node of Ranvier

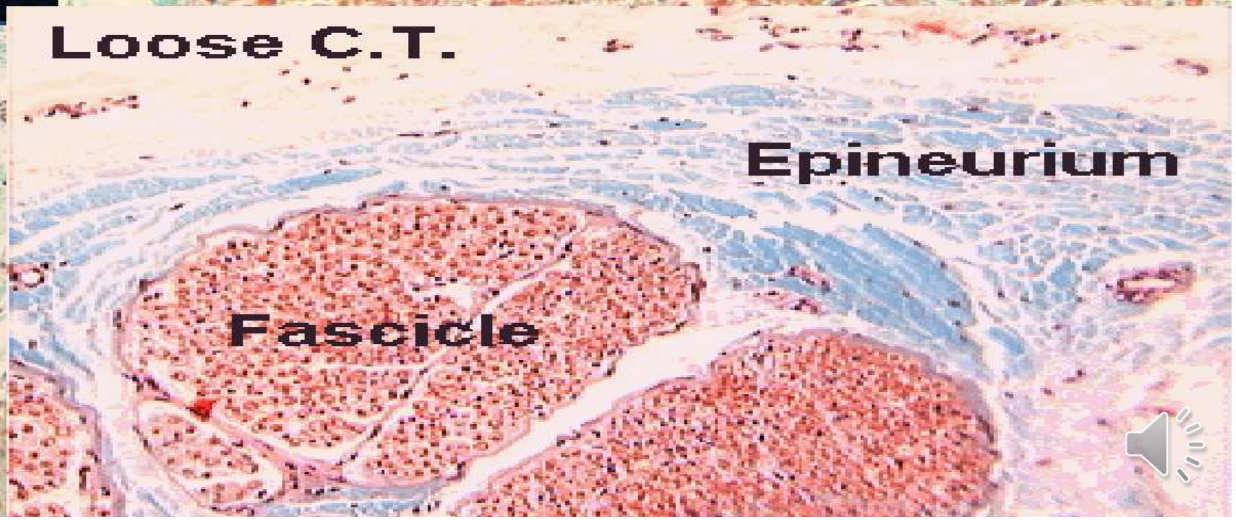



C.T.
Fascicle
Fascicle
C.T.
(axons)


Nucleus of Schwann Cell
Neurilemma
Endoneurium
Axon
Myelin Sheath
Node of Ranvier


Perineurium
Endoneurium
Blood vessels


Perineurium


Loose C.T.
Epineurium
Fascicle

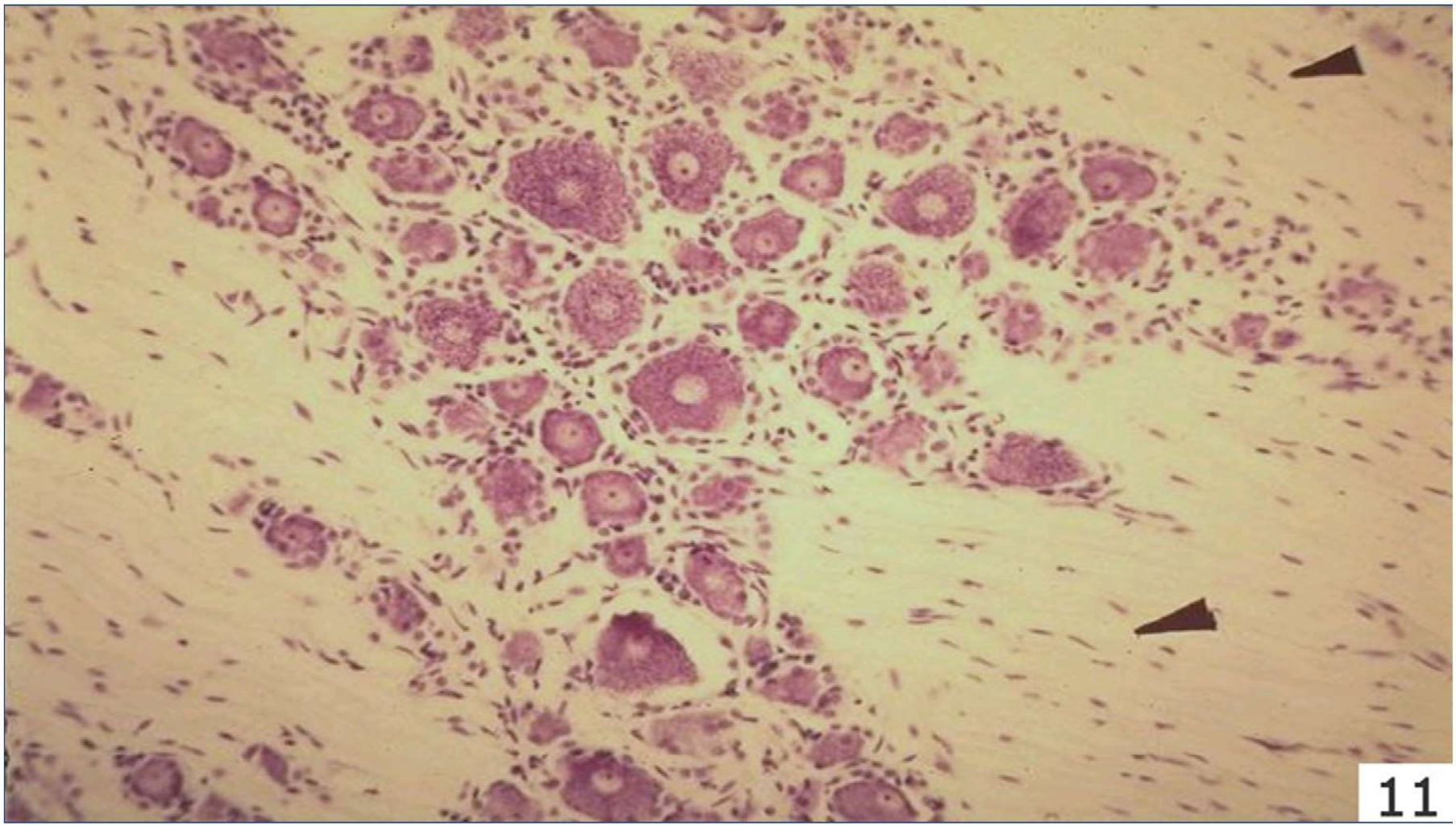


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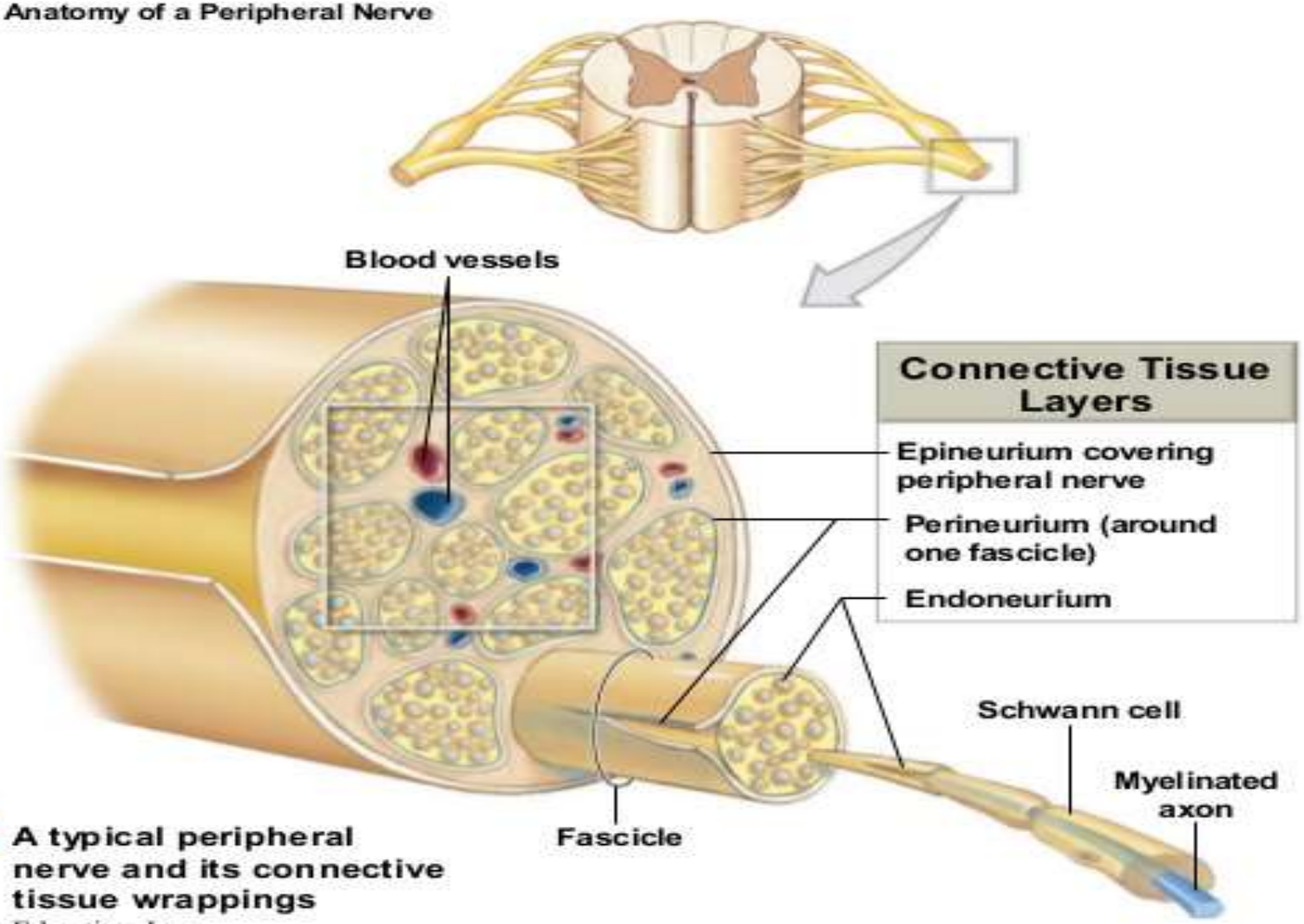
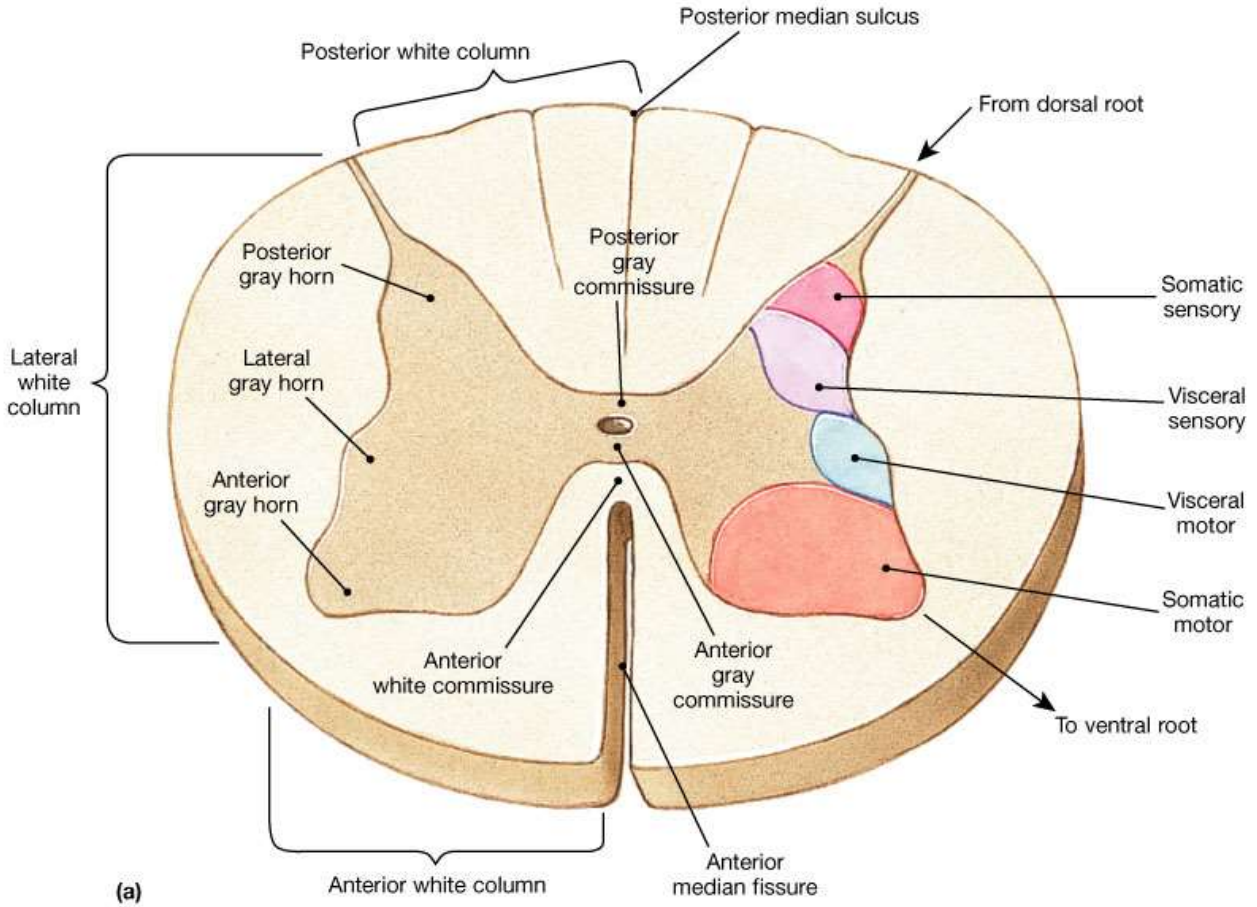
Figure 14.5a Anatomy of a Peripheral Nerve



a A typical peripheral nerve and its connective tissue wrappings

The Sectional Organization of the Spinal Cord

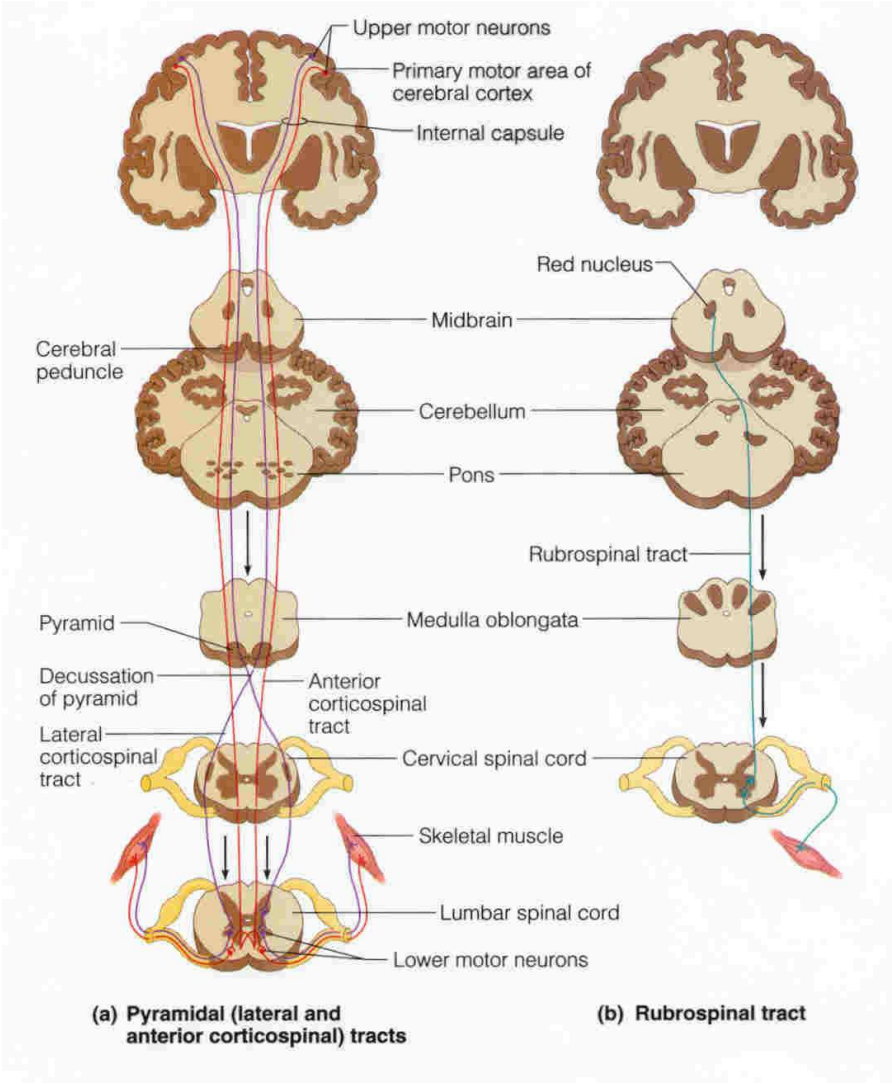


Some fiber tracts in the different funiculi

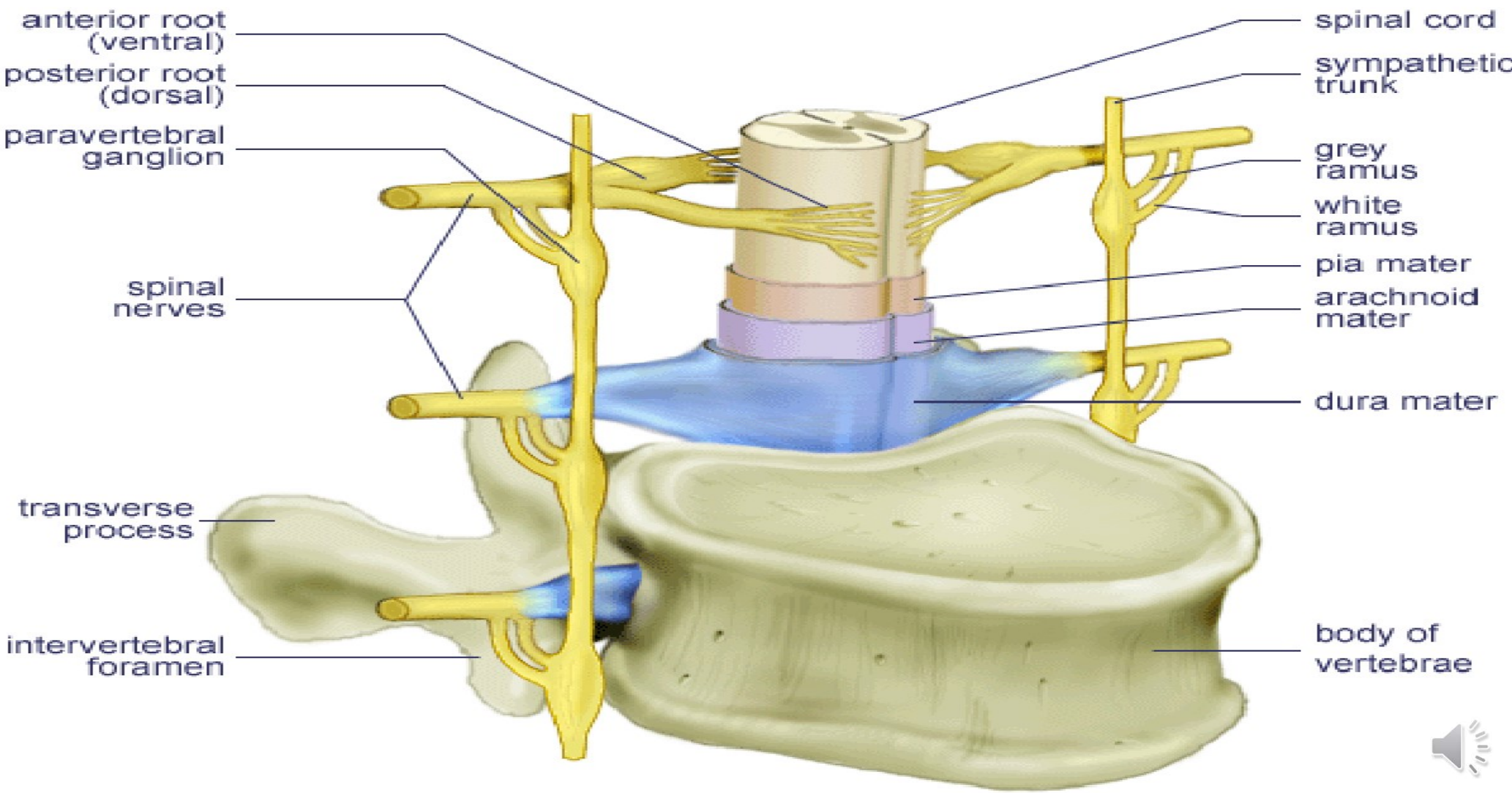
Posterior funiculus:
- Faciculus cuneatus and gracilis
  - Ascending sensory

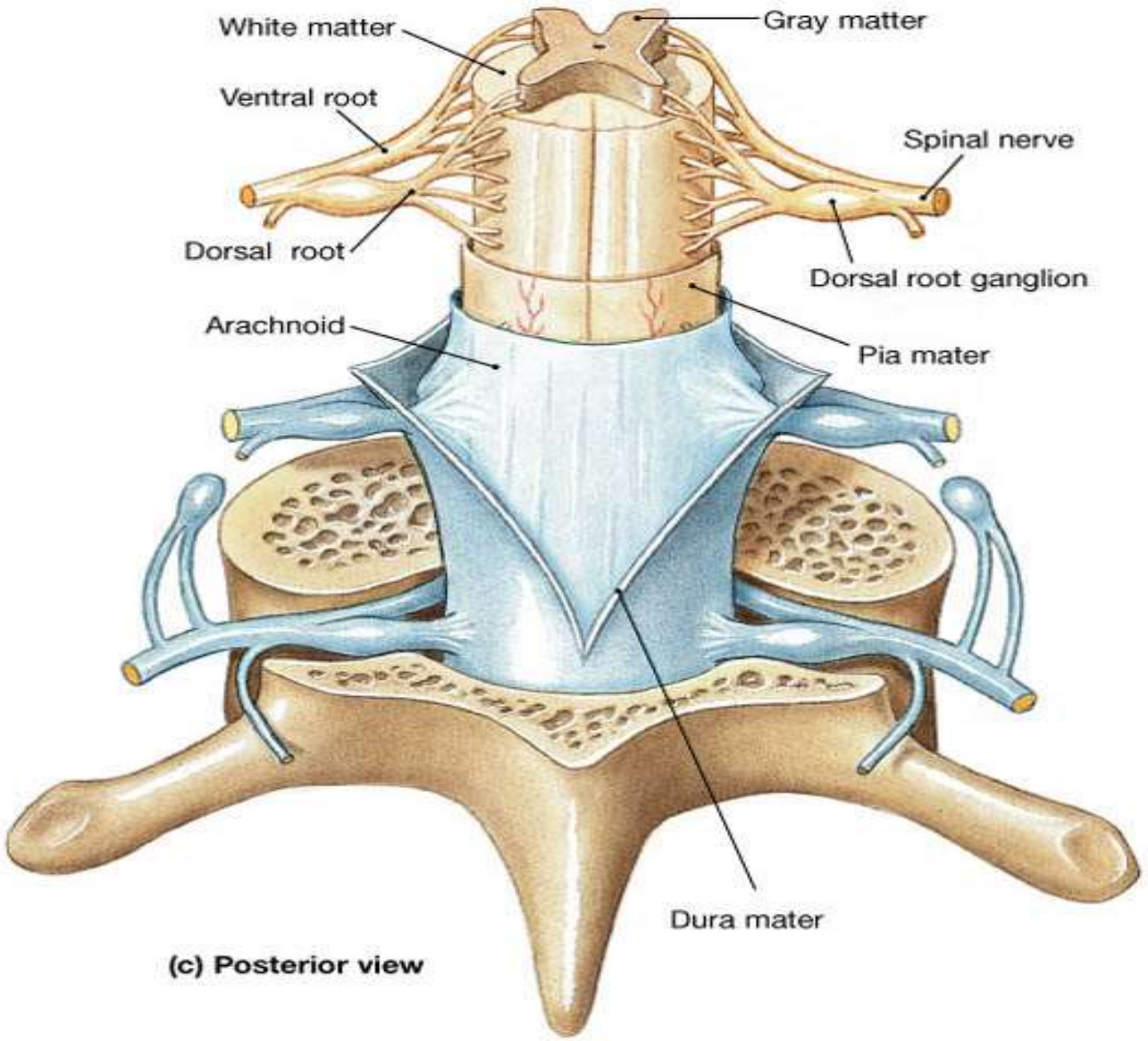
Lateral funiculus
- Spinothalamic tract
  - Ascending sensory
- Corticospinal tract
  - Descending motor

Anterior funiculus
- Spinothalamic tract
  - Ascending sensory
- Corticospinal tract
  - Descending motor



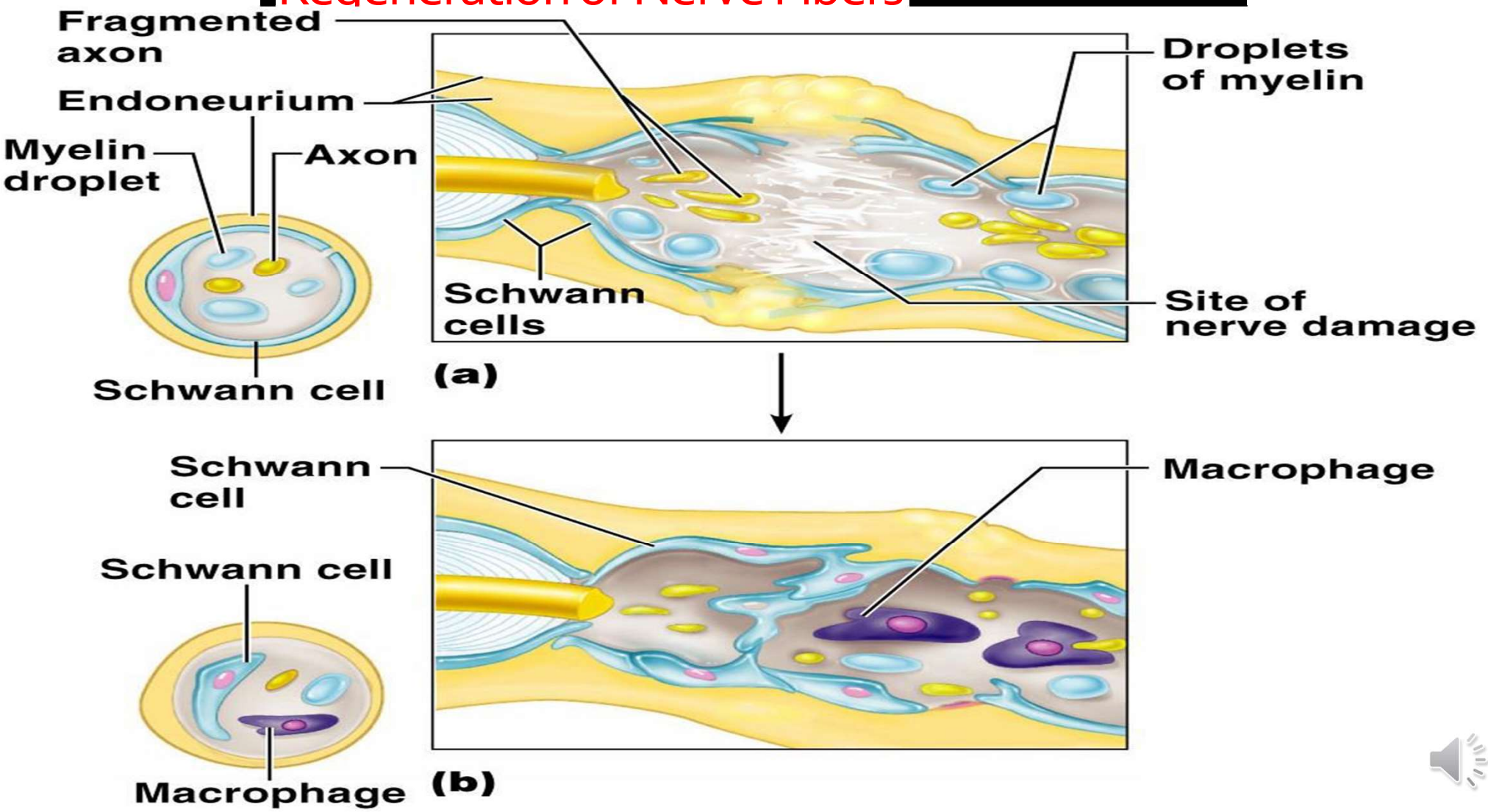
Autonomic Nervous System



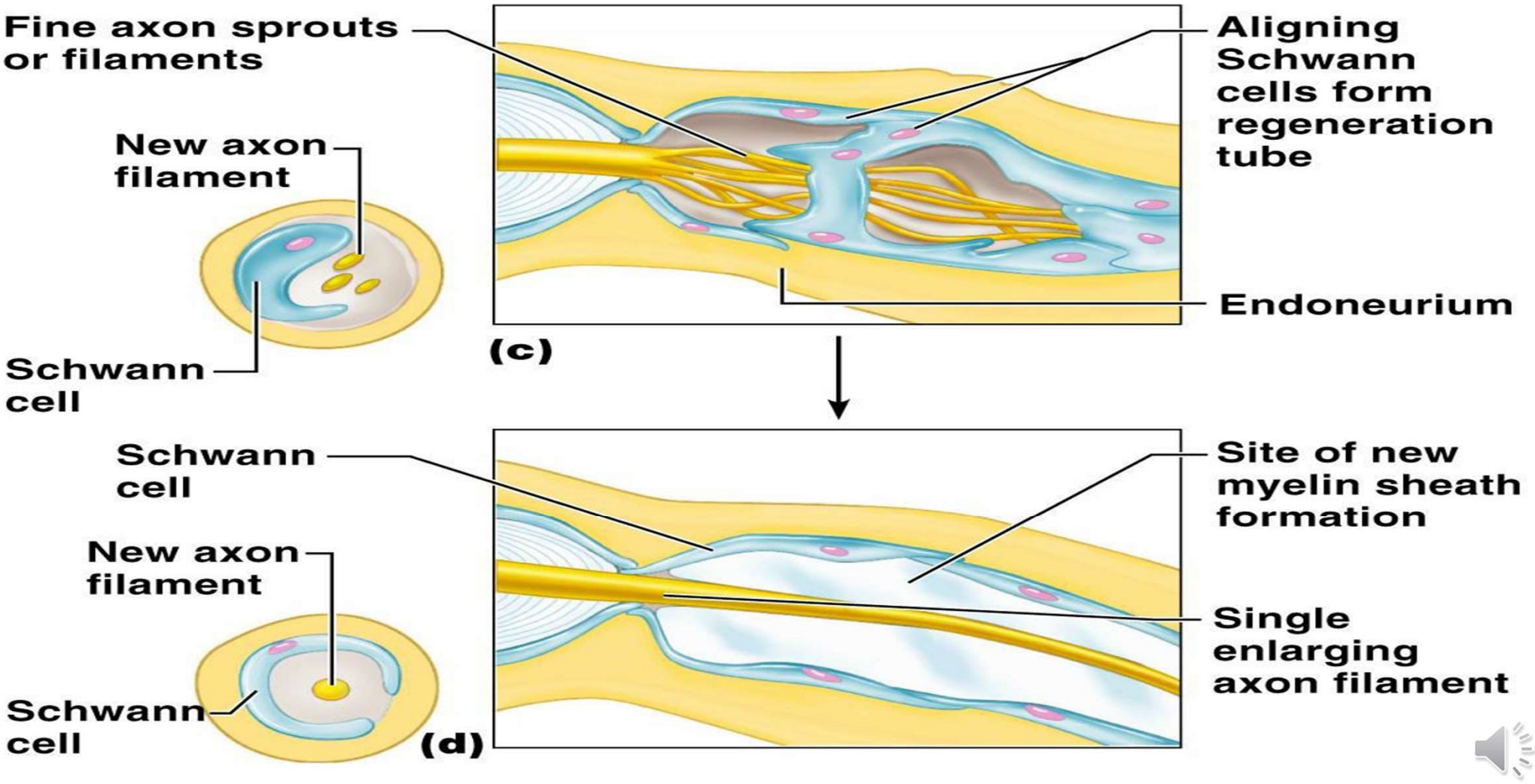


(c) Posterior view

Regeneration of Nerve Fibers



Regeneration of Nerve Fibers



Classification of nerves

- **Sensory and motor divisions**
- **Sensory (afferent)** – carry impulse to the CNS
- **Motor (efferent)** – carry impulses from CNS
- **Mixed** – sensory and motor fibers carry impulses to and from CNS; most common type of nerve