النادي الطلابي
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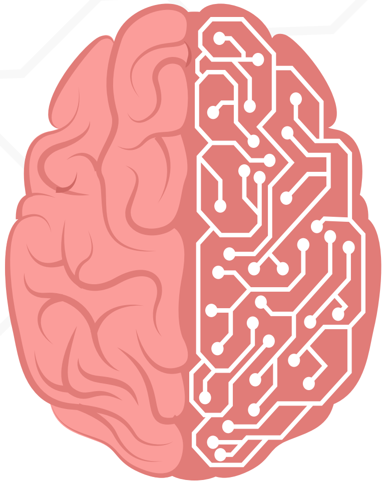

Physiology - CNS

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Motor system-Motor Functions of the Spinal Cord-

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Objectives

- List the ascending and descending tracts passing through the spinal cord
- Describe the muscle spindle

Muscle spindle: sensory receptor in the muscle, senses change in the muscle's length and the rate of change in the length

- Rate: velocity (velocity * time = distance. → If you know the velocity, you can predict where you're position will be in after a period of time (this occurs subconsciously))
- In an experiment they damaged the muscle spindles in monkeys → Monkeys would be walking and they want to stop before hitting the wall, but they hit the wall because they don't have the rate of change in length so they don't know how much time they need to stop before hitting the wall, so they keep hitting the walls

- Explain the functions and mechanism of action of the muscle spindle system

Objectives

- Outline the spinal cord reflex mechanism
- Follow up the neural circuitry and function of the spinal reflexes (Stretch reflex e.g knee and Ankle jerks, Flexor and crossed extensor reflexes)

The spinal cord is not just a pathway for tracts; there're reflexes that occur through the spinal cord without reaching the cerebral cortex

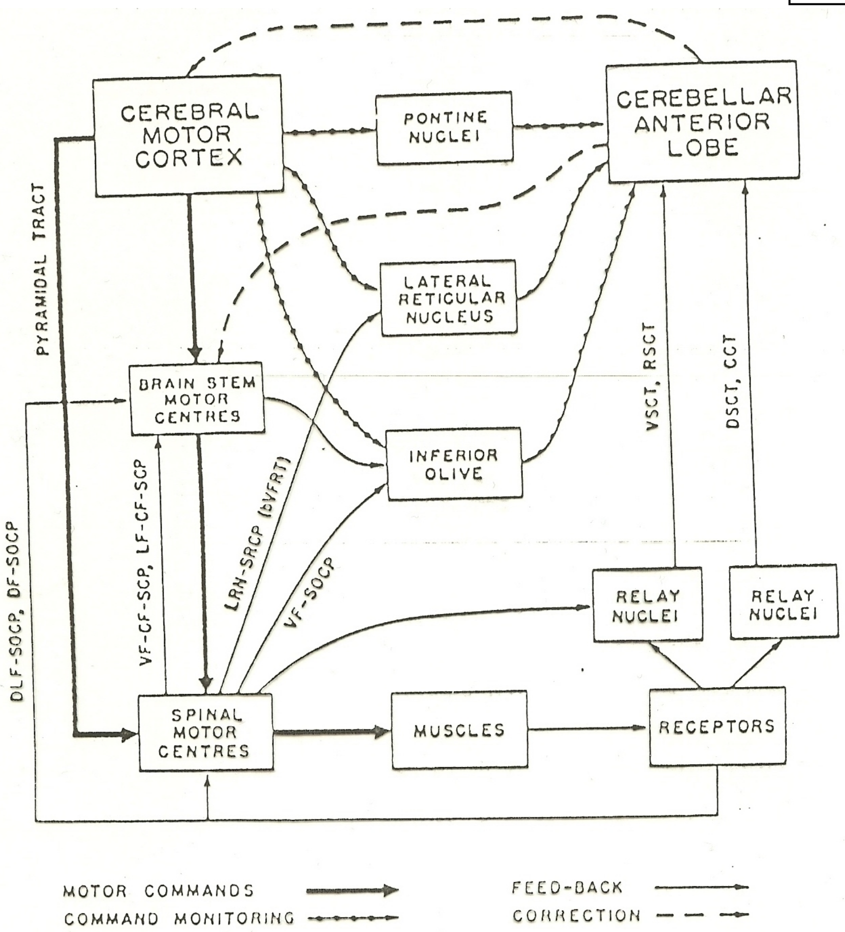
- e.g., if you cut the head of a chicken, it walks and runs, the walking circuitry is in the spinal cord. It stops and dies because it's losing the blood supply

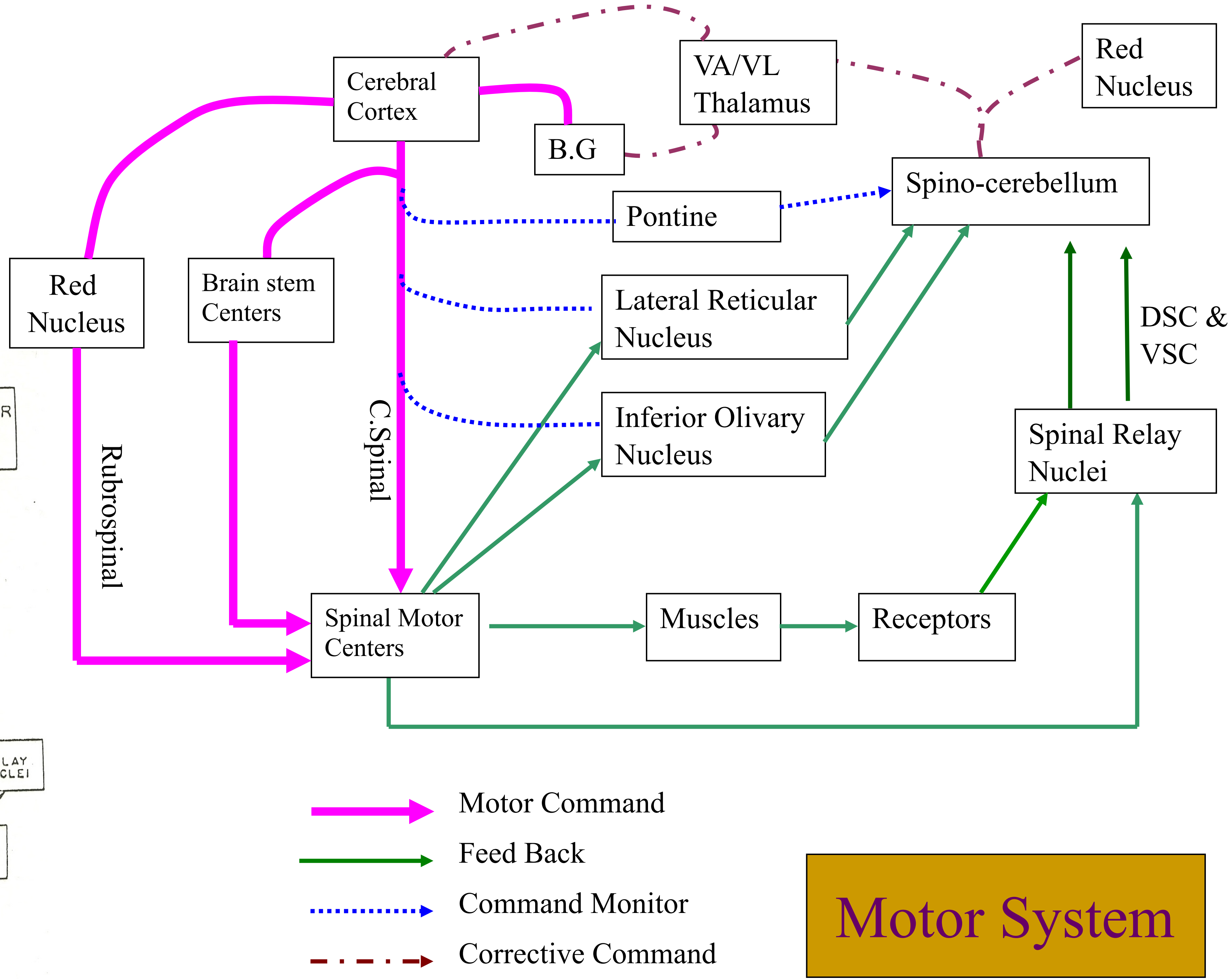
The spinal cord is important for reflexes

- Reflex: a rapid involuntary response to a stimulus

- Demonstrate spinal reflexes in the lab
- Interpret the results of spinal reflexes

Check the next 3 slides





Motor System

A motor system starts with motor commands from the cerebral cortex (specifically, from the motor cortex) to the spinal cord (this pathway is called corticospinal).
In the spinal cord, the upper motor neuron synapses with the lower motor neuron (alpha motor neuron) which goes to the muscles

- The cerebral cortex commands are never exact, they're always either more than intended or less than intended. (Intended movement: the movement you wanted to make). So there's feedback about the movement telling the cortex whether the command was more or less than intended or exactly as intended.
- How this feedback happens?

By a tract from the muscle to the cerebellum (called dorsal and ventral spinocerebeller), this tract is from [1] the muscle spindle, [2] golgi tendon or [3] large tactile spindle around the joint to the cerebellum and this tells the cerebellum about the movement, how it has been executed.
At the same time, the cerebellum knows the intended movement from the cortex by the corticopontocerebeller (fibers from the cortex to the pons to the cerebellum)
So now the cerebellum knows the real intention and how the movement is actually being performed.

So now the cerebellum knows the real intention and how the movement is actually being performed.
The cerebellum compares between the intended movement and the actually performed then the cerebellum will send to the cortex that the movement is exactly as the intended or not, through the thalamus (specifically, the ventro-anterior and ventro-lateral parts of the thalamus)

- the thalamus is the secretary of the cortex

Now, the cerebral cortex will send another new CORRECTED command
Even the new commands are not exact so more feedback and correction. There's continues correction until the movement is smooth without abnormalities
•the smoothness of movements comes from feedback & correction, feedback & correction, feedback & correction… from the cerebellum

- If the cerebellum is damaged, there'll be intention trimmer (action trimmer)

The correction is so fast

Other feedback tracts:

- through the inferior olivary nucleus
- through the lateral reticular nucleus (reticular formation)

The tracts the tell the cerebellum about the intention from the cortex (command monitor):

- Cortico-ponto-cerebellar
- Cortico-reticular-cerebellar
- Cortico-olive-cerebellar

If we're trying something for the first time (the cerebellum doesn't have information about it), the movement would be "cortical", we won't have smooth movement, instead there'll be a pendular movement
e.g., in writing → pressing on the pencil so hard.
Practice & repeating is the solution → fining of the movements.
The cerebellum will store information about the programs (writing, driving…)

The motor system "learns by doing" and performance improves with repetition.

The Spinal Cord is More Than Just a Conduit for Nerve Fibers

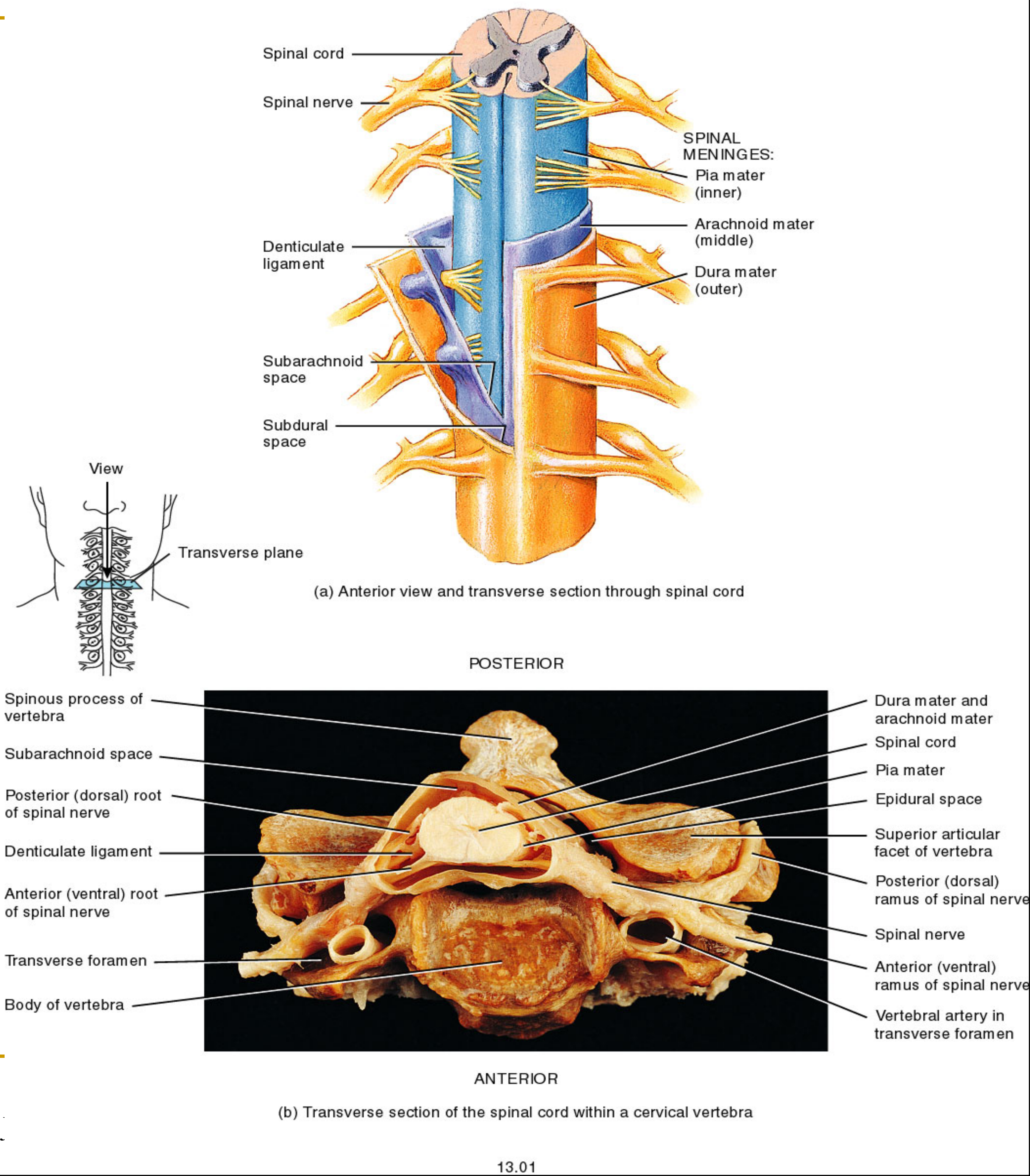
- Neuronal circuits for walking and various reflexes are contained within the spinal cord.
- Higher brain centers Cerebral cortex activate and command these circuits.
  - walking
  - maintaining equilibrium

The spinal cord and brain are in bone (the hardest tissue in our bodies)

- skull and vertebral column

Also, they're surrounded by meninges:

- Pia matter: innermost
- Arachnoid matter
- Dura matter: outermost
- ➢ Between the pia and arachnoid, there's CSF



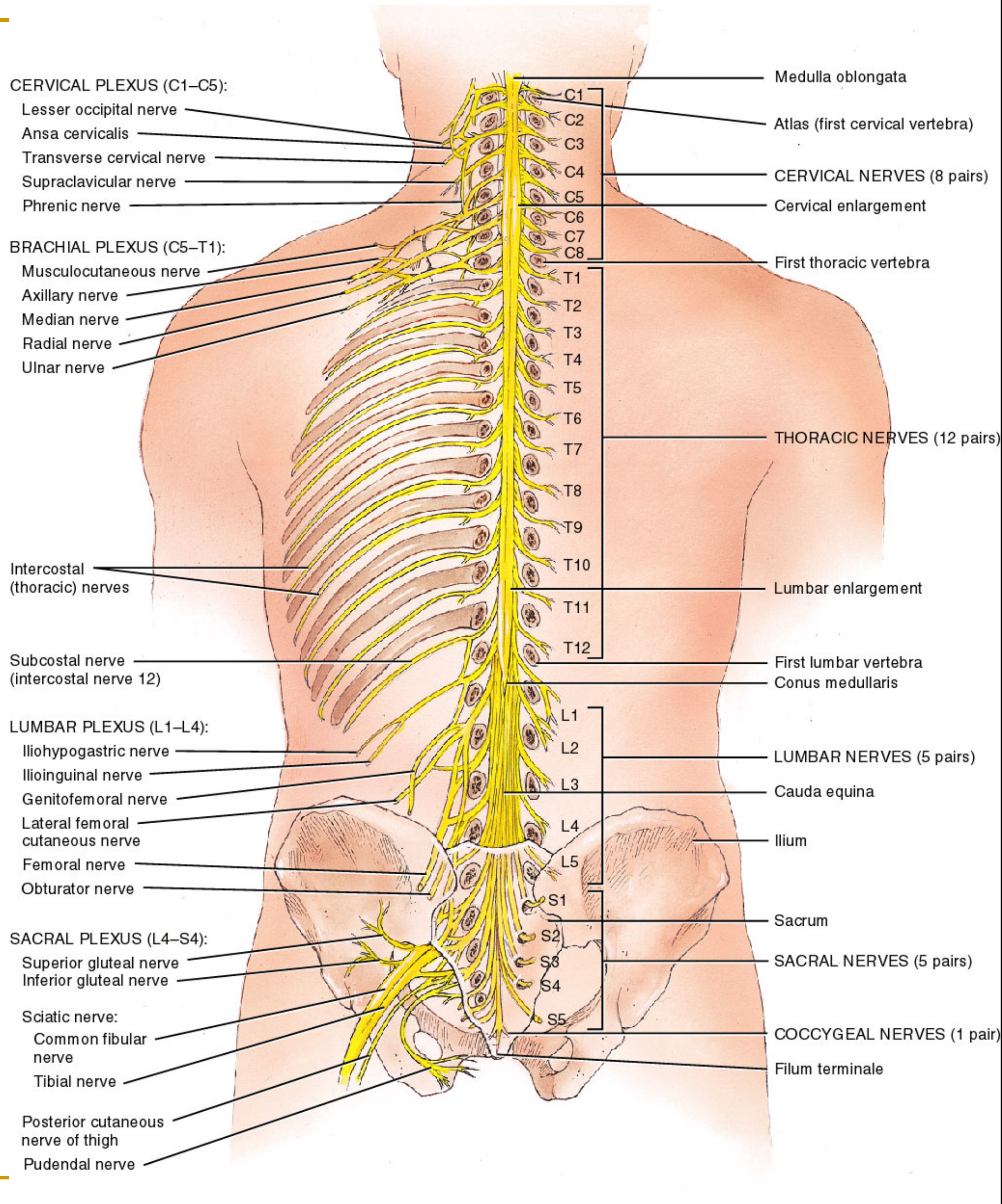
It started as a tube divided into 31 segments
Cervical (8), Thoracic (12), Lumbar (5), Sacral (5), Coccygeal (1)

Each segment gives rise to a spinal nerve on the right and a spinal nerve on the left
And they leave through the intervertebral foreman

While growing, the bone grows faster than the spinal cord, the spinal cord ends at L1-L2
so for example L1: its intervertebral foreman is below its segment

After the end of the spinal cord, there's Cauda equina (Horse tail appearance): nerves in the lower 1/3 of the vertebral canal

When we take a CSF specimen, from below L1-L2



Posterior view of entire spinal cord and portions of spinal nerves

13.02

Internal Anatomy of Spinal Cord

Gray matter (cell bodies and dendrites): H-shaped

- Posterior horn
- Anterior horn
- Lateral horn

In the center, the central canal (has CSF)

- ➢ If it dilates, it affects the crossing fibers (bilateral loss of pain, temperature and crude touch)

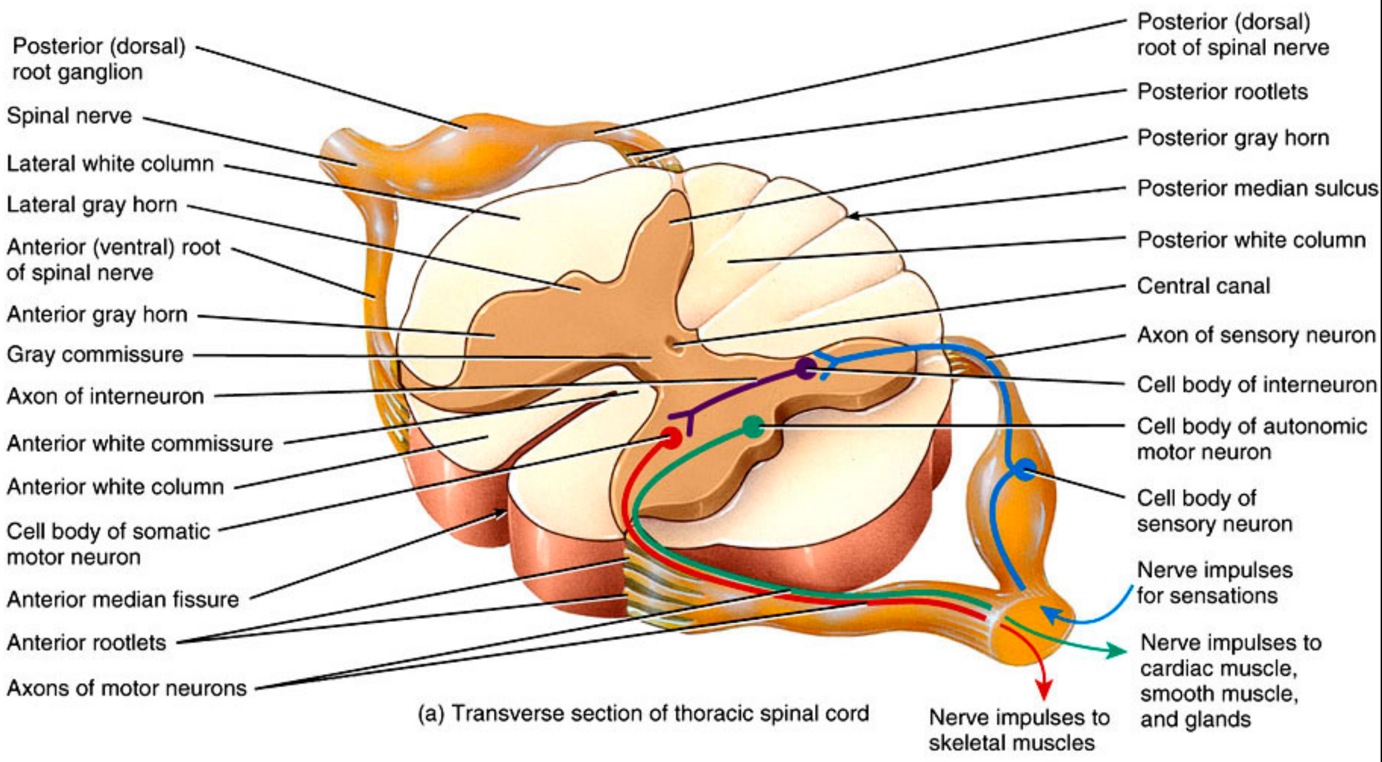
Anterior median fissure

Posterior median sulcus

White matter (axons, myelin = fat which is white)

- Posterior/Dorsal column
- Anterior column
- Lateral column

Left and right sides of each segment are exactly the same

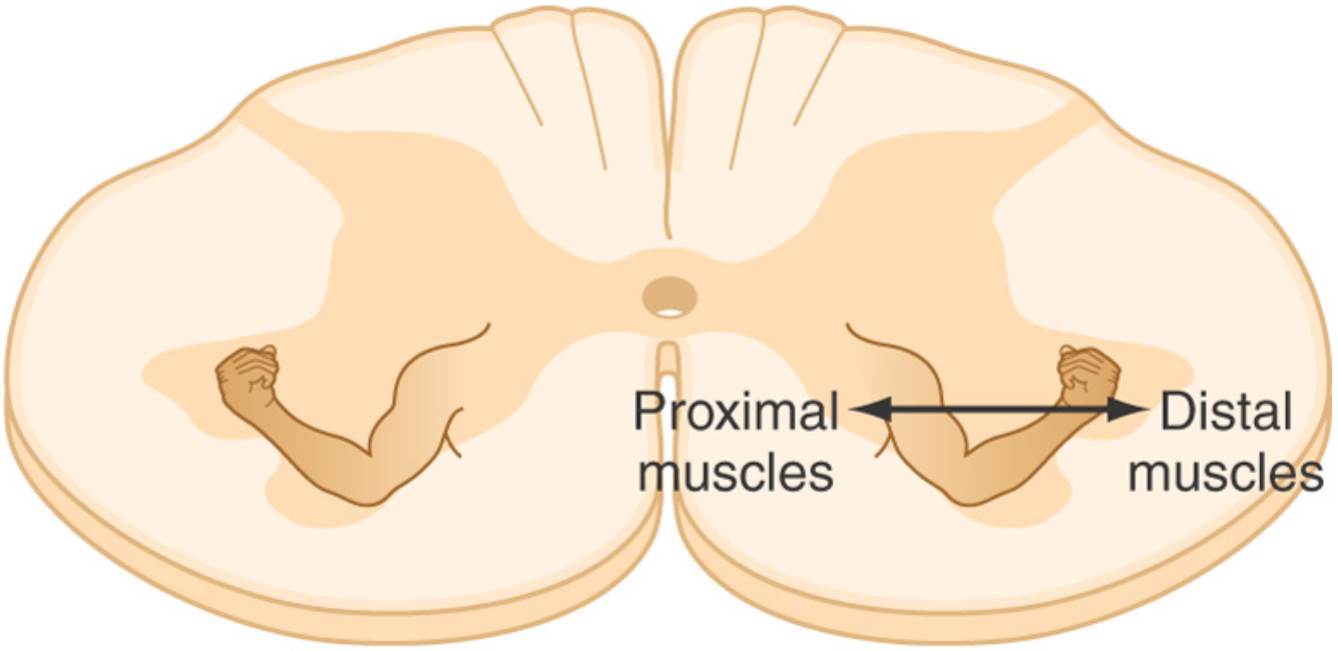


(a) Transverse section of thoracic spinal cord

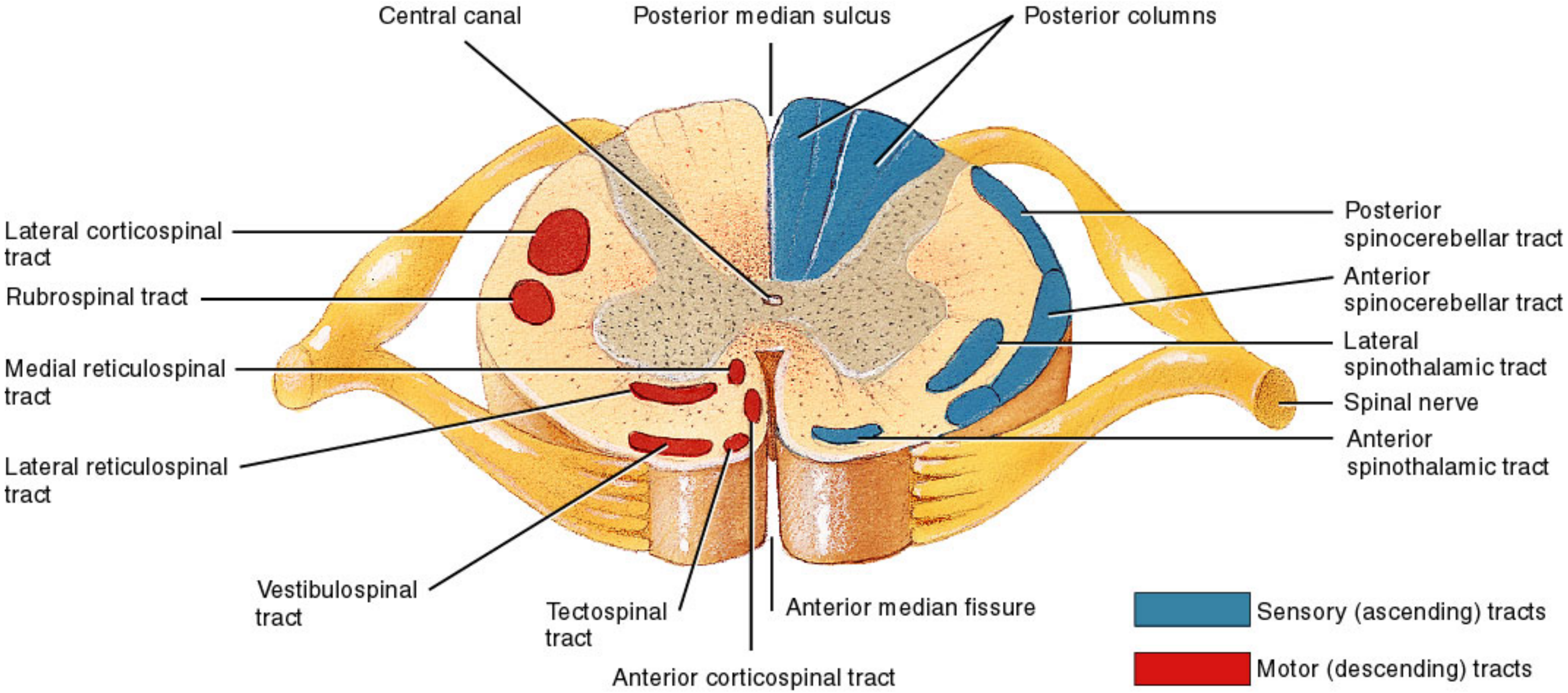
Figure 13.03 Tortora - PAP 12/e

Every part of our CNS (e.g., thalamus, basal ganglia, red nucleus), there's topographic organization of our body; meaning our body is represented (like in cortex)
In the spinal cord, there's areas representing the proximal muscles and other areas for distal muscles
destroying the area for proximal muscles → paralysis in the proximal muscles

B



(Redrawn from Purves D et al[eds]: Neuroscience, 3rd ed. Sunderland, MA, Sinauer, 2004.)


Central canal
Posterior median sulcus
Posterior columns
Lateral corticospinal tract
Rubrospinal tract
Medial reticulospinal tract
Lateral reticulospinal tract
Vestibulospinal tract
Tectospinal tract
Anterior corticospinal tract
Anterior median fissure
Posterior spinocerebellar tract
Anterior spinocerebellar tract
Lateral spinothalamic tract
Spinal nerve
Anterior spinothalamic tract
Sensory (ascending) tracts
Motor (descending) tracts

13.04

Tracts
(Axons in the CNS)

Blue: sensory

- Dorsal column medial lemniscal tract
  - ✓ In the posterior/dorsal column: fasciculus gracilis & fasciculus cuneatus
- Anteriolateral spinothalamic tract
- Dorsal & ventral (posterior & anterior) spinocerebellar tracts

Red: motor

- Lateral corticospinal tract (lies in the lateral column)
- Rubrospinal (in the lateral column) (related to the red nucleus)

These 2 tracts are the lateral motor pathway system: excitatory to the flexors and inhibitory to the extensors

- Anterior corticospinal tract (lies in the anterior column)
- Vestibulospinal tract (from the vestibular nucleus)
  - ✓ vestibular nucleus gets information from the inner ear & vestibule
- Tectospinal tract
  - ✓ tectum has quadri (4) colliculi: 2 superior & 2 inferior
    - ➢ The 2 superior gets information from vision
    - ➢ The 2 inferior gets information from auditory

  so this tract causes movement of the head in response to visual or auditory
- Reticulospinal tract

These 4 are the medial motor system pathway

Of course all of the tracts are on the right & left side :)

Motor Organization of the Spinal Cord

- Sensory fibers enter the cord and are transmitted to higher centers, or they synapse locally to elicit motor reflexes.
- Motor neurons are located in the anterior portion of the cord.
  - motor neurons are 50 - 100 % bigger than other neurons

Anterior Motor Neurons

- Alpha motor neurons
  - give rise to large type A alpha fibers (~14 microns).
  - stimulation can excite 3 - 100 ***extrafusal*** muscle fibers collectively called a motor unit
- Gamma motor neurons
  - give rise to smaller type A gamma fibers (~5 microns)
  - stimulation excites ***intrafusal fibers***, a special type of sensory receptor

Interneurons and Propriospinal Fibers

- Interneurons
  Outnumber the sensory and motor
  - 30 times as many as anterior motor neurons
  - small and very excitable
  - comprise the neural circuitry for the motor reflexes
- Propriospinal fibers
  - travel up and down the cord for 1 - 2 segments
  - provide pathways for multisegmental reflexes

Fibers between the segments (inter-segmental connections)
E.g., between T1 and T2

Sensory Receptors of the Muscle

- Muscle Spindle
  - sense muscle length and change in length

Senses change in the length and the rate of change in length
(Rate: velocity → to predict where you'll position be after some time)
Length: static
Rate: dynamic

- Golgi Tendon Organ
  - sense tendon tension and change in tension

Senses change in tension and the rate of change in tension

The Muscle Spindle

The number of receptors in any area is proportional to its function
Axial muscles - antigravity muscles - extensors are always active, so the number (density) of muscles spindles in them is much more than that of the flexors
You're always standing or sitting but you're not always writing

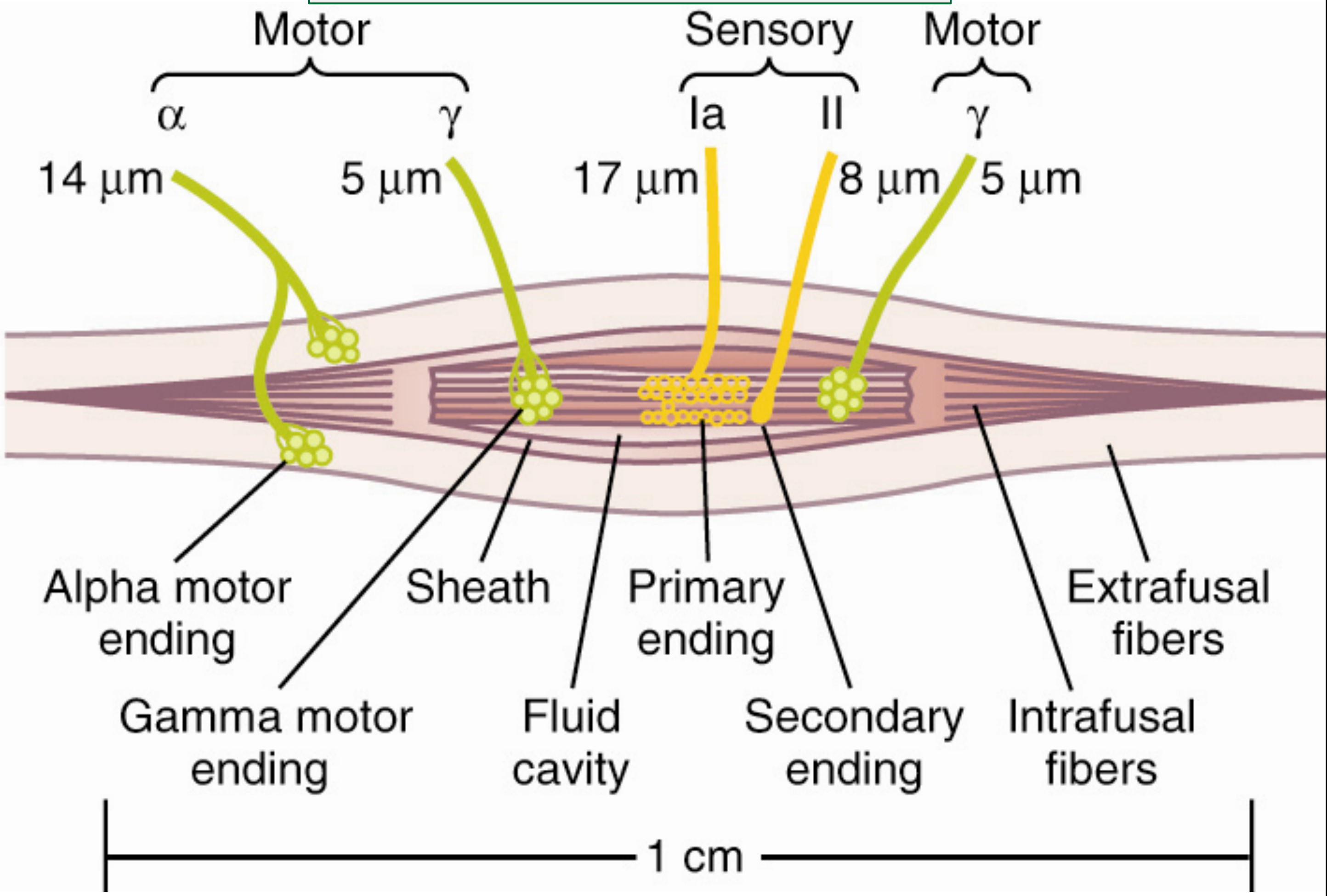
The muscle spindle is supplied by 1a and 2 (sensory)

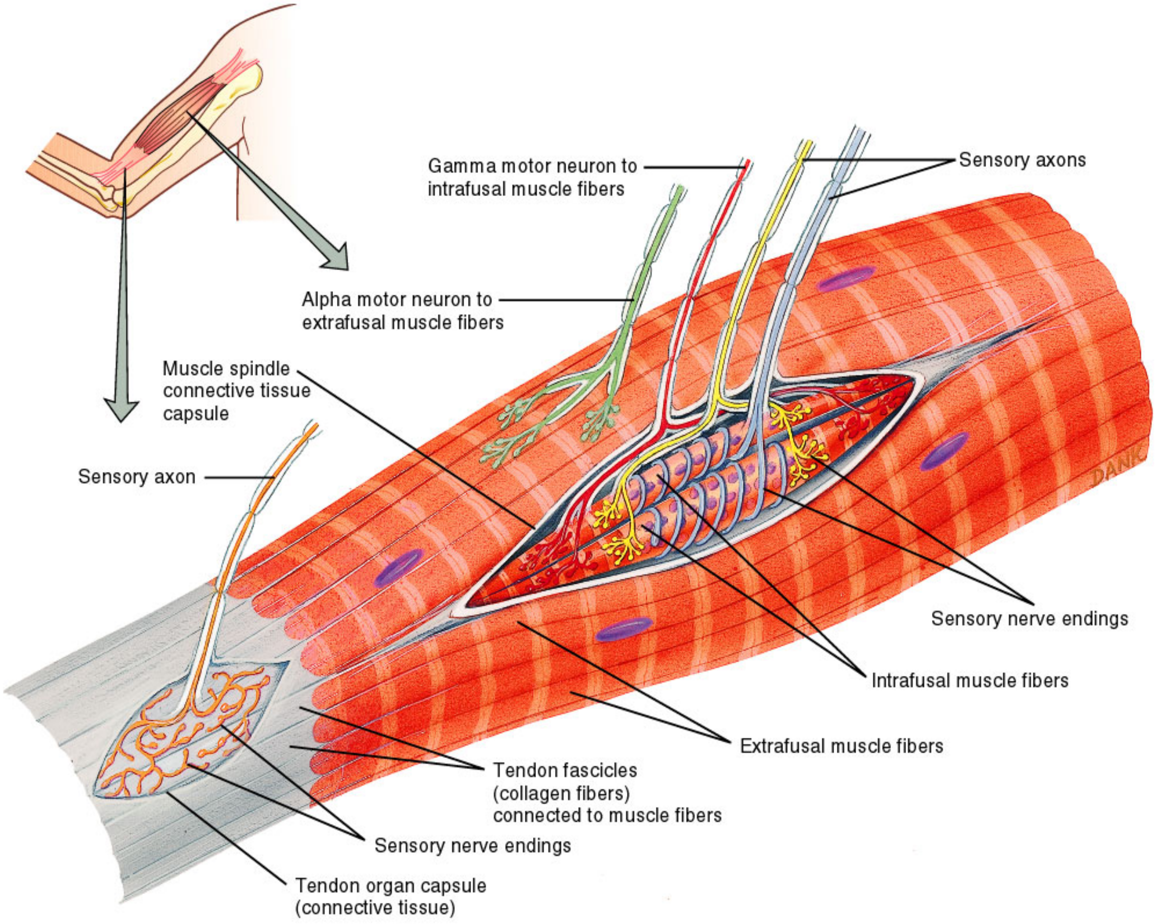
Notice on the sides of the muscle spindle are intrafusal muscle fibers
When they contract, they contract laterally stretching the central part (increasing the length of muscle spindle) stimulating the sensation

The motor gamma fibers supply the intrafusal
The motor alpha fibers supply the extrafusal

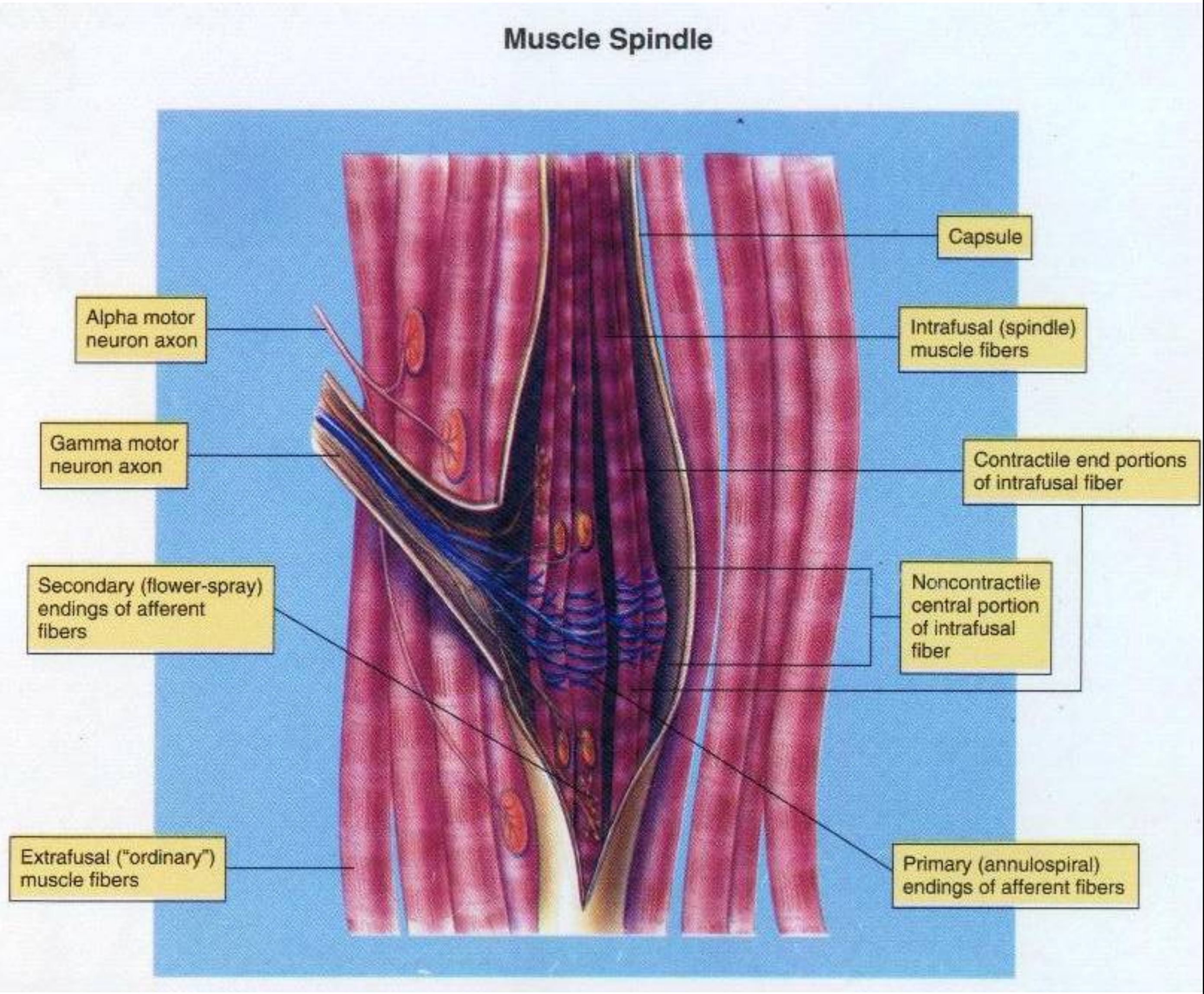
The central part stretches by:
Any stretch in the whole muscle spindle or contraction of the intrafusal muscles

1, 2, & 3 fibers are myelinated
4 fibers are unmyelinated
1a are large
2 smaller




Gamma motor neuron to
intrafusal muscle fibers
Sensory axons
Alpha motor neuron to
extrafusal muscle fibers
Muscle spindle
connective tissue
capsule
Sensory axon
Sensory nerve endings
Intrafusal muscle fibers
Extrafusal muscle fibers
Tendon fascicles
(collagen fibers)
connected to muscle fibers
Sensory nerve endings
Tendon organ capsule
(connective tissue)

15.04


Muscle Spindle
Capsule
Alpha motor
neuron axon
Intrafusal (spindle)
muscle fibers
Gamma motor
neuron axon
Contractile end portions
of intrafusal fiber
Secondary (flower-spray)
endings of afferent
fibers
Noncontractile
central portion
of intrafusal
fiber
Extrafusal ("ordinary")
muscle fibers
Primary (annulospiral)
endings of afferent fibers

Sensory fibers of muscle spindle

There're 2 parts in the muscle spindle:

1. Nuclear bag fiber:
   Sensory: supplied mainly by type 1a fibers which are called primary afferent - dynamic fiber (senses [1] the rate in change and [2] the length) – Dynamic
   Motor: supplied by static gamma fibers and dynamic gamma fibers
2. Nuclear chain fiber
   supplied by type 2 fibers (senses only the length – Static)
   Motor: only static gamma fibers

Static gamma fibers supplies both but mainly the nuclear chain

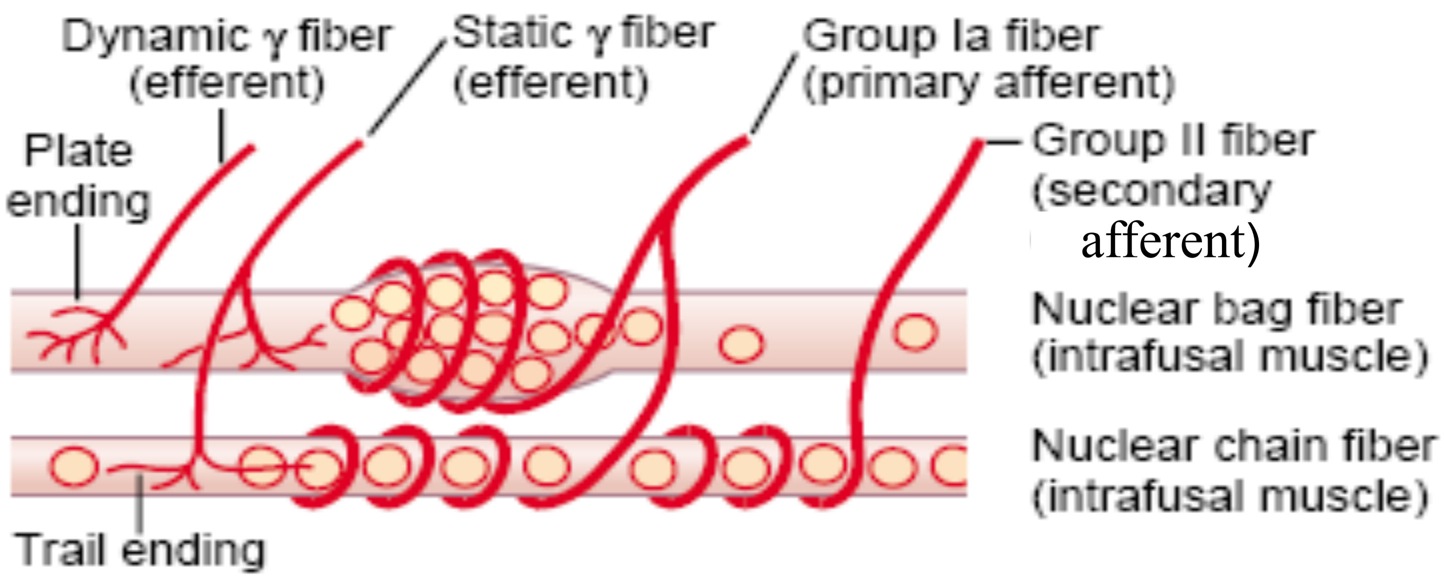


Figure 54–3

Details of nerve connections from the nuclear bag and nuclear chain muscle spindle fibers. (Modified from Stein RB: Peripheral control of movement. Physiol Rev 54:225, 1974.)

The function of the nuclear bag and chain: the next lecture

Static Response of the Muscle Spindle

- When the center of spindle is stretched *slowly* - the number of impulses generated by the primary and secondary endings increases in proportion to the *degree of stretch*.
- This is the '*static response*'.
- Function of the static nuclear bag and nuclear chain fibers.

Dynamic Response of the Muscle Spindle

- When the center of the spindle is stretched *rapidly* - the number of impulses generated by the primary endings increases in proportion to the *rate of change* of the length.
- This is the '*dynamic response*'.
- Function of the dynamic nuclear bag fiber.

Thank You