OVERVIEW

Today

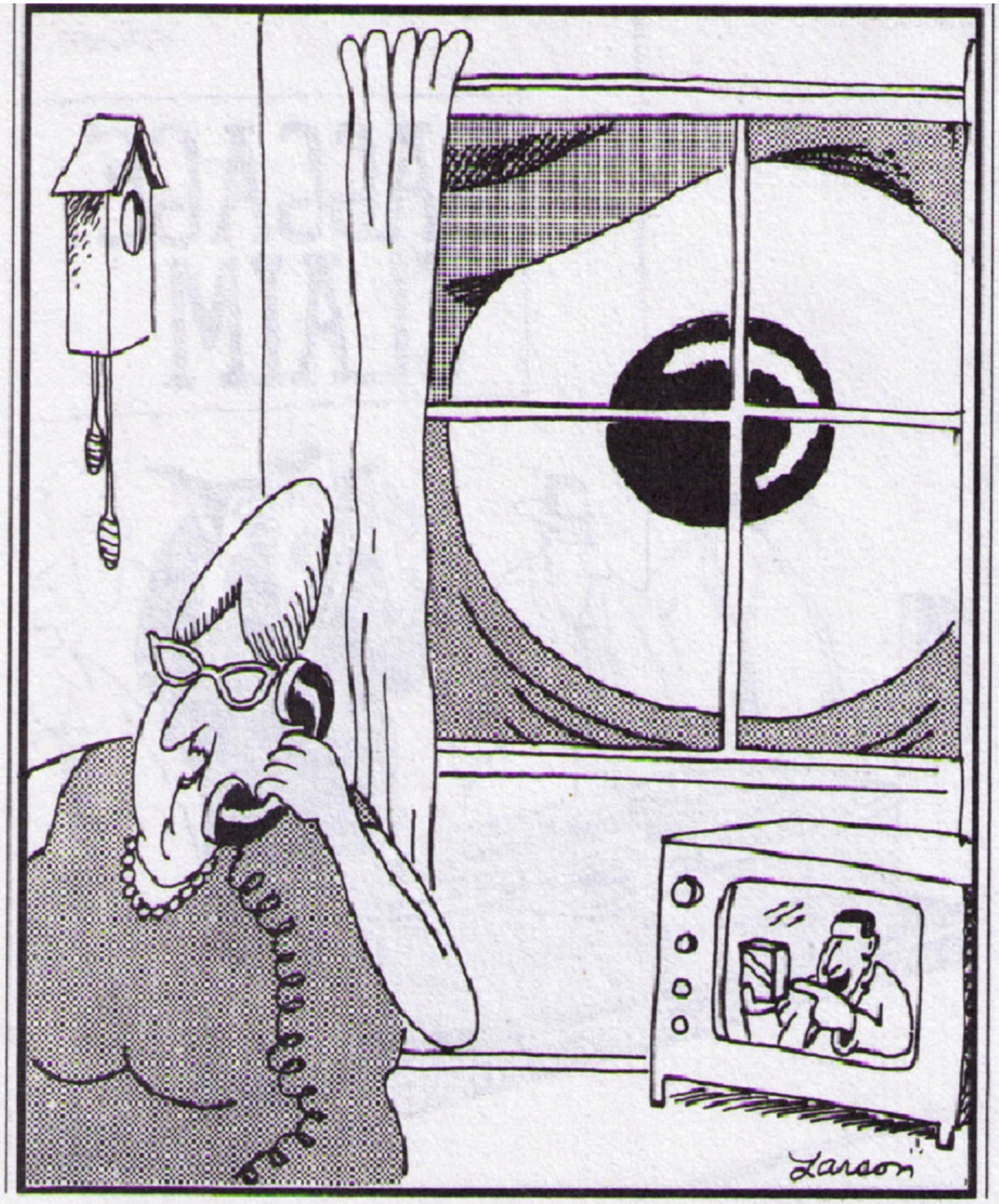
Sensory and Motor Neurons

Thursday

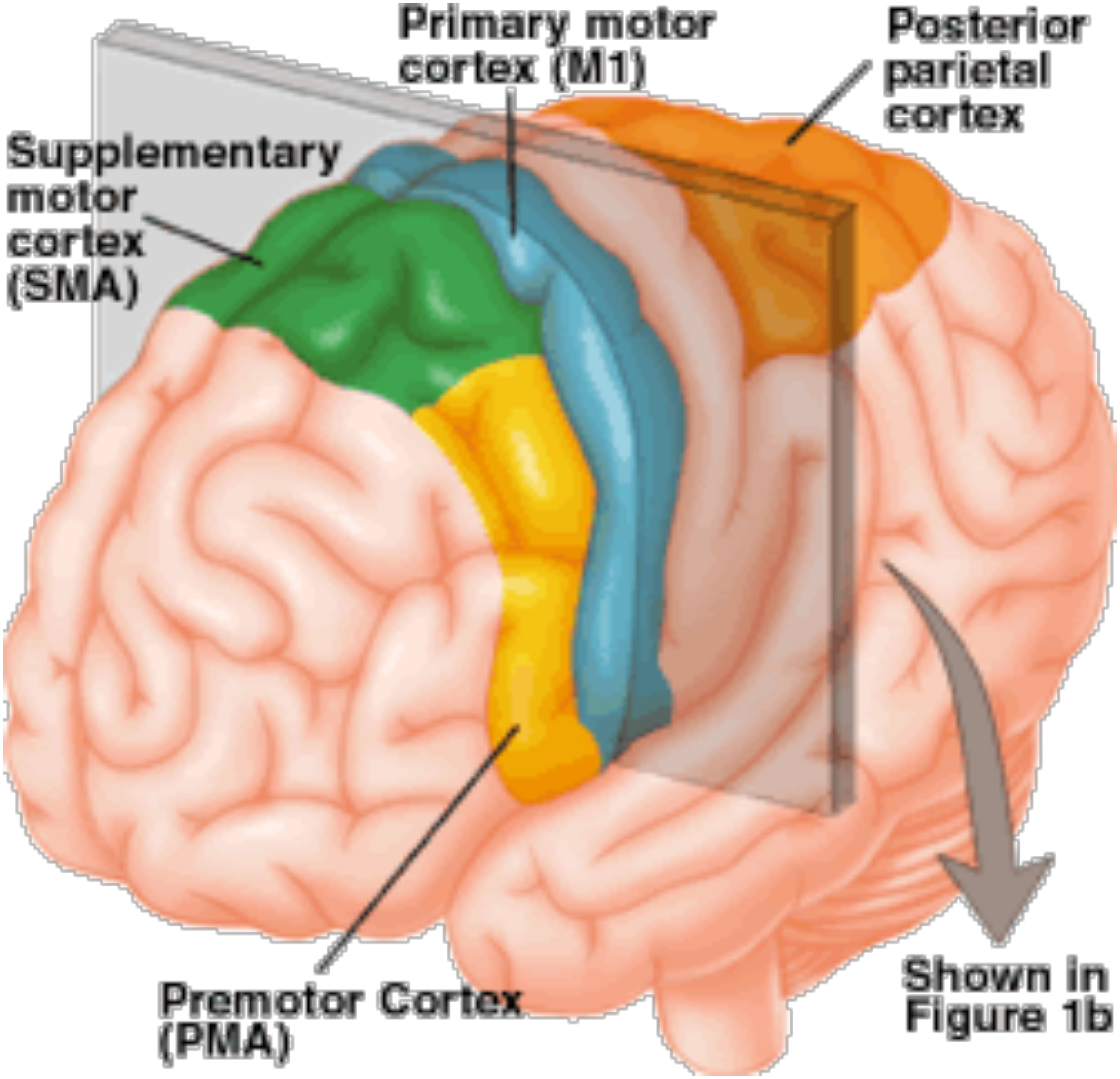
Parkinsons Disease

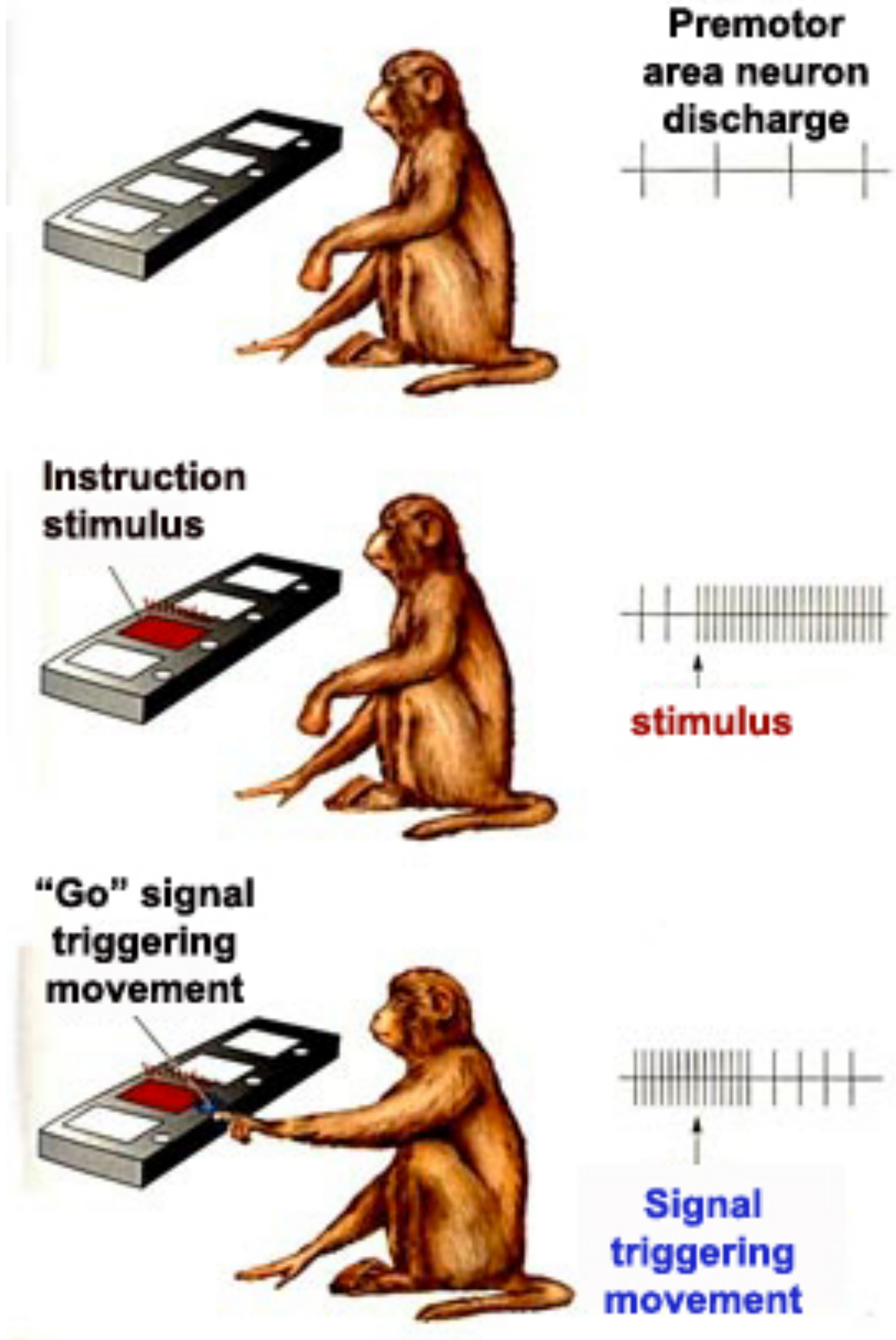
Administration

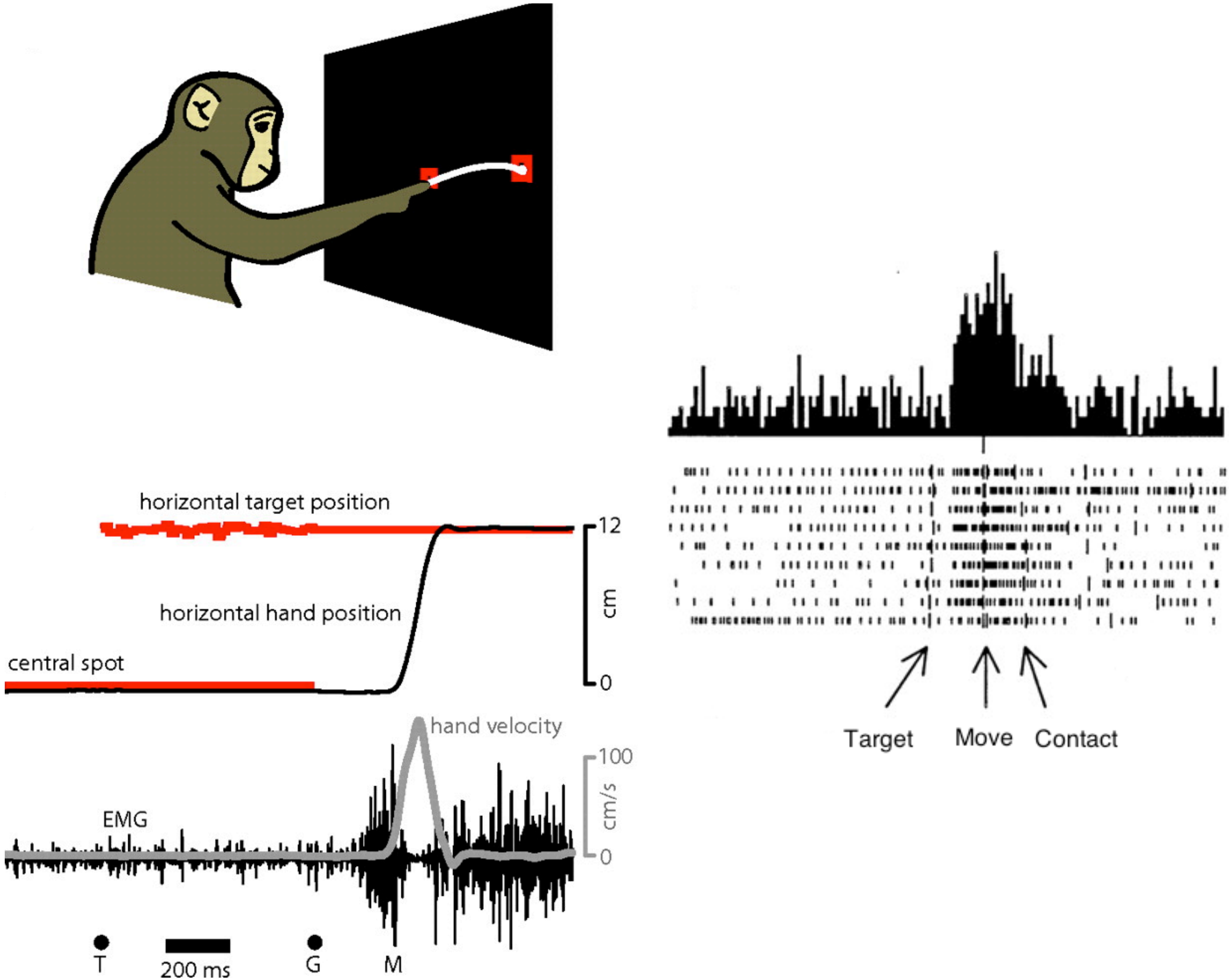
Exam One
Bonus Points
Slides Online



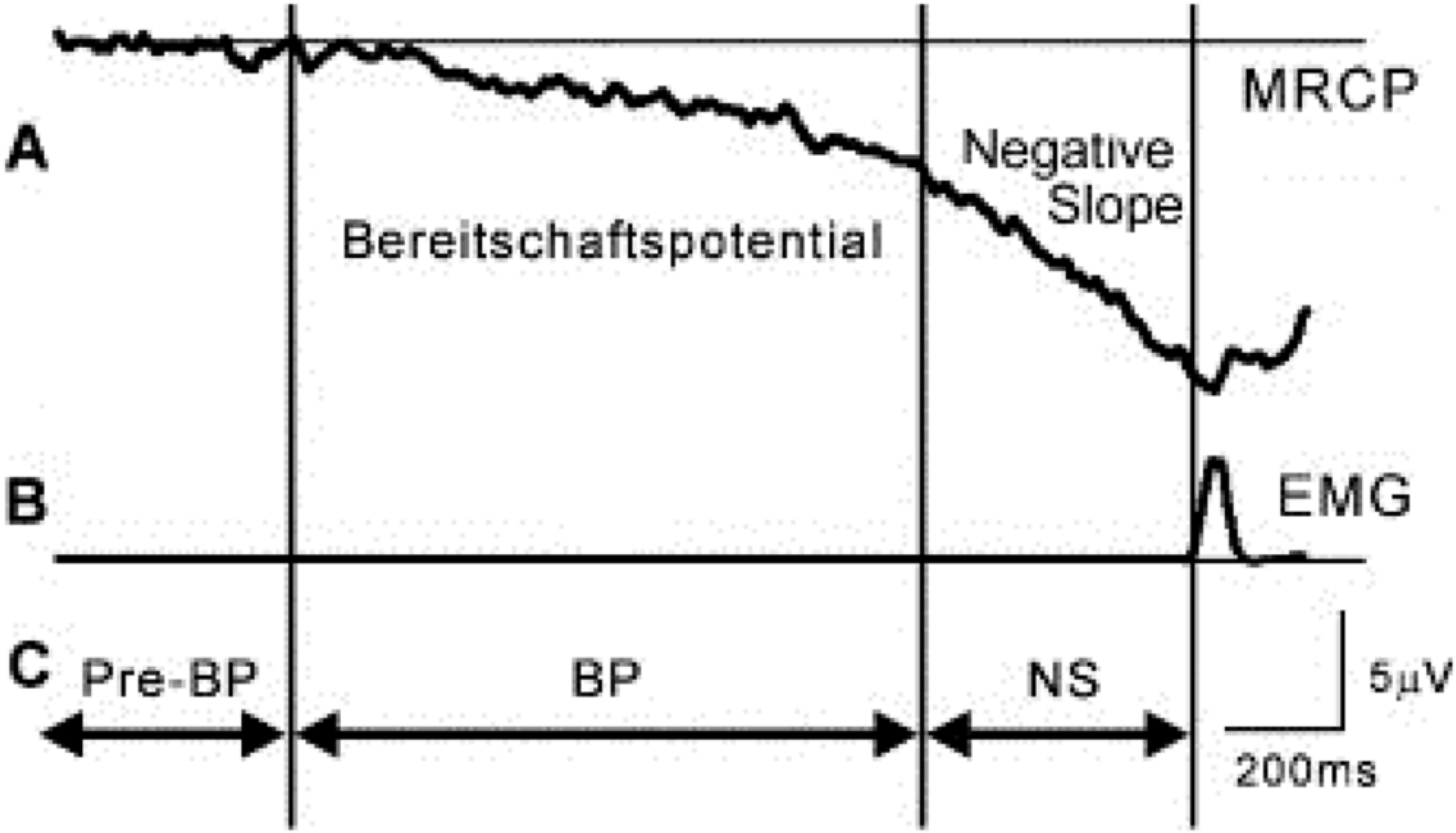
"Hello, Emily. This is Gladys Murphy up the street. Fine, thanks . . . Say, could you go to your window and describe what's in my front yard?"


Primary motor
cortex (M1)
Posterior
parietal
cortex
Supplementary
motor
cortex
(SMA)
Premotor Cortex
(PMA)
Shown in
Figure 1b

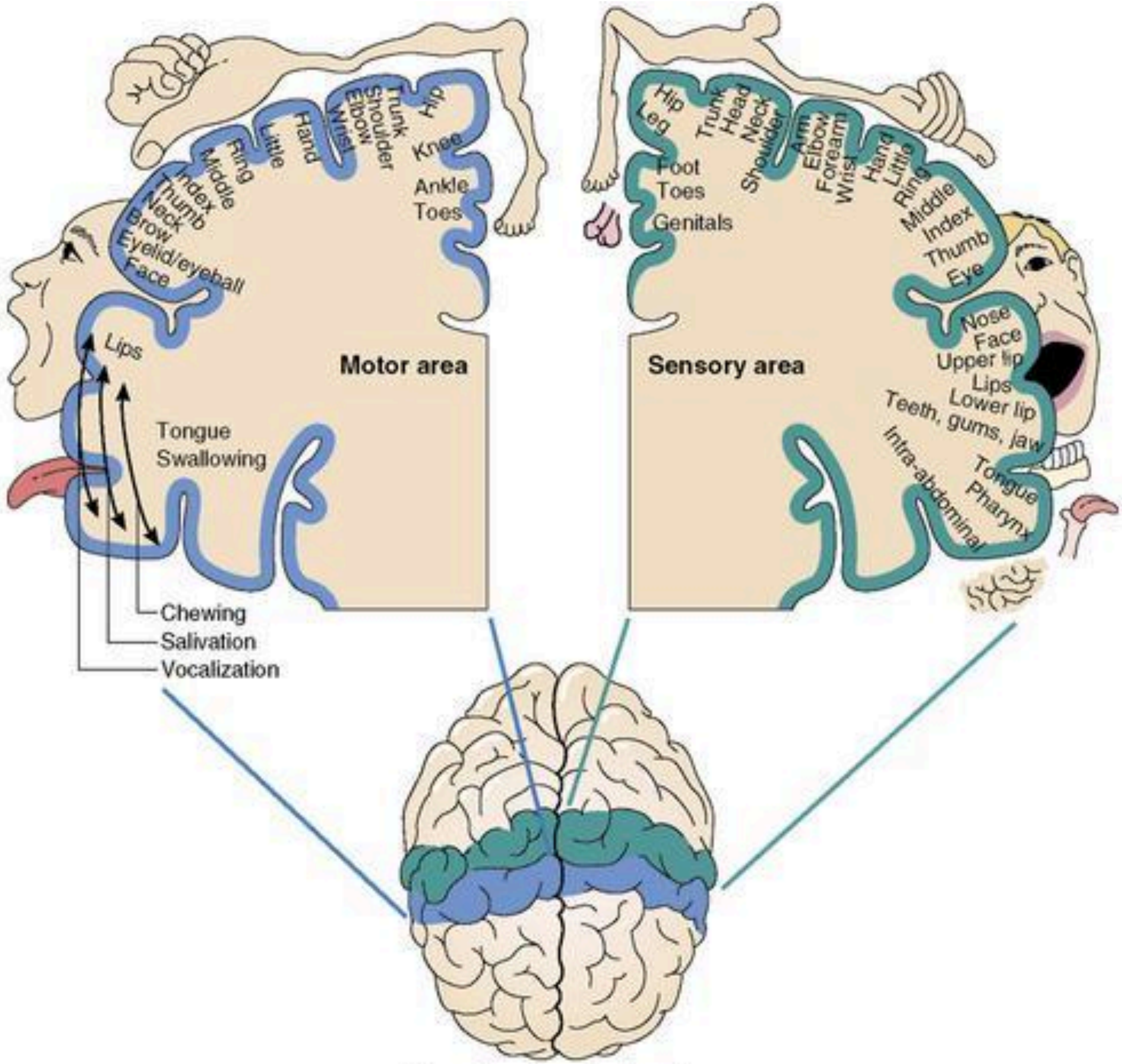

Premotor
area neuron
discharge
Instruction
stimulus
stimulus
"Go" signal
triggering
movement
Signal
triggering
movement



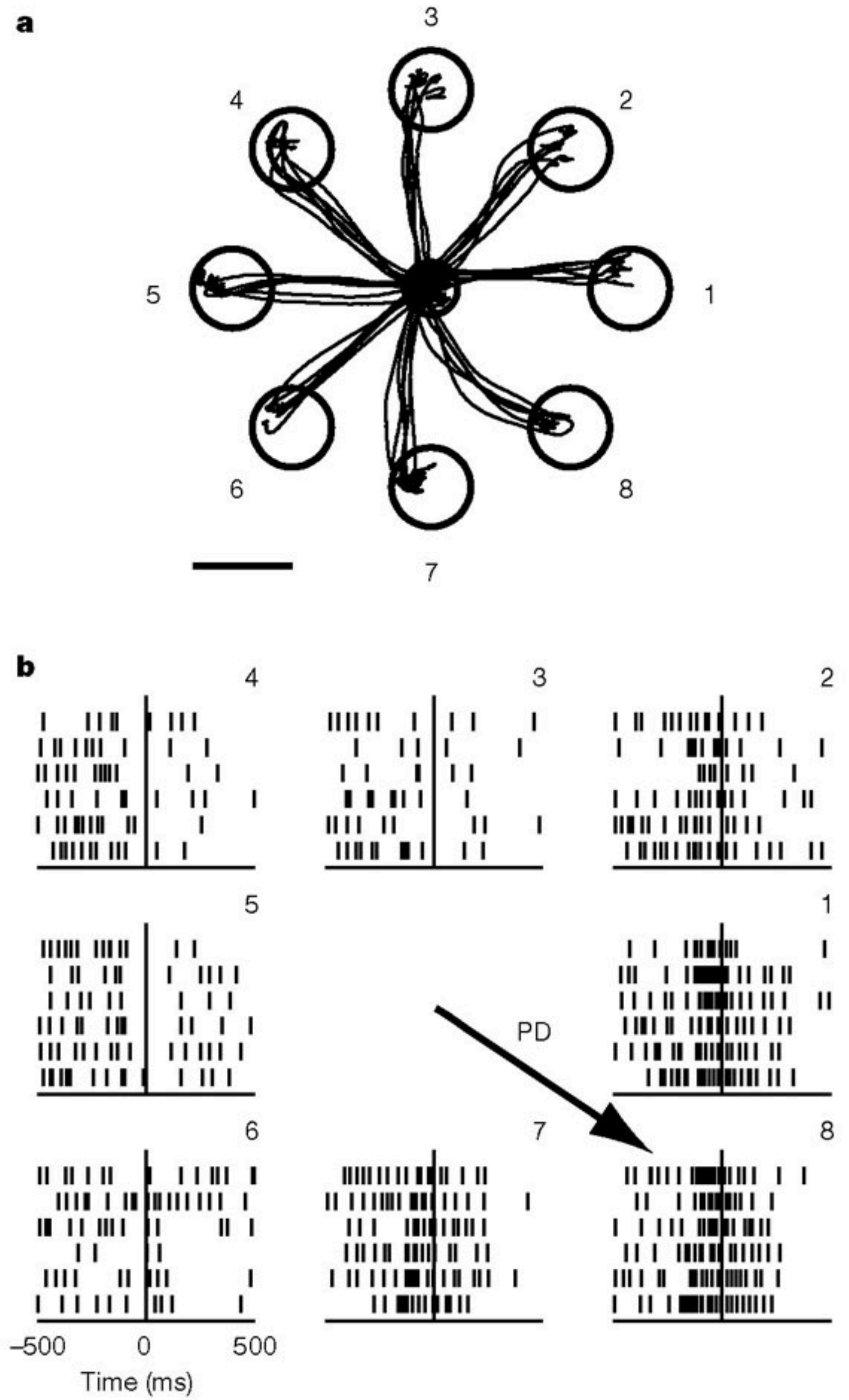
horizontal target position
12
cm
0
horizontal hand position
central spot
hand velocity
100
cm/s
0
EMG
T
200 ms
G
M
Target
Move
Contact

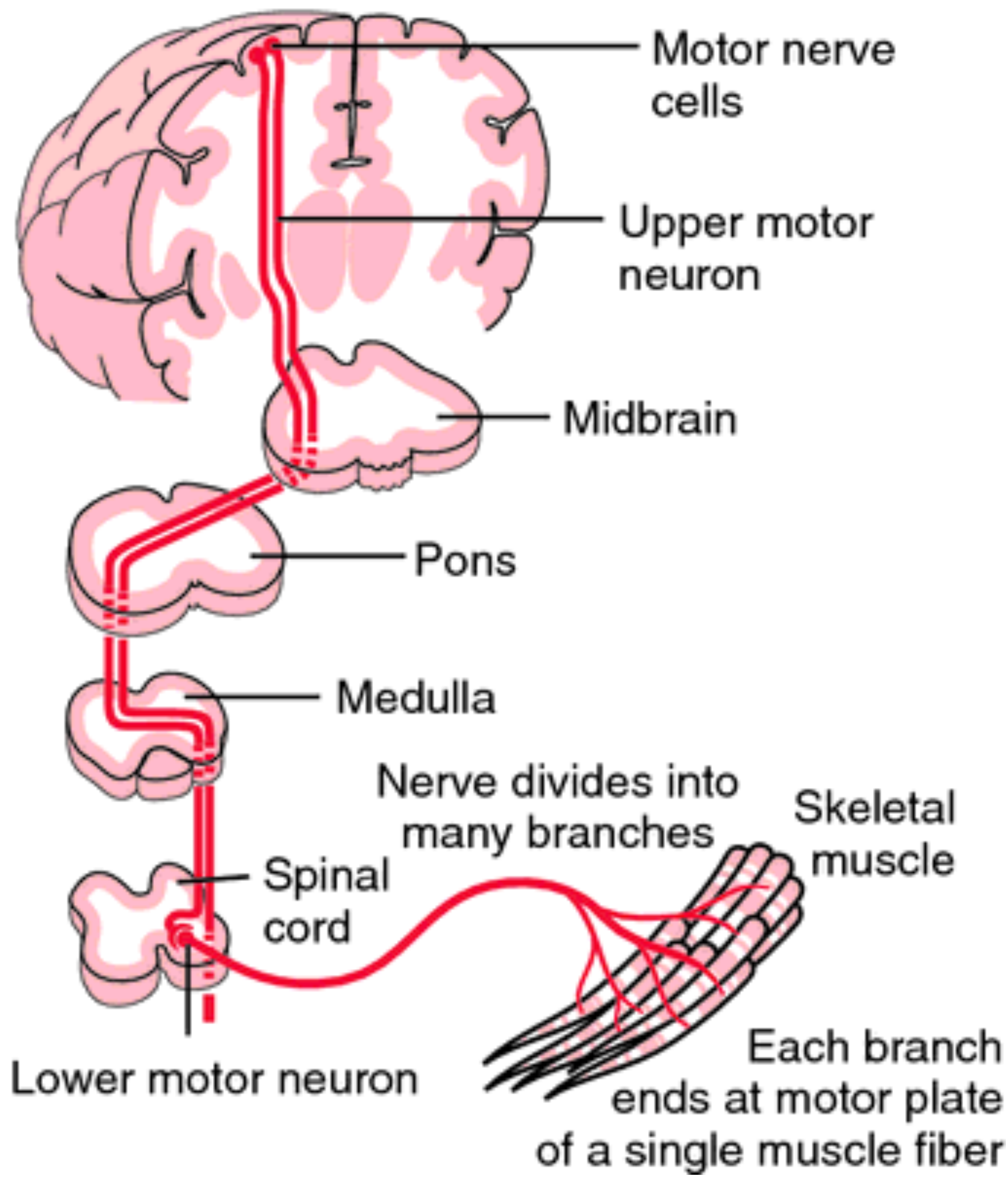


MRCP
A
Negative
Slope
Bereitschaftspotential
B
EMG
C
Pre-BP
BP
NS
5μV
200ms

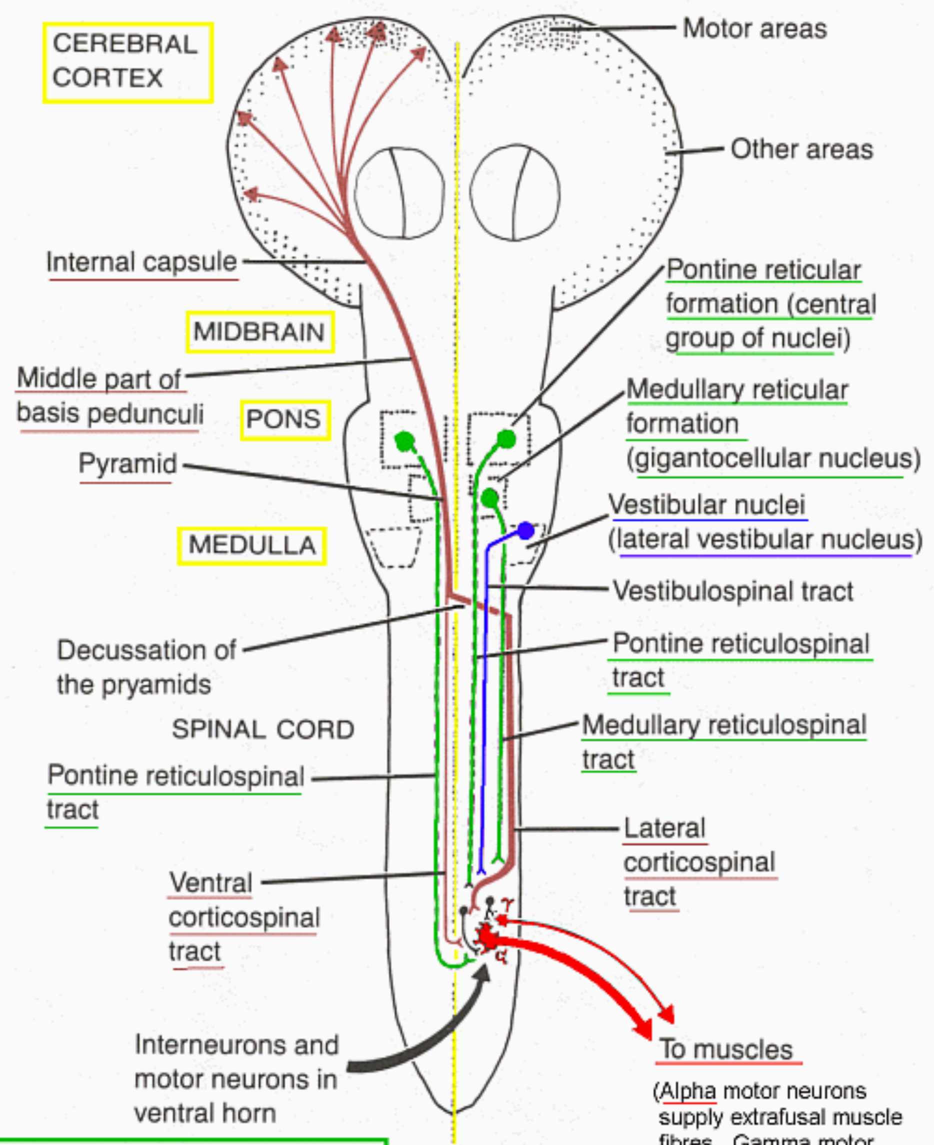


Top view of cerebral cortex


a
3
4
2
5
1
6
8
7
b
4
3
2
5
1
PD
6
7
8
–500
0
500
Time (ms)


Motor nerve cells
Upper motor neuron
Midbrain
Pons
Medulla
Nerve divides into many branches
Skeletal muscle
Spinal cord
Lower motor neuron
Each branch ends at motor plate of a single muscle fiber

Descending pathways involved in motor control



Note. The pontine and medullary reticular formation receive descending afferents, not shown here, from motor areas of the cerebra; cortex.

7 major descending motor control pathways from Cerebral Cortex or Brainstem Nuclei:

From Frontal Cortex:

i. Lateral Corticospinal tract

ii. Ventral Corticospinal tract

iii. Corticobulbar tract (→ cranial nerve motor nuclei).

From Brainstem Nuclei:

i. Rubrospinal tract

ii. Reticulospinal tract

iii. Vestibulospinal tract

iv. Tectospinal tract

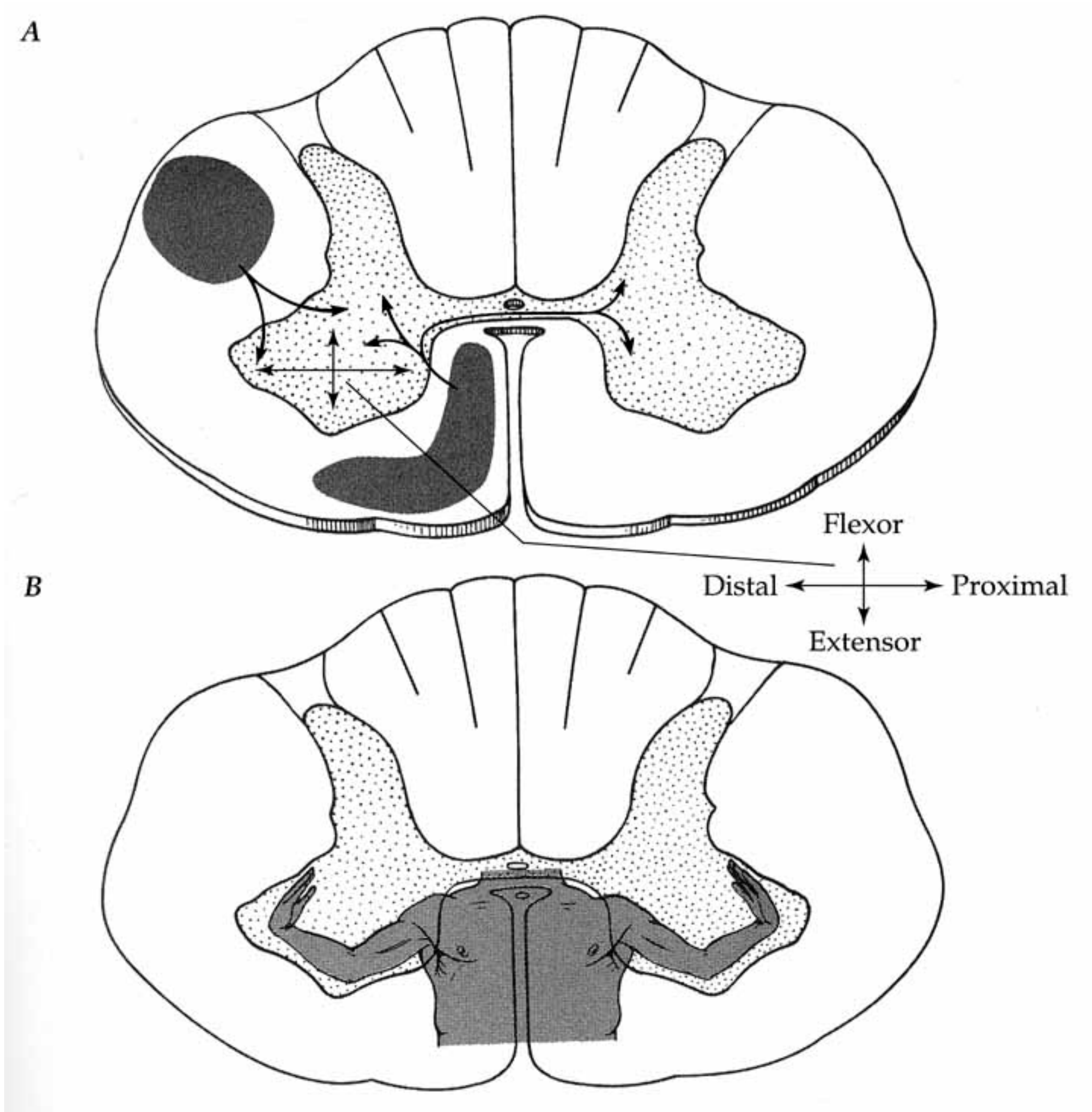
Interneuron Connections:

(sometimes an intermediary before motor neurons)

1. Segmental interneurons – short branches within single spinal cord segment

2. Propiospinal neurons – projects for multiple spinal segments before synapsing onto motor neuron - long projections coordinating movements of upper and lower limbs

Somatotopic Organization

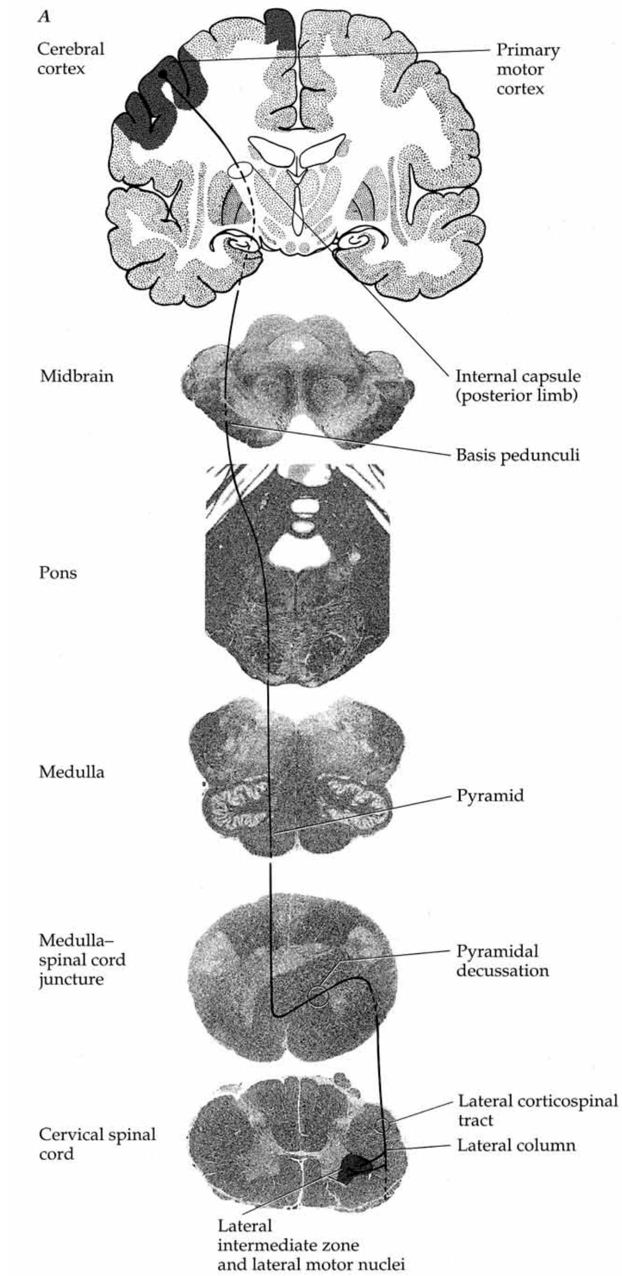


LATERAL DESCENDING PATHWAYS

Lateral Corticospinal Tract:

Starts at the 1° motor cortex decussation zone and lateral motor nuclei of cervical and lumbrosacral Cord.

Primary control of distal muscles

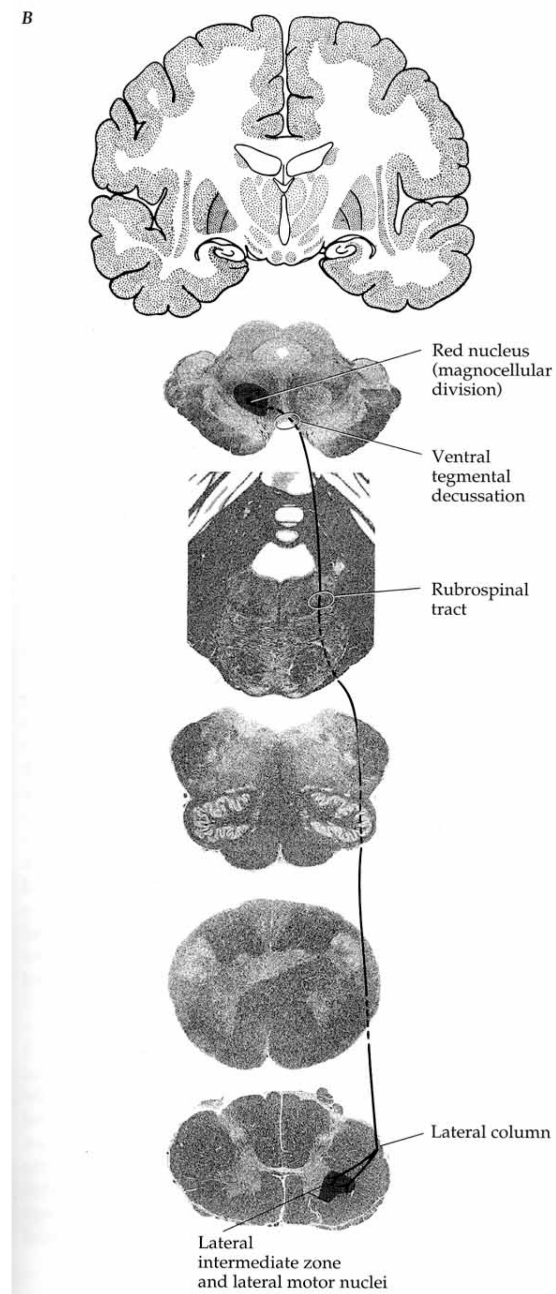


LATERAL DESCENDING PATHWAYS

Rubrospinal Tract

Red nucleus (magnocellular) → midbrain decussation → lateral intermediate zone and ventral horn.

Provides additional control



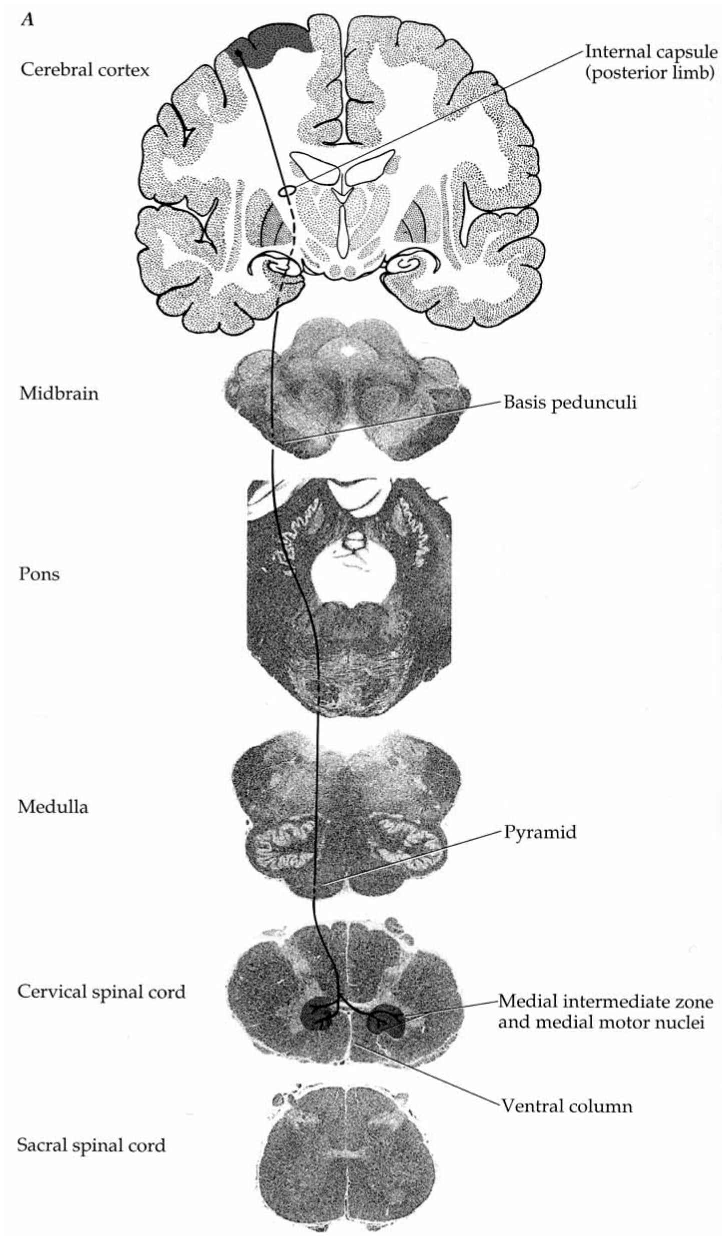
MEDIAL DESCENDING PATHWAYS

Medial (Ventral) Corticospinal Tract

Axial and girdle muscles.

Ipsilateral ventral column → bilateral projections to medial grey matter.

Controls especially for head, shoulder, and upper trunk muscles.

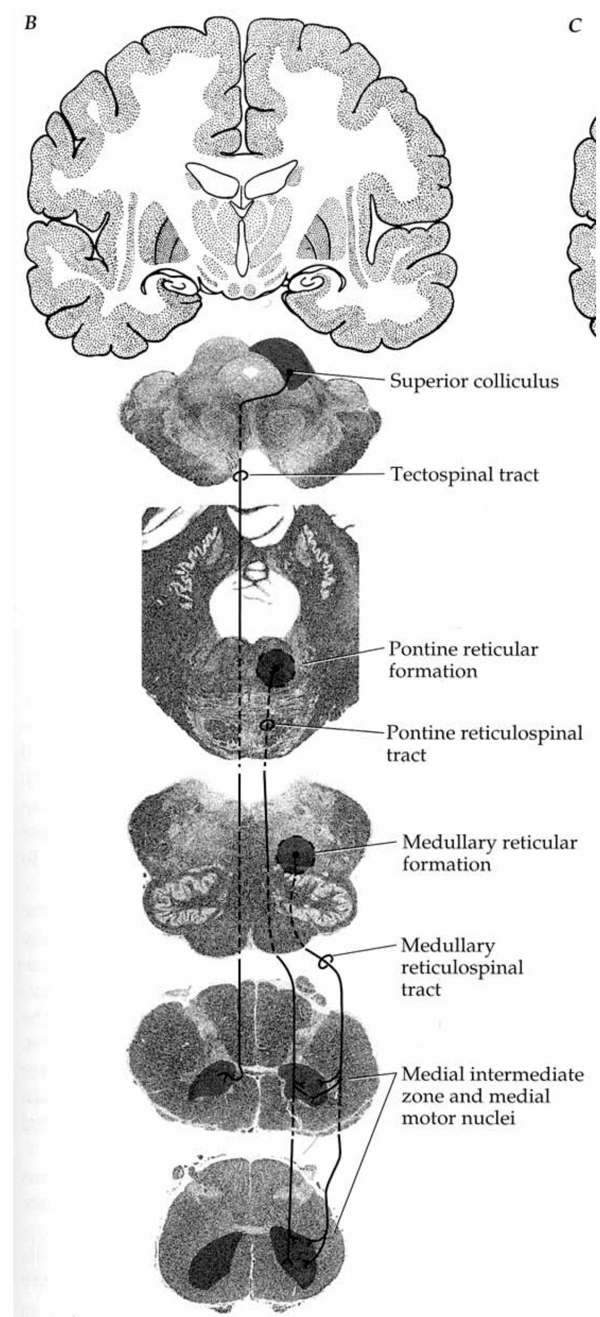


Reticulospinal Tract

Many terminate in cervical cord.
But, 2° projections to propiospinal neurons may influence lower axial muscles also.
Pontine → ventral column.
Medullary reticular formation → lateral column
Autonomic movements: posture and repetitive movements.

Tectospinal Tract

From superior coliculus → coordinates head and eye movements.

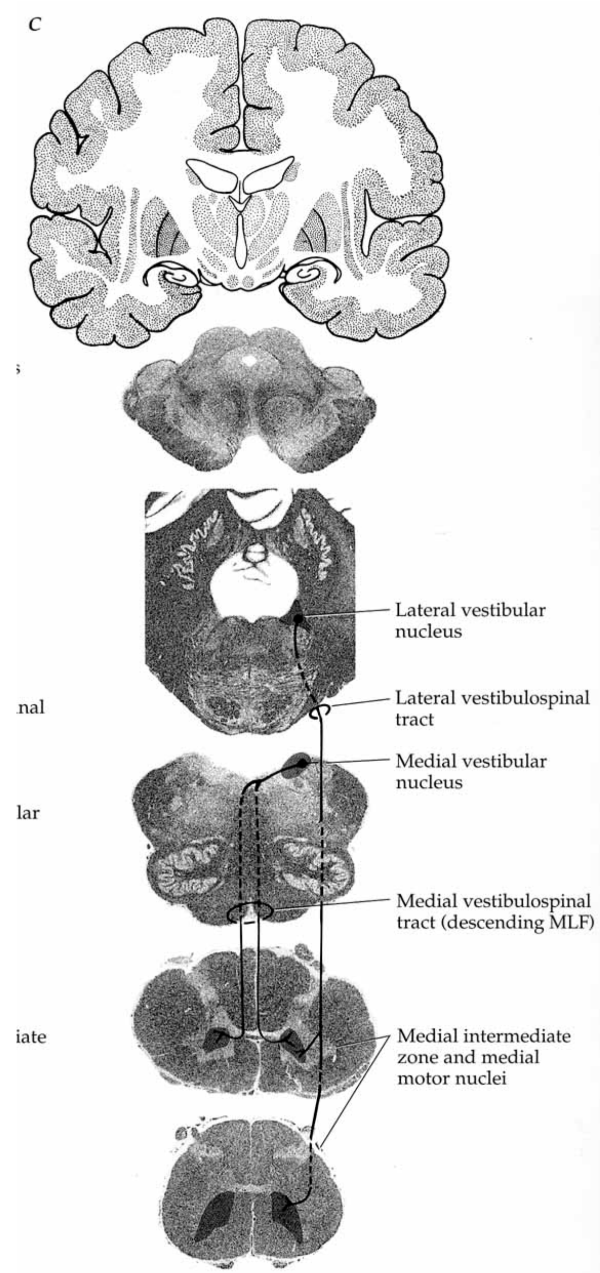


Vestibulospinal Tracts:

Lateral vestibular nucleus → lateral vestibulospinal tract (to all spinal limbs)

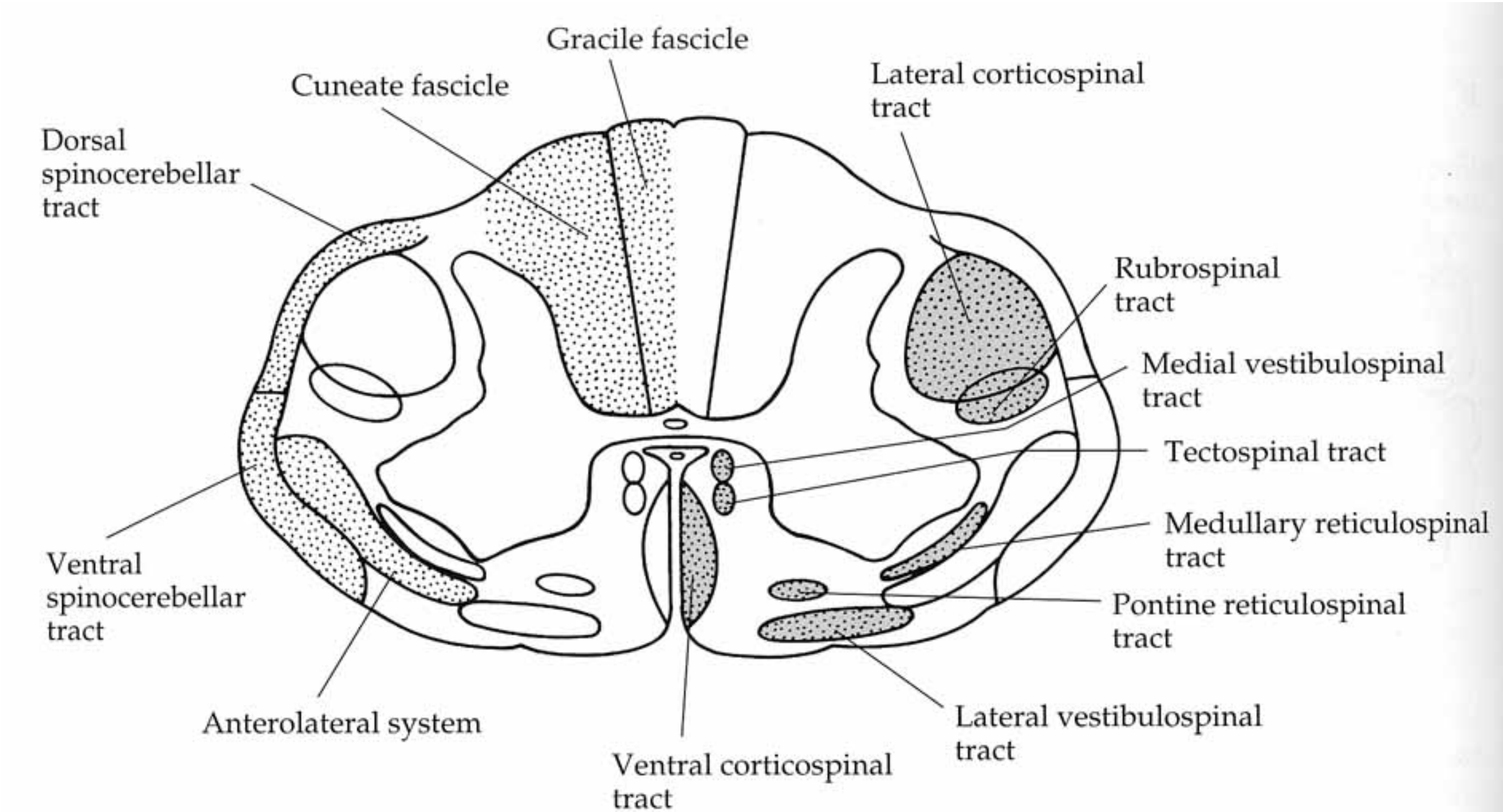
Maintains balance.

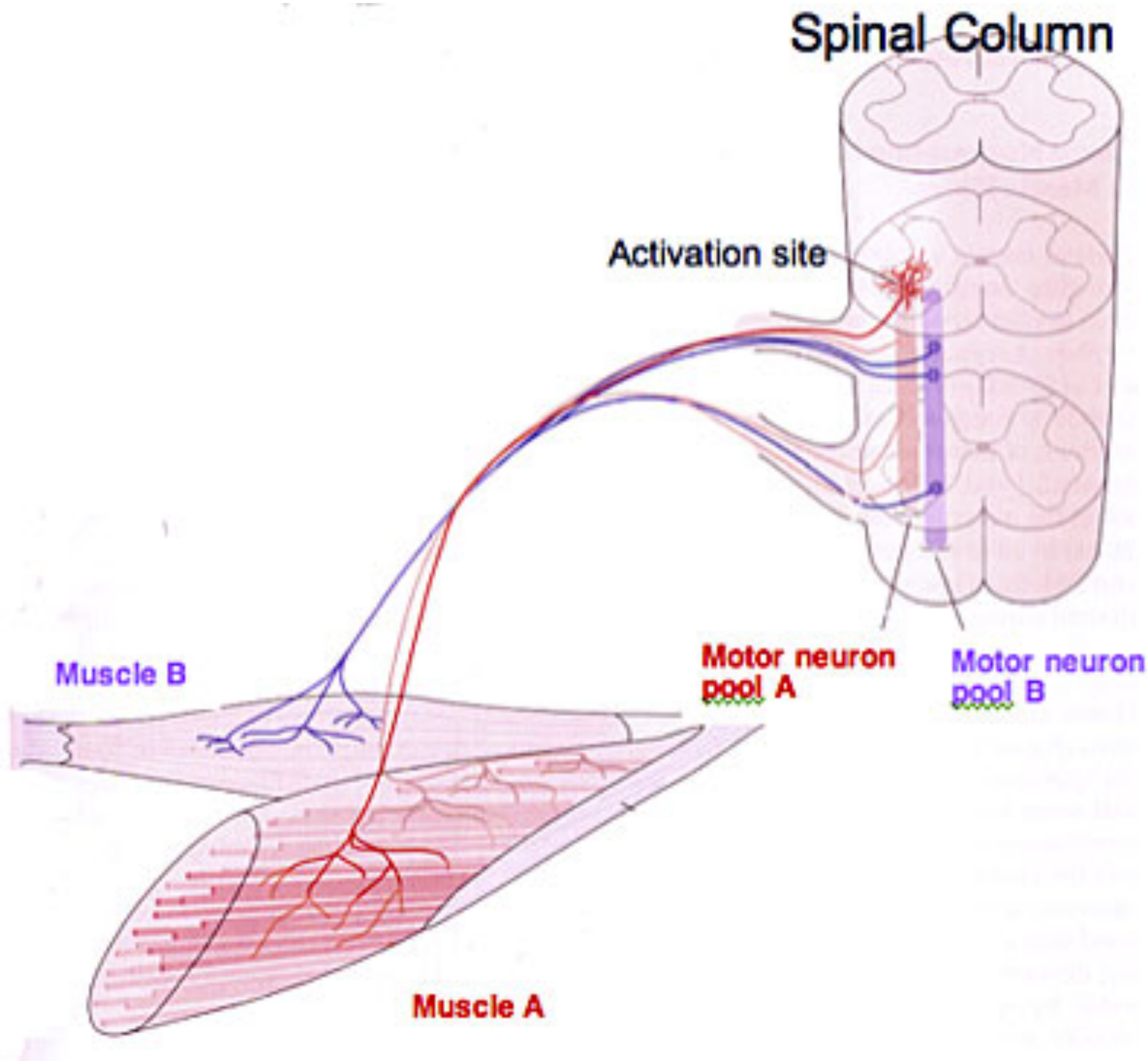
Medial nucleus → medial tracts for control of head position (cervical only).

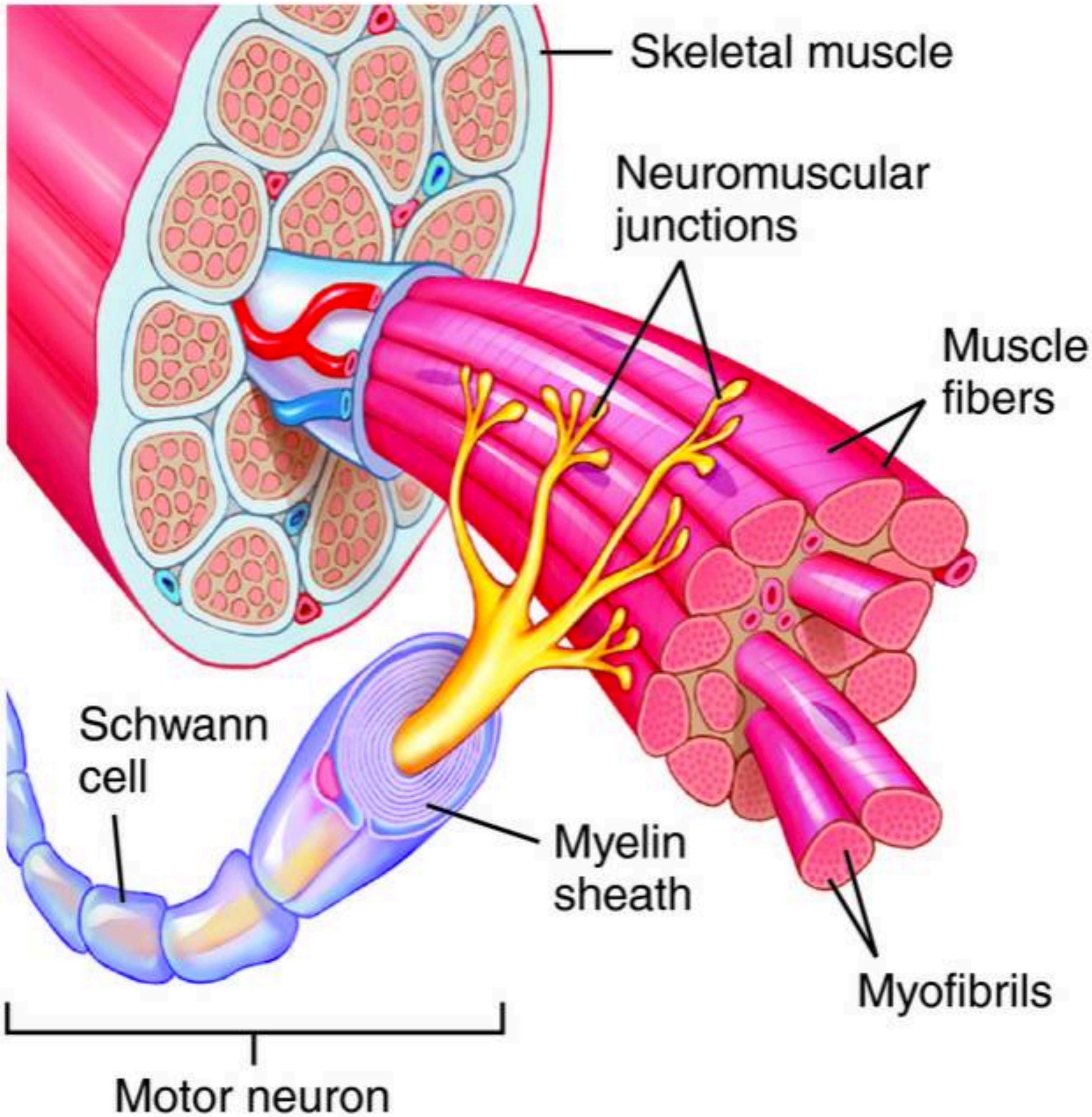


Organization of Tracts

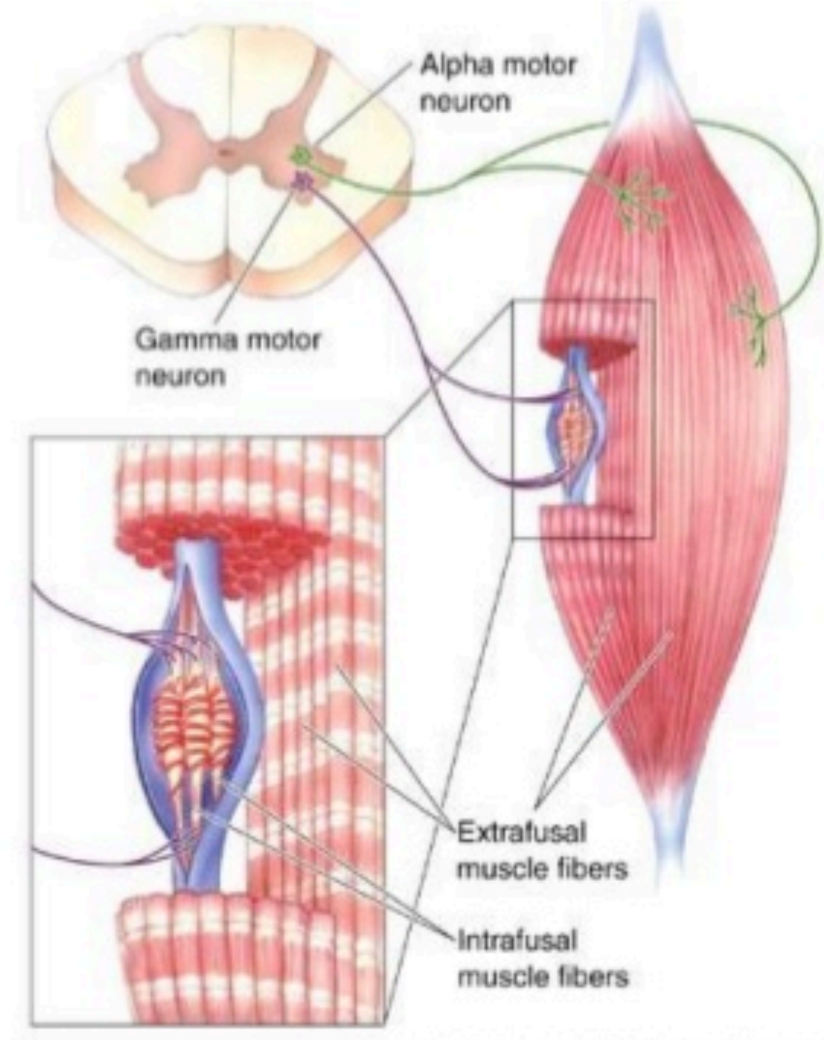
Note the descending and ascending tracts and their relative positions.

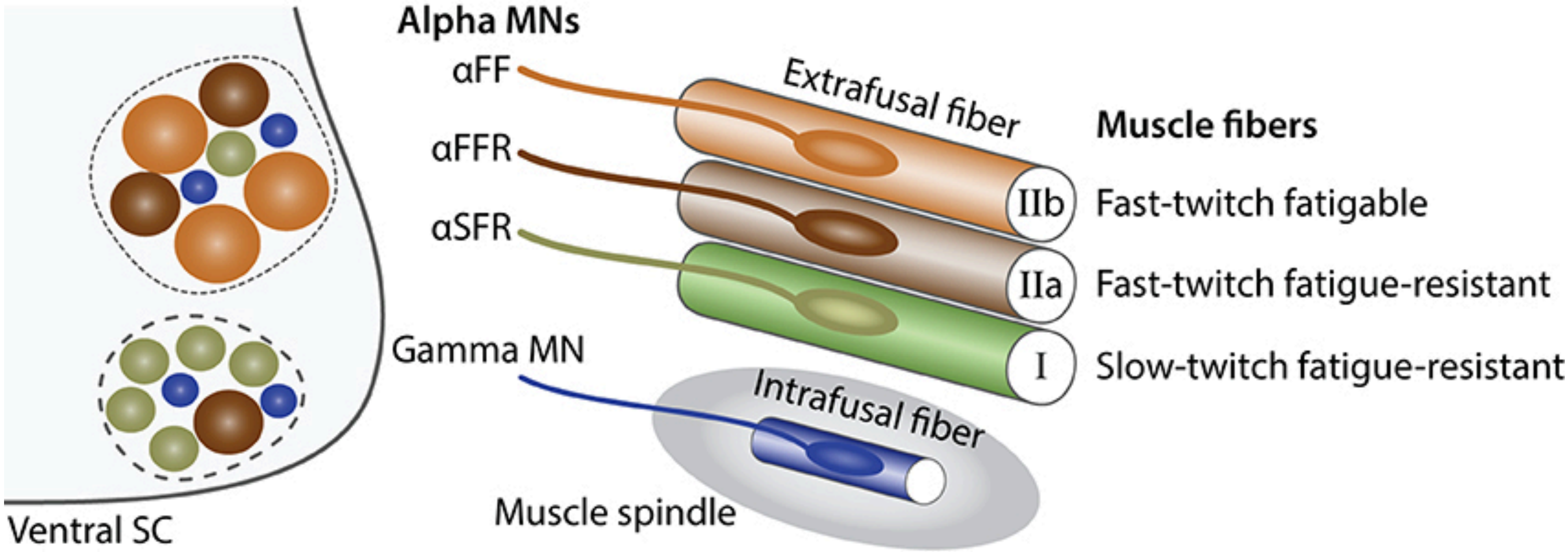



Spinal Column
Activation site
Muscle B
Motor neuron pool A
Motor neuron pool B
Muscle A

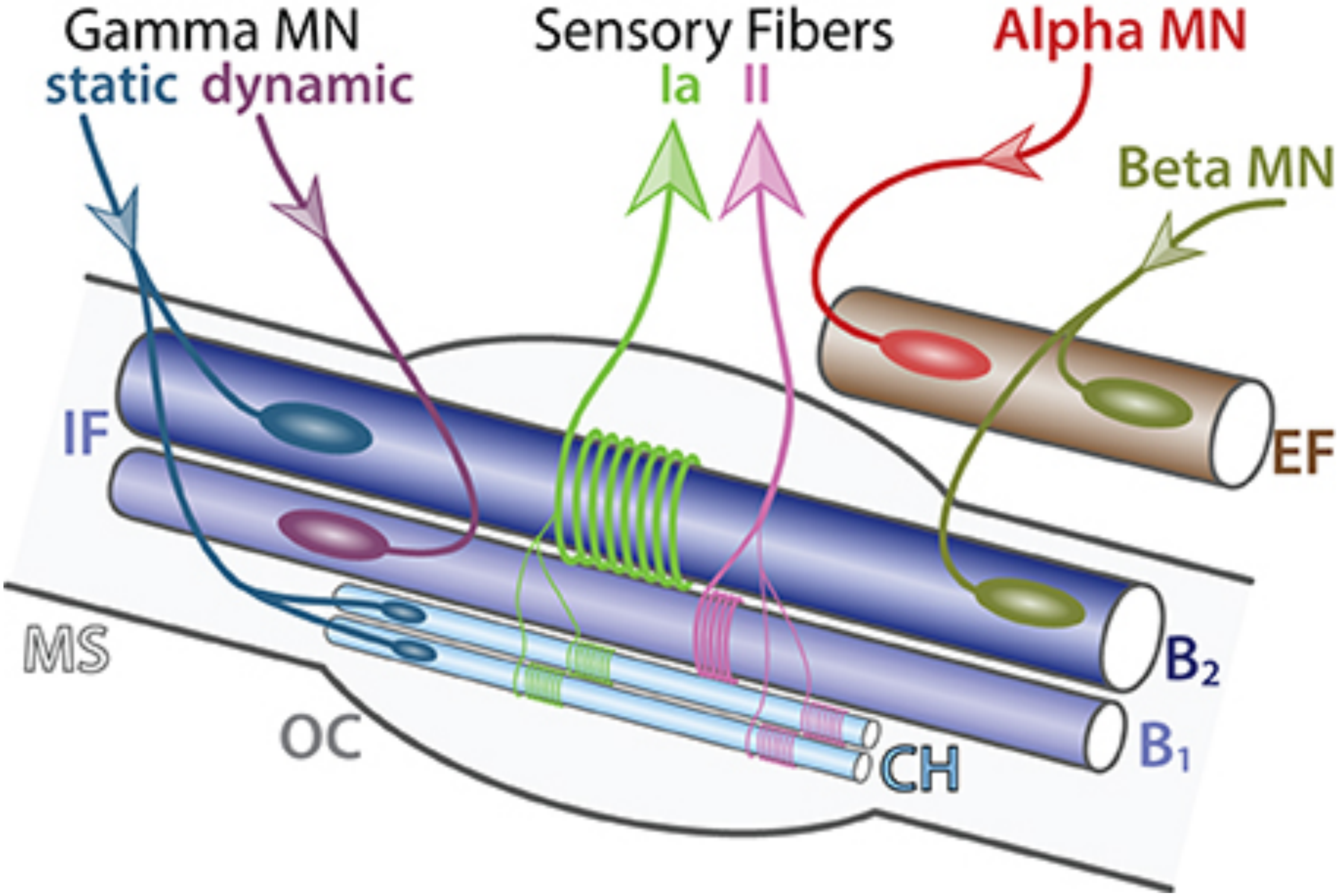

Skeletal muscle
Neuromuscular junctions
Muscle fibers
Schwann cell
Myelin sheath
Myofibrils
Motor neuron

- Two Types of Muscle Fiber
  - Extrafusal fibers: Innervated by alpha motor neurons
  - Intrafusal fibers: Innervated by gamma motor neurons





Alpha MNs
αFF
αFFR
αSFR
Gamma MN
Extrafusal fiber
Muscle fibers
IIb
Fast-twitch fatigable
IIa
Fast-twitch fatigue-resistant
I
Slow-twitch fatigue-resistant
Intrafusal fiber
Muscle spindle
Ventral SC



Beta Motor Neurons
Innervate intrafusal muscle fibers of muscle spindles, with collaterals to extrafusal fibres.

Why is the motor neuron system set up this way?

Sensory Pathways

Sensory Receptors

Transduce stimuli into electrical signals

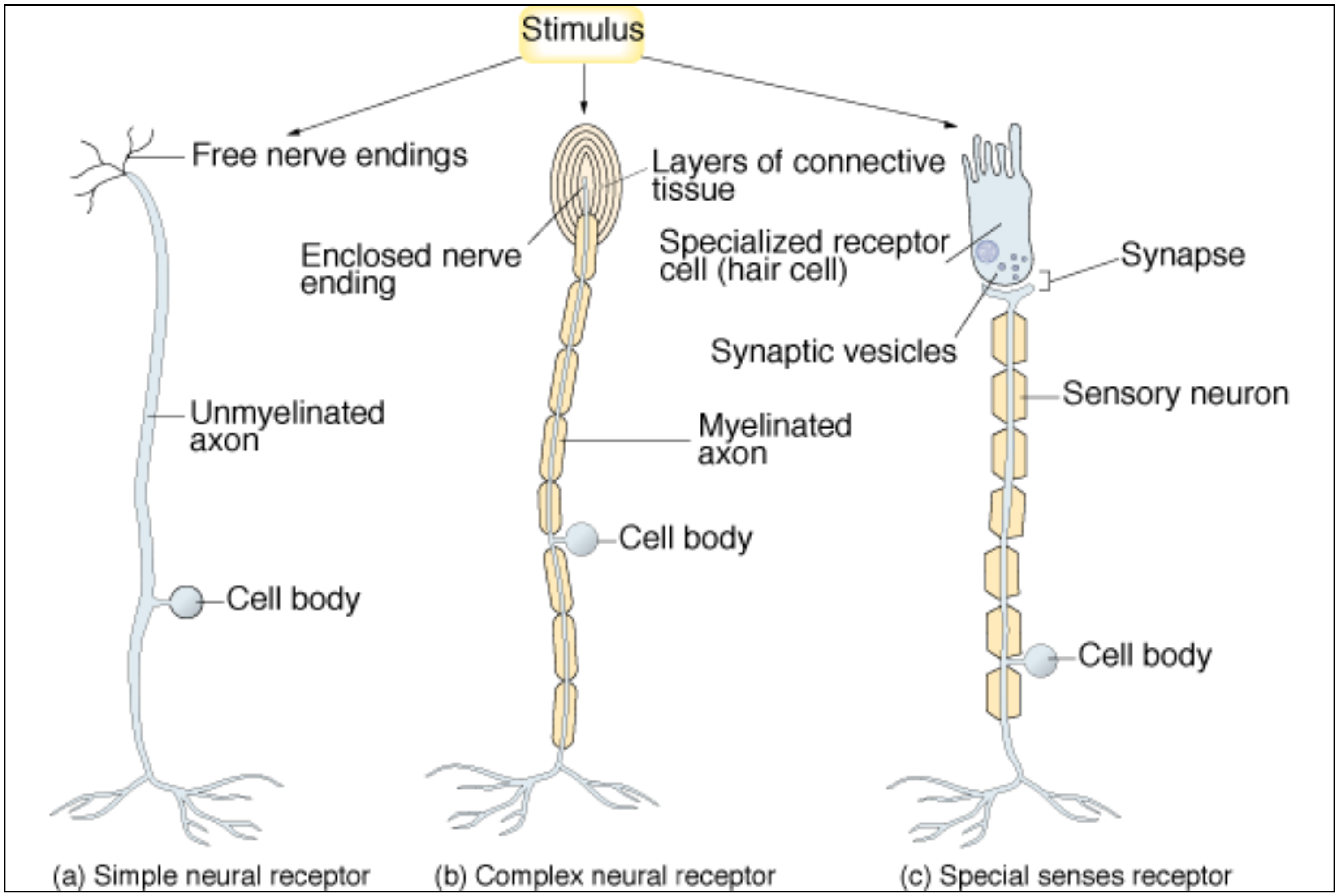
Three major divisions:

1. **<u>Interoceptor</u>**
   Information from within the body

2. **<u>Exteroceptor</u>**
   Information from the environment

3. **<u>Proprioceptor</u>**
   Information about the relative orientation of body segments

Receptors have a wide range of complexity…



How do we get information from mechanoreceptors?

Stimulus *transduced* to change in membrane potential

- **Receptor responds to specific energy form; but can respond to others…**

Need adequate stimulus to reach AP threshold

Specialized cells code strength

Stimulus characteristics are coded

Stimulus attributes are preserved by 4 properties:

1. Modality –

Type of neuron

2. Location –

Which neurons fire? Somatosensory cortex very organized (topographical map)

3. Intensity –

Number of activated receptors; frequency of APs

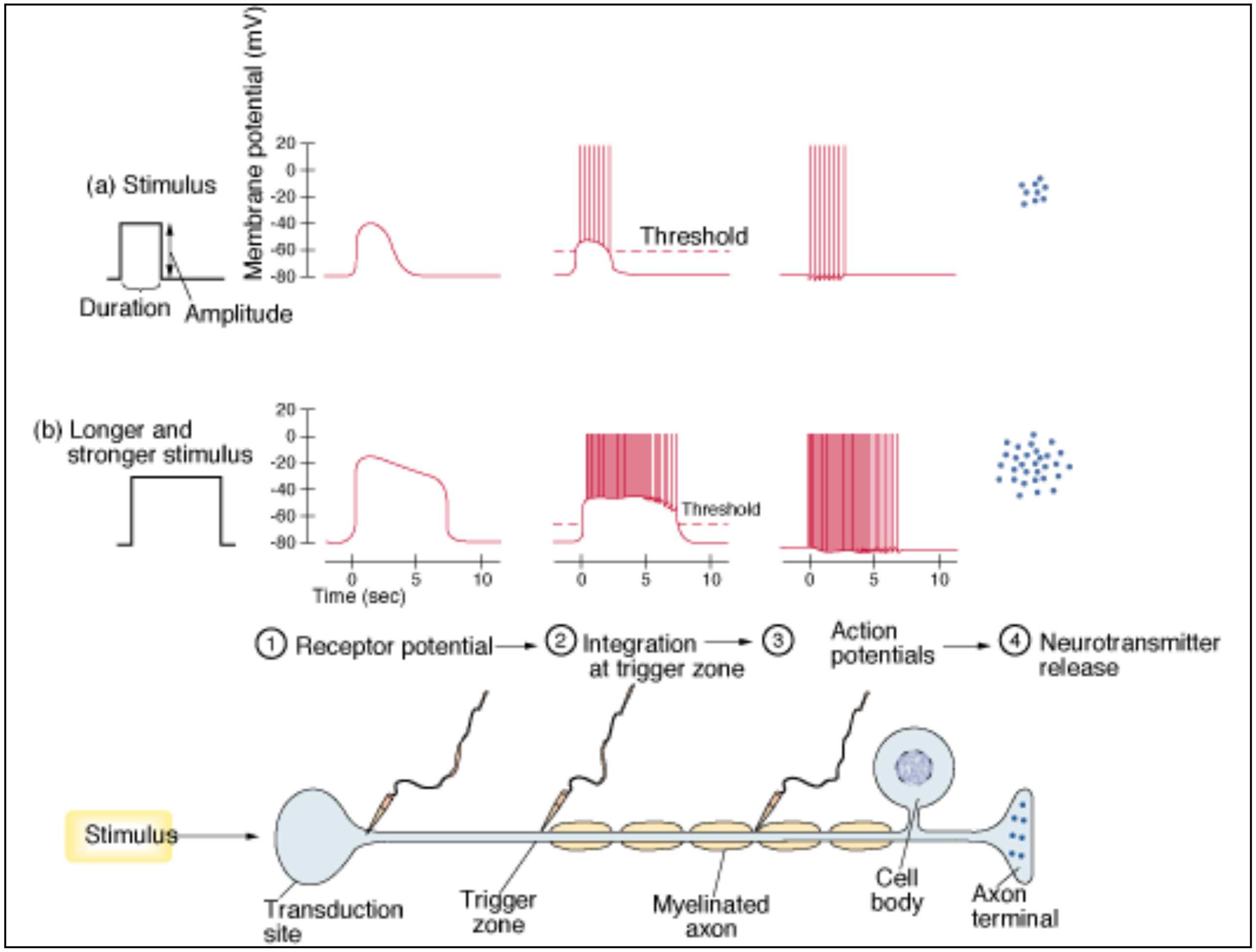
larger stimulus = ↑'d receptor potential, ↑'d AP firing frequency

4. Duration –

Coded by duration of AP trains in sensory neuron

Longer a stimulus persists, the longer the train of APs

Coding for intensity and duration of stimulus…



Somatic Senses

1. **<u>Touch</u>**
   Cutaneous

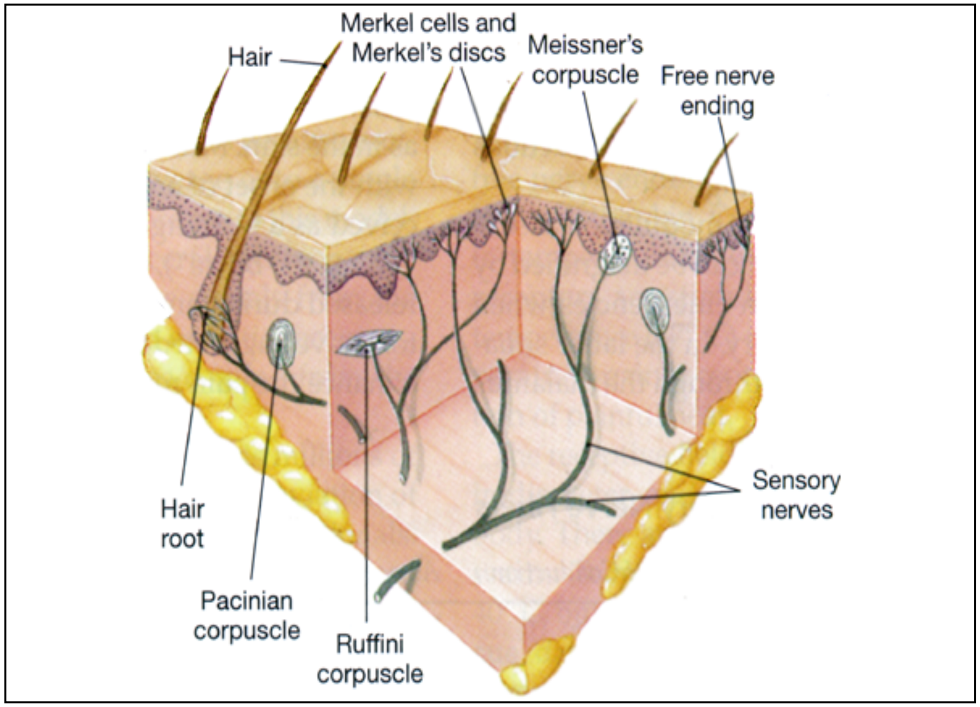
2. **<u>Proprioception</u>**
   Muscle & joint receptors

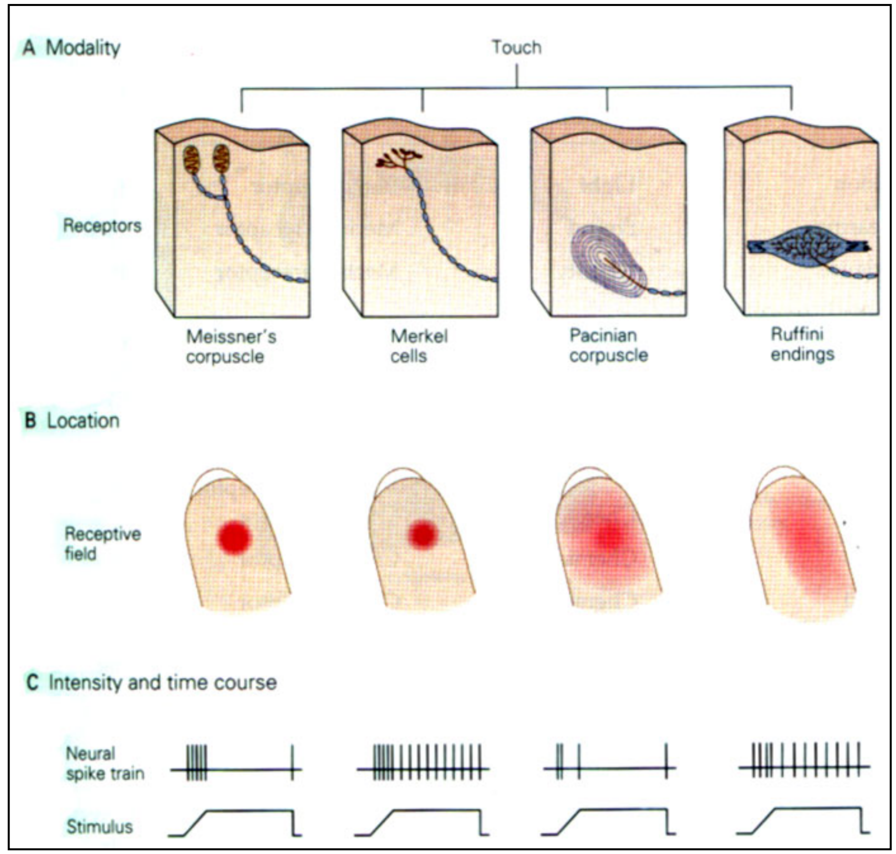
3. **Nociception**
   (pain, etc)

4. **Temperature**

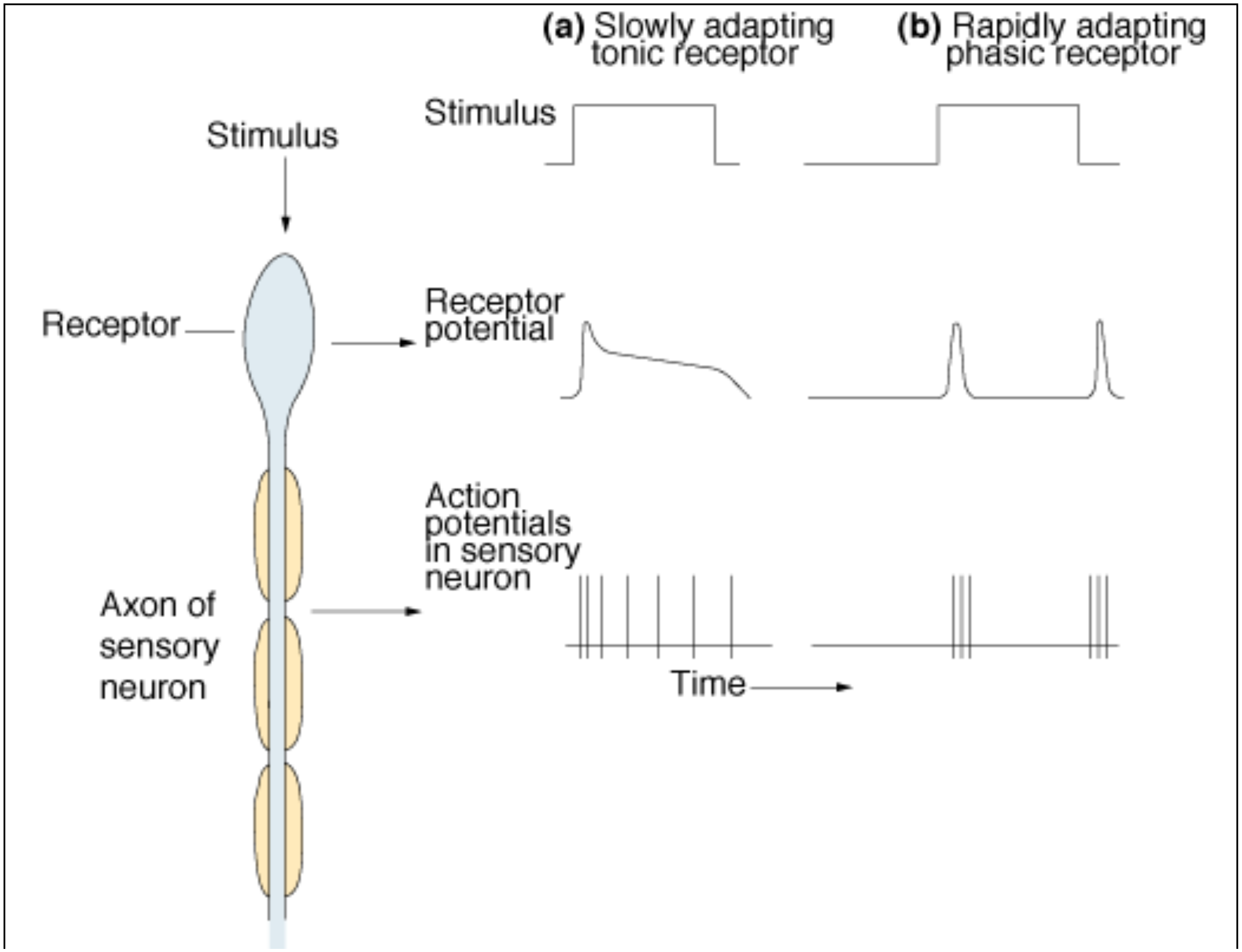
1 & 2 play important roles in motor control

Cutaneous Receptors





Two major classes of cutaneous receptors: Tonic & Phasic



Sensory receptors associated with muscles & joints…

Muscle:

Muscle spindles

Golgi tendon organs

Joint:

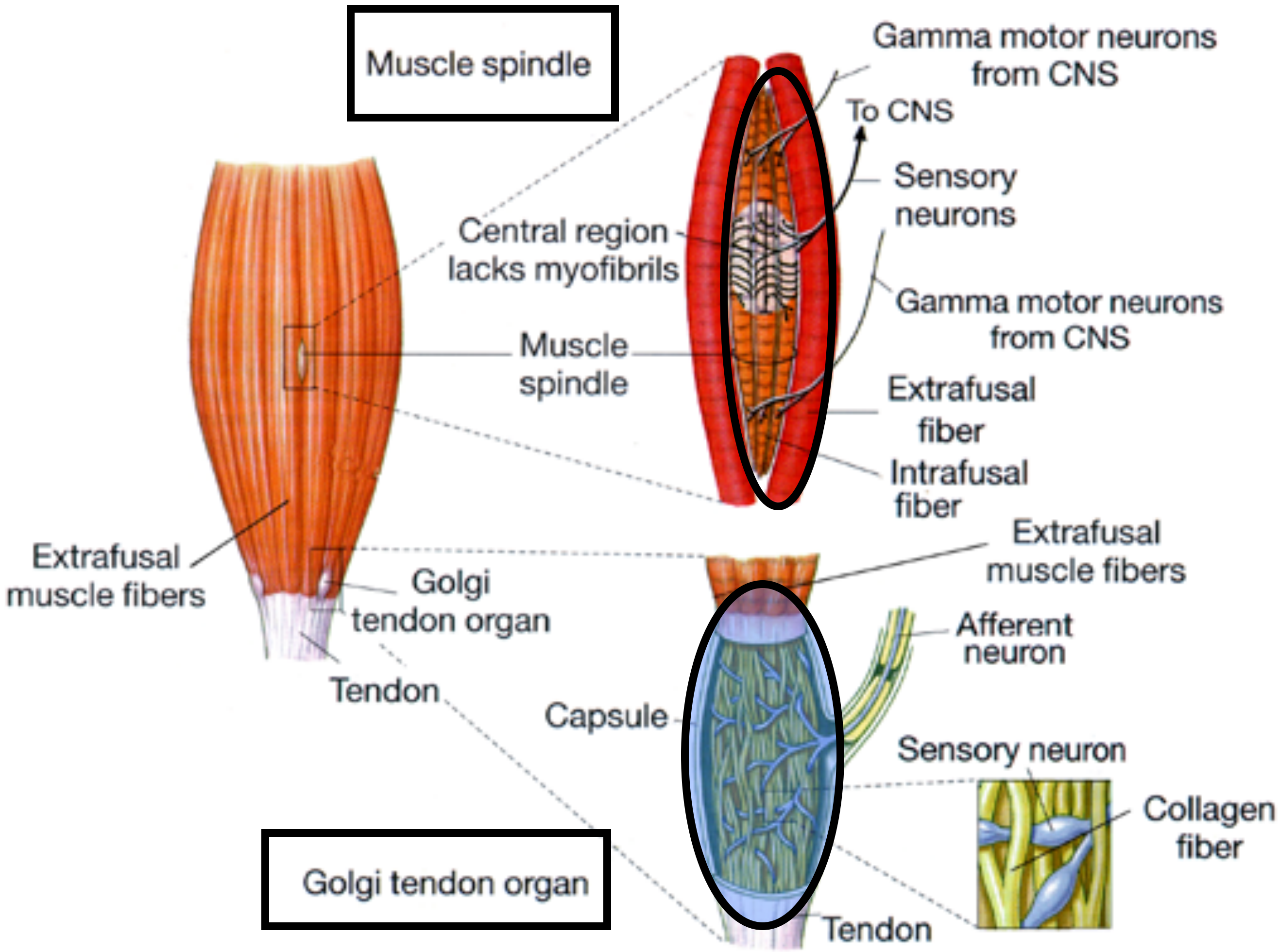
Joint capsule mechanoreceptors

Types of Sensory Neurons

Type 1a	Primary	Rate of change of muscle
Type 1b	N/A	in GTO
Type II	Secondary	Fire when muscle static

Table I Somatosensory Receptors and their Peripheral Axons					
Receptor Type	**Axon[3] Group**	**CAP Peak**	**Conduction Velocity**	**Axon Diameter**	**Information Processed**
Muscle Spindle: Annulospiral endings	1a	Aα	70-120 m/sec	1-20 μM	Muscle length and velocity
Muscle Spindle: Flower Spray endings	II	Aβ	30-70 m/sec	6-12 μM	Muscle length
Golgi Tendon Organ	Ib	Aα	70-120 m/sec	12-20 μM	Muscle tension
Joint: Pacinian	II	Aβ	30-70 m/sec	6-12 μM	Joint movement
Joint: Ruffini	II	Aβ	30-70 m/sec	6-12 μM	Joint angle
Joint: Golgi Tendon Organ	II	Aβ	30-70 m/sec	6-12 μM	Joint torque
Meissner corpuscle	II	Aβ	30-70 m/sec	6-12 μM	Touch, flitter or movement
Pacinian corpuscle	II	Aβ	30-70 m/sec	6-12 μM	Vibration
Ruffini corpuscle	II	Aβ	30-70 m/sec	6-12 μM	Skin stretch
Hair follicle	II & III	Aβ & Aδ	10-70 m/sec	2-12 μM	Touch movement
Merkel complex	II	Aβ	30-70 m/sec	6-12 μM	Fine touch
Free Nerve endings	III	Aδ	5-30 m/sec	1-6 μM	Sharp pain or cool/cold
Free nerve endings	IV	C	0.5-2 m/sec	<1.5 μM	Dull or aching pain, or touch or warm

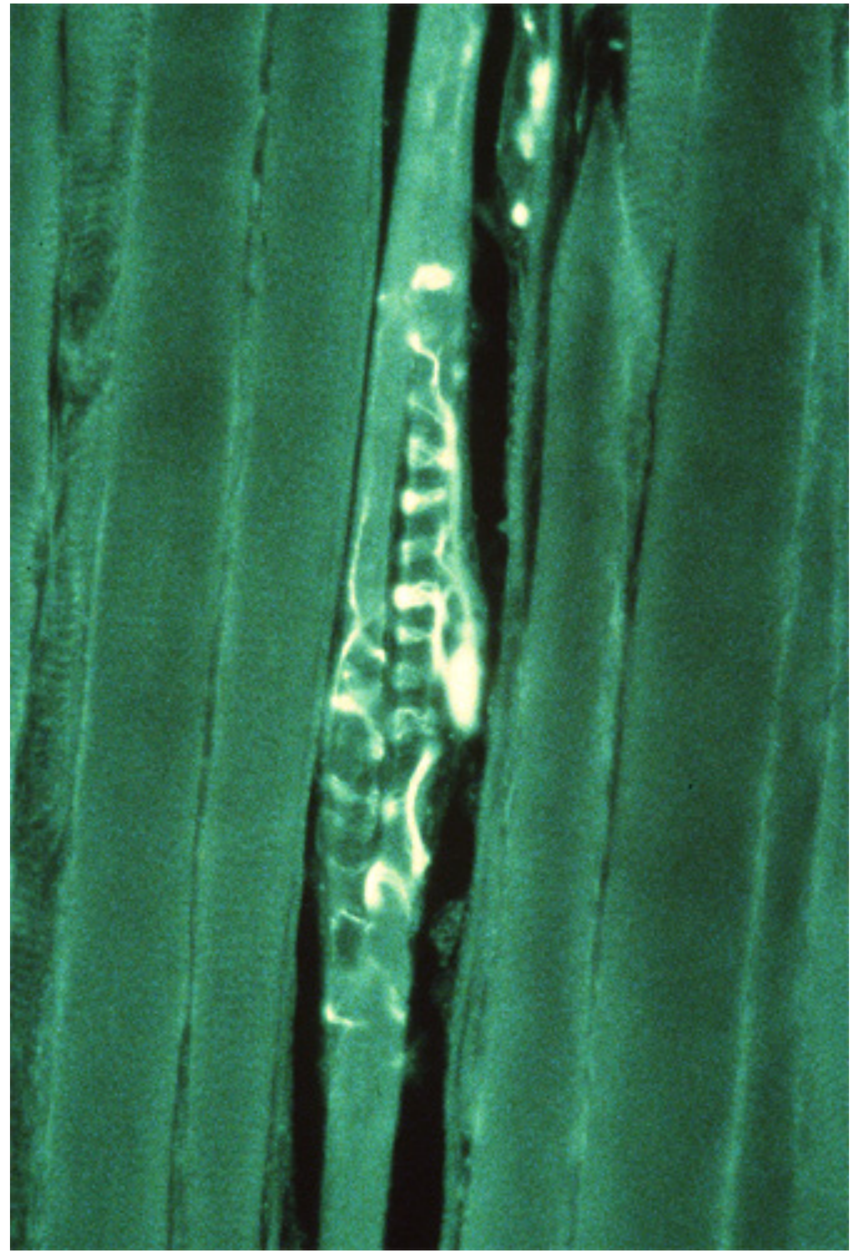
Sensory Receptors in Muscle



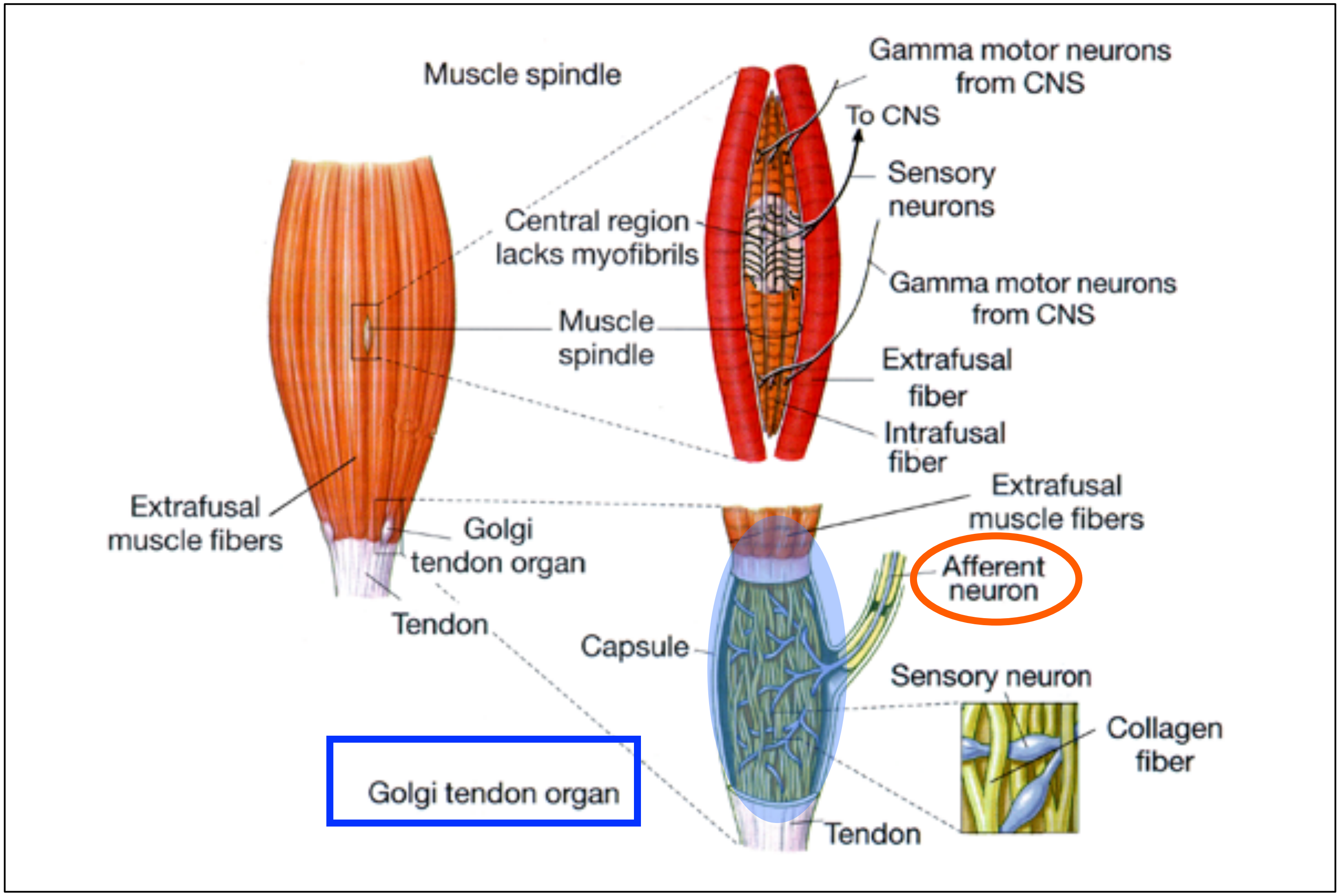
Muscle Spindles

Stretch-sensitive **mechanoreceptors**

Provide info about ***muscle length*** **&** ***velocity of contraction*** **to CNS**



Golgi Tendon Organ (GTO)



Golgi Tendon Organ (GTO)

Receptors at junction of tendons & muscle fibers

Innervated by Group Ib afferents

- **stretching a muscle: pinching of sensory fibers -- neuron firing**
- **contracted muscle: pulls tendon during contraction -- sensory neuron fires**

GTOs are our major “force sensors” in skeletal muscle

How does the sensory system "know" about sensory feedback?

Segregation of information…

- **Organization based on the anatomical location of an input & the proximity of relay nuclei**

Topographic organization...

- **Motor & sensory maps**

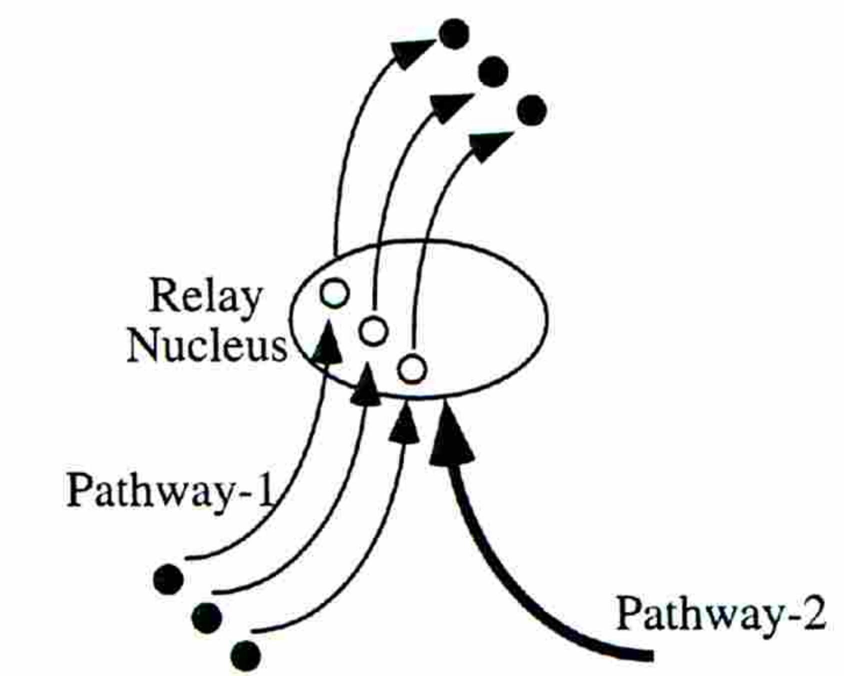


Figure 17.1 Typical features of pathways within the central nervous system involve the presence of synaptic relays, integration of information from different pathways, and topographic organization.

Different groups of afferents have different projections in spinal cord

- **Size determines termination point within spinal cord**
- **Some inputs make monosynaptic connections with MNs (remember muscle spindle pathways)**

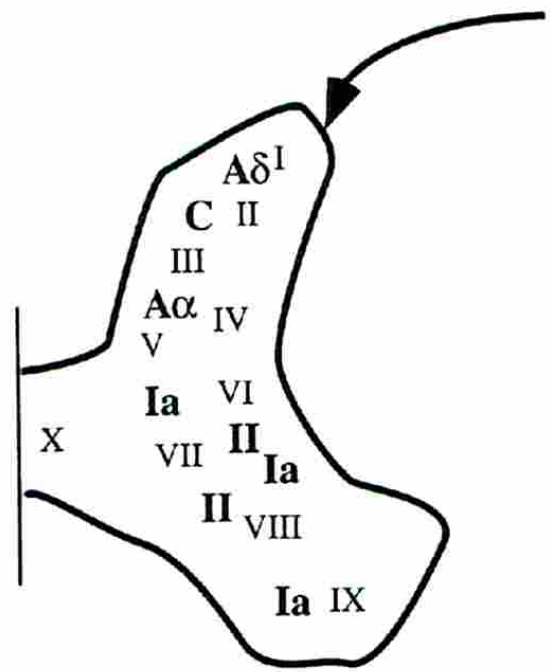


Figure 17.2 Afferent fibers enter the spinal cord through the dorsal columns. Small, unmyelinated fibers (Aδ, C) typically terminate in Rexed laminae I and II. Larger sensory fibers terminate in laminae III-IV, while muscle afferents (Ia, II) terminate anywhere from lamina V to lamina IX.

Sensory Processing

Brain is broken into different areas

Brodmann's areas

speech, touch, vision, motor areas, etc...

Specialized processing within different cerebral areas; e.g…

Rapidly adapting skin mechanoreceptors

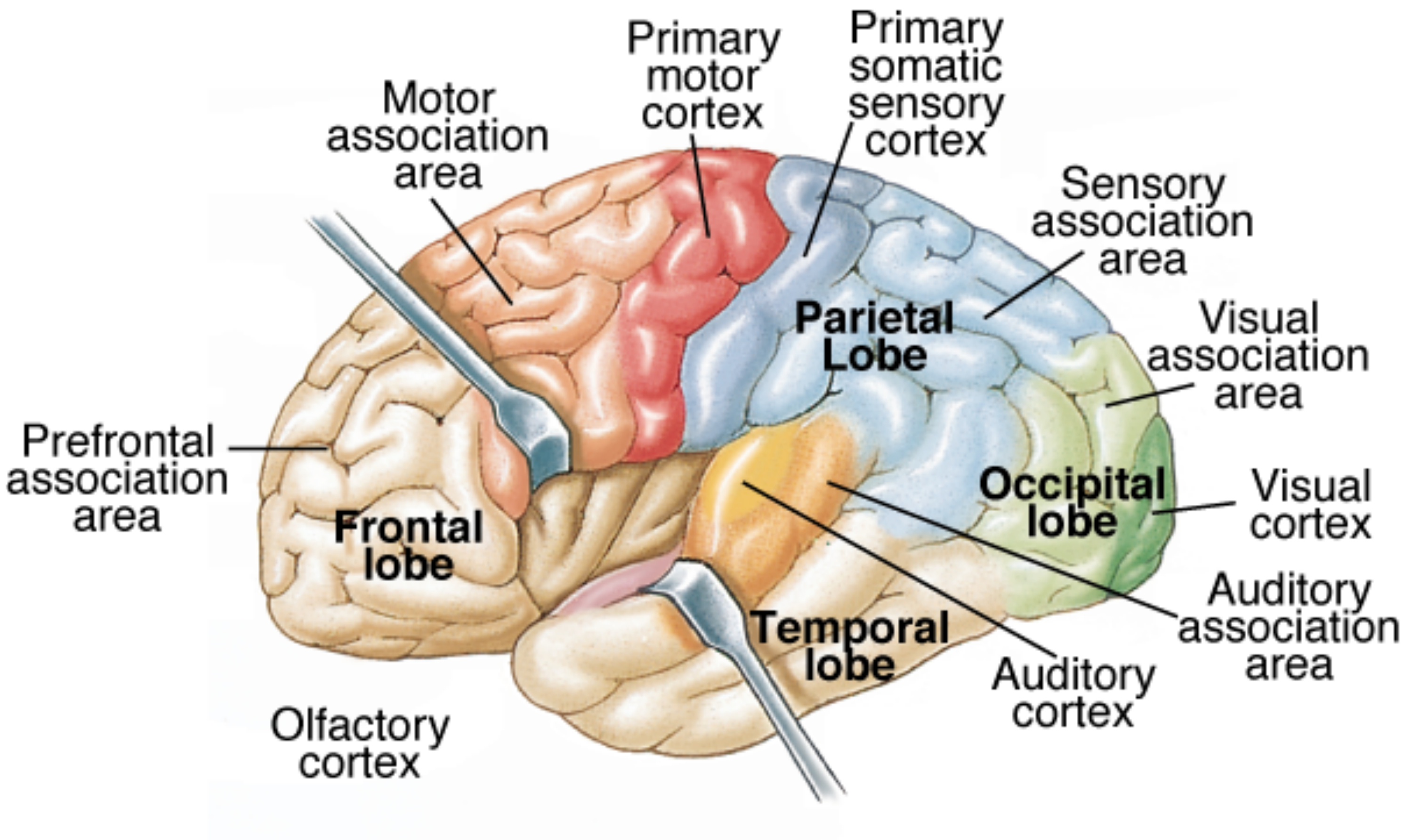
- **Area 1**

Slowly adapting skin mechanoreceptors

- **Area 3b**

Thalamus receives & relays information

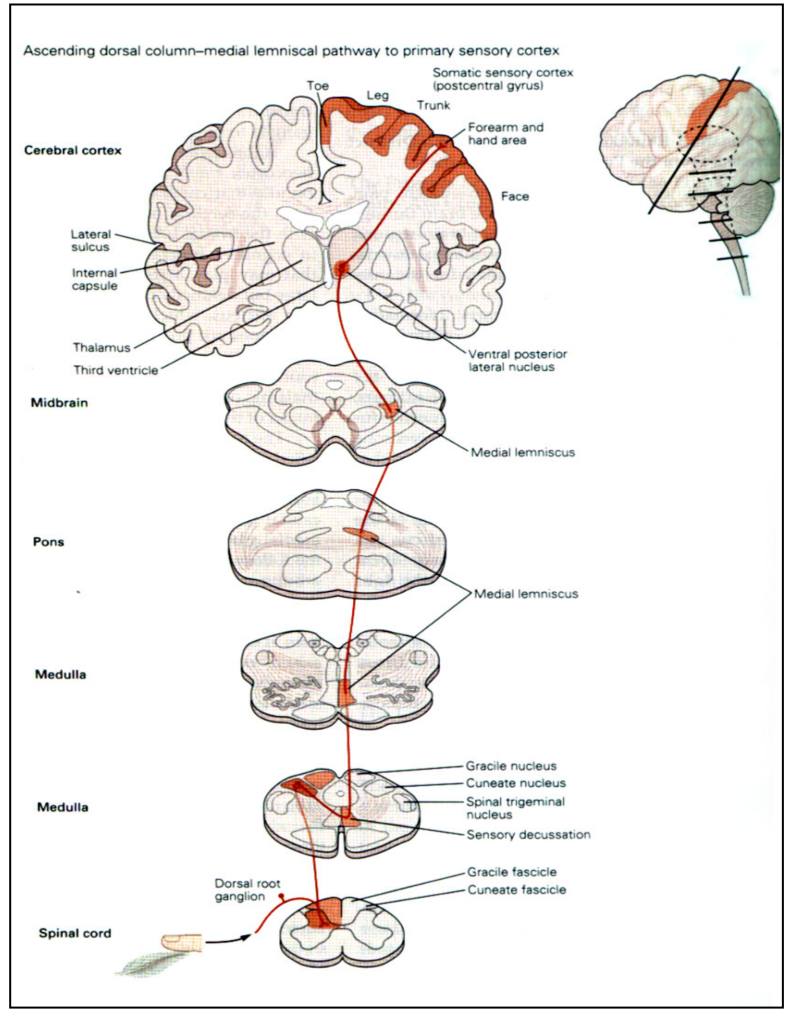
Functional areas of the cerebral cortex…



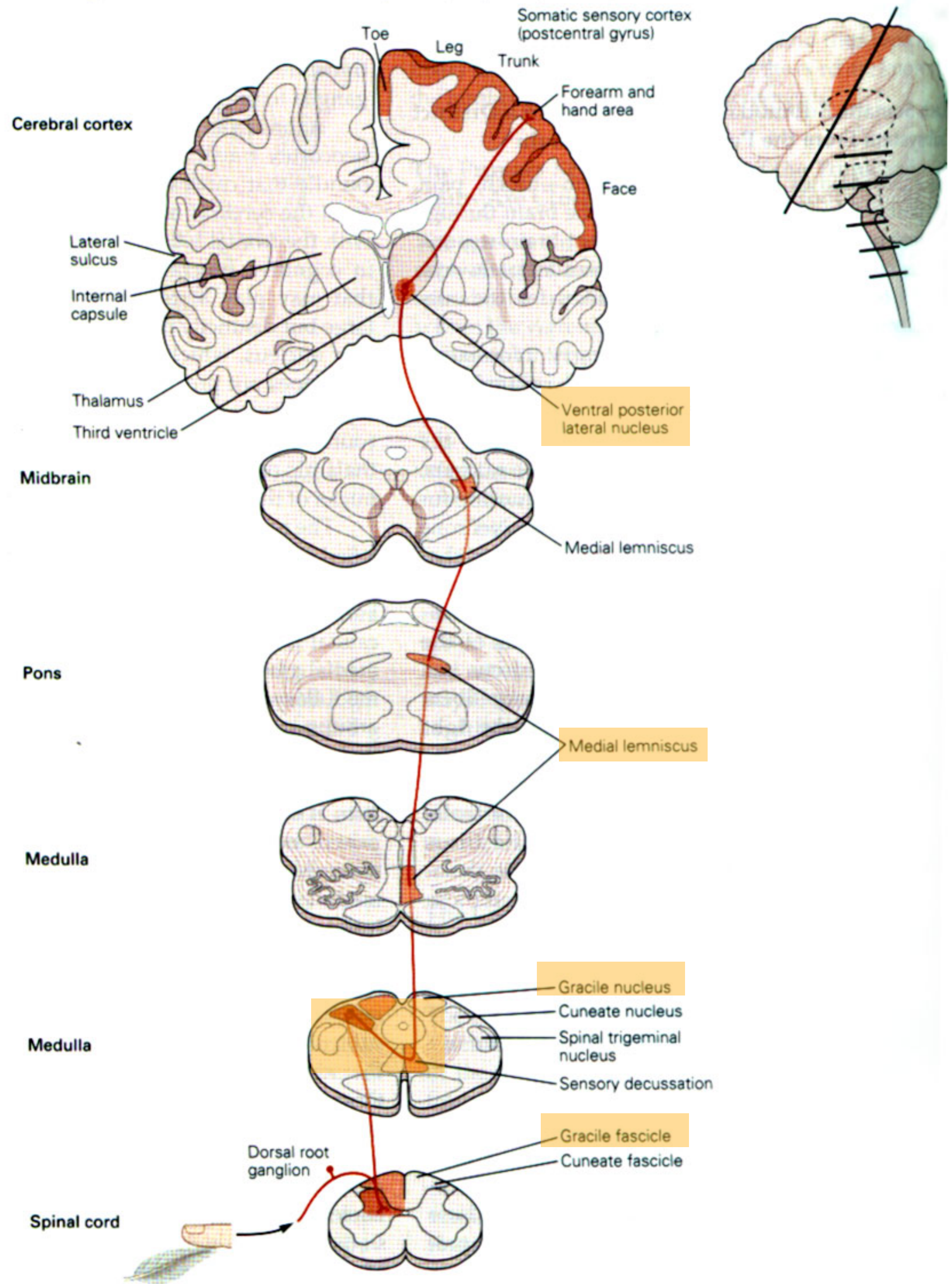
Bear et al. (1996)

Dorsal Column Pathway

- **Major somatosensory ascending pathway**
  - **Group I muscle afferents**
  - **Tactile mechanoreceptors**
- **Terminate in the cuneatous & gracilis nuclei in medulla**
- **Eventually arrives in somatosensory cortex**

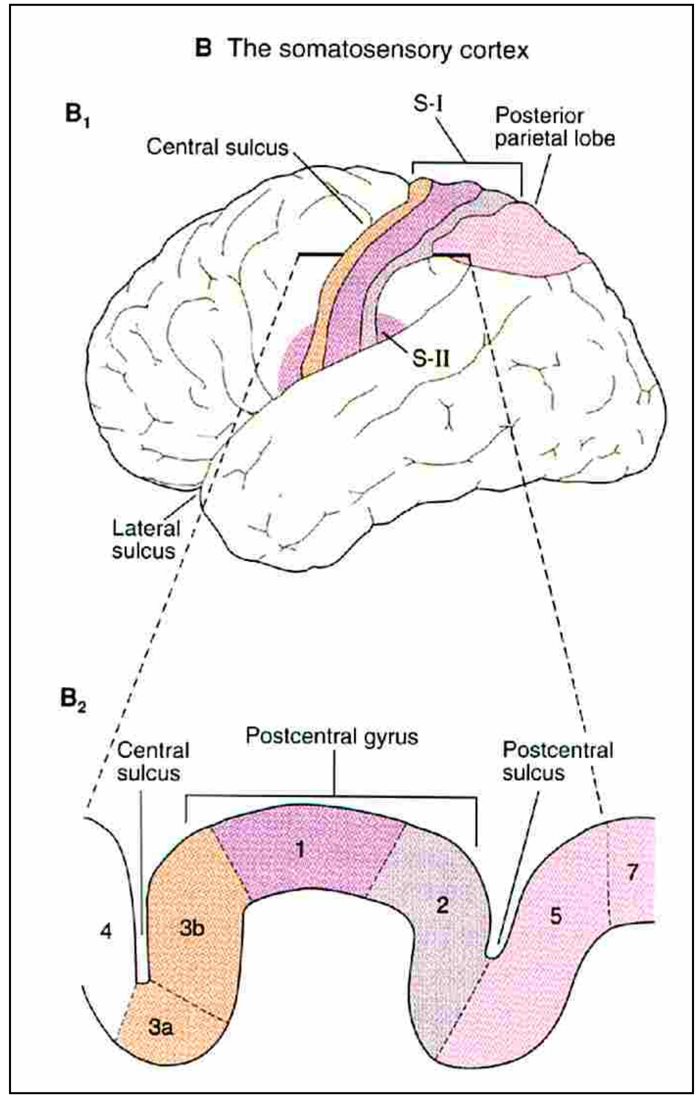


Ascending dorsal column–medial lemniscal pathway to primary sensory cortex



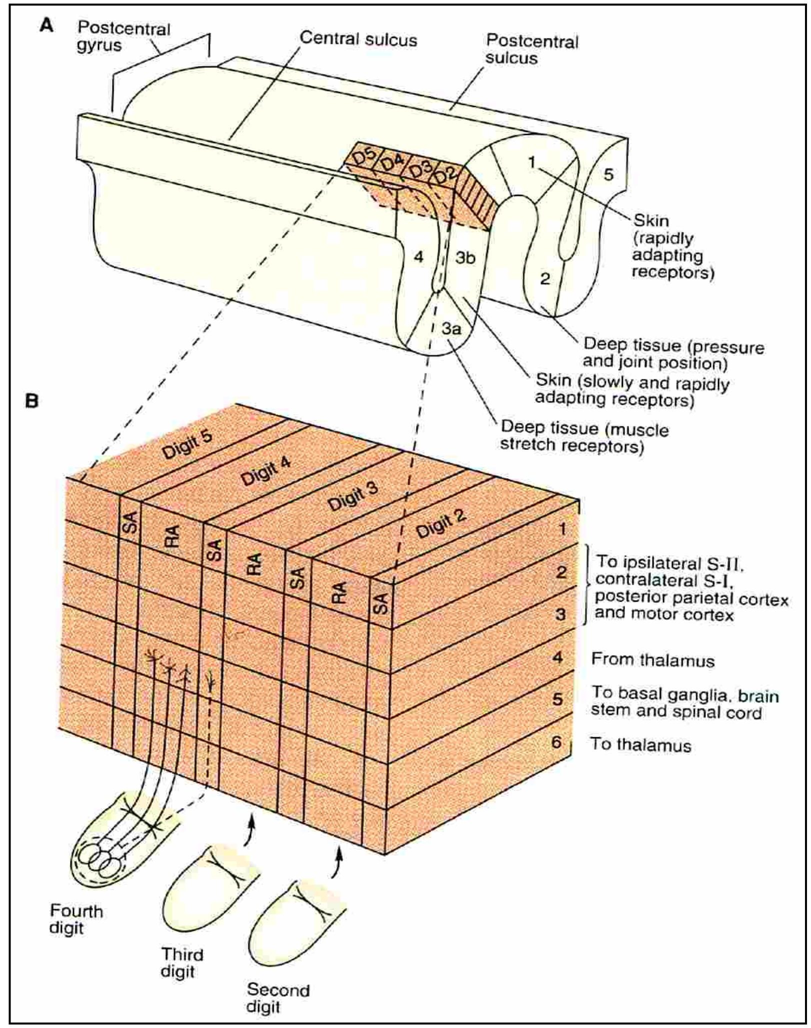
Somatosensory Cortex

- **Subdivided into distinct regions, based on anatomical connections & function**
  - **e.g. inputs from similar regions & receptors are grouped together**
  - **Columnar organization**

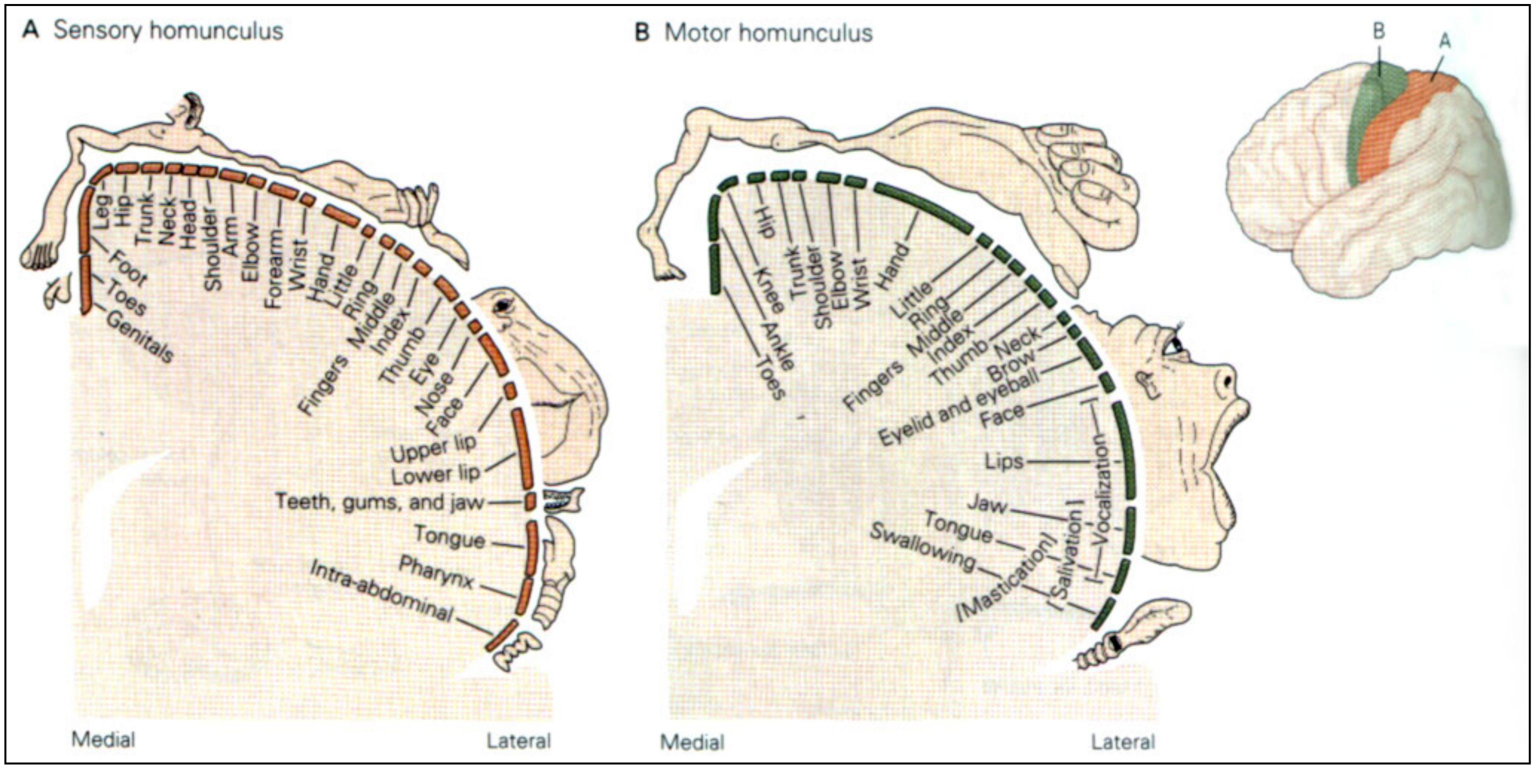


Somatosensory Cortex

- **Organized into columns based on anatomy**
  - **e.g. first, second digit**
- **Organized into subcolumns based on modality**
  - **e.g. SA & RA receptors**
- **Organized into layers based on connections in brain**
  - **e.g. thalamic inputs/outputs**



Mapping the cortex...



- **There are both sensory AND motor maps...**
  - **HOMUNCULUS (see also Kandel et al. Fig 38-1)**
- **Distortions in size representation – why?**

Sensory receptors: What's important?

Muscle Receptors

- **Muscle Spindles**
- **Golgi Tendon Organs**

Cutaneous Receptors

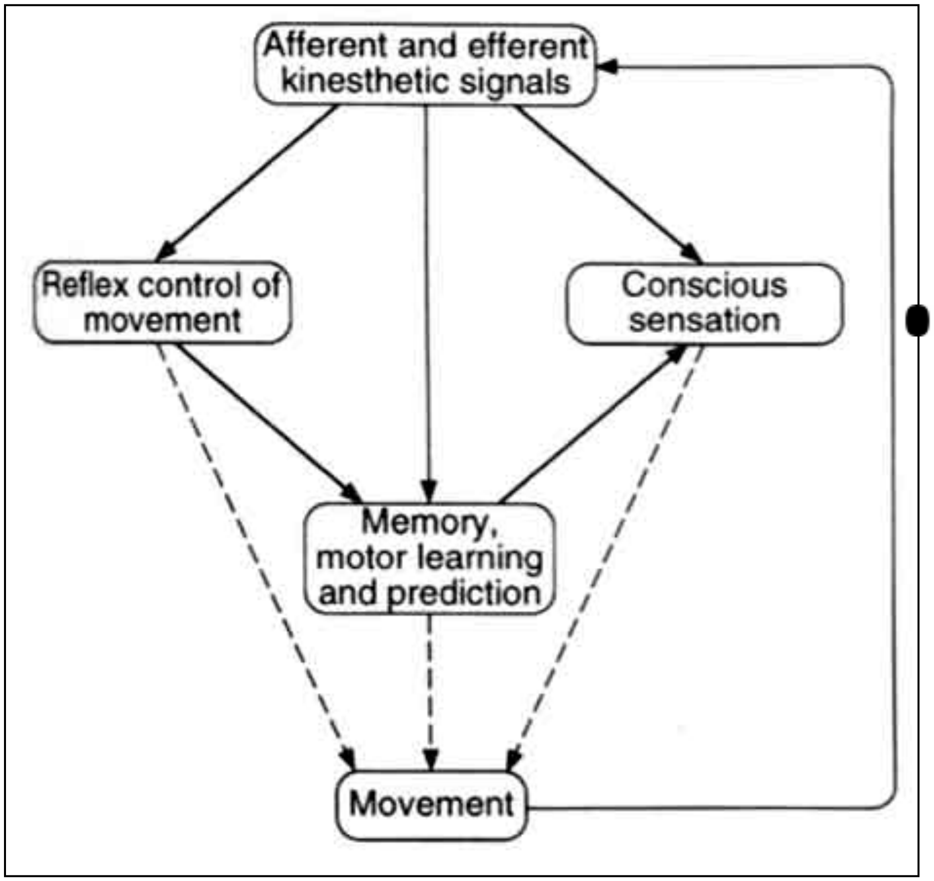
- **Meissners Corpuscles**
- **Merkel Discs**
- **Ruffini Endings**
- **Pacinian Corpuscles**

Nociceptors

Chemoreceptors

Joint Receptors

Bottom line?



- **Feedback from joint receptors, muscle spindles, GTOs, & cutaneous afferents all play roles in kinesthesia & proprioception**

- **Interaction between movement goal & feedback**