# *Physiology of Nervous System*

# Nervous vs. Endocrine System

- Similarities:
  - They both monitor stimuli and react so as to maintain homeostasis.
- Differences:
  - The NS is a rapid, fast-acting system whose effects do not always persevere.
  - The ES acts slower (via blood-borne chemical signals called Hormones) and its actions are usually much longer lasting.

# ***The nervous system***

A network of billions of nerve cells linked together in a highly organized fashion to form the rapid control center of the body

# Basic Functions of the Nervous System

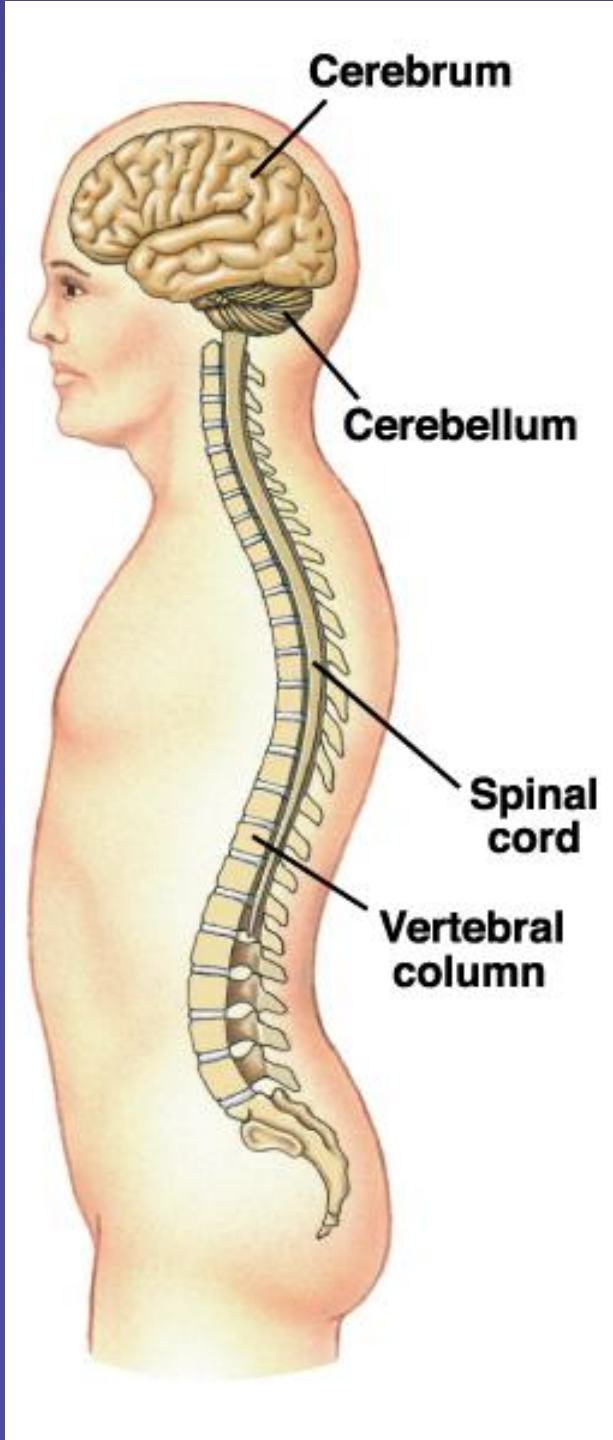
1. Sensation
   - Monitors changes/events occurring in and outside the body. Such changes are known as *stimuli* and the cells that monitor them are *receptors*.
2. Integration
   - The parallel processing and interpretation of sensory information to determine the appropriate response
3. Reaction
   - Motor output.

     - The activation of muscles or glands (typically via the release of neurotransmitters (NTs)

   - Memory

# Organization of the Nervous System

- 2 big initial divisions:
  1. Central Nervous System →
     - The brain + the spinal cord
       - The center of integration and control
  2. Peripheral Nervous System
     - The nervous system outside of the brain and spinal cord
     - Consists of:
       - 31 Spinal nerves
         - » Carry info to and from the spinal cord
       - 12 Cranial nerves
         - » Carry info to and from the brain



# Peripheral Nervous System

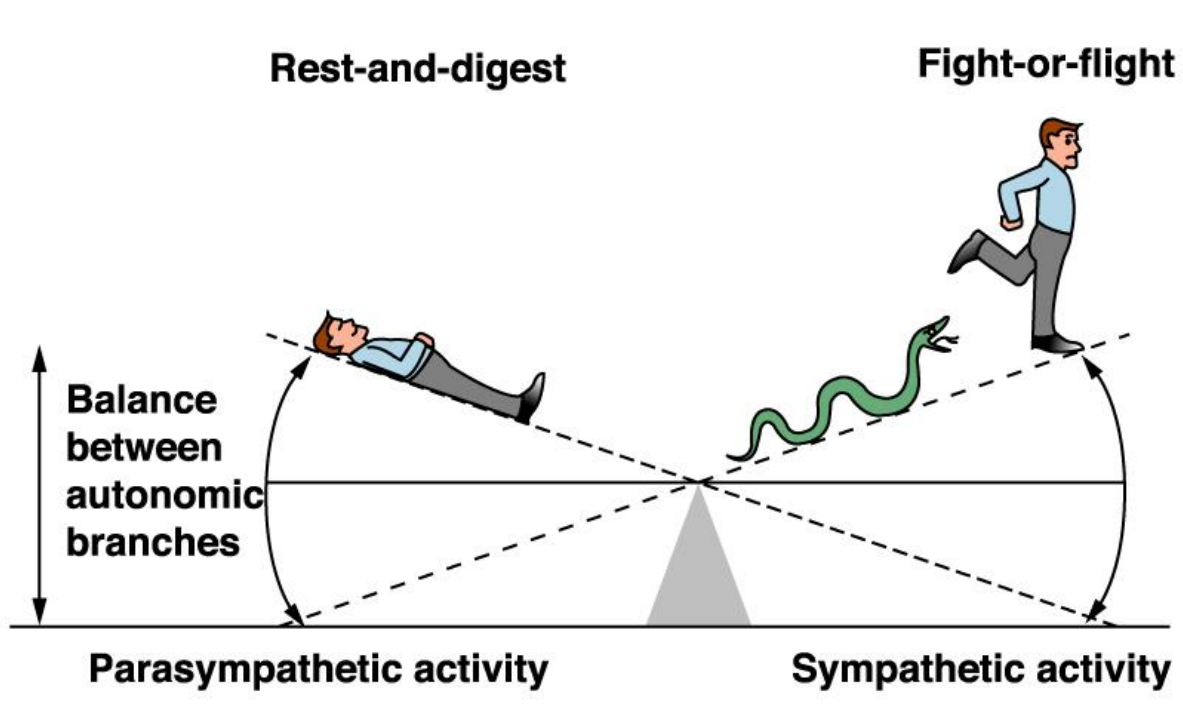
- Responsible for communication btwn the CNS and the rest of the body.
- Can be divided into:
  - Sensory Division
    - Afferent division
      - Conducts impulses from receptors to the CNS
      - Informs the CNS of the state of the body interior and exterior
      - Sensory nerve fibers can be **somatic** (from skin, skeletal muscles or joints) or **visceral** (from organs in the ventral body cavity)
  - Motor Division
    - Efferent division
      - Conducts impulses from CNS to effectors (muscles/glands)
      - Motor nerve fibers

# Motor Efferent Division

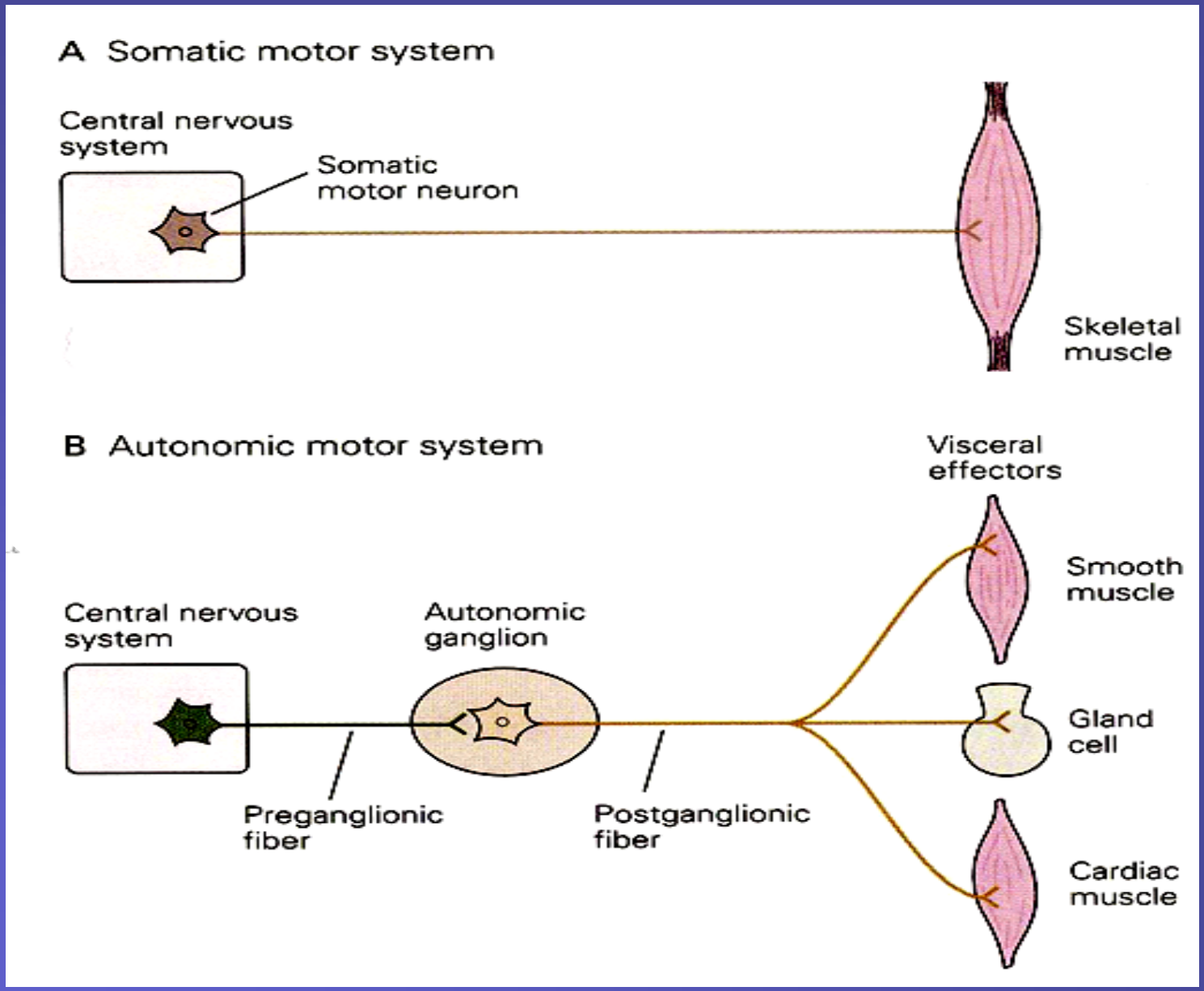
- Can be divided further:
  - Somatic nervous system
    - VOLUNTARY (generally)
    - Somatic nerve fibers that conduct impulses from the CNS to skeletal muscles
  - Autonomic nervous system
    - INVOLUNTARY (generally)
    - Conducts impulses from the CNS to smooth muscle, cardiac muscle, and glands.

# Autonomic Nervous System

- Can be divided into:
  - Sympathetic Nervous System
    - "Fight or Flight"
  - Parasympathetic Nervous System
    - "Rest and Digest"



# General organization of ANS



# Receptors on the effector organ

**Cholinergic receptors**:

***Nicotinic***: Ganglion, Skeletal muscle

***Muscarinic*** ($M_1$,$M_2$,$M_3$):

**TABLE 21.3**
**Summary of Cholinergic Receptor Types and Some of Their Effects in Parasympathetic Targets**

| *Receptor* | *Tissue* | *Response* |
|---|---|---|
| Nicotinic | Most parasympathetic targets (and all autonomic ganglion cells) | Relatively fast post-synaptic response |
| Muscarinic (M1) | Smooth muscles and glands of the gut | Smooth muscle contraction and glandular secretion (relatively slow response) |
| Muscarinic (M2) | Smooth and cardiac muscle of cardiovascular system | Smooth muscle contraction; some inotropic effect on cardiac muscle |
| Muscarinic (M3) | Smooth muscles and glands of all targets | Smooth muscle contraction, glandular secretion |

# Adrenergic receptors:

***Alpha*** (α1, α2):

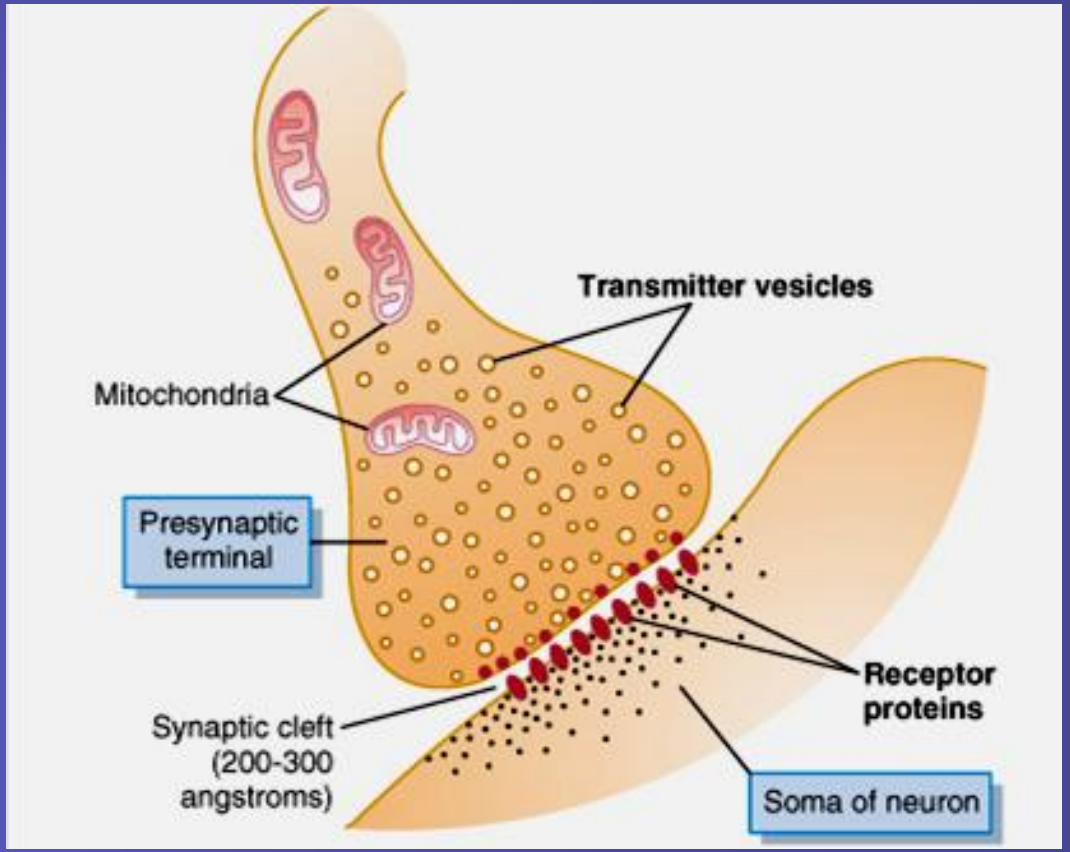
***Beta*** (β1, β2, β3):

**TABLE 21.2**
**Summary of Adrenergic Receptor Types and Some of Their Effects in Sympathetic Targets**

| *Receptor* | *Tissue* | *Response* |
|---|---|---|
| $\alpha_1$ | Smooth muscle of blood vessels, iris, ureter, hairs, uterus, bladder | Contraction of smooth muscle |
| | Smooth muscle of gut | Relaxation of smooth muscle |
| | Heart muscle | Positive inotropic effect ($\beta_1 >> \alpha_1$) |
| | Salivary gland | Secretion |
| | Adipose tissue | Glycogenolysis, gluconeogenesis |
| | Sweat glands | Secretion |
| | Kidney | $Na^+$ reabsorbed |
| $\alpha_2$ | Adipose tissue | Inhibition of lipolysis |
| | Pancreas | Inhibition of insulin release |
| | Smooth muscle of blood vessels | Contraction |
| $\beta_1$ | Heart muscle | Positive inotropic effect; positive chronotropic effect |
| | Adipose tissue | Lipolysis |
| | Kidney | Renin release |
| $\beta_2$ | Liver | Glycogenolysis, gluconeogenesis |
| | Skeletal muscle | Glycogenolysis, lactate release |
| | Smooth muscle of bronchi, uterus, gut, blood vessels | Relaxation |
| | Pancreas | Insulin secretion |
| | Salivary glands | Thickened secretions |

# Synaptic transmission

- ***Synapses***
  - ***Electrical:*** fast, in SM & heart cells
  - ***Chemical:*** by neurotransmitter



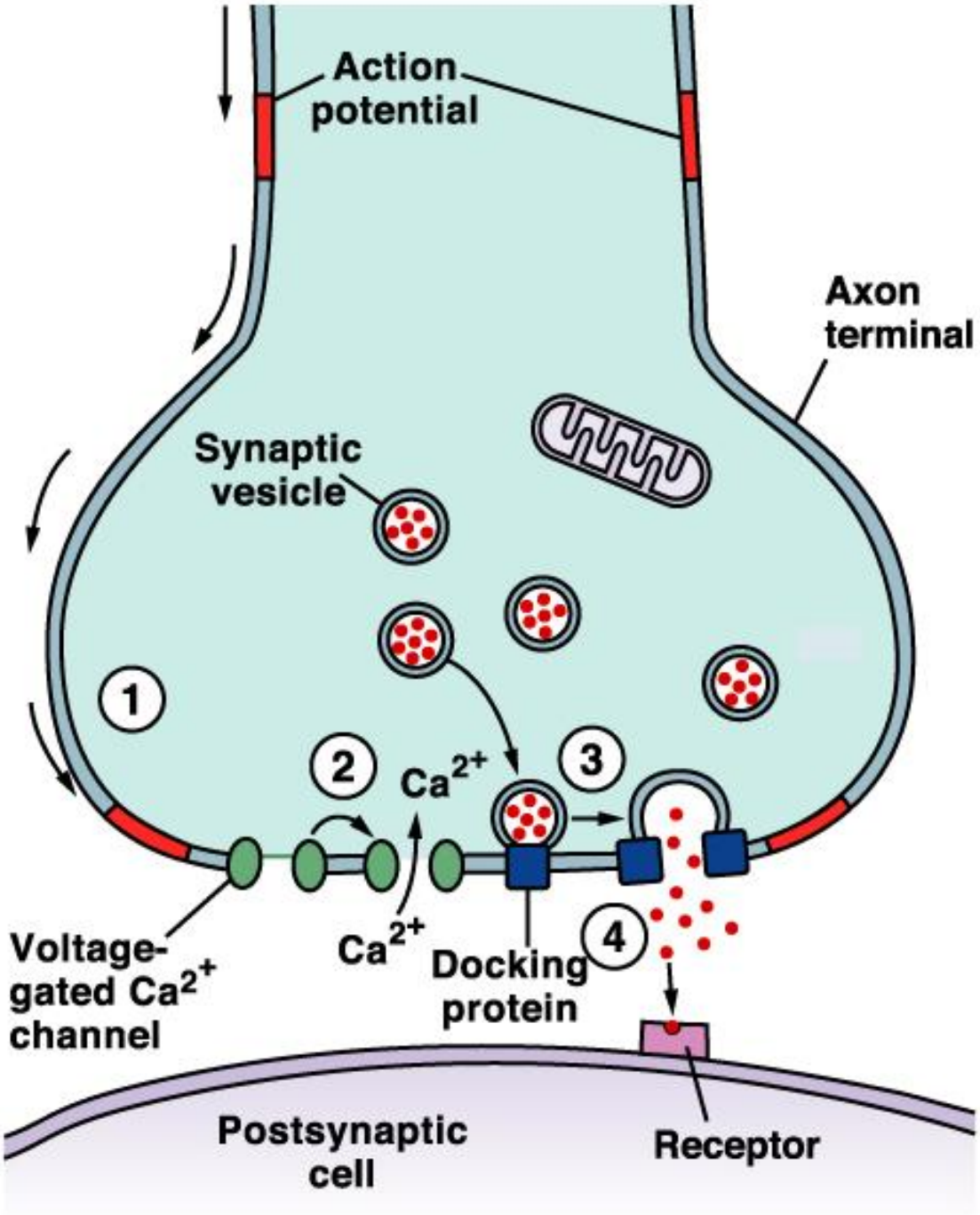
# Neurotransmitters

- **Small molecules**
  - **Biogenic amines**
    - **Ach**
    - **Dopamine**
    - **Norepinephrine**
    - **Epinephrine**
    - **5-HT**
    - **Histamine**
  - **Amino acids**
    - **Aspartate**
    - **GABA**
    - **Glutamate**
    - **Glycine**
  - **Nucleotides**
    - **Adenosine**
    - **ATP**
  - **Gaseous**
    - **Nitric oxide**

- **Neuropeptide**

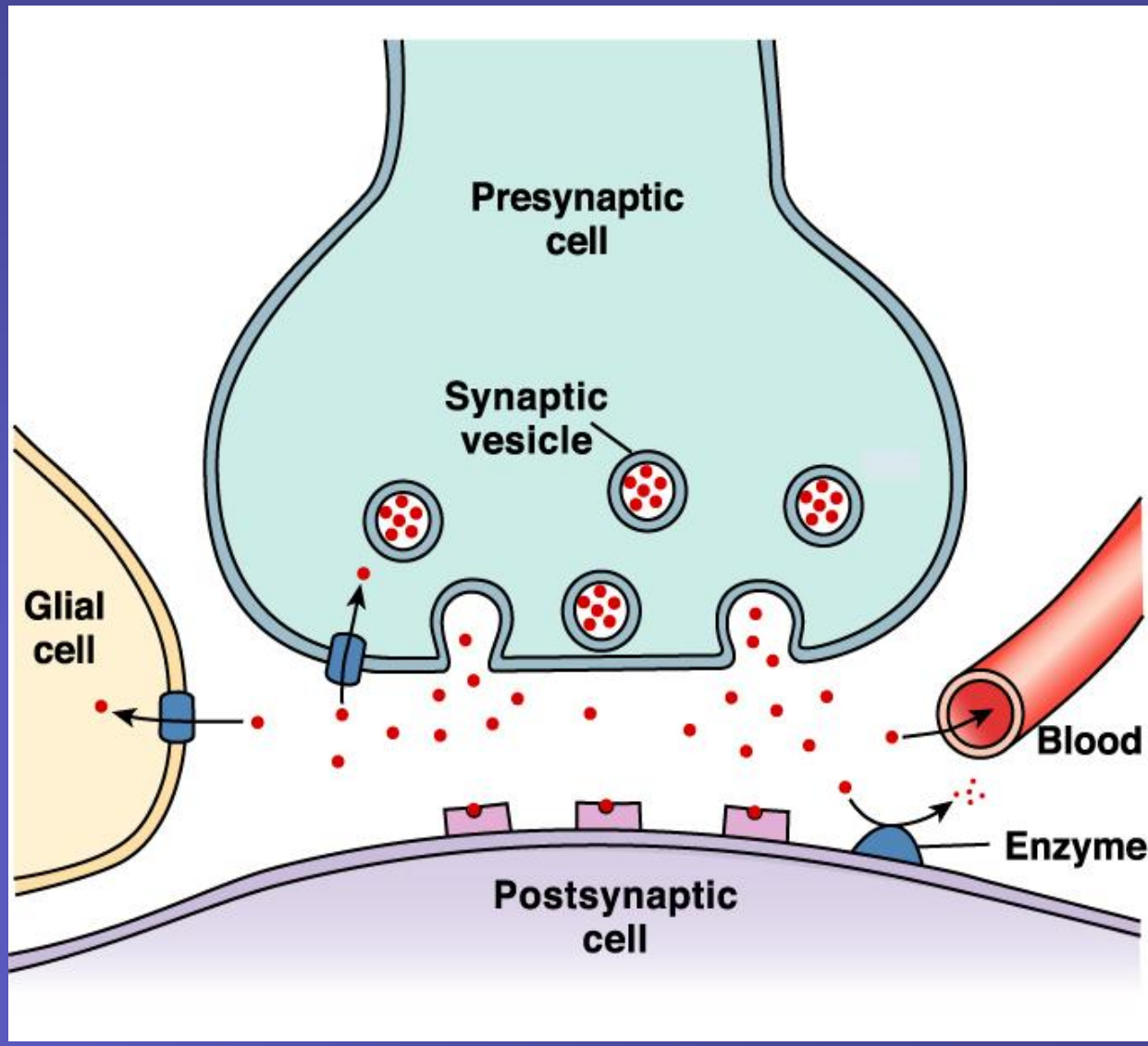
- **Neuropeptides**
  - **Opioid peptides**
    - **Enkephalin**
    - **β – endorphin**
    - **Dynorphins**
  - **Pituitary peptide**
    - **Oxytocin**
    - **Vasopressin**
    - **ACTH**
    - **TSH**
  - **Gastrointestinal peptides**
    - **CCK**
    - **Sub-P**
    - **Neurotensin**
    - **Gastrin**
    - **Somatostatin**
    - **……**

# Neurotransmitter Release



# Neurotransmitter Removal

- Why did we want to remove ACh from the neuro-muscular junction?
- NTs are removed from the synaptic cleft via:
  - **Enzymatic degradation**
  - **Diffusion**
  - **Reuptake**




SOLID

# Sensory receptors; neural circuits for processing information

Chapter46

Sensory neurons (afferent neurons) send info to neurons in the brain and spinal cord. There,interneurons integrate the information and then perhaps send commands to motor neurons (efferent neurons) which synapse with muscles or glands

**Types of sensory receptors**

- Mechanoreceptors
- Thermoreceptors
- Nociceptors
- Electromagnetic receptors (Photoreceptor)
- Chemoreceptors

# Receptors transduce specific types of energy Into an electrical signal

-Receptor potential

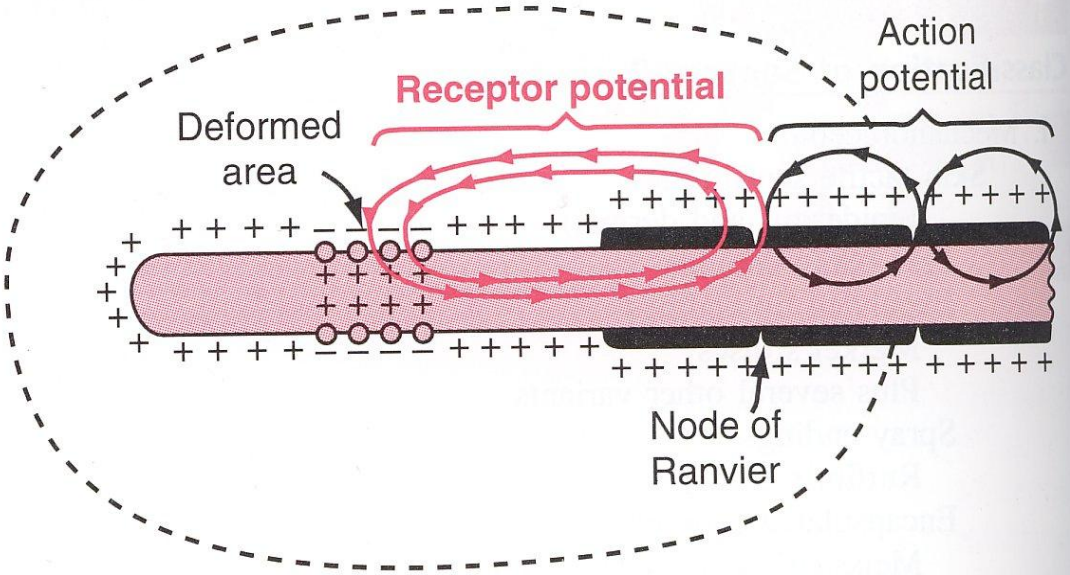
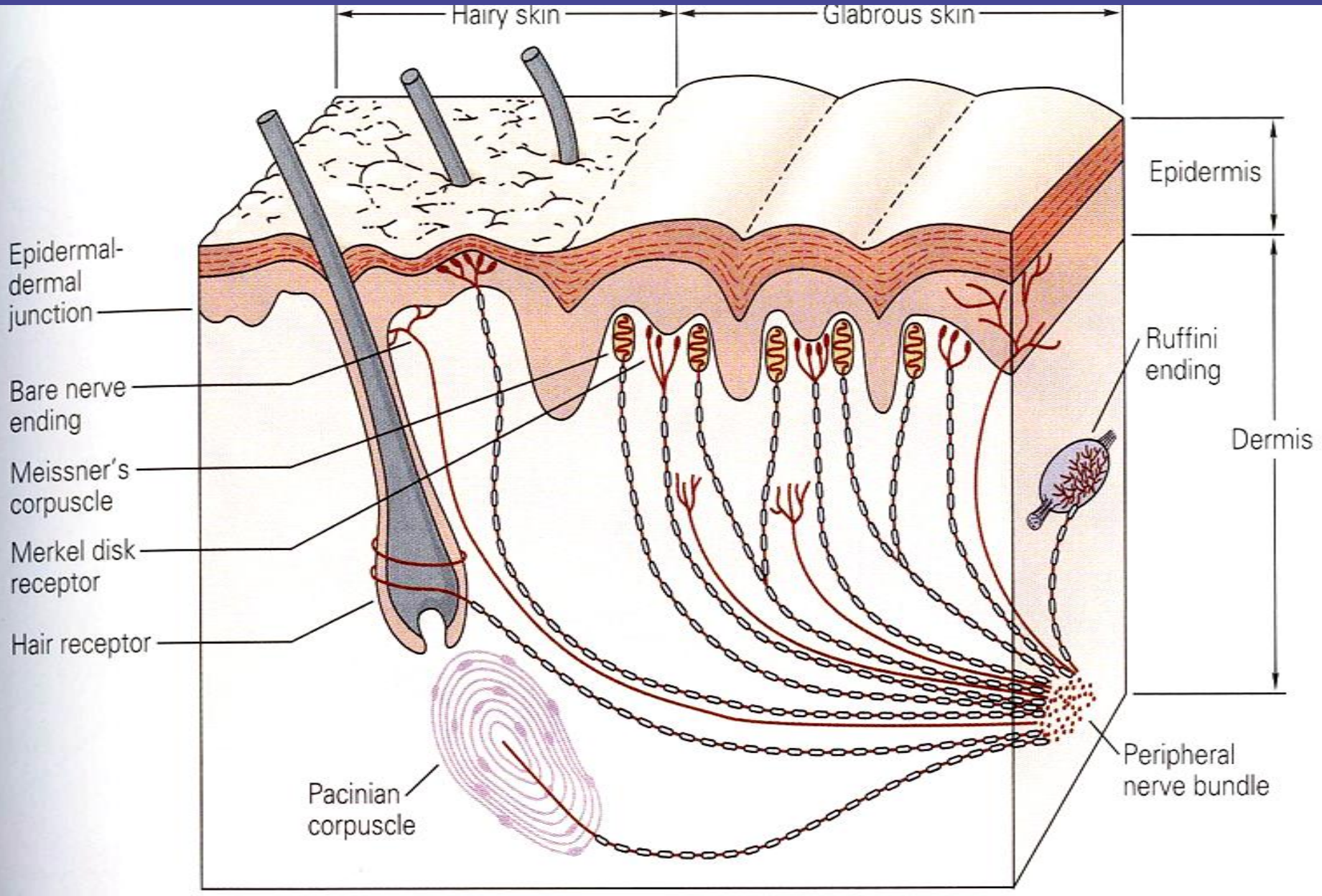



FIGURE 46–3

Excitation of a sensory nerve fiber by a receptor potential produced in a pacinian corpuscle. (Modified from Loëwenstein WR: Excitation and inactivation in a receptor membrane. Ann N Y Acad Sci 94:510, 1961.)


Hairy skin
Glabrous skin
Epidermis
Dermis
Epidermal-dermal junction
Bare nerve ending
Meissner's corpuscle
Merkel disk receptor
Hair receptor
Ruffini ending
Pacinian corpuscle
Peripheral nerve bundle

-Relation of the receptor potential to action potential

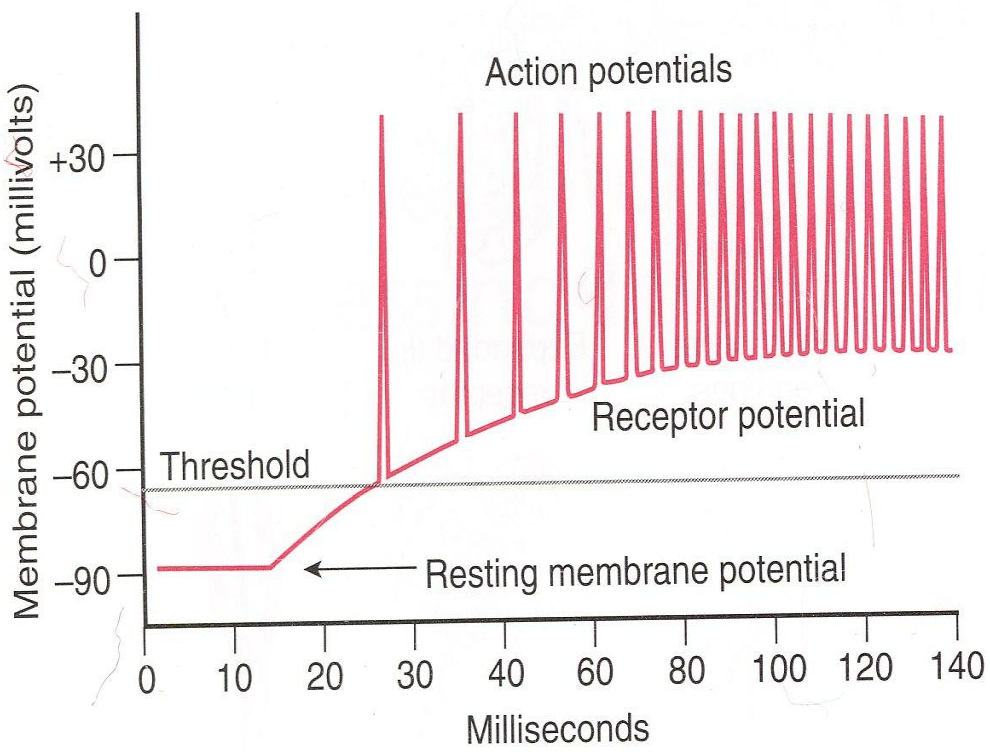


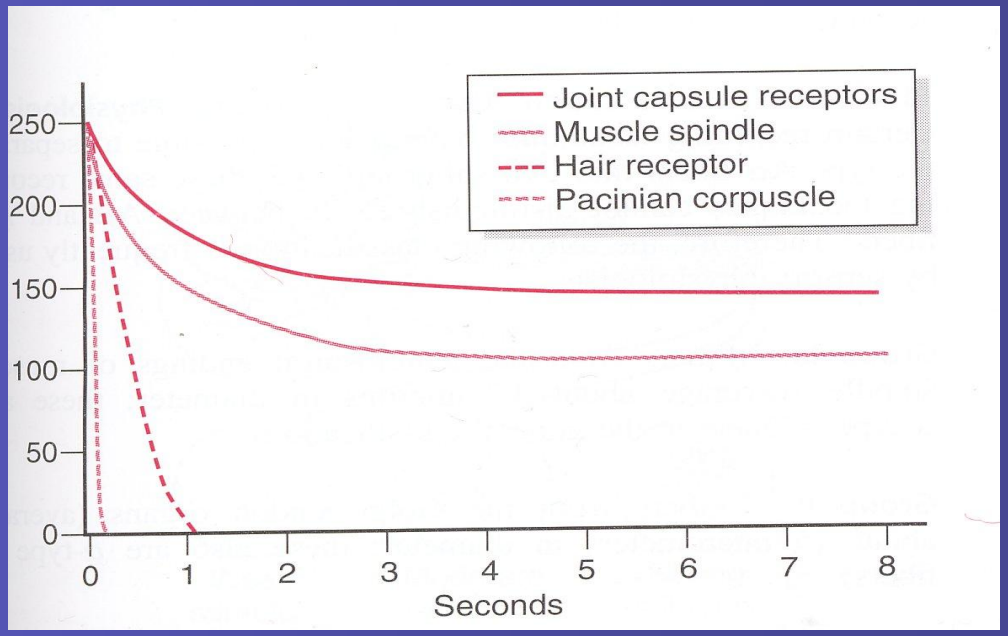

FIGURE 46–2

Typical relation between receptor potential and action potentials when the receptor potential rises above the threshold level.

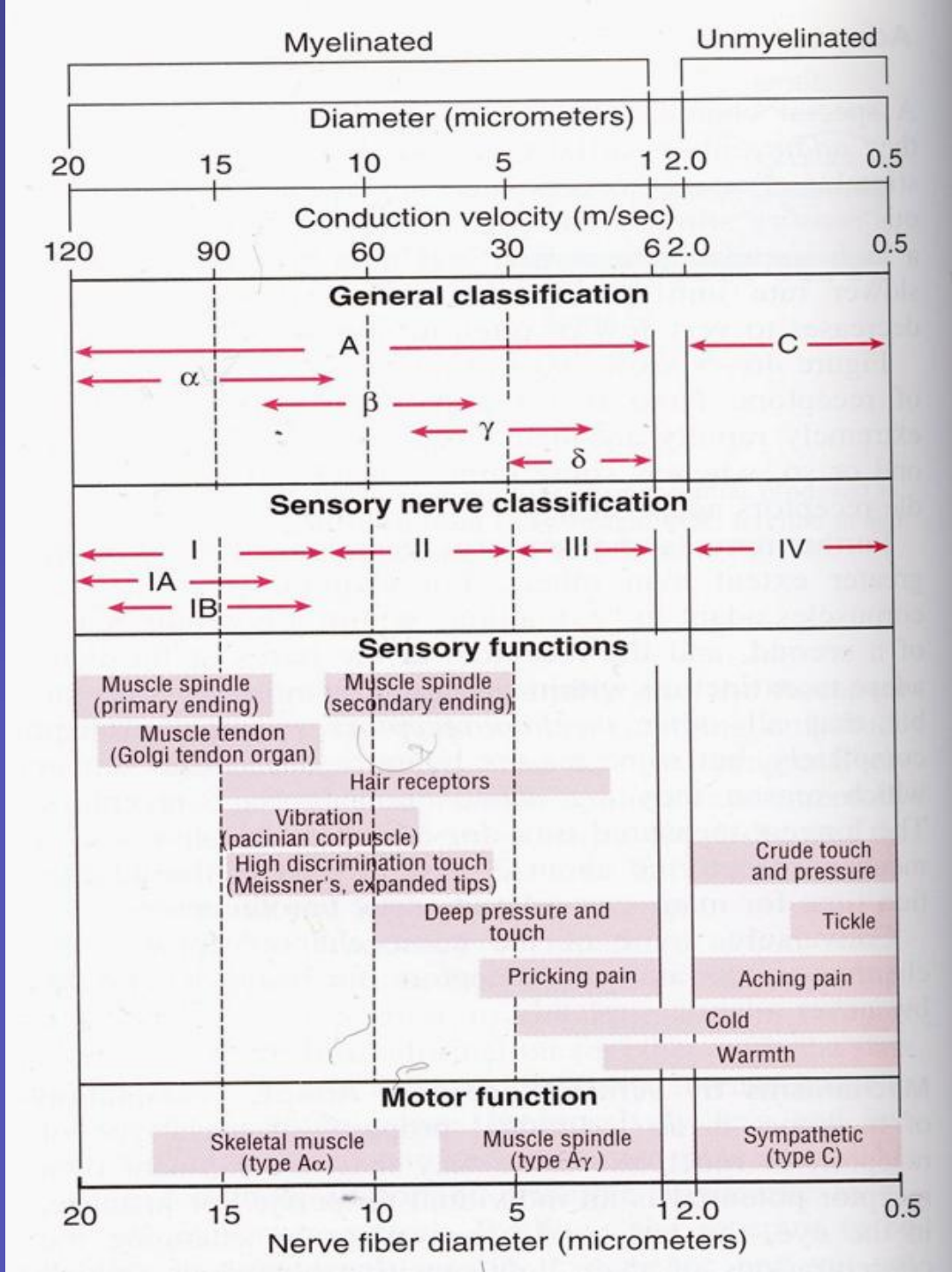
# Adaptation of receptor -Duration of sensation

Mechanism of adaptation: Readjustment of receptor structure,
Accommodation of nerve fiber

-Slowly adapting (tonic) receptors: BR, ChR, …
-Rapidly adapting (phasic) receptors



# Physiological classification of nerve fibers



# Different types of neural circuit

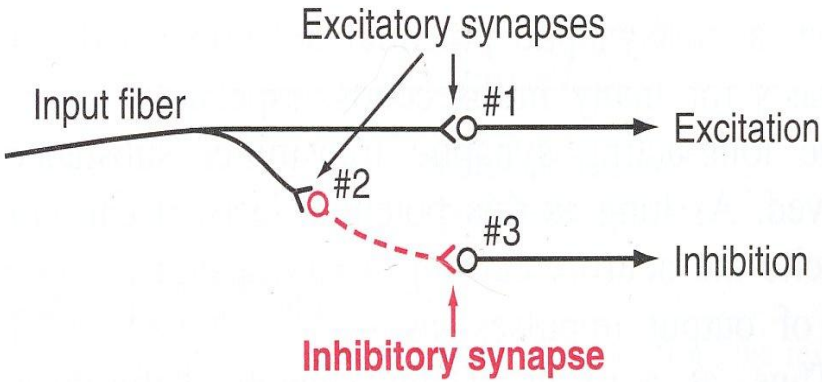



FIGURE 46–13

Inhibitory circuit. Neuron 2 is an inhibitory neuron.

# Somatic Sensation I

## General Organization

## Tactile & Position sense

# Somatic senses

- Mechanoreceptive : tactile and position
- Thermoreceptive:
- pain

# Sensory pathways transmit somatic signals into the CNS

- Dorsal column – medial lemniscal system
  - ✓ Precise touch
  - ✓ Position sense
  - ✓ Pressure sense
  - ✓ Phasic sensation; vibration
- Anterolateral system
  - ✓ Pain
  - ✓ Thermal sensation
  - ✓ Crud touch
  - ✓ Tickle & itch sensation
  - ✓ Sexual sensation

# Dorsal column – medial lemniscal system

Anatomy

Pathway: (Trigeminal sens. N)

VPL & VPM. N

Spatial orientation of fibers

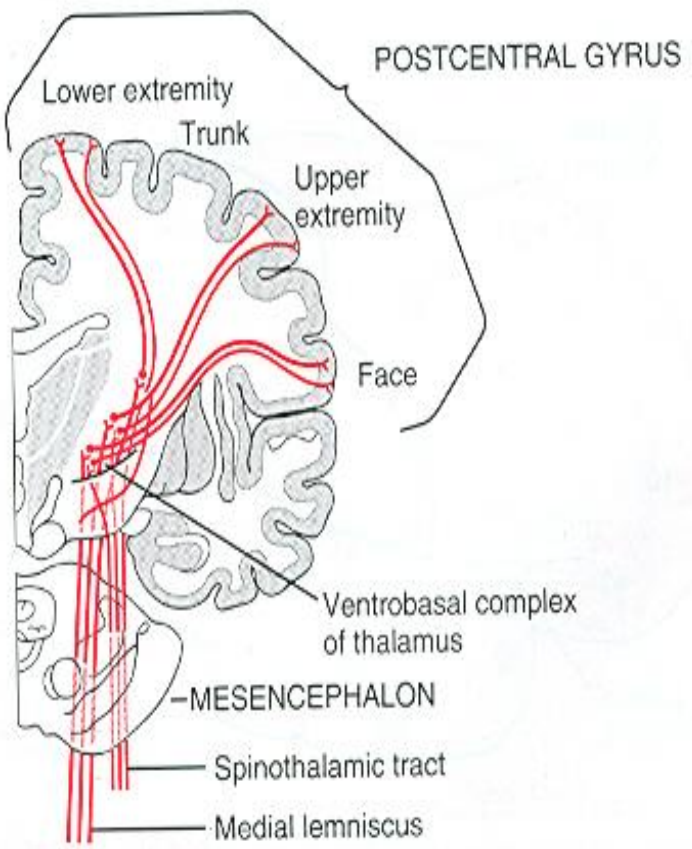



FIGURE 47–4

Projection of the dorsal column–medial lemniscal system through the thalamus to the somatosensory cortex. (Modified from Brodal A: Neurological Anatomy in Relation to Clinical Medicine. New York: Oxford University Press, 1969, by permission of Oxford University Press.)

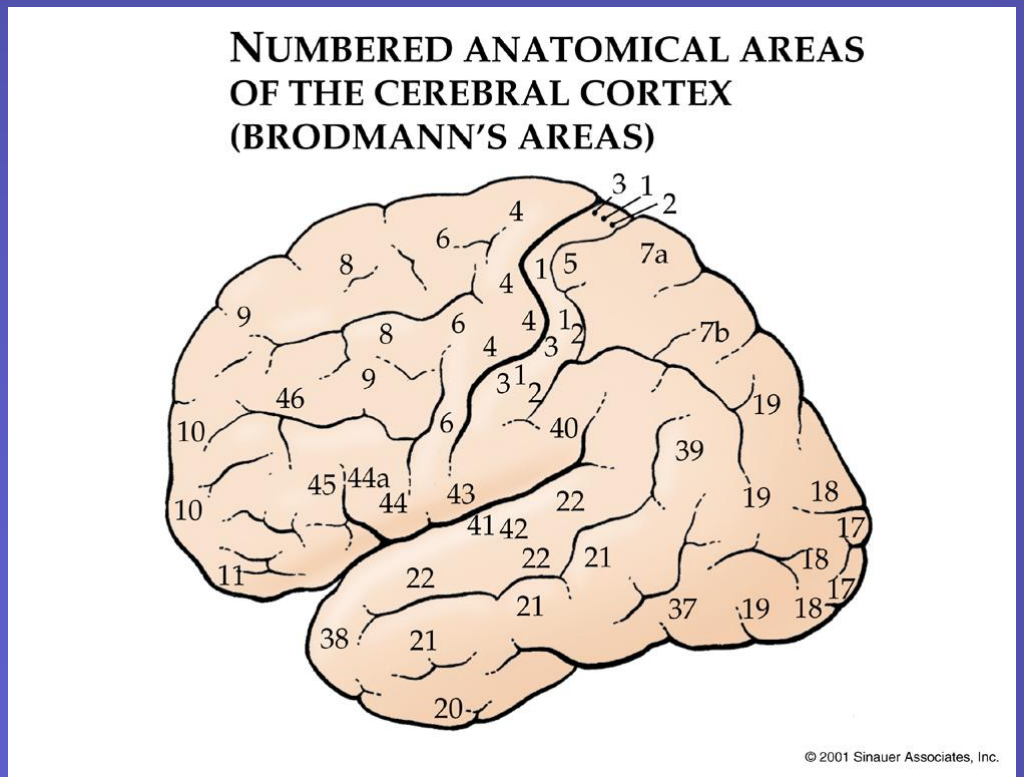
# Somatosensory cortex *

Somatosensory cortex I & II

Spatial orientation of signals from different part of body in somatosensory area I

Function of somatosensory area I

Cortical neurons are defined by their RF & modality (RF changed by experience)



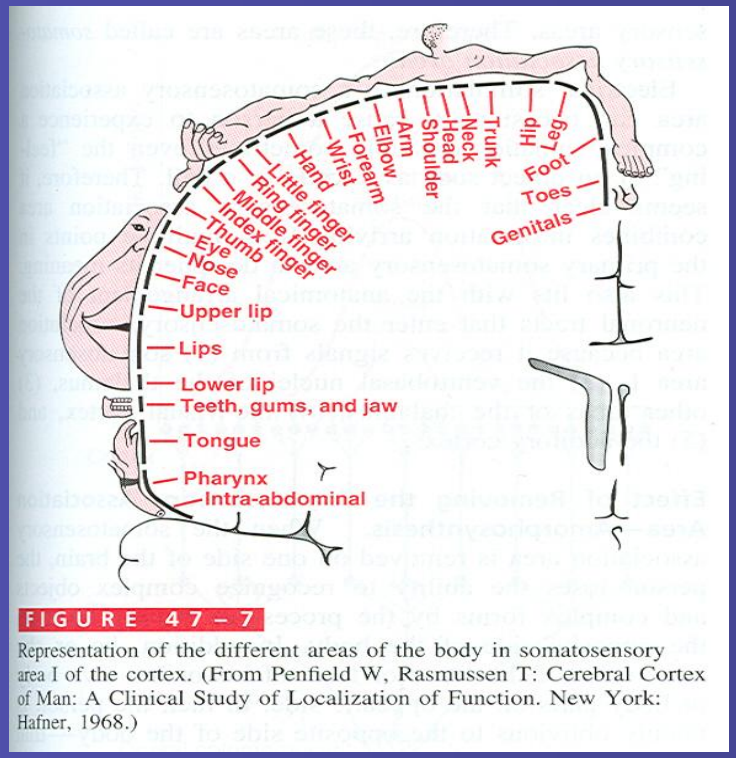




FIGURE 47–7

Representation of the different areas of the body in somatosensory area I of the cortex. (From Penfield W, Rasmussen T: Cerebral Cortex of Man: A Clinical Study of Localization of Function. New York: Hafner, 1968.)

# Layer of Somatosensory cortex

Layer I : molecular layer

Layer II : ext granular cell layer

Layer III : ext pyramidal cell layer

Layer IV : int granular cell layer

Layer V : int pyramidal cell layer

Layer VI : polymorphic layer

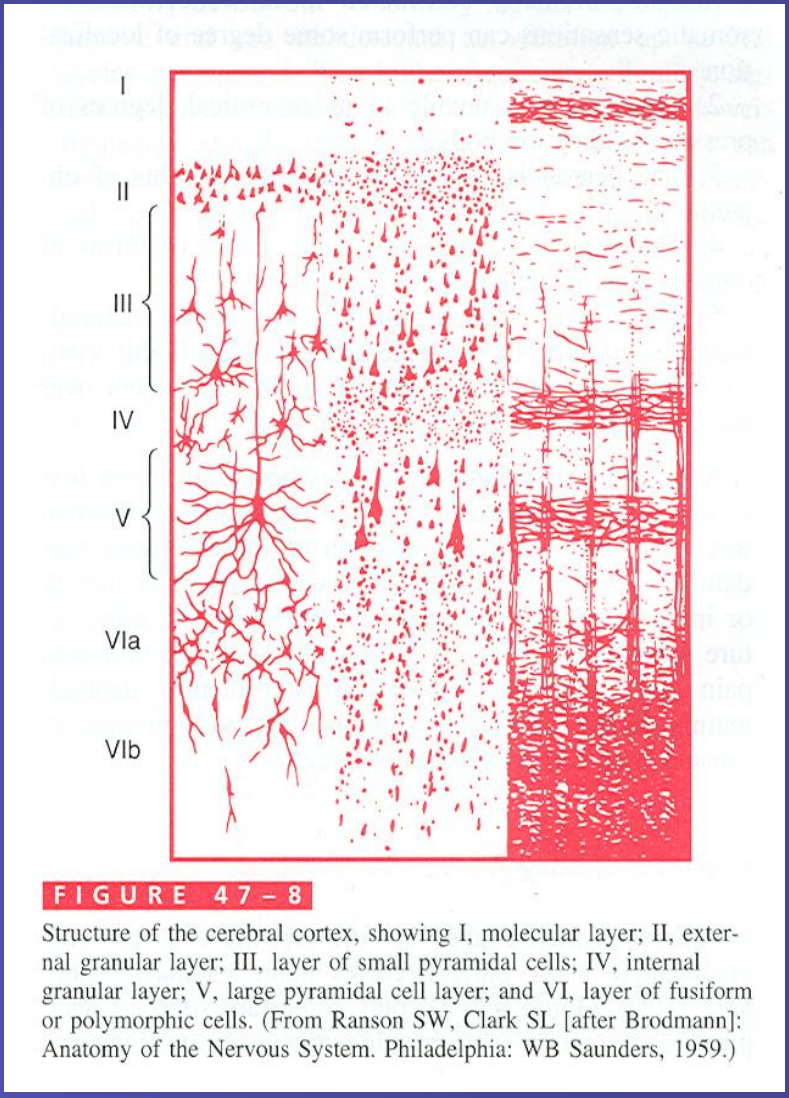



FIGURE 47–8

Structure of the cerebral cortex, showing I, molecular layer; II, external granular layer; III, layer of small pyramidal cells; IV, internal granular layer; V, large pyramidal cell layer; and VI, layer of fusiform or polymorphic cells. (From Ranson SW, Clark SL [after Brodmann]: Anatomy of the Nervous System. Philadelphia: WB Saunders, 1959.)

## Somatosensory association area (5&7)

Integrate tactile and proprioceptive information with visual properties of objects touched

Removal of Somatosensory association area

- Amorphosynthesis

❖ Neuron in higher cortical area have complex feature-detecting properties;

direction of movement, specific shape of object,

❖Cortical representation can be modified; lessen from syndactylic hand

✓Two-point discrimination

✓Surround inhibition:

Inhibitory networks sharpen spatial resolution by restricting the spread of excitation (dorsal column n, VPL, cortex)

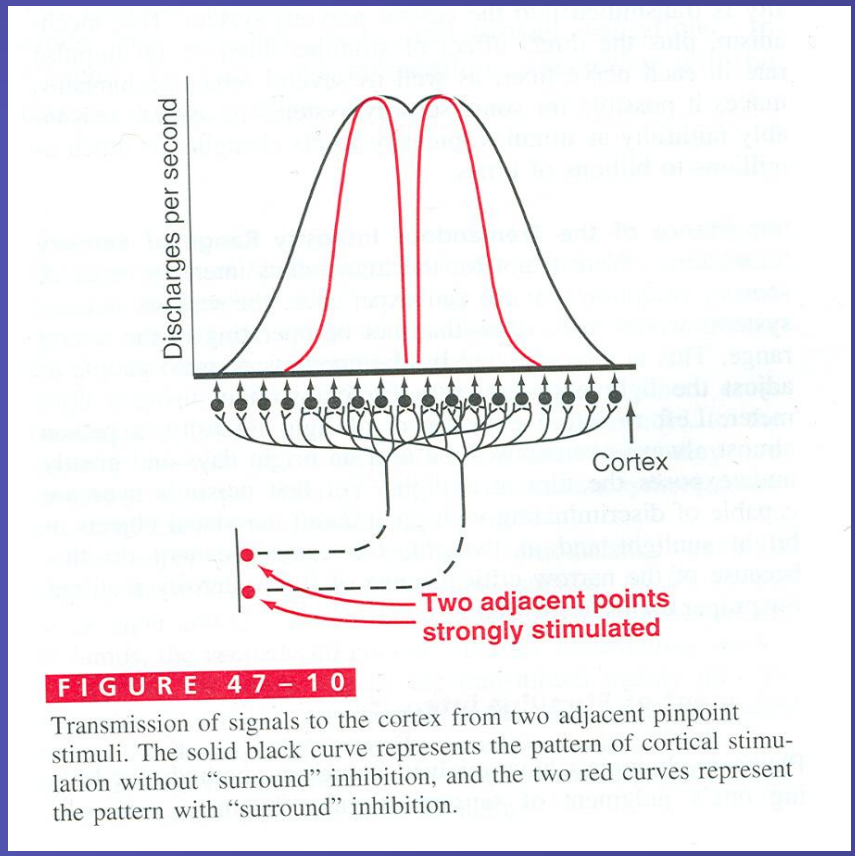



FIGURE 47–10

Transmission of signals to the cortex from two adjacent pinpoint stimuli. The solid black curve represents the pattern of cortical stimulation without "surround" inhibition, and the two red curves represent the pattern with "surround" inhibition.

**Anterolateral system:** Transmits less critical sensory signals

✓Anatomy

✓Characteristics of transmission in the anterolateral system

less velocity, poor spatial localization, less accurate gradation

Pain, Temp, tickle, itch & sexual sensation

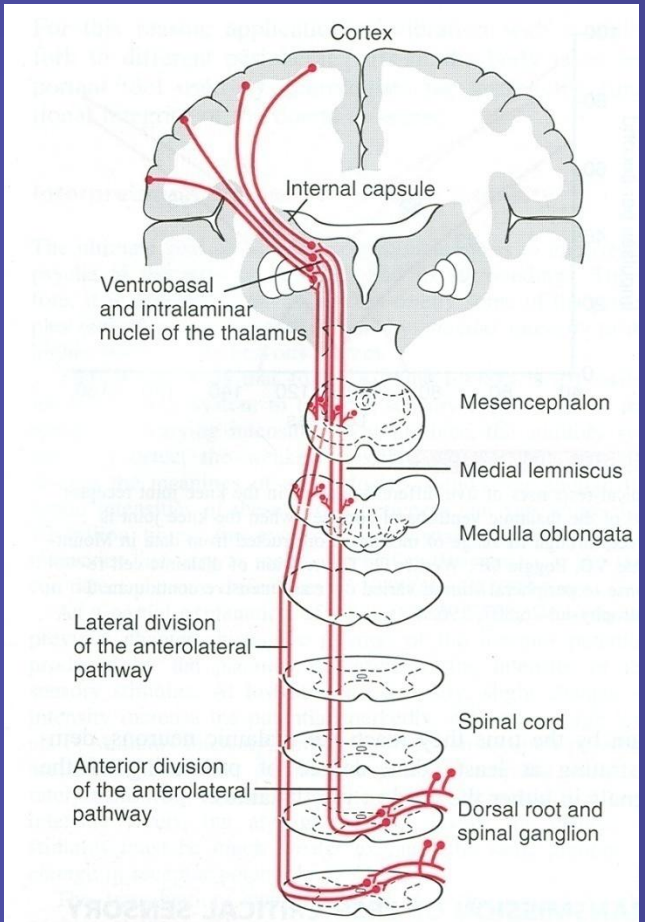



FIGURE 47–13

Anterior and lateral divisions of the anterolateral pathway.

- Function of thalamus in somatic sensation

- Cortical control of sensory sensitivity : Corticofugal signals

  ↓ lateral spread of signal… ↑ in sharpness

  keep normal range of sensory system sensitivity

- Segmental field of sensation: Dermatomes

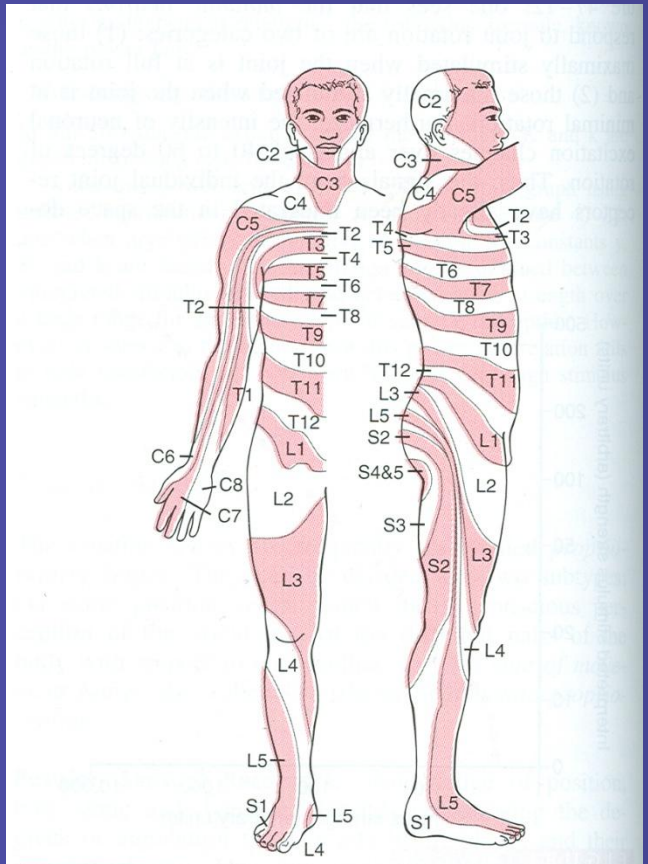
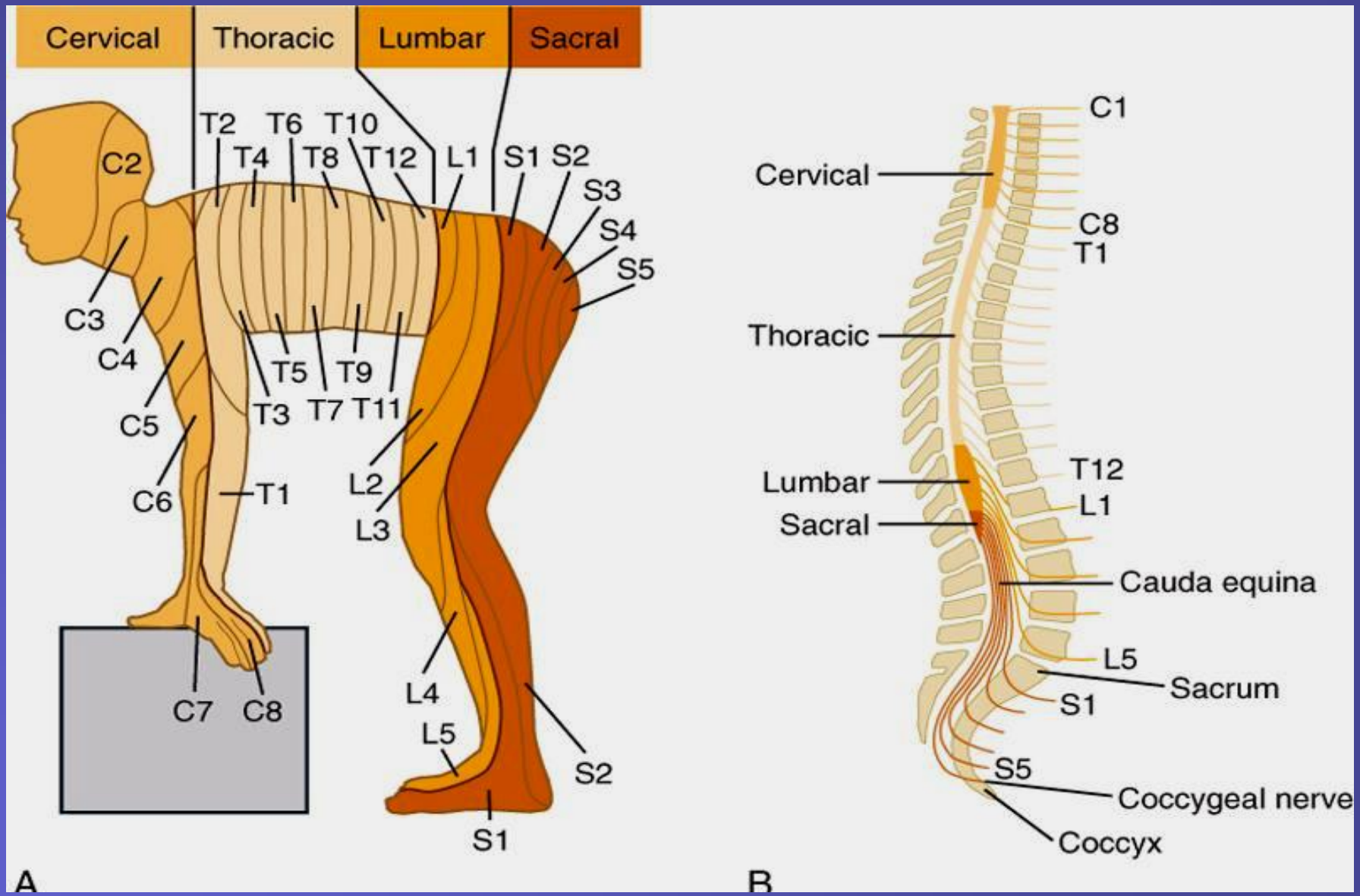



FIGURE 47–14

Dermatomes. (Modified from Grinker RR, Sahs AL: Neurology. 6th ed. Springfield, IL: Charles C Thomas, 1966. Courtesy of Charles C Thomas, Publisher, Ltd., Springfield, Illinois.)

# **Dermatomes:** Segmental field of sensation



# Somatic sensation II pain, headache , and thermal sensation

Chapter 48

# Perception of pain

- **Purpose of pain**

- **Types of pain :**

  **- Fast pain ( acute)**
  **- Slow pain (chronic)**

# Pain receptor and their stimulation

- Nociceptors are free nerve ending

- Three Major class of nocicepors:

  Thermal, Mechanical and Chemical

- Nociceptors are nonadapting

-Importance of chemical pain stimuli during tissue damage

-Tissue ischemia and muscle spasm cause pain

- Peripheral pain fibers (fast & slow fiber)

  - Aδ ( 6 - 30 m/s)
  - C ( 0.5 - 2 m/s)

# Two pathway transmit pain signals into the CNS

- Neospinothalamic tract for fast pain
  - Terminate in Brain Stem and Thalamus
  - Localize fast pain in the body
  - Use Glutamate as neurotransmitter

- Paleospinothalamic tract for slow pain
  - Terminate in Brain Stem and Thalamus
  - Source of pain cannot localized
  - Use Substance-P as neurotransmitter

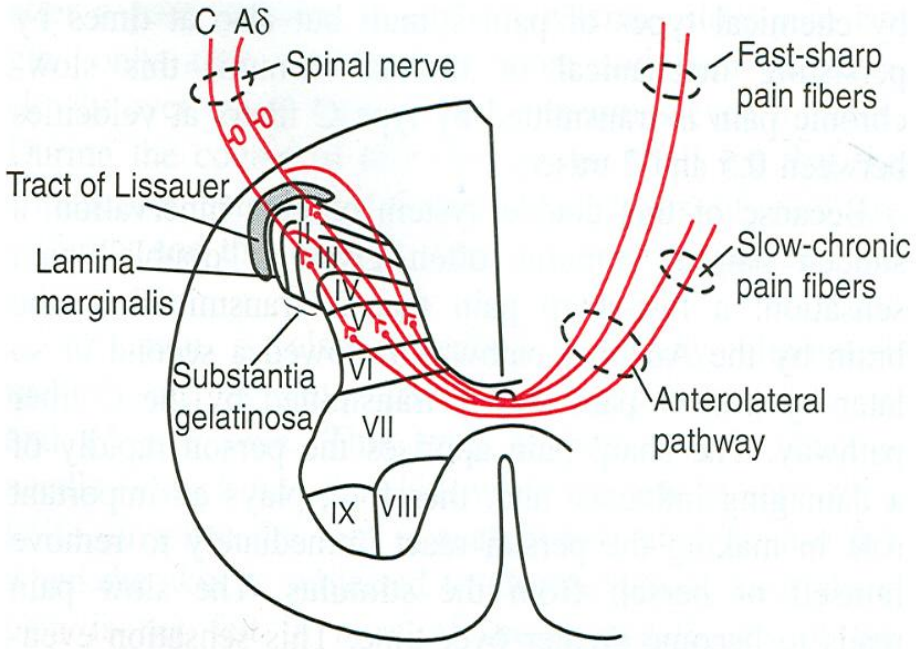



**FIGURE 48–2**

Transmission of both fast-sharp and slow-chronic pain signals into and through the spinal cord on their way to the brain.

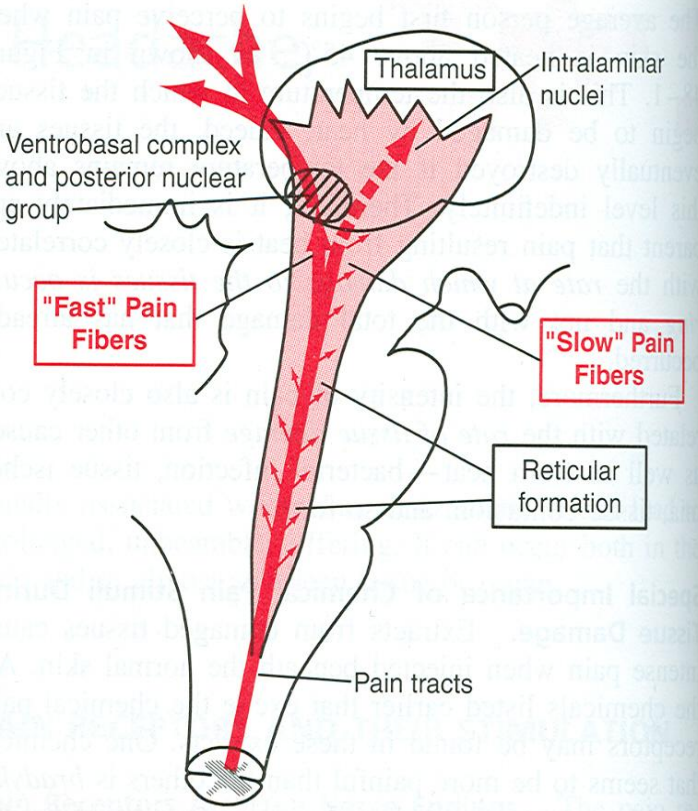



**FIGURE 48–3**

Transmission of pain signals into the brain stem, thalamus, and cerebral cortex by way of the fast pricking pain pathway and the slow burning pain pathway.

- Role of Reticular formation, Thalamus and Cerebral cortex in appreciation of pain

-Pain signals have strong arousal effect

-Surgical interruption of pain pathway

# Pain suppression (Analgesia) system in the brain and spinal cord

- The brain opiate system

- Direct stimulation of the brain → Analgesia

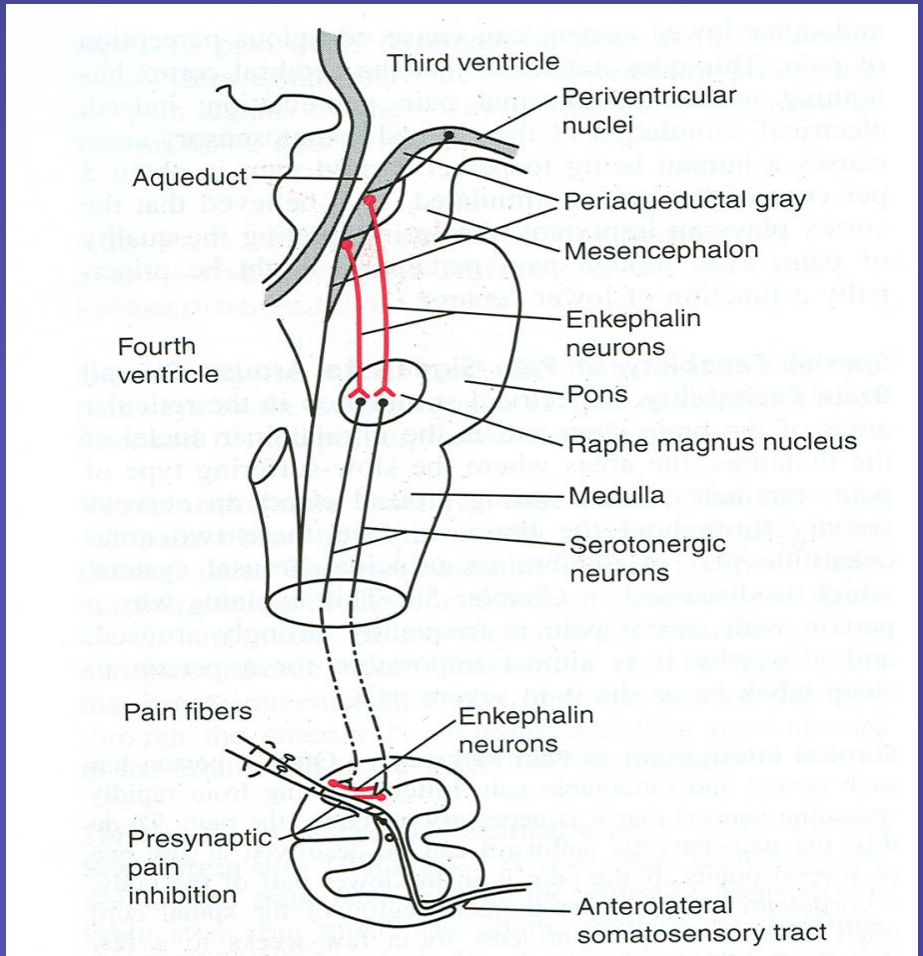
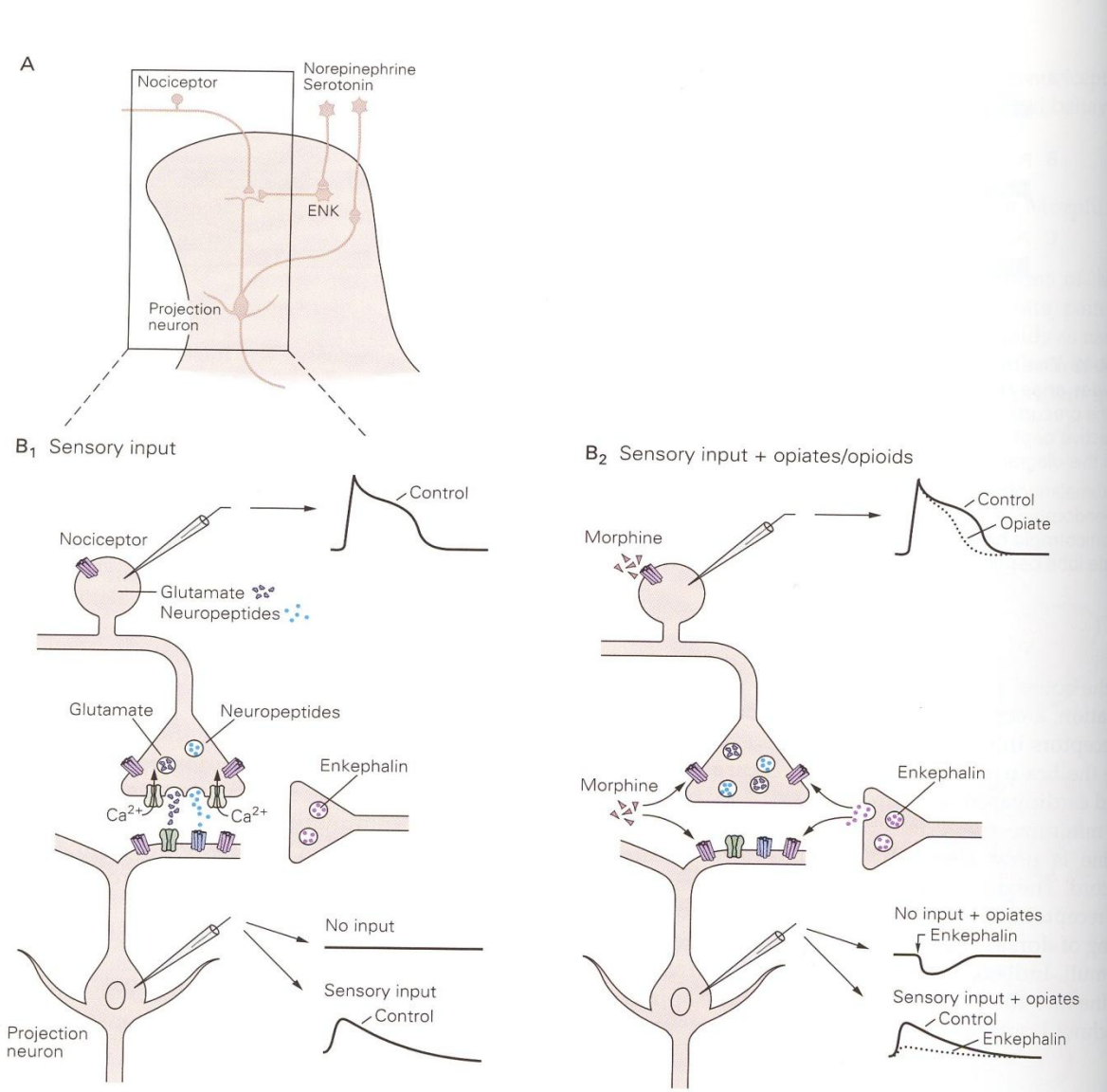



**FIGURE 48–4**

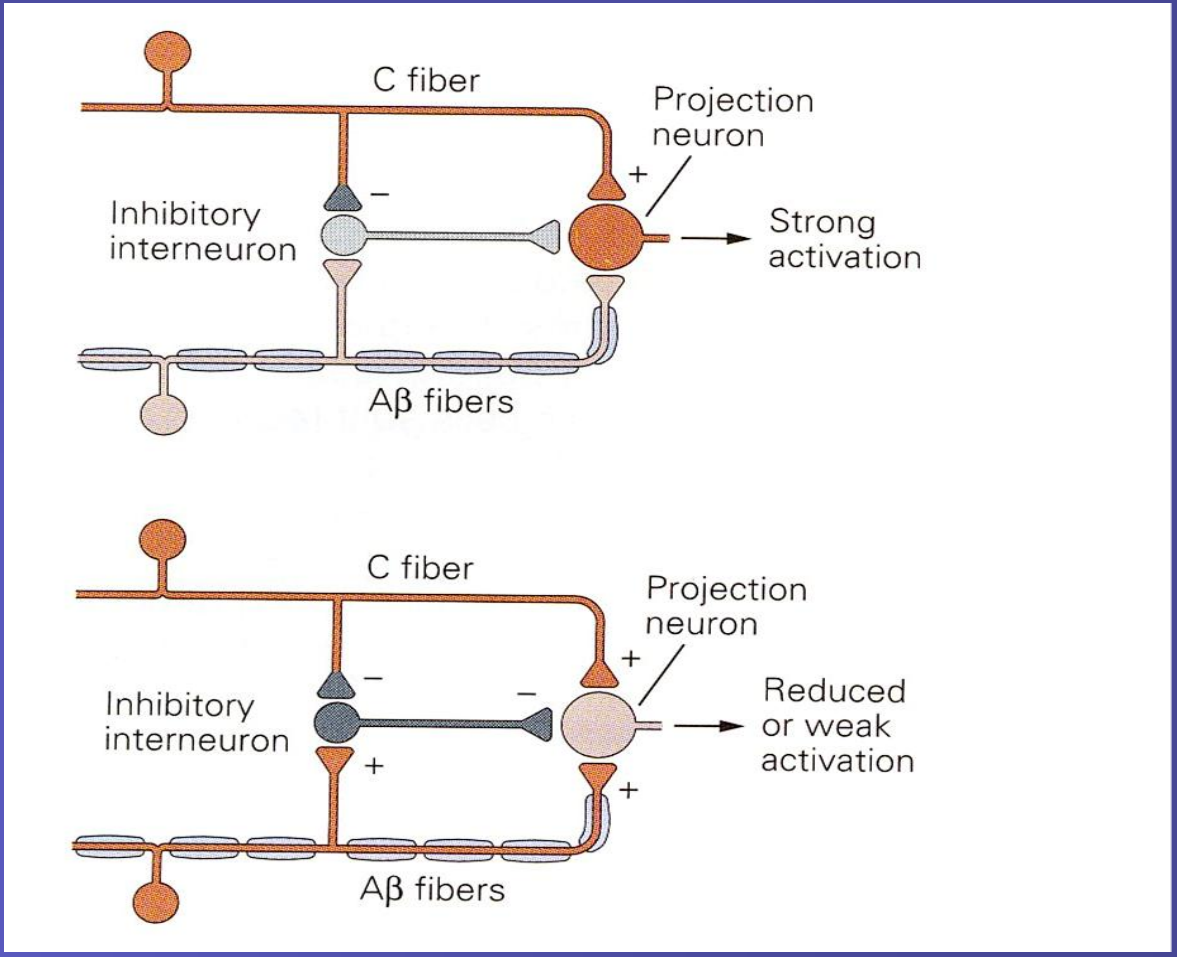
Analgesia system of the brain and spinal cord, showing inhibition of incoming pain signals at the cord level and the presence of *enkephalin-secreting neurons* (the red-colored neurons) that suppress pain signals in both the cord and the brain stem.

# The brain opiate system

- Opioide receptors:
  - μ, δ, κ



# -The gate control theory



# Referred pain

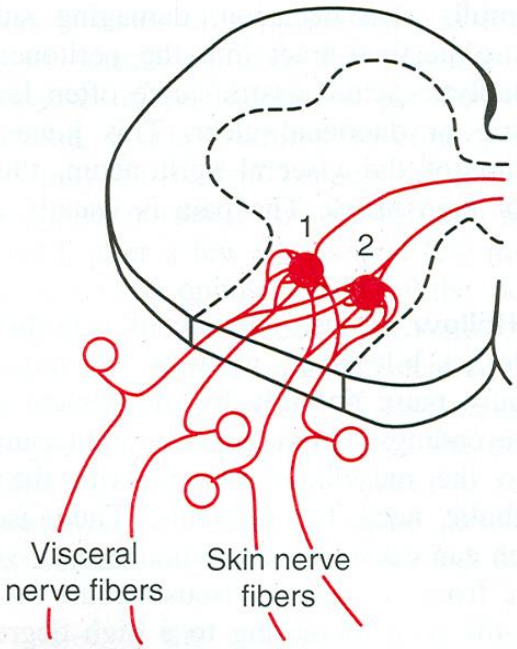



FIGURE 48–5

Mechanism of referred pain and referred hyperalgesia.

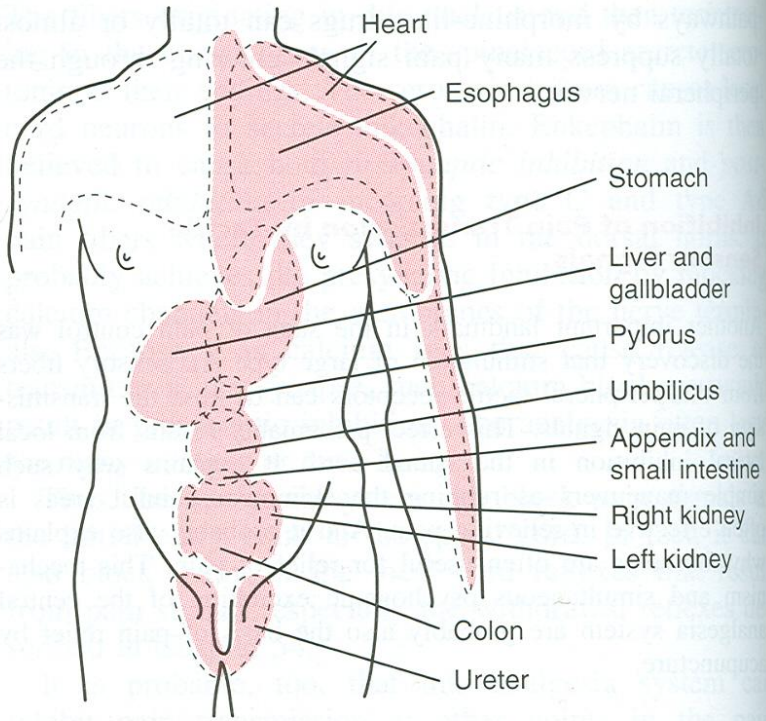



FIGURE 48–6

Surface areas of referred pain from different visceral organs.

# Visceral pain

Causes:
- Ischemic
- Spasm
- Chemical stimuli
- Over distention

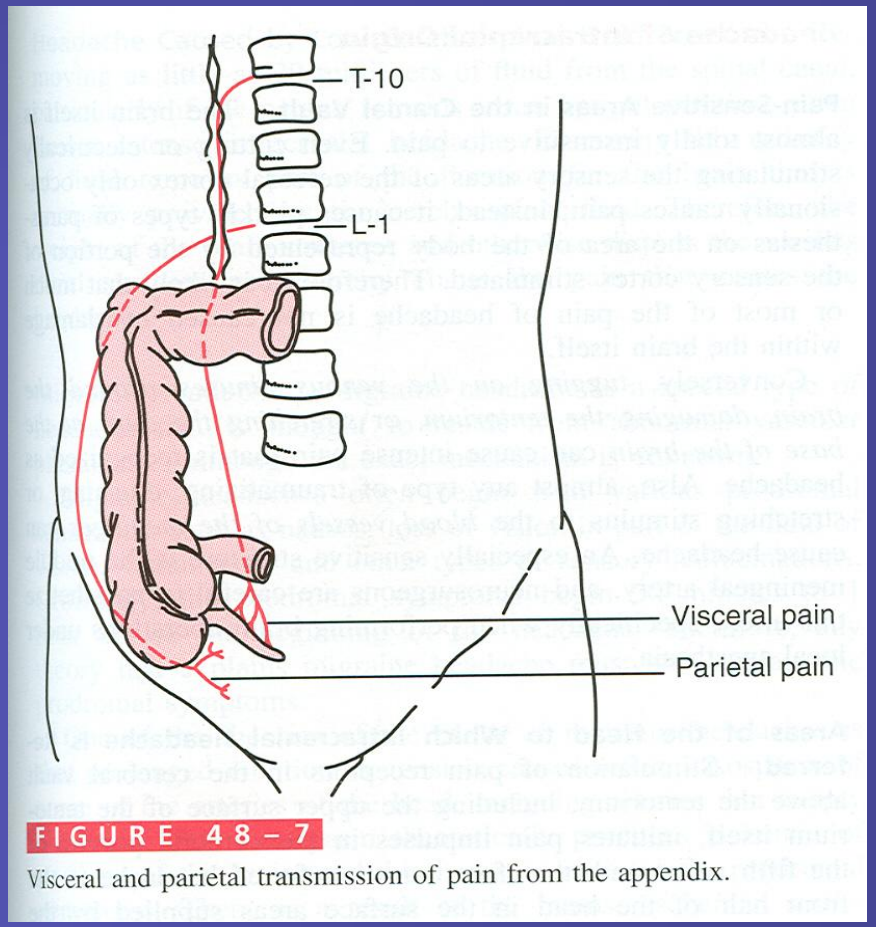
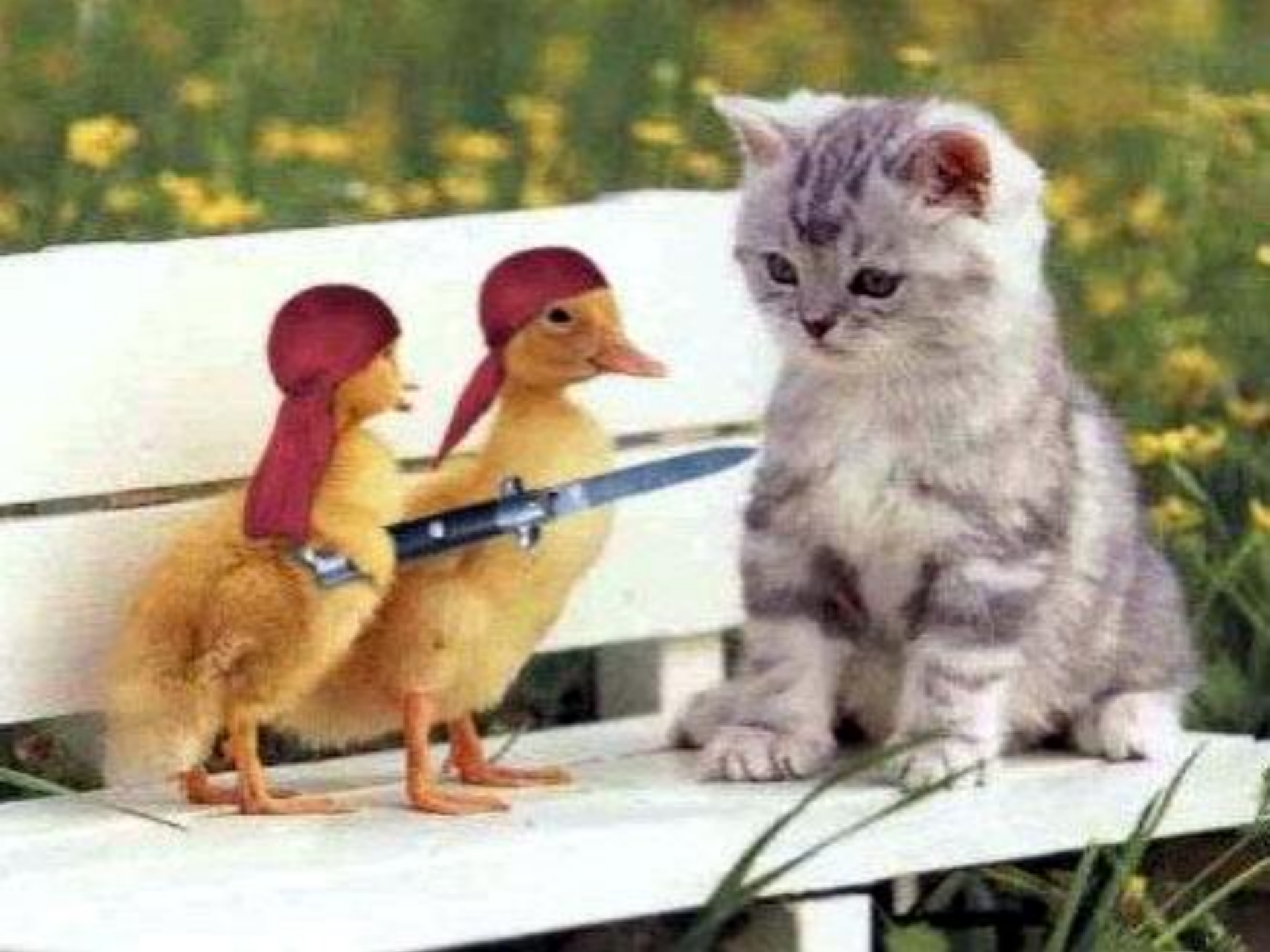



FIGURE 48–7

Visceral and parietal transmission of pain from the appendix.

# Pain syndromes

- **Allodynia**: Pain results from stimuli that normally are innocuous
- **Hyperalgesia**: Excessive response to noxious stimuli
- **Phantom pain:** Persistent sensation of pain that appear to originate from the region of an amputated limb



# Organization of movement

**Three categories of movement:**

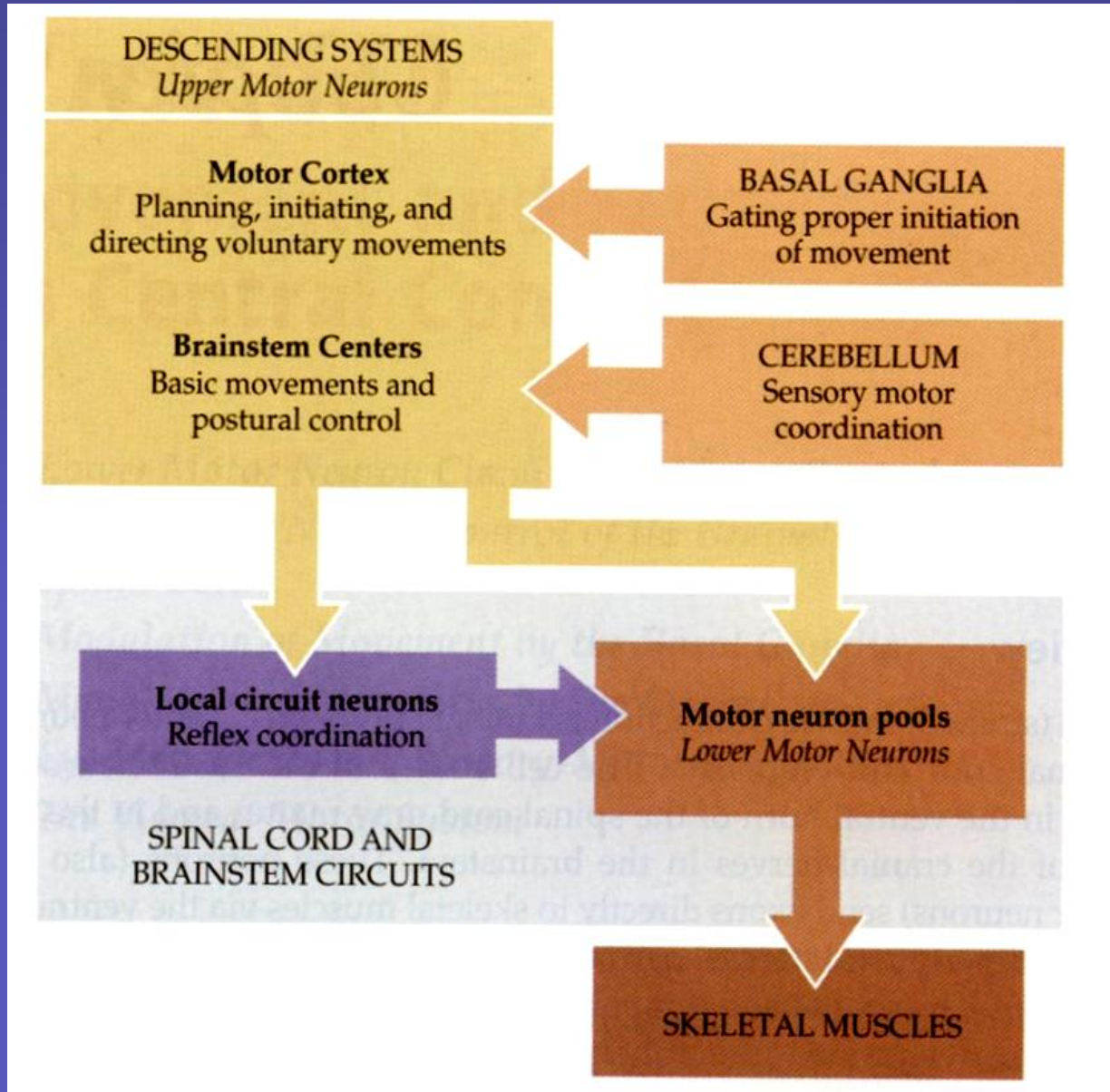
- ***Reflexive:*** **simple, stereotyped motor response to specific stimuli**

- ***Rhythmic***

- ***Voluntary:*** **purposeful, depend on behavioral task, improve with experience and learning, generated internally**

# Hierarchical organization of motor system

**The spinal cord, BS, forebrain contain successively more complex motor circuit**



# Lower vs. Upper Motor Neuron Damage

- **UMN disease:**

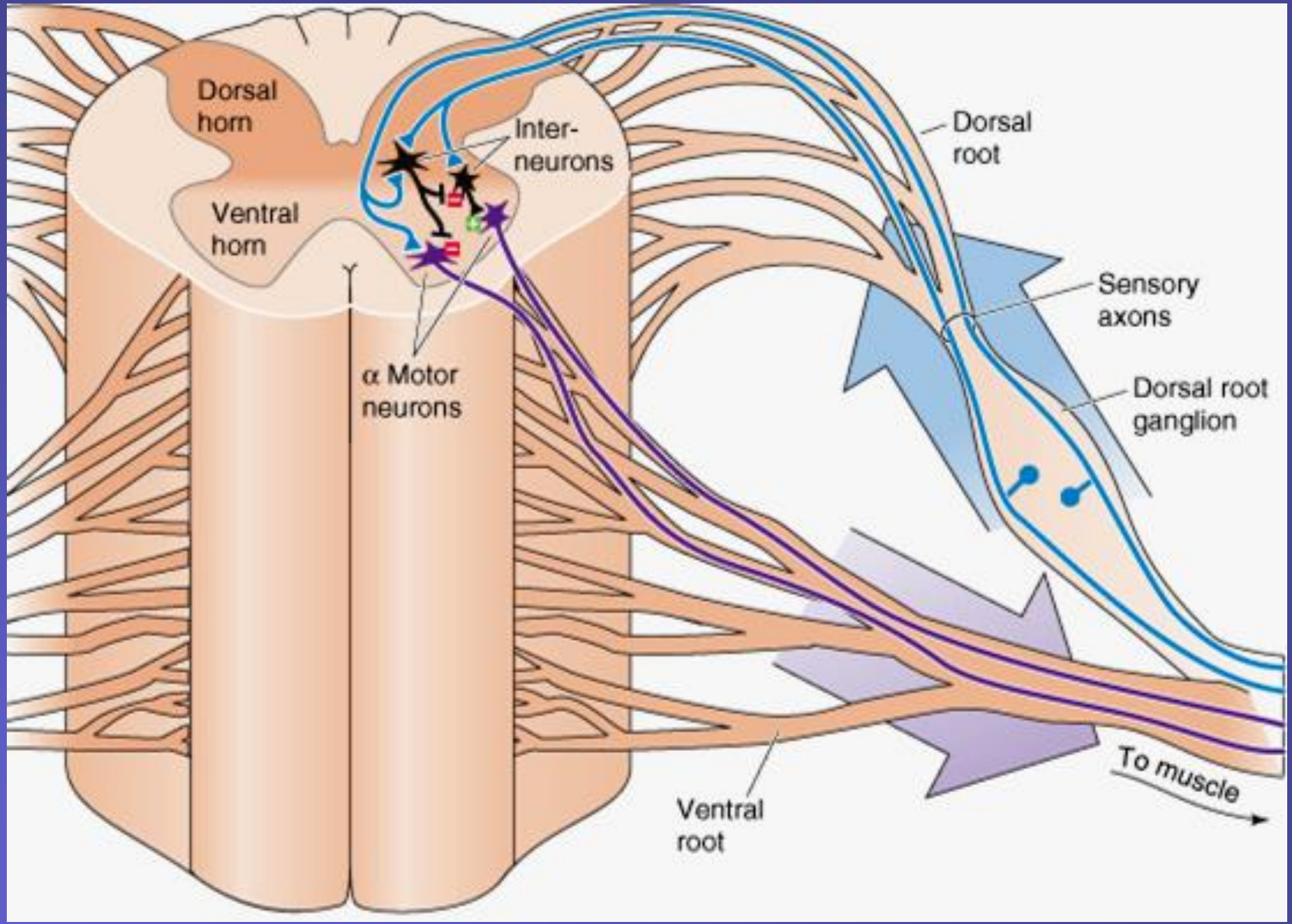
  **Spastic paralysis, hypertonia (increased resistance to passive movement), hyperactive stretch reflexes, diffuse damage**

- **LMN disease:**

  **Flaccid paralysis, hypotonia, hyporeflexia or areflexia**

  **Muscle atrophy, Muscle affected in patchy way**

# *Motor function of the spinal cord ; cord reflexes*


Dorsal horn
Ventral horn
Inter-neurons
Dorsal root
Sensory axons
α Motor neurons
Dorsal root ganglion
Ventral root
To muscle

# Organization of the spinal cord for motor function

1. Anterior motor neurons:

   - Alpha motor neurons (αmn)….Aα fiber

   - Gamma motor neurons (γmn)……Aγ fiber (fusimotor system)

2. Interneurons

   - Renshaw cells: Recurrent inhibition

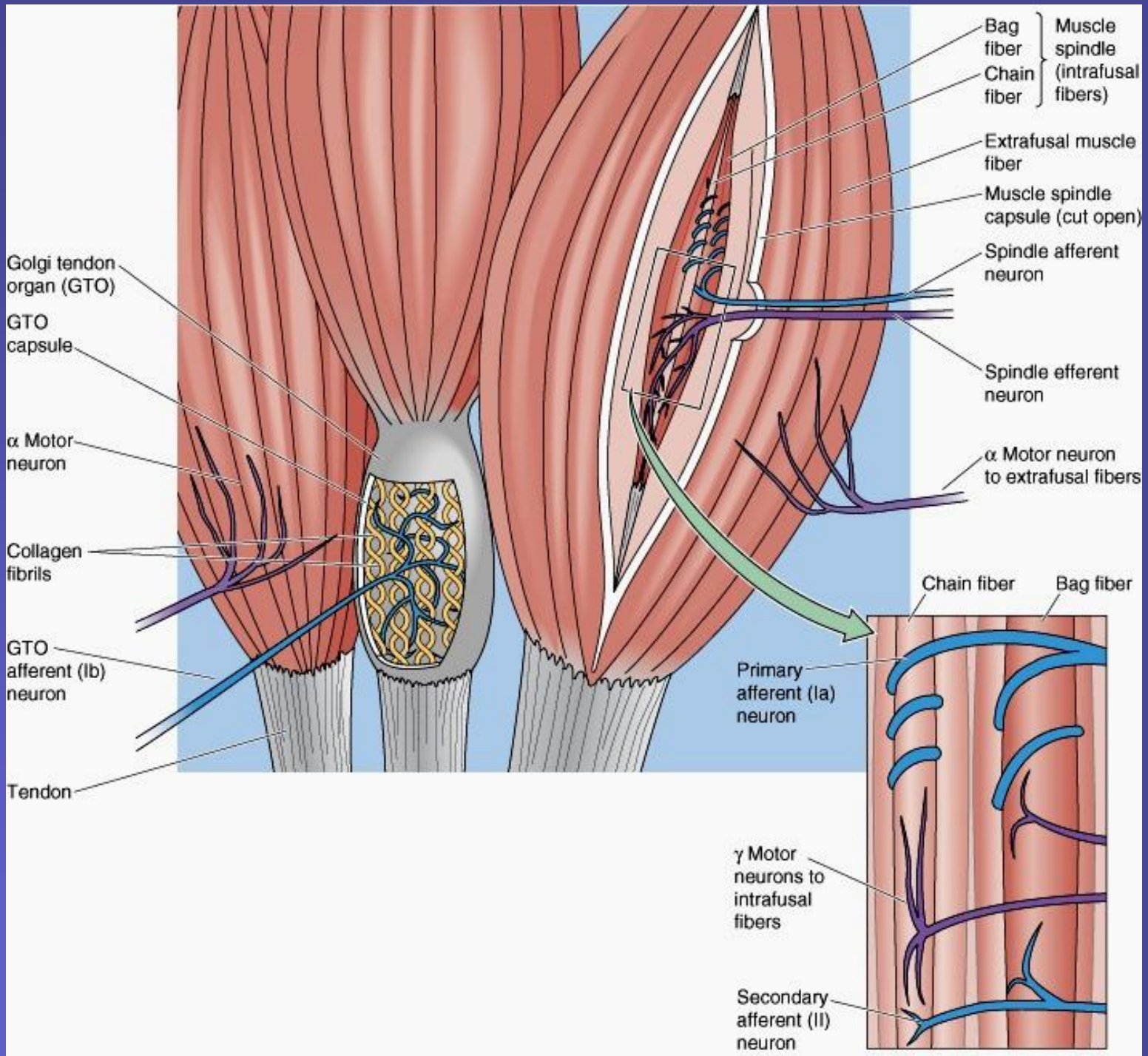
***Motor unit*** : an αmn , its motor axon and all of the skeletal muscle fiber that is supplies.

# Sensory receptors responsible for eliciting spinal reflexes

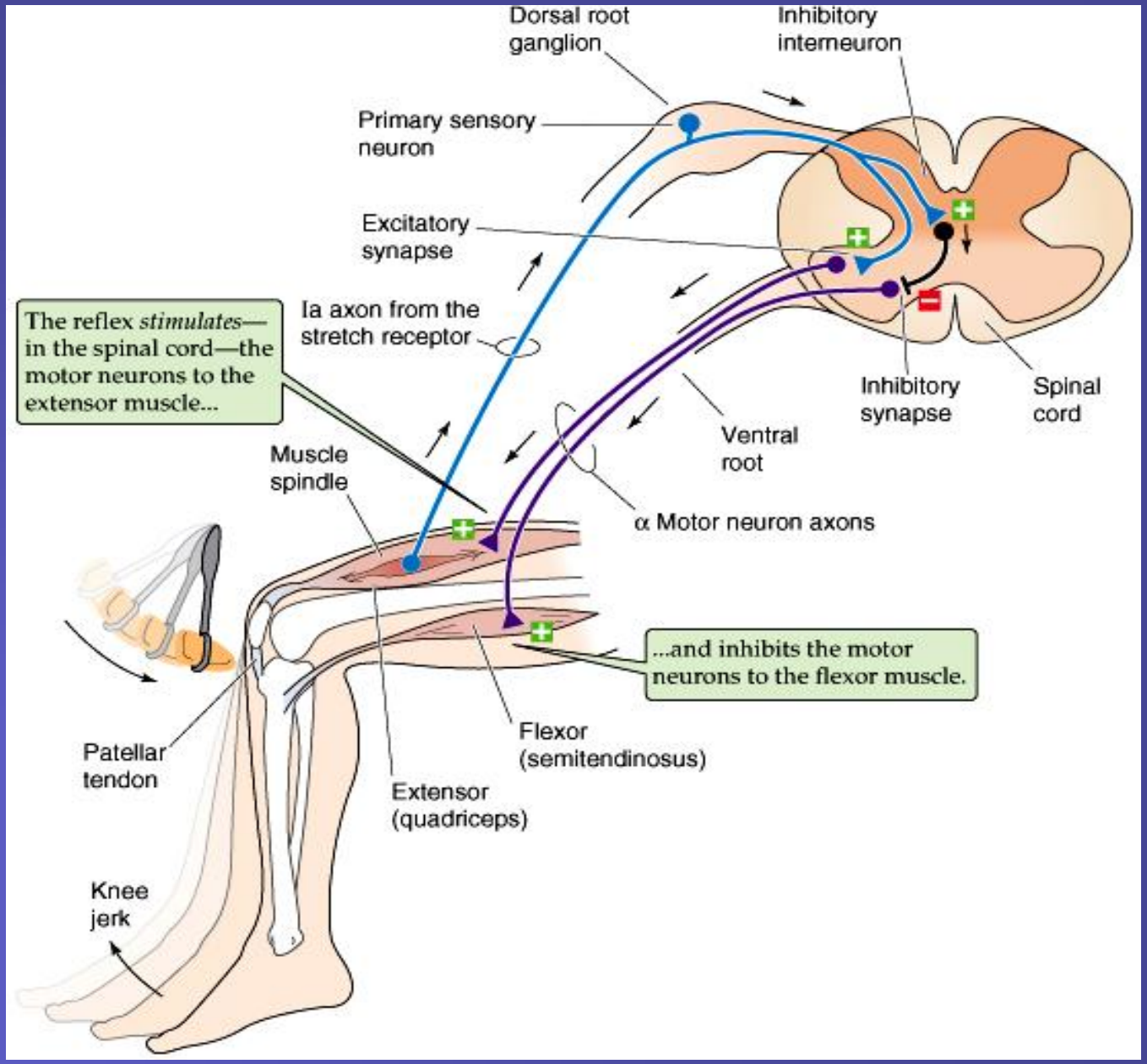
**Muscle Sensory receptors:**

***Muscle Spindle*: signals the change in the length of the muscle**

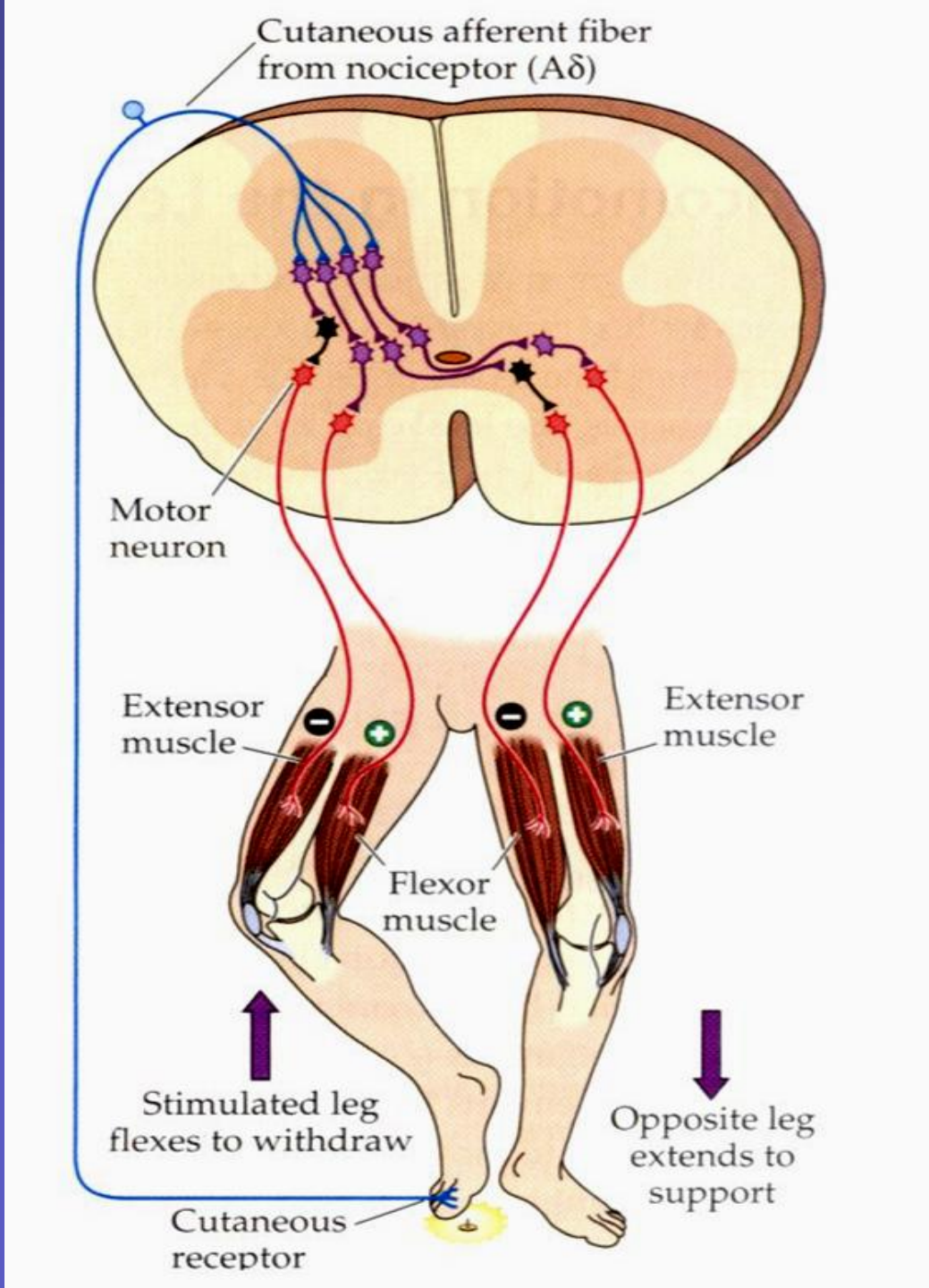
***Golgi Tendon Organ*: signals the force in the muscle**


Bag fiber
Chain fiber
Muscle spindle (intrafusal fibers)
Extrafusal muscle fiber
Muscle spindle capsule (cut open)
Spindle afferent neuron
Spindle efferent neuron
α Motor neuron to extrafusal fibers
Golgi tendon organ (GTO)
GTO capsule
α Motor neuron
Collagen fibrils
GTO afferent (Ib) neuron
Tendon
Chain fiber
Bag fiber
Primary afferent (Ia) neuron
γ Motor neurons to intrafusal fibers
Secondary afferent (II) neuron

# Clinical application of the stretch reflex: Knee jerk (Muscle jerk)



# Withdrawal reflex



# Spinal Shock

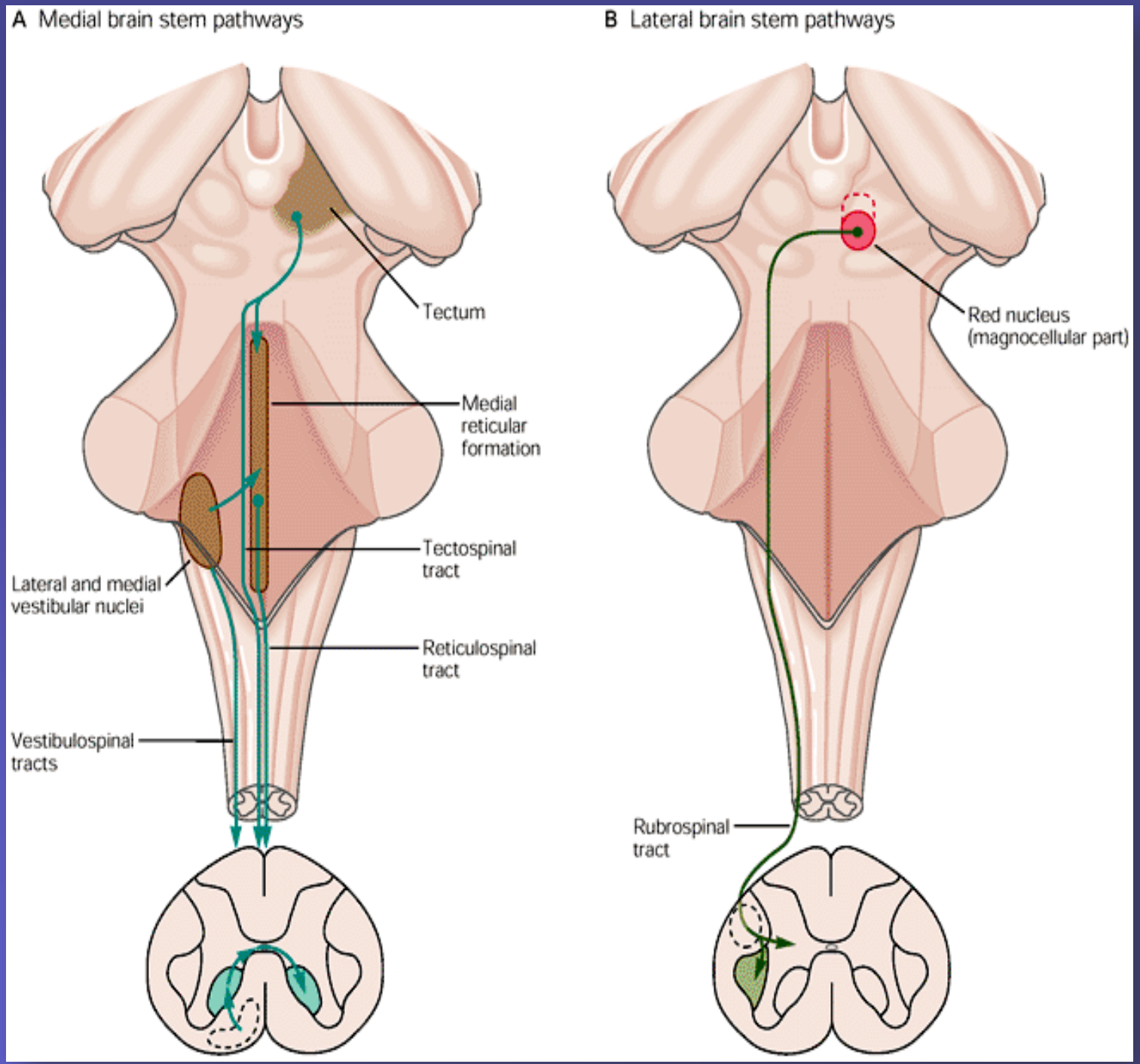
**Transection of spinal cord in human leads to period of spinal shock characterized by a flaccid paralysis, areflexia, loss of autonomic function, and loss of all sensation below the level of the transection followed by hyperreflexia**

# Brain stem control of movement

**BS nuclear groups give rise to descending motor tracts that influence motor neurons and their associated interneurons**

**(posture, locomotion, and eye movements)**

- **Red nucleus (magnocellular part)**
- **Vestibular nuclear complex**
- **Reticular formation**
- **Tectum**

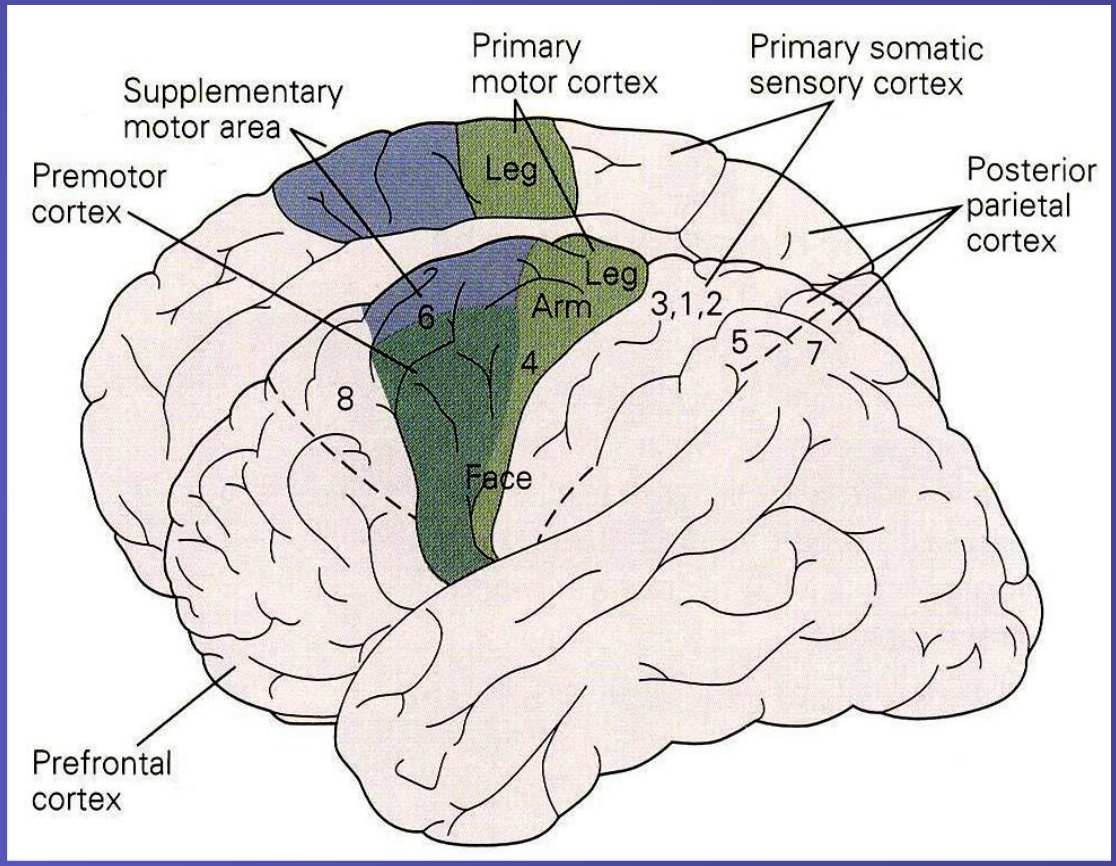

A Medial brain stem pathways
Tectum
Medial reticular formation
Tectospinal tract
Lateral and medial vestibular nuclei
Reticulospinal tract
Vestibulospinal tracts
B Lateral brain stem pathways
Red nucleus (magnocellular part)
Rubrospinal tract

# The motor cortex and corticospinal tract

**Primary Motor cortex (4)**

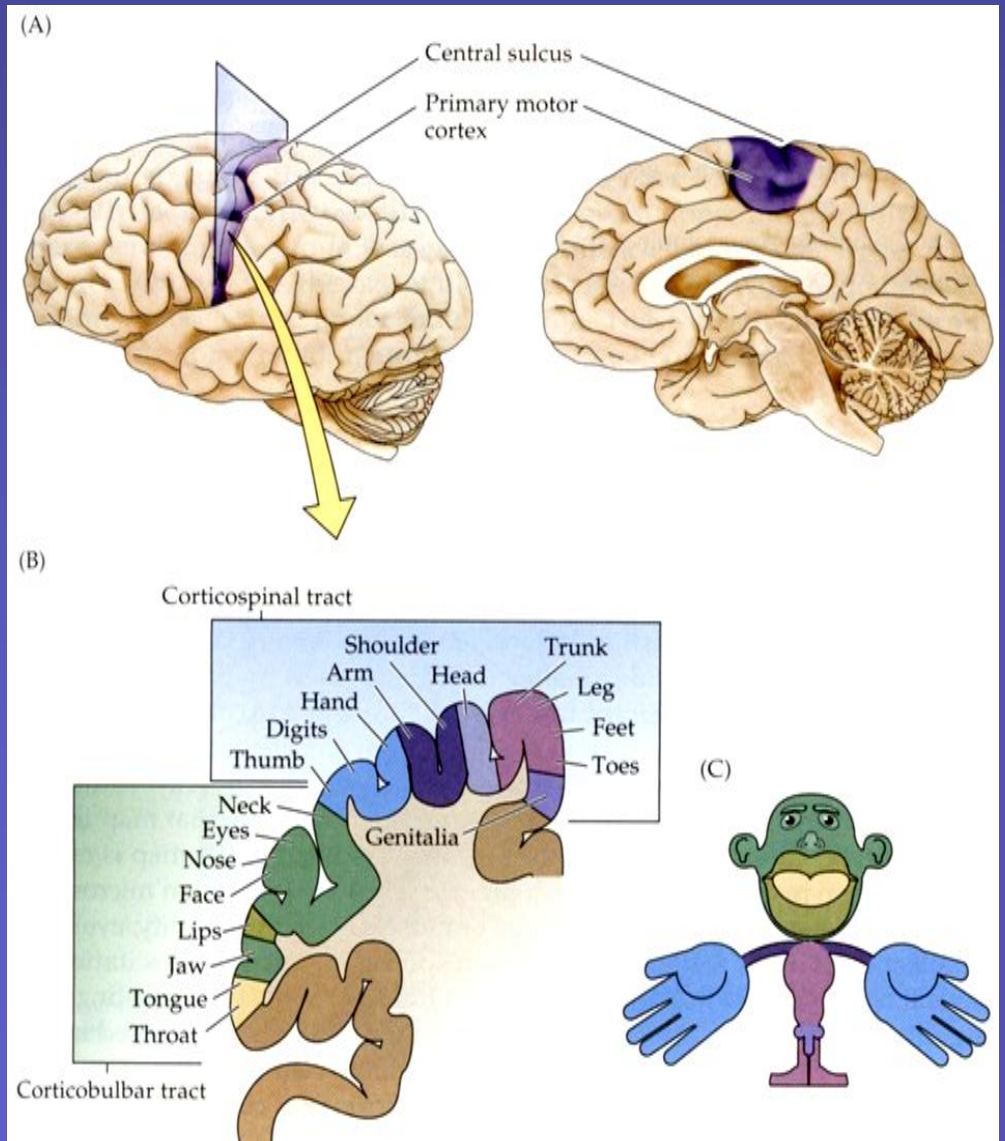
**Premotor control area (6)**

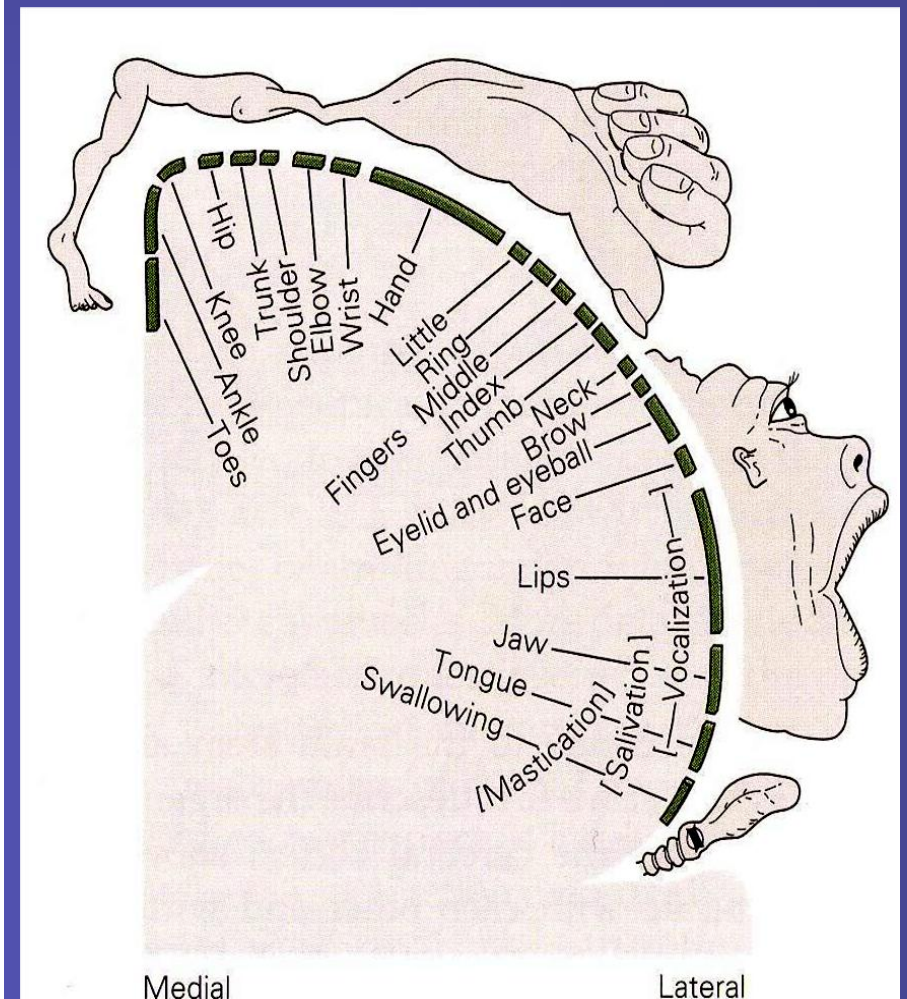
**Supplementary motor area**



# Somatotopic organization of primary motor cortex

## *Plasticity:* change of motor maps with experience

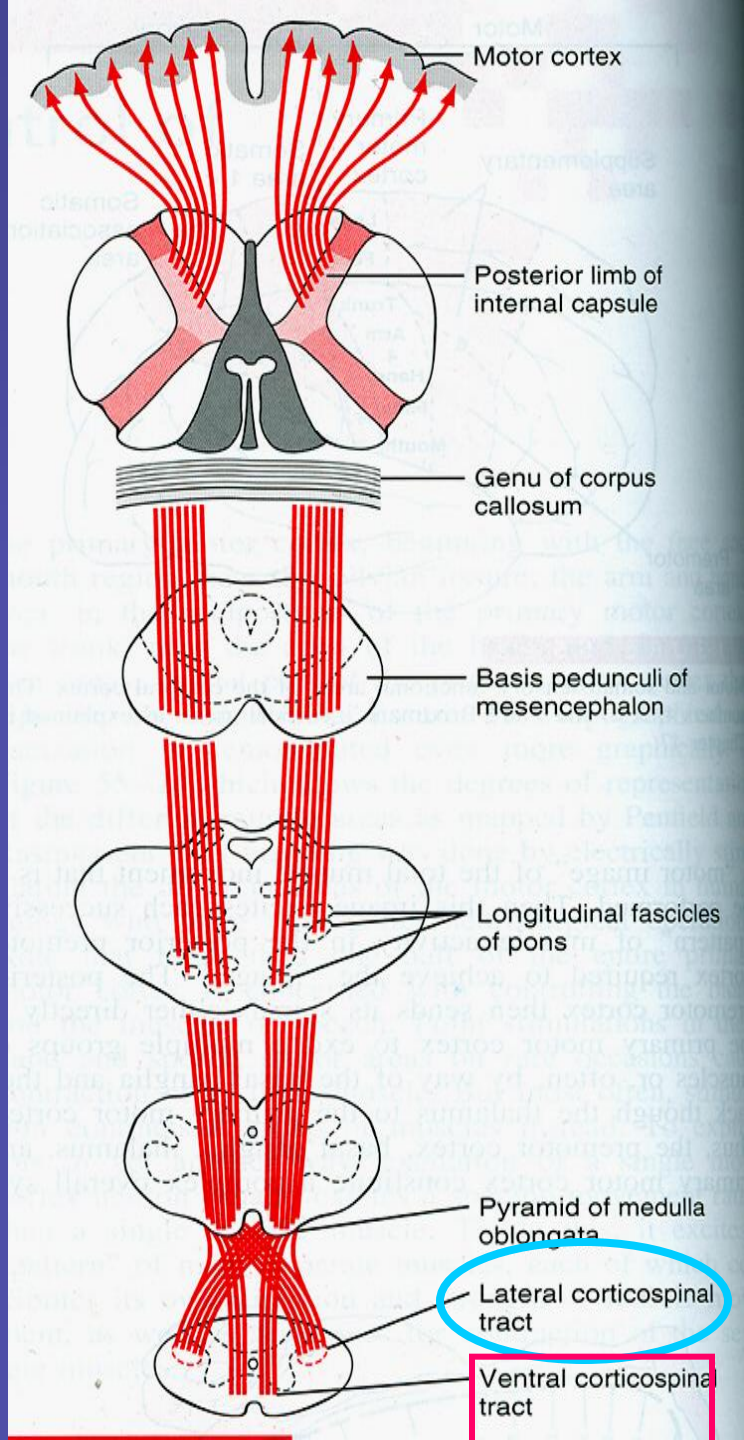


# Corticospinal tract (Pyramidal system)

- ✓Corticospinal tract: lat & ventral
- ✓Primary MA: 30%
- ✓ Premotor &SMA: 30%
- ✓ Somatosensory area: 40%

Giant pyramidal cells (Betz cell)



# Descending motor pathways

- **Lateral system:**
  - Lat CS tract
  - Rubrospinal tract

**Concerned with goal directed movemnet**

- **Medial system:**
  - Ventral CS
  - Reticulospinal
  - Med & Lat Vestibulospinal
  - Tectospinal

**Provide basic postural control sys**