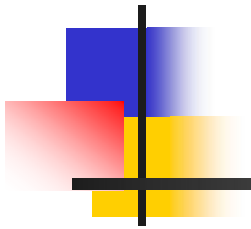


Section 3

Basic Principles of Reflex

一. Reflex and Reflex Arc

1. Definition of reflex

The way by which the nervous system exerts its regulatory effects is reflex.

The basic unit of integrated reflex activity is the reflex arc.

2. Constitution of Reflex Arc & Basic Process of Reflex

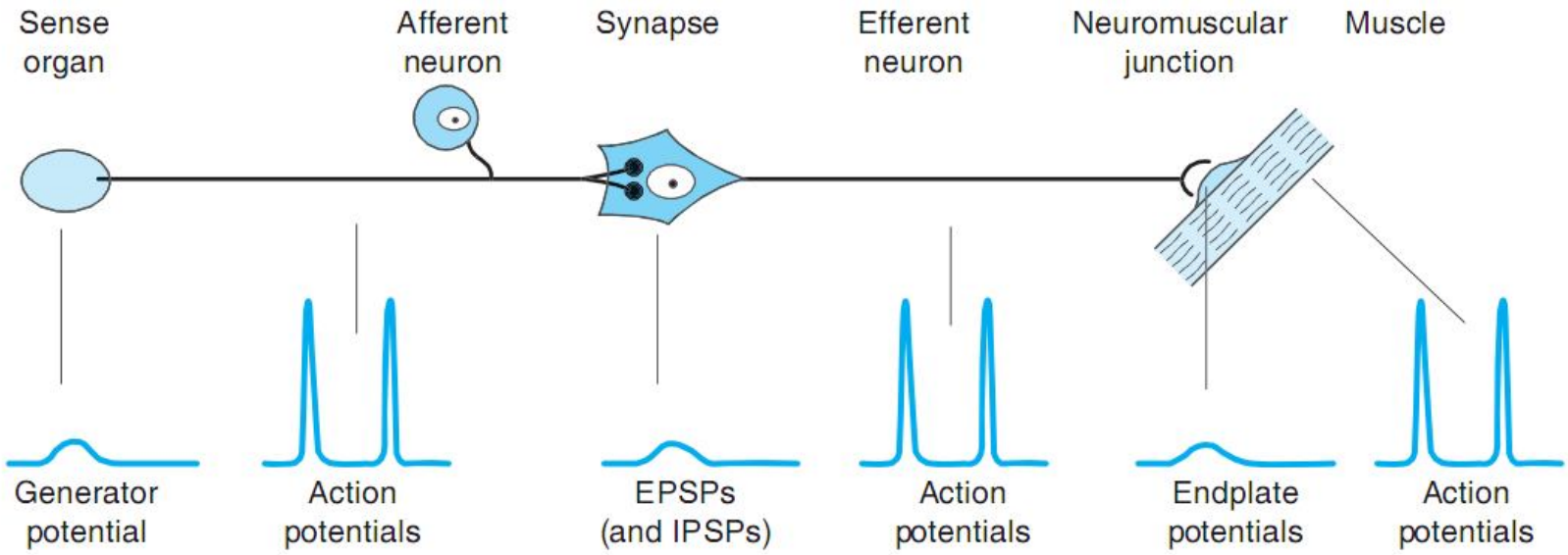
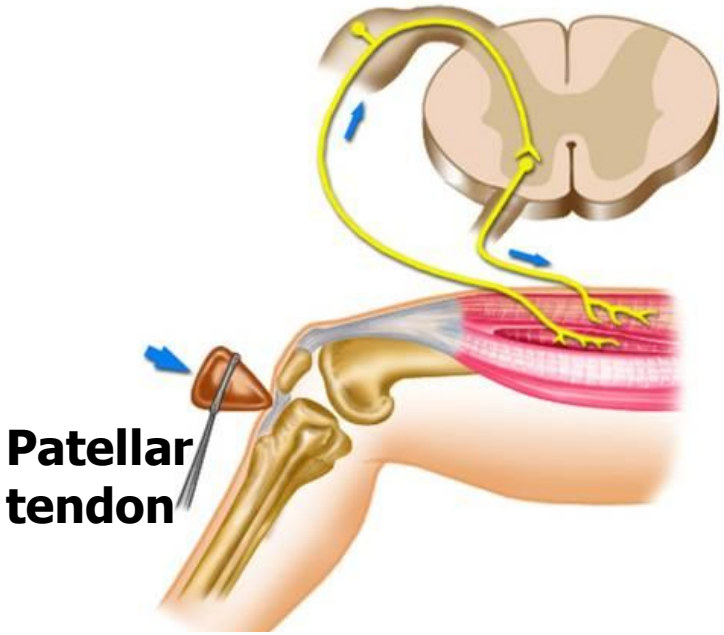
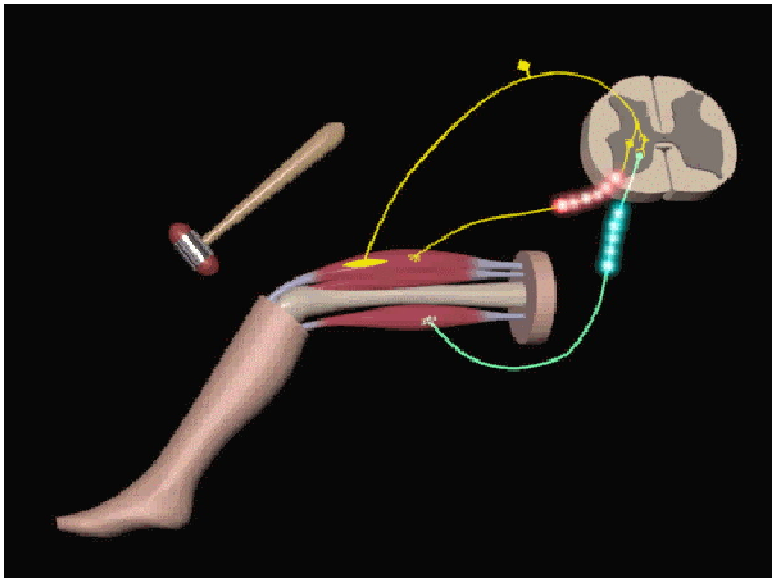


Figure 6–1. The reflex arc. Note that at the receptor and in the CNS a nonpropagated graded response occurs that is proportionate to the magnitude of the stimulus. The response at the neuromuscular junction is also graded, though under normal conditions it is always large enough to produce a response in skeletal muscle. On the other hand, in the portions of the arc specialized for transmission (afferent and efferent axons, muscle membrane), the responses are all-or-none action potentials.

二. Monosynaptic reflex & polysynaptic reflex



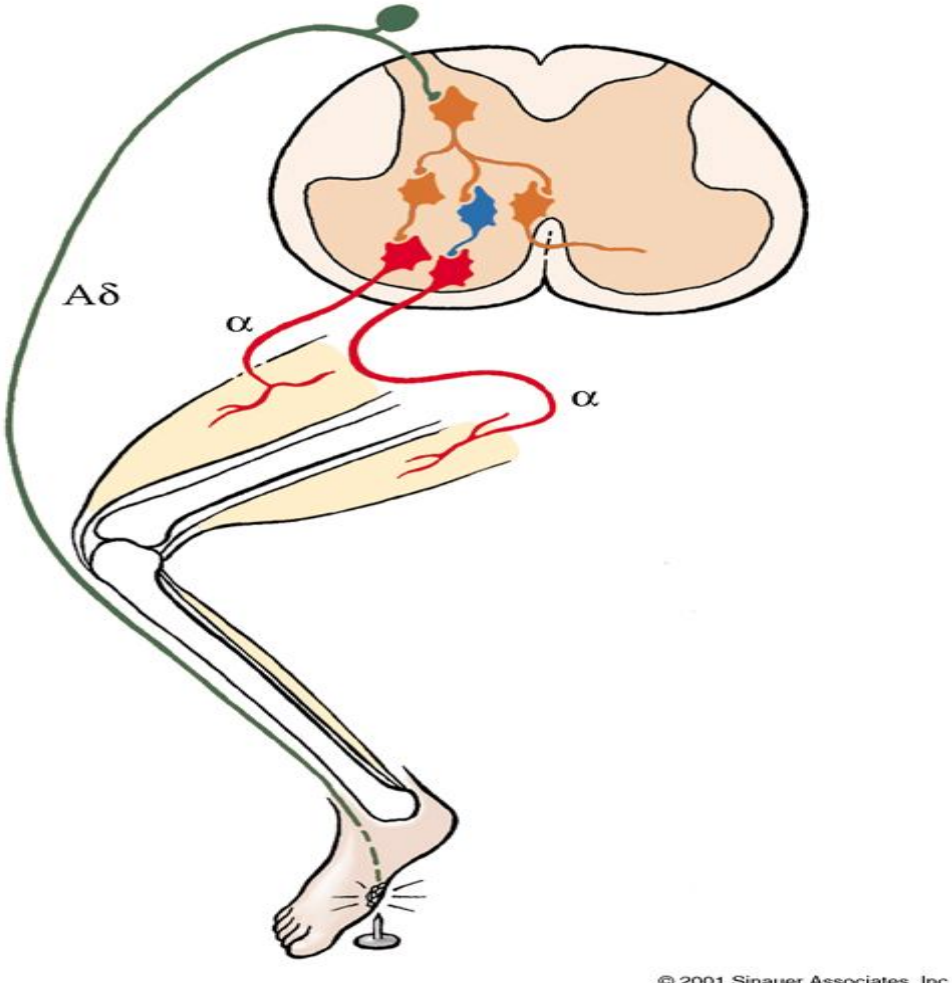


Stretch reflex:

knee jerk

There is a single synapse between the afferent and efferent neurons

Polysynaptic reflex

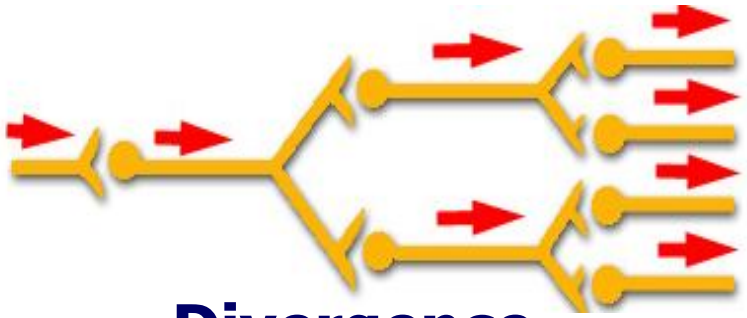


Flexor withdrawal reflex

The number of synapses in the arcs varying from two to many hundreds between the afferent and efferent neurons.

三. General Properties of Reflexes

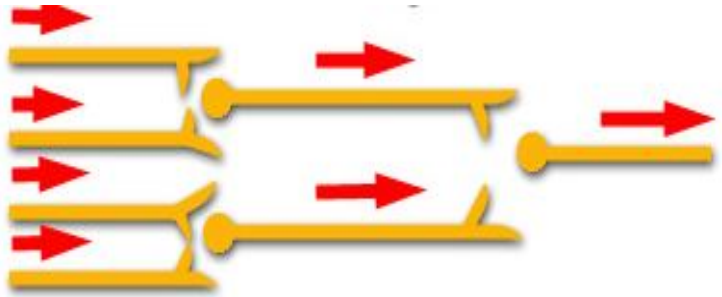
1. Connecting Mode of Central Neurons



Divergence

The axons of most neurons divide into many branches that diverge to end on many postsynaptic neurons.

This mode is common in afferent nerve pathway.



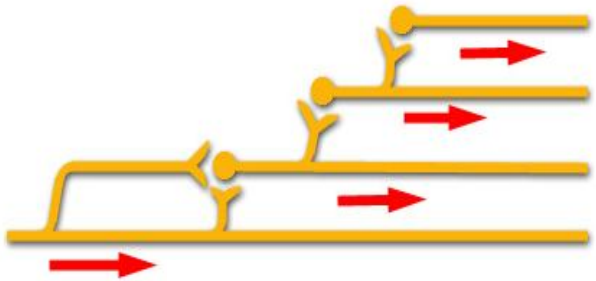
Convergence

Many presynaptic neurons converge to any single postsynaptic neuron.

This mode is common in efferent nerve pathway.

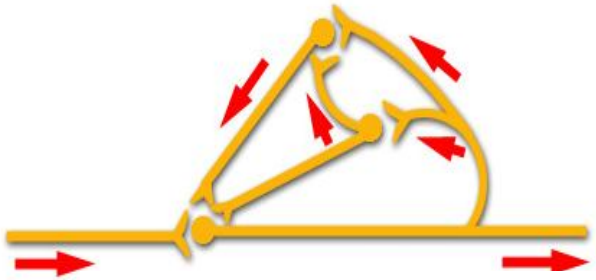
三. General Properties of Reflexes

1. Connecting Mode of Central Neurons



Chain circuit

The spatial range of the propagated transsynaptic response can be extended.

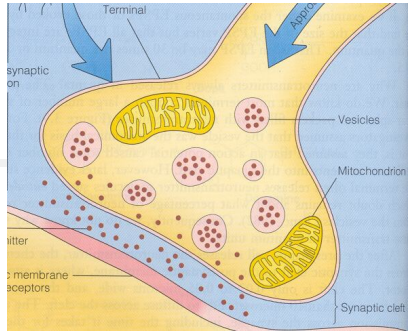


Recurrent circuit

If positive feedback occurs through the circuit, the interneuron is excitatory and the activity produced by afferent signals may be prolonged and reverberated.

After discharge

2. Characteristics of excitatory propagation in the CNS



① **One-way conduction**

Synapses generally permit conduction of impulse in one direction, from presynaptic to the postsynaptic neurons.

② **Central delay**

It takes for the synaptic mediator to be released and to act on the membrane of the postsynaptic cell.

Characteristics of excitation conducting along nerve fiber

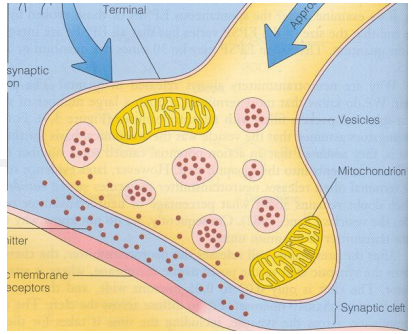
1. Both structural & functional integrality

2. Isolated propagation

3. Bi-directional propagation

4. Relative indefatigability

2. Characteristics of excitatory propagation in the CNS



① One-way conduction

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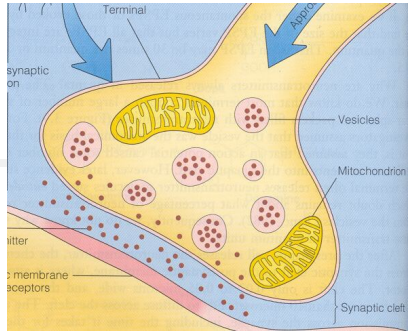
2. Characteristics of excitatory propagation in the CNS



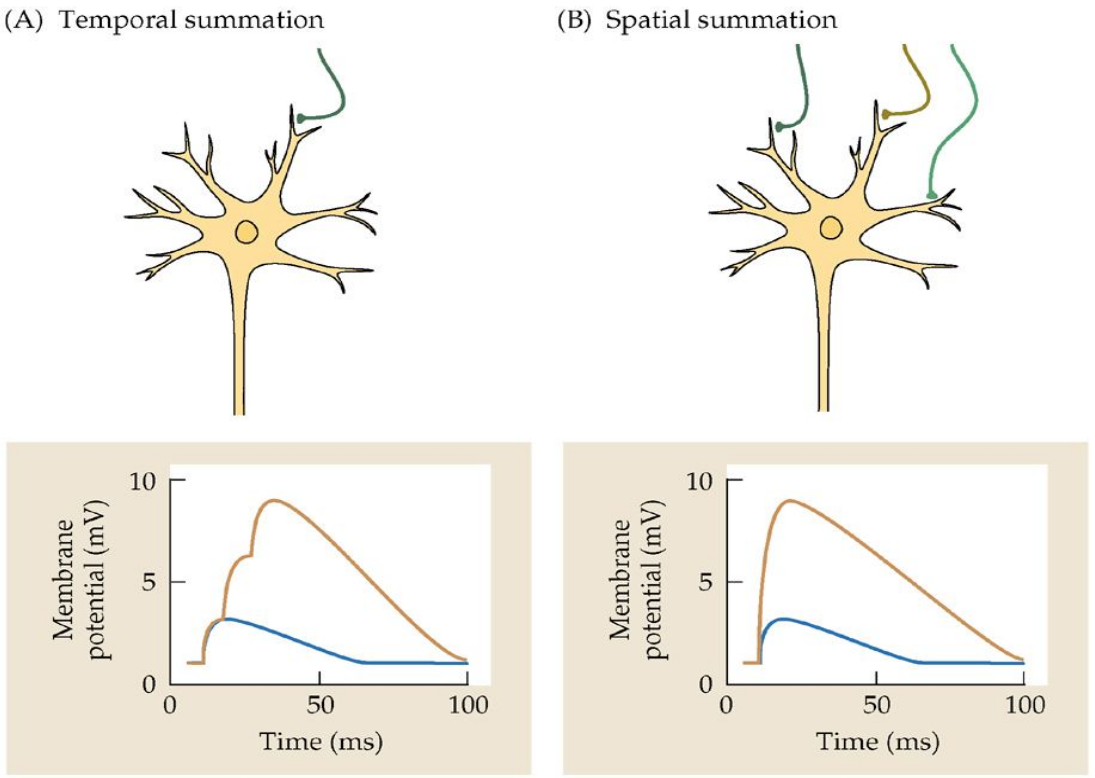
② Central delay

It takes for the synaptic mediator to be released and to act on the membrane of the postsynaptic cell.

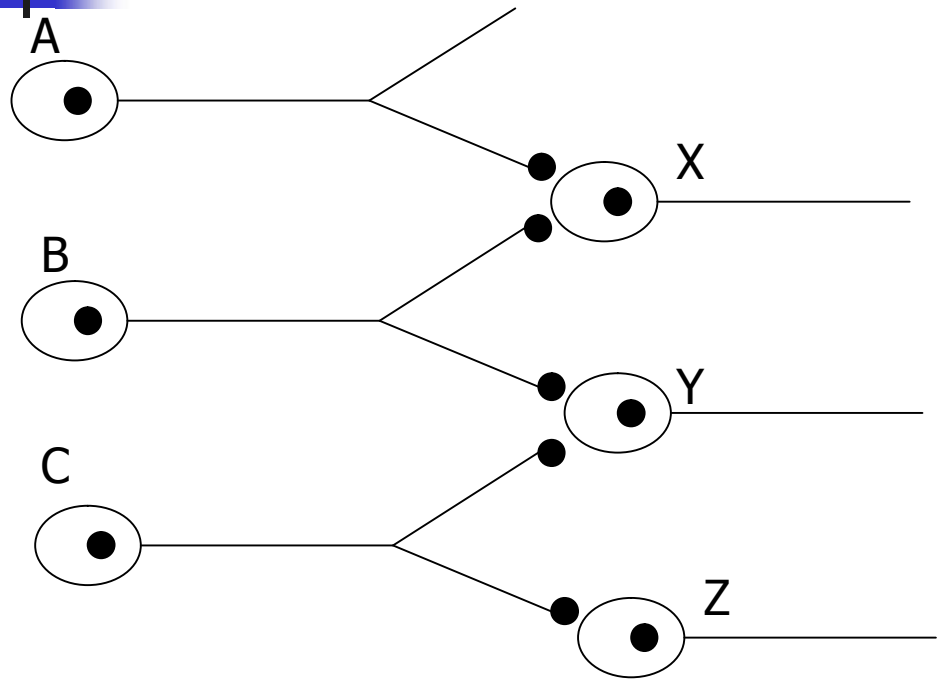
an interval at least 0.5ms

2. Characteristics of excitatory propagation in the CNS

③ Summation and occlusion



occlusion



The response to stimulation of B and C together is not as great as the sum of responses to stimulation of B and C separately.

Simple nerve net. Neurons A, B and C have excitatory endings on neurons X, Y and Z.

2. Characteristics of excitatory propagation in the CNS

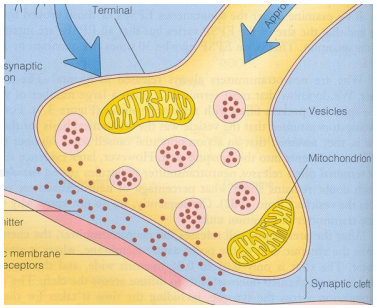
④ Change of excitatory rhythm

In reflex center, the postsynaptic neurons receive multiple inputs from different presynaptic neurons. And also the situation of a certain postsynaptic neuron may always be varied under different conditions.

⑤ After discharge

Recurrent circuit

2. Characteristics of excitatory propagation in the CNS



⑥ **Susceptible to changes of internal environment**

Since the synthesis of neurotransmitter is dependent on metabolic process, the synapse is more sensitive than nerve fiber to hypoxia and ischemia.

The synaptic cleft is connected to the intrinsic fluid, it is more susceptible to the action of drugs and to general anesthetic agents.

⑦ **Easy to get fatigue**

四. Central Inhibition

1. Postsynaptic inhibition

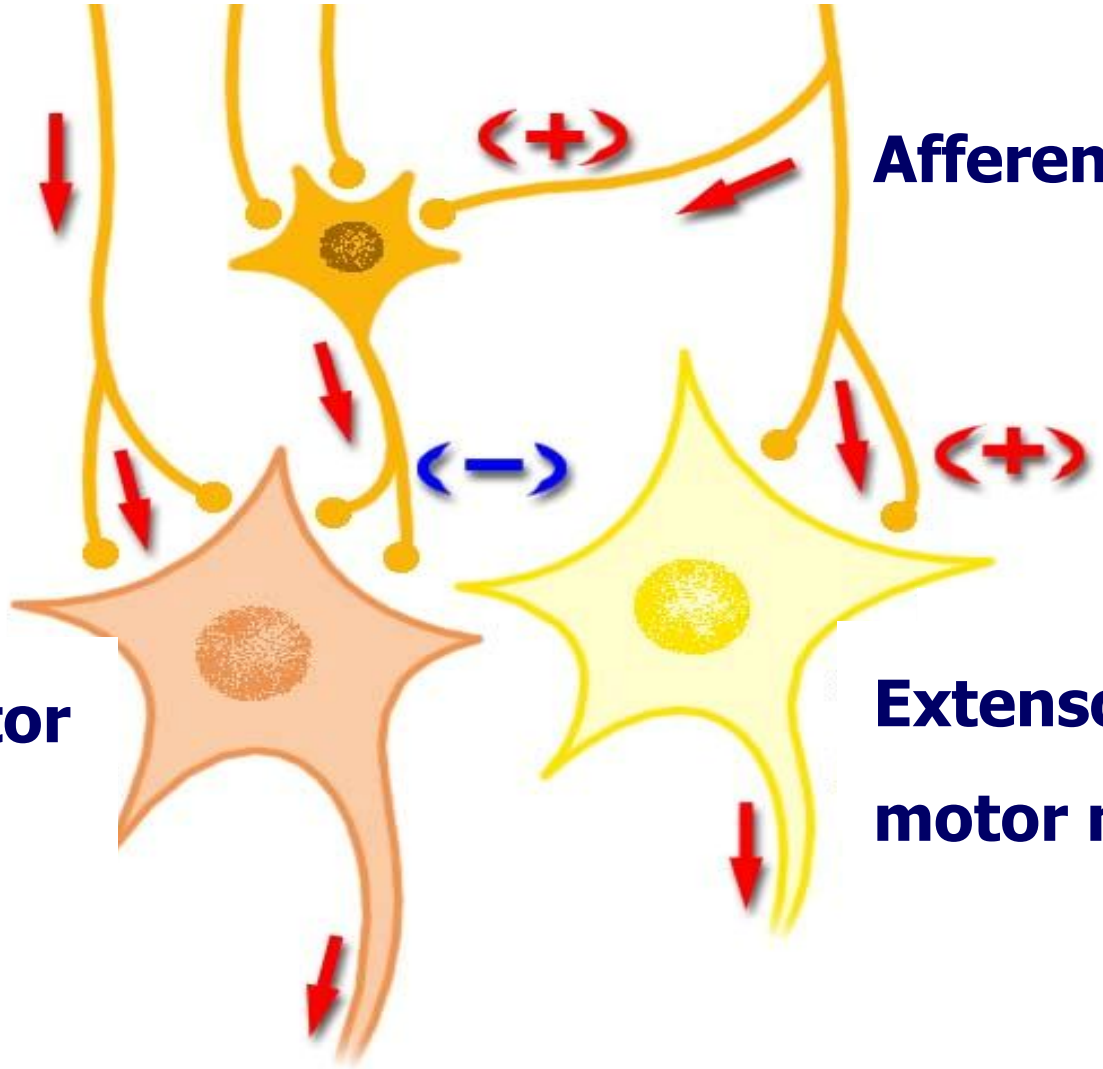
2. Presynaptic inhibition

1. Postsynaptic inhibition

(1) Afferent collateral inhibition

(2) Recurrent inhibition

Afferent collateral inhibition



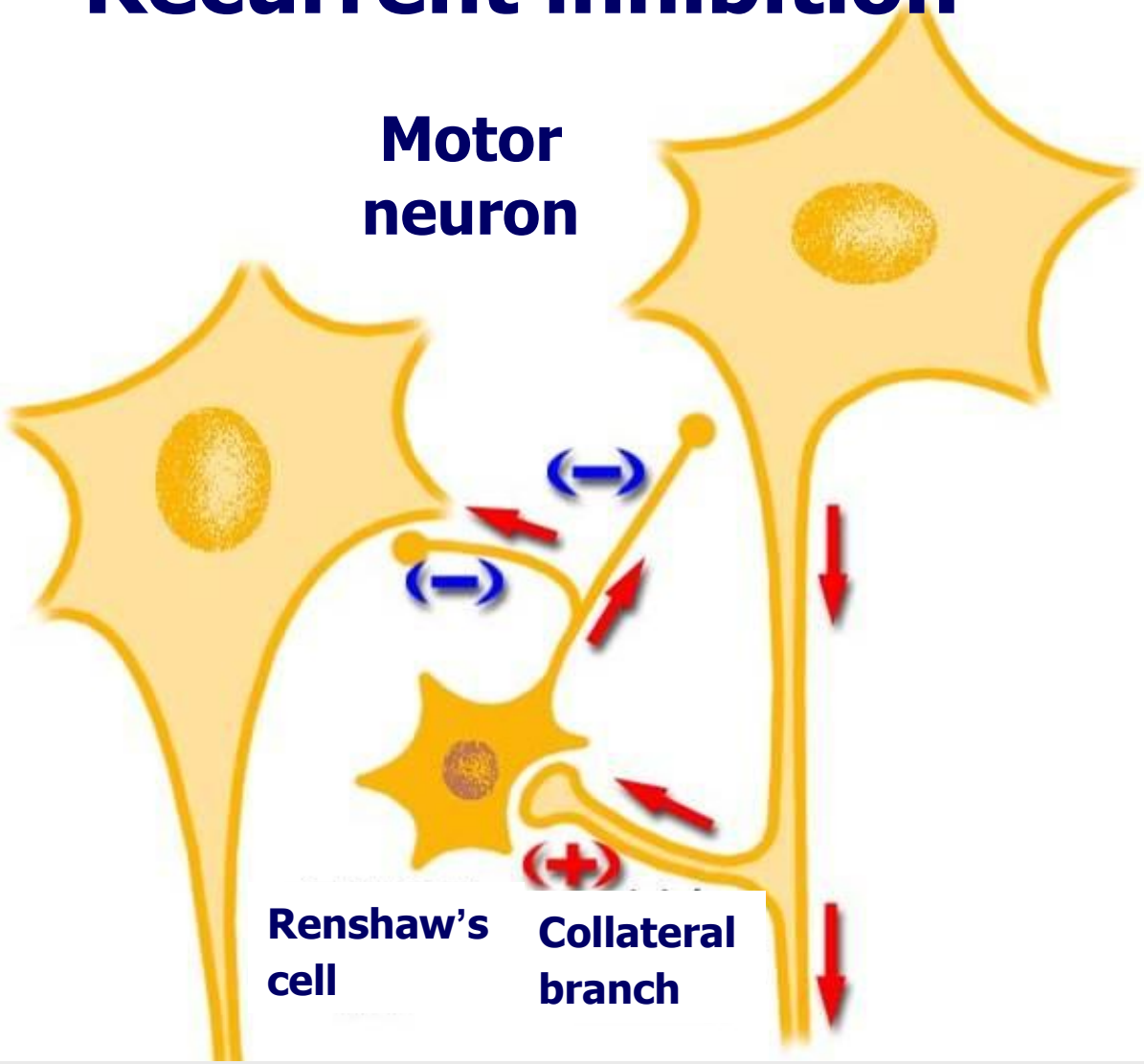
Afferent fiber

Flexor motor neuron

Extensor motor neuron

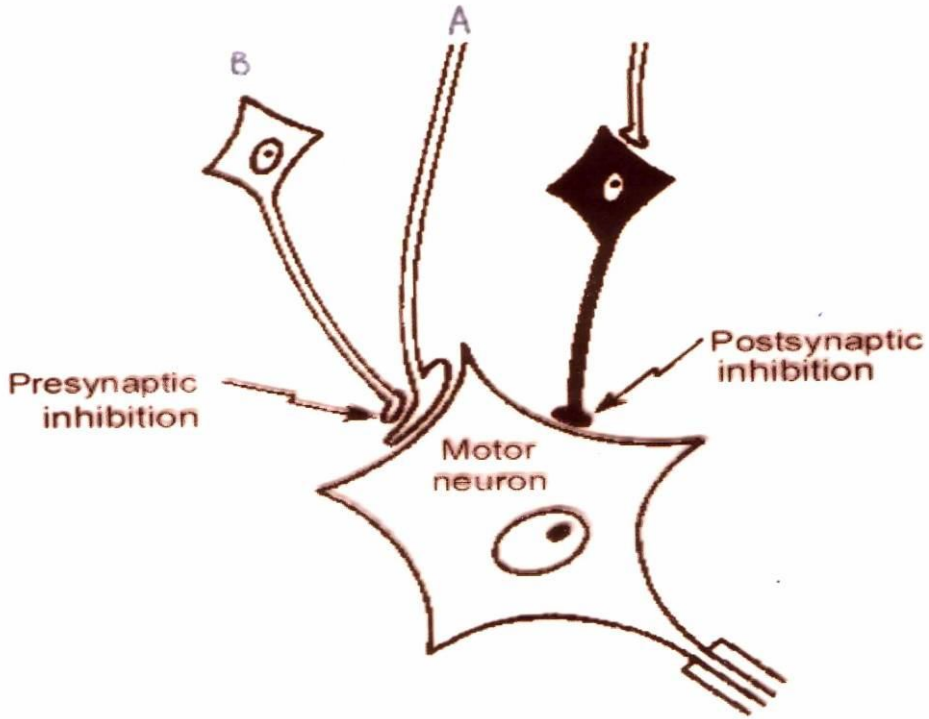
coordinate the activity between different center

Recurrent inhibition

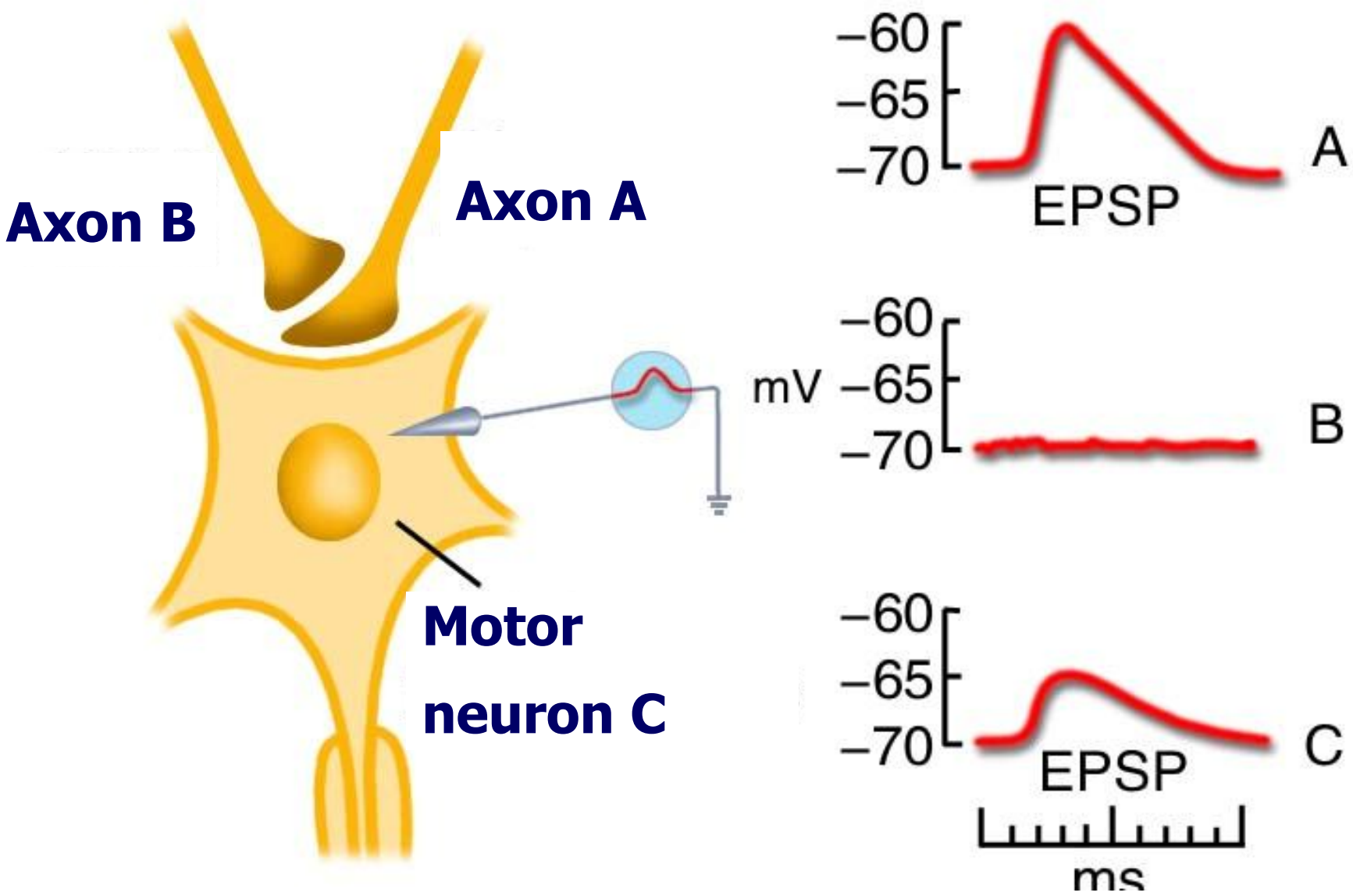


Renshaw's cells receive an excitatory collateral from the alpha neuron's axon and send an inhibitory axon to synapse with the cell body of the initial alpha neuron and an alpha motor neuron of the same motor pool.

2. Presynaptic inhibition

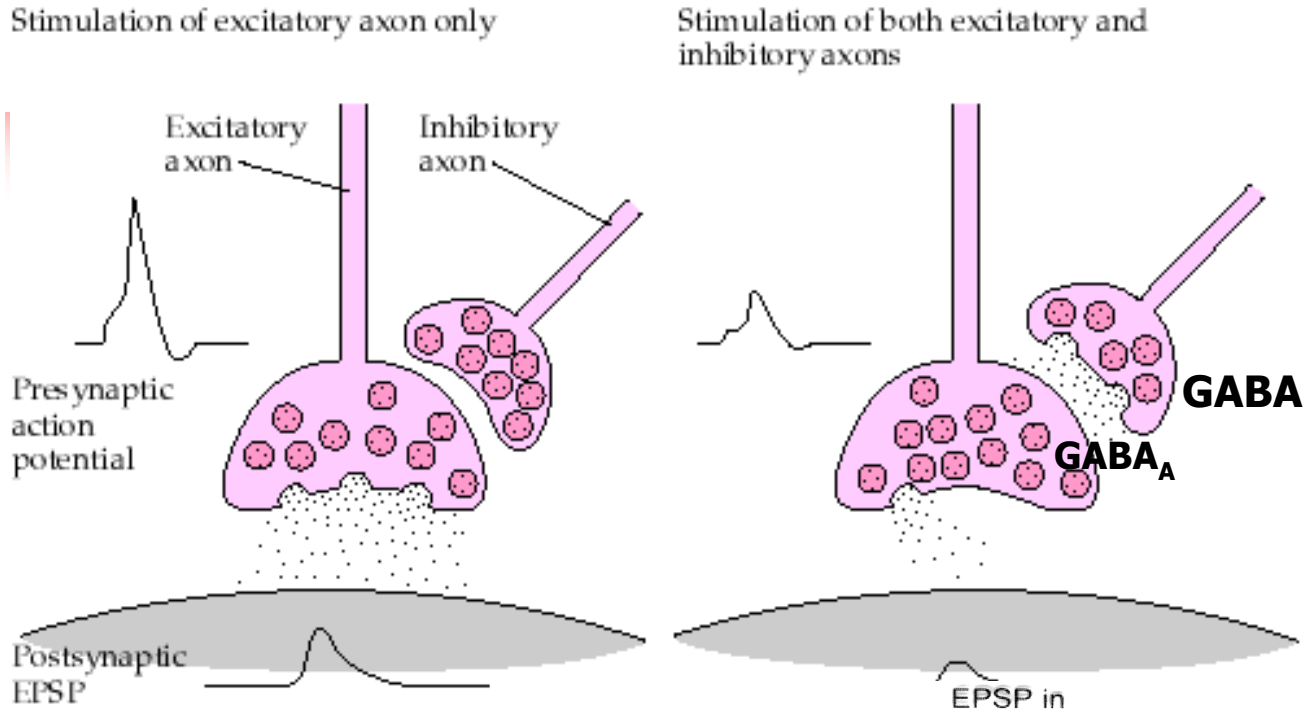


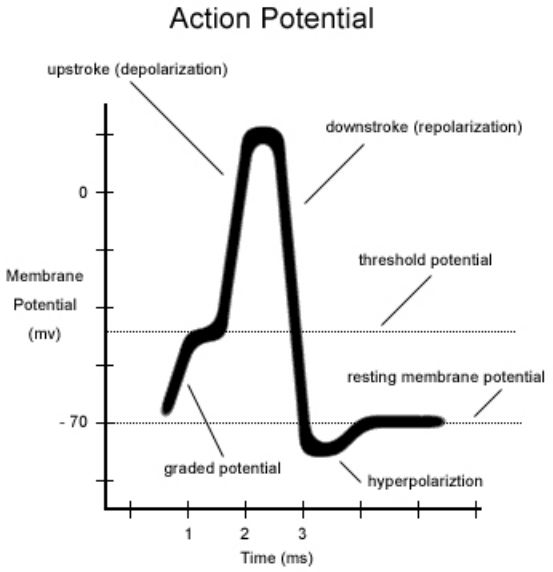
A process mediated by neurons that end on excitatory endings, forming axoaxonal synapses.



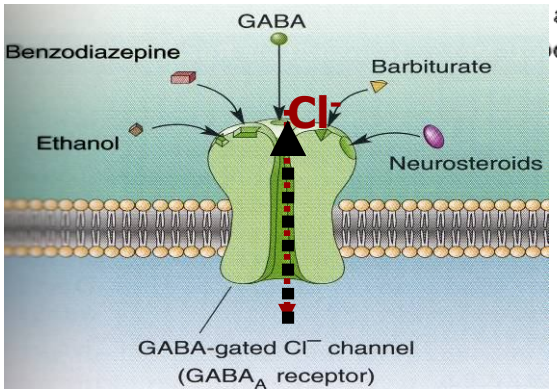
Presynaptic inhibition

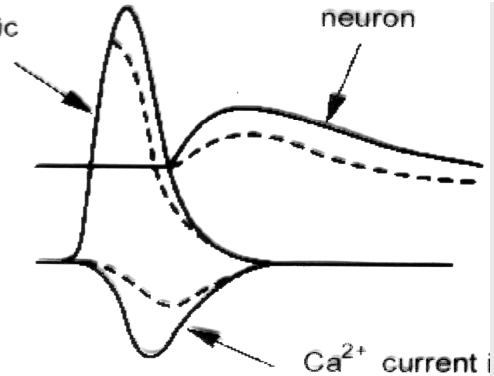
2. Presynaptic inhibition





Feldman
Fundamentals of Neuropsychopharmacology
Fig. 6-10





Presynaptic inhibition

Cl$^-$ flow out

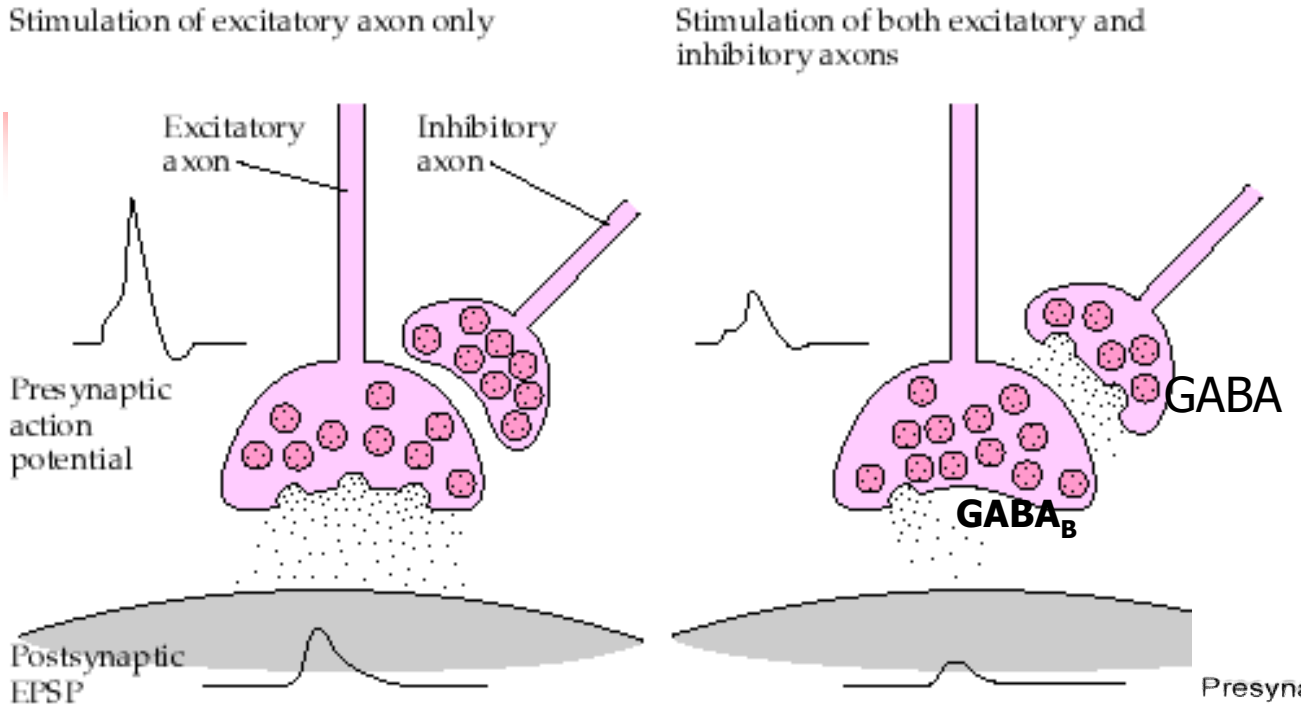
(Na$^+$- K$^-$-2Cl$^-$ symporter, Cl$^-$- HCO3$^-$ exchanger)

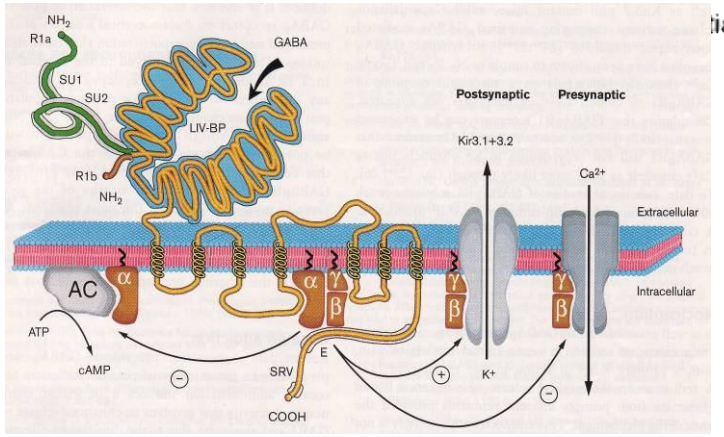
→ depolarization

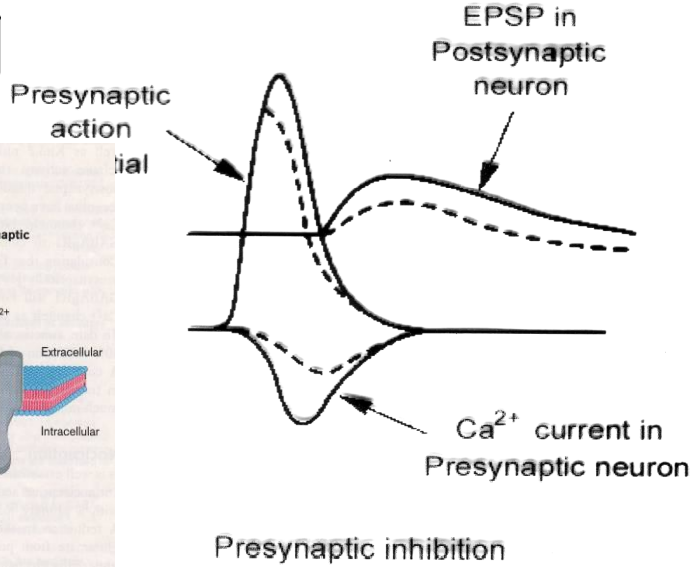
→ decrease the size of AP

→ reduce Ca^{2+}entry

2. Presynaptic inhibition







Presynaptic inhibition

Three mechanisms of presynaptic inhibition have been described:

First, activation of the presynaptic receptors $GABA_A$ increases Cl^-conductance, and this has been shown to decrease the size of the action potentials reaching the excitatory ending. This in turn reduces Ca^{2+} entry and consequently the amount of excitatory transmitter released.

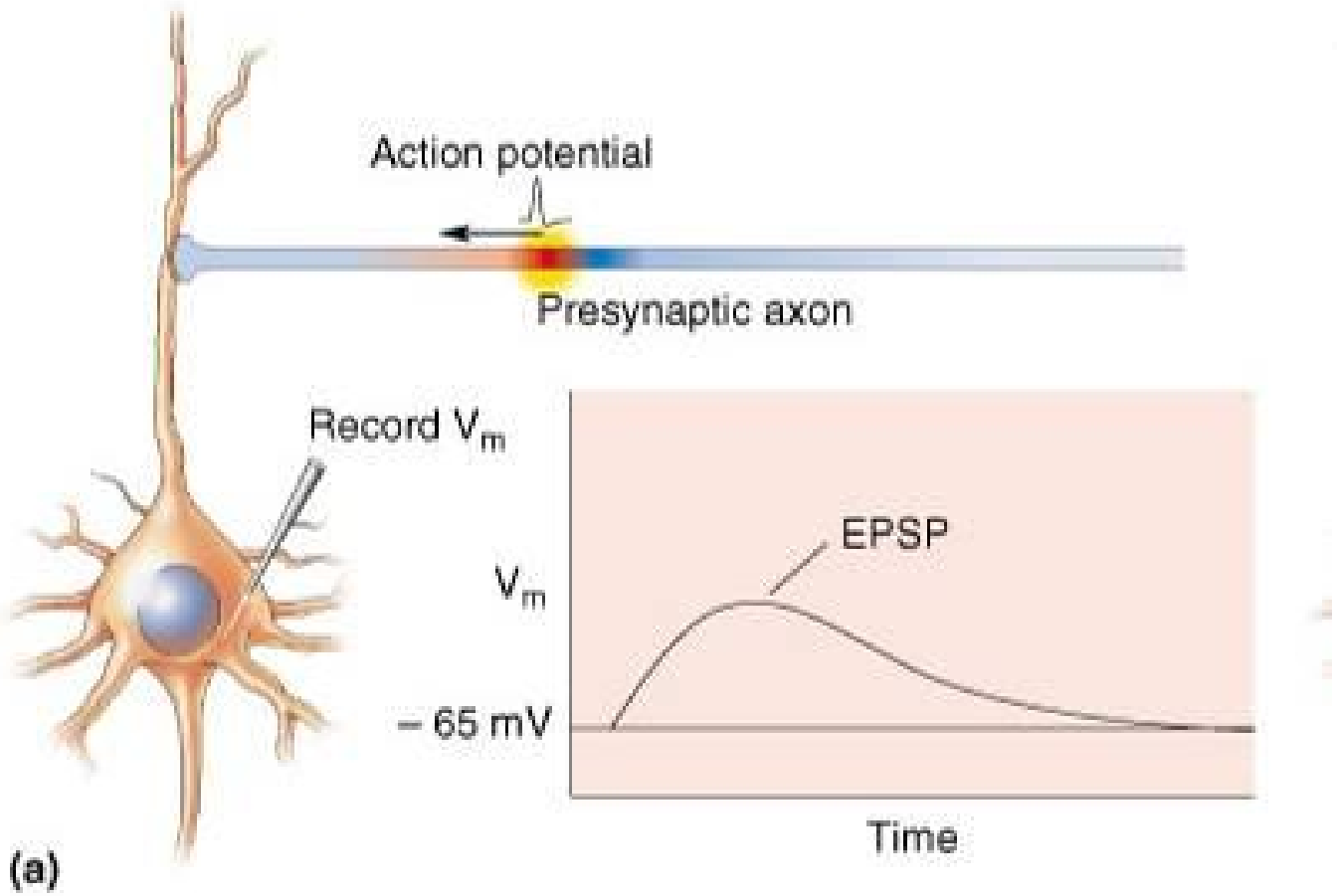
Second, activation of the presynaptic G protein receptors $GABA_B$ produces K^+ efflux and also decreases the Ca^{2+} influx.

Finally, there is evidence for direct inhibition of transmitter release via activating G protein coupled-receptor.

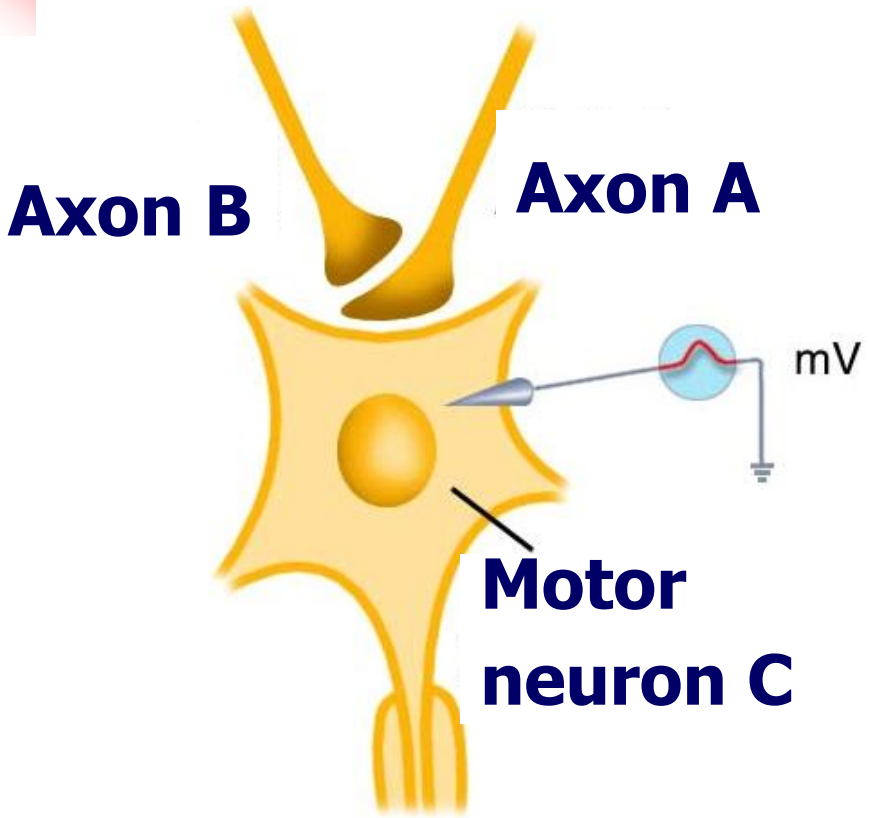
Central Facilitation

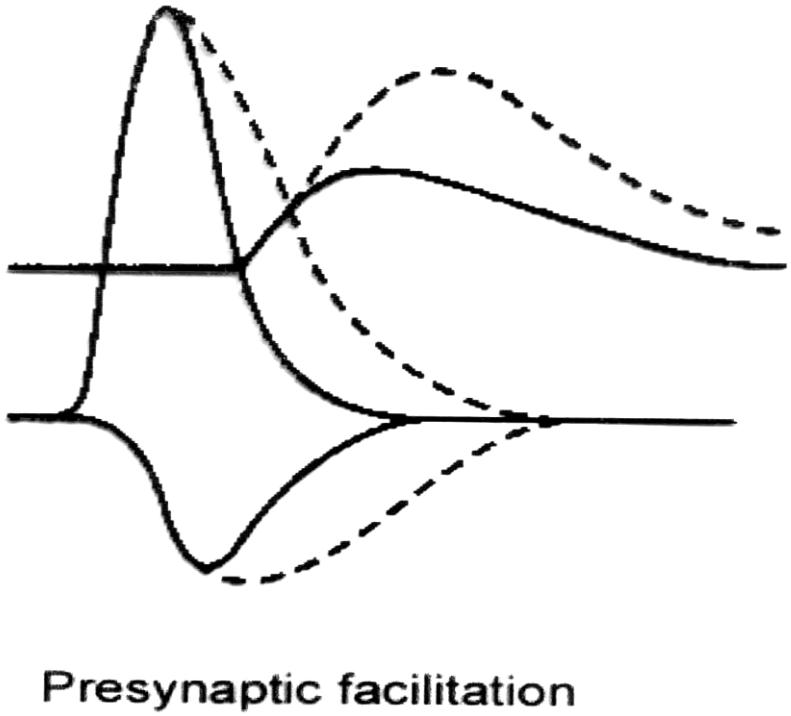
- **Postsynaptic facilitation**
- **Presynaptic facilitation**

Postsynaptic facilitation



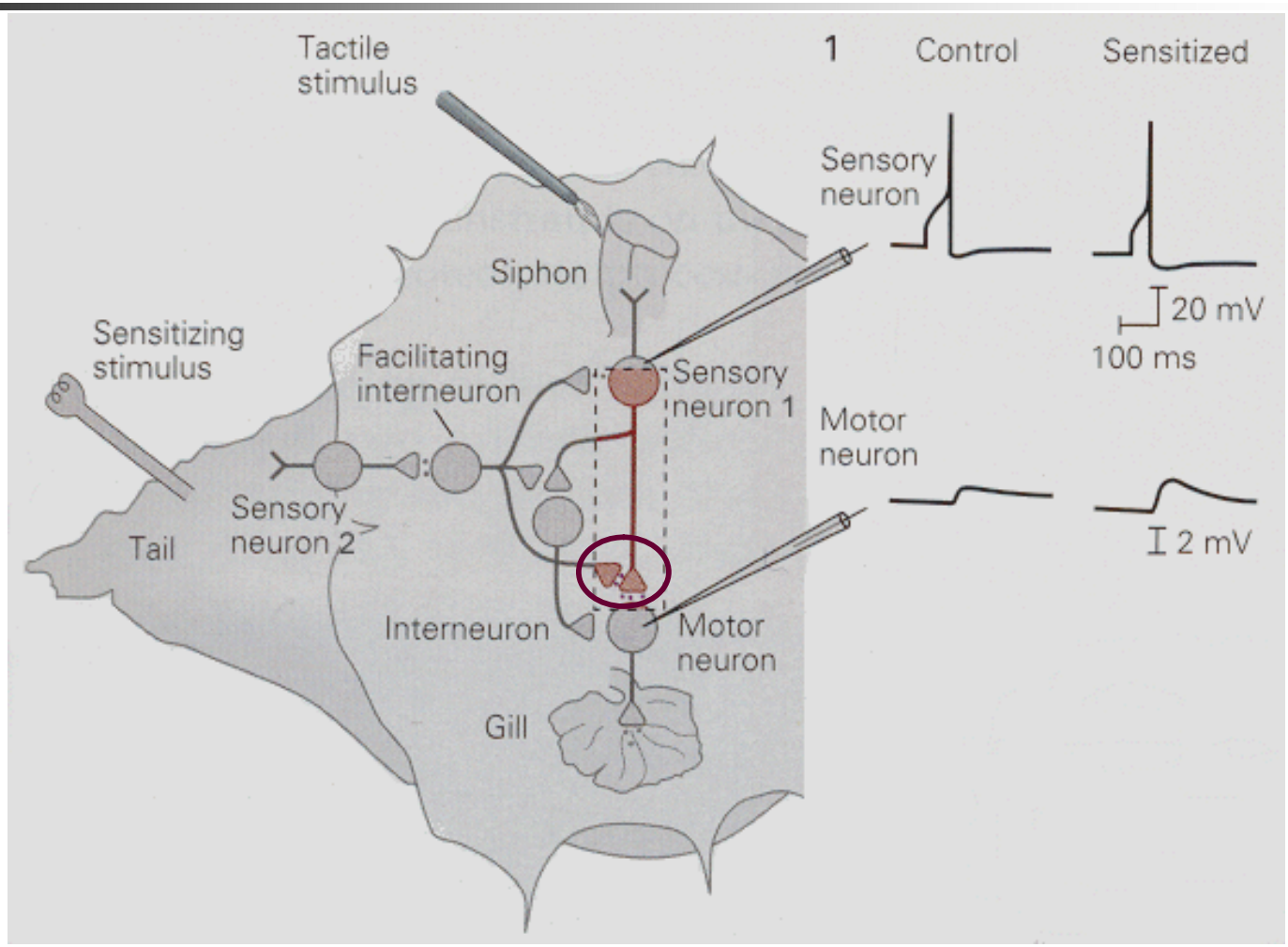
Presynaptic facilitation

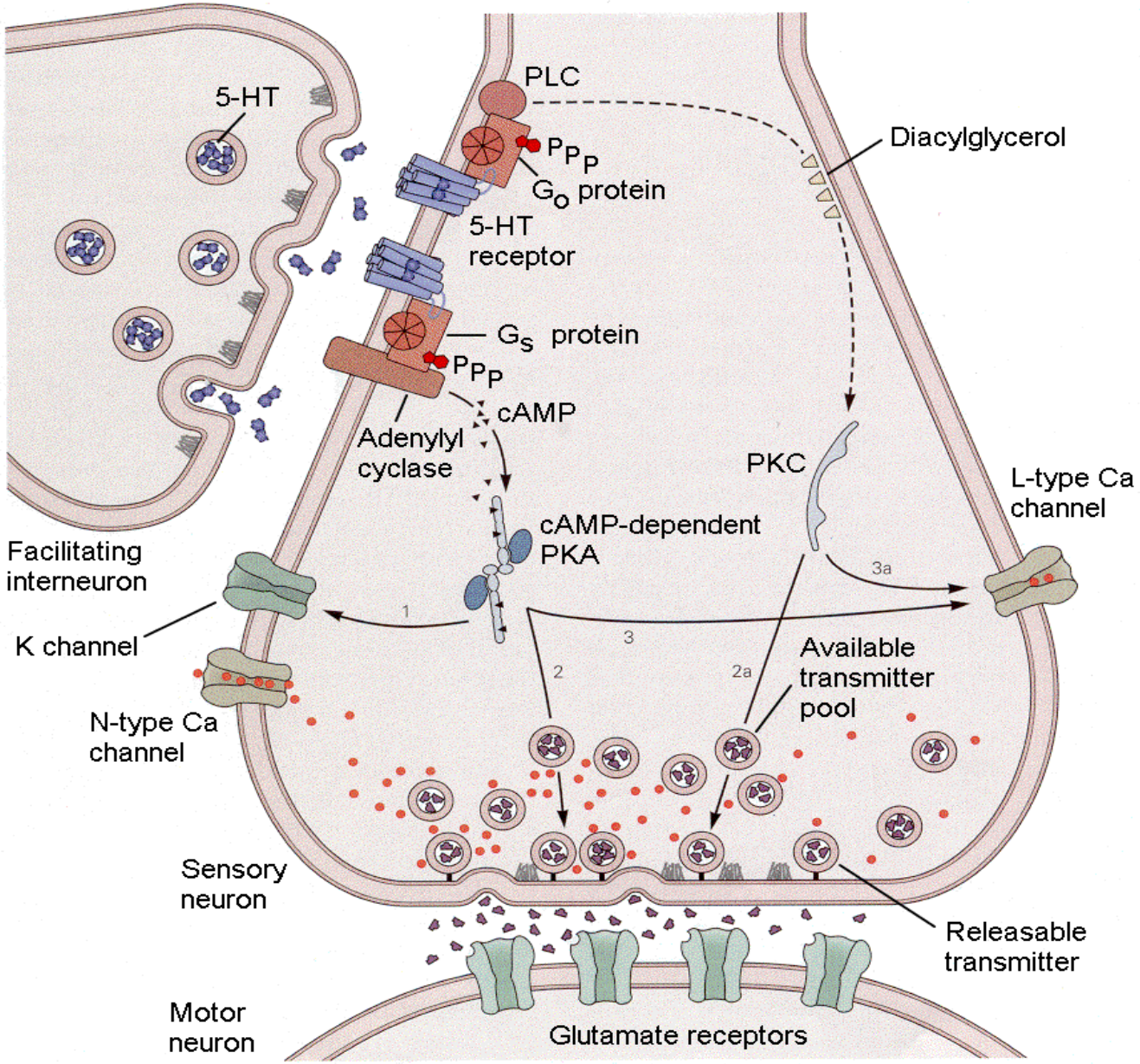




Presyanptic facilitation is produced when the AP is prolonged and the Ca^{2+} channels are open for a longer period.

Sensitization




5-HT
PLC
Diacylglycerol
PPP
G_o protein
5-HT
receptor
G_s protein
PPP
cAMP
Adenylyl
cyclase
PKC
L-type Ca
channel
cAMP-dependent
PKA
Facilitating
interneuron
3a
1
3
2
2a
K channel
Available
transmitter
pool
N-type Ca
channel
Sensory
neuron
Releasable
transmitter
Motor
neuron
Glutamate receptors

Sensitization

Mechanism:

Interneuron (5-HT)

AC ↑→ cAMP ↑→ PKA ↑

→ K^+ channel close

→ Ca^{2+} ↑

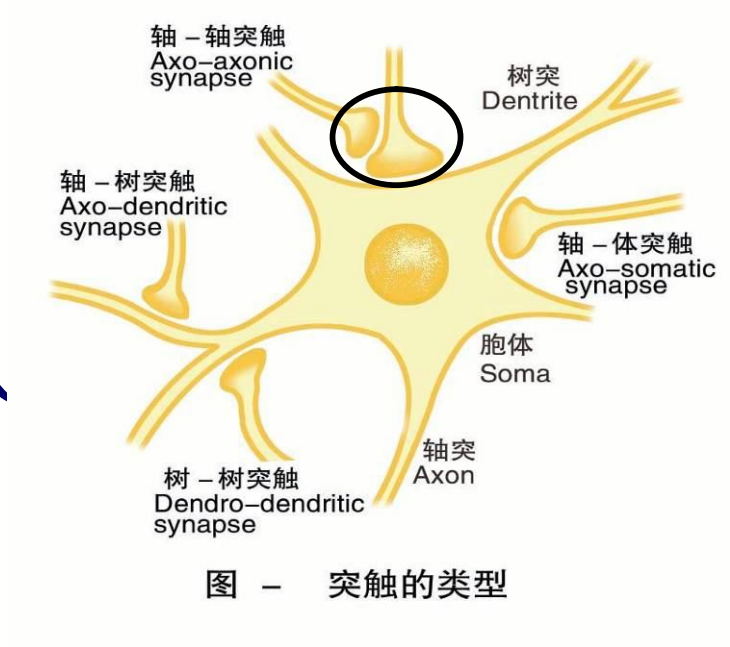
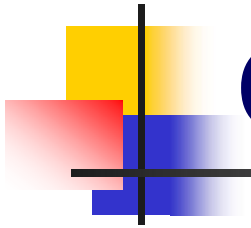
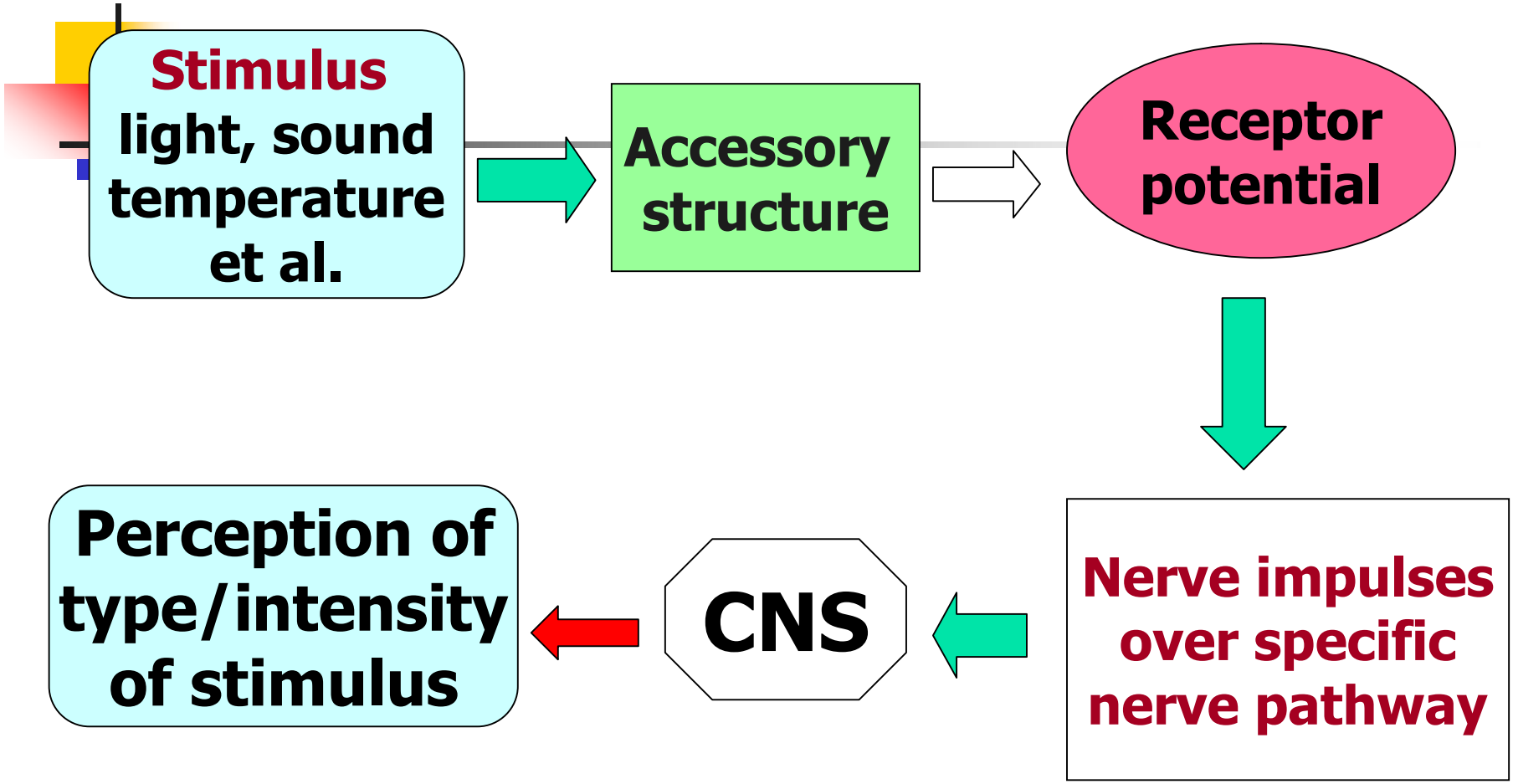


图 － 突触的类型

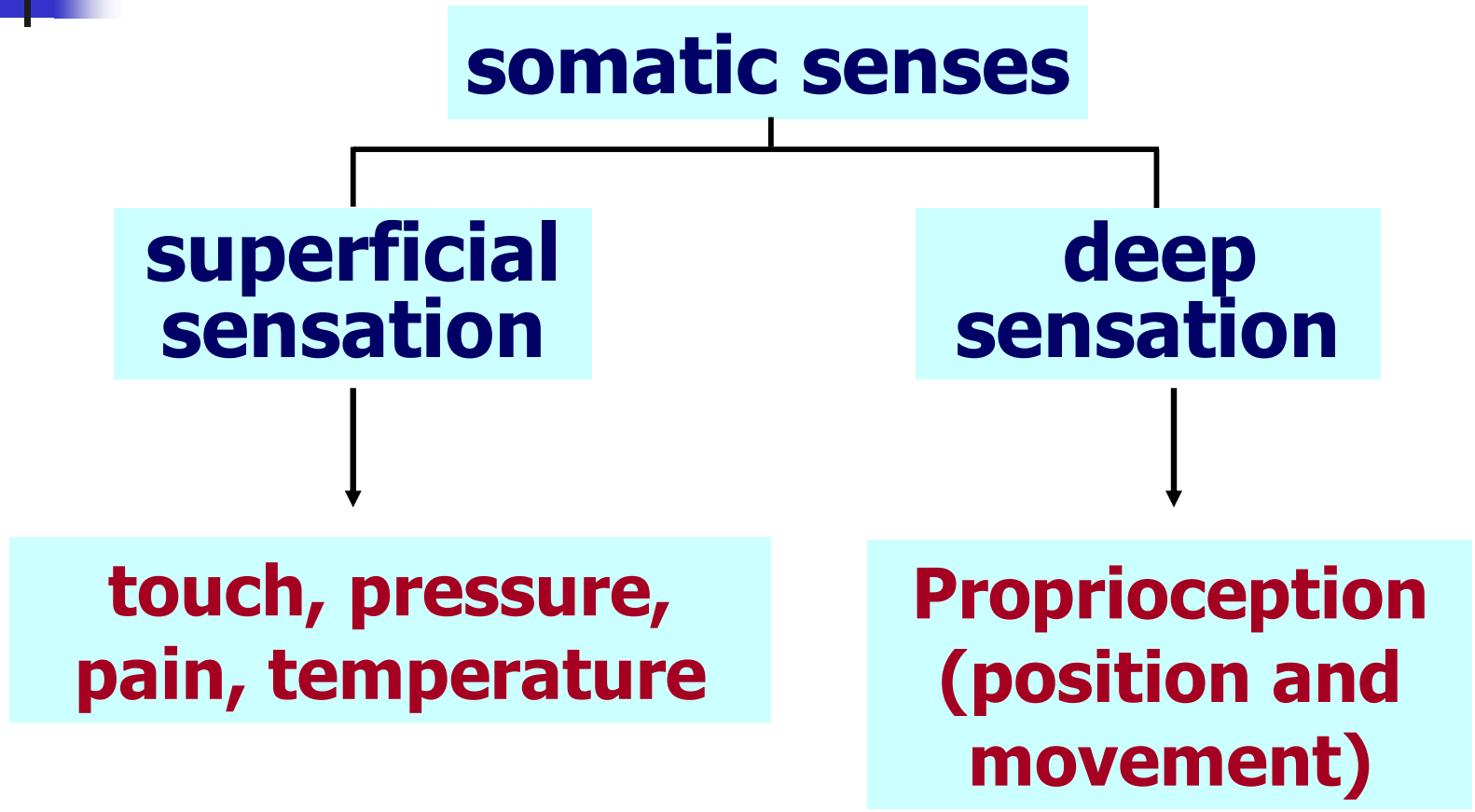


Chapter 42

Sensory Functions of the Nervous System

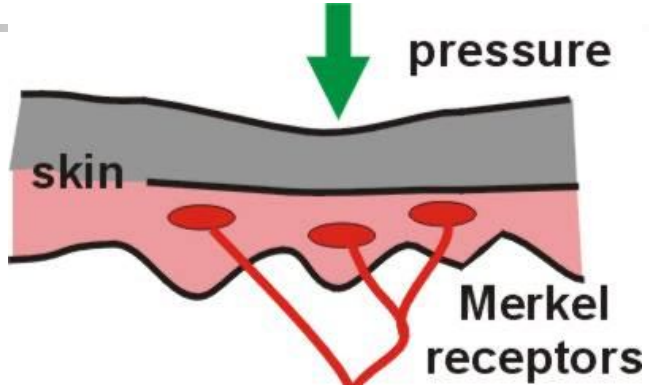

Stimulus
light, sound
temperature
et al.
Accessory
structure
Receptor
potential
Nerve impulses
over specific
nerve pathway
CNS
Perception of
type/intensity
of stimulus

一. Somatic senses & receptors of somatic senses

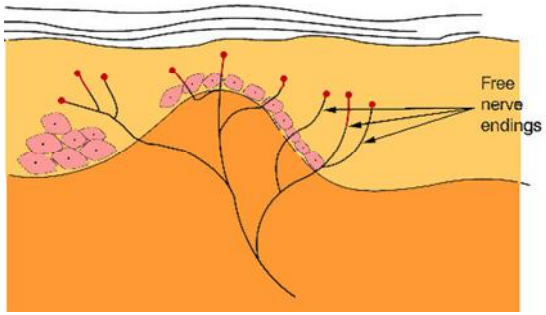


Receptors of somatic sensations and its classification

- Mechanoreceptor

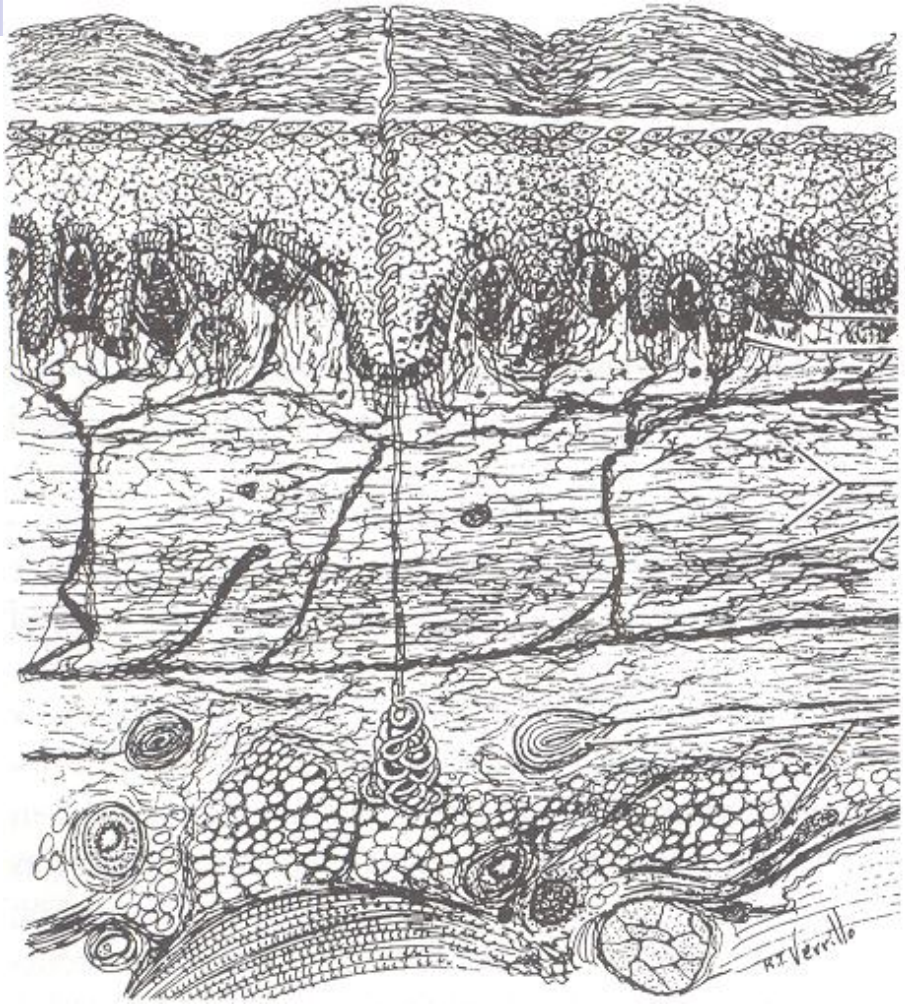


- Thermal receptor
- Nociceptor



- Proprioceptor

Mechanoreceptor



Free nerve ending

hair follicle sensor

Meissner's corpuscle

Merkel's disks

Ruffini endings

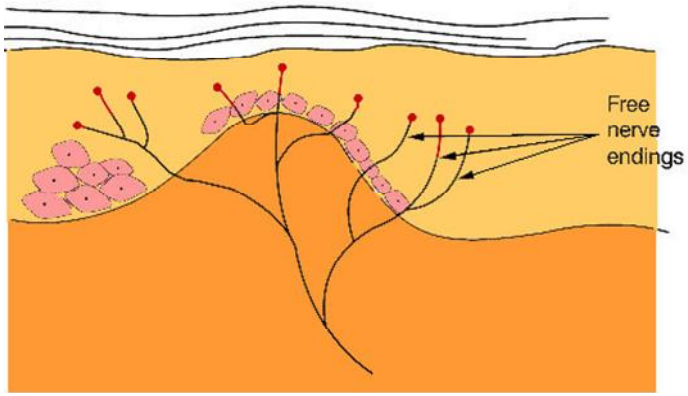
Pacinian corpuscles

Receptors of somatic sensations and its classification

- **Thermal receptor**

Heat R $\xrightarrow{32\sim45^{\circ}C}$ **C fiber**

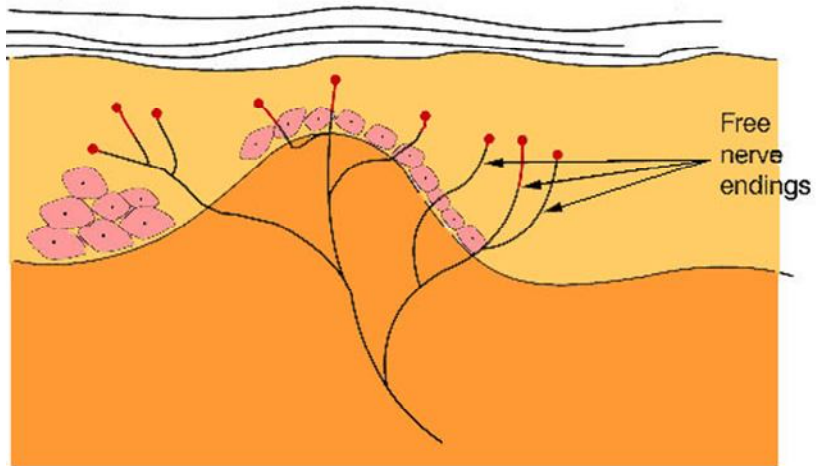
Cold R $\xrightarrow{<30^{\circ}C}$ **Aδ fiber**



Receptors for cold are more abundant than those for heat, and are located closer to the surface of skin.

Receptors of somatic sensations and its classification

- **Nociceptor for PAIN**
  - They are naked nerve endings
  - Plays a protective role
  - Continuously relays impulses to the brain



1. A δ fibers: 2–5 μm in diameter, which conduct at rates of 12–30 m/s.
2. C fibers: 0.4–1.2 μm in diameter. They conduct at rates of 0.5-2m/s.

Two kinds of pain:

- **Fast pain (Aδ fiber):**

  stimuli that produce strong shearing force in skin-cut, strong blow (hitting thumb with hammer), tug on a hair.

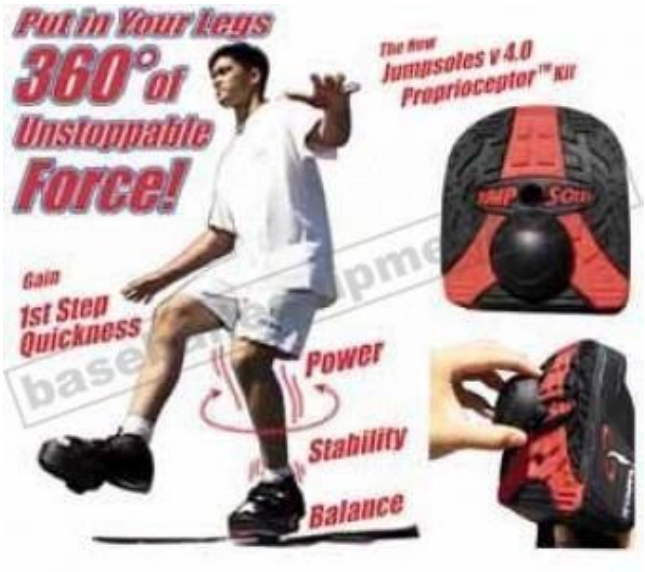
  "bright", sharp, localized sensation

- **Chronic pain (C fiber):**

  many kinds of tissue damaging stimuli, damaging heat, and chemicals released by mechanically damaged tissue.

  dull, intense, diffuse and unpleasant feeling

Proprioceptor



Muscle spindle

Golgi tendon organ

For Body Awareness

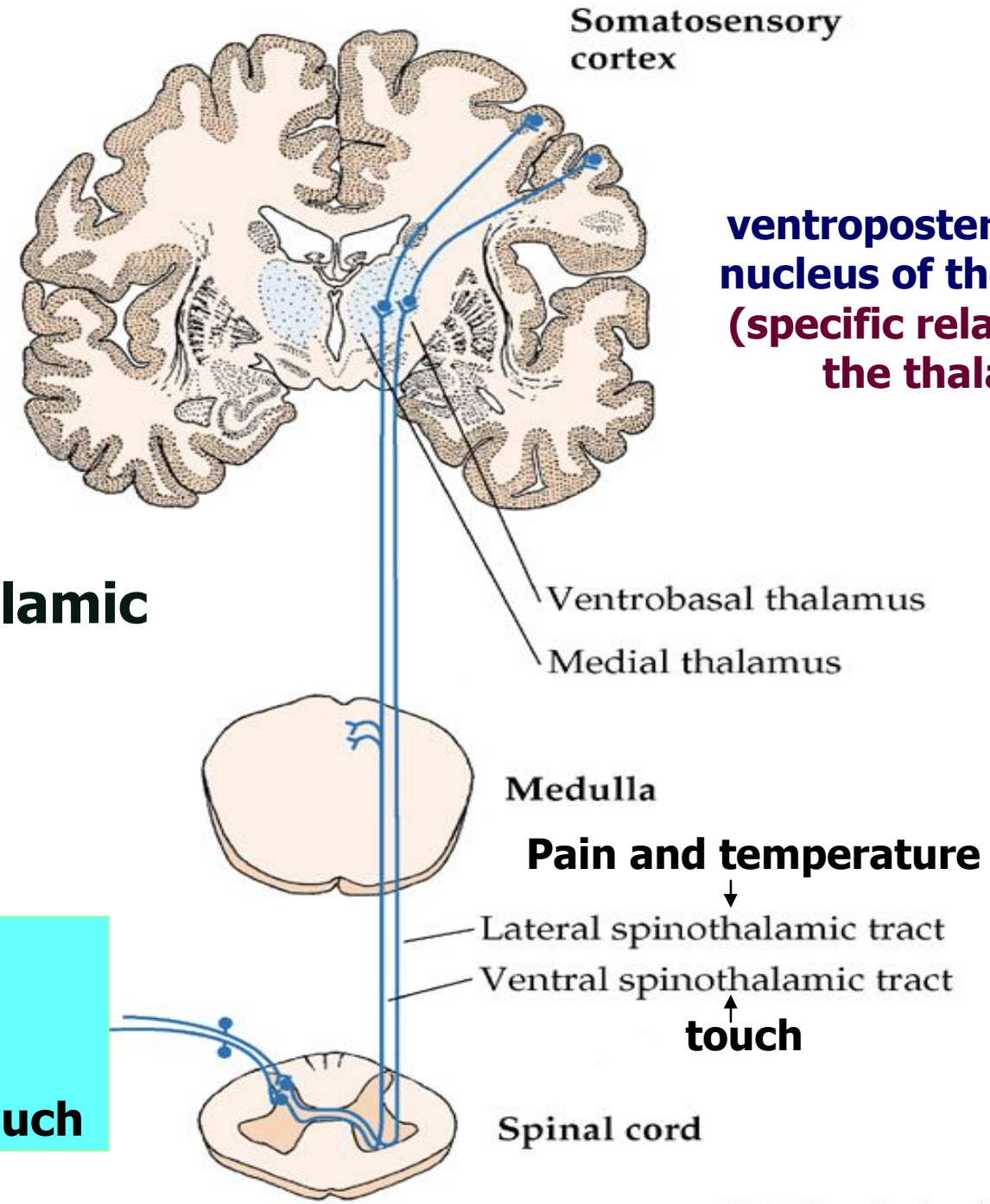
Gives information on body position, joint stretch, etc.

The proprioceptive input goes to the cerebellum, but some passes via the medial lemnisci and thalamic radiations to the cortex.

Sensory Pathways

- Conducting pathways of superficial sensation
- Conducting pathways of deep sensation

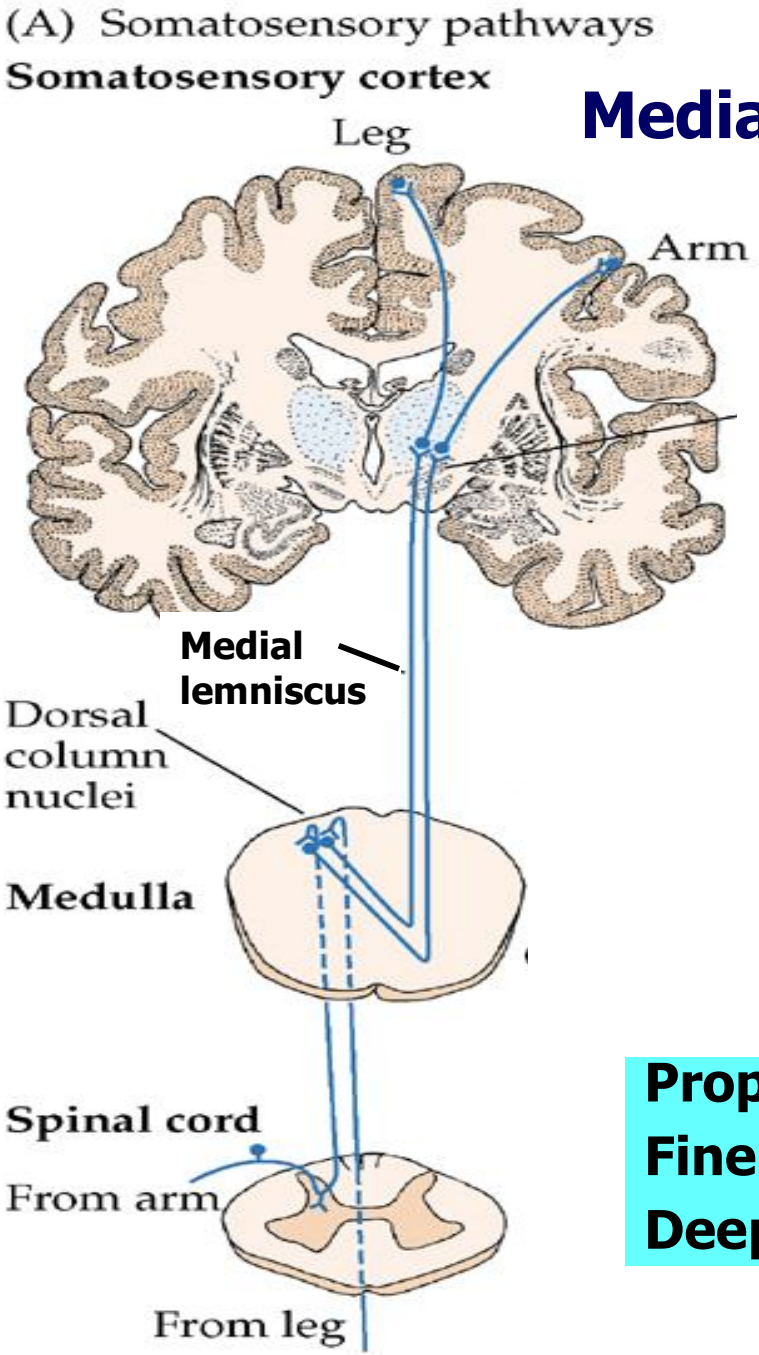
Spinothalamic pathway



ventroposterior lateral nucleus of the thalamus (specific relay nuclei of the thalamus)

Pain
Hot
Cold
Light touch

Medial lemniscal pathway



ventroposterior lateral nucleus of the thalamus (specific relay nuclei of the thalamus)

Gracilis and cuneatus nuclei

Proprioception
Fine touch
Deep pressure

Thalamus & its sensory projection

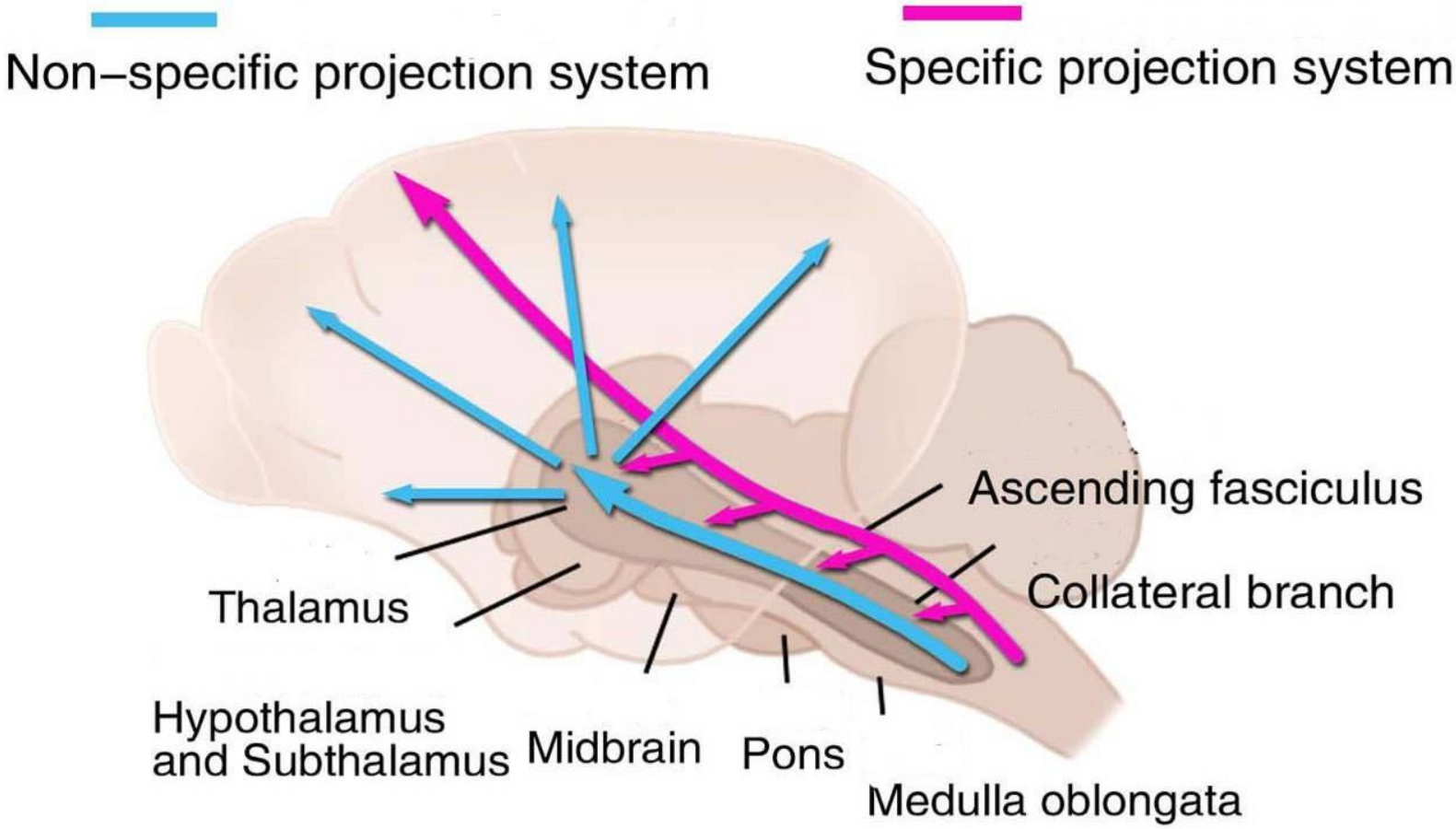
Three kinds of relay nucleus

- specific sensory relay nucleus
- associated nucleus
- nonspecific thalamic nuclei

Sensory projection system

- Specific projection system
- Nonspecific projection system

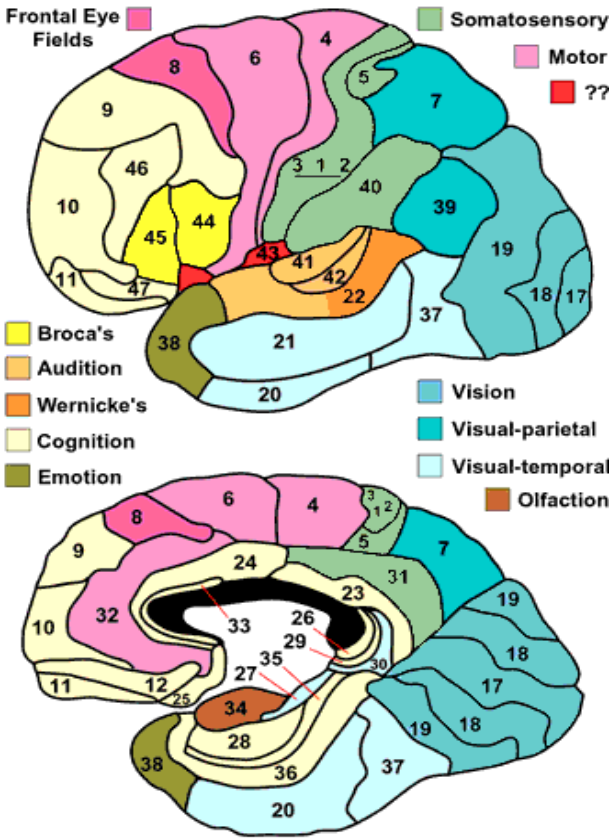
Sensory projection system

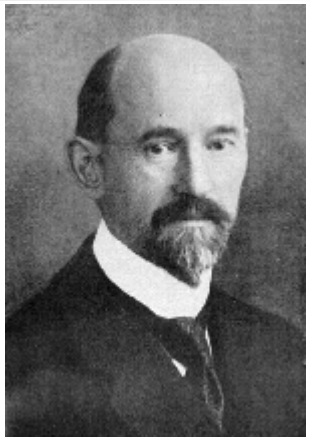


Functions of sensory projection system

- The specific projection system is in charge of the production of specific sense and arousing output of nerve impulse of the cerebral cortex.
- While the function of nonspecific projection system is to maintain and change the excitation state of the cerebral cortex and it cannot produce specific sense.

Sensory analysis function of cerebral cortex





Brodmann

(1870-1959)

Germany

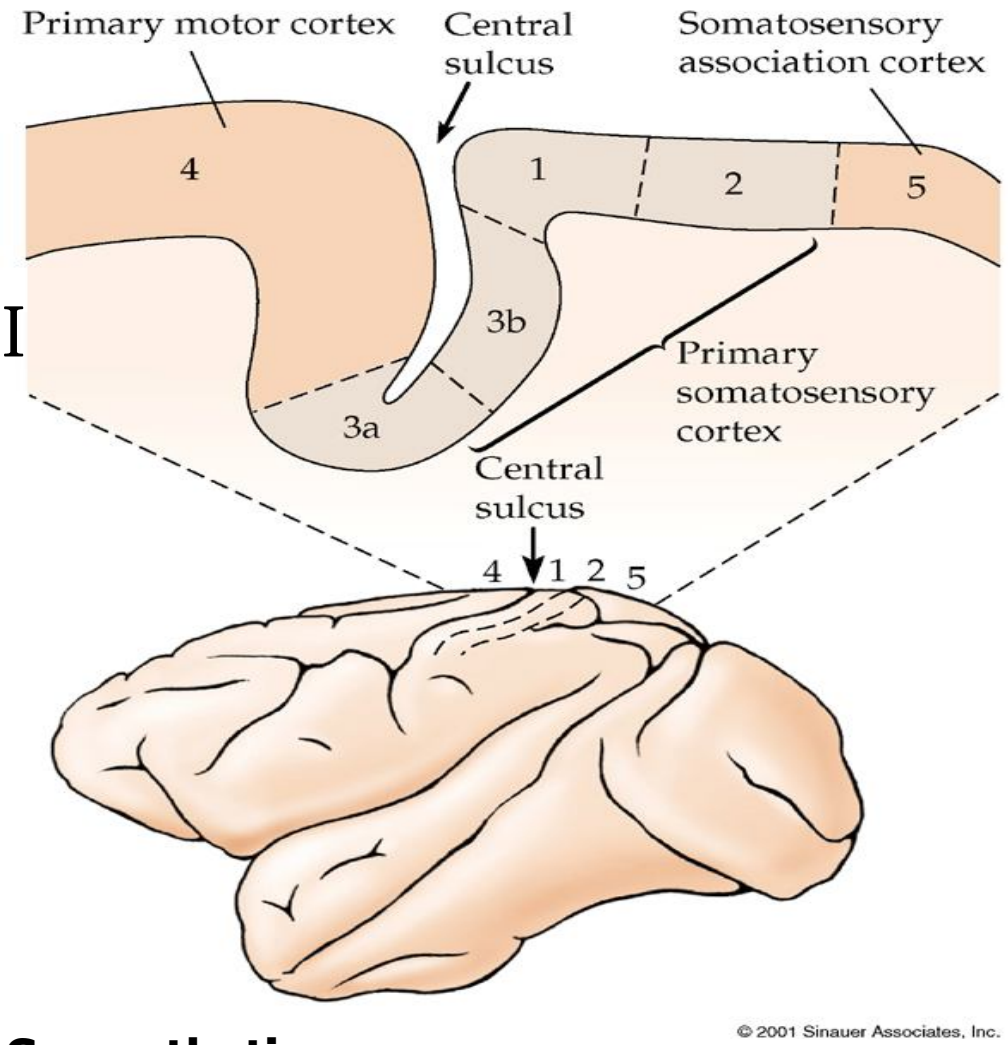
Brodmann was a histologist who divided the cerebral cortex into numbered areas based on their histologic characteristics.

Representative area of somatic sensory

Somatic sensory area Ⅰ (SⅠ)

(Brodmann's areas: 3-1-2)

postcentral gyrus

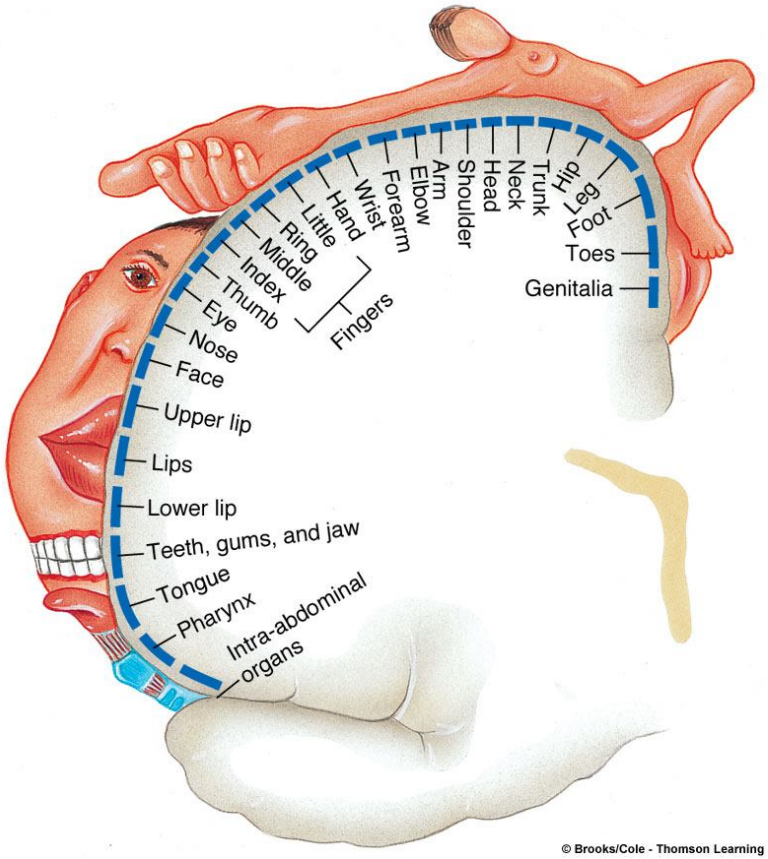


<u>The Somesthetic sensory area</u>

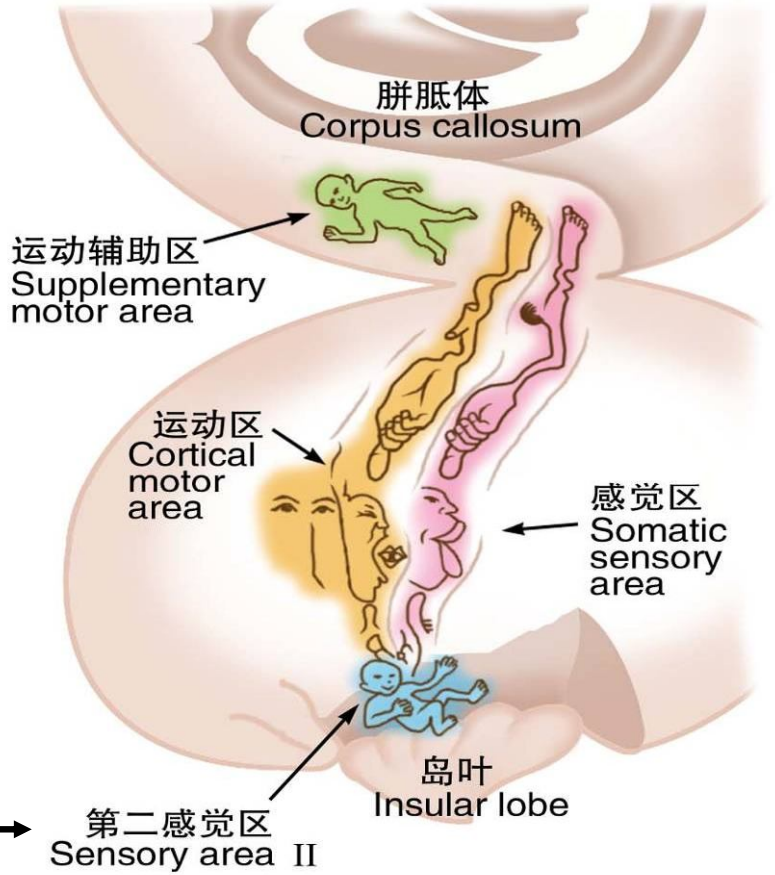
- The somesthetic area occupies the entire parietal lobe

Important rules of the somatic sensory area Ⅰ for analyzing sensory signals from the thalamus

1. Legs on top and the head at the foot of the gyrus. While the face is upright.
2. The cortical areas for sensation from the trunk and back are small, whereas the hand and the mouth occupy large areas.



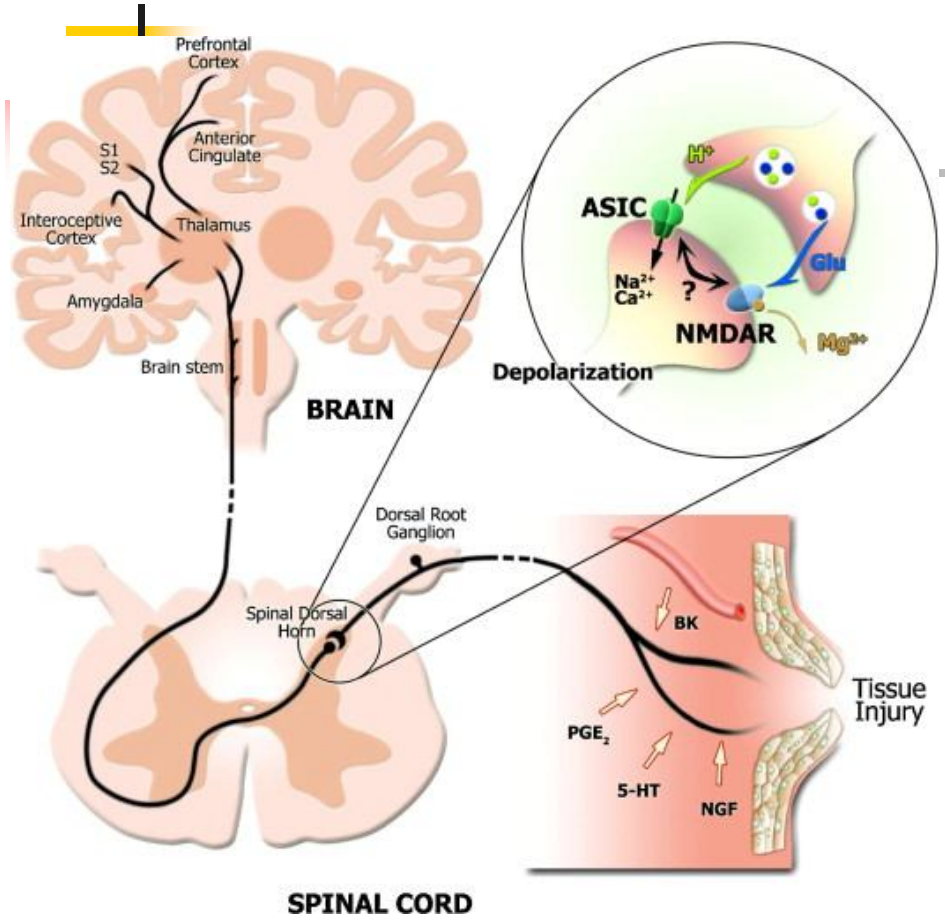
Somatic sensory area Ⅱ (SⅡ)



SII is located in the superior wall of the sylvian fissure.

The head is represented at the inferior end of the postcentral gyrus and the feet at the bottom of the sylvian fissure.

Visceral Sensory - pain



- During tissue injury, inflammatory factors, including **bradykinin, prostaglandins and 5-HT**, sensitize or excite the terminals of the nociceptor.
- Activation of the nociceptor triggers a release of excitatory transmitter glutamate in the spinal dorsal horn (SDH).
- And then the noxious stimuli are transmitted to the supraspinal structures.

[brainstem, thalamus, amygdale, insular cortex, somatosensory cortex (S1), secondary somatosensory cortex (S2), anterior cingulate cortex and prefrontal cortex]

Visceral Pain and Referred Pain

Characteristics of visceral pain:

1. poorly localized
2. unpleasant
3. associated with nausea and autonomic symptoms
4. visceral pain often rediates or is referred to other areas

Referred Pain

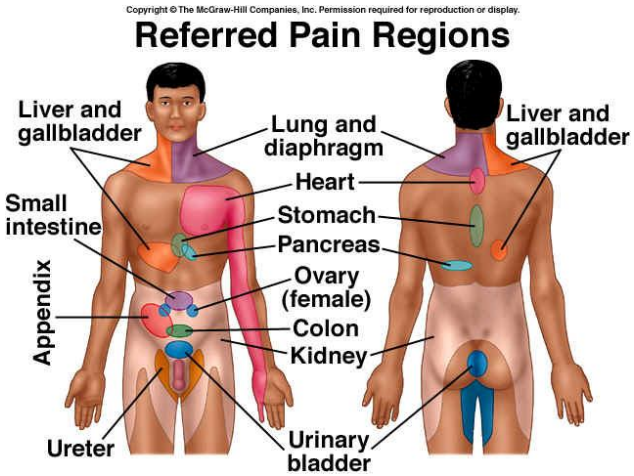
Pain of visceral origin is referred to sites on the skin.

For example:

Cardiac pain to the inner aspect of left arm;

Pain in the tip of the shoulder caused by irritation of the central portion of the diaphragm;

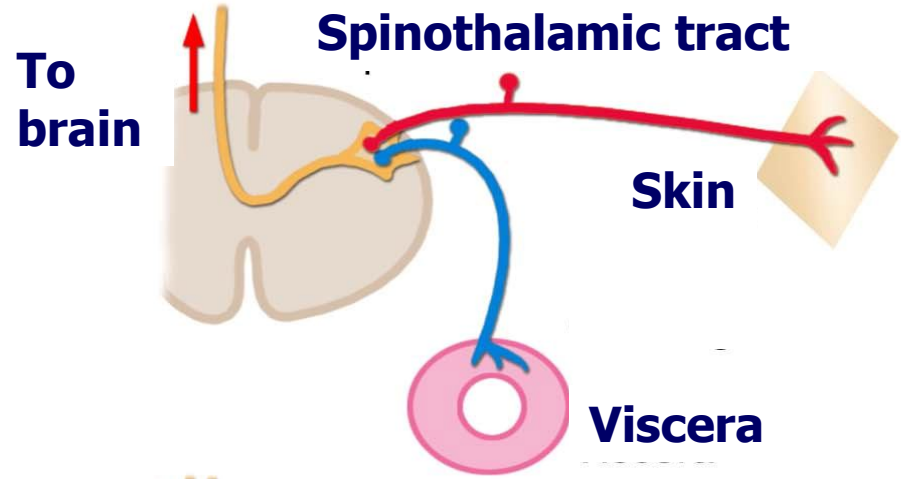
Appendicitis: for the elder, in some case, they suffer stomachache.



Mechanism of Referred Pain

- Convergence theory
- Facilitation theory

Convergence theory



Peripheral and visceral neurons converge in the ipsilateral dorsal horn

↓

Viscera pain fiber stimulate the second-order neurons

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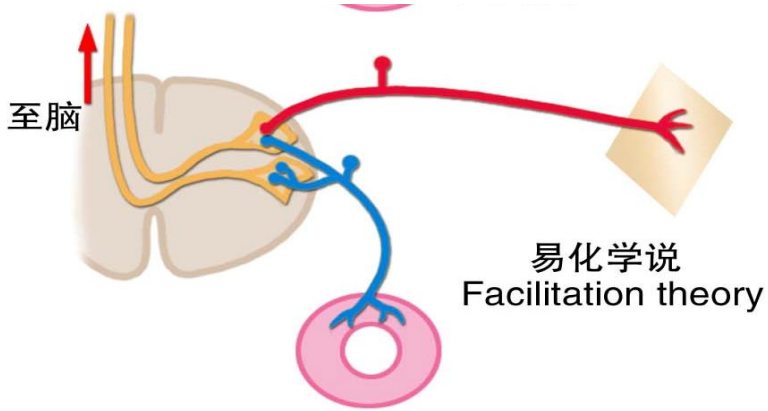
Since the brain is unused to getting such pain signals from the viscera, it deciphers that the pain is coming from the area of referral.

Facilitation theory



Peripheral and visceral neurons project to the adjacent neurons in the ipsilateral dorsal horn

↓

Visceral stimulus facilitate the second-order neurons of the peripheral neuron

↓

The second-order neurons are excited when the normal signal arrived from peripheral tissue