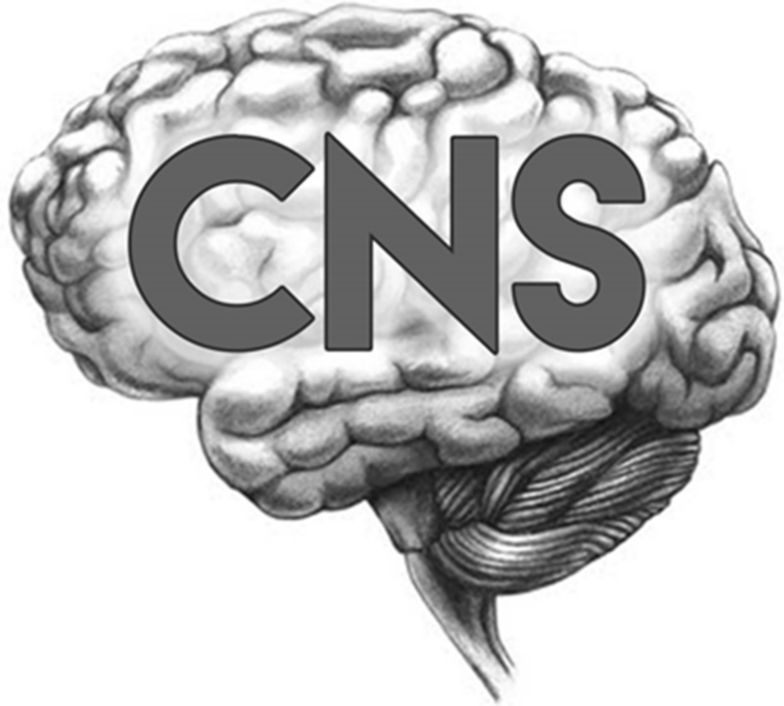


PHYSIOLOGY

○ Sheet ☑ Slide ○ Handout

Number

7

Subject

Sensory System –Synapses, Sensory Receptors; Neuronal Circuits For Processing Information

Doctor

Faisal Mohammed

Date: **00/00/2016**

Price:

Sensory System –Synapses, Sensory Receptors; Neuronal Circuits For Processing Information

Faisal I. Mohammed, MD, PhD

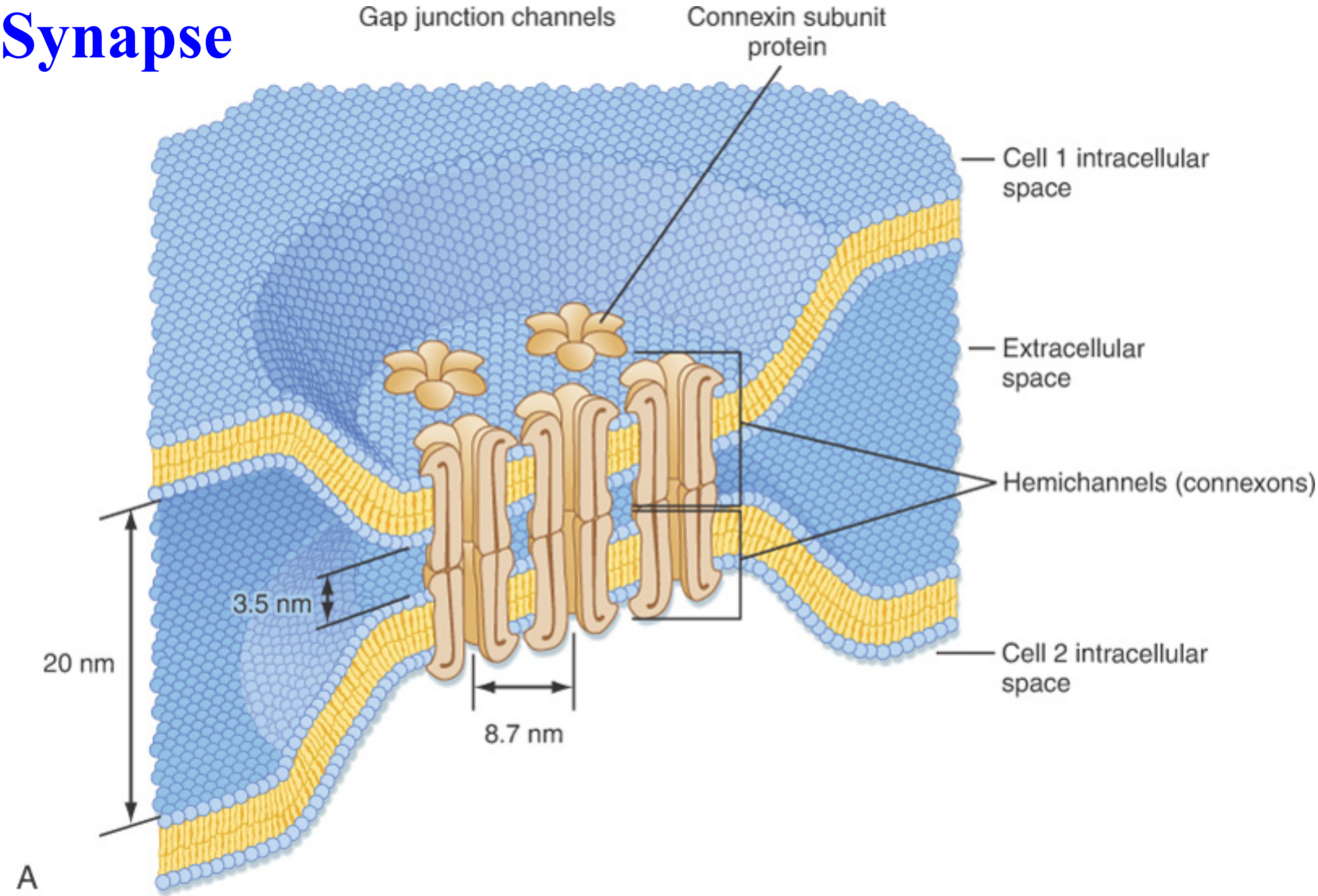
Objectives

- Define receptors (Transducers) and classify them
- Describe the generator (receptor) potential and its importance in sensory coding
- List the types of somatic receptors in the skin
- Explain the mechanism of sensory coding
- Interpret the mechanism of receptor adaptation and classify the types of receptors accordingly (Phasic and Tonic receptors)
- Describe sensory neuronal processing and its functional importance

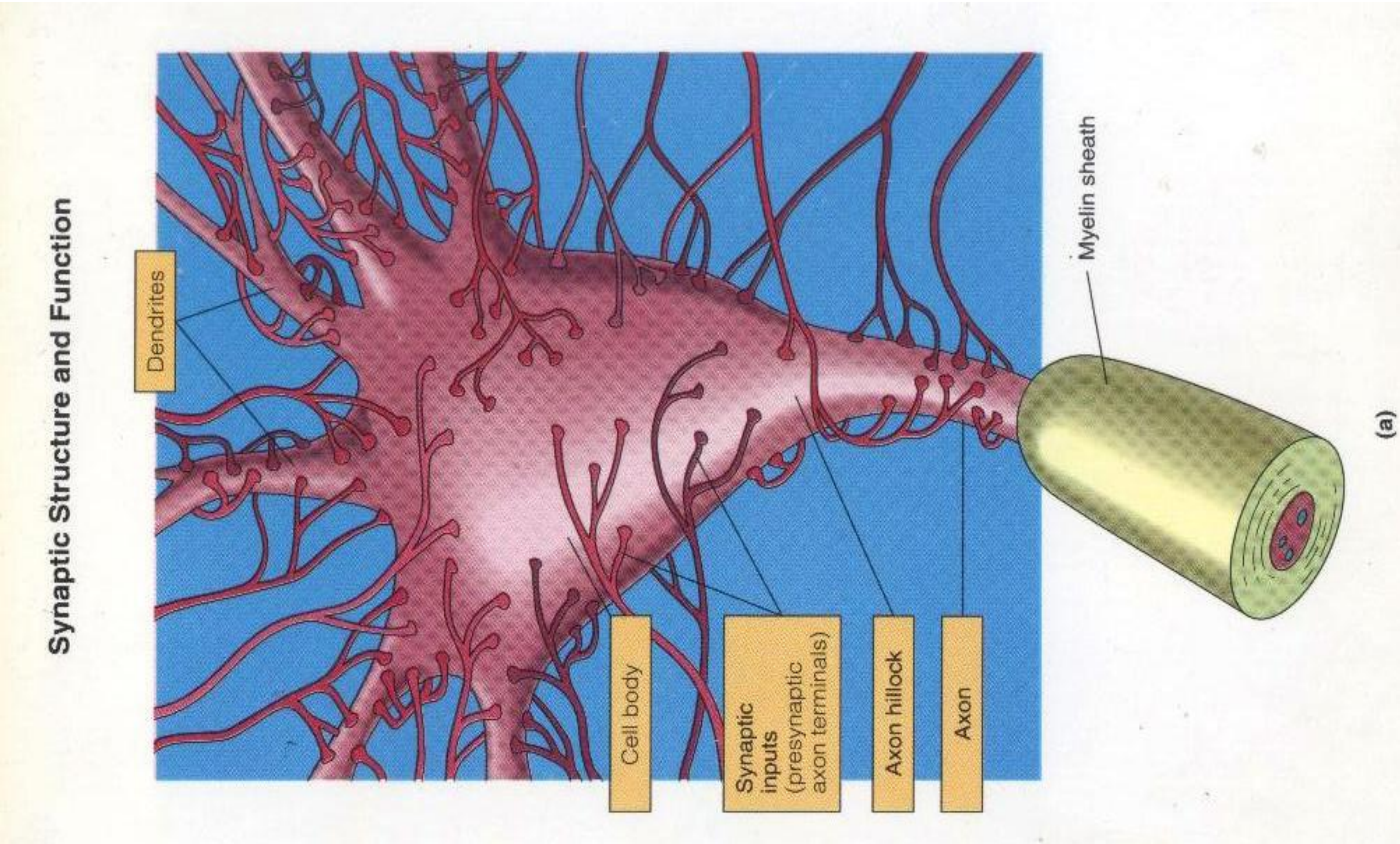
Signal Transmission at the Synapse

- 2 Types of synapses
  - Electrical
    - ionic current spreads to next cell through gap junctions
    - faster, two-way transmission & capable of synchronizing groups of neurons
  - Chemical
    - one-way information transfer from a presynaptic neuron to a postsynaptic neuron
      - axodendritic -- from axon to dendrite
      - axosomatic -- from axon to cell body
      - axoaxonic -- from axon to axon

Electrical Synapse

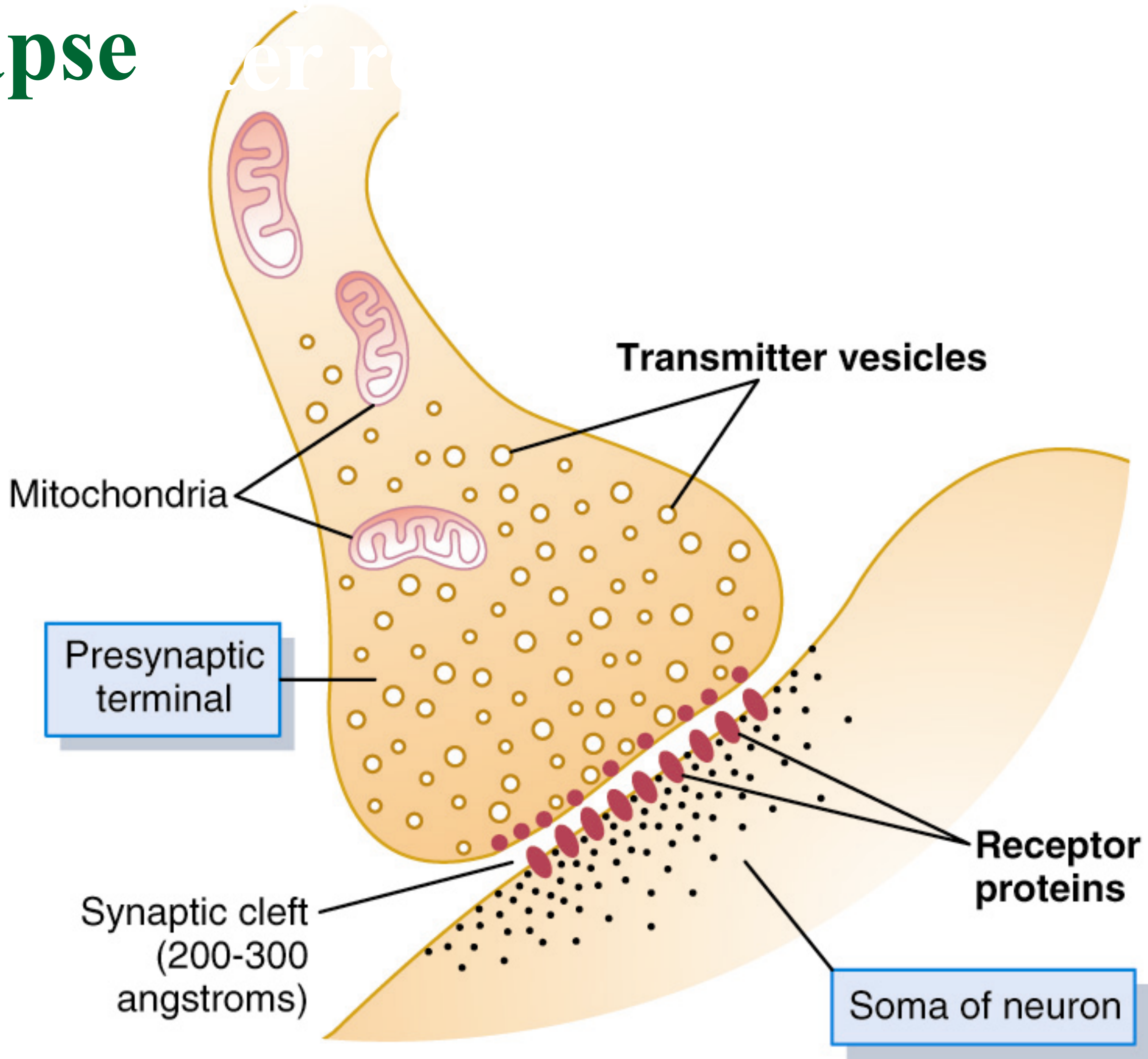


(From De Zeeuw CI, Lang EJ, Sugihara I, et al: J Neurosci 16: 3420, 1996. Copyright 1996 by the Society for Neuroscience.)



Synaptic Structure and Function
Dendrites
Cell body
Synaptic inputs (presynaptic axon terminals)
Axon hillock
Axon
Myelin sheath
(a)

Chemical synapse

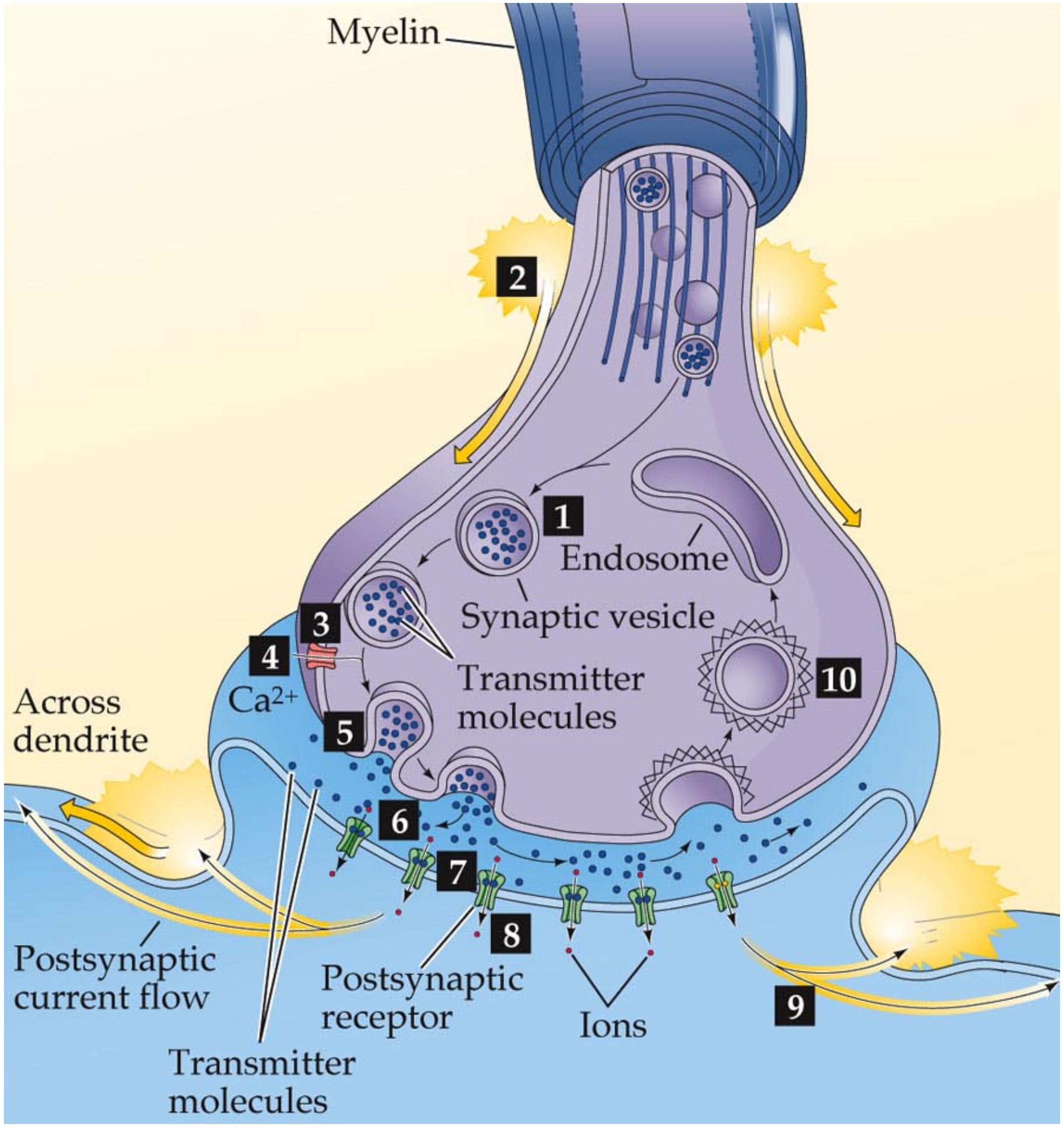


Mechanism of Neurotransmitter Release

- Presynaptic membranes contain *voltage - gated calcium channels.*
  - depolarization of the presynaptic membrane by an action potential opens voltage-gated Ca^{2+} channels
  - influx of Ca^{2+} induces the release of the neurotransmitter substance
  - the exact mechanism is unknown but it results in the fusion of the synaptic vessel to the membrane and release of transmitter by exocytosis

▪ Neurotransmitter Release: exocytosis and endocytosis

1. Transmitter synthesized and stored
2. Action Potential
3. Depolarization: open voltage-gated Ca^{2+} channels
4. Ca^{2+} enter cell
5. Ca^{2+} causes vesicles to fuse with membrane
6. Neurotransmitter released (exocytosis)
7. Neurotransmitter binds to postsynaptic receptors
8. Opening or closing of postsynaptic channels
9. Postsynaptic current excites or inhibits postsynaptic potential to change excitability of cell
10. Retrieval of vesicles from plasma membrane (endocytosis)



Neurotransmitters

Table 45–1

Small-Molecule, Rapidly Acting Transmitters

Class I
- Acetylcholine

Class II: The Amines
- Norepinephrine
- Epinephrine
- Dopamine
- Serotonin
- Histamine

Class III: Amino Acids
- Gamma-aminobutyric acid (GABA)
- Glycine
- Glutamate
- Aspartate

Class IV
- Nitric oxide (NO)

Table 45–2

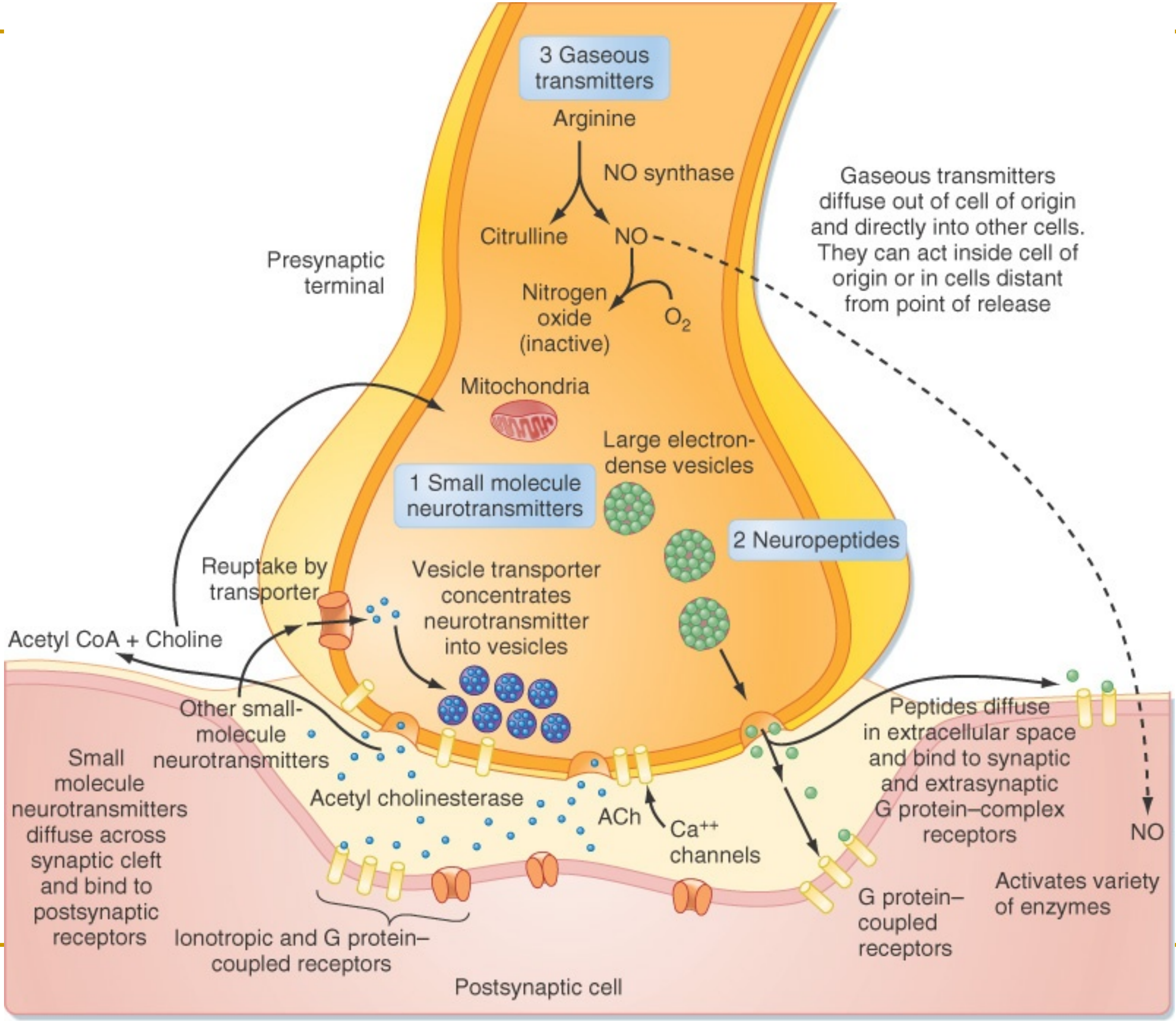
Neuropeptide, Slowly Acting Transmitters or Growth Factors

Hypothalamic-releasing hormones
- Thyrotropin-releasing hormone
- Luteinizing hormone–releasing hormone
- Somatostatin (growth hormone inhibitory factor)

Pituitary peptides
- Adrenocorticotropic hormone (ACTH)
- β-Endorphin
- α-Melanocyte-stimulating hormone
- Prolactin
- Luteinizing hormone
- Thyrotropin
- Growth hormone
- Vasopressin
- Oxytocin

Peptides that act on gut and brain
- Leucine enkephalin
- Methionine enkephalin
- Substance P
- Gastrin
- Cholecystokinin
- Vasoactive intestinal polypeptide (VIP)
- Nerve growth factor
- Brain-derived neurotropic factor
- Neurotensin
- Insulin
- Glucagon

From other tissues
- Angiotensin II
- Bradykinin
- Carnosine
- Sleep peptides
- Calcitonin



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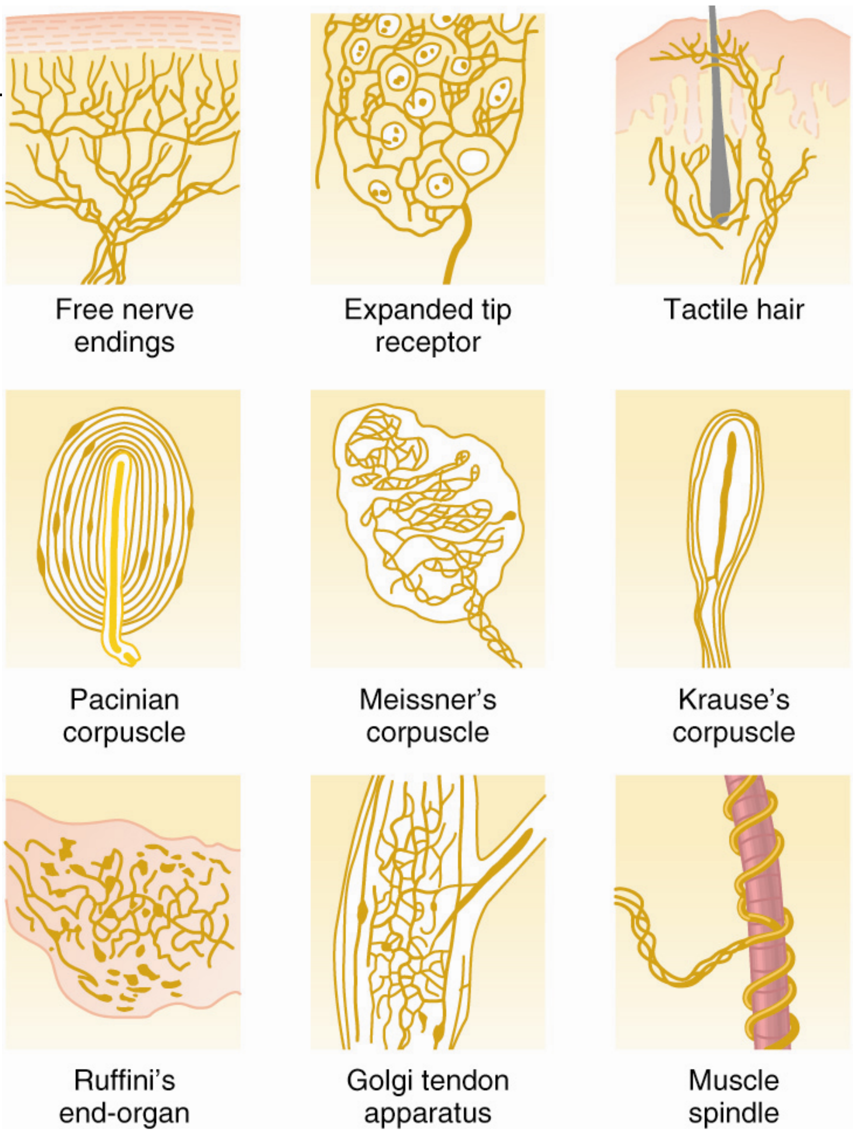
Types of Sensory Receptors: Classification by Modality (Stimulus they transduce)

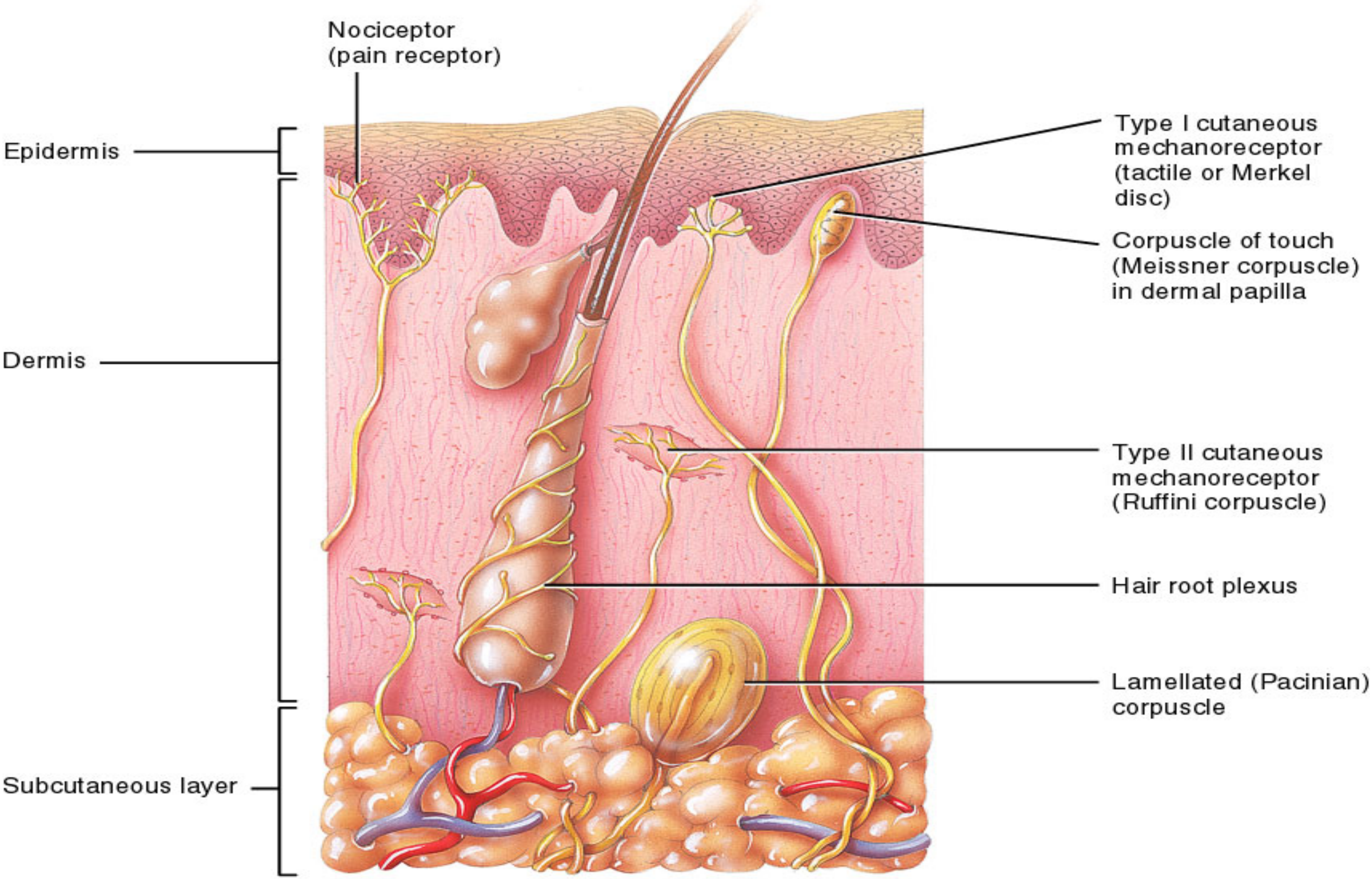
- Mechanoreceptors
  - detect deformation, Touch and Prssure
- Thermoreceptors
  - detect change in temperature
- Nociceptors
  - detect tissue damage (pain receptors)
- Electromagnetic (Photoreceptors)
  - detect light (Rods and Cones)
- Chemoreceptors
  - taste, smell, CO_2, O_2, etc.

Classification by Location

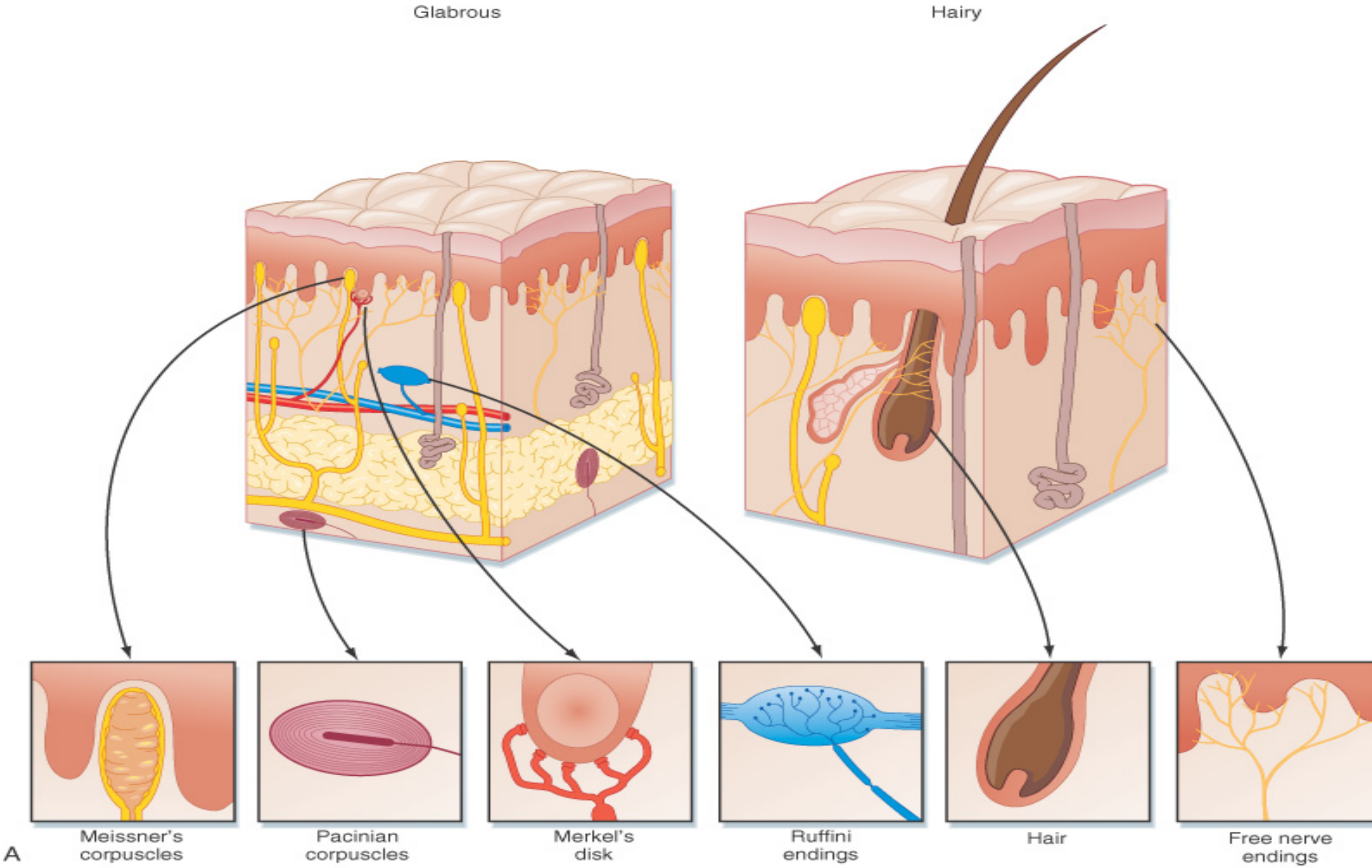
- Exteroceptors – sensitive to stimuli arising from outside the body
  - Located at or near body surfaces
  - Include receptors for touch, pressure, pain, and temperature
- Interoceptors – (visceroceptors) receive stimuli from internal viscera
  - Monitor a variety of stimuli (distension of viscera, pain)
- Proprioceptors – sense of position- monitor degree of stretch
  - Located in musculoskeletal organs (muscle, tendons and skin around joints)

Types of Sensory Receptors




Nociceptor
(pain receptor)
Epidermis
Dermis
Subcutaneous layer
Type I cutaneous mechanoreceptor (tactile or Merkel disc)
Corpuscle of touch (Meissner corpuscle) in dermal papilla
Type II cutaneous mechanoreceptor (Ruffini corpuscle)
Hair root plexus
Lamellated (Pacinian) corpuscle

15.02



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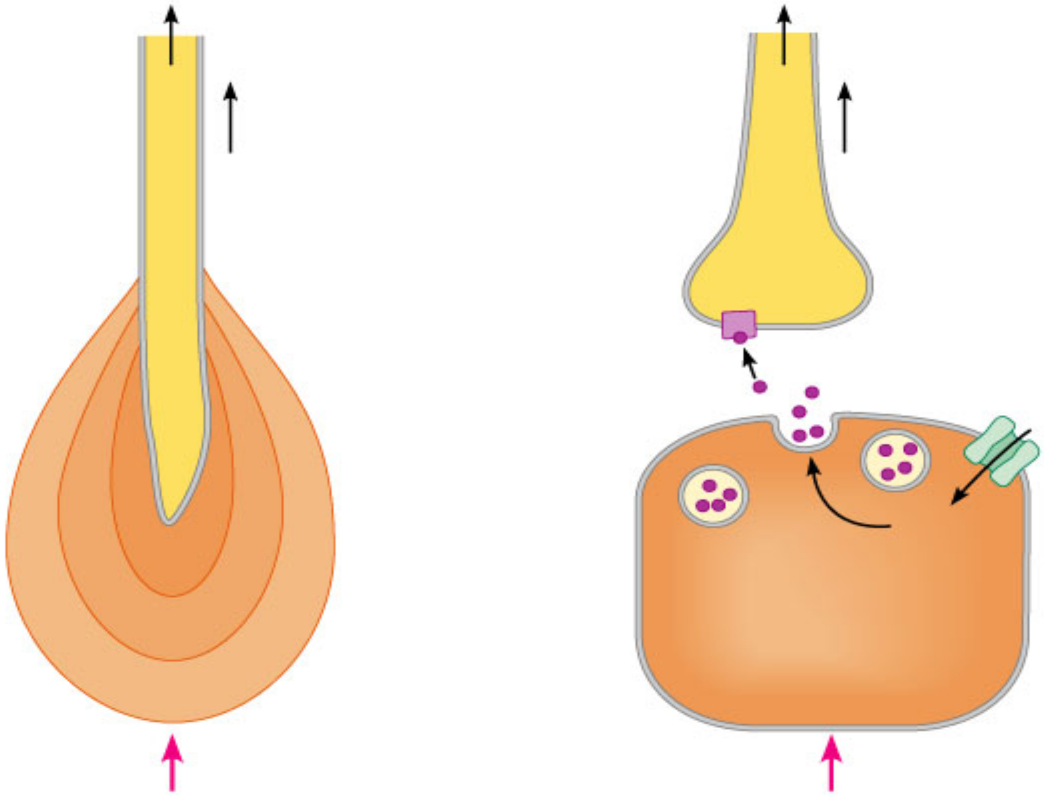
Sensory Receptors: General structure

Receptor area is None-excitable region so as it can discriminate different intensities, otherwise it will not be able to differentiate strengths of stimuli

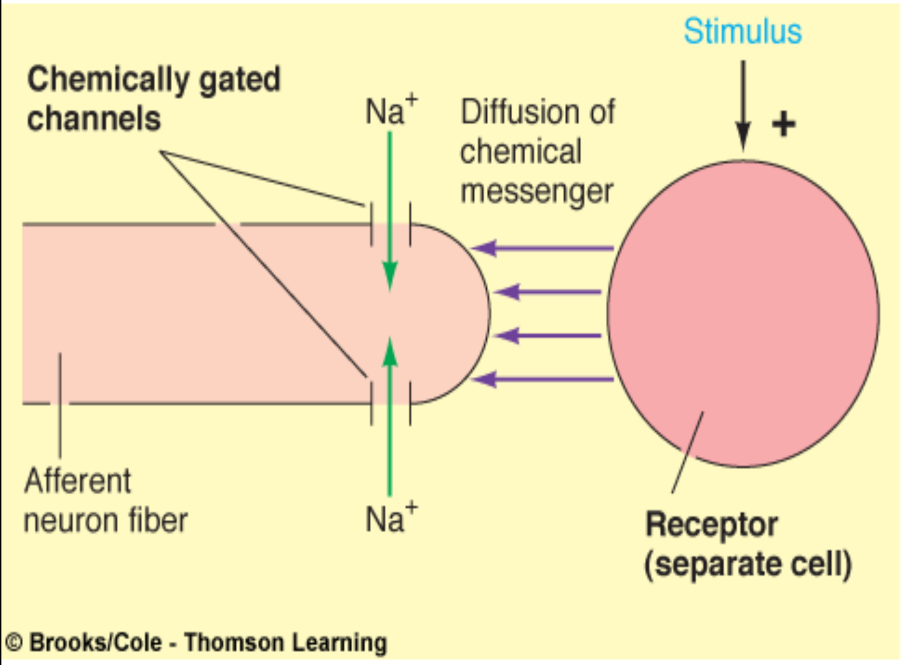


(a)

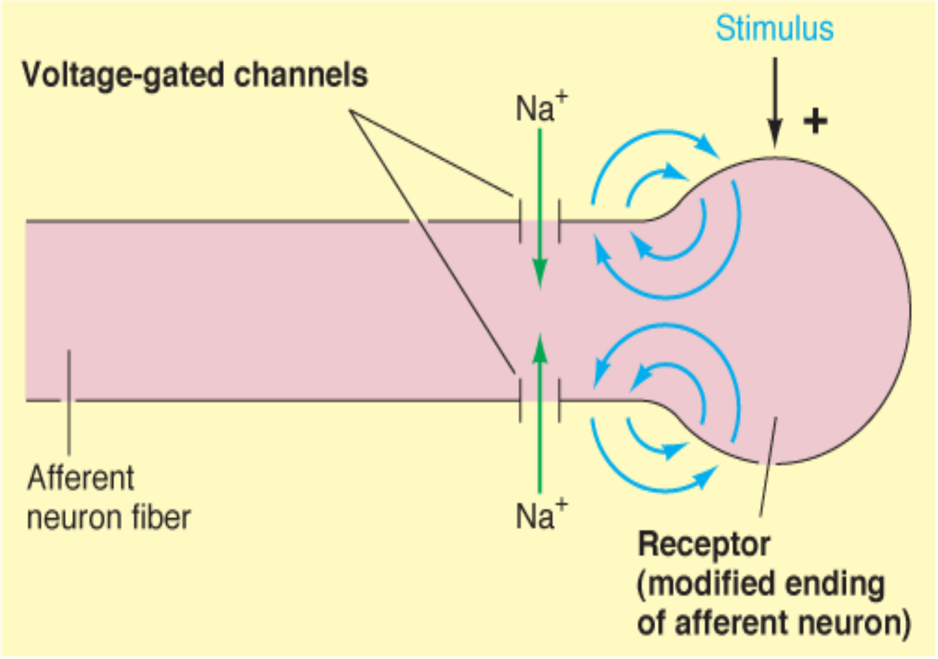
(b)

Conversion of Receptor and Generator Potentials into Action Potentials

Receptor Potential



Generator Potential



Law of Specific Nerve Energies

- Sensation characteristic of each sensory neuron is that produced by its normal or adequate stimulus.
- Adequate stimulus:
  - Requires least amount of energy to activate a receptor.
- Regardless of how a sensory neuron is stimulated, only one sensory modality will be perceived (specificity of receptors)
  - Allows brain to perceive the stimulus accurately under normal conditions.

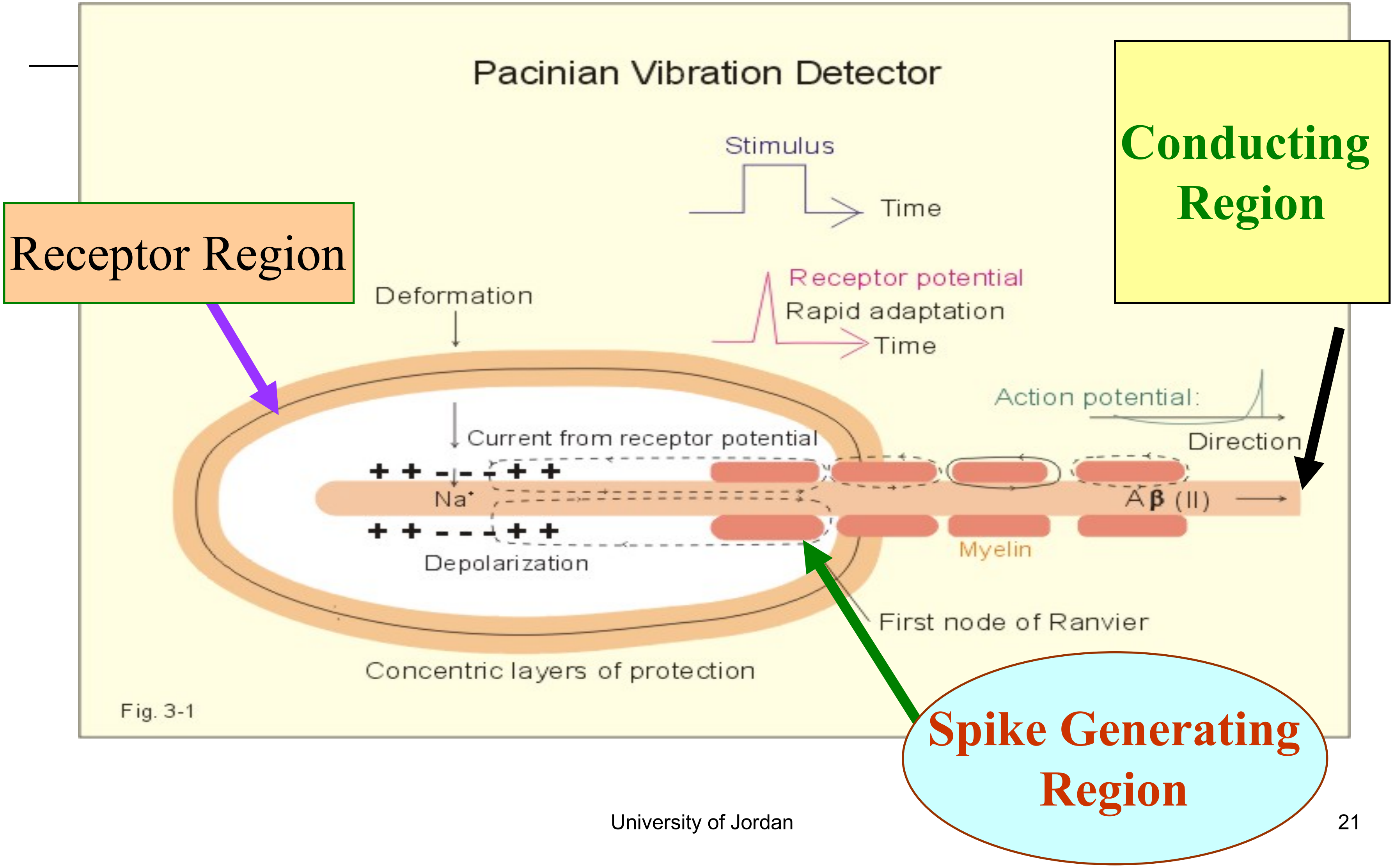
Sensation

- Each of the principle types sensation; touch, pain, sight, sound, is called a *modality of sensation*.
- Each receptor is responsive to one type of stimulus energy. Specificity is a key property of a receptor, it underlines the most important coding mechanism, *the labeled line principle*
- How the sensation is perceived is determined by the characteristics of the receptor and the central connections of the axon connected to the receptor.

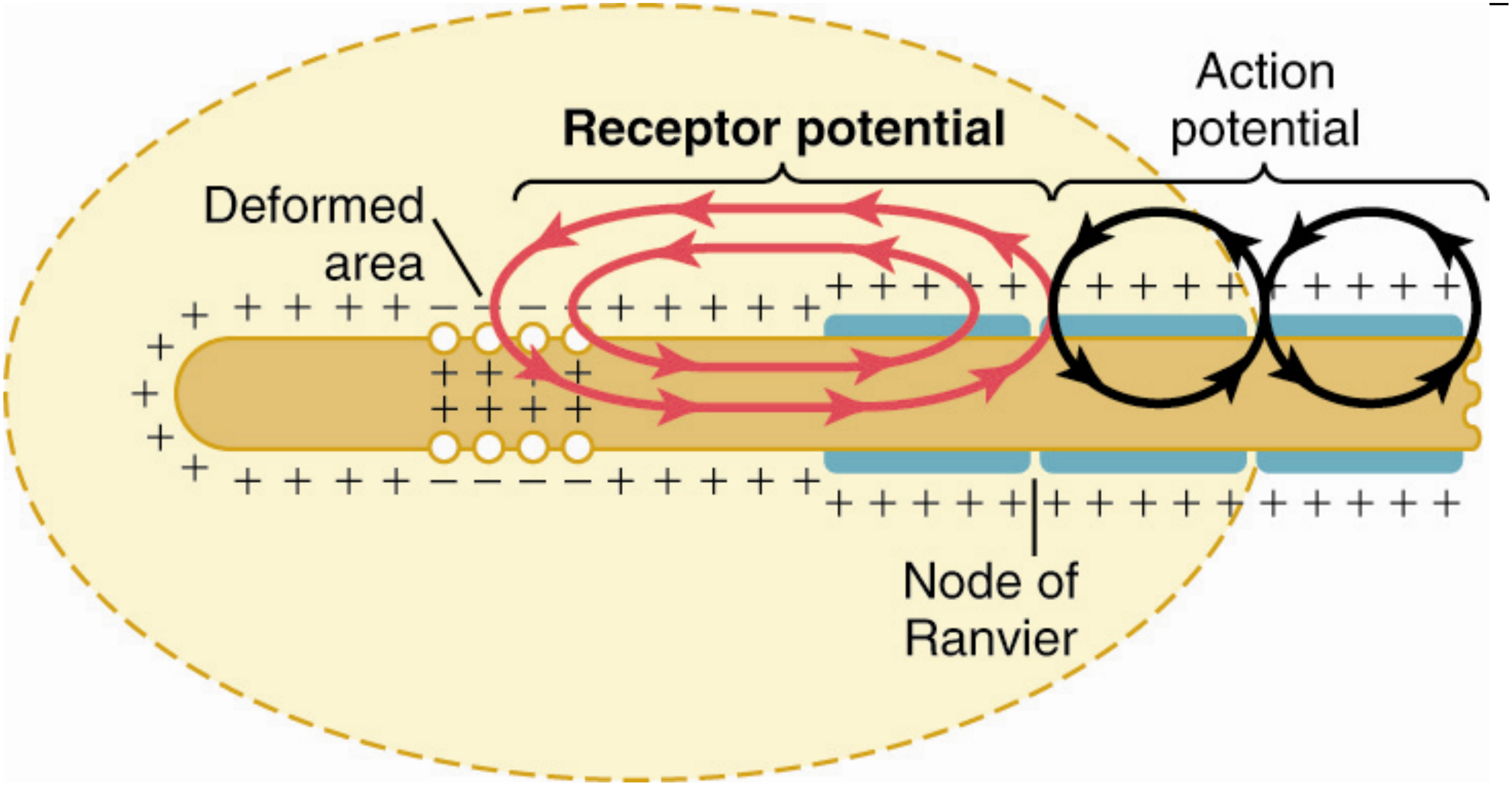
Receptor Excitation

- mechanical deformation which stretches the membrane and opens ion channels
- application of chemicals which also opens ion channels
- change in temperature which alters the permeability of the membrane through changing the metabolic rate
- electromagnetic radiation that changes the membrane characteristics

General Structure of Receptors



Receptor Excitation

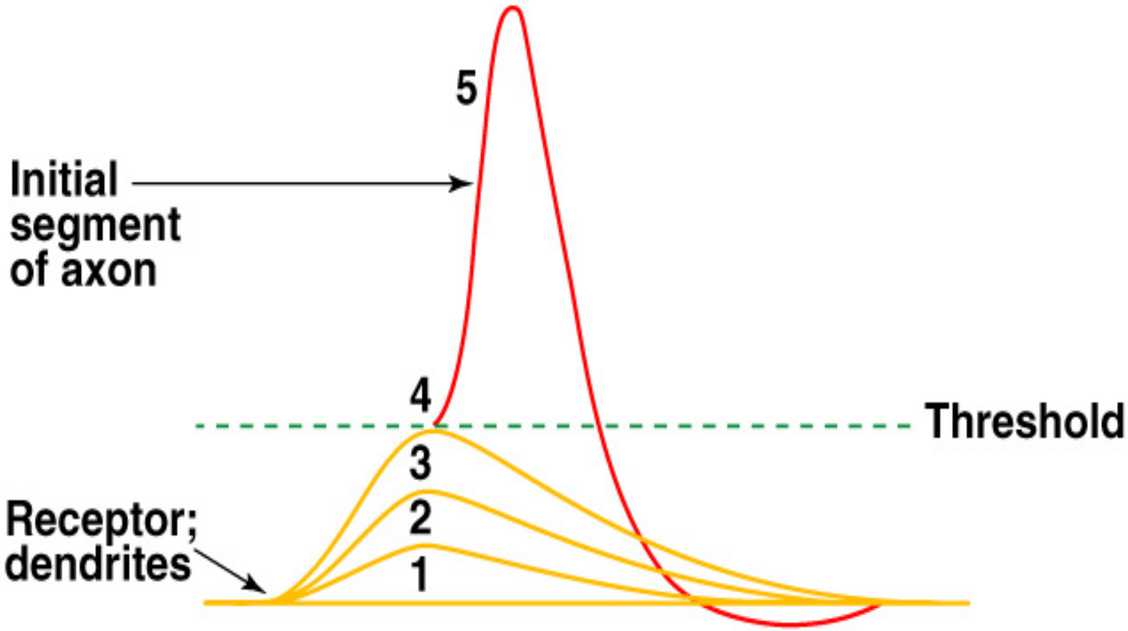


Receptor Potential

- The membrane potential of the receptor
  - Excitation of the receptor results from a change in this potential.
  - When the receptor potential rises above the threshold, action potentials appear and the receptor is active.
  - The greater the intensity of the stimulus, the greater the receptor potential, and the greater the rate of action potential generation.

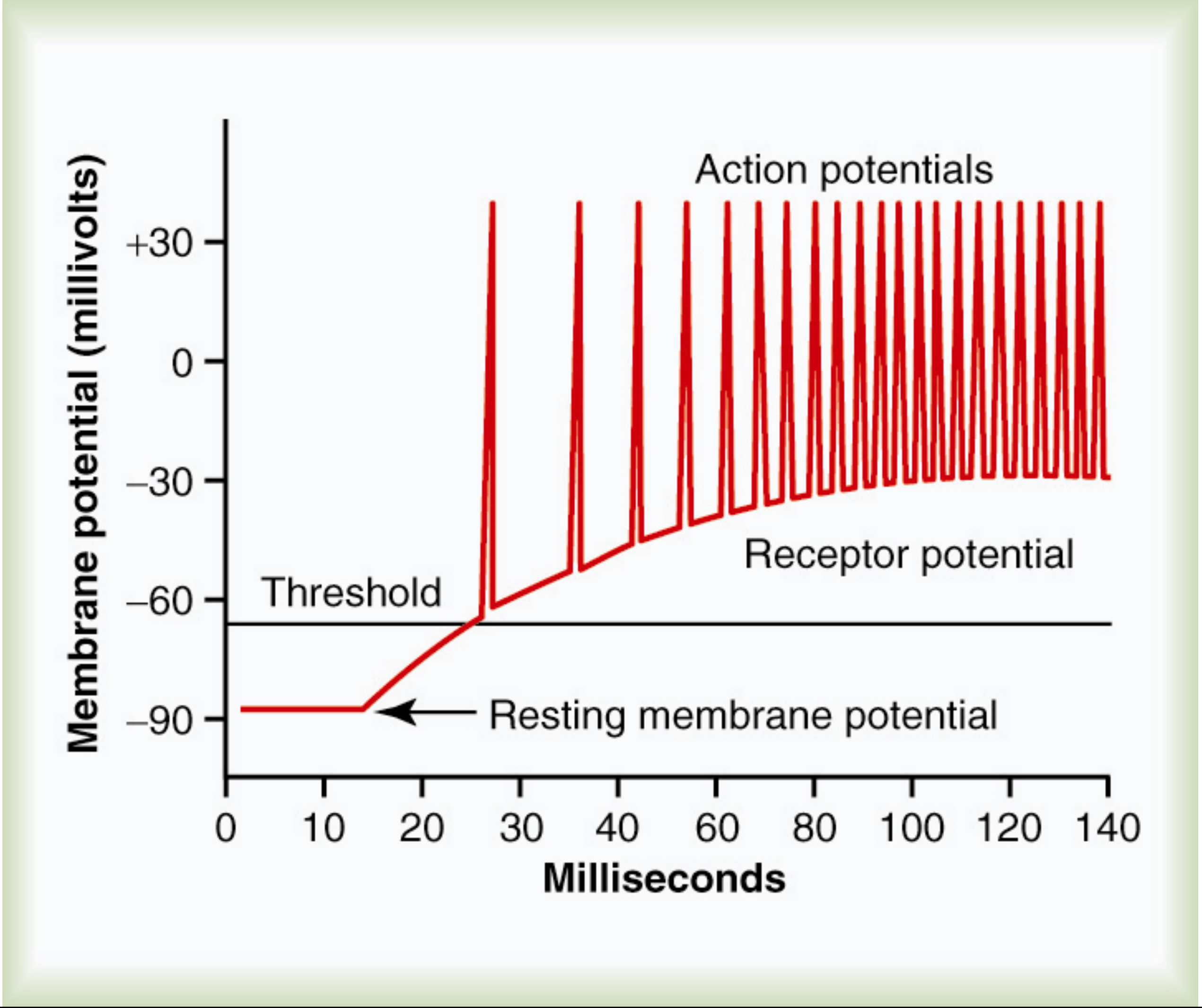
Generator Potentials

- In response to stimulus, sensory nerve endings produce a local graded change in membrane potential.
- Potential changes are called receptor or generator potential.
  - Analogous to EPSPs.

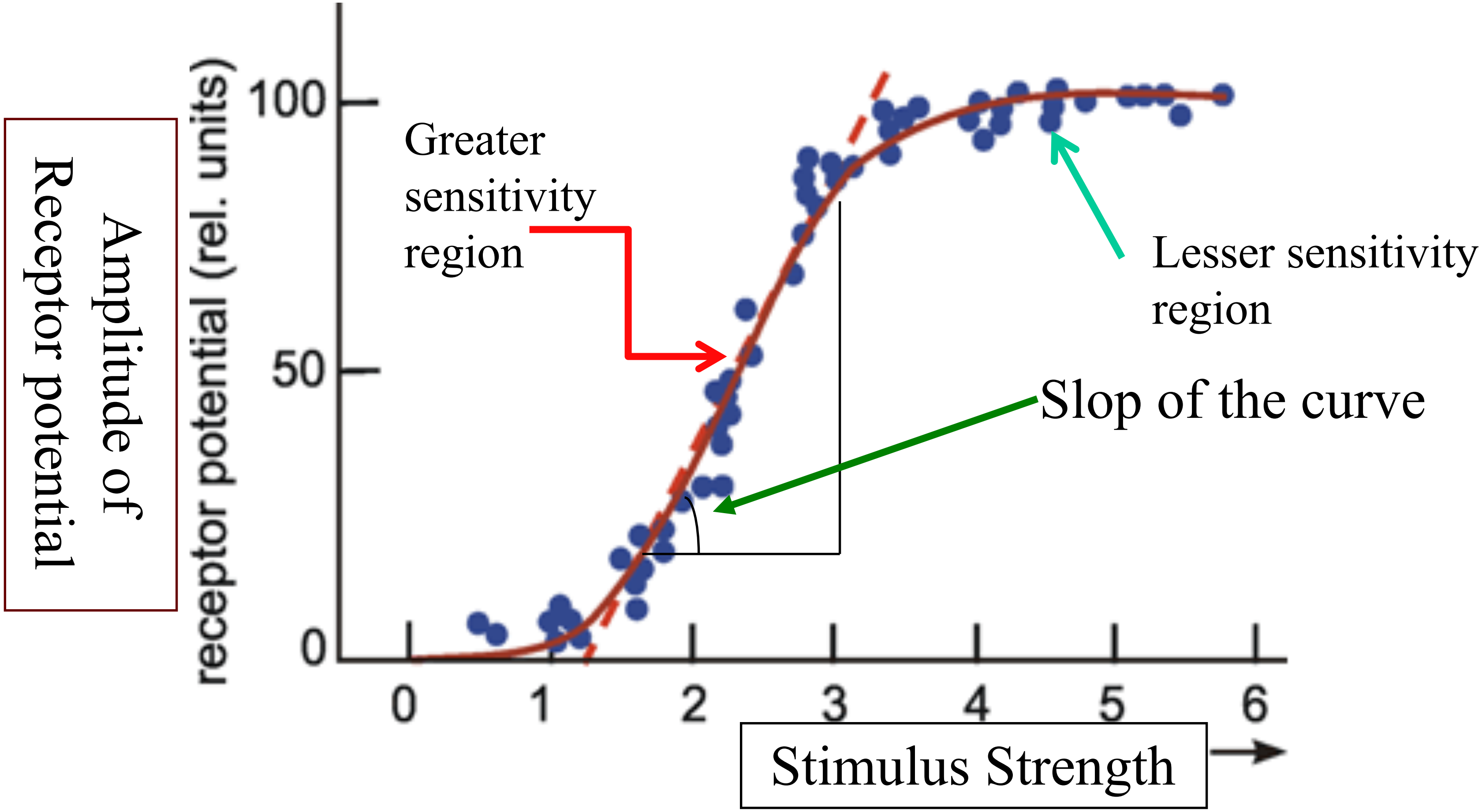


- Phasic response:
  - Generator potential increases with increased stimulus, then as stimulus continues, generator potential size diminishes.
- Tonic response: Generator potential proportional to intensity of stimulus.

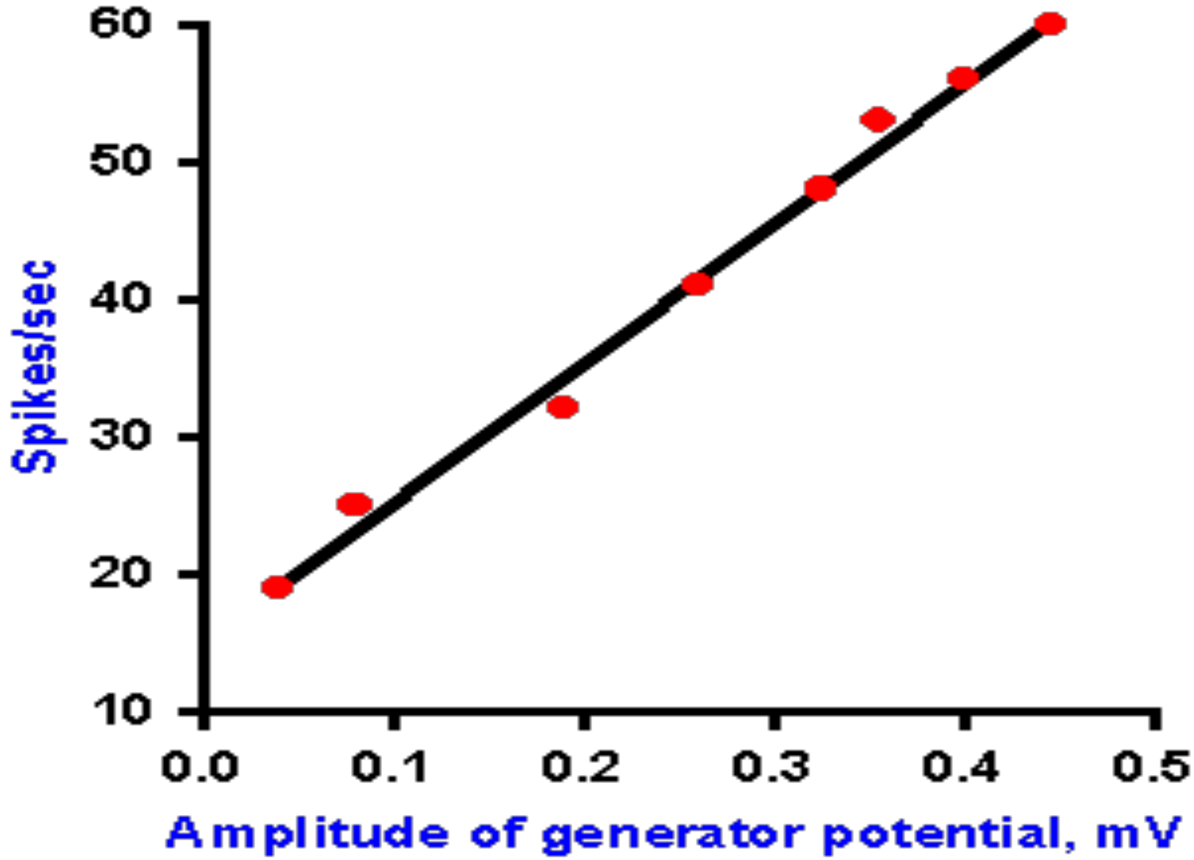
Relationship between Receptor Potential and Action Potentials



The effect of stimulus strength on RP amplitude

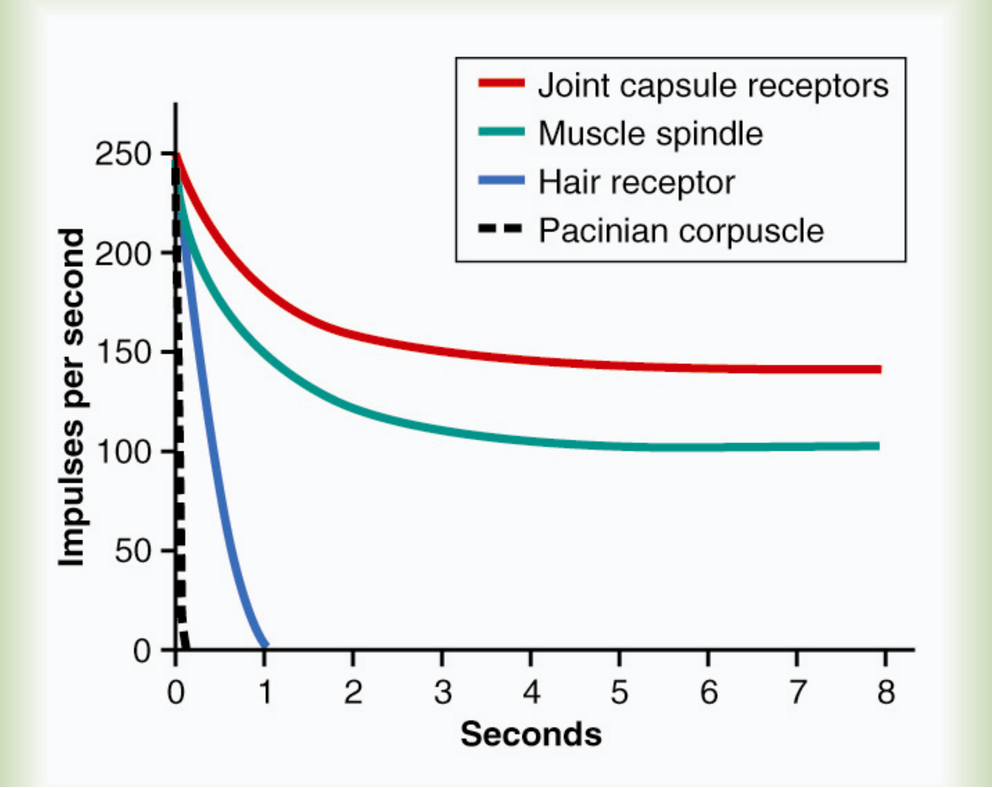


The effect of the amplitude of RP on the frequency of impulses generated



Adaptation of Receptors

- When a continuous stimulus is applied, receptors respond rapidly at first, but response declines until all receptors stop firing.



Adaptation

- Rate of adaptation varies with type of receptor.
- Therefore, receptors respond when a change is taking place (i.e., think of the feel of clothing on your skin.)

Adaptation of Sensory Receptors

- Receptors responding to pressure, touch, and smell adapt quickly
- Receptors responding slowly include Merkel's discs, Ruffini's corpuscles, and interoceptors that respond to chemical levels in the blood
- Pain receptors and proprioceptors do not exhibit adaptation

Mechanism of Adaptation

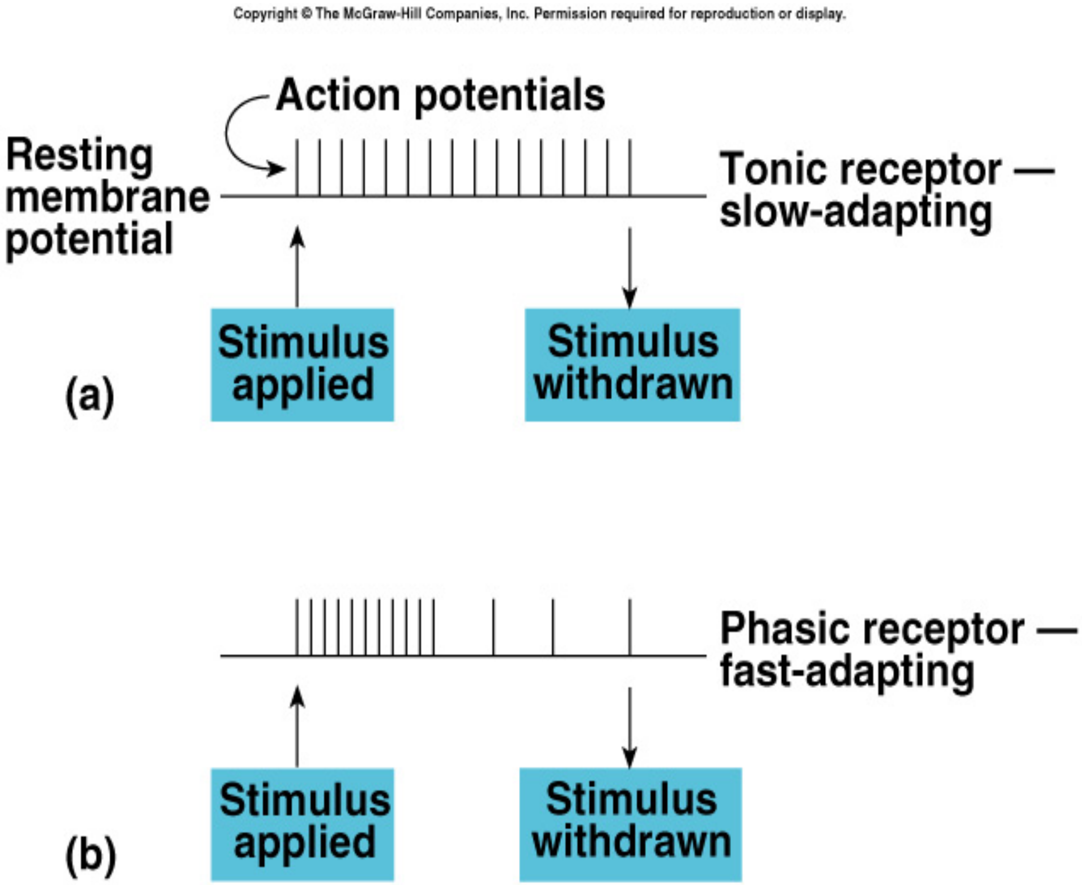
- varies with the type of receptor
- *photoreceptors* change the amount of light sensitive chemicals
- *mechanoreceptors* redistribute themselves to accommodate the distorting force (i.e., the pacinian corpuscle)
- some mechanoreceptors adapt slowly, some adapt rapidly

Slowly Adapting (Tonic) Receptors

- continue to transmit impulses to the brain for long periods of time while the stimulus is present
- keep brain apprised of the status of the body with respect to its surroundings
- will adapt to extinction as long as the stimulus is present, however, this may take hours or days
- these receptors include: *muscle spindle*, *golgi tendon apparatus, Ruffini's endings, Merkels discs, Macula, chemo- and baroreceptors*

Sensory Adaptation

- Tonic receptors:
  - Produce constant rate of firing as long as stimulus is applied.
    - Pain.
- Phasic receptors:
  - Burst of activity but quickly reduce firing rate (adapt) if stimulus maintained.
  - Sensory adaptation:
    - Cease to pay attention to constant stimuli.



Rapidly Adapting (Phasic) Receptors

- respond only when change is taking place
- Rate and Strength of the response is related to the Rate and Intensity of the stimulus
- important for predicting the future position or condition of the body
- very important for balance and movement
- types of rapidly adapting receptors: *pacinian corpuscle, semicircular canals* in the inner ear

Transmission of Receptor Information to the Brain

- the larger the nerve fiber diameter the faster the rate of transmission of the signal
- velocity of transmission can be as fast as 120 m/sec or as slow as 0.5 m/sec
- nerve fiber classification
  - type A - myelinated fibers of varying sizes, generally fast transmission speed
    - subdivided into α, β, δ, γ
  - type C - unmyelinated fibers, small with slow transmission speed

Types of Nerve Fiber

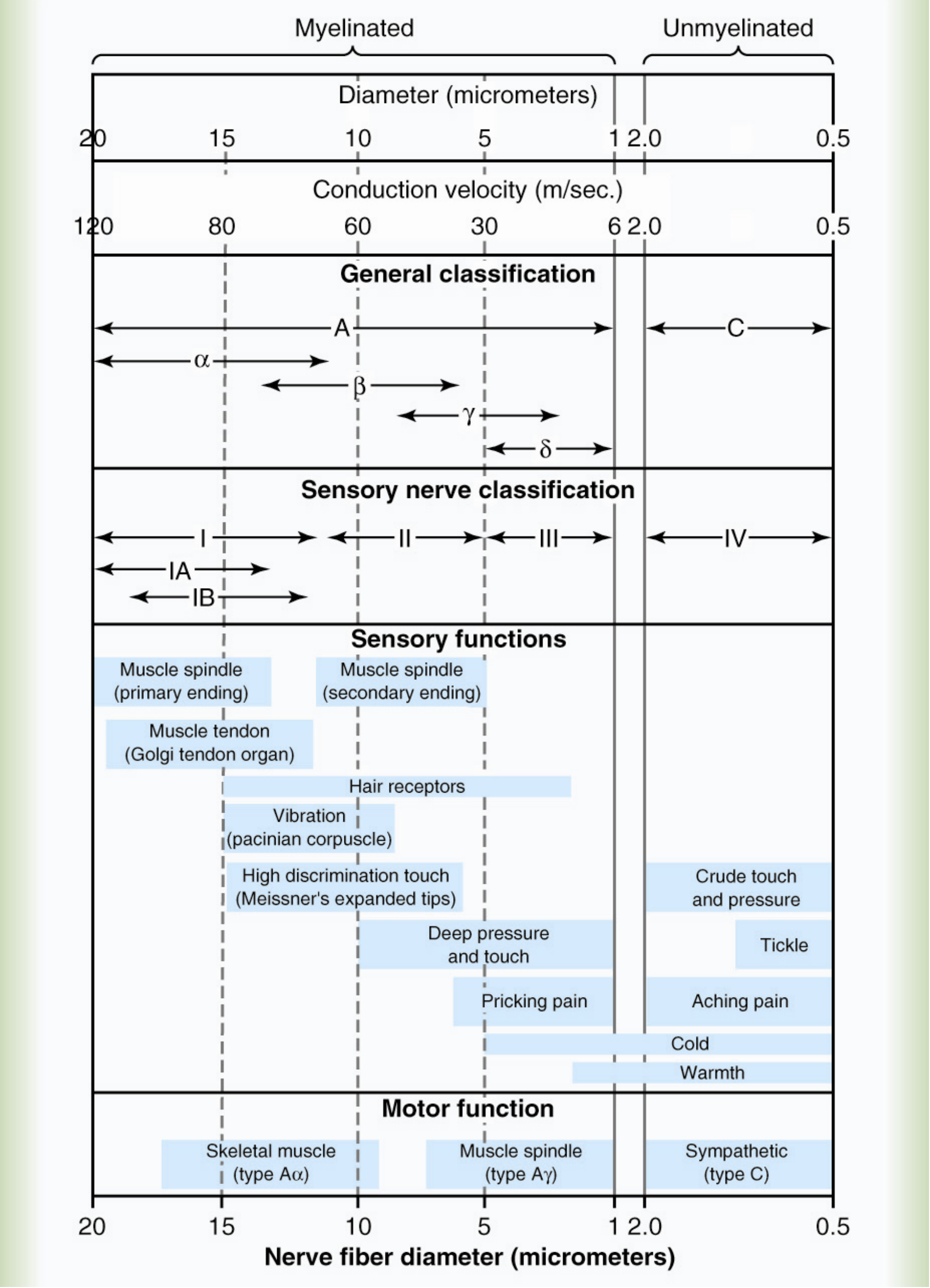
-Myelinated fibers –

Type A (types I, II and III)

- A α
- A β
- A γ
- A δ

-Umyelinated Fibers-

Type C (type IV)



Importance of Signal Intensity

- Signal intensity is critical for interpretation of the signal by the brain (i.e., pain).
- Gradations in signal intensity can be achieved by:
- 1) increasing the number of fibers stimulated, **spatial summation**
- 2) increasing the rate of firing in a limited number of fibers, **temporal summation**.

An example of spatial summation

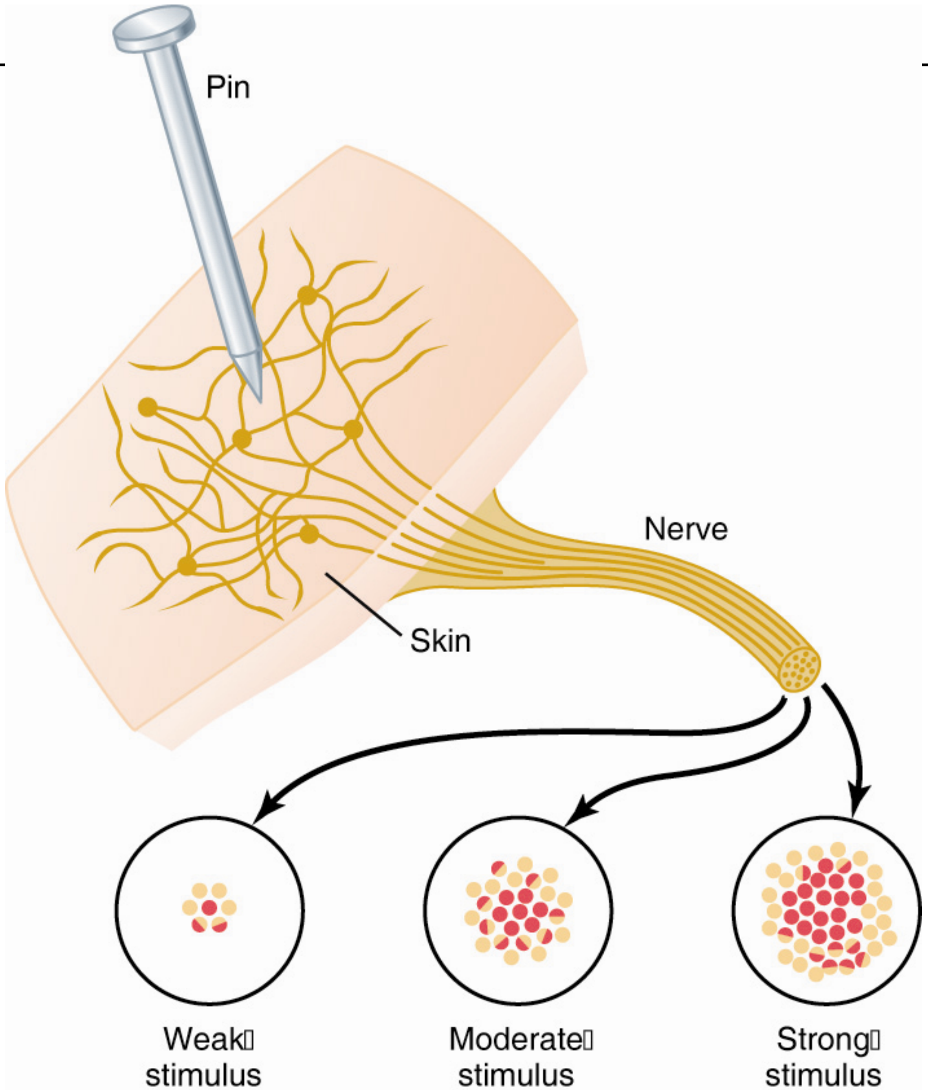


Figure 46-7;
Guyton & Hall

Coding in the sensory system

- Intensity is coded for by:
  - Frequency of action potential
  - The No. of neurons stimulated
- Location is coded for by the labeled line principles
- Type of stimulus is coded for by the kind of receptor stimulated (Adequate stimulus) and specificity of the receptors.

Coding of Sensory Information

STIMULUS PROPERTY	MECHANISM OF CODING
Type of Stimulus (stimulus modality)	Distinguished by the type of receptor activated and the specific pathway over which this information is transmitted to a particular area of the cerebral cortex
Location of Stimulus	Distinguished by the location of the activated receptive field and the pathway that is subsequently activated to transmit this information to the area of the somatosensory cortex representing that particular location
Intensity of Stimulus (stimulus strength)	Distinguished by the frequency of action potentials initiated in an activated afferent neuron and the number of receptors (and afferent neurons) activated

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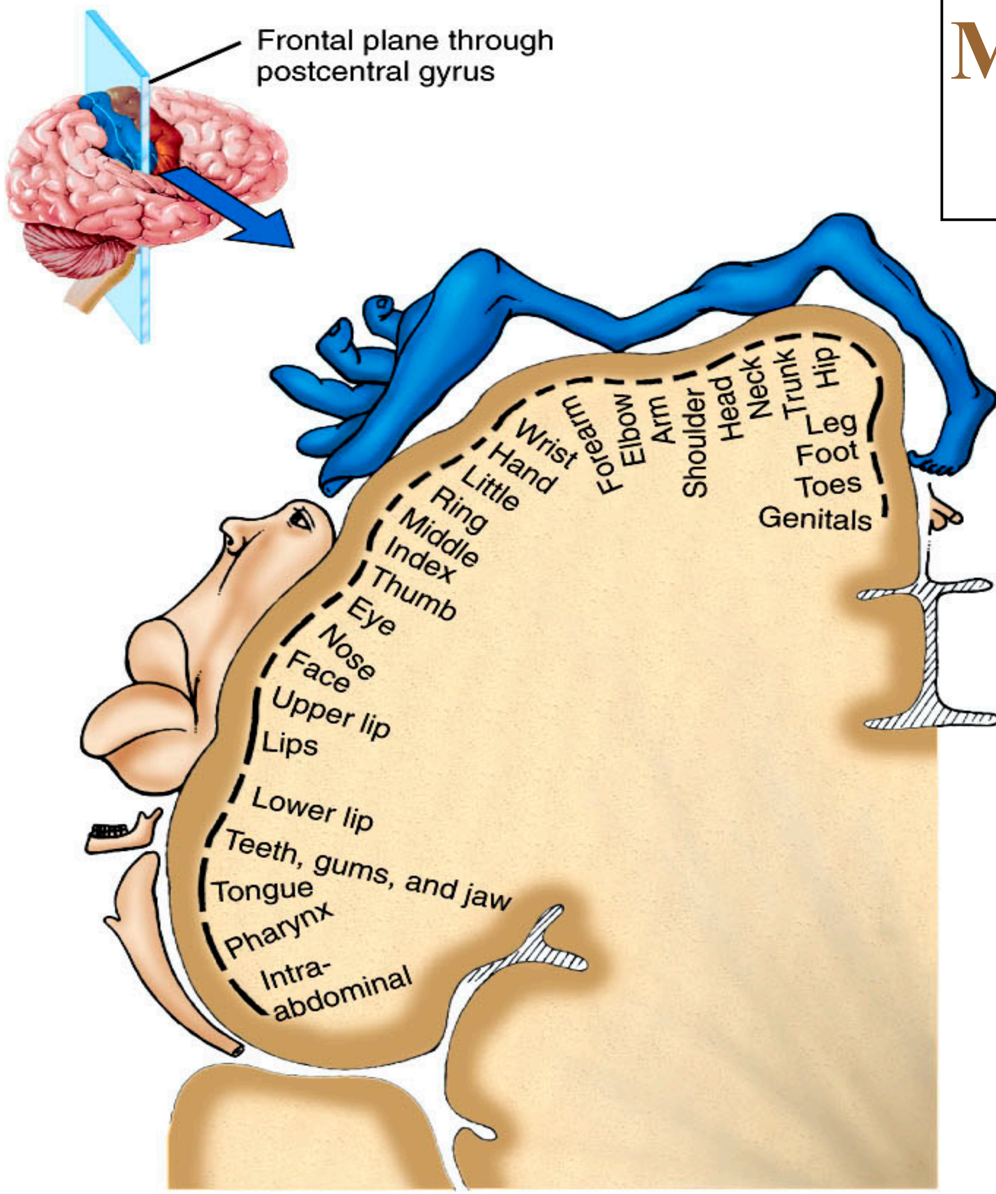
Mapping of the Primary Somatosensory Area



(a) Frontal section of primary somatosensory area in right cerebral hemisphere

Figure 16.08 Tortora - PAP 12/e

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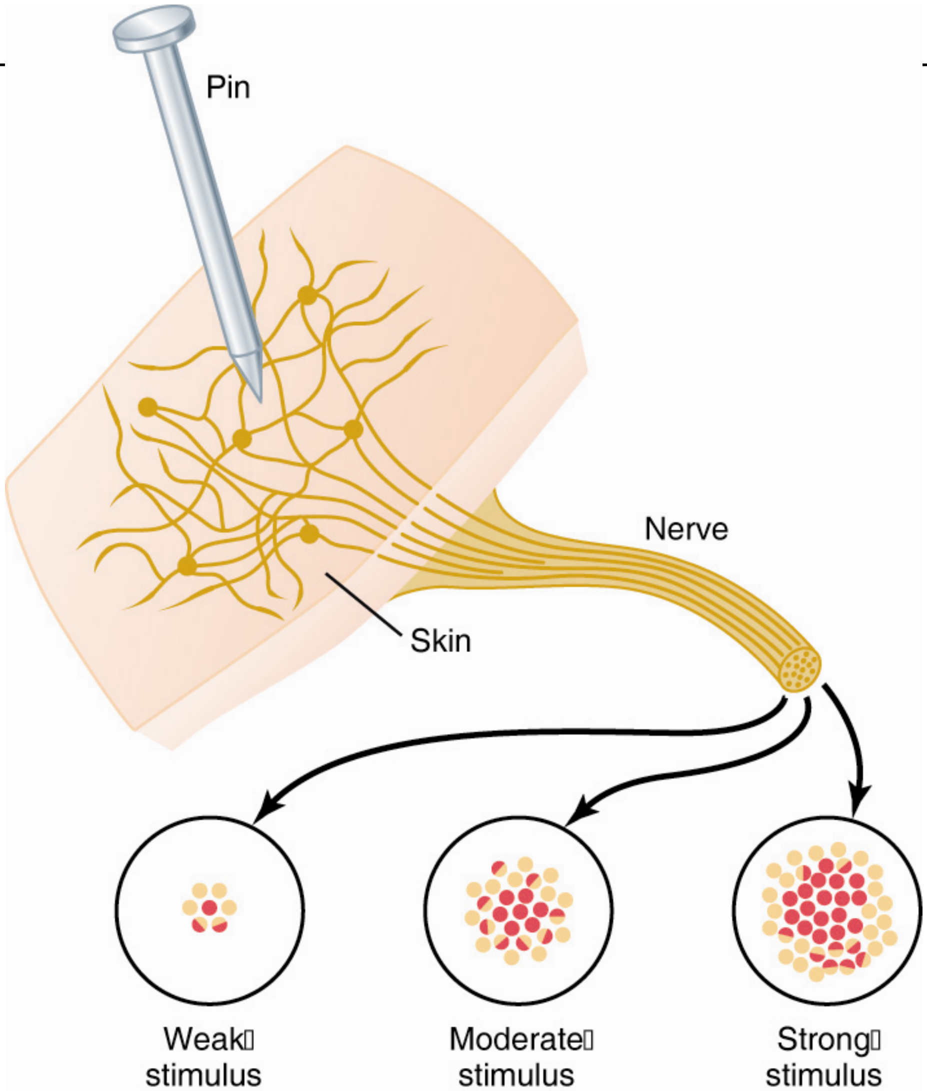
- Mapping of the postcentral gyrus.
- Size of the cortical region representing a body part depends on density of receptors on that part and the sensory impulses received from that part.

Receptive Fields

- Area of skin whose stimulation results in changes in the firing rate of the neuron.
  - Area of each receptor field varies inversely with the density of receptors in the region.
- Back and legs have few sensory endings.
  - Receptive field is large.
- Fingertips have large # of cutaneous receptors.
  - Receptive field is small.



An example of spatial summation

Figure 46-7; Guyton & Hall

Two-Point Touch Threshold

- Minimum distance at which 2 points of touch can be perceived as separate.
  - Measures of distance between receptive fields.
- Indication of tactile acuity.
  - If distance between 2 points is less than minimum distance, only 1 point will be felt.

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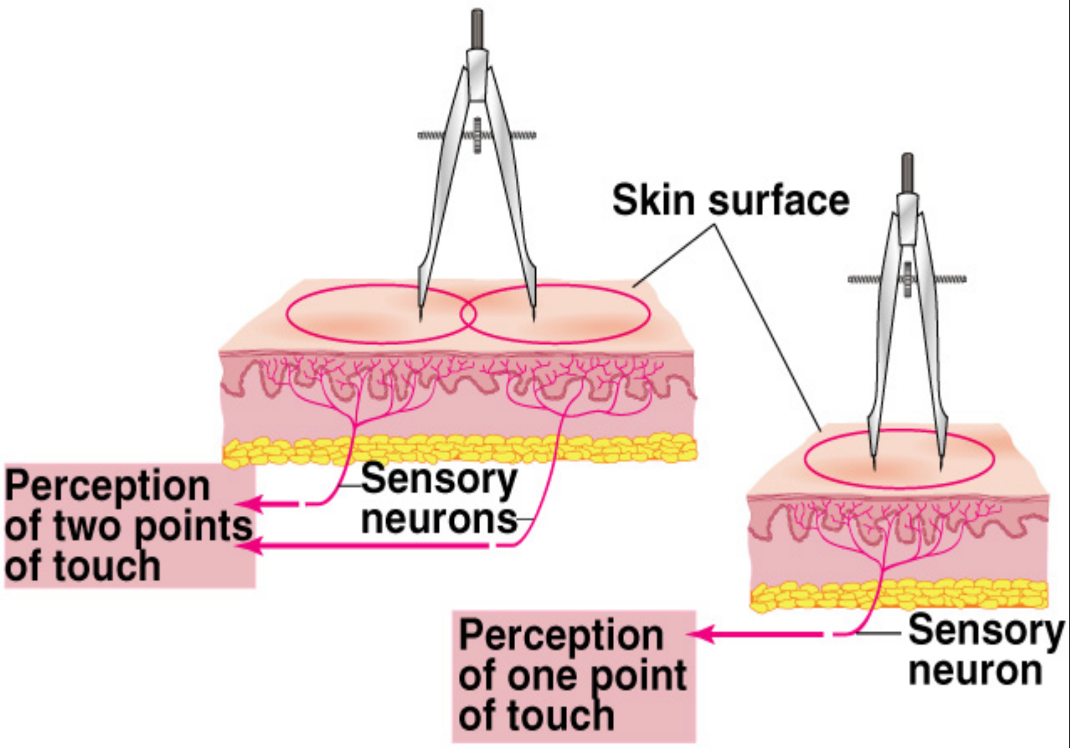
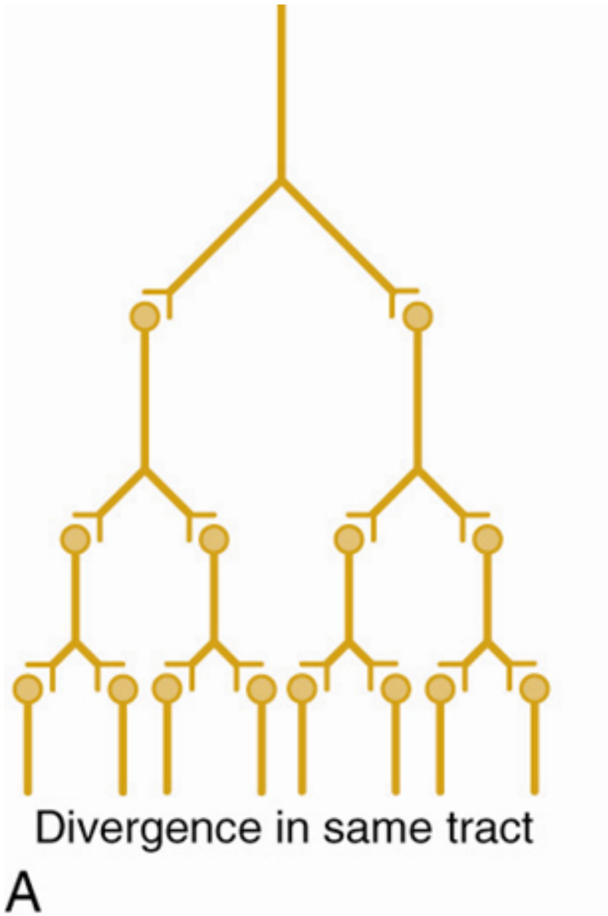
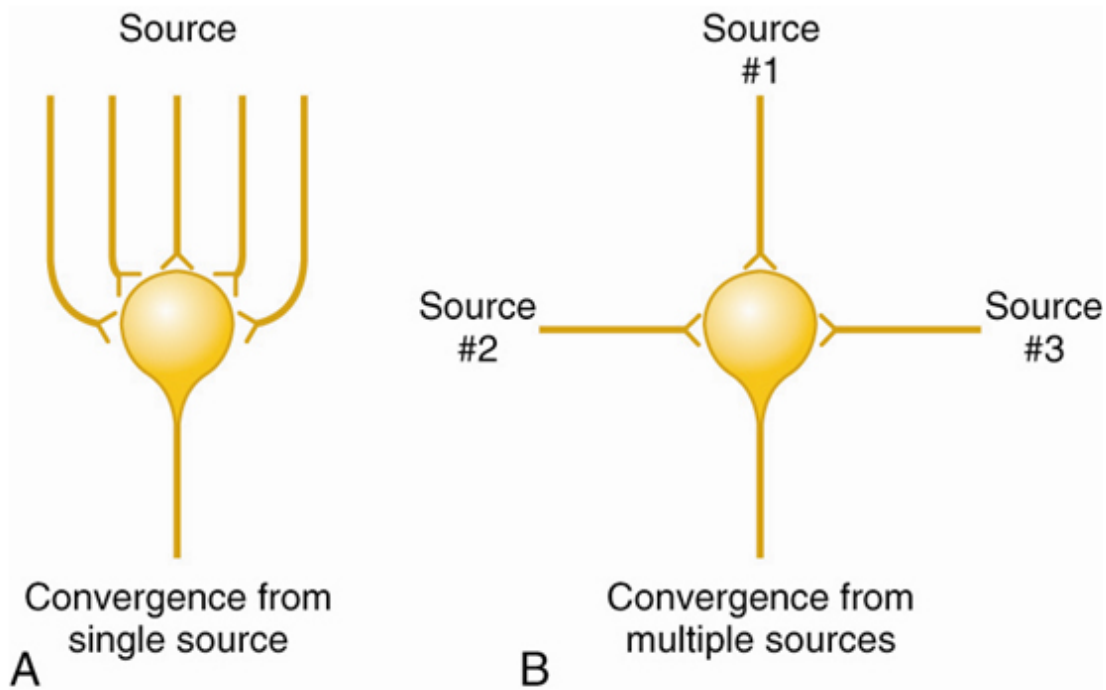
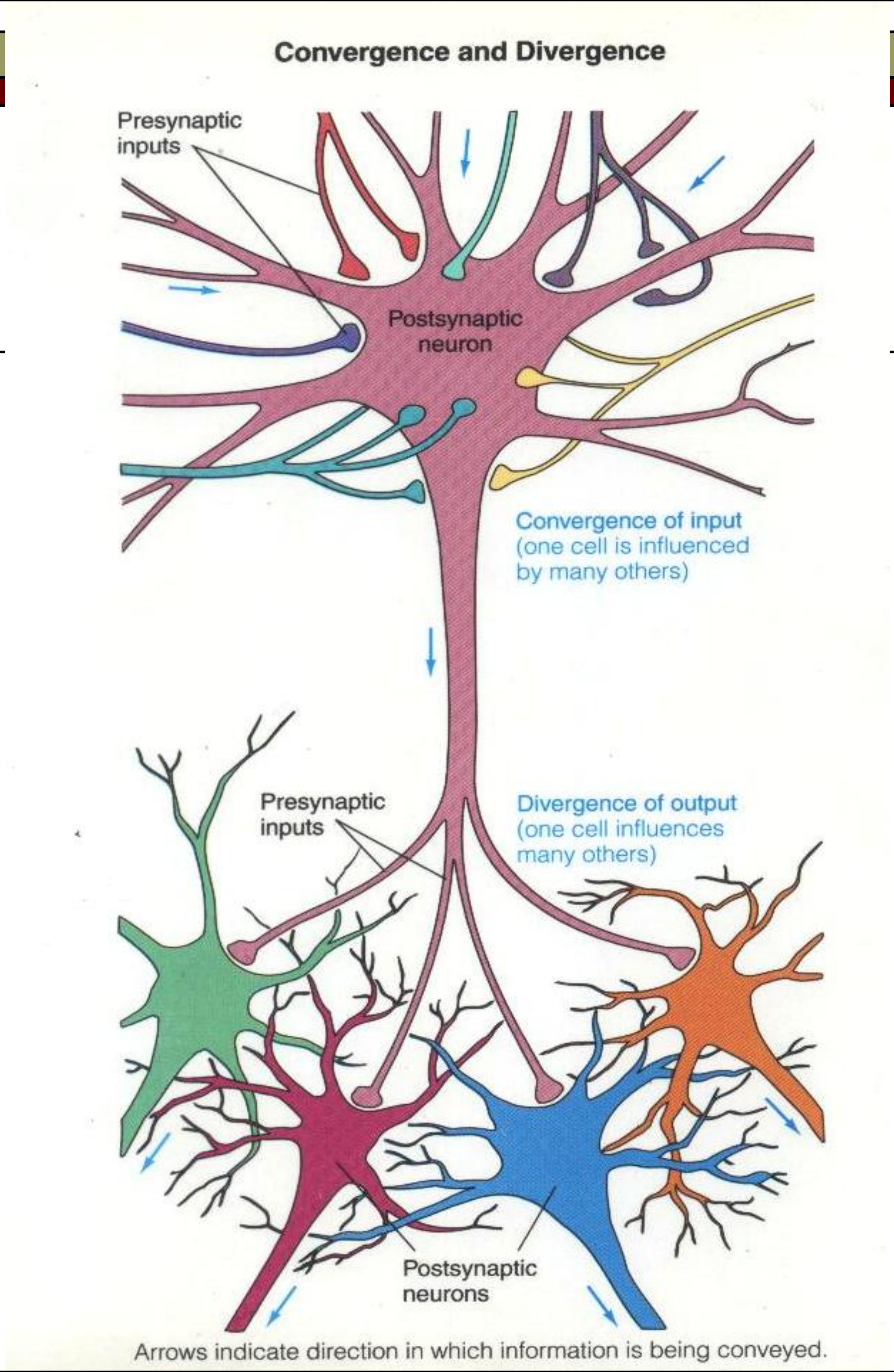


Neuronal Pools: Localization of sensory Information modification

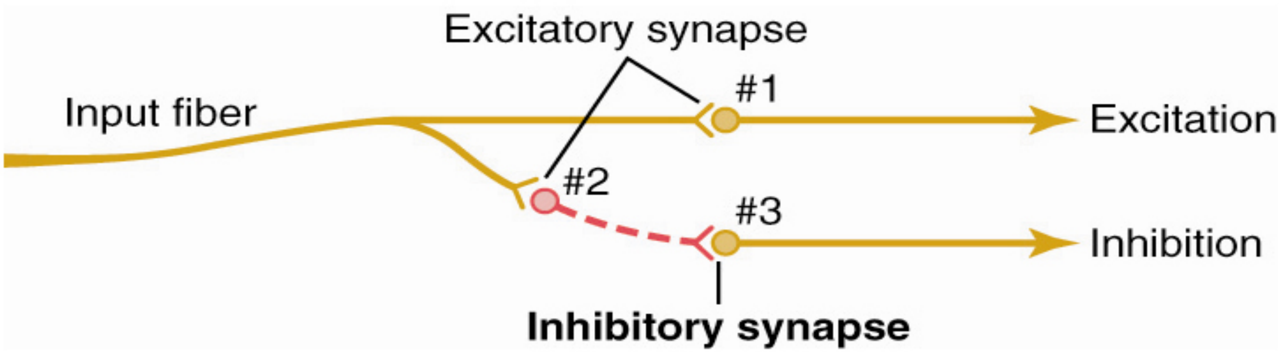






Convergence and Divergence
Presynaptic inputs
Postsynaptic neuron
Convergence of input (one cell is influenced by many others)
Presynaptic inputs
Divergence of output (one cell influences many others)
Postsynaptic neurons
Arrows indicate direction in which information is being conveyed.

Neuronal Pools: Modification of Localization: Sharpening of signals



Lateral inhibition

Lateral Inhibition

- Sharpening of sensation.
  - When a blunt object touches the skin, sensory neurons in the center areas are stimulated more than neighboring fields.
  - Stimulation will gradually diminish from the point of greatest contact, without a clear, sharp boundary.
    - Will be perceived as a single touch with well defined borders.
  - Occurs within CNS.

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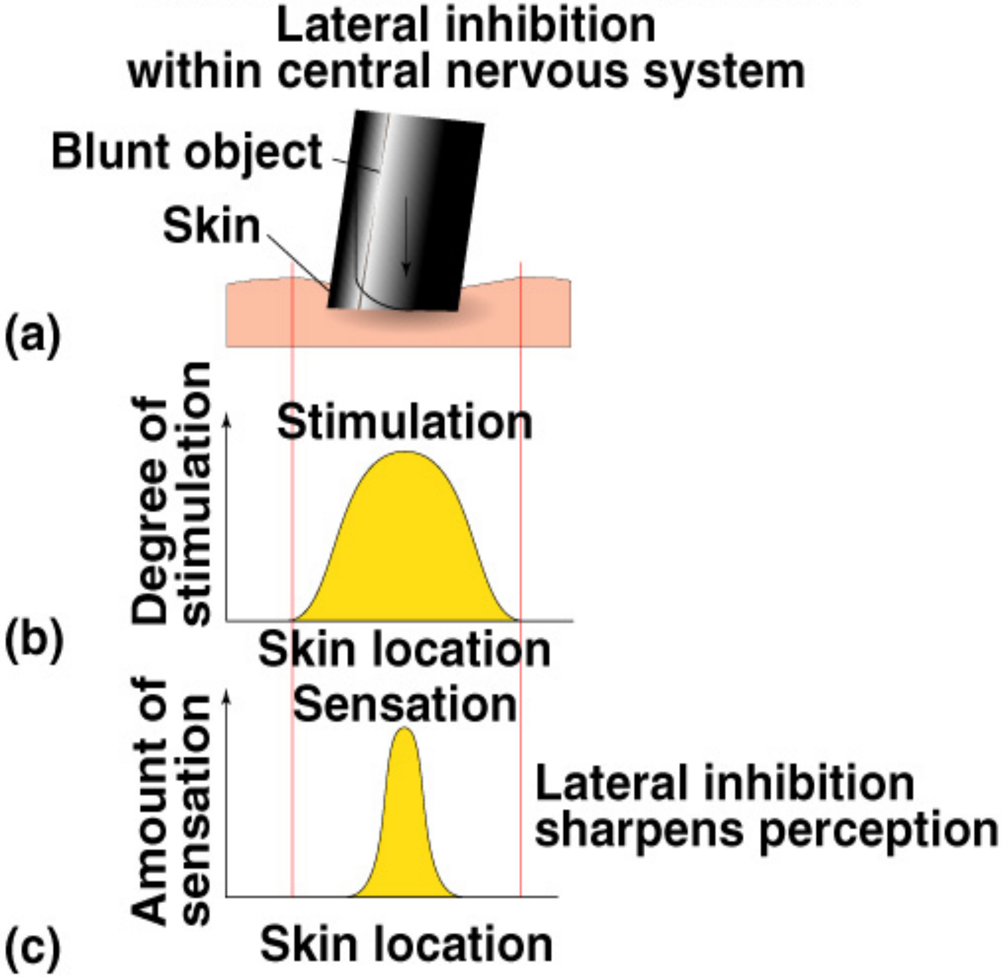

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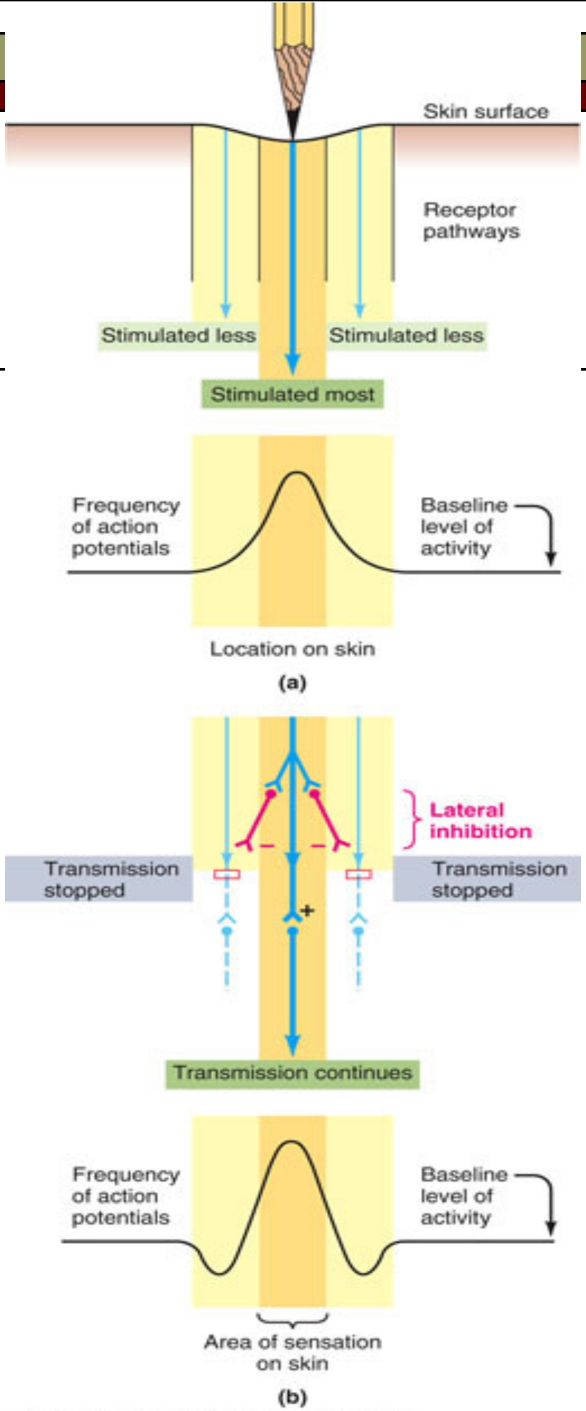
Lateral Inhibition in the sensory System as a way of sharpening of the stimulus



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