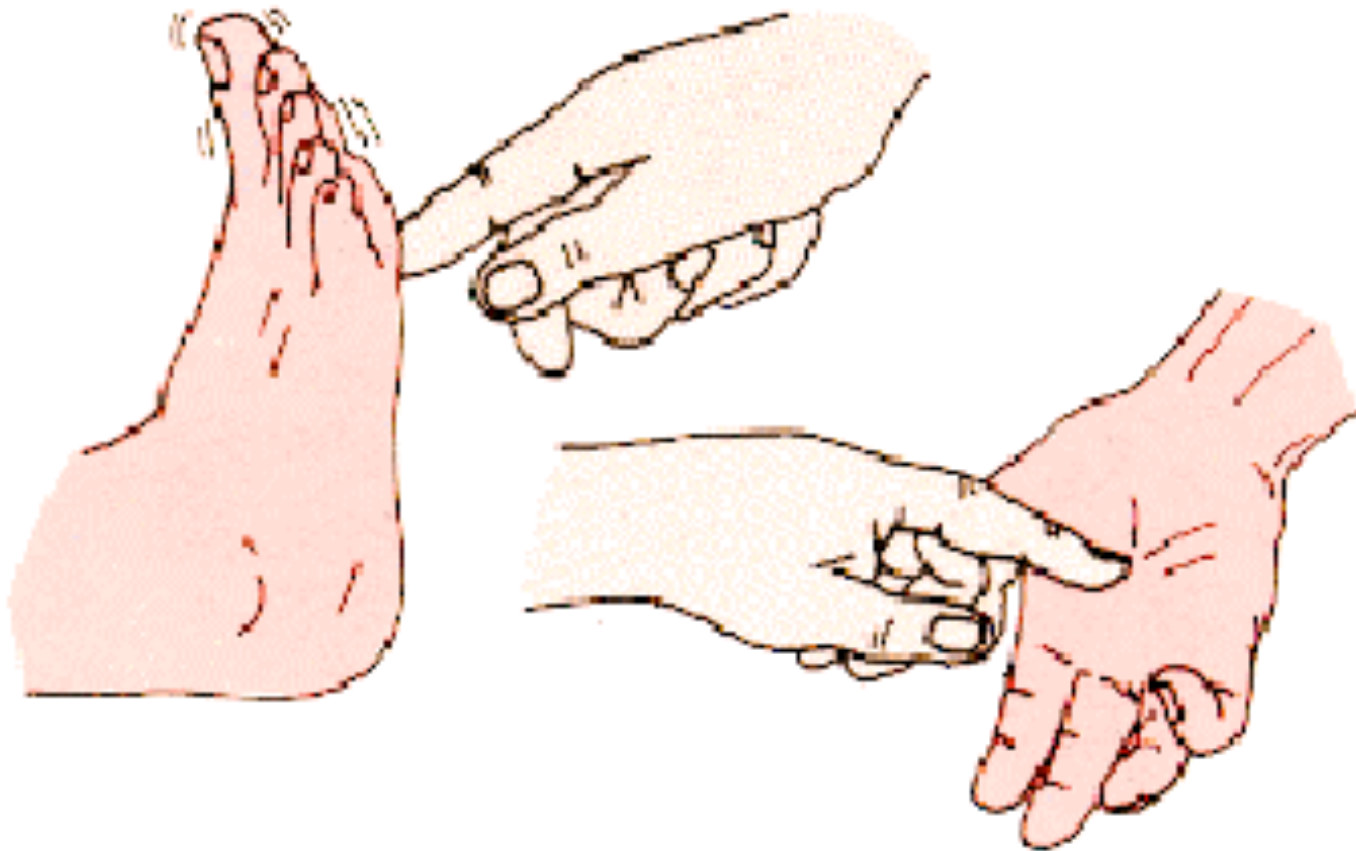


# General Physiology of Sensitivity



*“Most of the activities  
of the nervous system  
depend on sensory experience.”*

**A. C. Guyton**

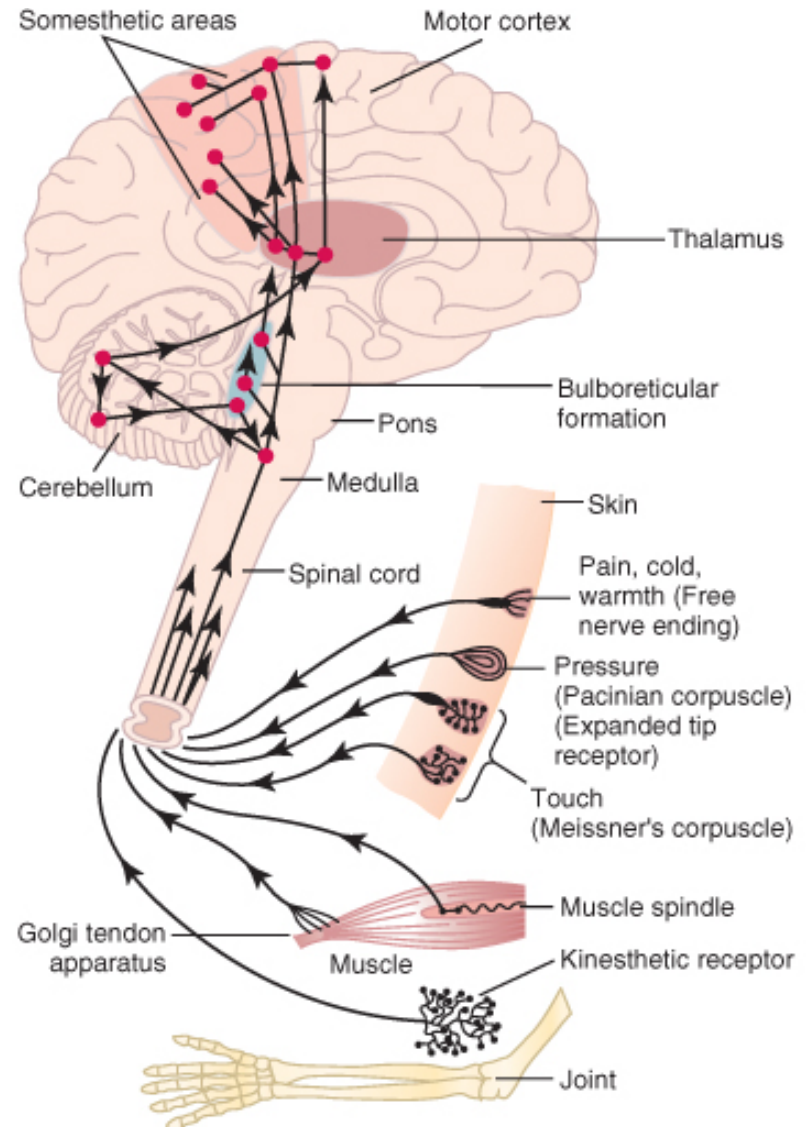
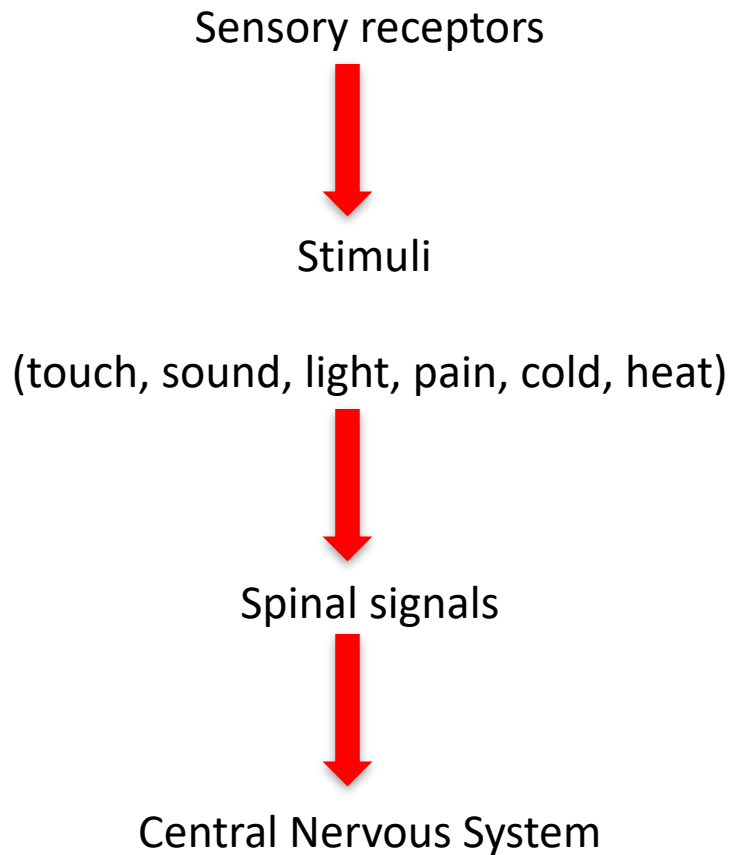


# Outline

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- Types of sensory receptors and stimuli they detect
- Beginning of the marked line
- Classification of sensory receptors
- Receptor potential
- Classification of types of fibers
- Temporal and spatial summation of sensory receptors
- Conduction of the sensory stimulus

# Types of Sensory Receptors and Stimuli they Detect



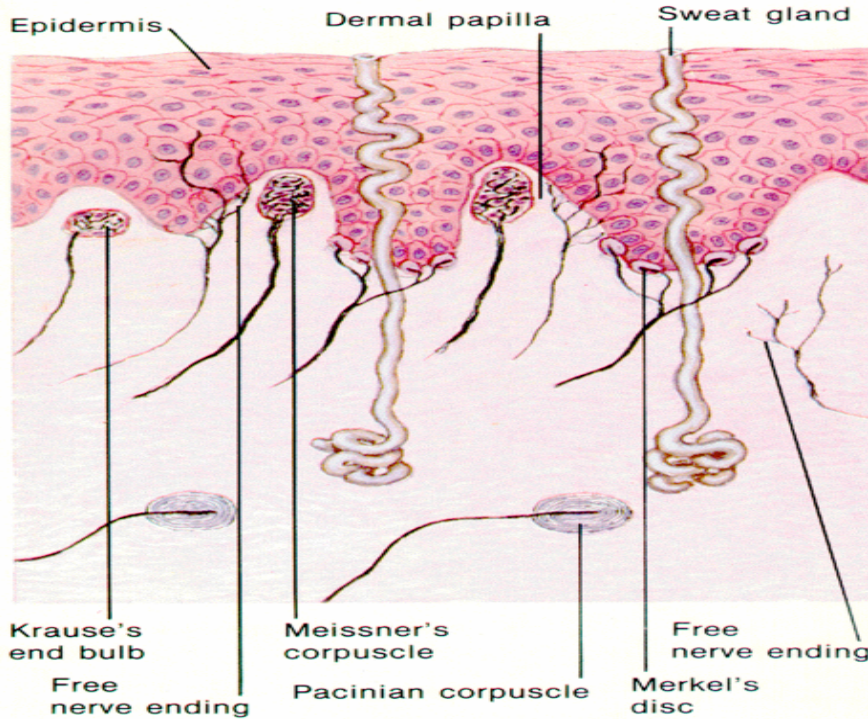
# Types of Sensory Receptors and Stimuli they Detect

- **MECHANORECEPTORS**
  - MECHANICAL STIMULI
- **THERMORECEPTORS**
  - THERMIC STIMULI
- **NOCICEPTOR**
  - PAINFUL STIMULI
- **ELECTROMAGNETIC RECEPTORS**
  - LIGHT STIMULI
- **CHEMORECEPTOR**
  - CHEMICAL STIMULI (TASTE, SMELL, O<sub>2</sub> AND CO<sub>2</sub> IN BLOOD, OSMOLARITY)

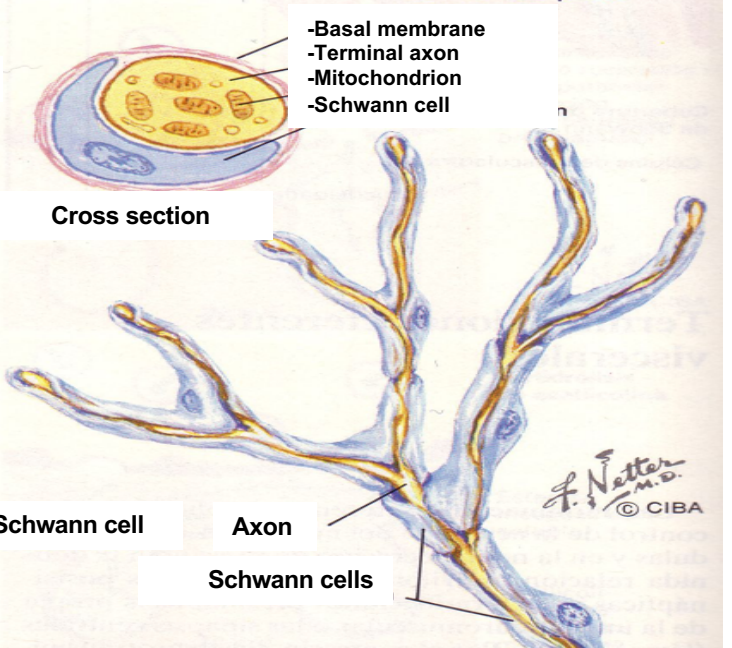
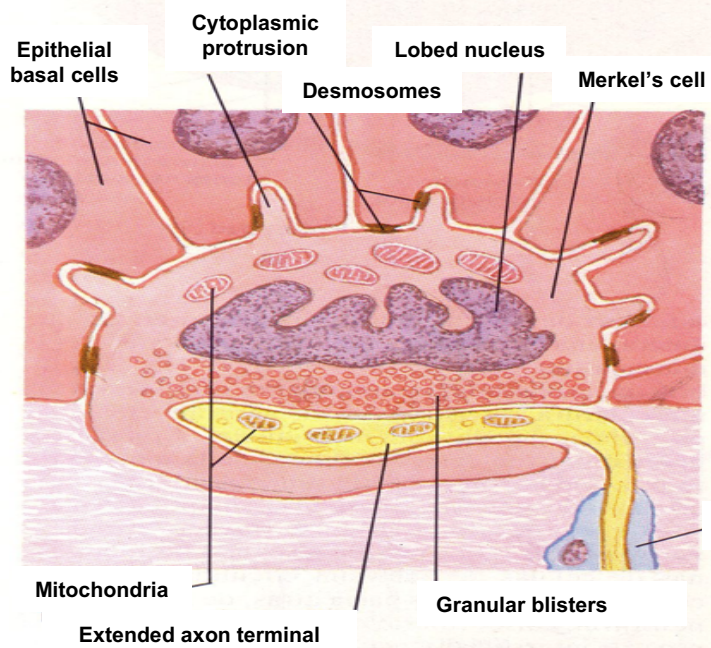
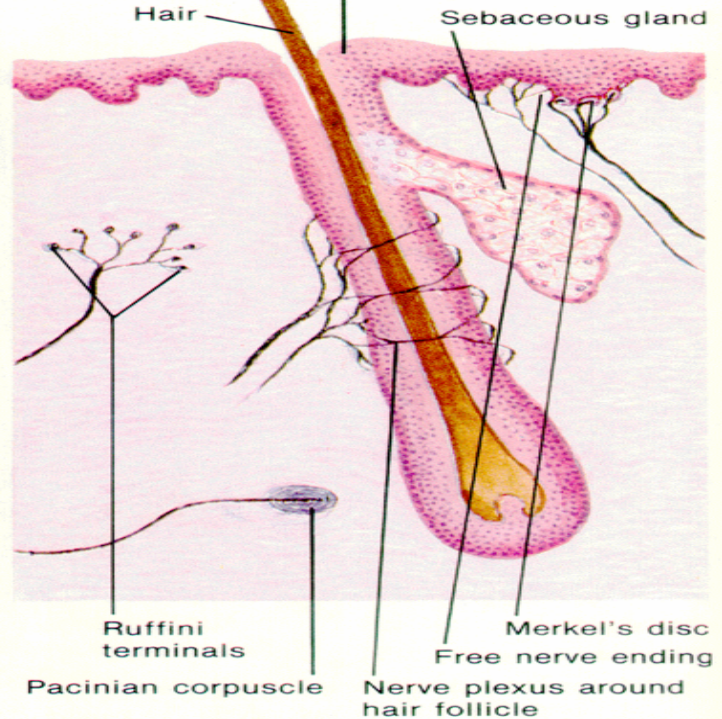
# Classification of Sensory Receptors

<b>Classification of sensory receptors</b>	
<p><b>I. Mechanoreceptors</b>            Cutaneous and tactile sensitivities (epidermis and dermis)              Free nerve endings              Bulbous endings                Merkel's discs                Other variants              Flower-spray endings              Ruffini endings              Encapsulated endings                Meissner's corpuscles                Krause corpuscles              Hair end-organs            Sensitivities of deep tissue              Free nerve endings              Bulbous endings              Flower-spray endings                Ruffini endings              Encapsulated endings                Pacinian corpuscles                Other variants              Muscle endings                Muscle spindles                Golgi tendon receptor            Ear              Acoustic receptors of the cochlea            Balance              Vestibular receptors            Blood pressure              Baroreceptors of the carotid sinus and of the aorta</p>	<p><b>II. Thermoreceptors</b>            Cold              Receptors for cold            Heat              Receptor for heat</p> <p><b>III. Nociceptors</b>            Pain              Free nerve endings</p> <p><b>IV. Electromagnetic receptors</b>            Vision              Cone cells              Rod cells</p> <p><b>V. Chemoreceptors</b>            Taste              Taste buds            Olfaction              Olfactory epithelium            Arterial oxygen              Receptors of carotid and aortic bodies            Osmolality              Neurons of the supraoptic nerves or of their vicinity            CO<sub>2</sub> in blood              Receptors of the medulla oblongata or of its surface                and of the carotid and aortic bodies            Glucose, aminoacids, fatty acid in blood              Receptors in the hypothalamus</p>

**A. Glabrous skin**



**B. Hairy skin**



# Specificity of the Receptors

- The receptors are **SPECIFIC** to each sensation, and are nearly **INSENSITIVE** to the rest of the sensations



Free nerve endings



Expanded tip receptor



Tactile hair



Pacinian corpuscle



Meissner's corpuscle



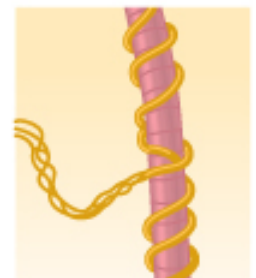
Krause's corpuscle



Ruffini's end-organ



Golgi tendon apparatus



Muscle spindle



# Beginning of the Marked Line

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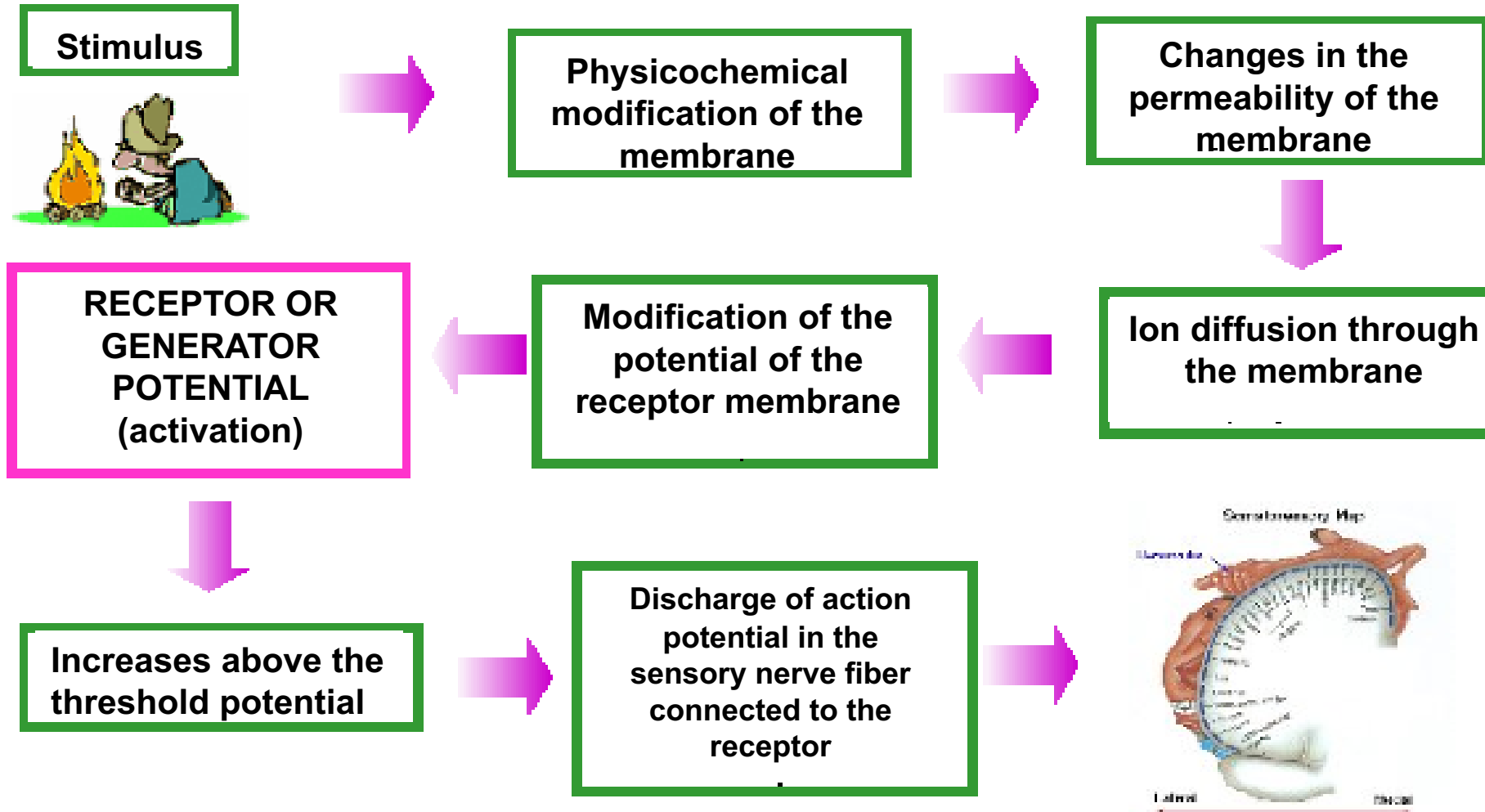
- **SENSATION MODALITY**: sensitive types (pain, touch, sight, sound...)
- Each nervous fasciculation ends at a specific point of the CNS
- The type of sensation is determined by the area that conducts the fiber
- **BEGINNING OF THE MARKED LINE**: specificity of the nerve fibers to transmit a single type of sensation

# Receptor Potential

- Receptor potential: change in the electrical potential of the membrane when a stimulus excites the receptor
  1. Mechanical deformation of the receptor and amplitude of the ionic channels
  2. Application of chemical products and amplitude of the ionic channels
  3. Change of amplitude and permeability modification
  4. Electromagnetic radiation

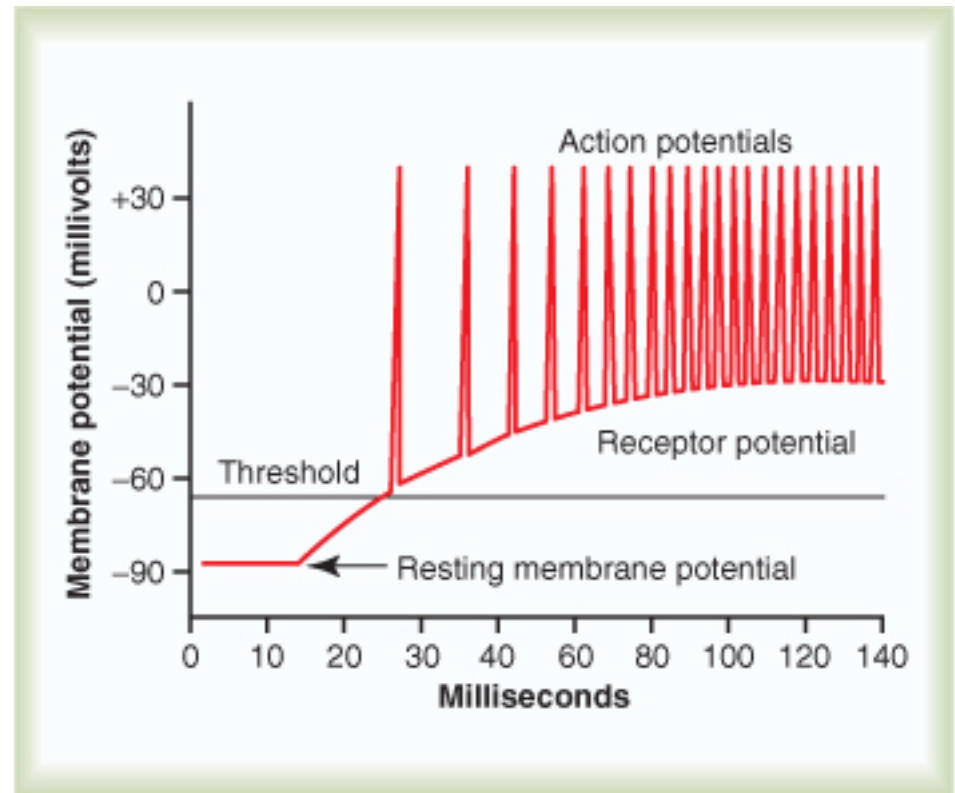
# SENSORY TRANSDUCTION: Phases

Capacity of the sensory receptor for transforming the stimulus into nervous signals

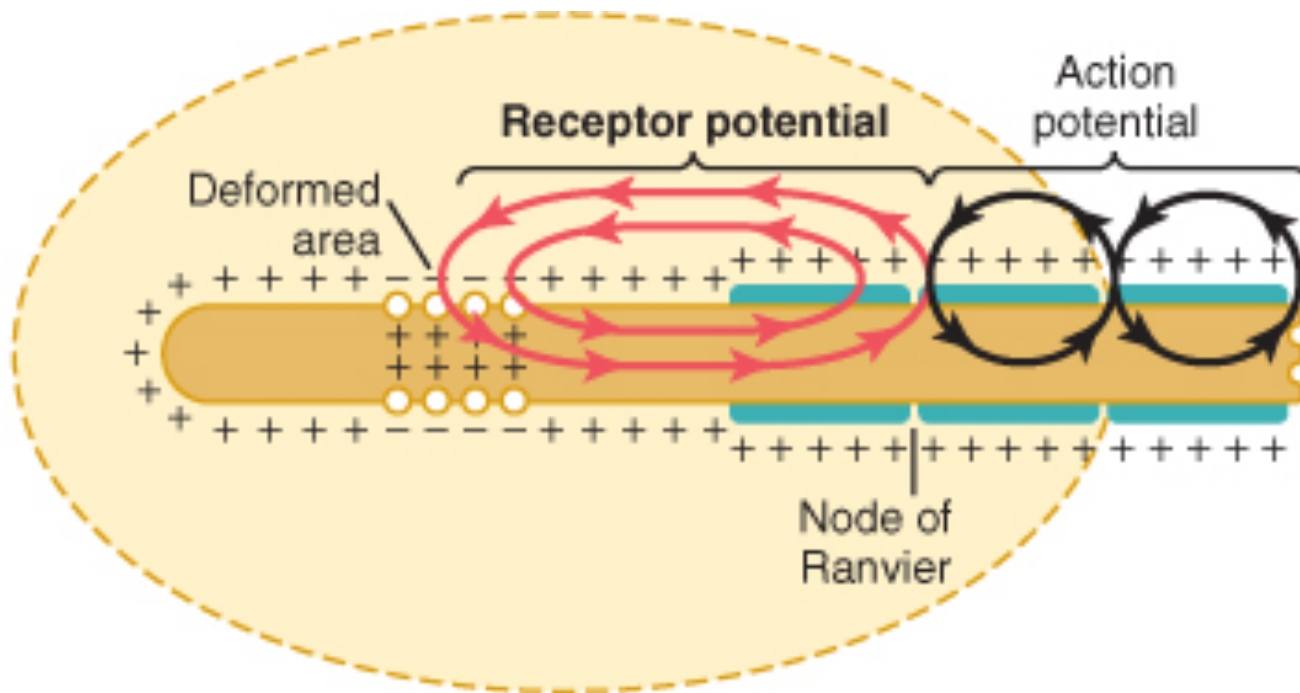


# Maximal Amplitude of the Potential

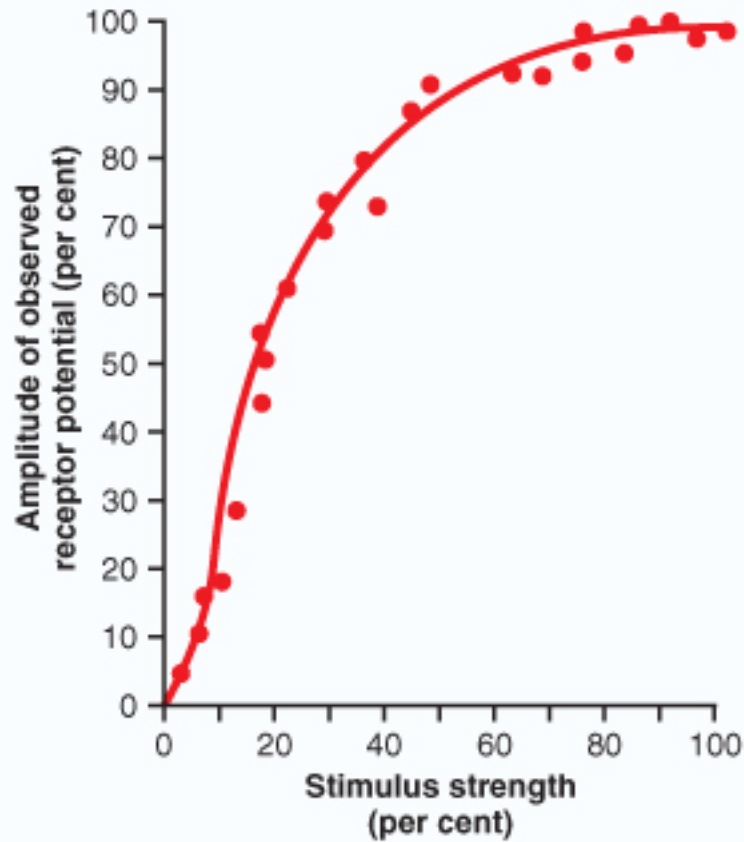
- The maximal amplitude is 100 mV (max. permeability to sodium ions)
- The frequency of the action potential increases as the receptor potential increases

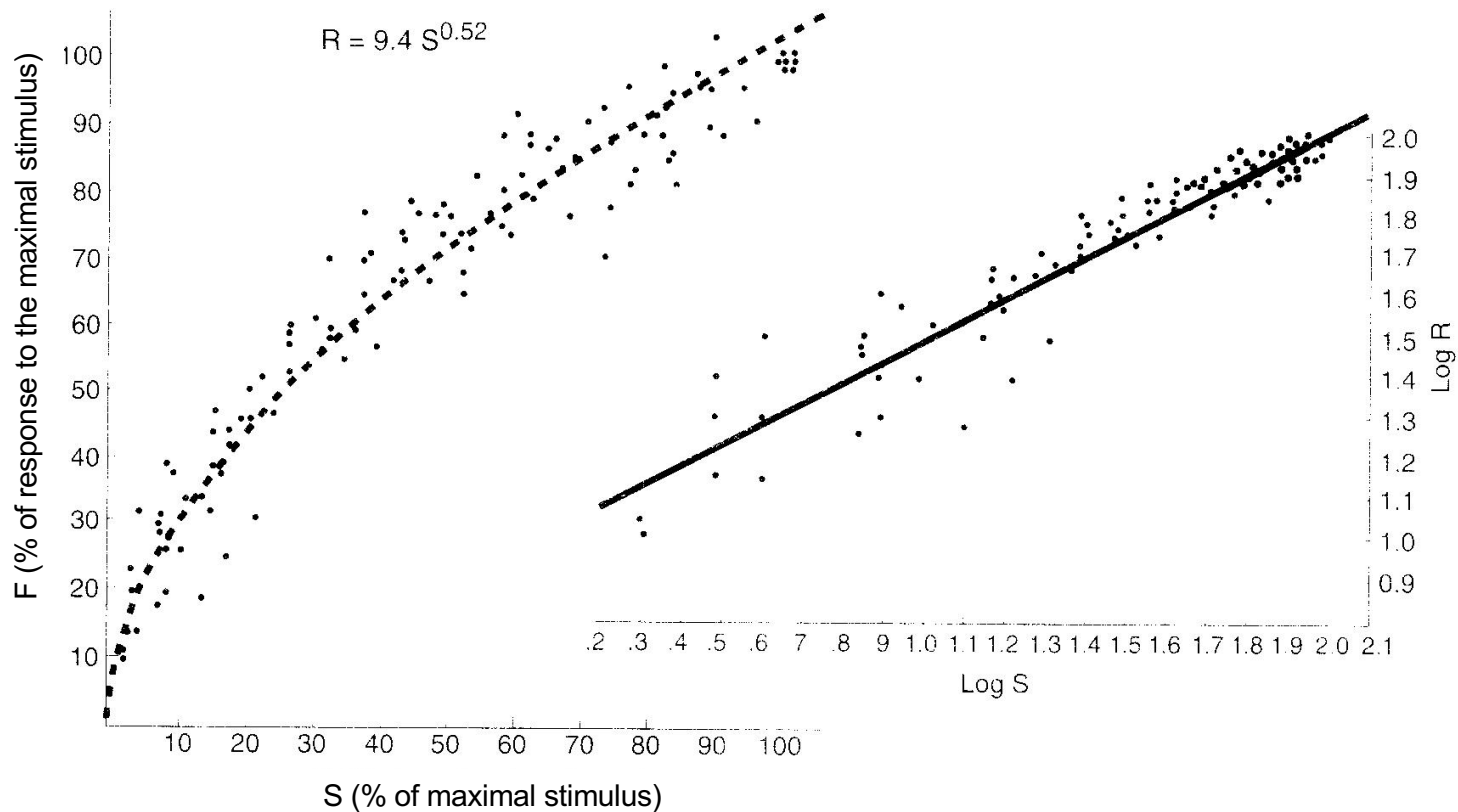


# Example in the Pacini Corpuscle



# Relation of the Amplitude-Intensity Stimulus

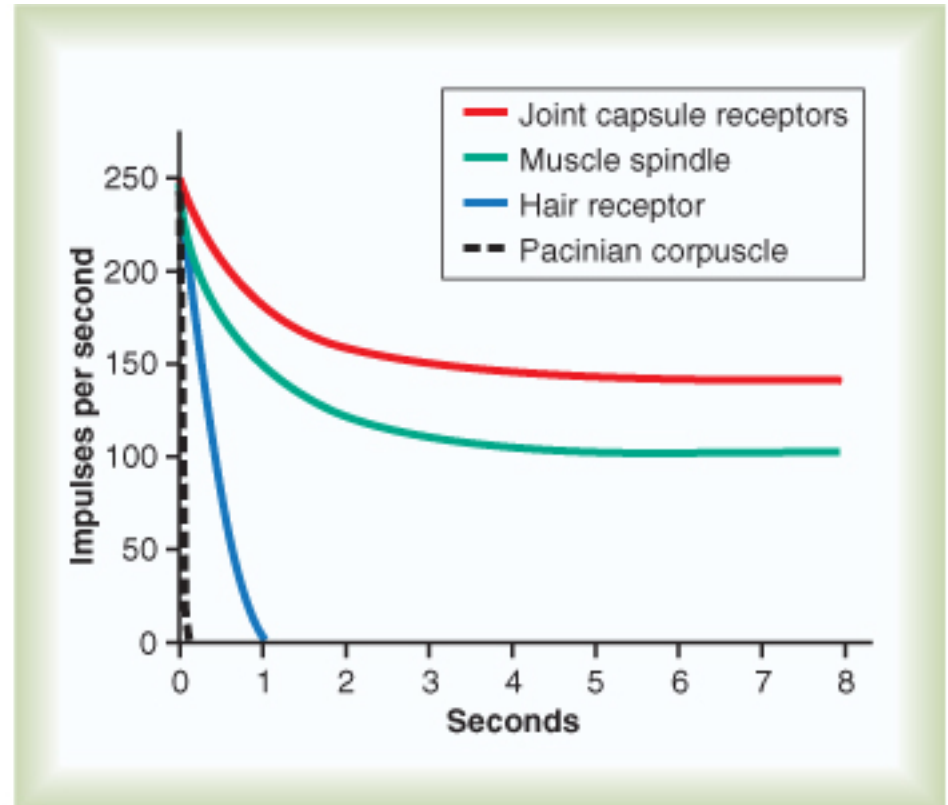




**Figure 5-4:** Relation between the magnitude of the tactile stimulus (S) and the frequency of the action potentials in the sensory nerve fibers (R). The dots are individual values in cats and were charted in linear coordinates (**left**) and in logarithmic coordinates (**right**). The equation shows the exponential relation estimated between R and S (Reproduced with the authorization of Werner G. Mountcastle VB: Neural activity in mechanoreceptive cutaneous afferents. Stimulus-response relations, Weber functions, and information transmission. J Neurophysiol 1965;28:359).

# Adaptation of the Receptors

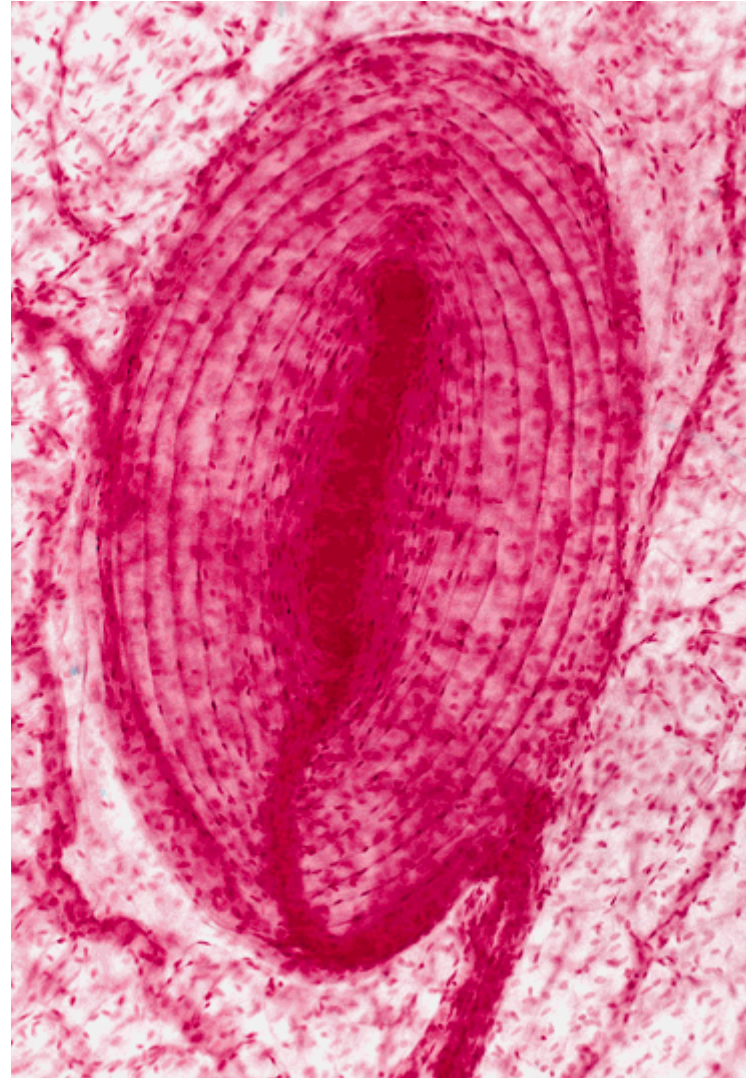
- The receptors stop sending action potentials
- Total adaptation (Pacini) partial (hair) or minimum (pain)





# Adaptation Mechanism of the Receptors

- Varies with type of receptor
- Pacini:
  1. Viscoelastic structure
  2. Electric accommodation in the terminal nerve fibril (closing of the sodium channel)



# Tonic/phasic Receptors

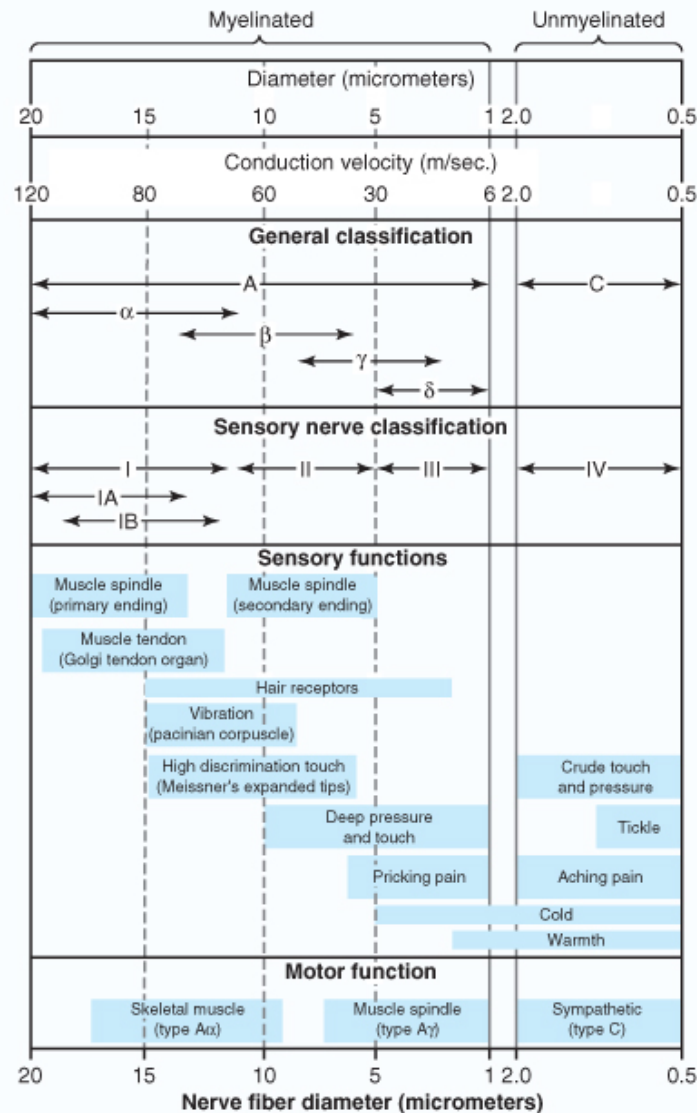
---

- **TONIC: slow adaptation**
  - Minutes/hours
  - Situation of the body and relation with the environment
  - Muscle spindle, Golgi tendon apparatus, macula of the vestibular apparatus, pain, arterial baroreceptors, chemoreceptors of the carotid and aortic tissue

# Tonic/phasic Receptors

- PHASIC=OF SPEED=OF MOVEMENT: fast adaptation
  - Only activate when the intensity of the stimulus changes
  - Have an important function to predict body movements related to speed (turn-balance, running)
  - Pacini

# Classification of Sensory Fibers



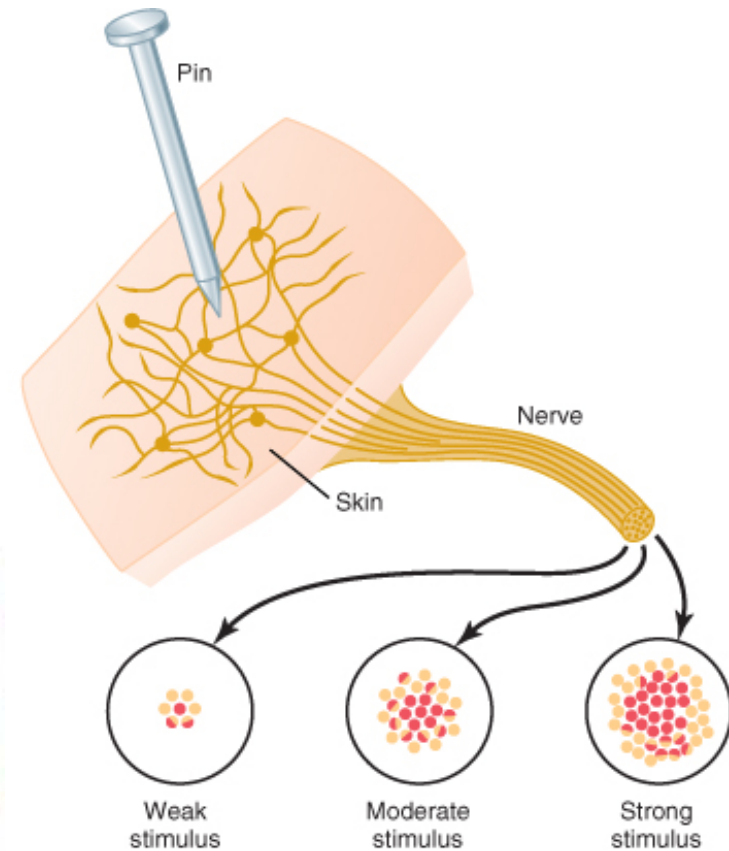
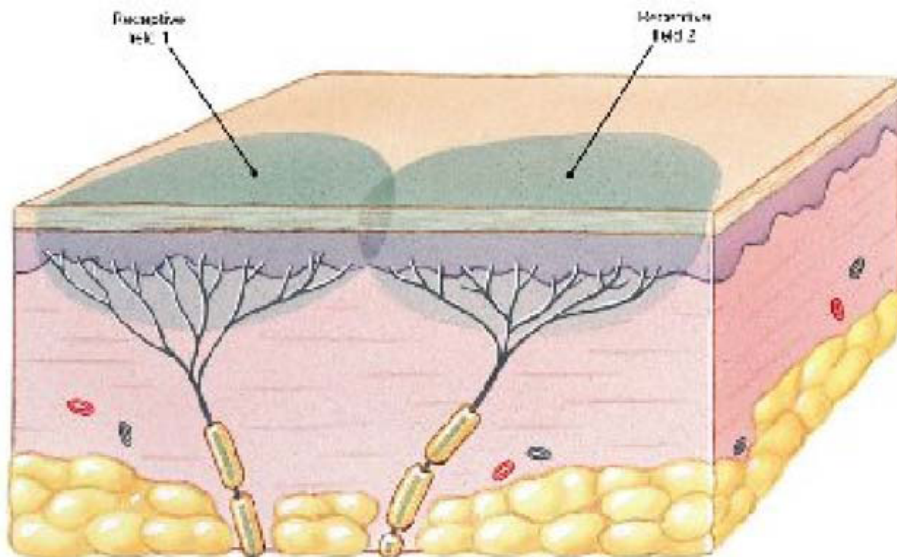
# General Classification

- Type A : myelinated, big and medium size (spinal nerves). Fast speed
  - $\alpha$  (70 to 120 m/s) proprioception
  - $\beta$  (35-75 m/s) touch and pressure
  - $\gamma$  (15-40 m/s) motor transmission muscle spindles
  - $\delta$  (6-30 m/s) pain, cold, touch
- Type C: Unmyelinated, slow speed (0,5-2 m/s)

# Spatial Summation

## RECEPTIVE FIELD

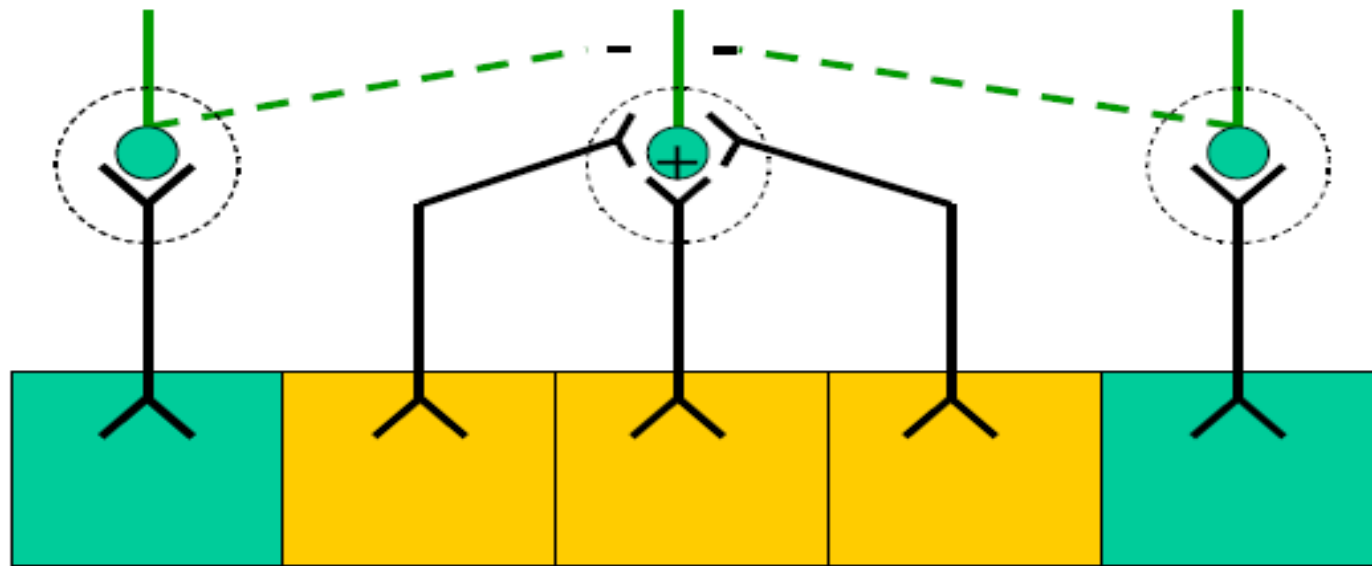
Endings that come from a single fiber



# Lateral Inhibition

## Lateral Inhibition

Helps accurately locate the stimulus,  
by delimiting its frontiers



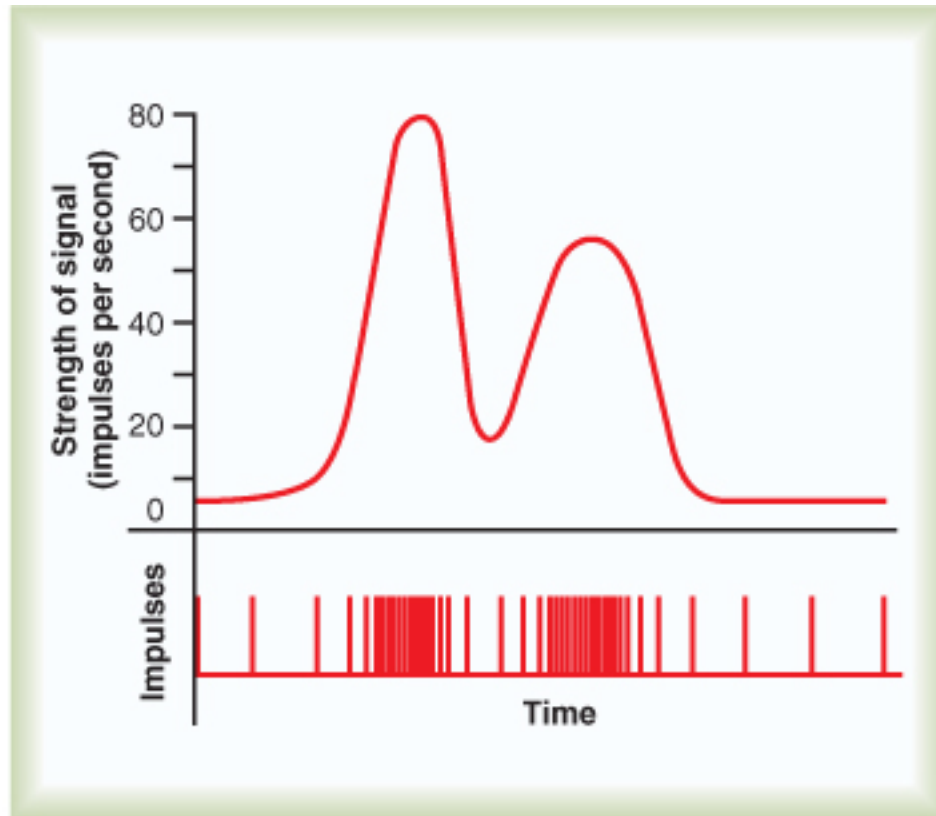
Field of  
inhibitory  
receptor

Field of  
excitatory  
receptor

Field of  
inhibitory  
receptor

# Temporal Summation

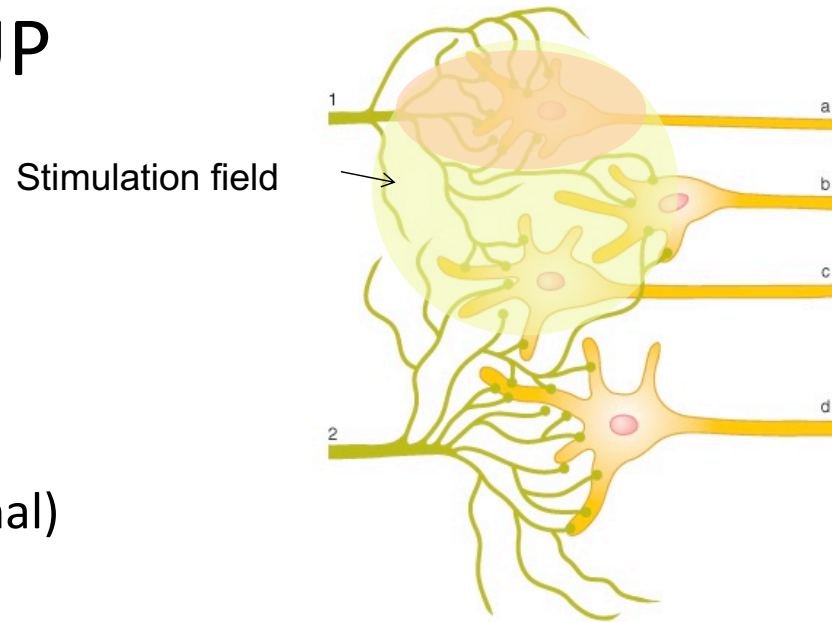
- Higher intensity to the stimulus when the frequency of the nerve impulses increases





# Conduction of the Sensory Stimulus

- NEURONAL GROUP

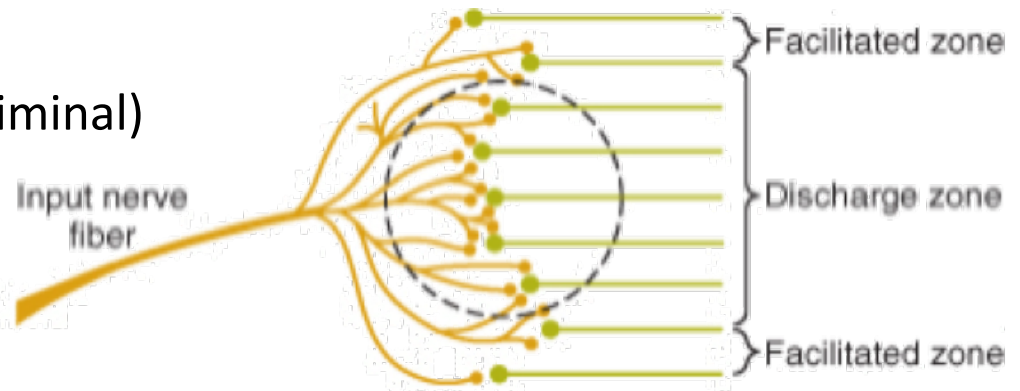


- Exciting stimulus

(above the threshold, liminal)

- Facilitation

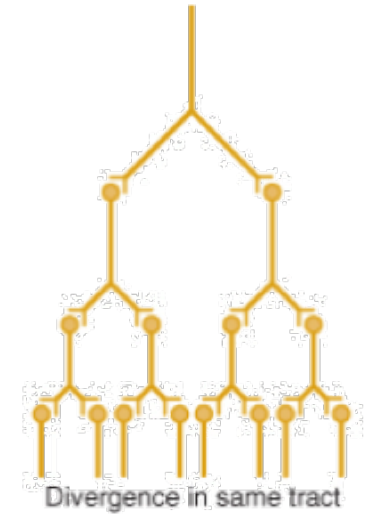
(below the threshold, subliminal)



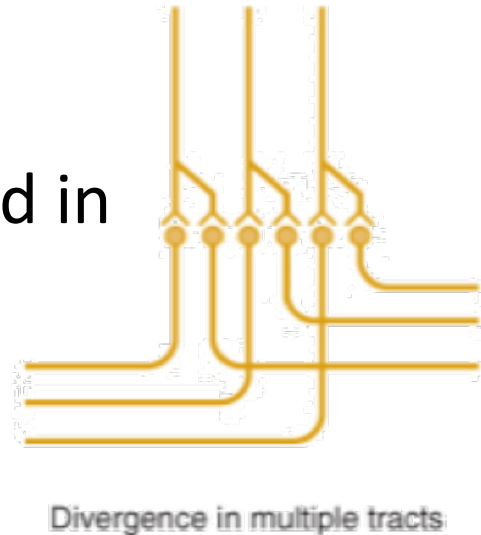
# Converging and Diverging Signals

- DIVERGENCE

- In the same fasciculation (amplifier)  
(corticospinal, skeletal muscles)

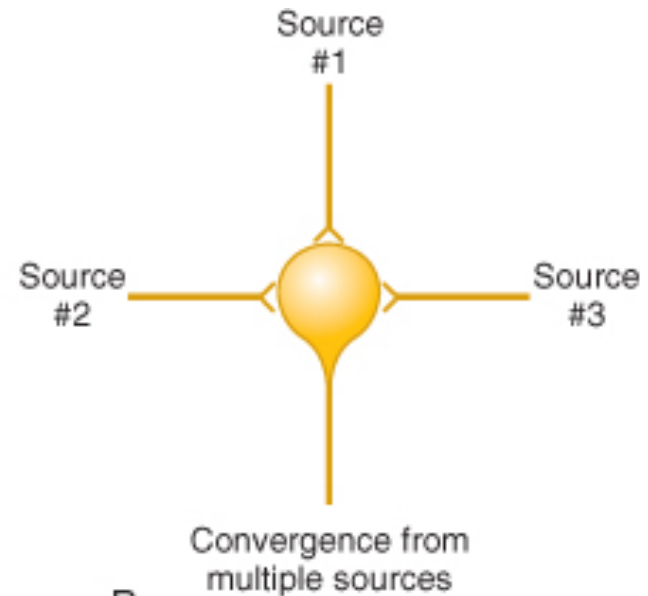


- In multiple fasciculations  
(the information is distributed in  
different directions)



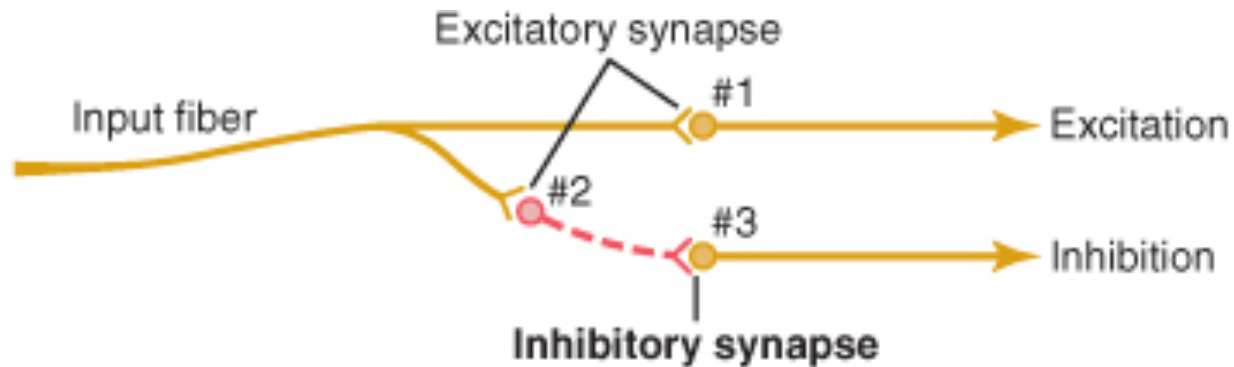
# Converging and Diverging Signals

- CONVERGENCE (summation)



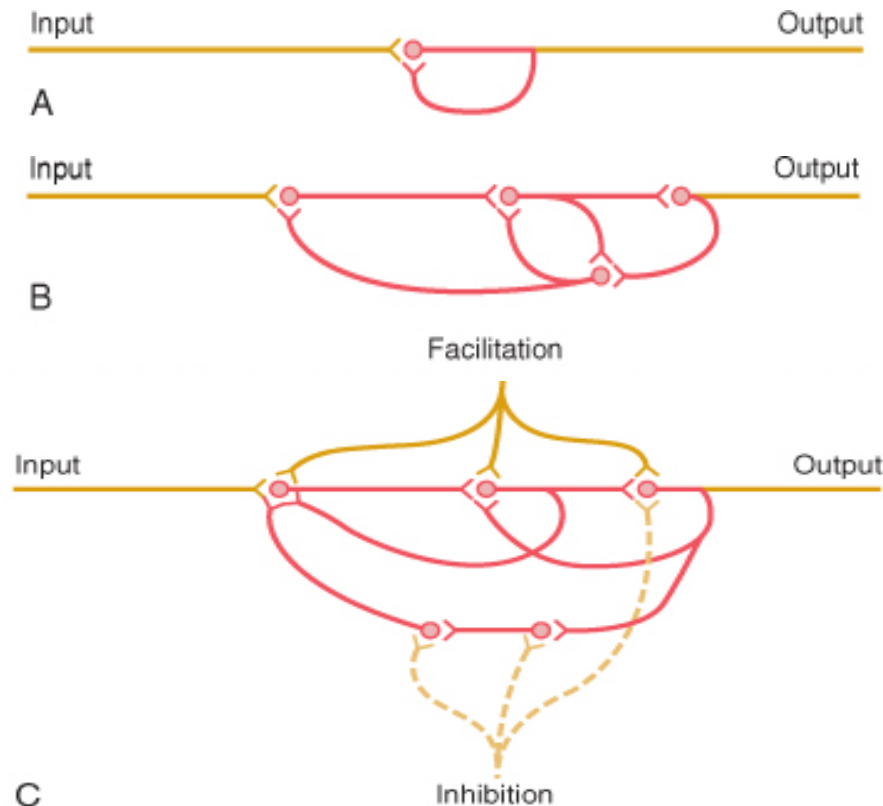
# Inhibition

- Reciprocal inhibition circuit (antagonistic muscles)

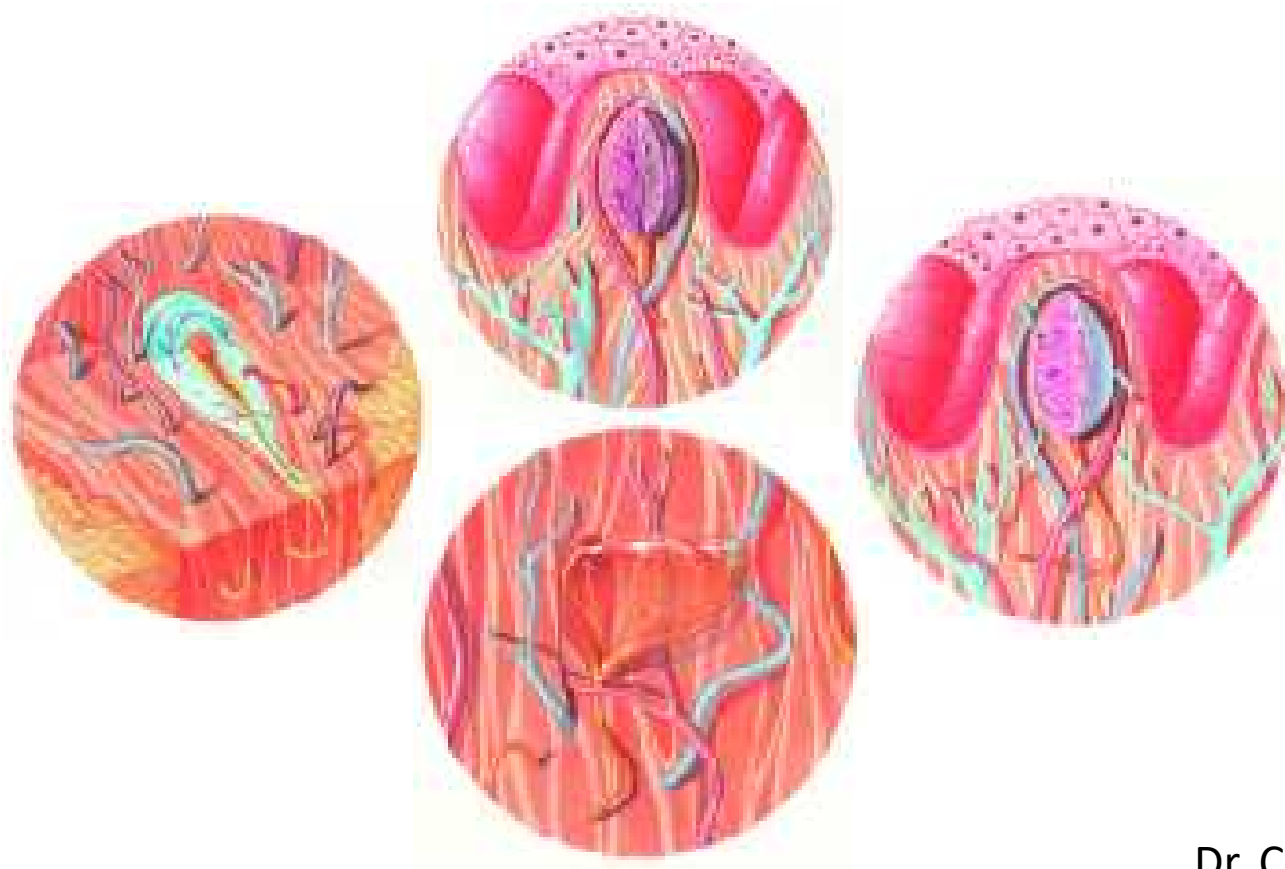


# Postdischarge

- ✓ Synaptic postdischarge
- ✓ Reverberant (oscillatory) postdischarge



# Physiology of Somatic Sensitivity: Somatic Mechanoreceptor Senses



# Outline

---

- Classification of somatic sensitivities
- Tactile sensations
- Tactile receptors
- Tickling and itch
- Sensory pathways
- Conduction to CSN
- Somatosensory cortex

# Classification of Somatic Sensitivities

---

- **Mechanoreceptor**
  - Tactile (touch, pressure, vibration)
  - Positional (static position, acceleration)
- **Thermoreceptor**
  - Cold
  - Heat
- **Pain**

Other classifications: exteroceptor, proprioceptor,  
visceral and deep



# Tactile Sensations

---

- Detected by the same type of receptors but in different anatomic locations
  - **Touch: skin, subcutaneous cell tissue**
  - **Pressure: deep tissue**
  - **Vibration:** every location but only for those that quickly adapt themselves. Vibration is the result of the repetition of fast sensory signals.

# Tactile Receptors

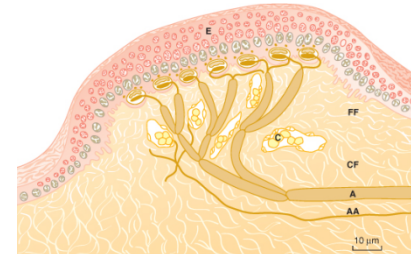
- Free nerve endings
  - Touch and pressure
- Meissner's corpuscle
  - In the glabrous skin, fingertips
  - High spatial discrimination
  - Fast adaptation - low frequency vibration
- Merkel disks
  - On skin with hair
  - Powerful initial signal that partially adapts, followed by a weaker but steadier signal



Free nerve endings

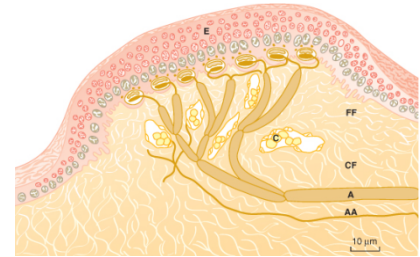


Meissner's corpuscle

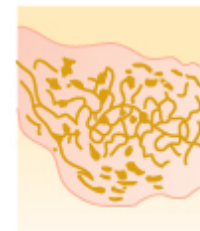


# Tactile Receptors

- Iggo dome receptor
  - Groupings of Merkel's disks
- Tactile hair
  - Fast adaptation, movement, initial contact
- Ruffini's end organ
  - Deeper, slow adaptation, continuous deformation
- Pacinian corpuscles
  - Fast local compression, very fast adaptation, vibration



Tactile hair



Ruffini's end-organ



Pacinian corpuscle

# Conductive Fibers

- $A\delta$  (6-30 m/s): free nerve endings
- $A\beta$  (35-75 m/s): the rest
- C (0.5-2 m/s): some free nerve endings

Gross signals (touch, pressure, gross tickling) ->  
slow conduction

Discriminative signals (localized, different  
intensity) -> fast conduction

# Vibration

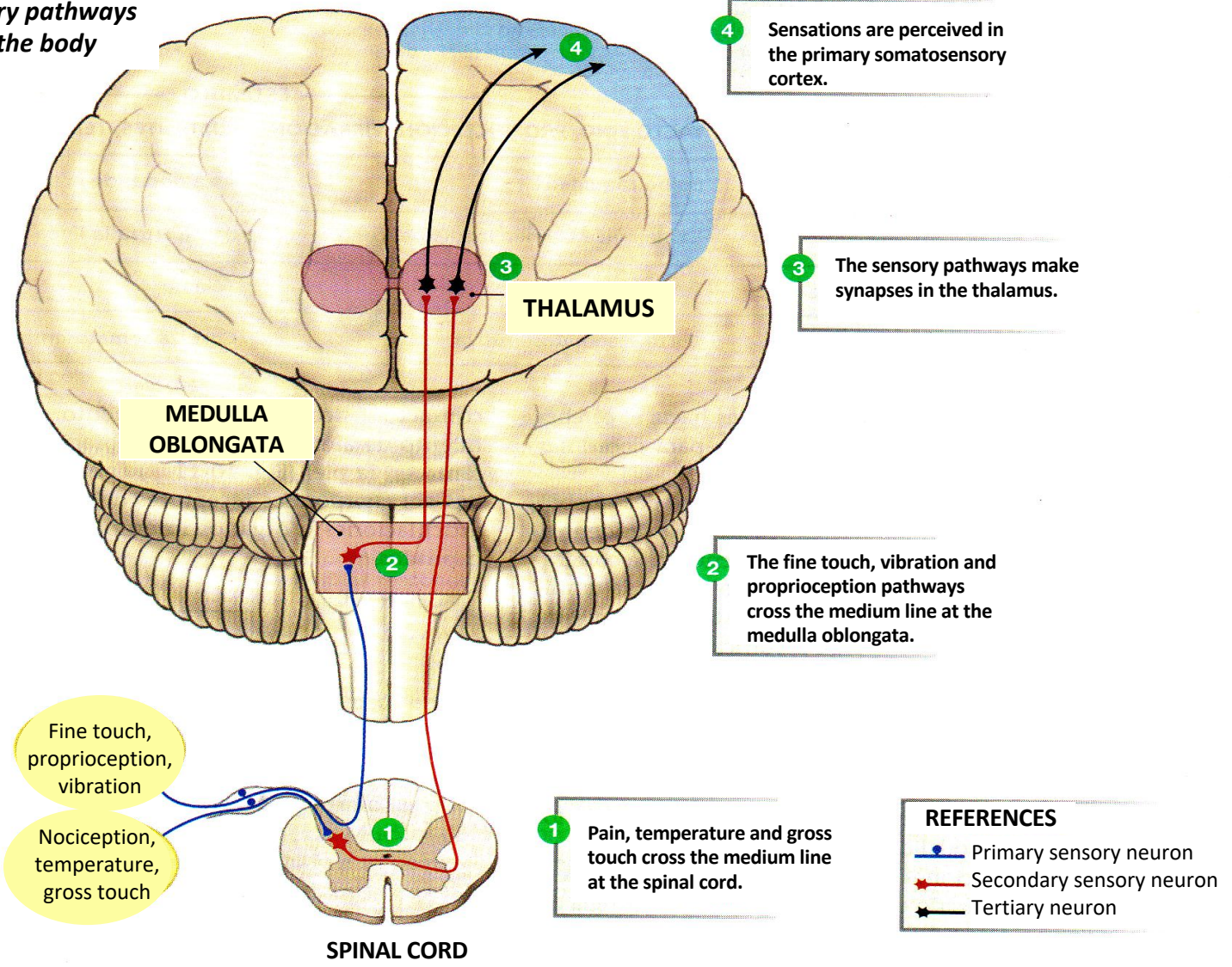
- Every tactile conductor
- Pacinian corpuscles
  - High frequency 30-800 cycles/s
  - Fast conduction
- Meissner's corpuscles
  - Low frequency 2-80 cycles/s
  - Slower adaptation

# Tickling and itch (pruritus)

- Superficial free nerving endings
- Fast adaptation
- Type C fibers
- Pain signals suppress the itching signals



■ **FIGURE 10-9** *The sensory pathways cross the medium line of the body*

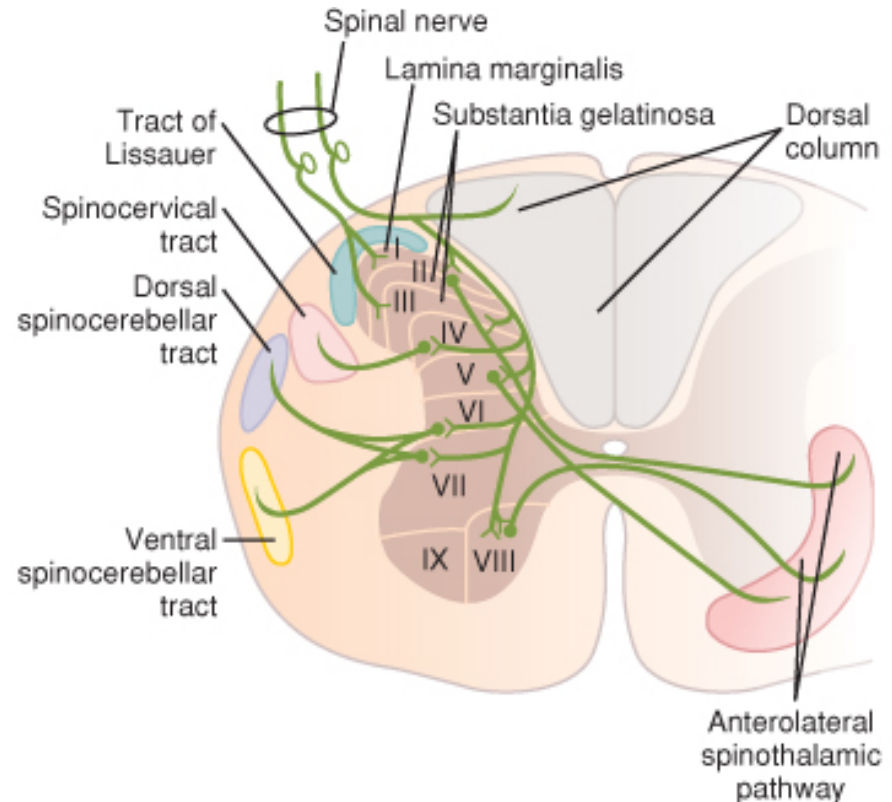


Taken from Silverthorn U. Fisiología Humana. Un enfoque integrado.  
 Editorial Médica Panamericana. Madrid. 2008

# Sensory Pathways

- Thoracic spine-medial lemniscus system
- Anterolateral system

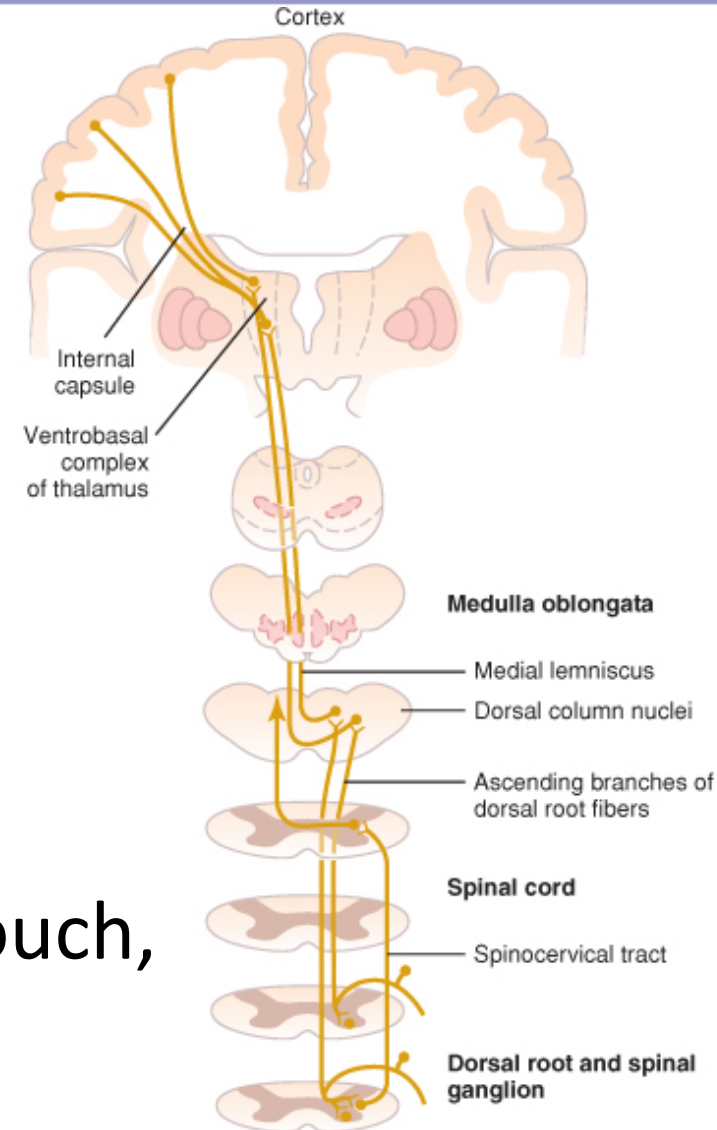
They partially  
join  
in the thalamus



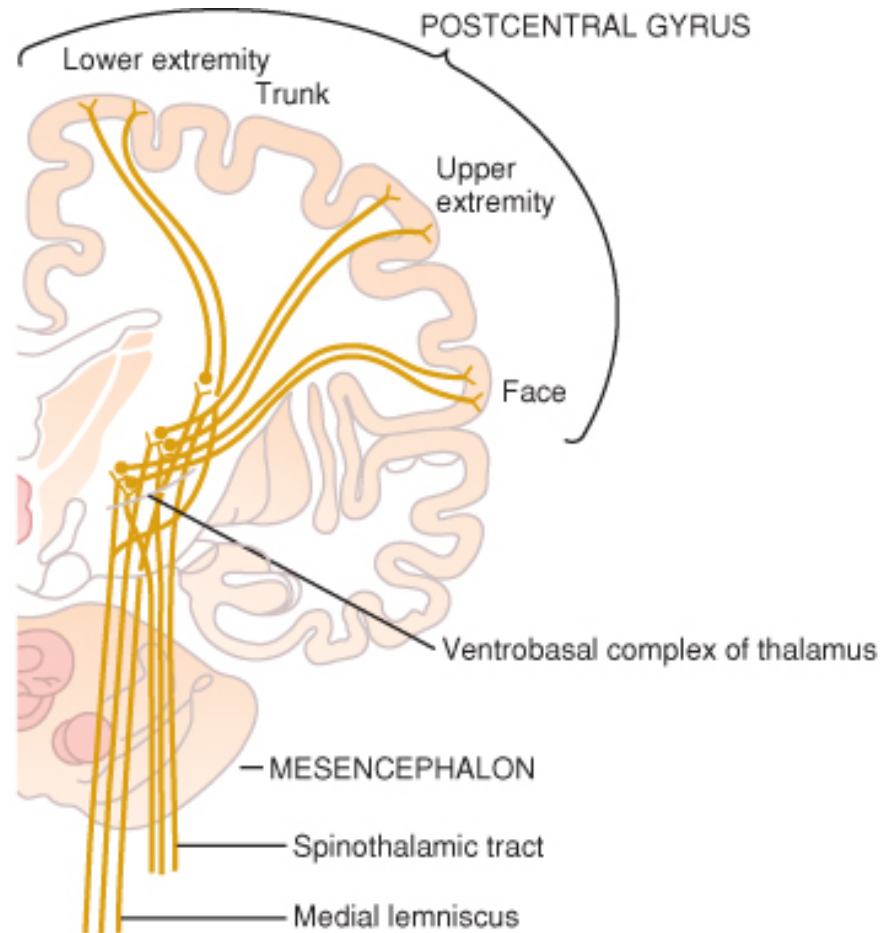


# Thoracic Spine-Medial lemniscus System

- Big myelinated fibres
- 30-110 m/s
- Higher spatial orientation
- Sensory information
  - ✓ Speed
  - ✓ Temporal accuracy
  - ✓ Spatial accuracy
  - ✓ Localized touch, subtle touch, vibration, joint position

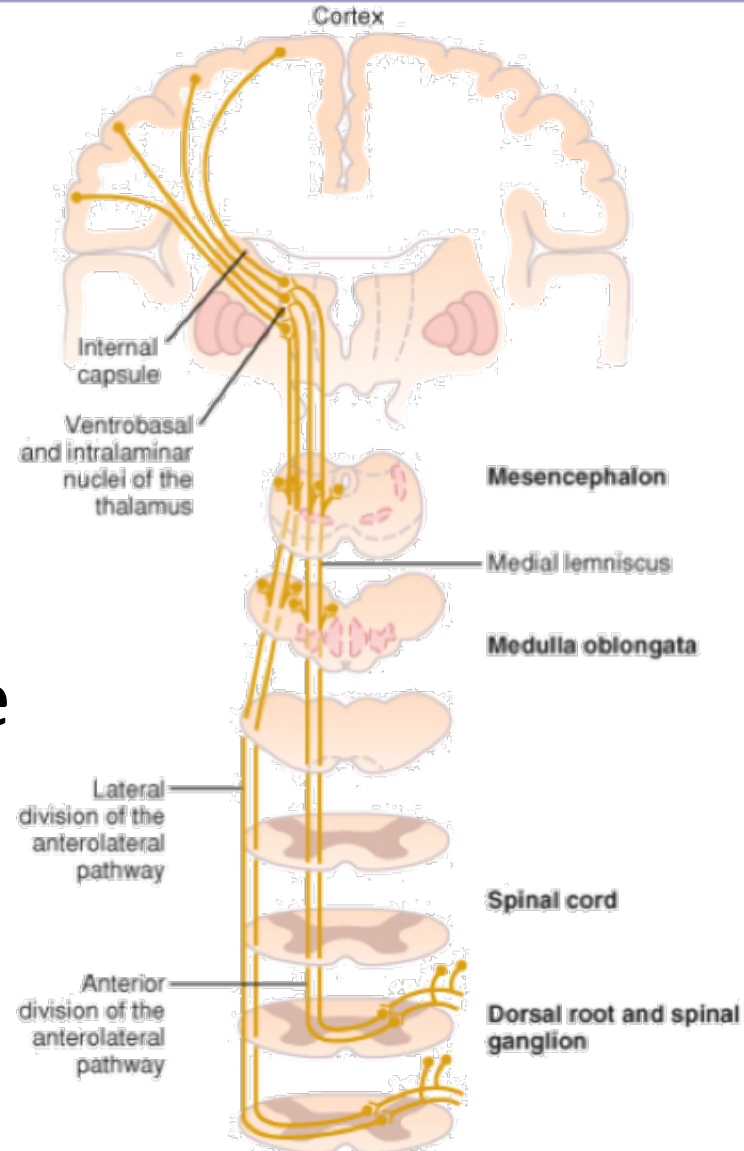


# Thoracic Spine-Medial Lemniscus System



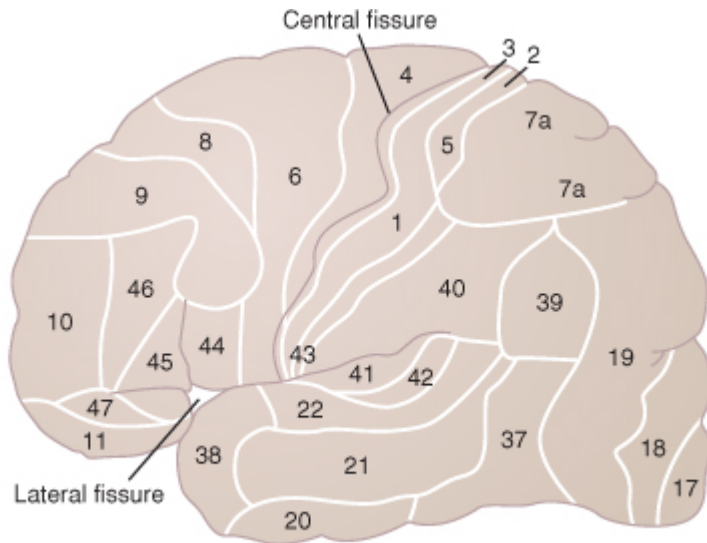
# Anterolateral System

- Small myelinated fibers
  - 40 m/s
  - Lower spatial orientation
  - Wide range of sensory modalities
- ✓ Pain, temperature, pressure and gross tact, tickling and itch, sexual feelings

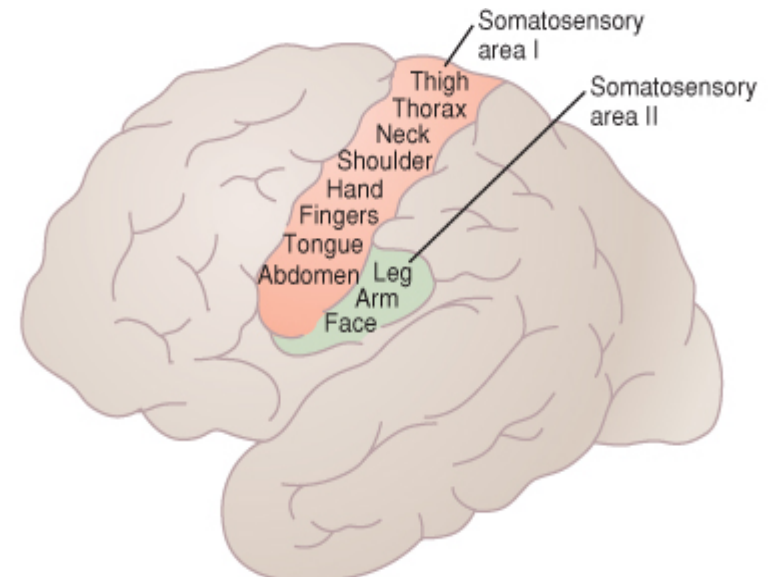


# Somatosensory Cortex

Brodmann areas



Somatosensory areas

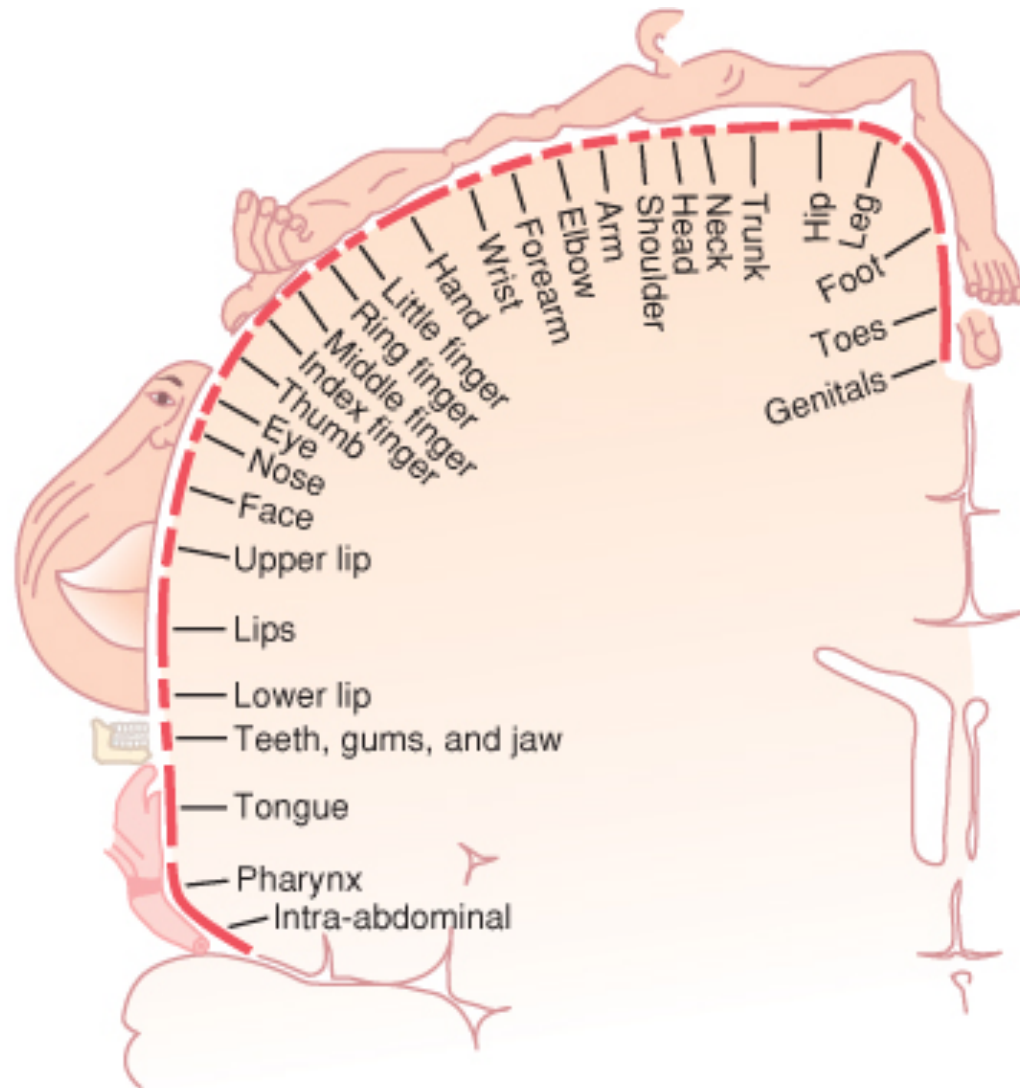


# Somatosensory Area I

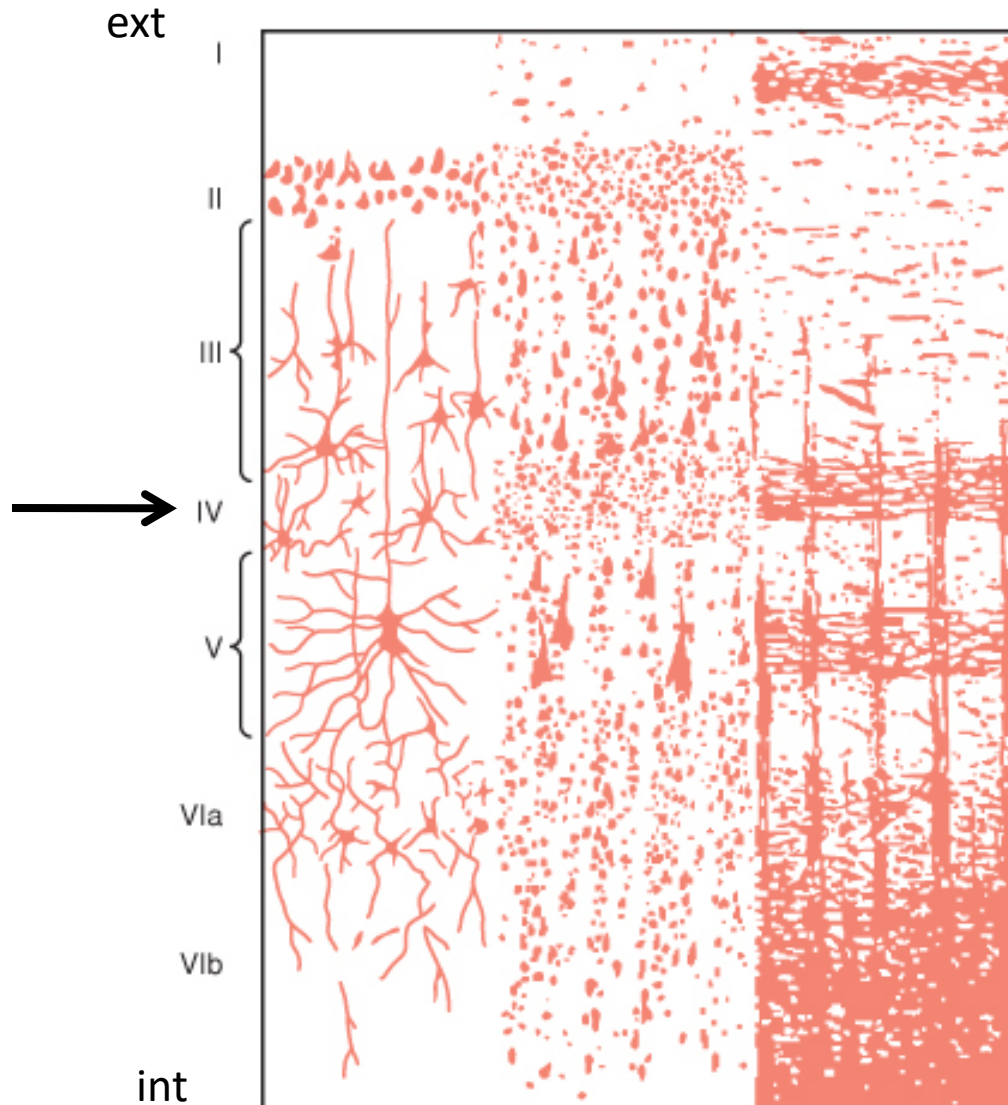
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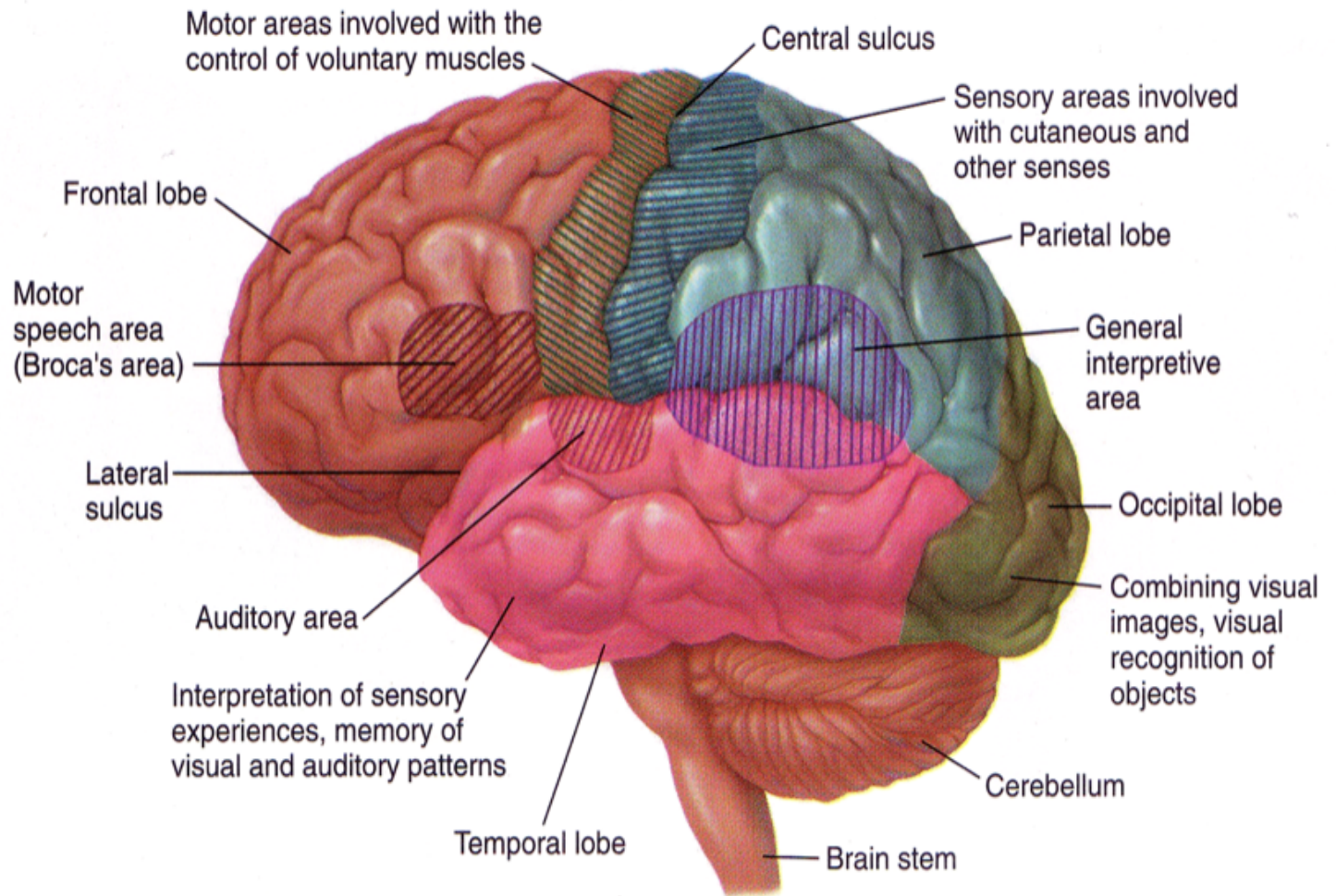
- Difficulty for finding the sensation (when gross)
- Degree of pressure against the body
- Assessment of the weight of objects
- Astereognosis (assessment of shapes and objects)
- Assessment of textures
- AMORPHOSYNTHESIS (resection of one somatosensory area)

# Somatosensory Cortex



# Layers of Somatosensory Cortex

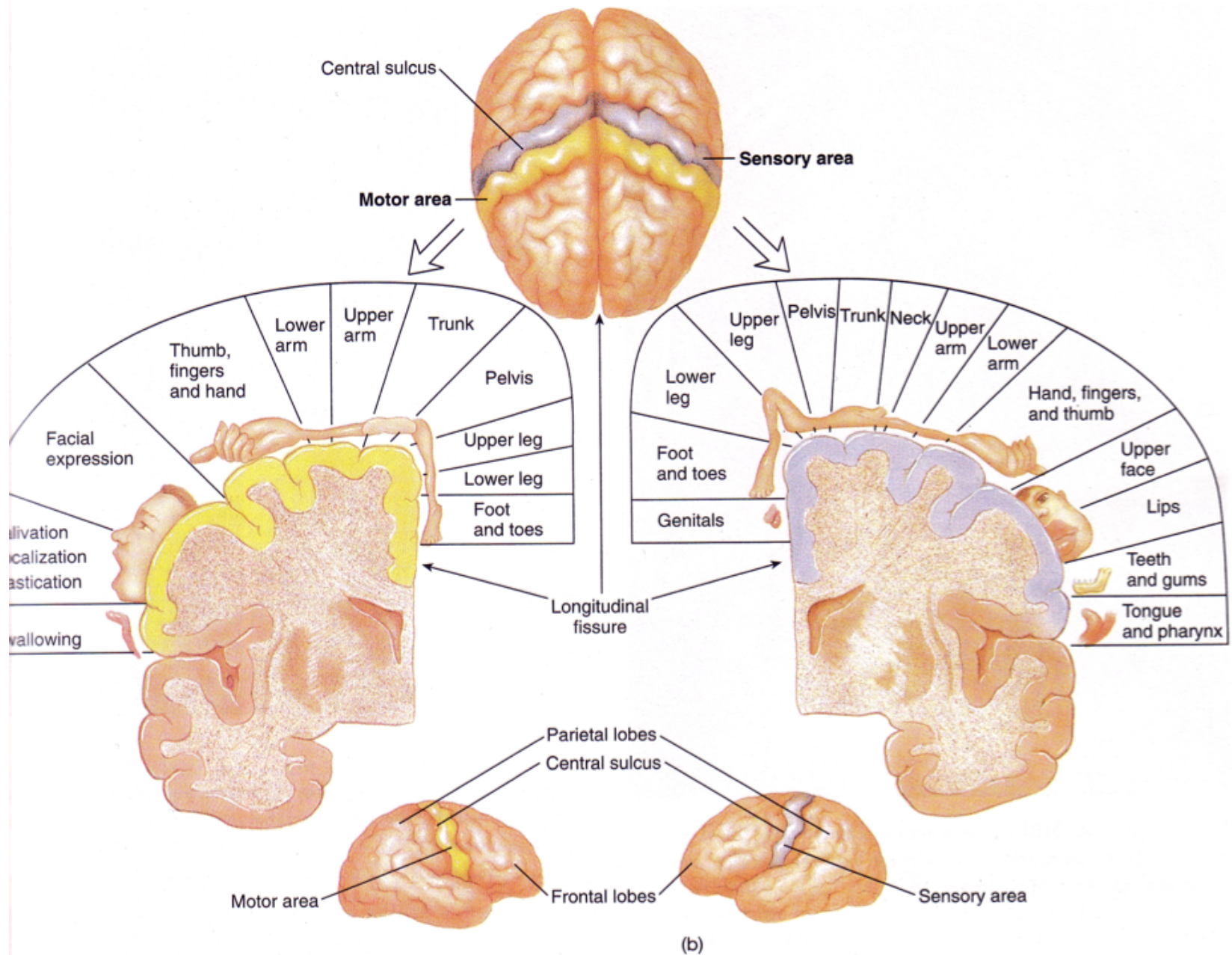




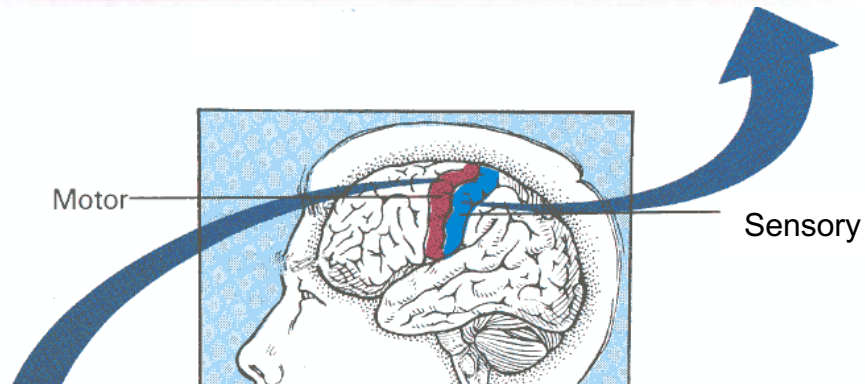
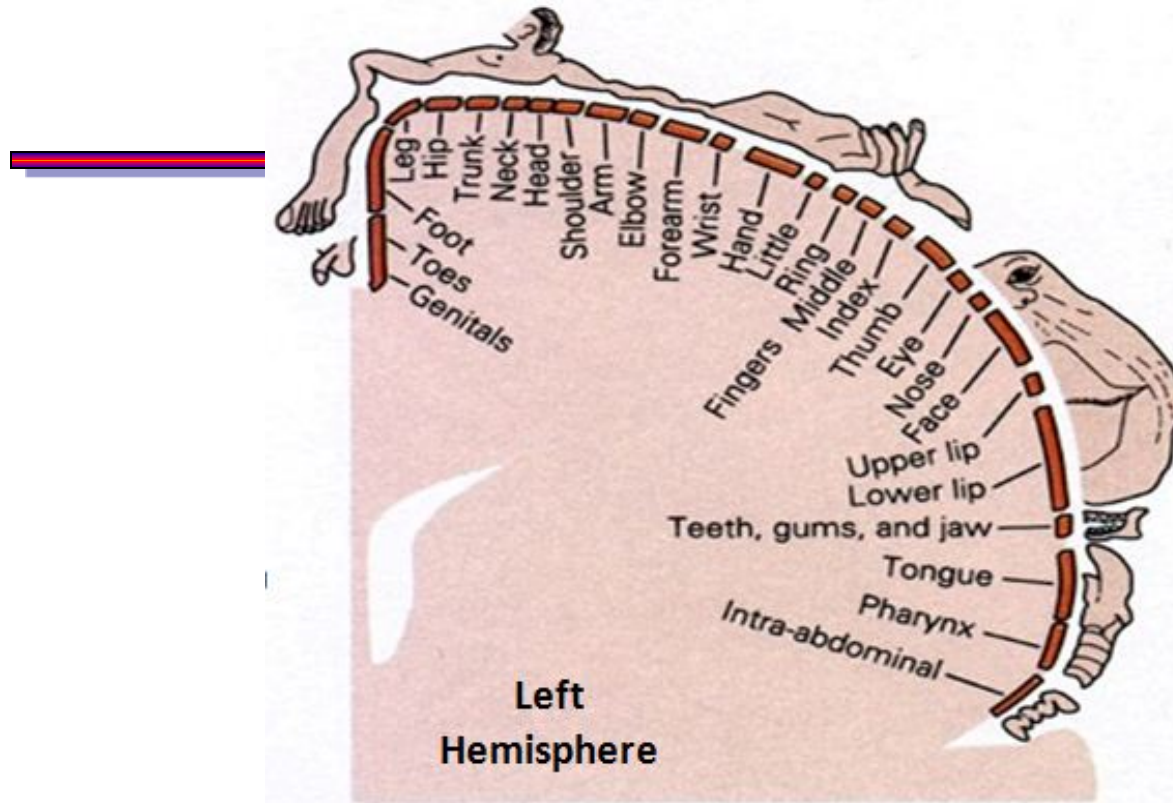
**Figure 8.6** The lobes of the left cerebral hemisphere. This diagram shows the principal motor and sensory areas of the cerebral cortex.

Taken from Stewart-Ira-Fox. Human Physiology. McGraw-Hill. 6th ed. Boston.1999

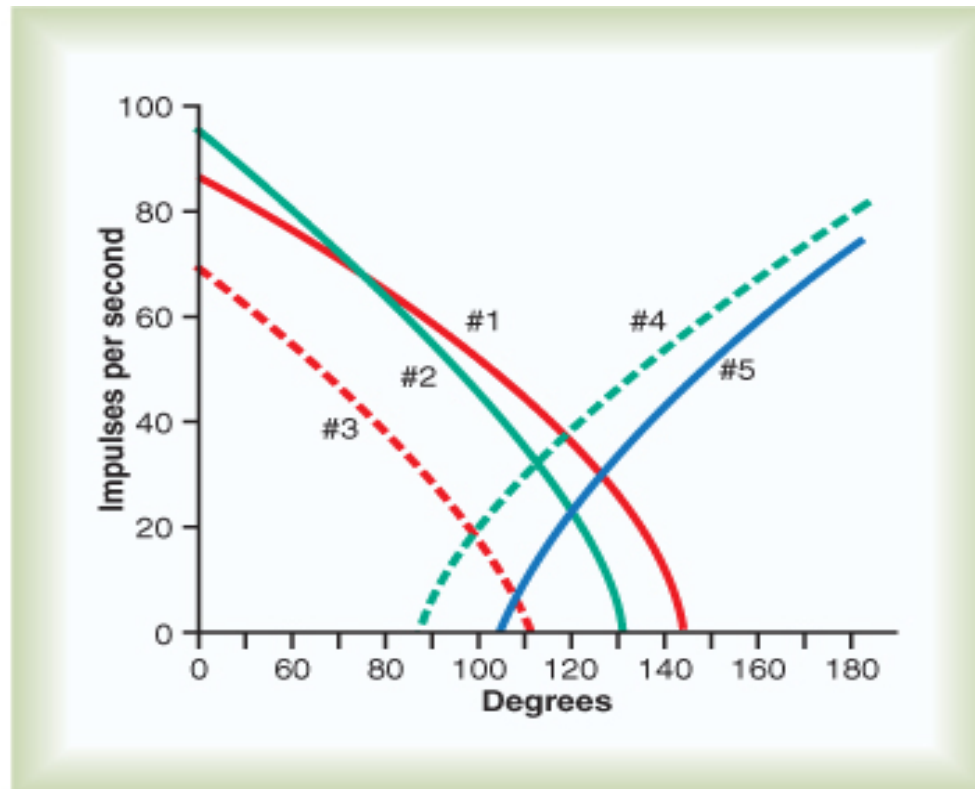




# A Primary somatosensory area



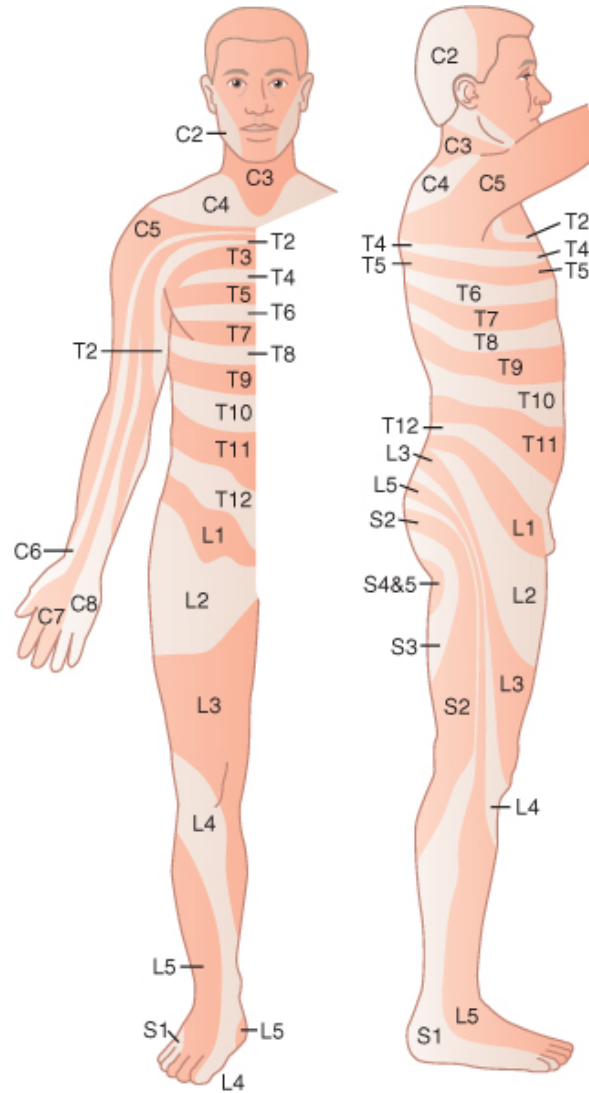
Taken from Thibodeau & Patton (Mosby/Doyma Libros, 1995)



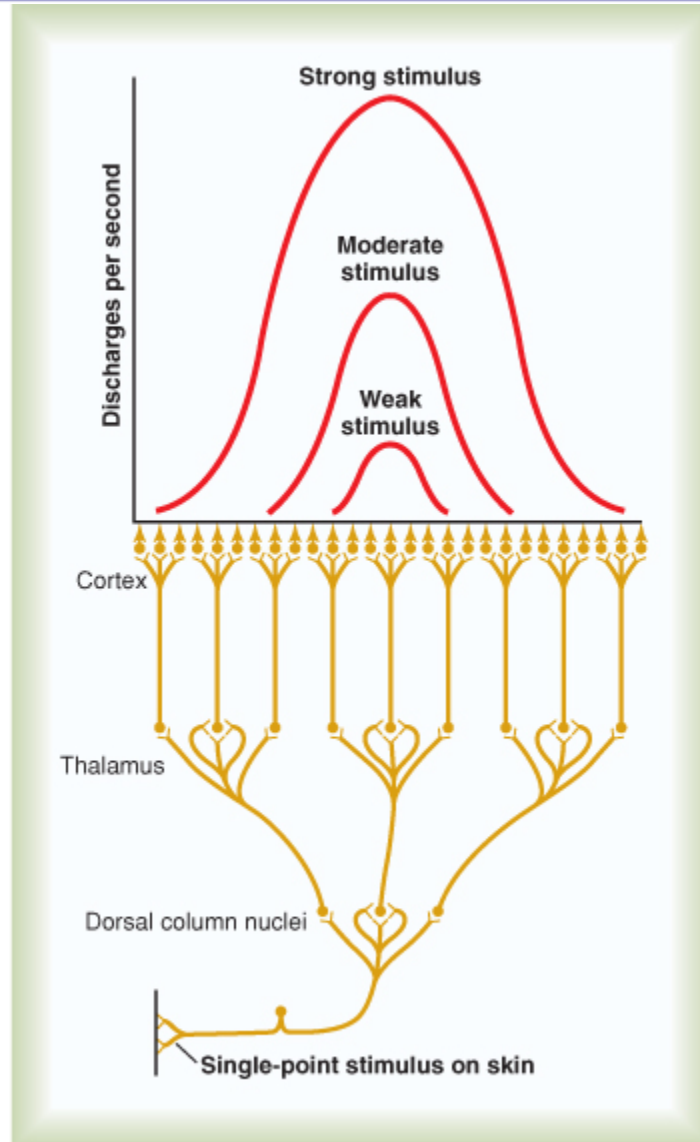
© Elsevier. Guyton & Hall: Textbook of Medical Physiology 11e - [www.studentconsult.com](http://www.studentconsult.com)

Reaction of 5 different thalamic neurons of the ventrobasal complex of the thalamus, depending of the higher or lower degree of extension or flexion of the knee.

# Dermatome



# Signal Transmission of a Stimulus





# PHYSIOLOGY OF PAIN

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# Outline

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- Concept of pain
- Importance of pain
- Types of pain
- Receptors and pain stimuli
- Types of fibres
- Pathways

# Concept of Pain

---

- Pain is the sensory experience produced by stimuli that injure or threaten tissue integrity.
- It is perceived as something that hurts.
- It is a protective feeling and is very helpful for the doctor when it comes to making a diagnosis.



# Importance of Pain

---

- It is present in most diseases.
- It is a **PHYSIOLOGICAL** process (it is pathological not to feel pain when we should).
- Some painful sensations may be pathological.
- It is an alarm, a protective and survival mechanism.

# Types of Pain

- According to how long it takes to appear in case of a noxa (agent that causes pain):

- **FAST/ACUTE**

At most, it takes 0.1 seconds to appear.

It is electric, sharp.

- **SLOW/CHRONIC**

It takes 0.1 or more seconds to appear.

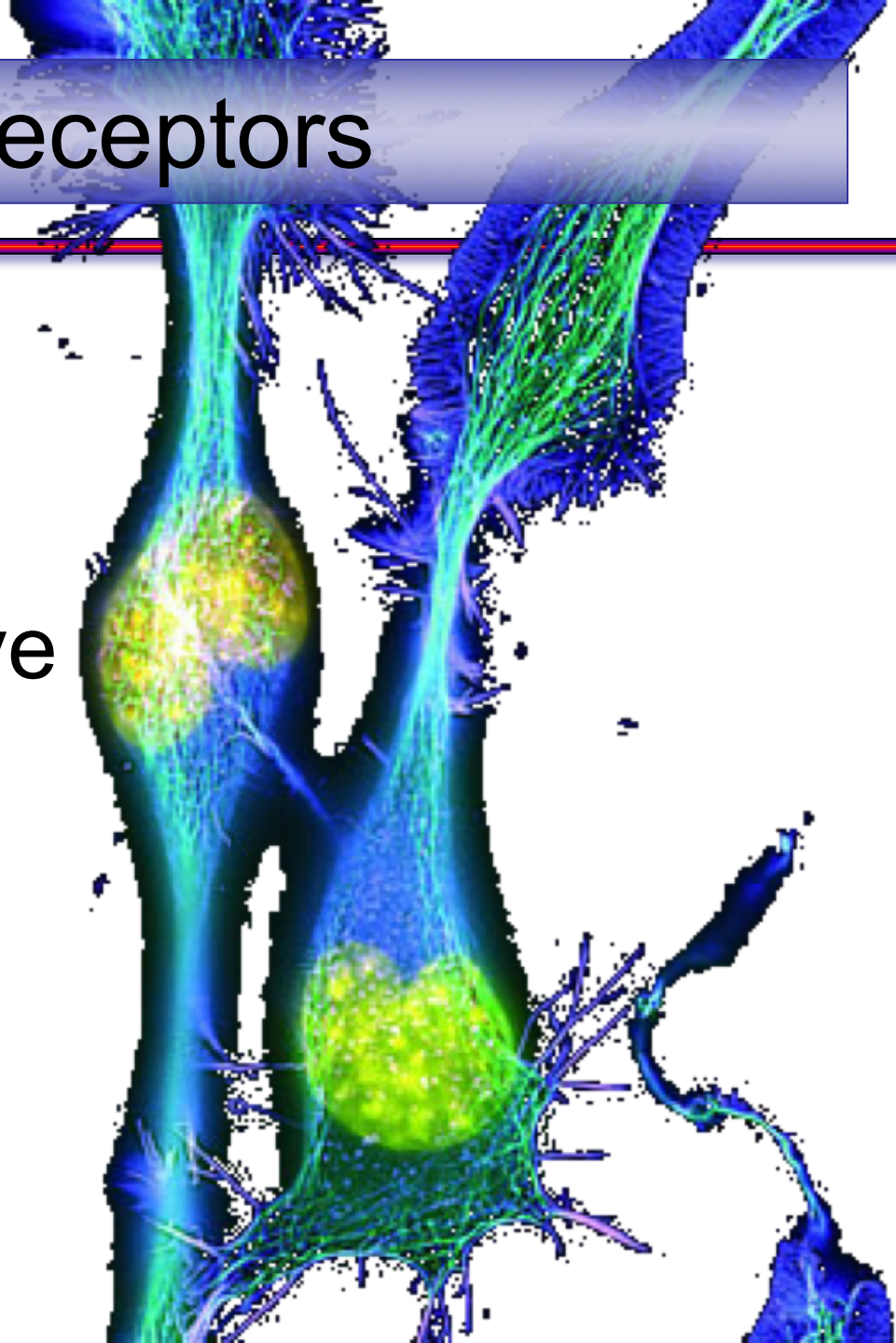
It is deaf, deep, burning, pulsating.

Its intensity usually increases in time.

Can be mixed.

# Pain Receptors

- **NOCICEPTORS:**  
Free nerve endings  
In general, any nerve ending that can identify pain stimuli.



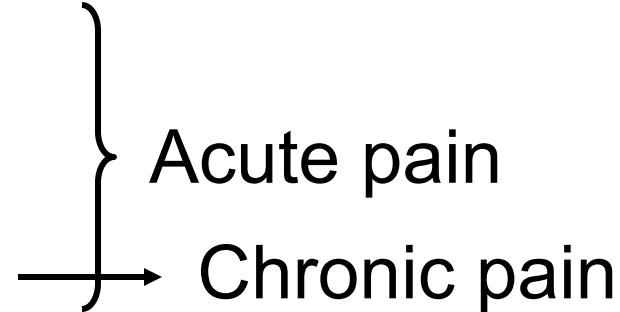
# Pain Stimuli

- Any agent that causes destruction of cells or tissue:

- Mechanical stimuli

- Thermal stimuli

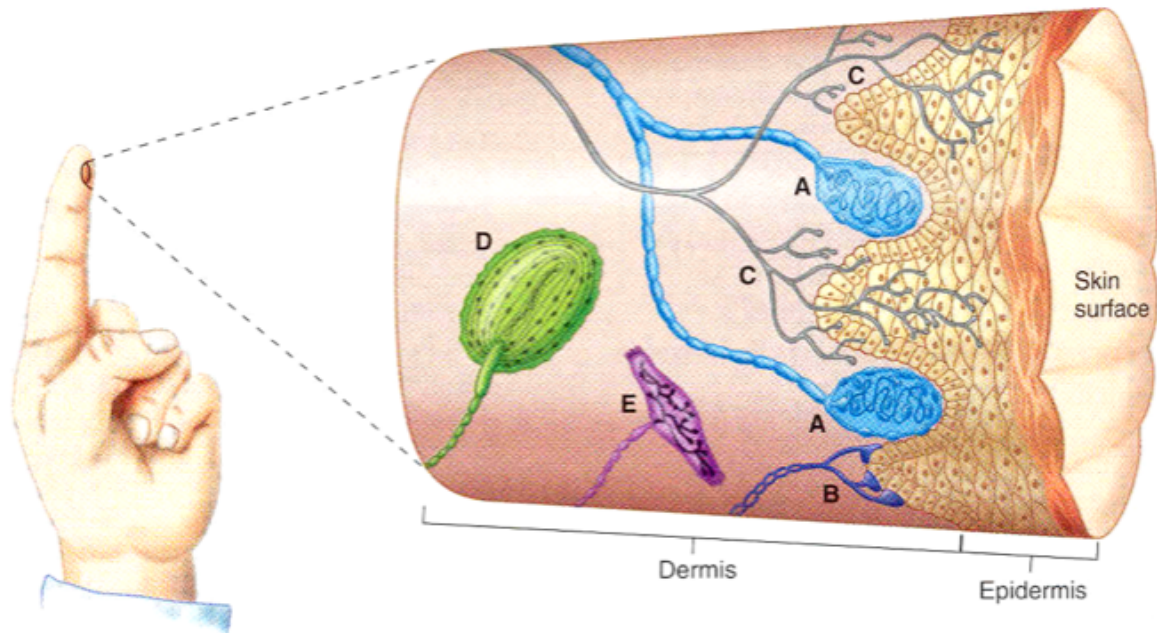
- Chemical stimuli:



- Any chemical substance that causes cell destruction:

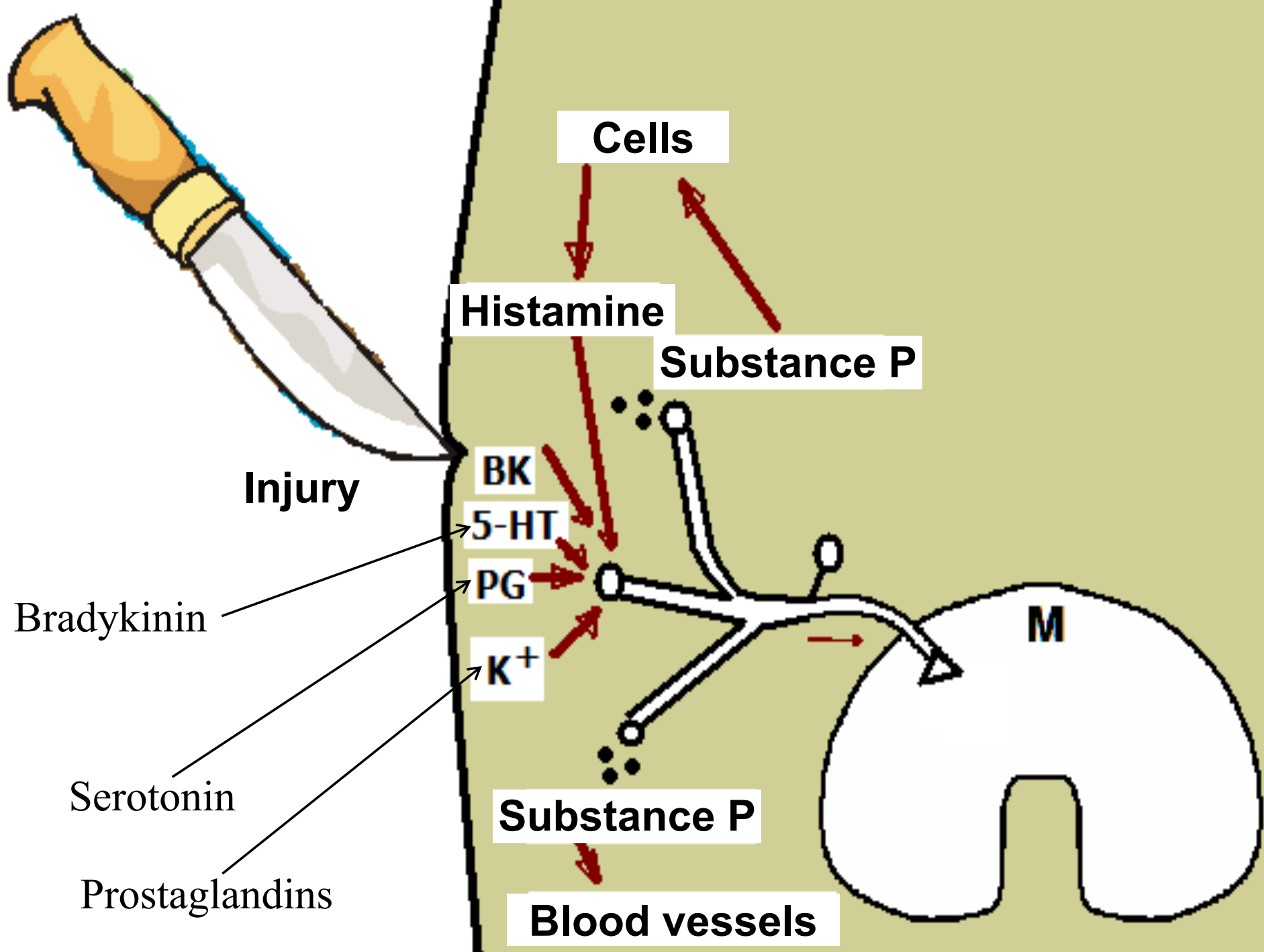
- Swelling: bradykinin, serotonin, histamine, proteolytic enzyme

- Neurotransmitters: acetylcholine, substance P, glutamate



- A - Tactile (Meissner's) corpuscle (light touch)
- B - Tactile (Merkle's) corpuscles (touch)
- C - Free terminal (pain)
- D - Lamellated (Pacinian) corpuscle (deep pressure)
- E - Ruffini corpuscle (warmth)

From Kandel, R. E.; Schwarz, J. H. y Jessell, T. M. *Principios de Neurociencia*. McGraw-Hill. Interamericana. 4<sup>a</sup> ed. Madrid. 2001.



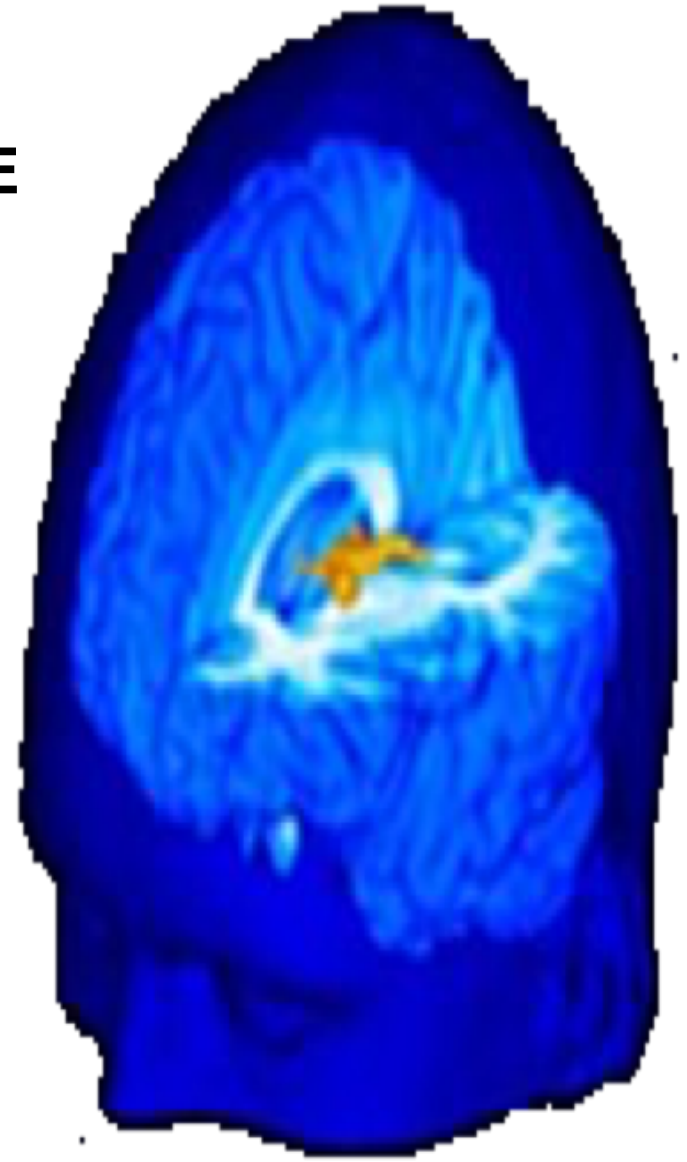
# Adaptation

---

- Nociceptors DO NOT adapt.
- The pain signal is able to modulate.
- Physiological role: to let the person know that the agent that causes the pain has not disappeared.



**NOT EVERYONE  
IS EQUALLY  
SENSITIVE TO  
PAIN AND NOT  
EACH OF OUR  
TISSUES IS  
EQUALLY  
SENSITIVE TO  
PAIN.**



**J. S. Mogil, J. Ritchie, S. B. Smith, K. Strasburg, et al. "Melanocortin-1 receptor gene variants affect pain and  $\mu$ -opioid analgesia in mice and humans". *Journal of Medical Genetics* 2005; 42:583-587.**



# Concepts

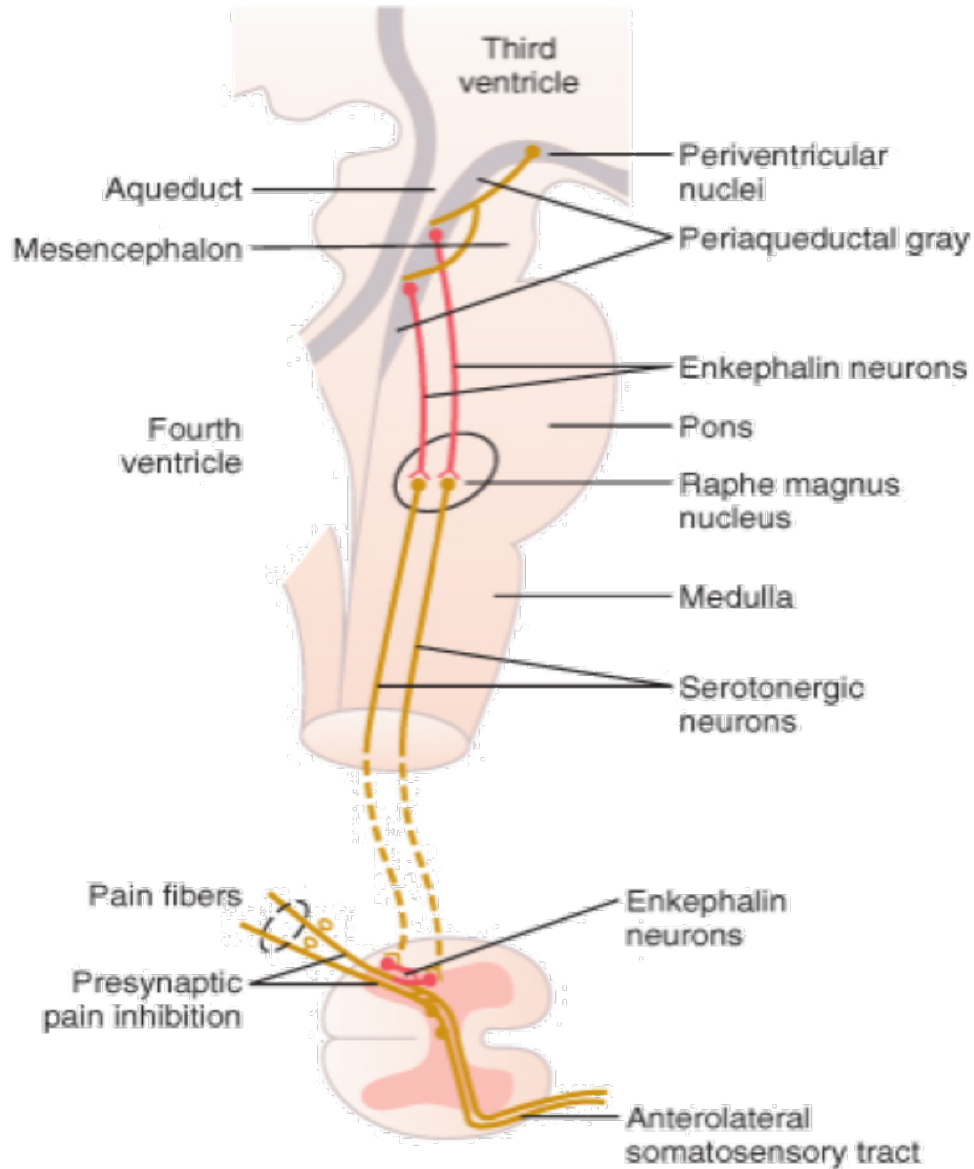
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- **HYPERALGESIA:** pathology that causes the pain threshold to decrease.
- **HYPOALGESIA:** pathology that causes the pain threshold to increase.
- **ANALGESIA:** absence of pain  
≠ ANAESTHESIA
- **ALGESIA:** normal pain sensation.

# Very Painful Stimuli

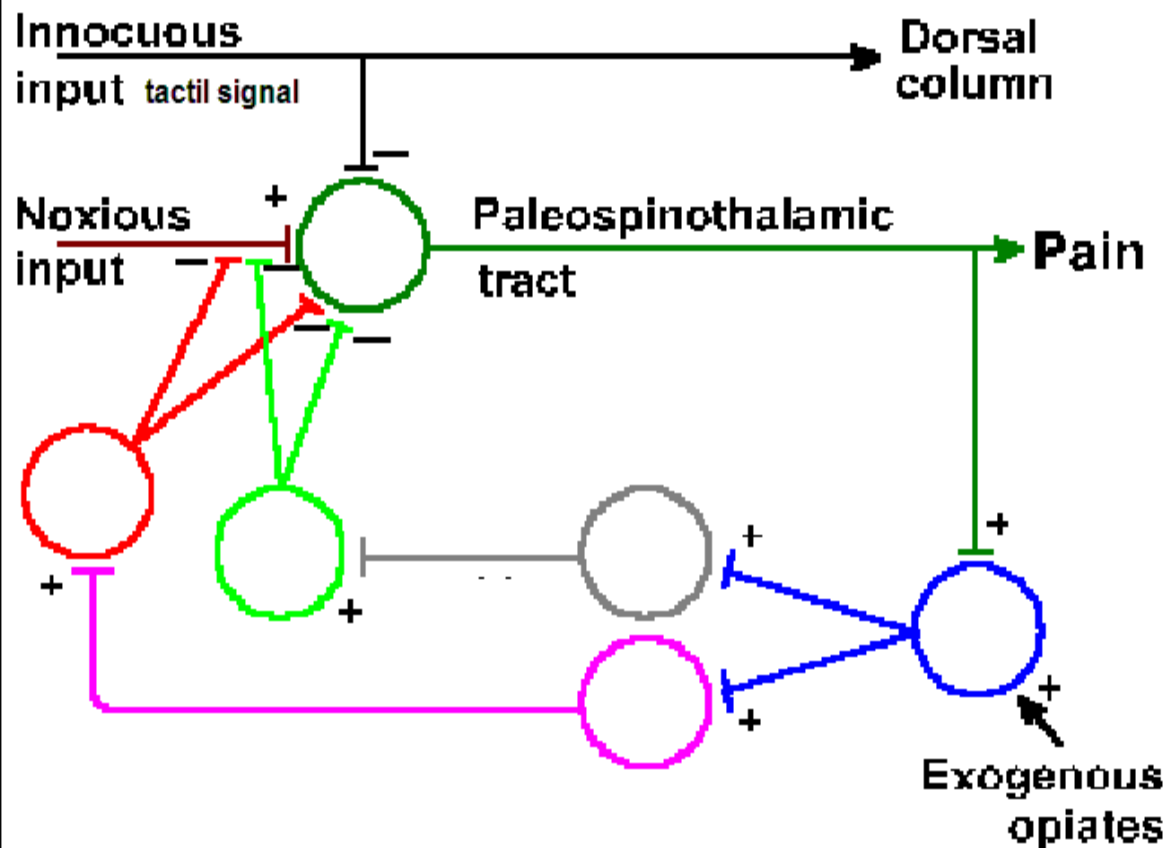
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- Thermal  $> 45\text{ }^{\circ}\text{C}$
- Chemical: bradykinin
- Tissue ischaemia
- Muscle spasm



## ANALGESIC SYSTEM

Guyton & Hall. *Tratado de Fisiología Médica*. 11<sup>a</sup> ed. Elsevier España, S. A. Madrid. 2006.



**Fig. 6-10. The endogenous pain suppression theory includes a negative feedback system in which spinothalamic tract cells (1), activated by noxious input, activate cells of the periaqueductal gray matter (2), which in turn activate descending pathways from the nucleus raphe magnus (3) and the locus ceruleus or nuclei subceruleus and parafacicularis (4). At the segmental spinal cord, interneurons (5 and 6) activated by these descending impulses inhibit further activation of spinothalamic tract cells. Also shown are the sites of action of dorsal column influences and morphine (Basbaum AI and Fields HL: *Ann Neurol* 4:451-462, 1978).**

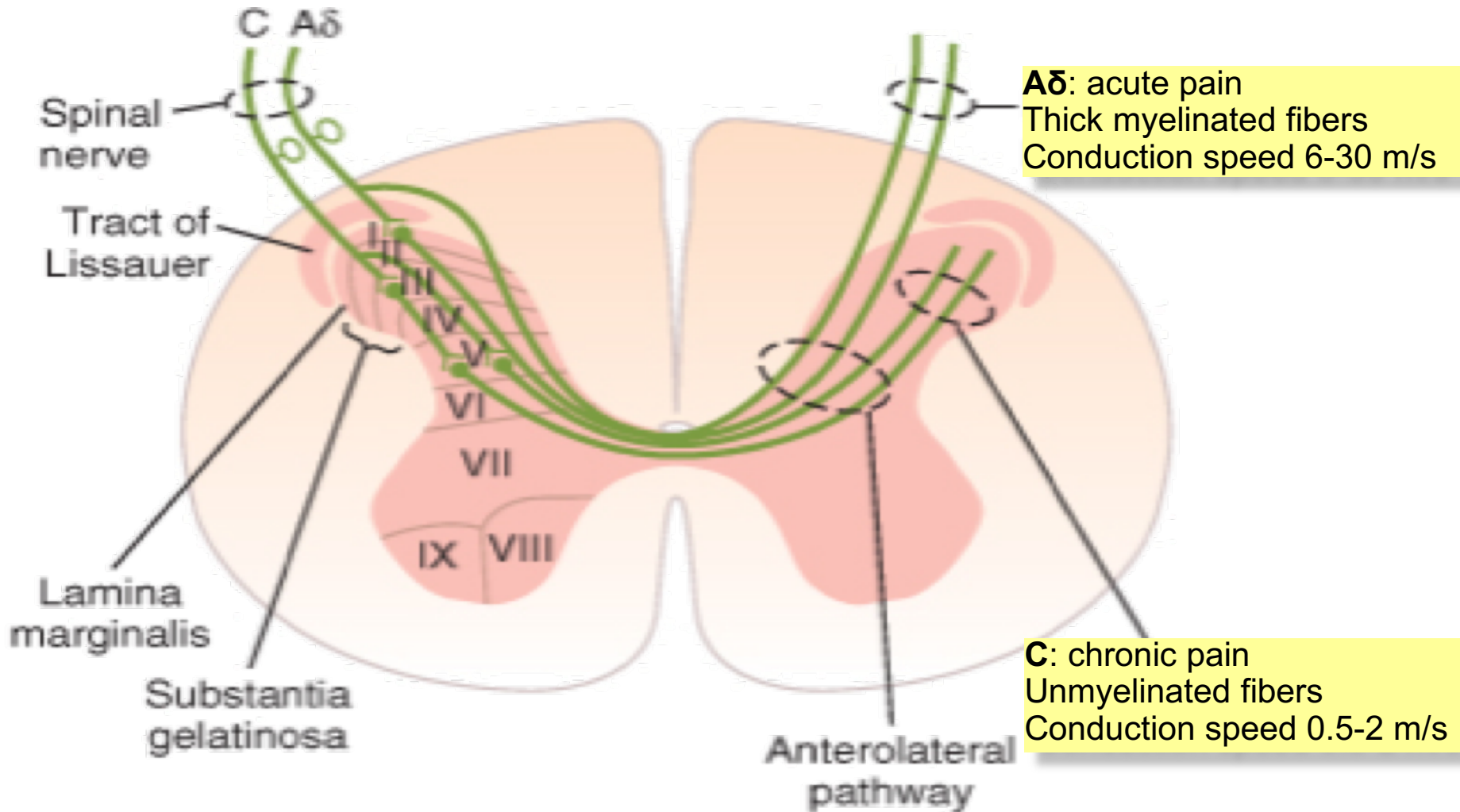
**Table 2–1.** Nerve fiber types in mammalian nerve.<sup>1</sup>

Fiber Type	Function	Fiber Diameter (μm)	Conduction Velocity (m/s)	Spike Duration (ms)	Absolute Refractory Period (ms)
<b>A</b>					
α	Proprioception; somatic motor	12–20	70–120	0.4–0.5	0.4–1
β	Touch, pressure	5–12	30–70		
γ	Motor to muscle spindles	3–6	15–30		
δ	<u>Pain</u> , cold, touch	2–5	12–30		
<b>B</b>	Preganglionic autonomic	<3	3–15	1.2	1.2
<b>C</b>					
Dorsal root	<u>Pain</u> , temperature, some mechanoreception, reflex responses	0.4–1.2	0.5–2	2	2
Sympathetic	Postganglionic sympathetics	0.3–1.3	0.7–2.3	2	2

<sup>1</sup> A and B fibers are myelinated; C fibers are unmyelinated.

Source: Review of Medical Physiology. William F. Ganong. Mc Graw Hill. 20<sup>th</sup> Ed.

# Types of Pain Fibers

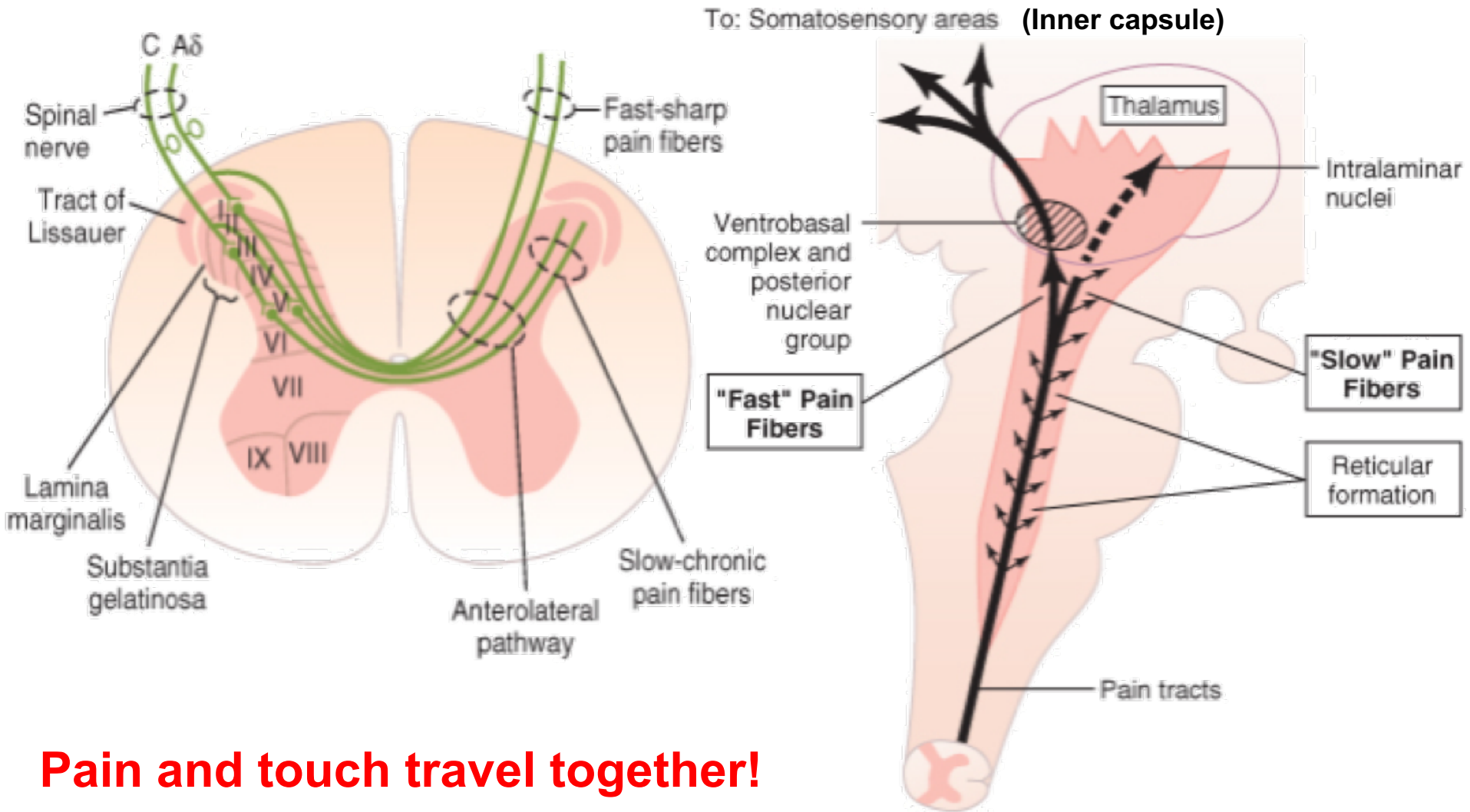


# Nerve Pathways that Conduct Pain

---

- **PALEOSPINOHALAMIC TRACT**
  - **Chronic pain**
    - Very hard to trace
    - Substance P
- **NEOSPINOHALAMIC TRACT**
  - **Acute pain**
    - Acute thermal and mechanical
    - Easier to trace
    - Glutamate

# Nerve Pathways that Conduct Pain



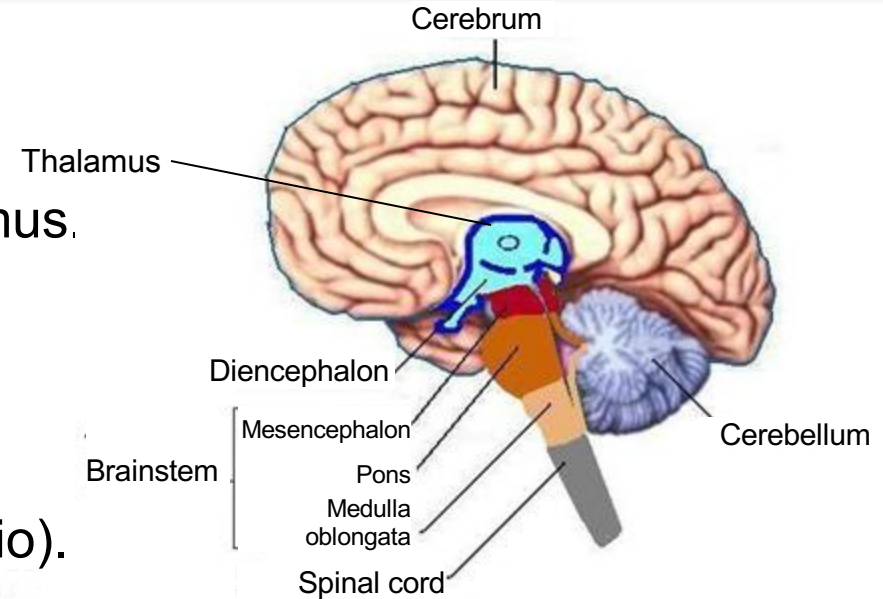
**Pain and touch travel together!**



# Nerve Pathways that Conduct Pain

## Spinothalamic tract:

- The fibers do not reach the cortex!
- They end at the:
  1. Intralaminar nuclei of the thalamus.
  2. Nuclei of the reticular formation of the medulla oblongata, pons and mesencephalon.
  3. Tectal region of the midbrain.
  4. Periaqueductal gray zone (Silvio).



## Mesencephalon:

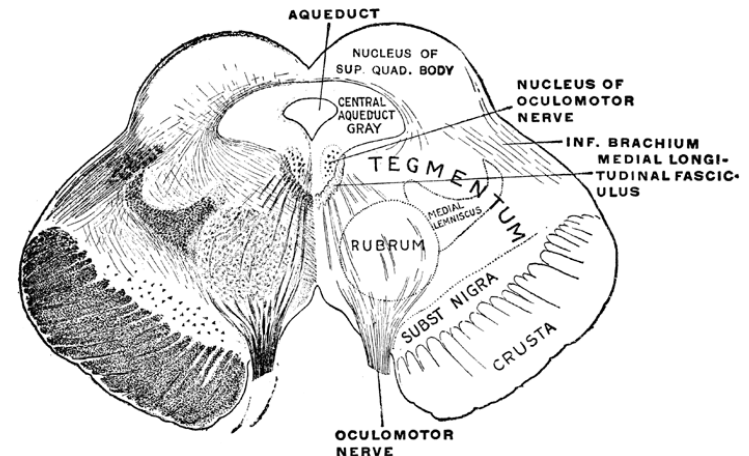
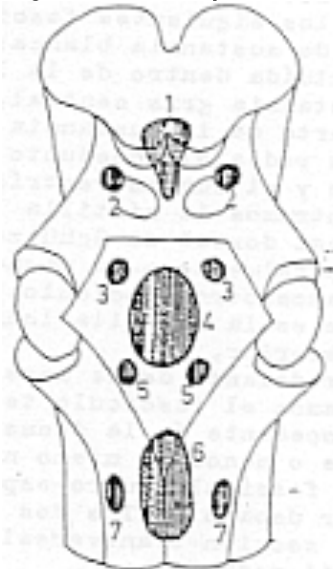
- Supratrochlear nucleus (1)
- Pontine peduncular nuclei (2)

## Pons:

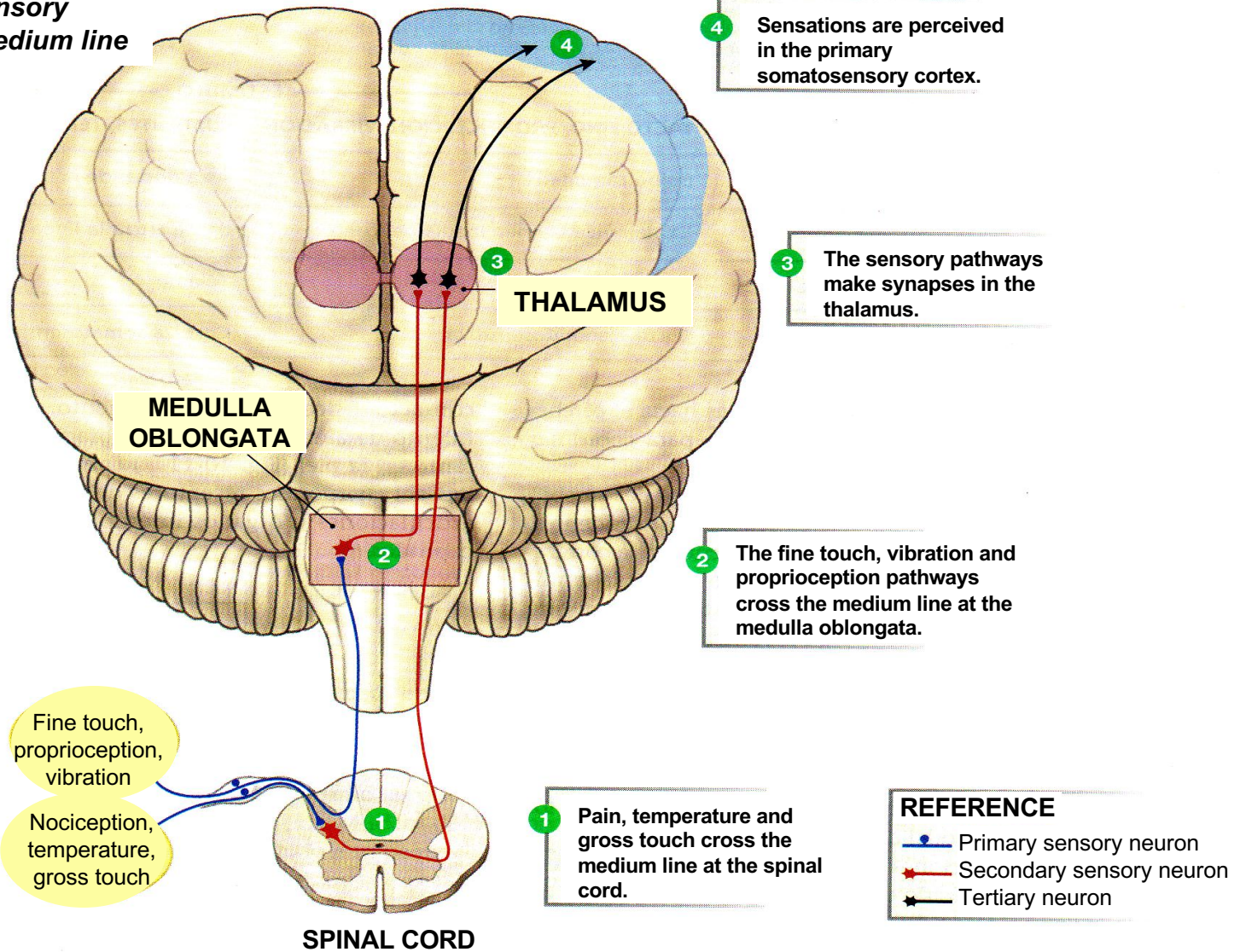
- Oral central nucleus (3)
- Main central nucleus (4)
- Caudal central nucleus (5)

## Medulla oblongata:

- Giant cell nucleus (6)
- Central nuclei of the medulla (7)



■ **FIGURE 10-9** *The sensory pathways cross the medium line of the body*





# PHYSIOLOGY OF PAIN (II)

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# Outline

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- System of analgesia
  - Opioid system
- Referred pain
  - Characteristics and types
- Hyperalgesia
- Trigeminal neuralgia
- Thermal sensitivity

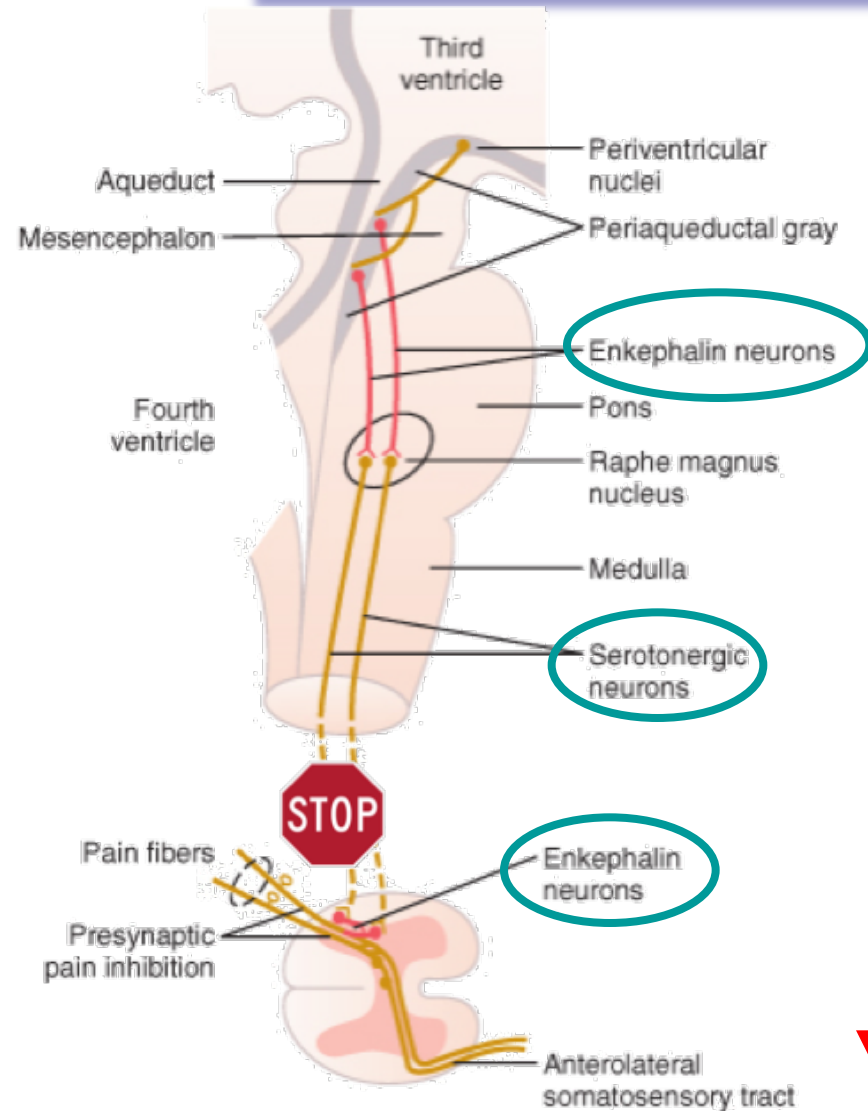
# Analgesia

Property of the brain to suppress the entry of pain signals to the nervous system

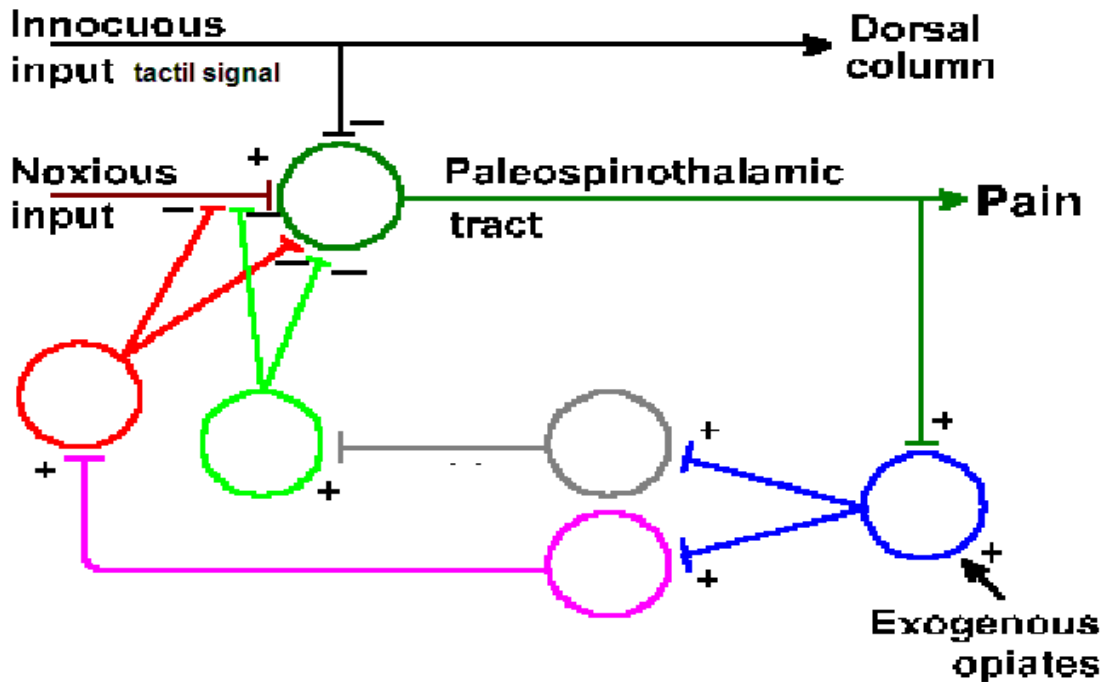
## VITAL COMPONENTS

1. Periaqueductal grey region and periventricular areas (**enkephalin**)
2. Raphe magnus nucleus (**serotonergic**)
3. Dorsal horn of the spinal cord (**enkephalin**)

**CANNOT BE VOLUNTARILY CONTROLLED!**



# Endogenous Opiate System



Endogenous opiates: complement the analgesia system

## ENDORPHINS AND ENKEPHALINES

The activation of peripheral tactile receptors decreases the pain signals of the site

Fig. 6-10. The endogenous pain suppression theory includes a negative feedback system in which spinothalamic tract cells (1), activated by noxious input, activate cells of the periaqueductal gray matter (2), which in turn activate descending pathways from the nucleus raphe magnus (3) and the locus ceruleus or nuclei subceruleus and parafacicularis (4). At the segmental spinal cord, interneurons (5 and 6) activated by these descending impulses inhibit further activation of spinothalamic tract cells. Also shown are the sites of action of dorsal column influences and morphine (Basbaum AI and Fields HL: *Ann Neurol* 4:451-462, 1978).

# Examples of Activation of the Analgesia/Opiate System

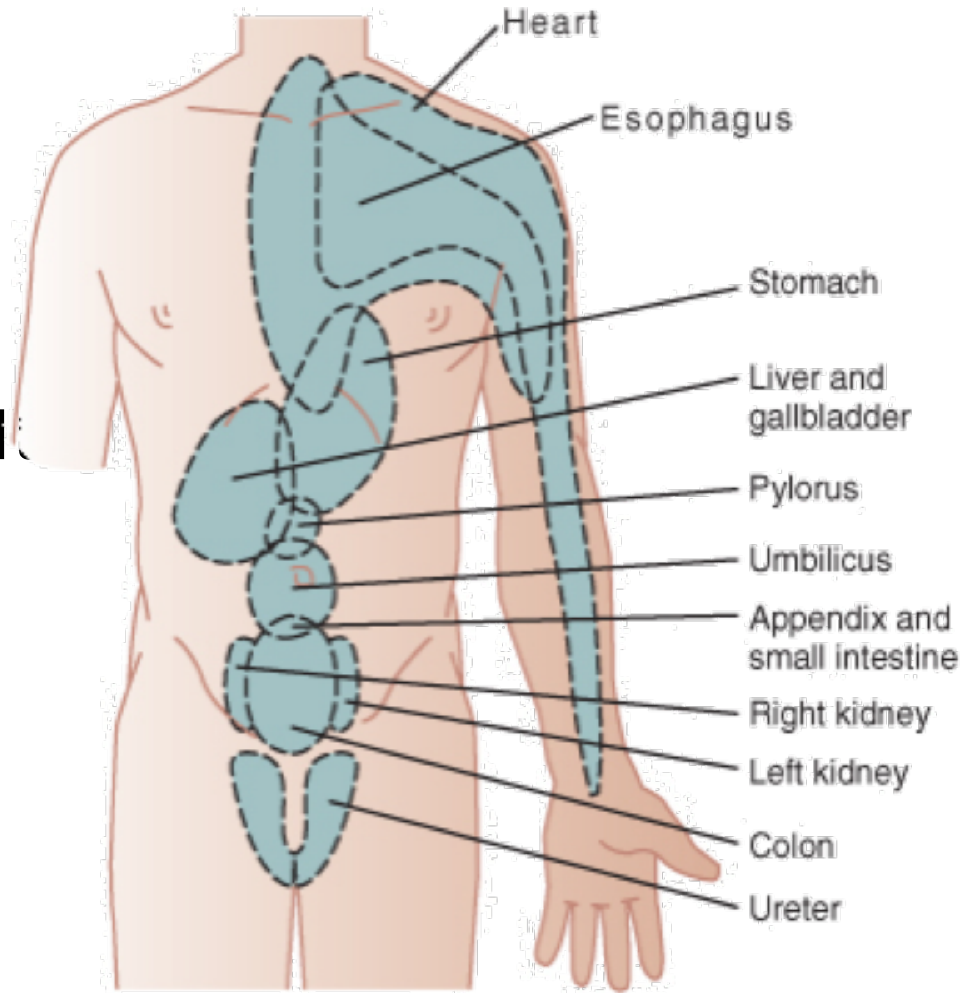
- Stress
- Physical activity
- Acupuncture
- Sophrology



<http://www.youtube.com/watch?v=PzIAuFynhUQ>

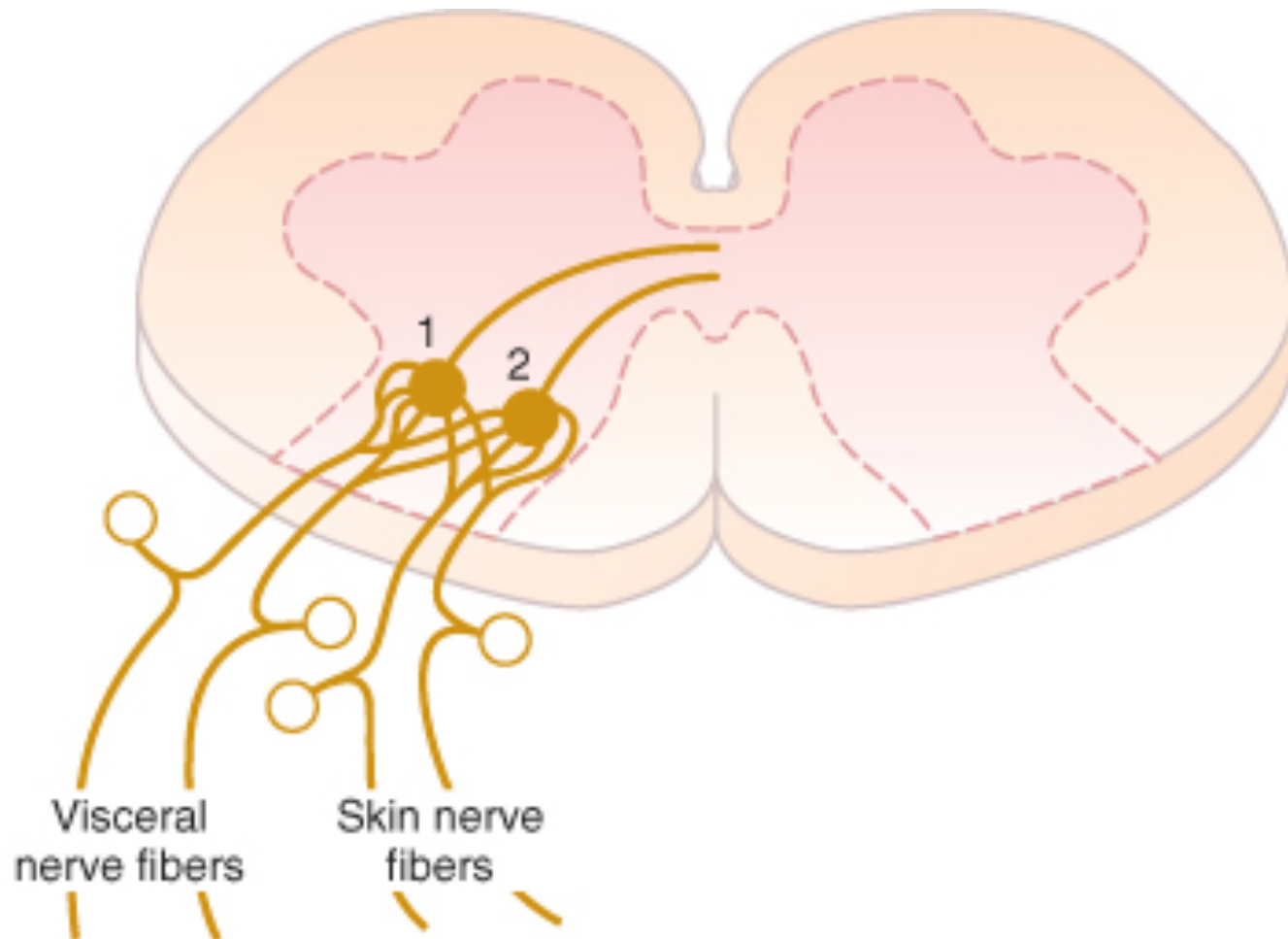
# Referred Pain

- Pain stimulus produced at a deep level (tissue or deep organ) but which the individual feels at a superficial level

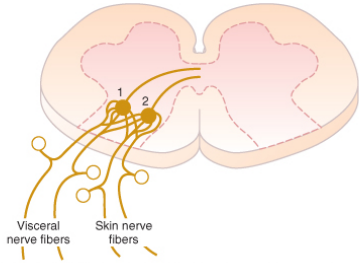




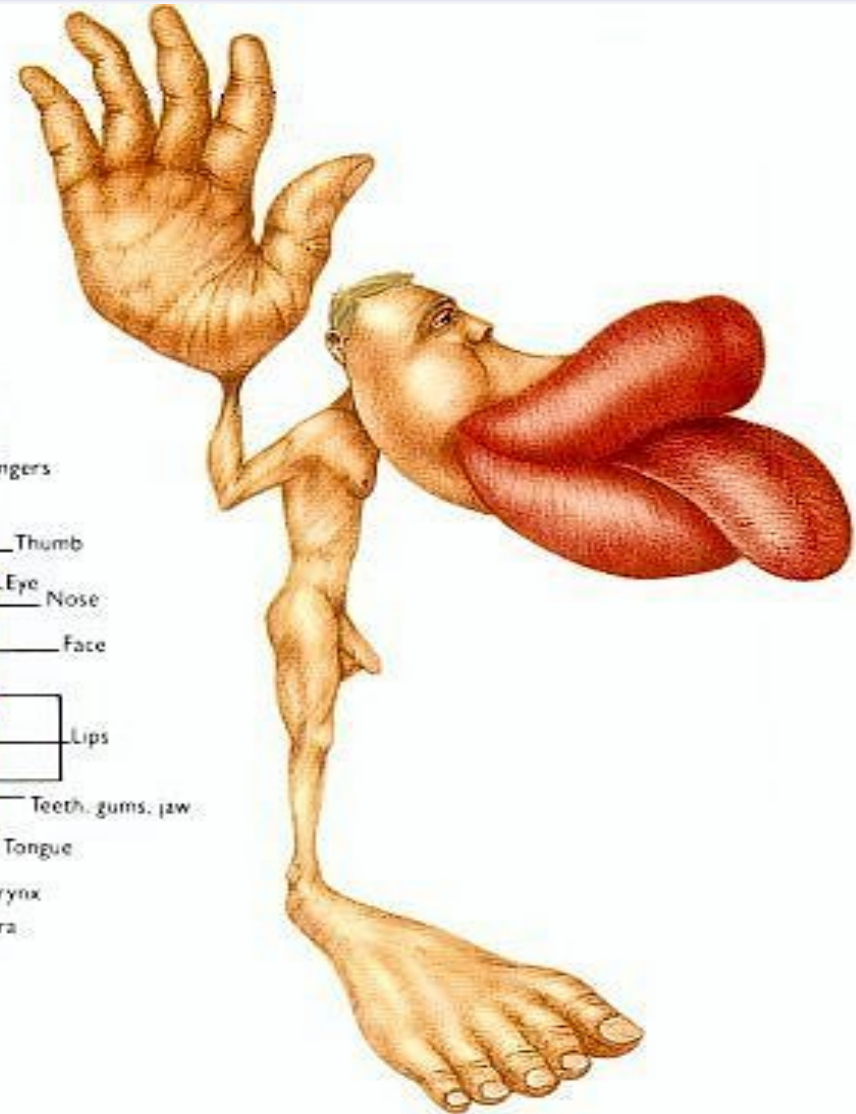
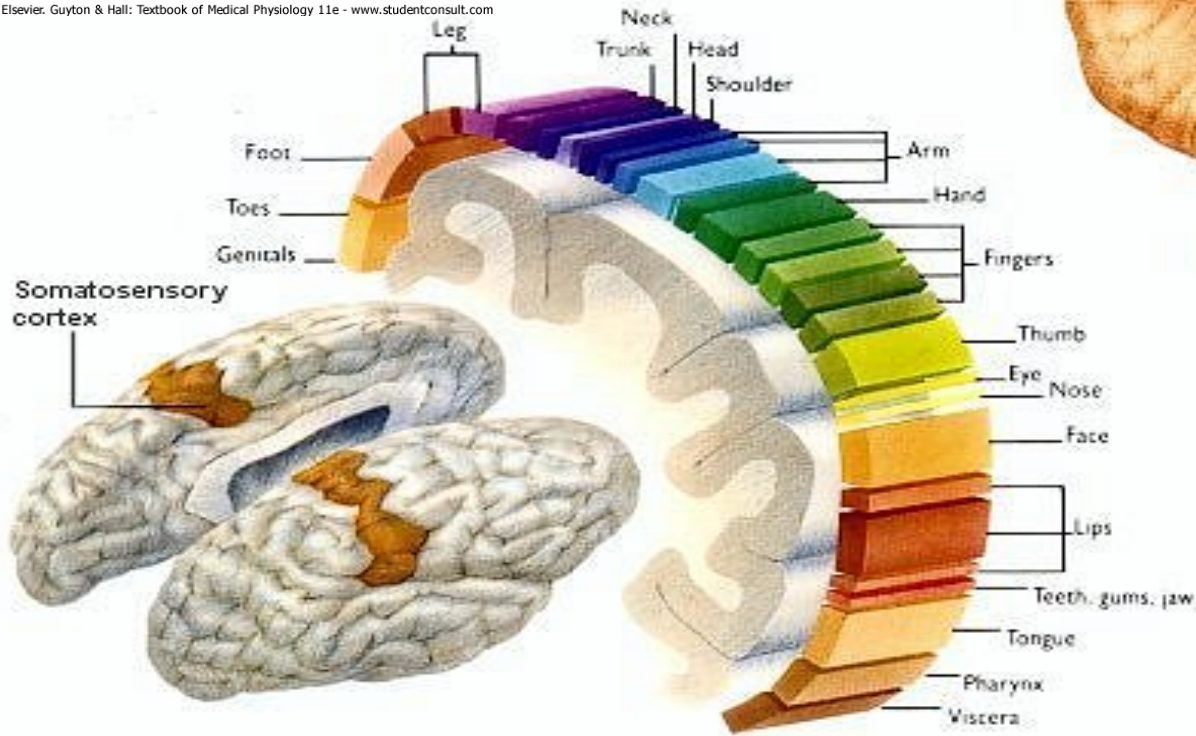
# Referred Pain



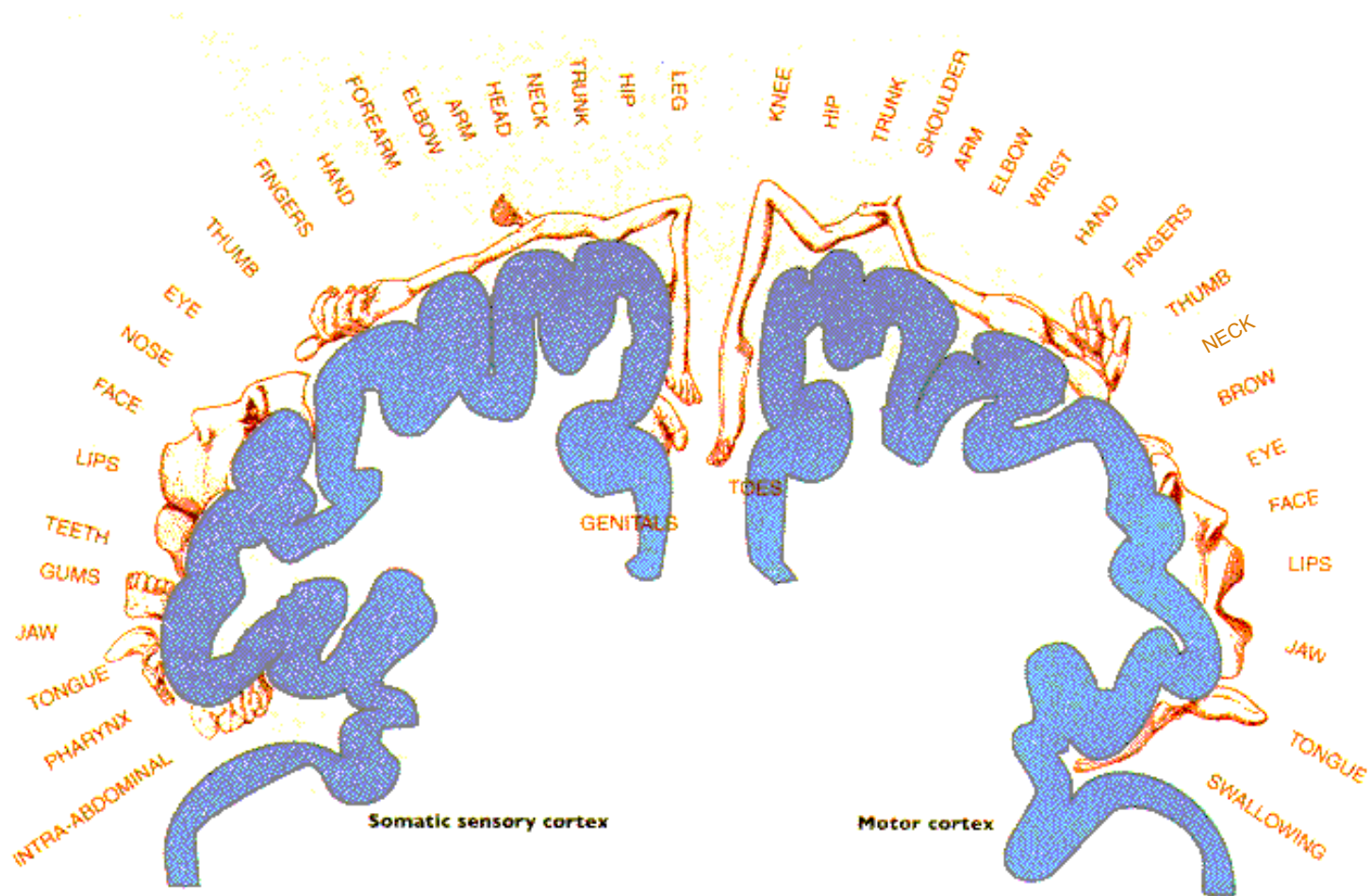
# Referred Pain



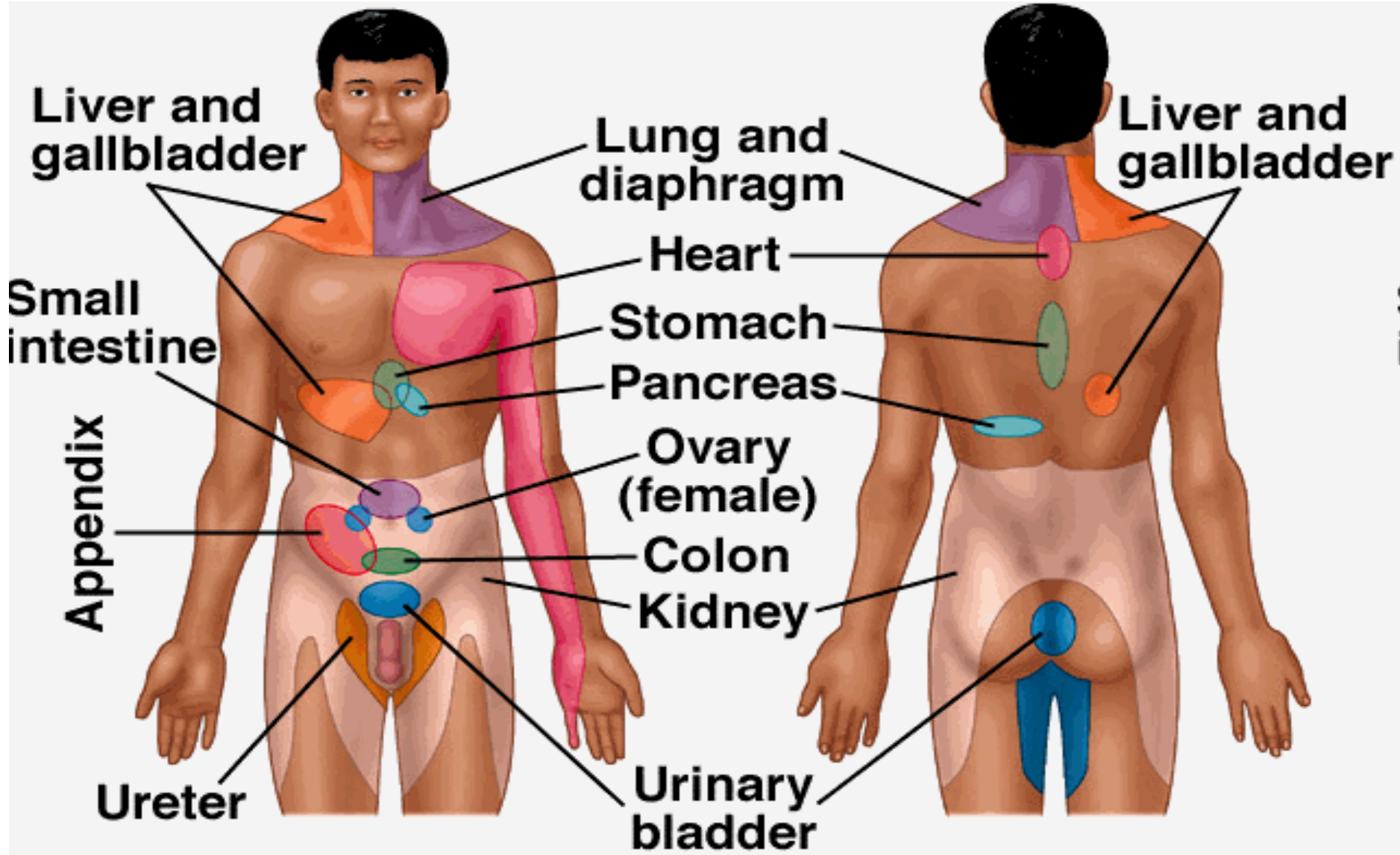
© Elsevier. Guyton & Hall: Textbook of Medical Physiology 11e - www.studentconsult.com



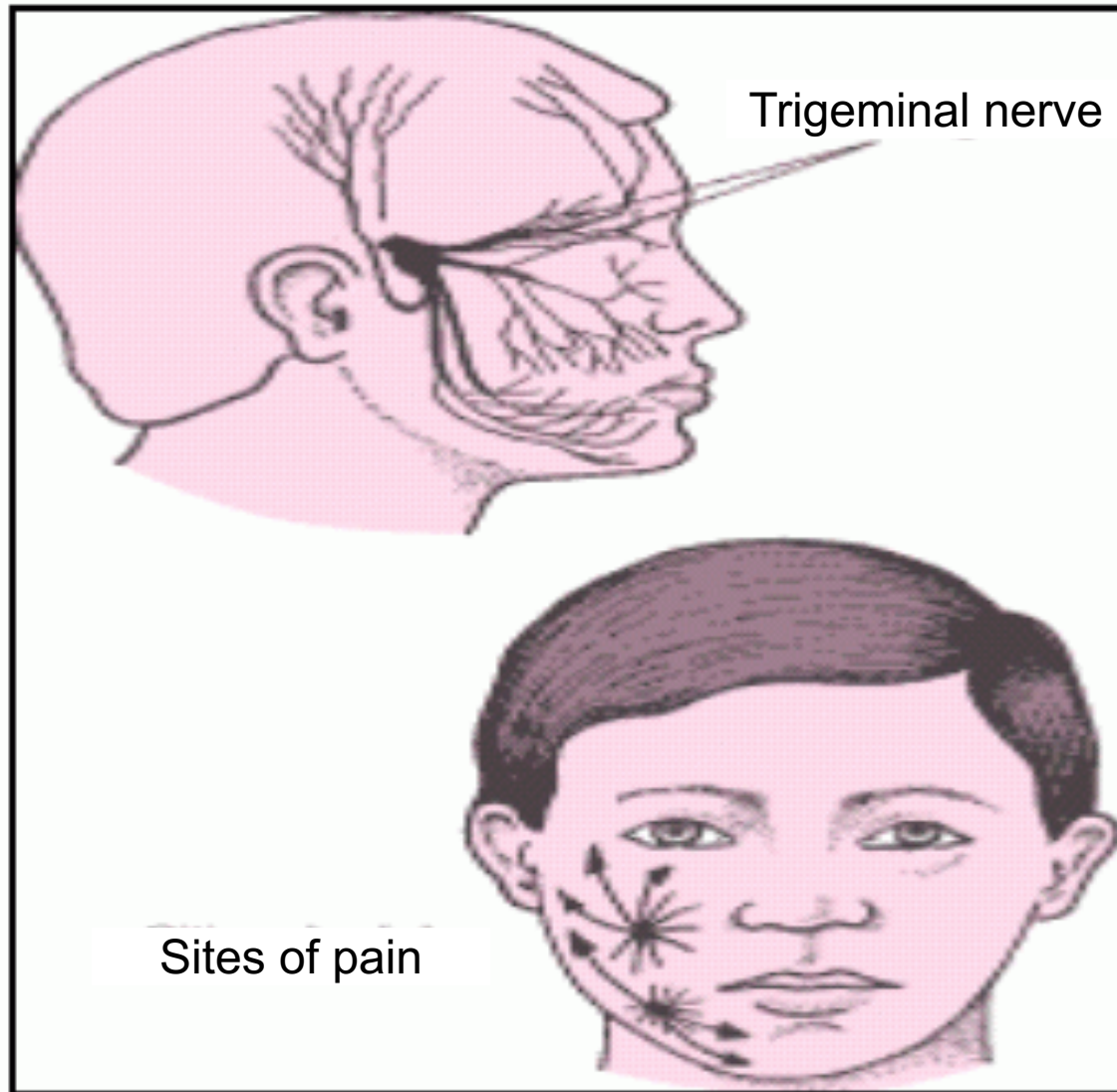
# Referred Pain



# Referred Pain



# Referred Pain



# Referred Pain

Sáez Yuguero, M. R.; Bermejo Fenoll, A.; Calvo Guirado, J. L.; Álvarez Martínez, E.  
*Jaw pain with cardiac origin*

## Jaw pain with cardiac origin

Sáez Yuguero, M. R.\*; Bermejo Fenoll, A.\*\*; Calvo Guirado, J. L.\*; Álvarez Martínez, E.\*\*\*

### SUMMARY

In the complex orofacial anatomic structures, many pain processes settle. The most common orofacial algie originate at a dental or periodontal level, or at musculoskeletal structures. However, the patient can manifest pain in this region, or else in teeth or musculoskeletal structures, and the original source be located at a distant point. This kind of pain is called heterotopic pain. A possible heterotopic pain source is cardiac pain.

The present article presents a clinical case in which bilateral jaw pain was the initial symptom of an ischemic cardiopathy wrongly diagnosed as arthrosis of the temporomandibular joint.

# Referred Pain



Fig. 1. Use of hands to locate the pain.

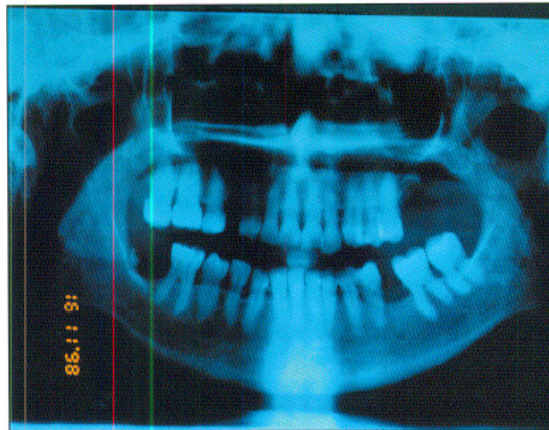


Fig. 2. Orthopantomograph of the patient without significant alterations.

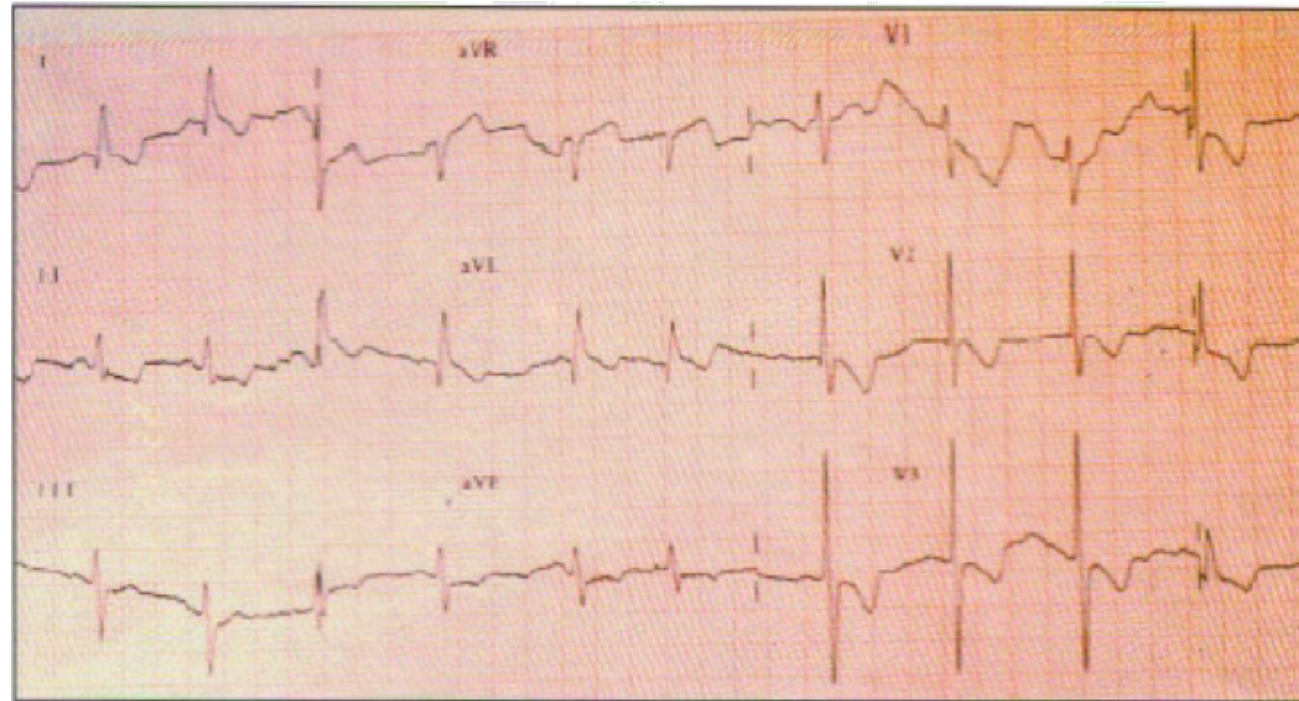


Fig. 4. ECG, negative T in II, III, to VF and of V4 to V6.

<http://www.youtube.com/watch?v=PpEpj-JgGDI>

# Clinical Alterations of Pain

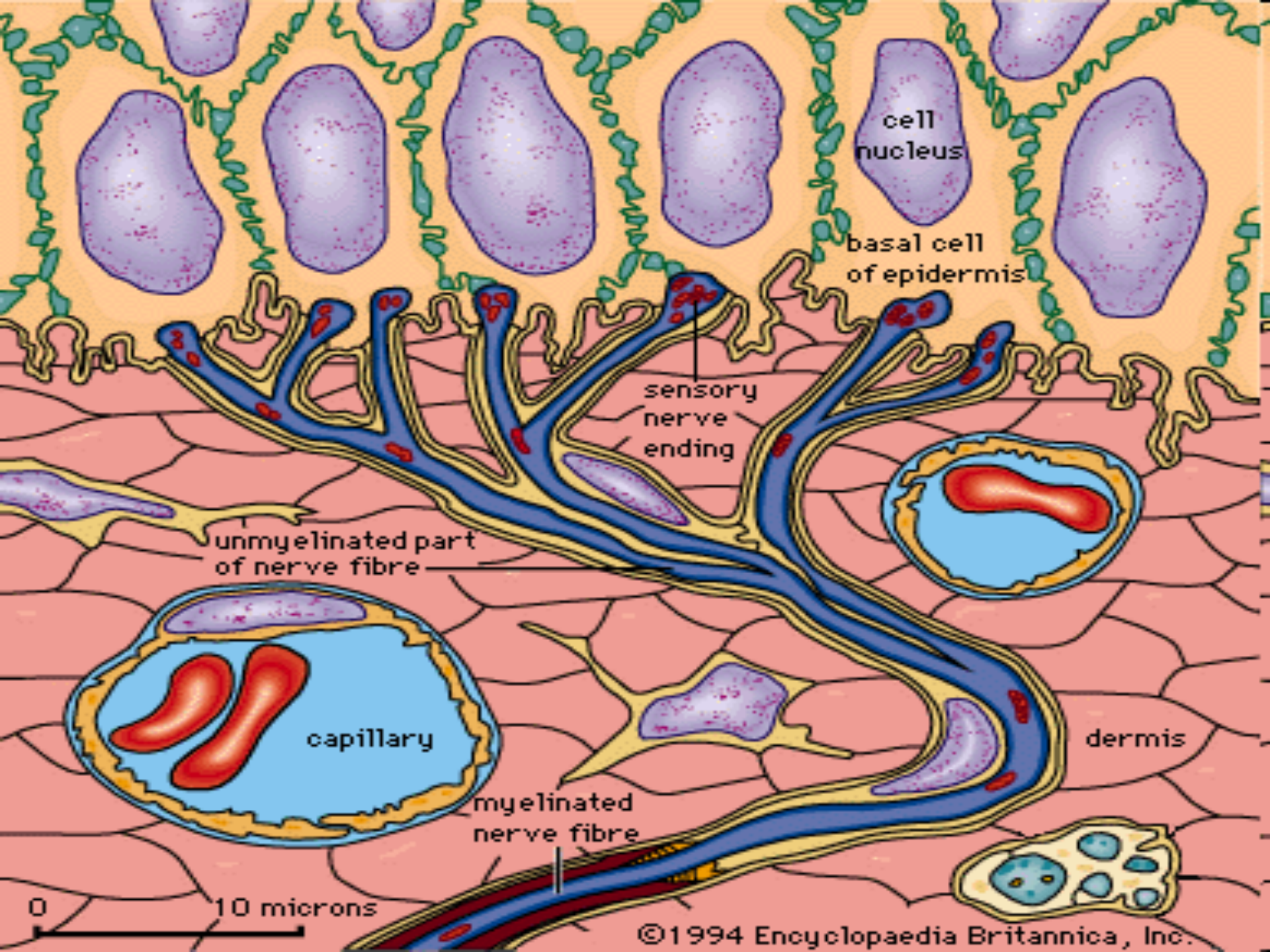
- **HYPERALGESIA:** decrease of the pain threshold
  - PRIMARY: increase of the receptor's sensitivity
  - SECONDARY: sensory facilitation
- **TRIGEMINAL SENSITIVITY:** acute pain that becomes chronic and may become paroxysmal
  - Trigeminal or glossopharyngeal neuralgia



# Thermal Sensitivity

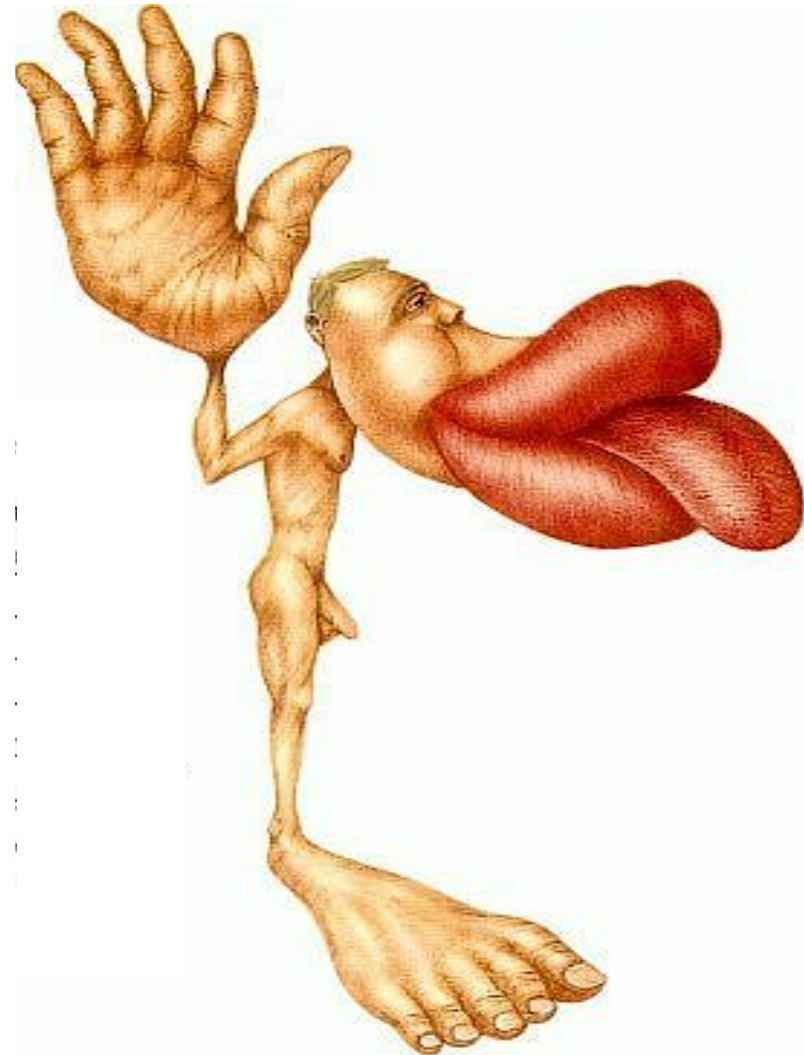
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- Two types of receptors:
  - Cold
  - Heat
  - (Pain)
- These receptors are nerve endings located in the deepest part of the epidermis, with endings in the basal cells of the epidermis

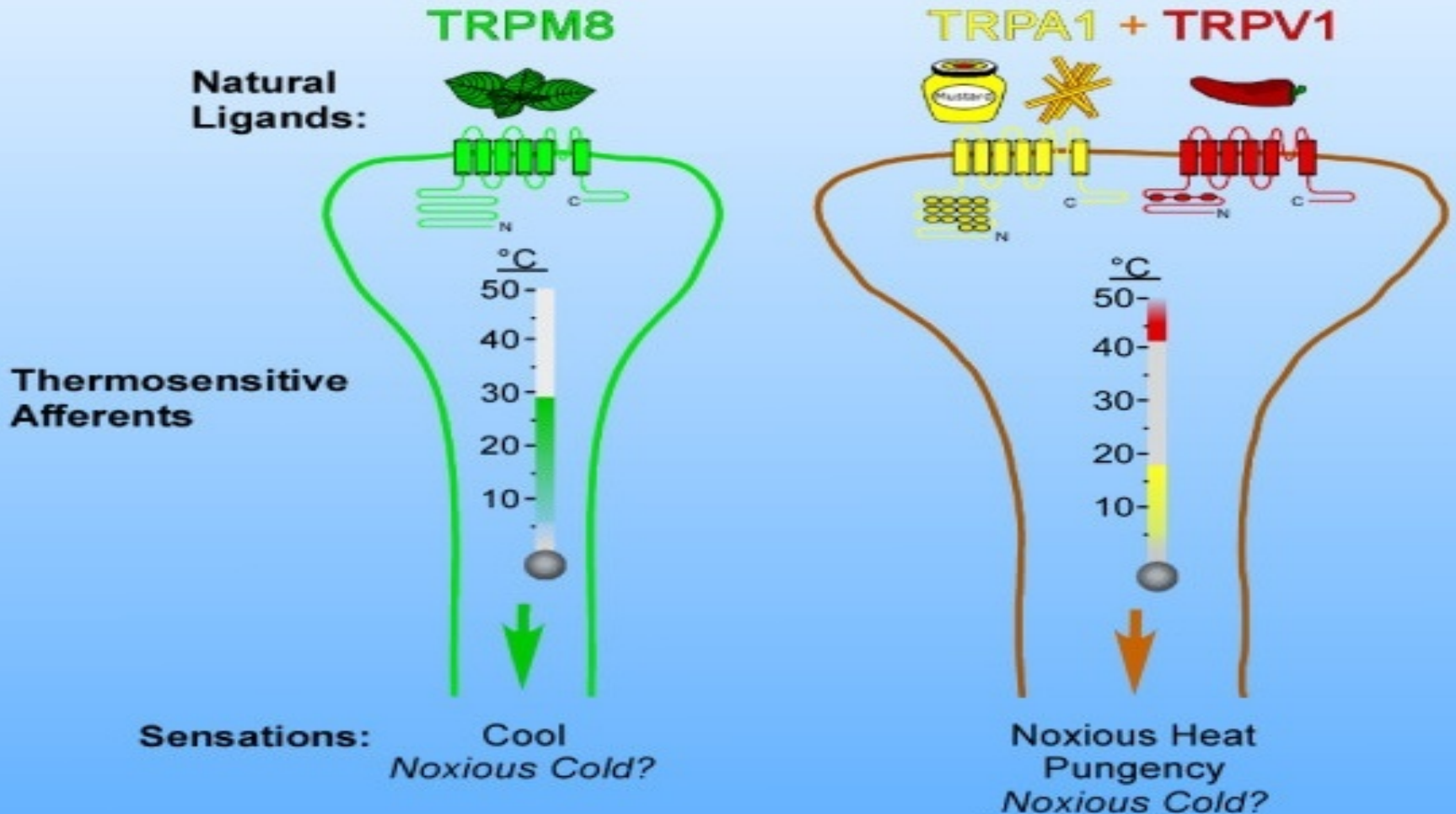


# Thermal Sensitivity

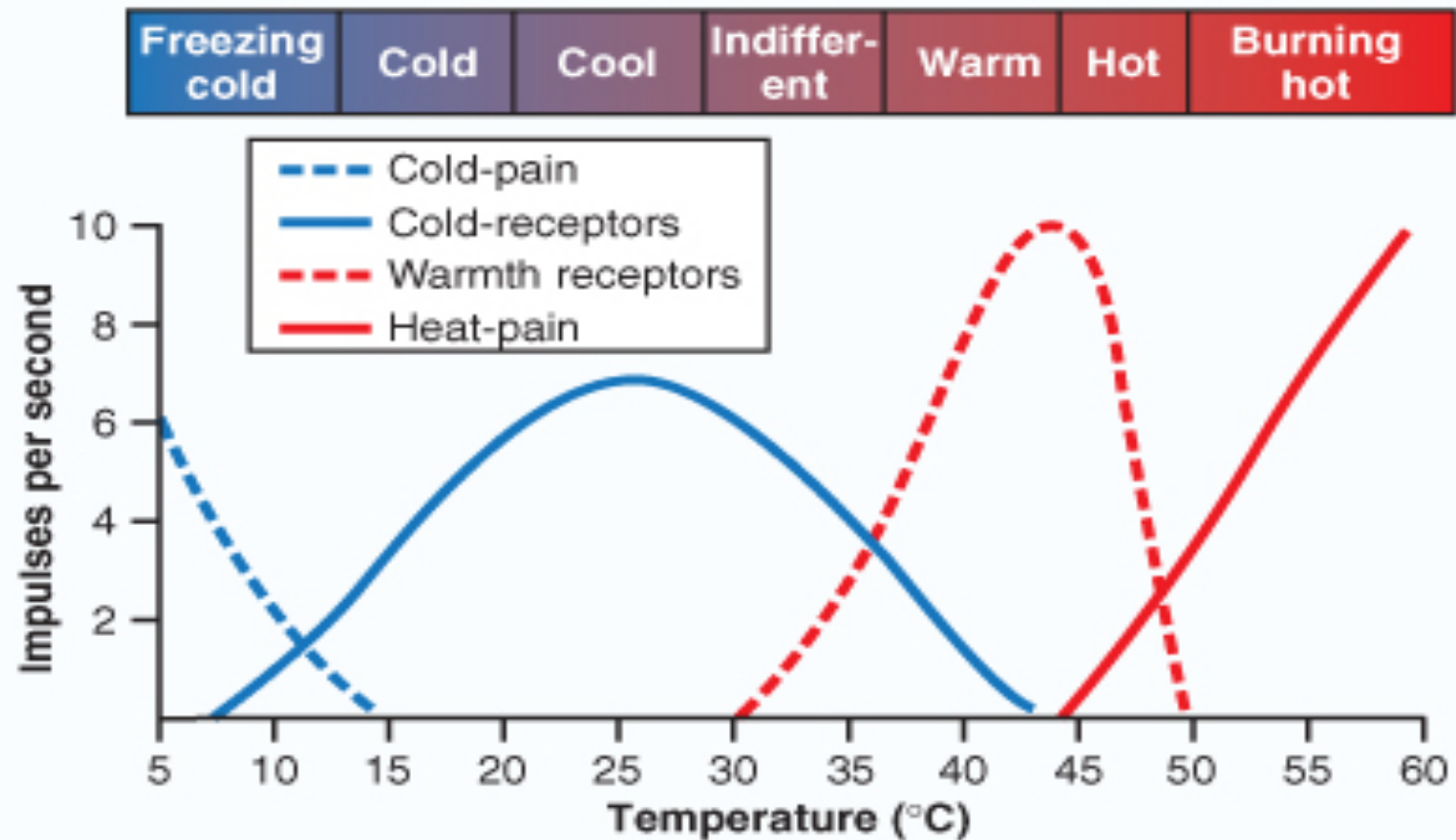
- Conduction fibers
  - Cold:  $a\delta$  (myelinated, fast)
  - Heat: C (unmyelinated, slow)
- Partial adaptation of the receptors
- Scarce receptors, fields of receptors - Variable distribution in the body
- Conduction pathways similar to those of pain



# Thermal Sensitivity



# Thermal Sensitivity





# Chemical senses: taste and smell



# Chemoreceptors

---

**STIMULUS: SPECIFIC CHEMICAL SUBSTANCES**

**CHEMORECEPTORS: EXAMPLE. CAROTID SINUS**

**DISTANCE CHEMORECEPTORS: SMELL**

**CONTACT CHEMORECEPTORS: TASTE**

**CONTACT CHEMORECEPTORS: TRIGEMINAL SYSTEM**

# Script

---

- Taste
  - Primary taste sensations
  - Taste threshold
  - Taste buds
  - Signals transmission
- Smell
  - Olfactory membrane
  - Olfactory membrane stimulation
  - Signals transmission



# Taste

- Allows the person to choose a meal according to their wishes, and often metabolic needs of body tissues for each specific substance
- Chemoreceptors detect molecules in solution in saliva



# Primary Taste Sensations

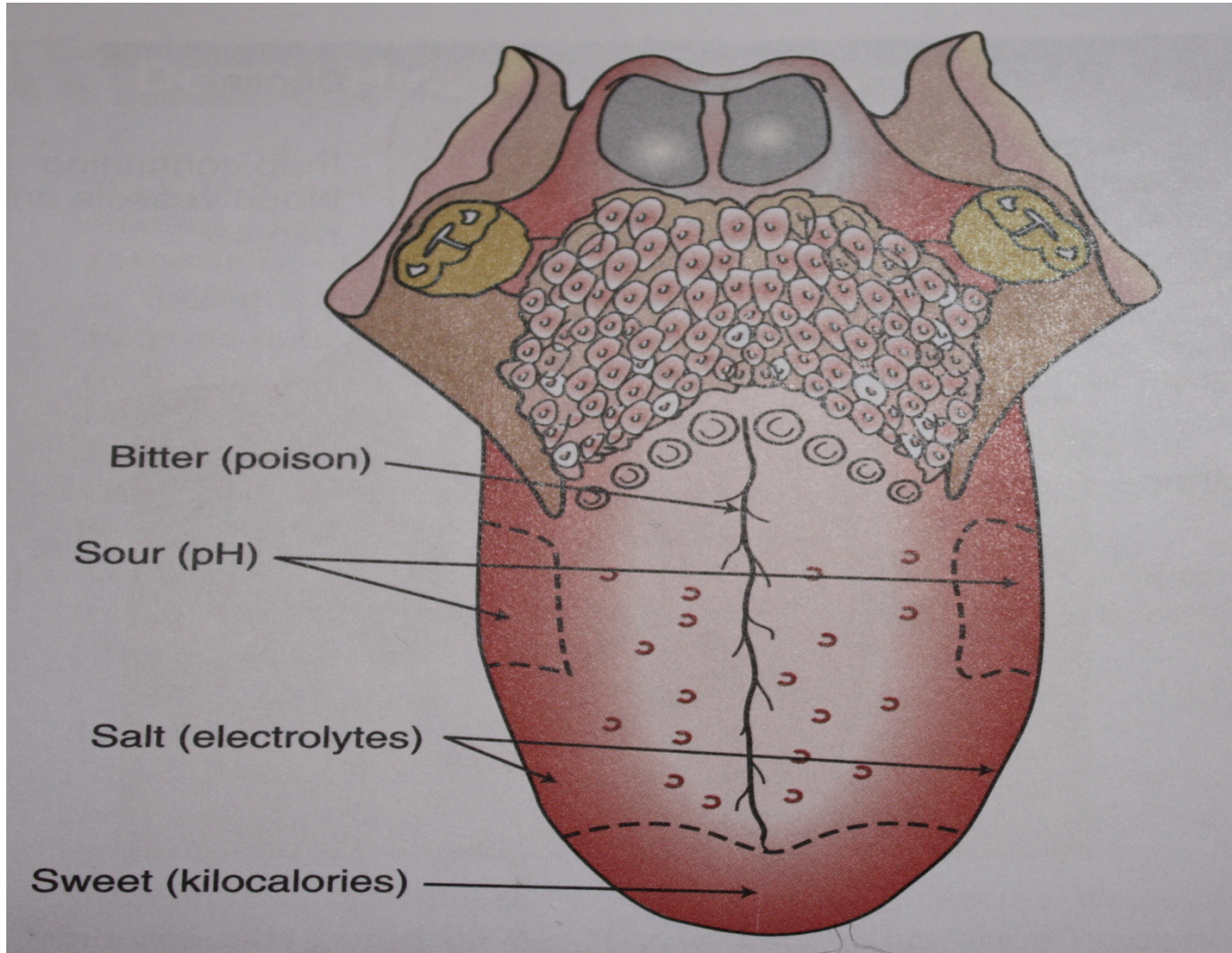
- 13 possible chemical receptors (associated with sodium, potassium, chloride, adenosine, inosine, sweet, bitter, glutamate, hydrogen)
- Five general primary taste sensations
  - Sour
  - Salt
  - Sweet
  - Bitter
  - Umami
- The taste is the result of these combinations, we can feel hundreds of them.

# Primary Taste Sensations

---

- **Sour:** acids, hydrogen ion concentration
- **Salt:** ionized salts, sodium ion
- **Sweet:** organic compounds (sugars, aldehydes, glycols, alcohols...)
- **Bitter:** organic compounds (long chain with nitrogen, alkaloids)
- **Umami:** in Japanese “delicious”. Food with L-glutamate (meat extracts, cheese). Glutamate is a flavor enhancer

# Primary Taste Sensations

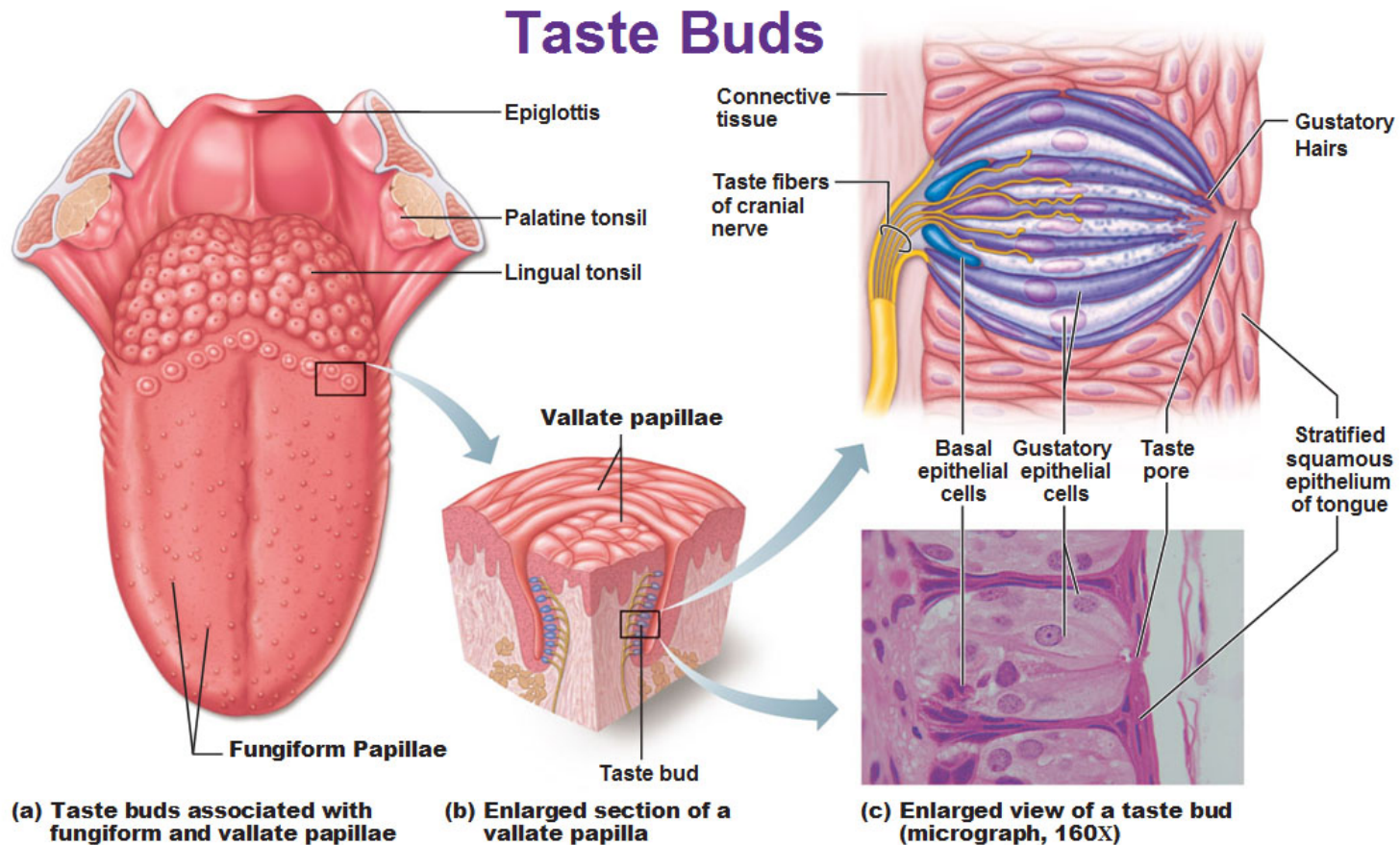
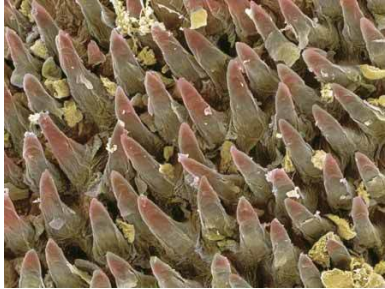


# Taste Threshold

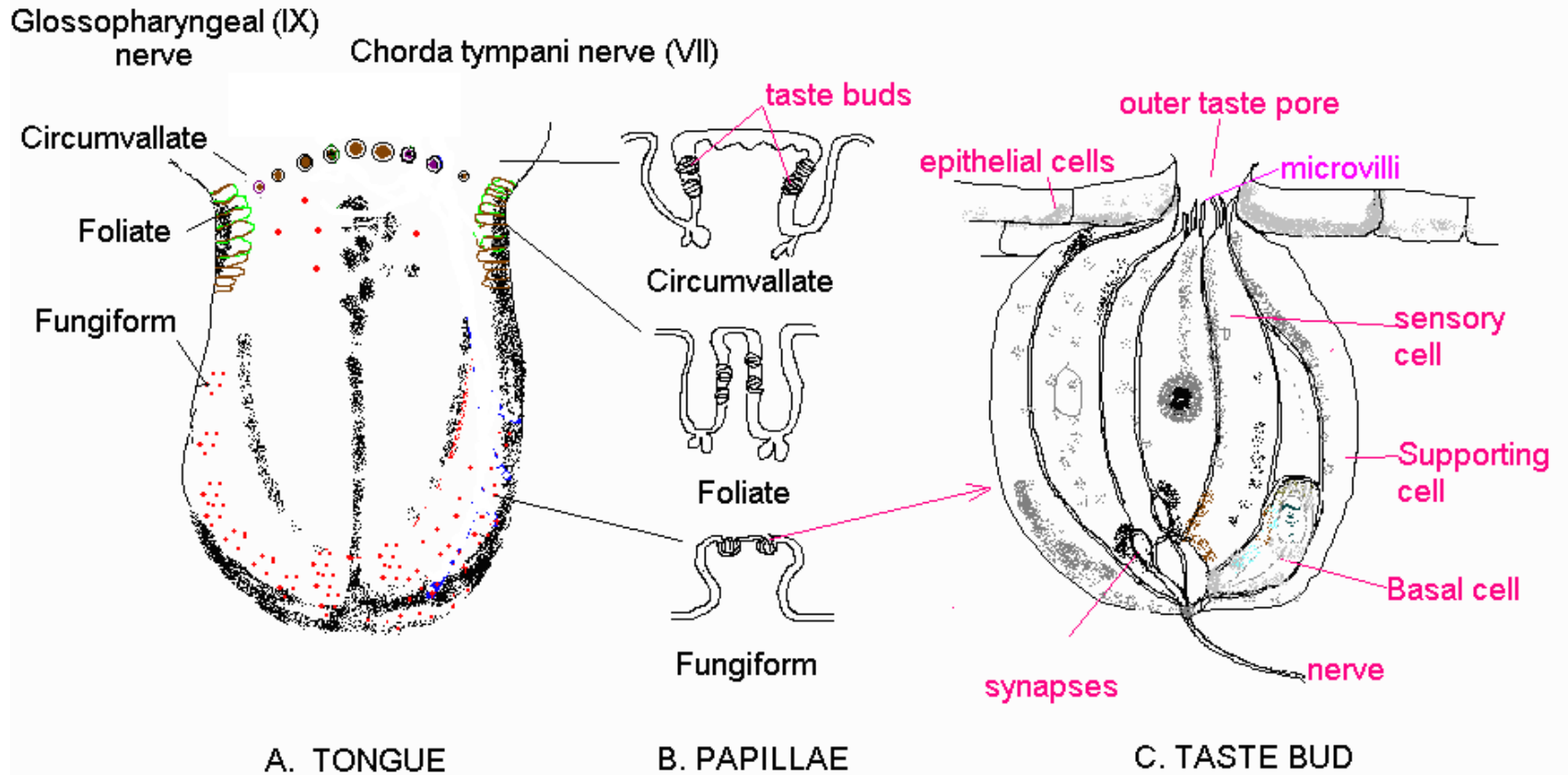
- Increased sensitivity to bitter taste sensations (toxic alkaloids protective function)



# Taste Buds



# STRUCTURE OF TASTE BUD



# TASTE BUDS

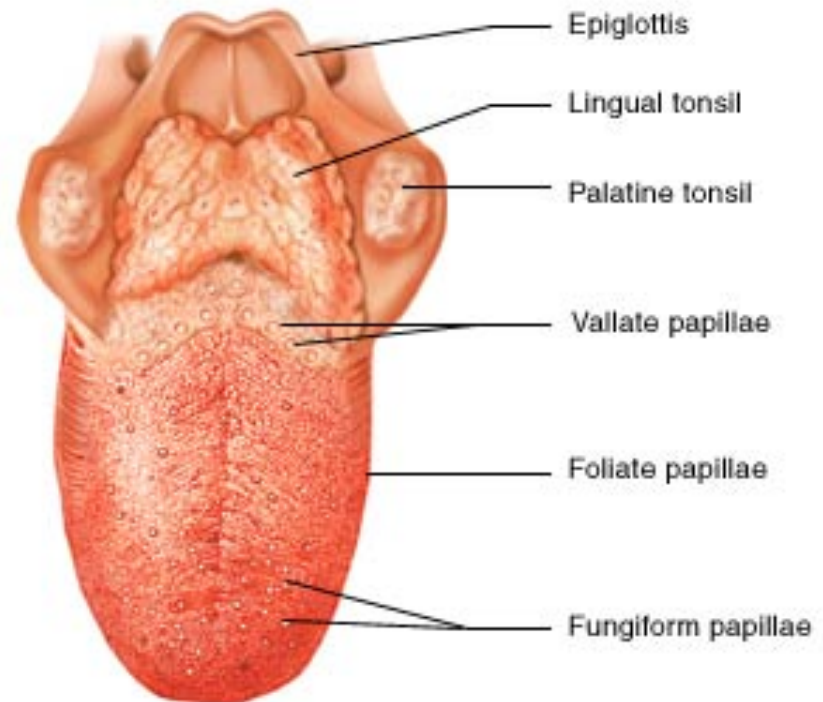
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- Supporting cells + taste cells (continuous replacement)
- Taste pore
- Cilium taste: receiving surface. Each bud of 5-18 cilia
- Gustatory nerve fibers: some vesicles, neurotransmitters

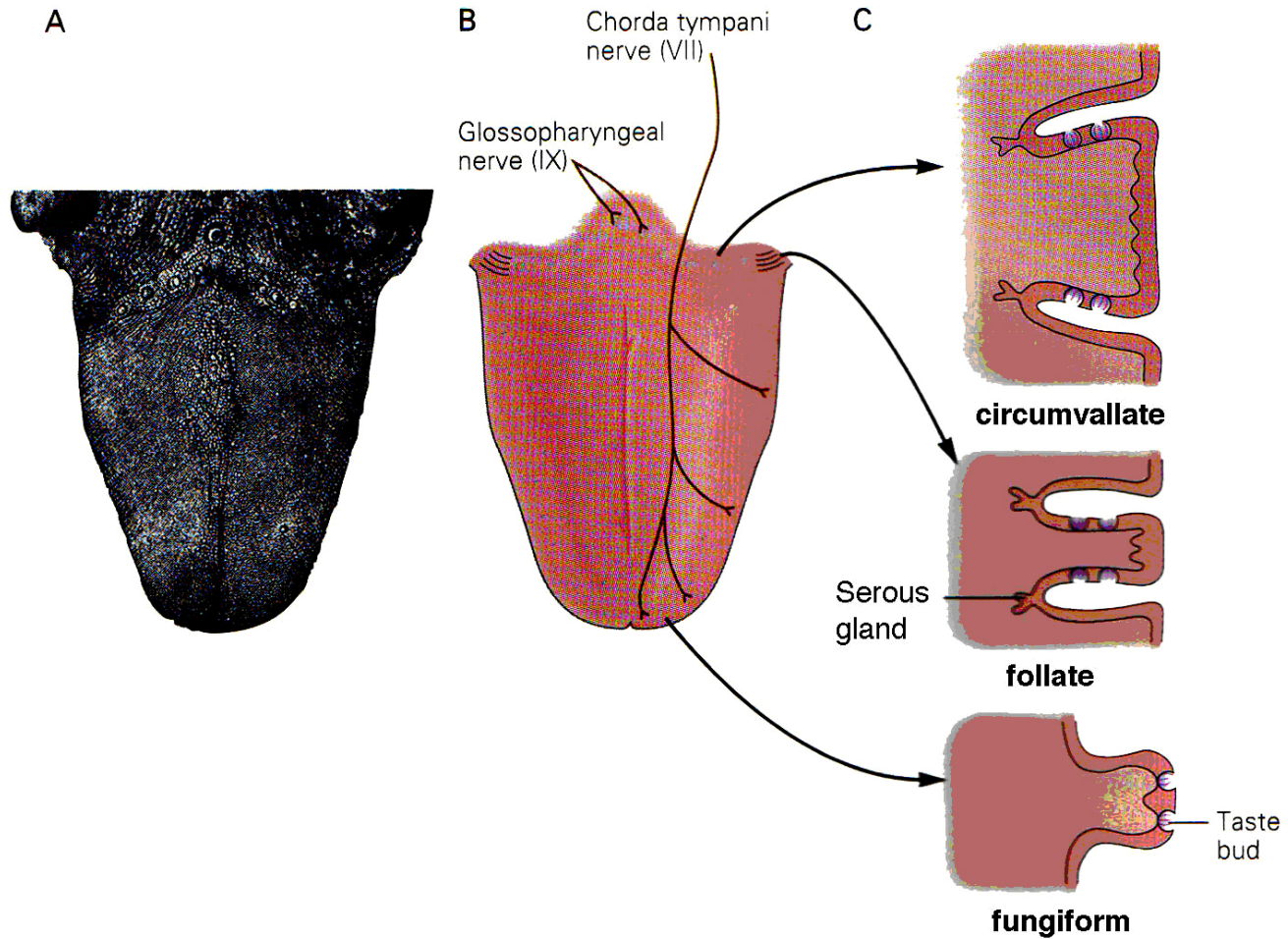


# Location of Taste Buds

- Most in vallate papilla
- Less in fungiform papilla
- Less in foliate papilla
- Mucosa of the epiglottis, palate, pharynx
- 3000-10000 buds, decreases with age



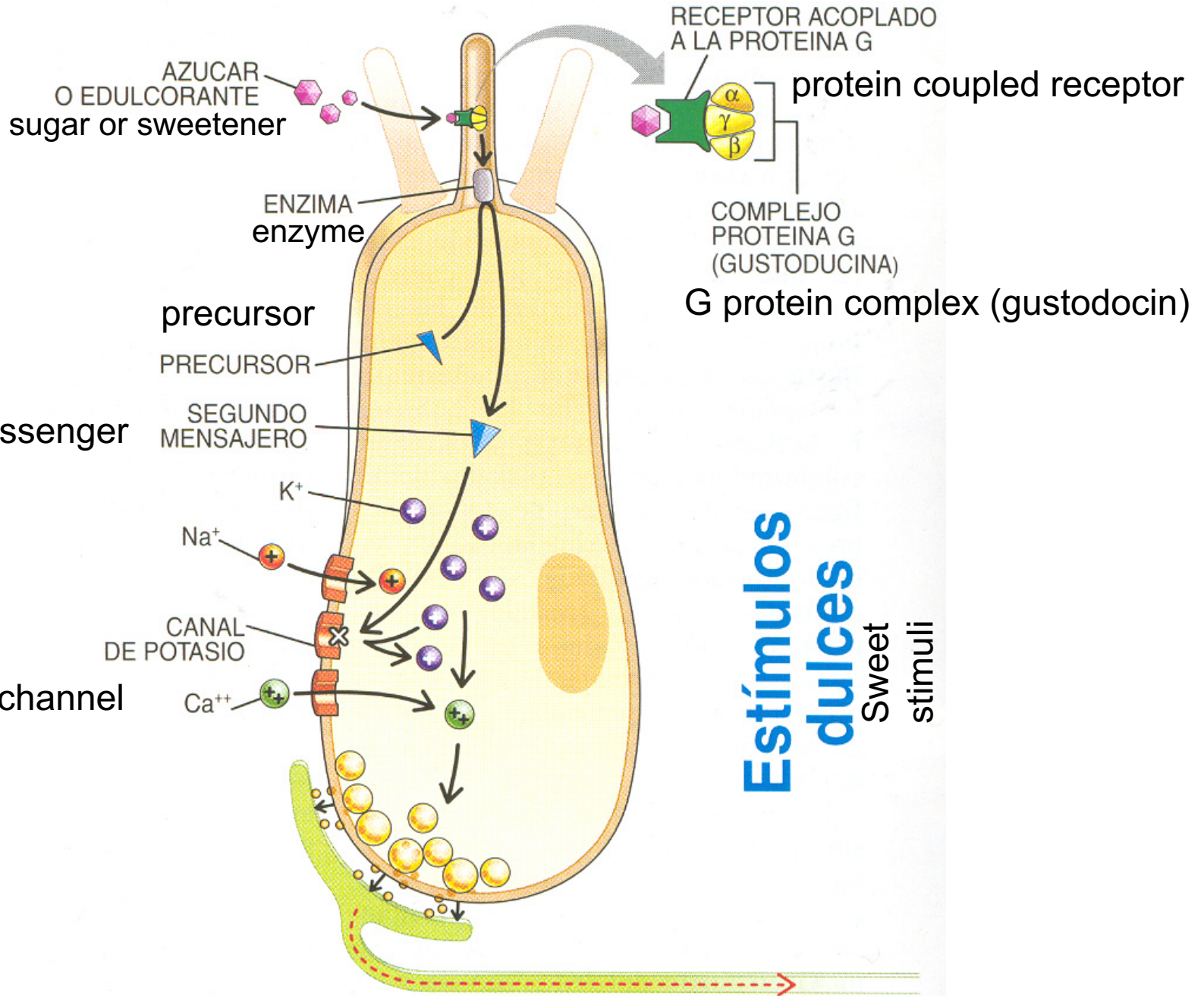
# Gustatory Papilla

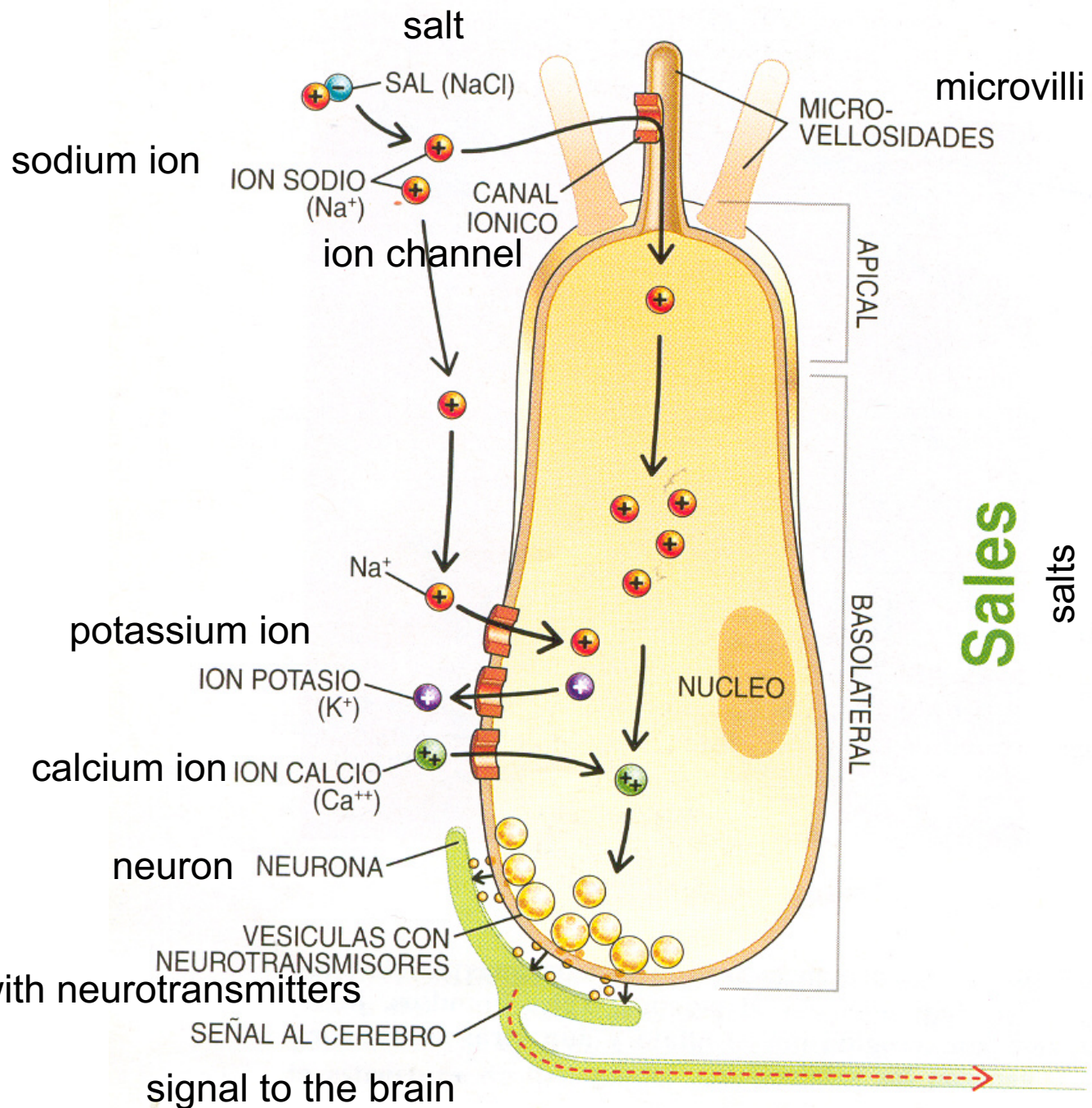


# Stimulation of Taste Buds

---

- At low concentrations of substances, each bud specifically responds to a primary taste sensation.
- At high concentrations they can be activated by two or more substances.

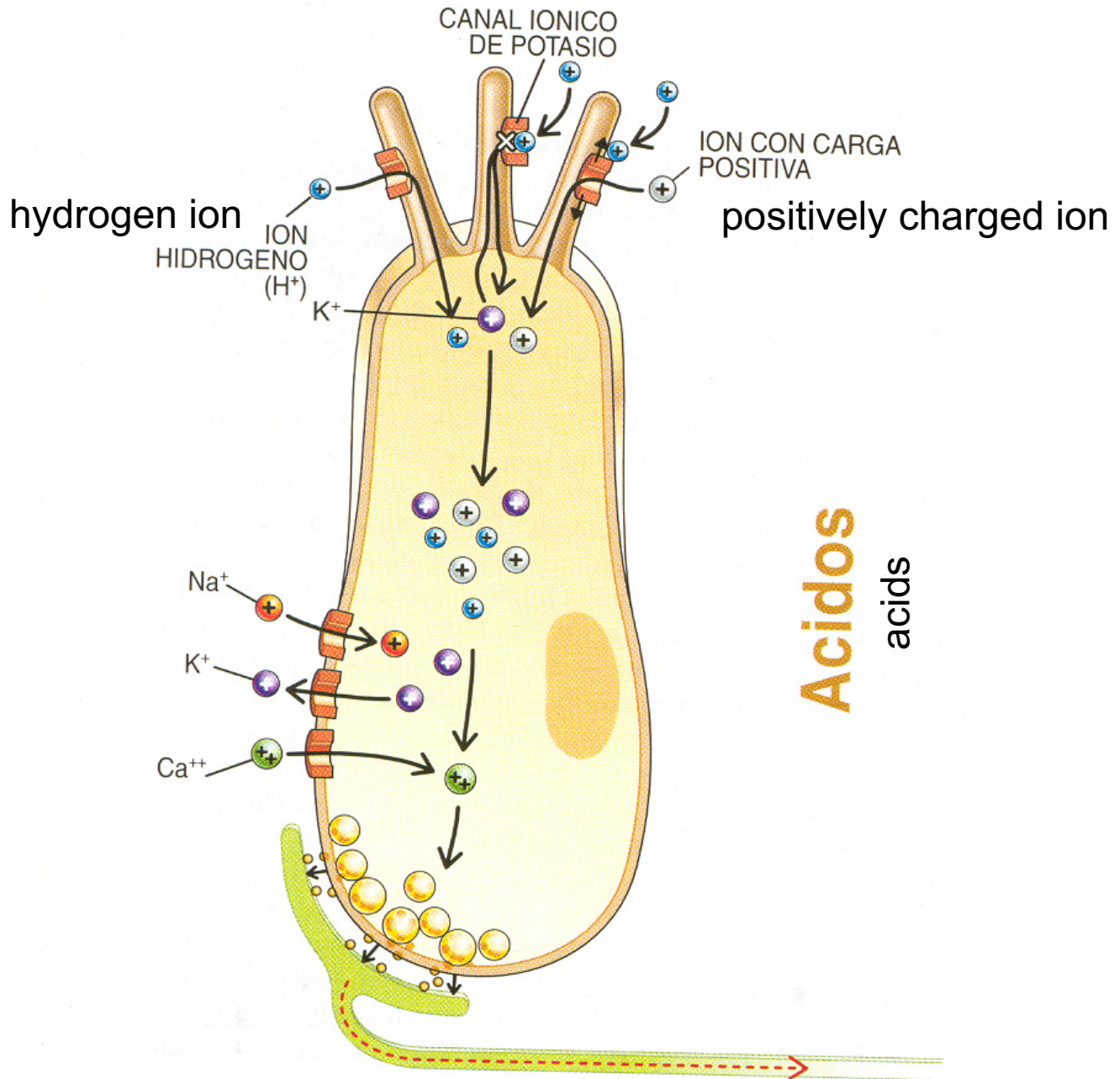




Sales

salts

# potassium ion channel



quinine and bitter substances

QUININA  
Y SUSTANCIAS  
AMARGAS

ENZIMA  
enzyme

PRECURSOR

SEGUNDO  
MENSAJERO  
second messenger

RETICULO  
ENDOPLASMATICO  
(CON Ca<sup>++</sup>)  
endoplasmic reticulum

Na<sup>+</sup>

K<sup>+</sup>

Ca<sup>++</sup>

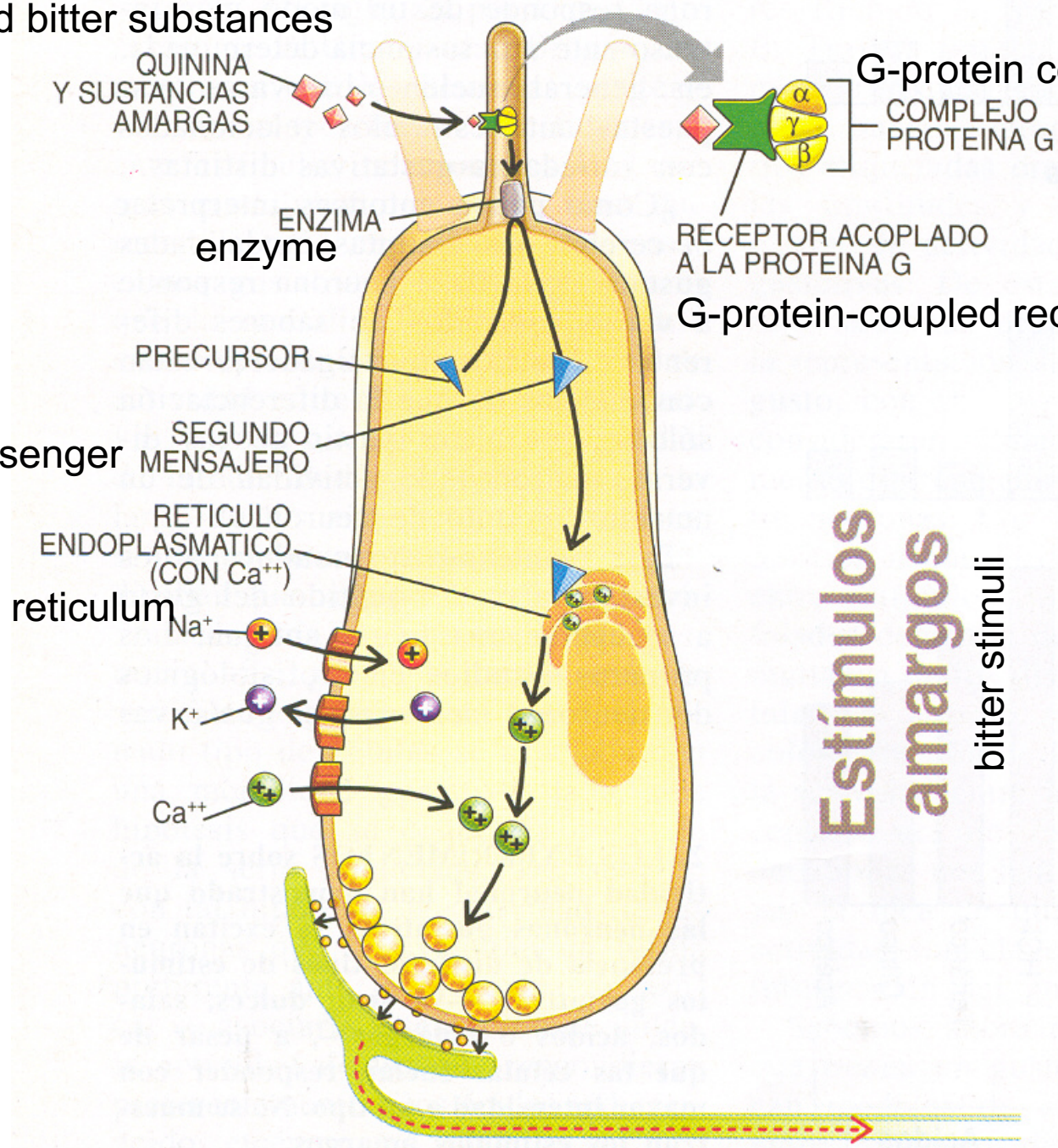
G-protein complex

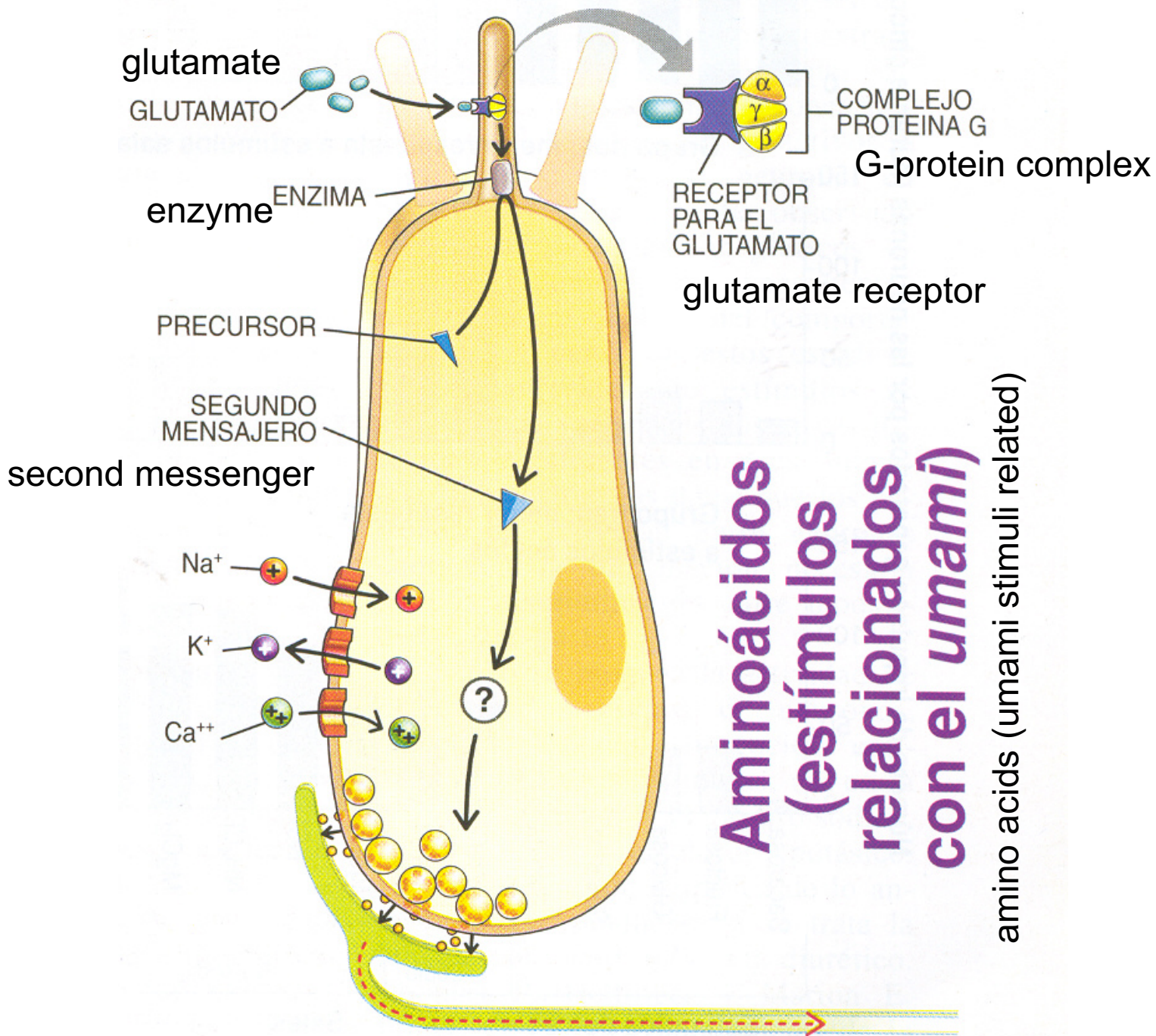
COMPLEJO  
PROTEINA G

RECEPTOR ACOPLADO  
A LA PROTEINA G

G-protein-coupled receptor

Estímulos  
amargos  
bitter stimuli

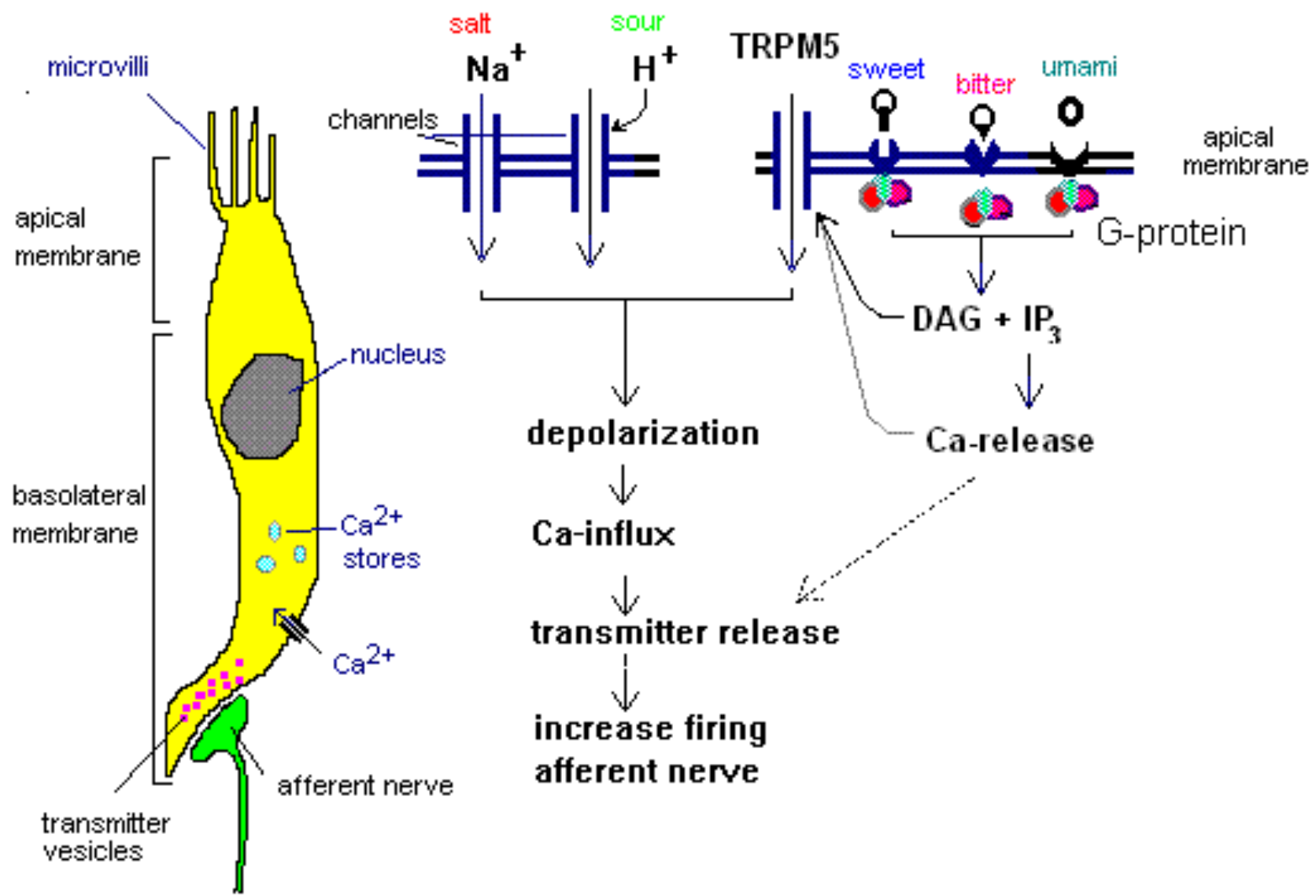




**Aminoácidos (estímulos relacionados con el umami)**

amino acids (umami stimuli related)





salt sour

TRPM5

sweet bitter umami

microvilli

channels

Na<sup>+</sup>

H<sup>+</sup>

apical membrane

apical membrane

nucleus

G-protein

basolateral membrane

Ca<sup>2+</sup> stores

DAG + IP<sub>3</sub>

Ca-release

Ca<sup>2+</sup>

depolarization

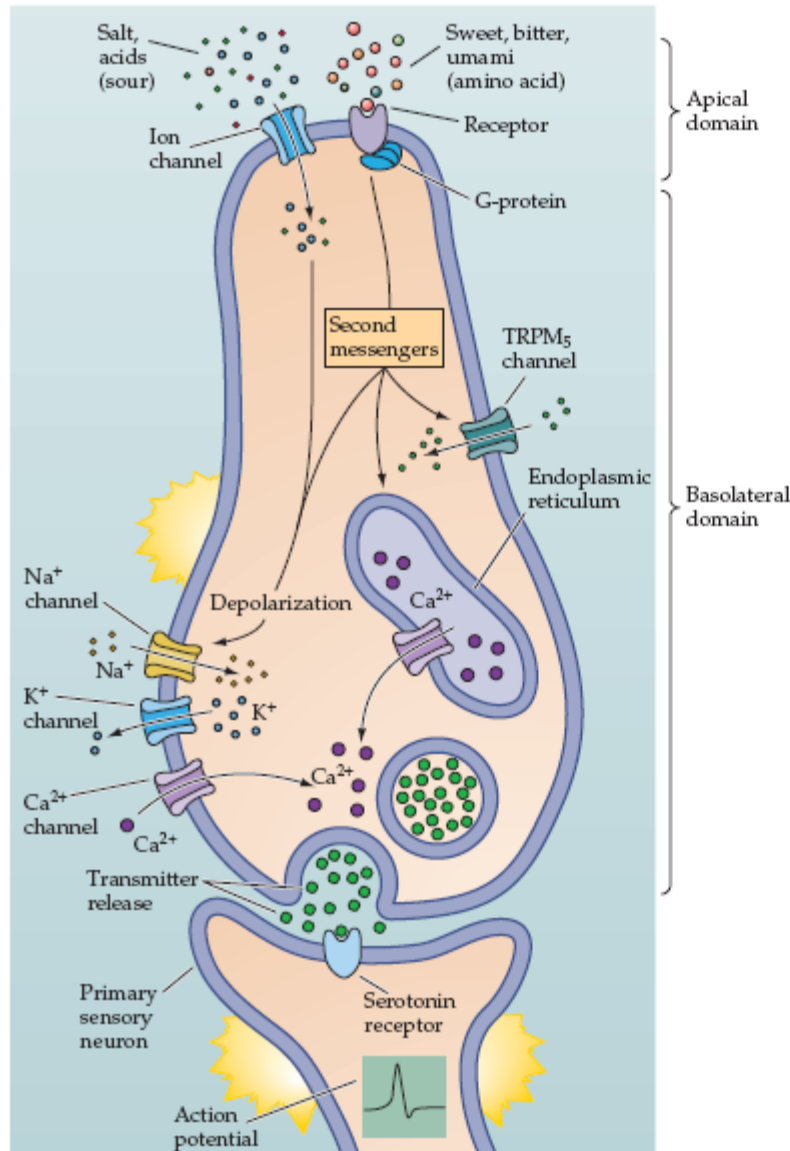
Ca-influx

transmitter release

increase firing afferent nerve

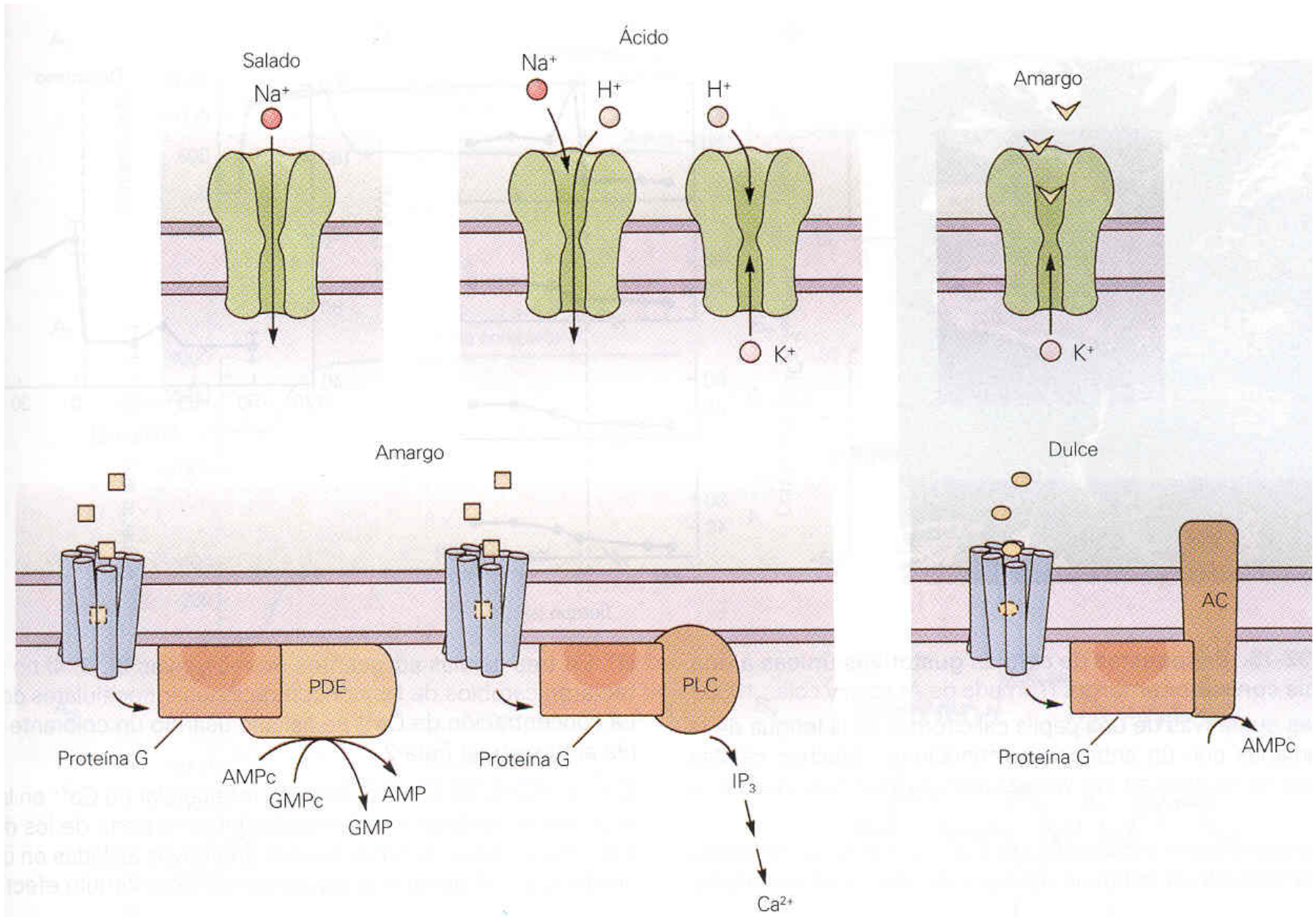
transmitter vesicles

afferent nerve

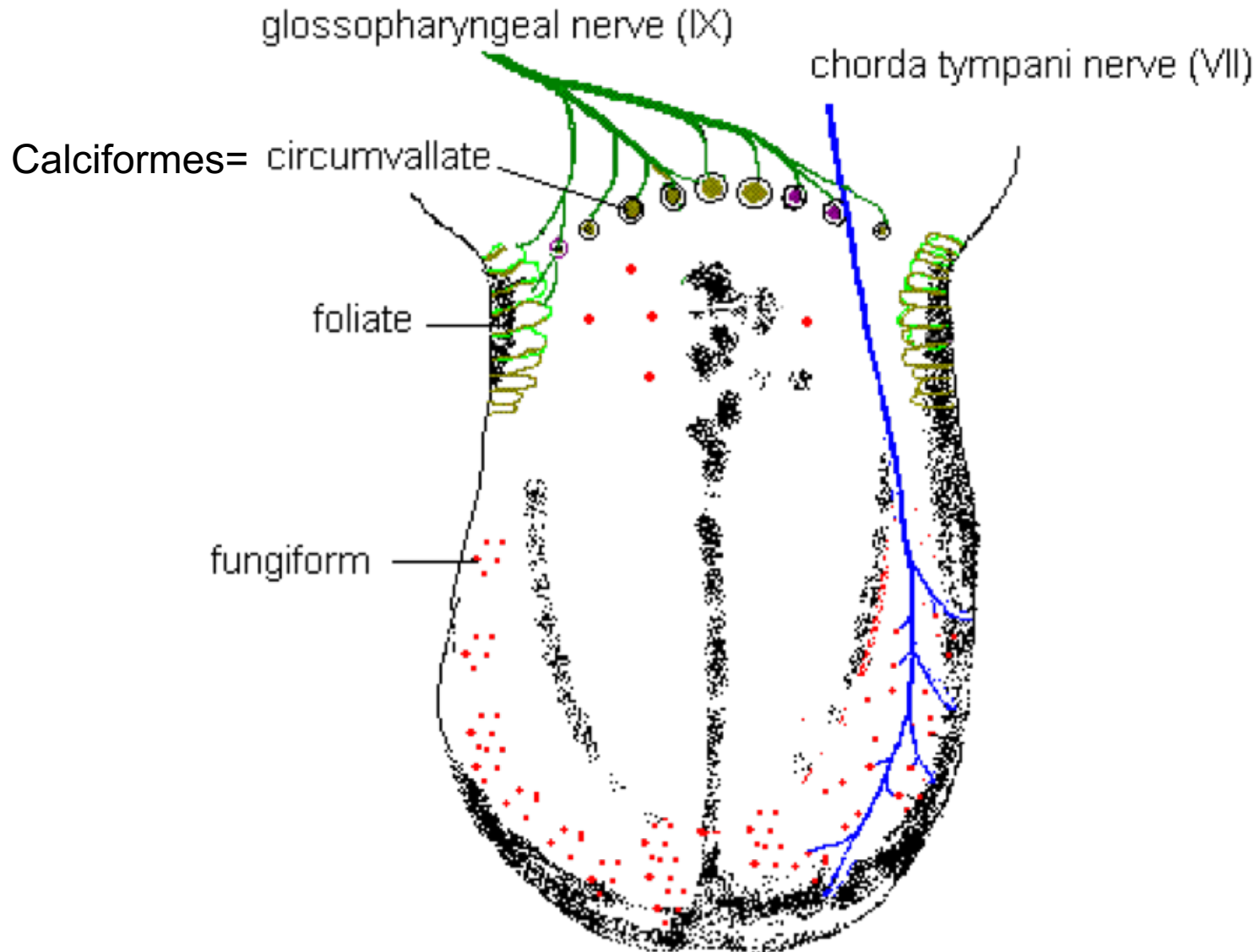


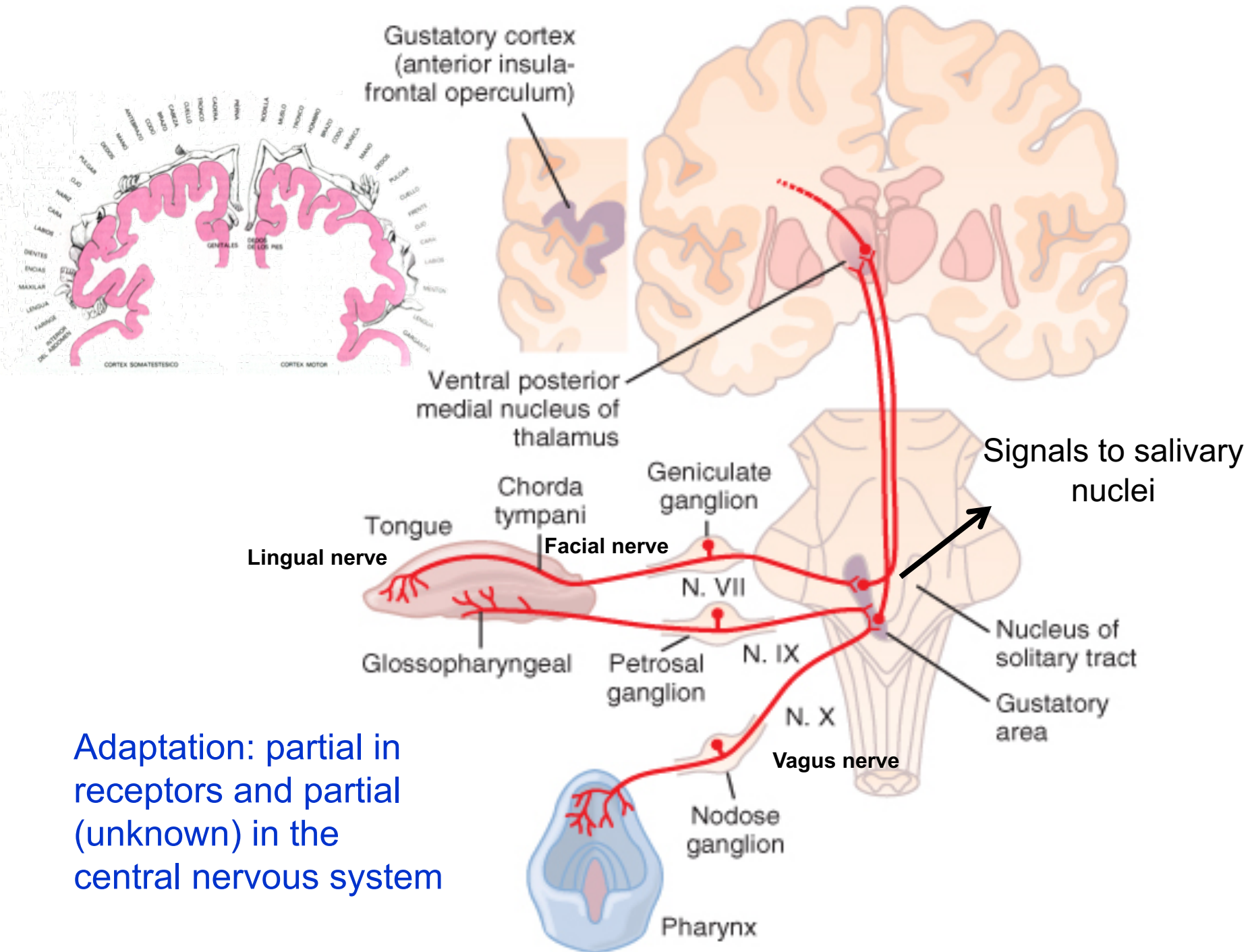
**Figure 14.15** Basic components of sensory transduction in taste cells. Taste cells are polarized epithelial cells with an apical and a basolateral domain separated by tight junctions. Tastant-transducing channels (salt and sour) and G-protein-coupled receptors (sweet, amino acid, and bitter) are limited to the apical domain. Intracellular signaling components that are coupled to taste receptor molecules (G-proteins and various second messenger-related molecules) are also enriched in the apical domain. Voltage-regulated Na<sup>+</sup>, K<sup>+</sup>, and Ca<sup>2+</sup> channels that mediate release of neurotransmitter from presynaptic specializations at the base of the cell onto terminals of peripheral sensory afferents are limited to the basolateral domain, as is endoplasmic reticulum that also modulates intracellular Ca<sup>2+</sup> concentration and contributes to the release of neurotransmitter. The neurotransmitter serotonin, among others, is found in taste cells, and serotonin receptors are found on the sensory afferents. Finally, the TRPM<sub>5</sub> channel, which facilitates G-protein-coupled receptor-mediated depolarization, is expressed in taste cells. Its localization to apical versus basal domains is not yet known.

# TRANSDUCTION MECHANISM



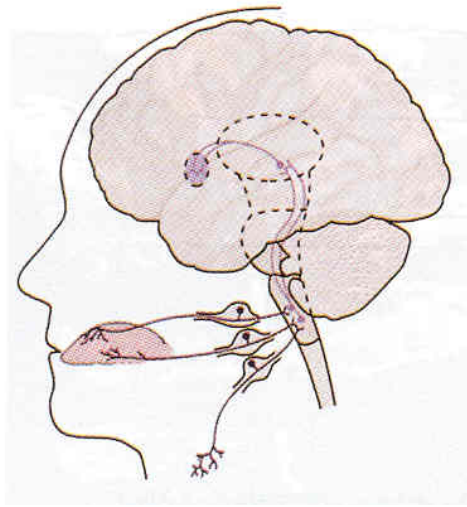
# Taste Signal Transmission





Adaptation: partial in receptors and partial (unknown) in the central nervous system

# Gustatory Pathways



gustatory cortex (anterior operculum insulofrontal)

Corteza gustativa  
(opérculo insulofrontal anterior)

ventral posterior medial nucleus of the thalamus

Núcleo medial posterior ventral del tálamo

geniculate ganglion

Ganglio geniculado

chorda tympani

Cuerda del tímpano

N. VII

Lengua tongue

N. IX

Glossofaríngeo glossopharyngeal

Ganglio petroso petrosal ganglion

Núcleo del haz solitario

nucleus of the solitary bundle

Área gustativa gustatory area

gustatory area

gustatory area

gustatory area

gustatory area

gustatory area

gustatory area

gustatory area

gustatory area

gustatory area

N. X

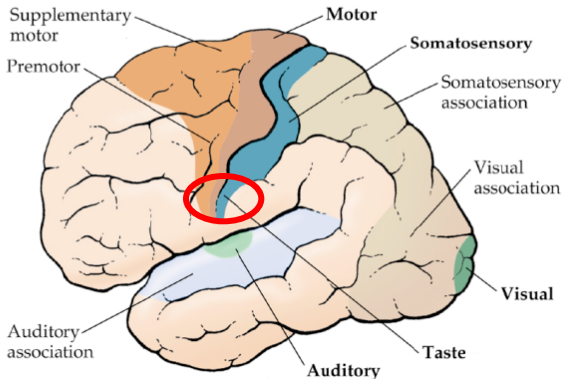
Ganglio nodoso

ganglion nodosum

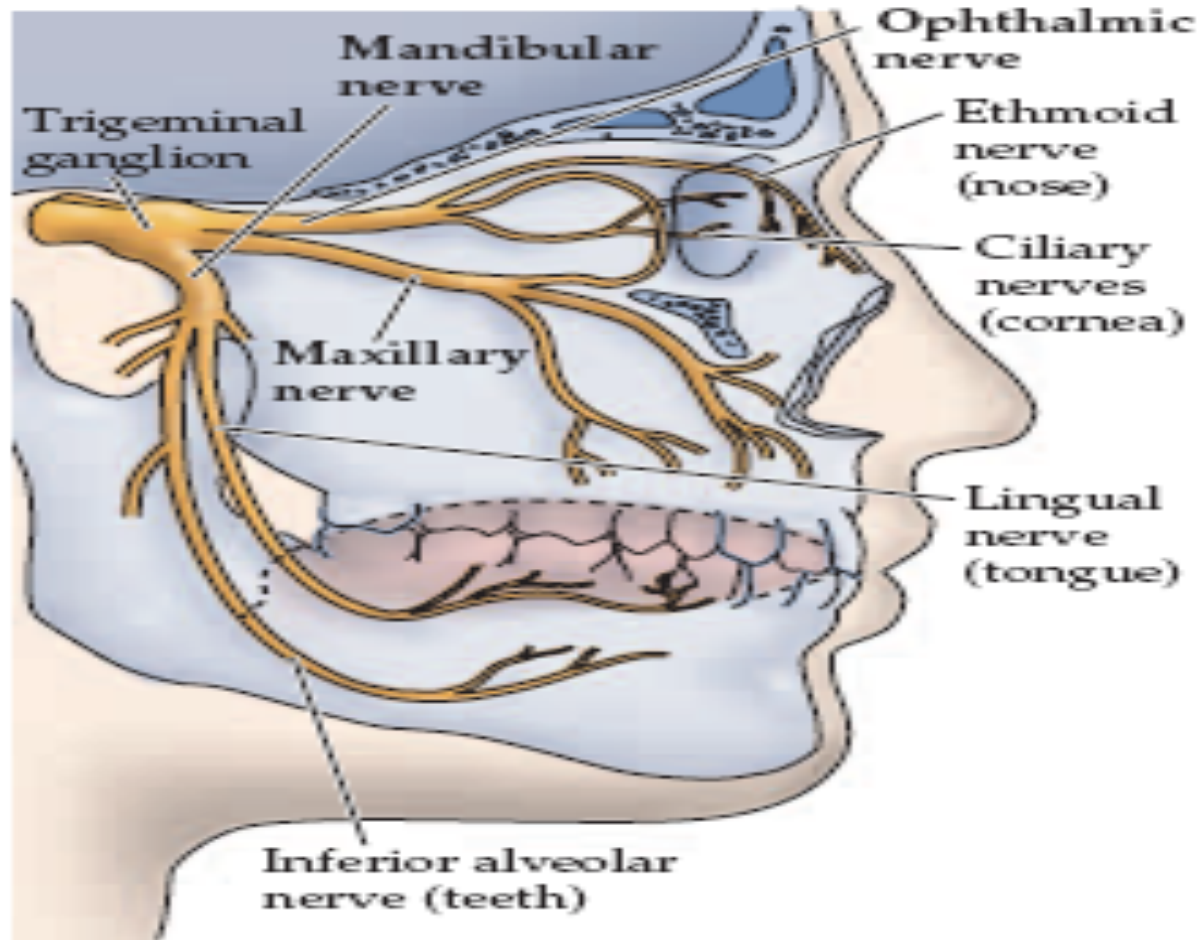
Faringe pharynx

## LOCALIZATION OF MOTOR AND SENSORY FUNCTIONS

LATERAL VIEW



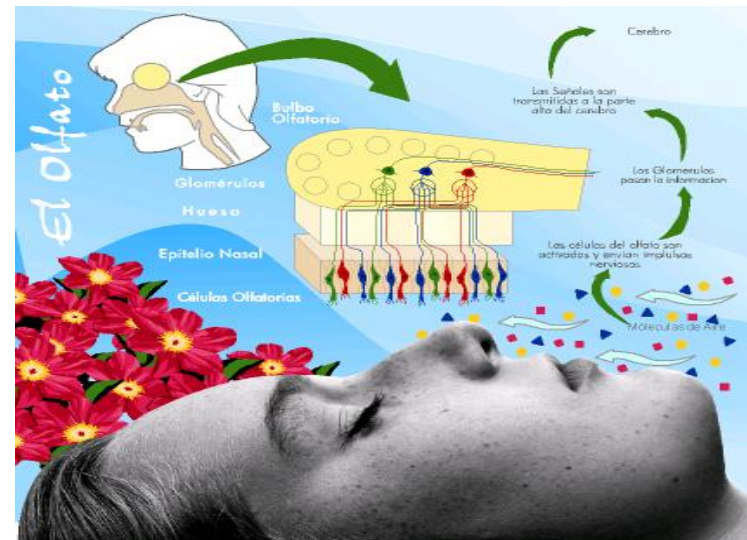
# Chemosensitive Trigeminal System



**Figure 14.18** Diagram of the branches of the trigeminal nerve that innervate the oral, nasal, and ocular cavities. The chemosensitive structures innervated by each trigeminal branch are indicated in parentheses.

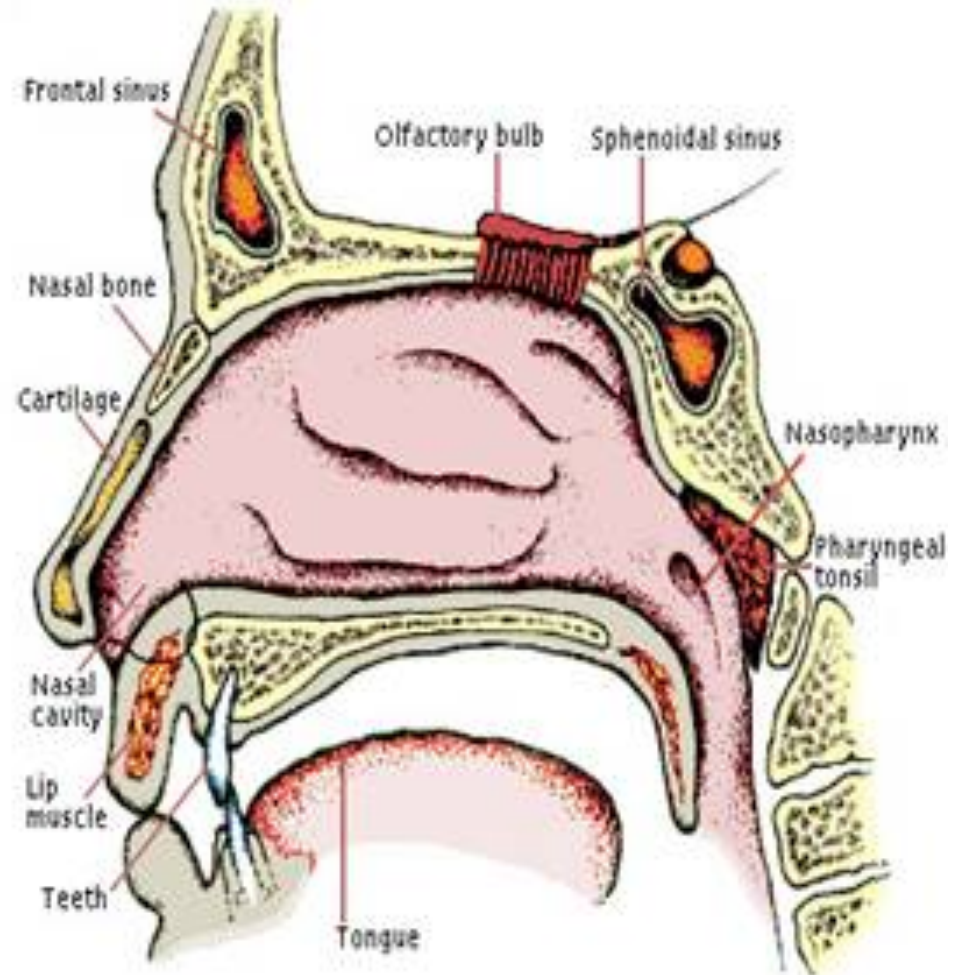
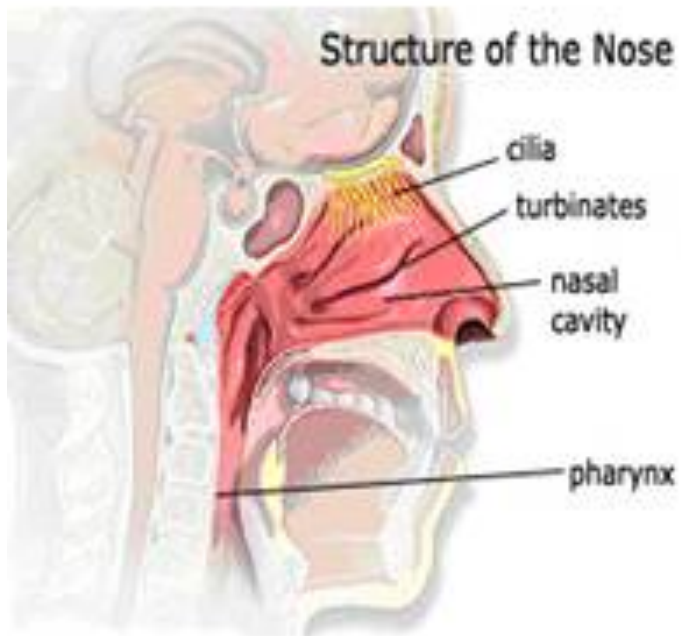
# Smell

- Very unknown, subjective
- Underdeveloped in higher animals
- Interaction with taste
- Olfactory membrane chemoreceptors detect molecules in solution in the mucus



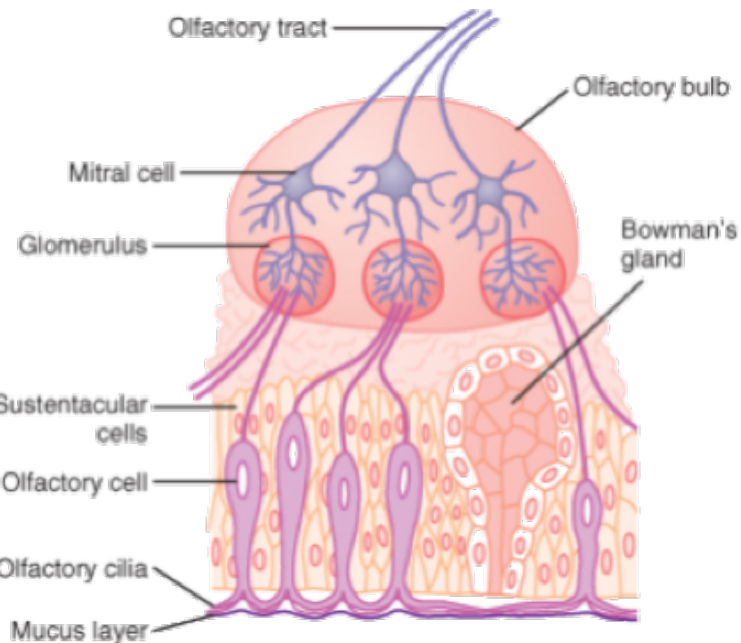
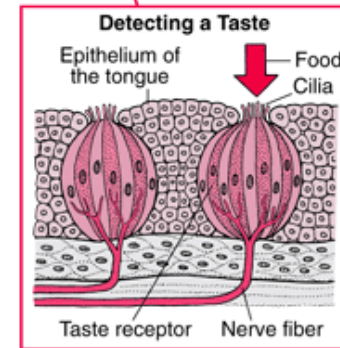
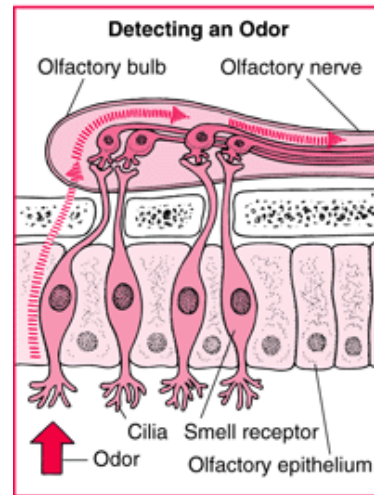
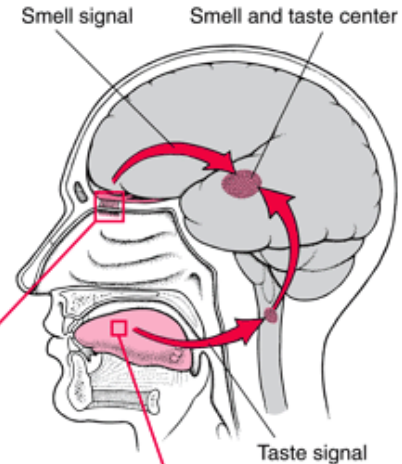


# Olfactory Membrane



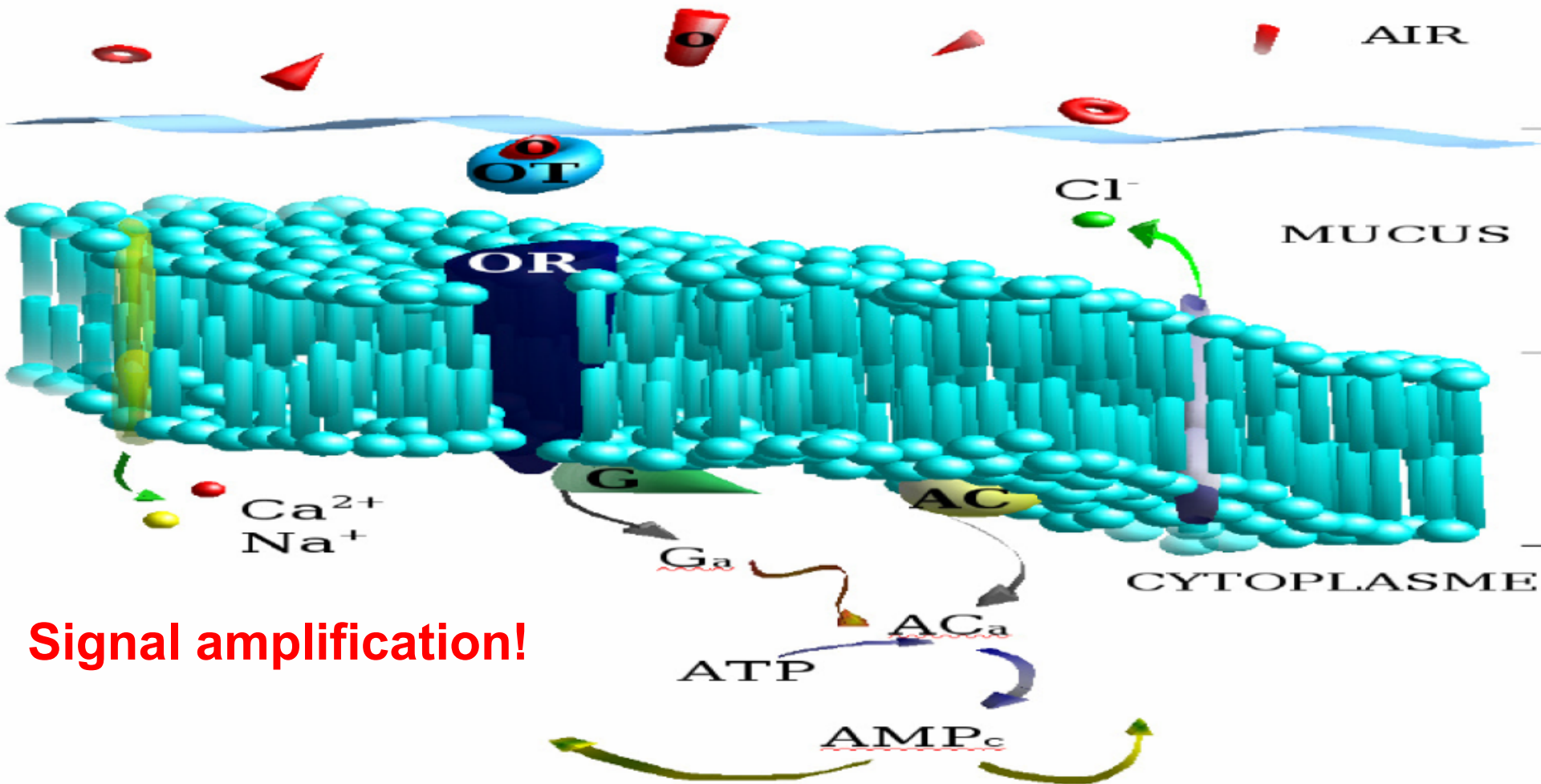
# Olfactory Membrane

- The receptors are the olfactory cells
- Are modified neurons
- About 100 millions



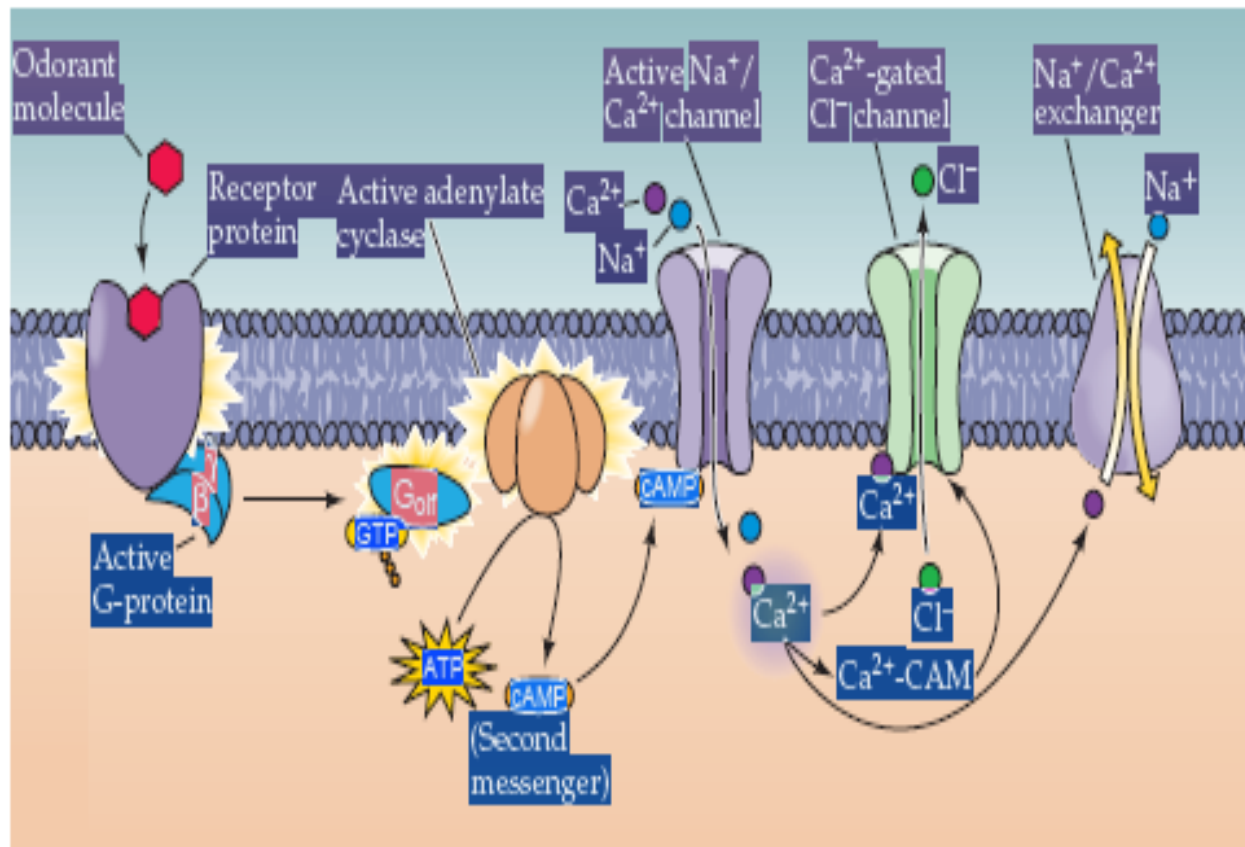
Migration from the hippocampus (relationship with Alzheimer's disease)

# Stimulation of Olfactory Cells

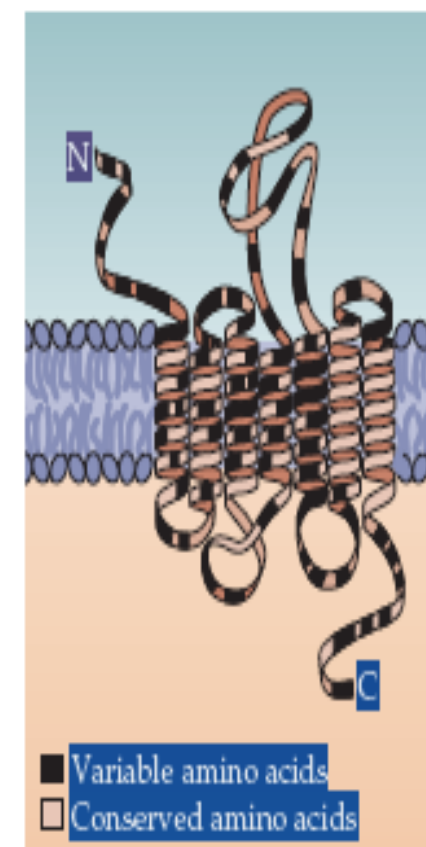


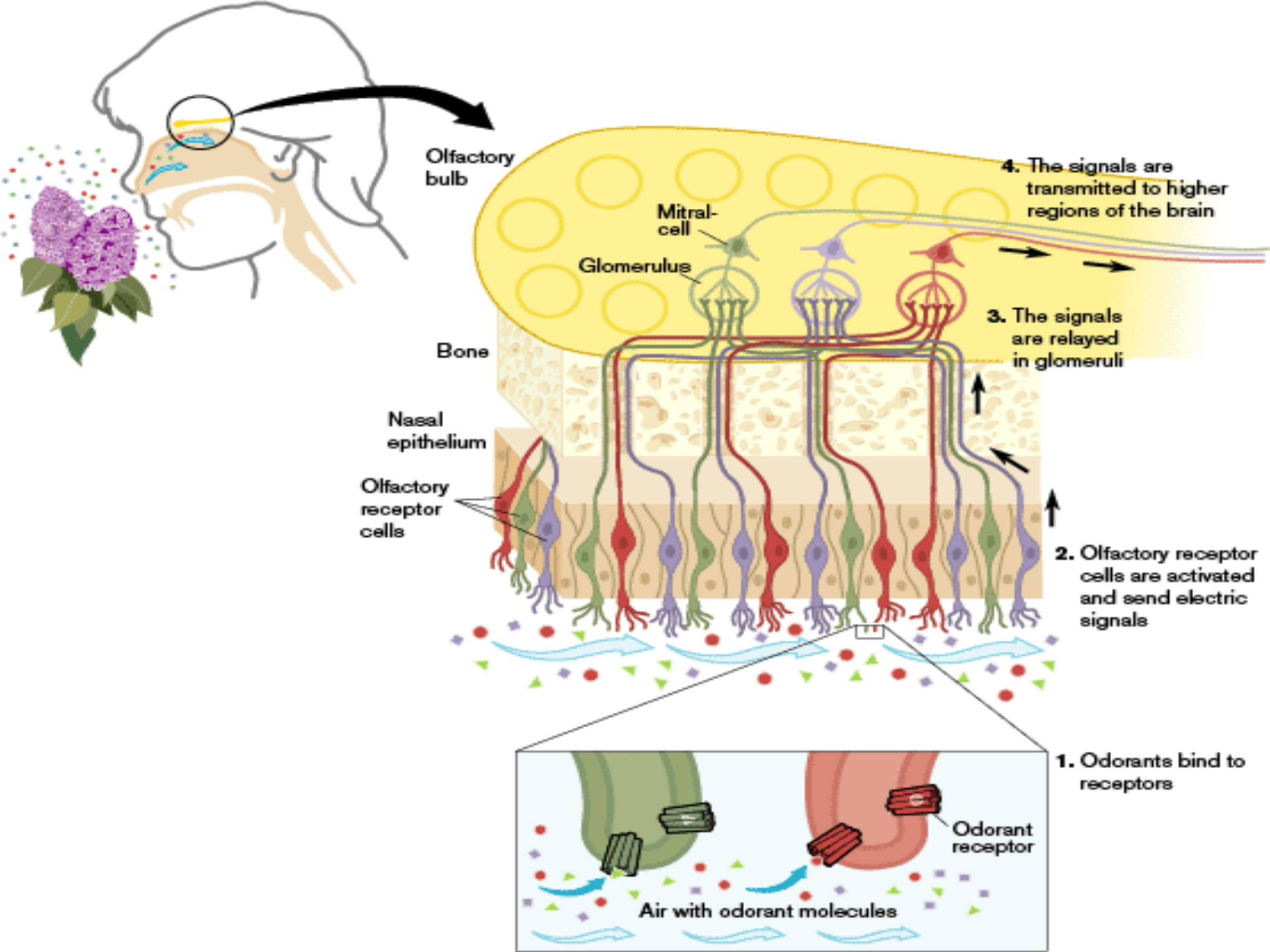
# Transduction

(A)

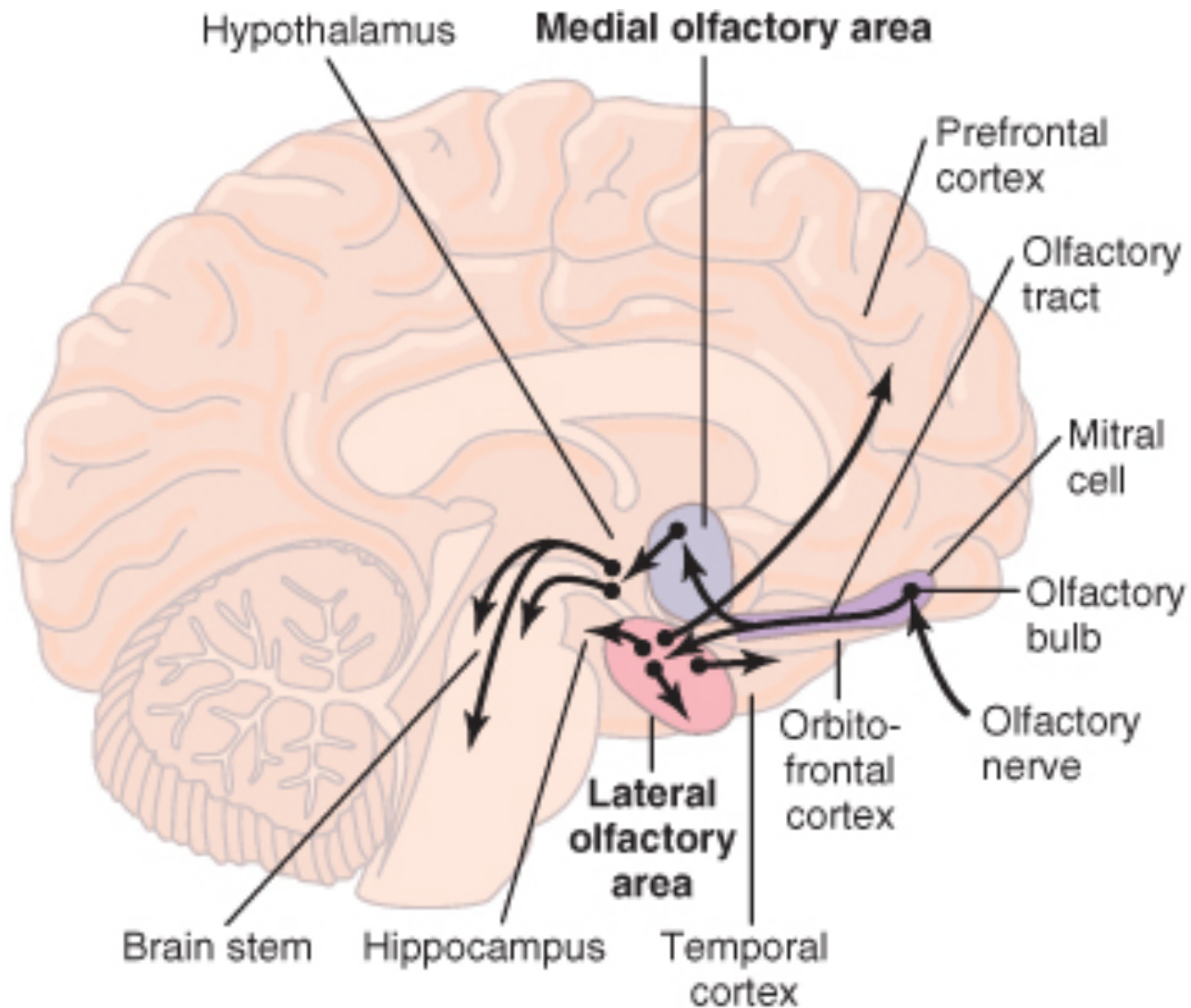


(B)





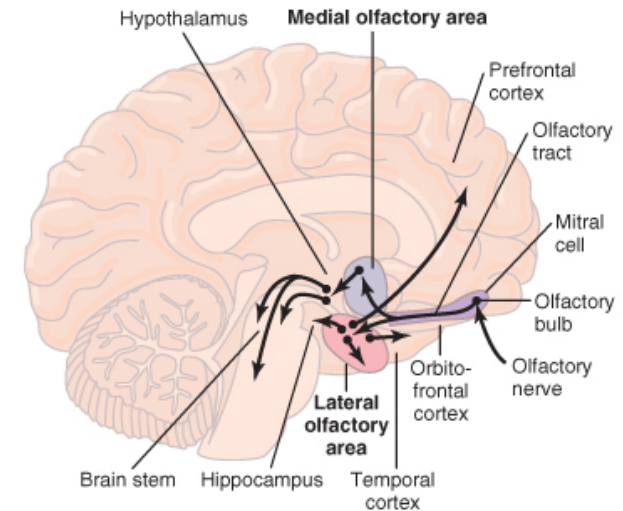
# Signal Transmissions



# Signal Transmissions

## Archaic olfactory system:

- Medial olfactory area
- Septal nuclei (hypothalamus and limbic system)
- Basic behavior: licking the lips, salivate, other alimentation reactions
- Part of the rhinencephalon has been replaced by memory



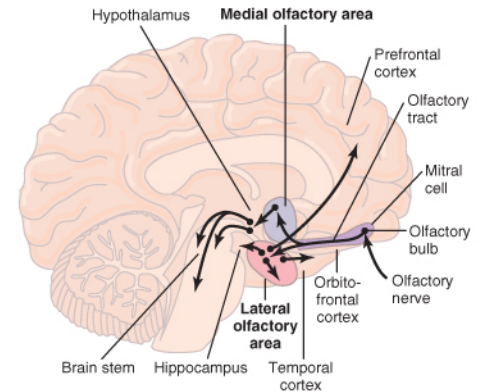
# Signal Transmissions

## Old olfactory system:

- Lateral olfactory area
- Prepiriform and piriform cortex

and cortical portion of the amygdaloidal nuclei

- Connections with the limbic system and hippocampus
- Behavioral behavior: personal experiences lived in relation to food

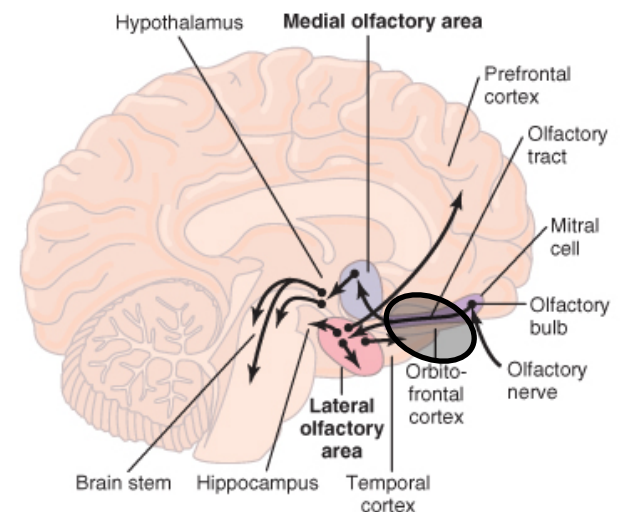
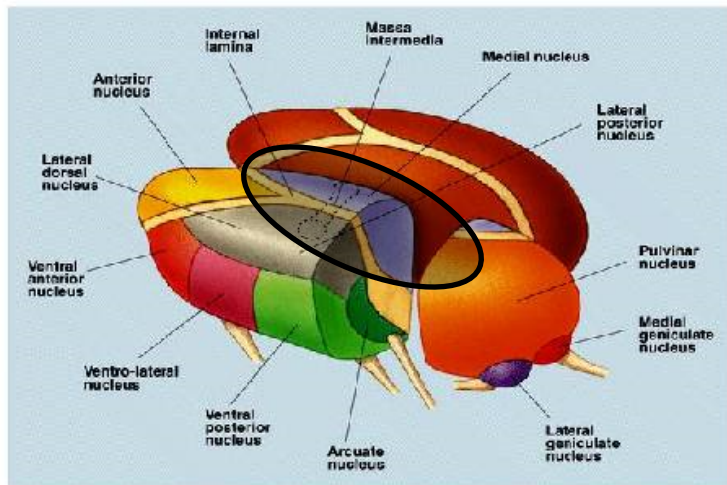




# Signal Transmissions

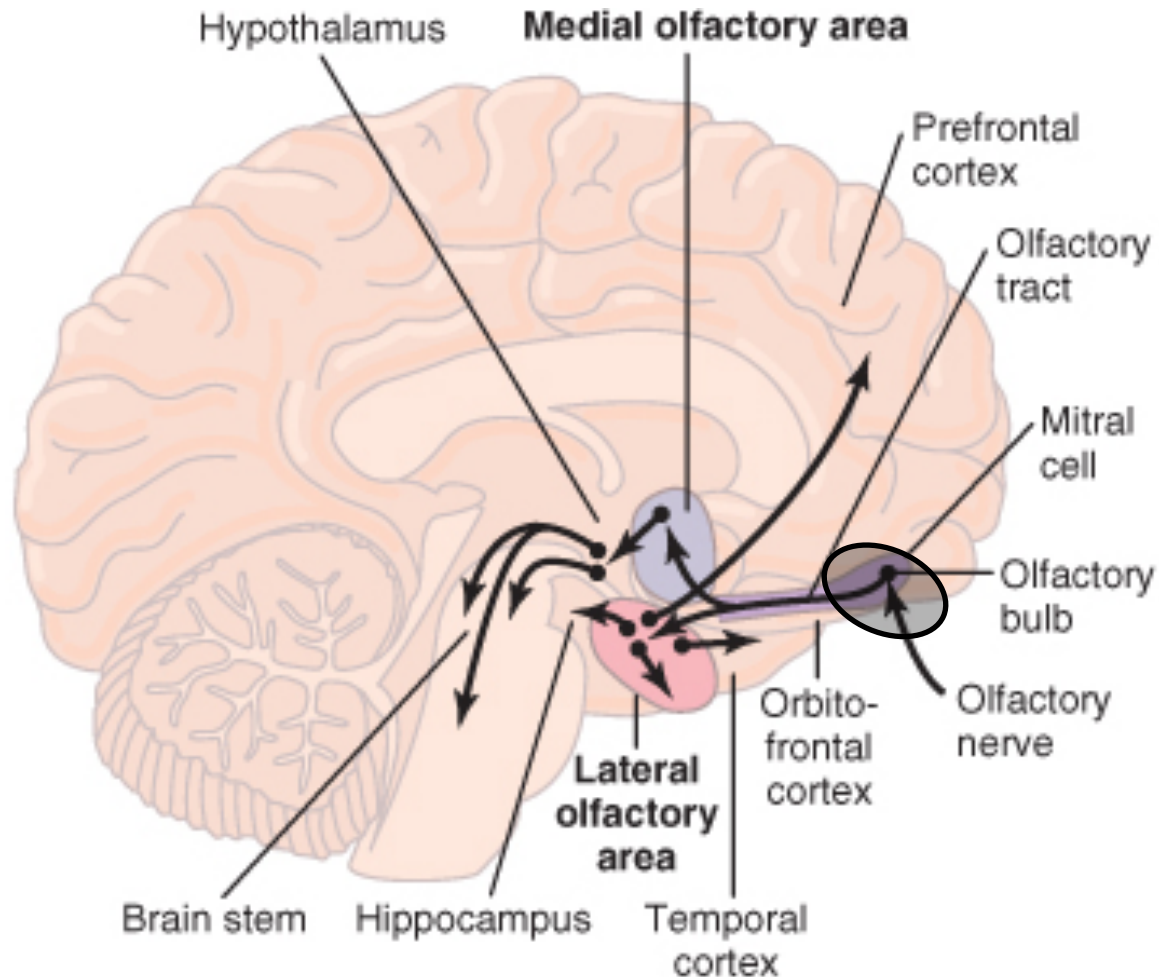
## Modern way:

- Goes through the thalamus by dorsomedial nucleus and reaches the orbitofrontal cortex lateroposterior quadrant.
- Conscious perception and smell analysis.

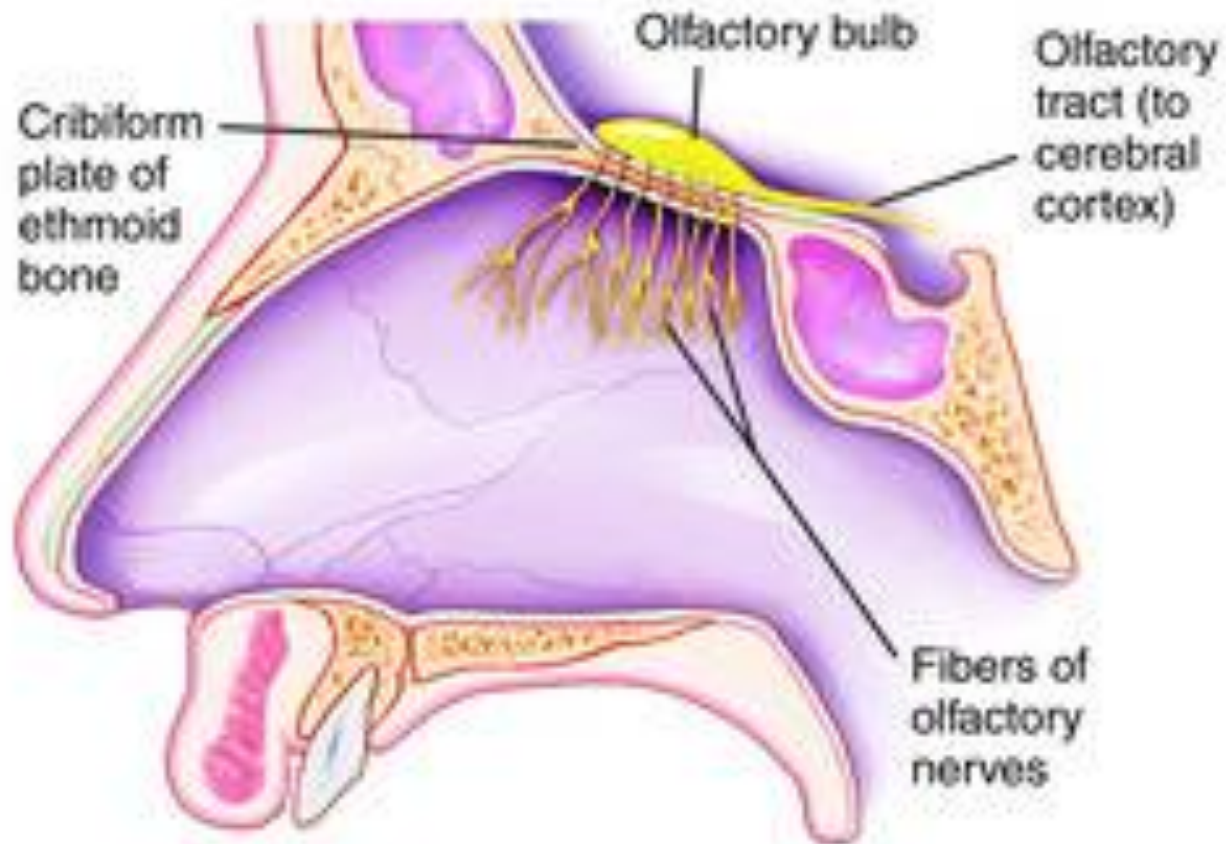


# Centrifugal Control

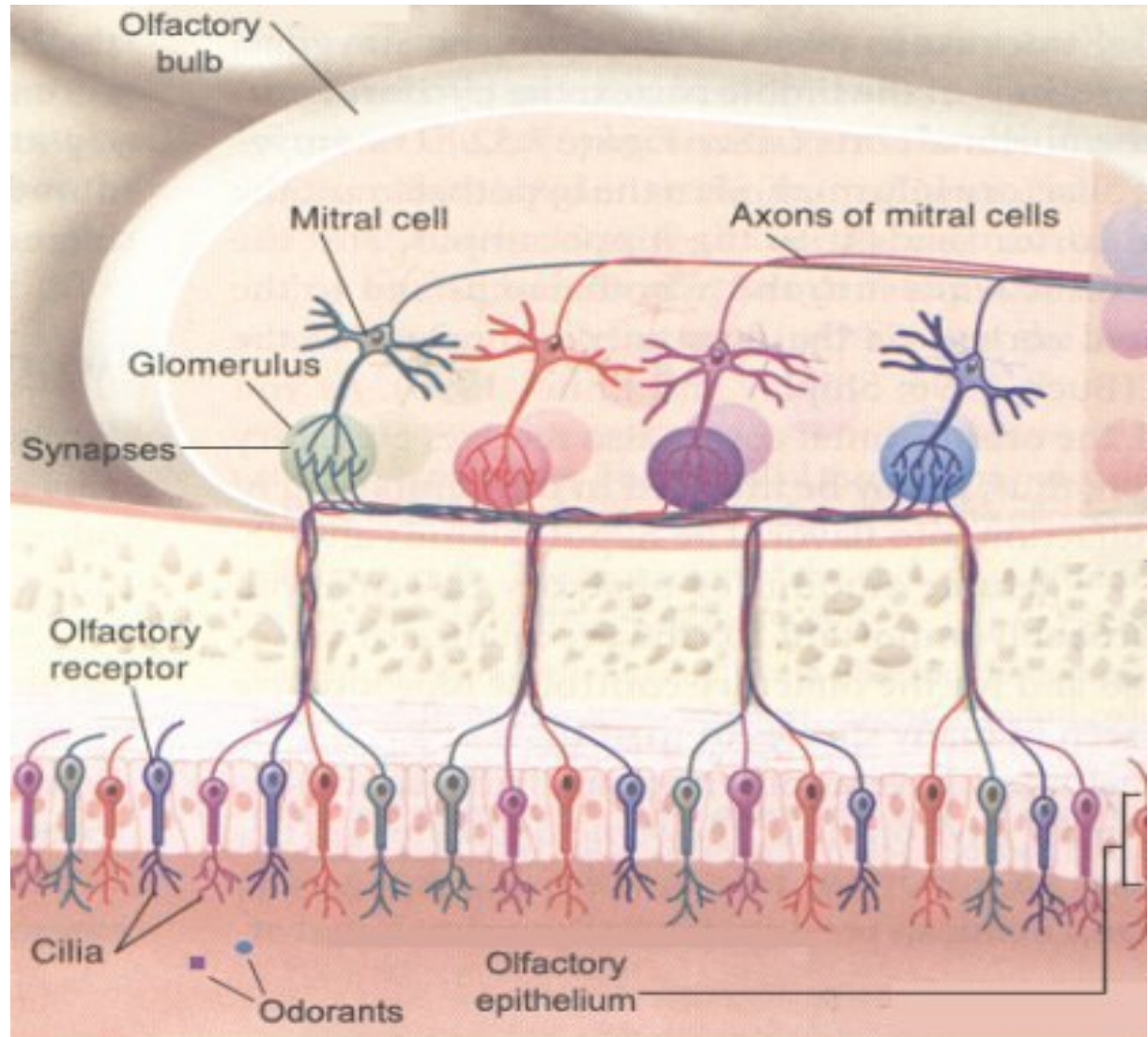
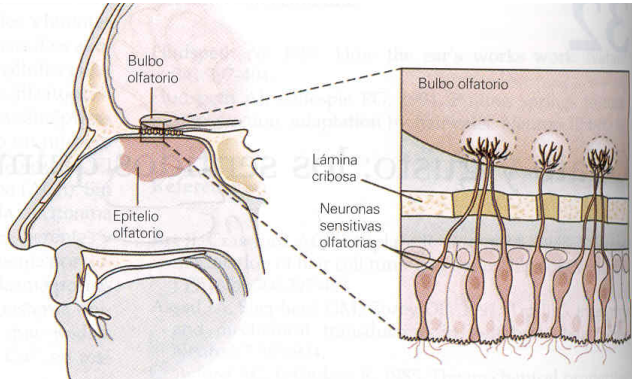
Negative feedback-SNC-bulb mitral cells: distinction of odors



# Olfactory Tract

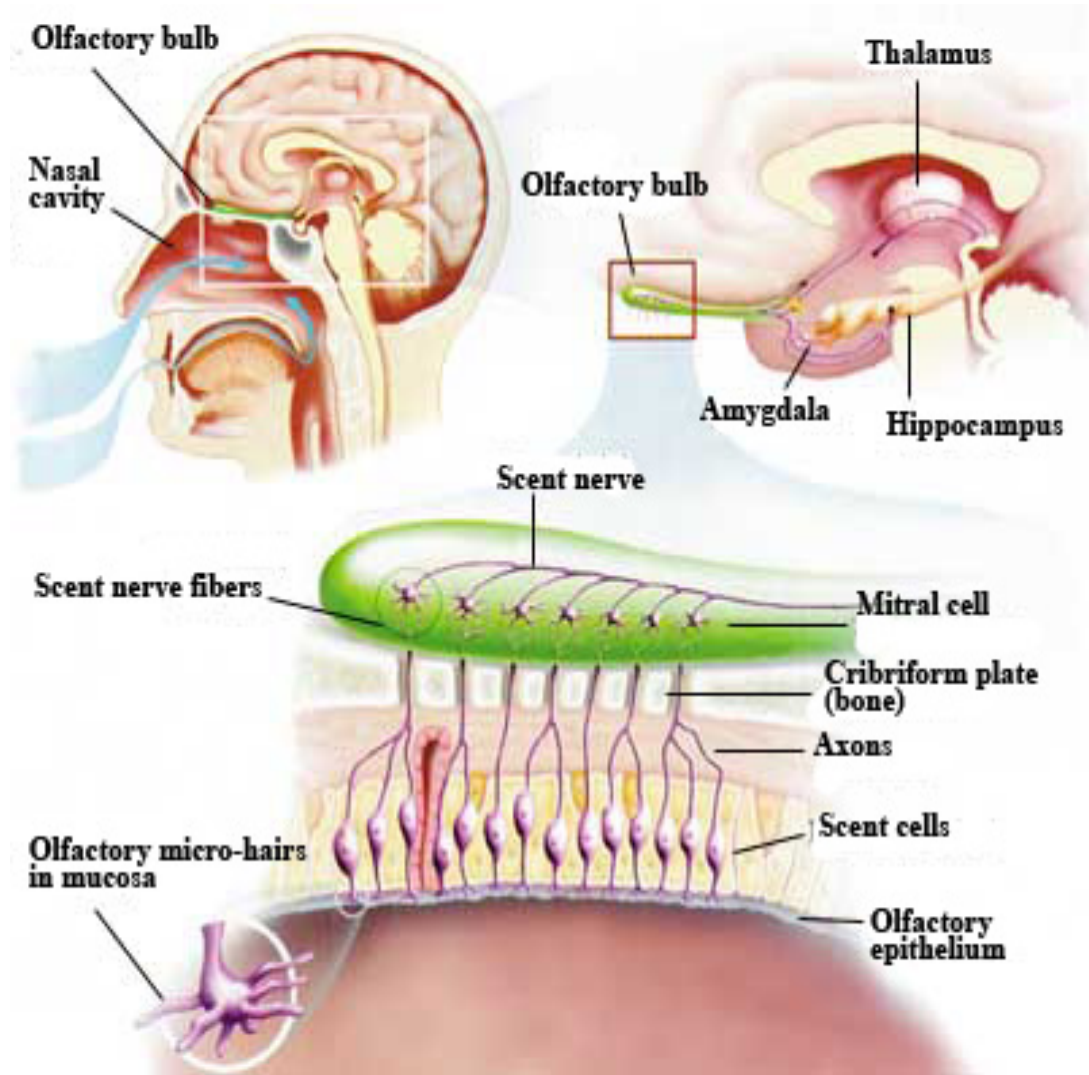


# Olfactory Tract



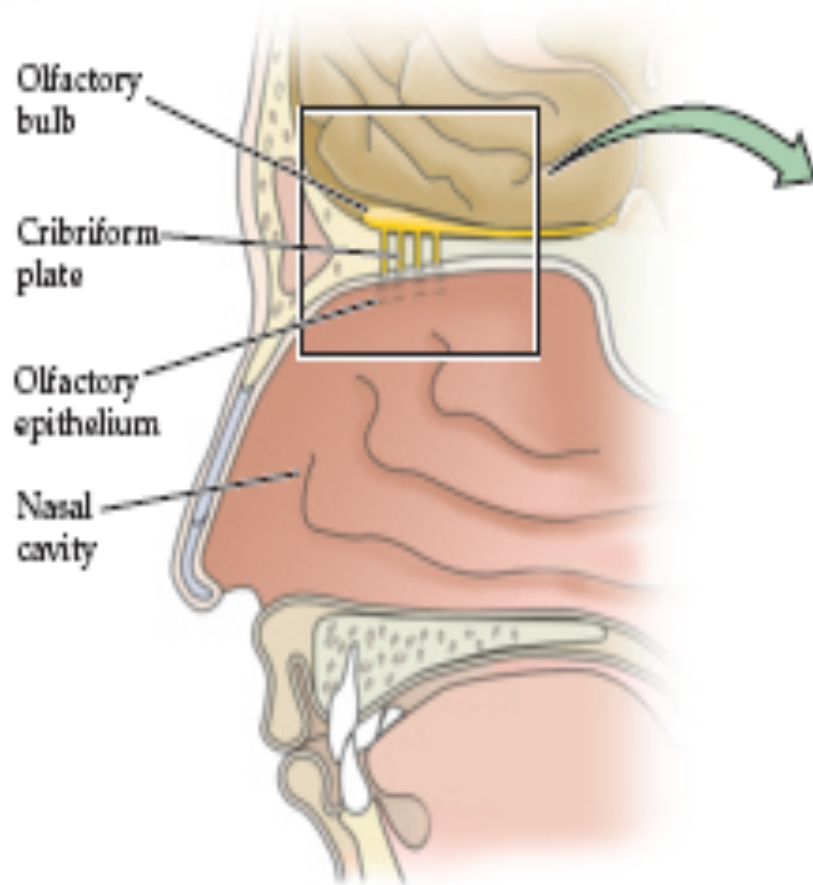
# Olfactory Tract

- Hypothalamus; basic behavior: licking the lips, salivary, other reactions to food
- Behavioral behavior: personal experiences in relation to food (related to limbic system)
- Thalamus: conscious perception of smell analysis

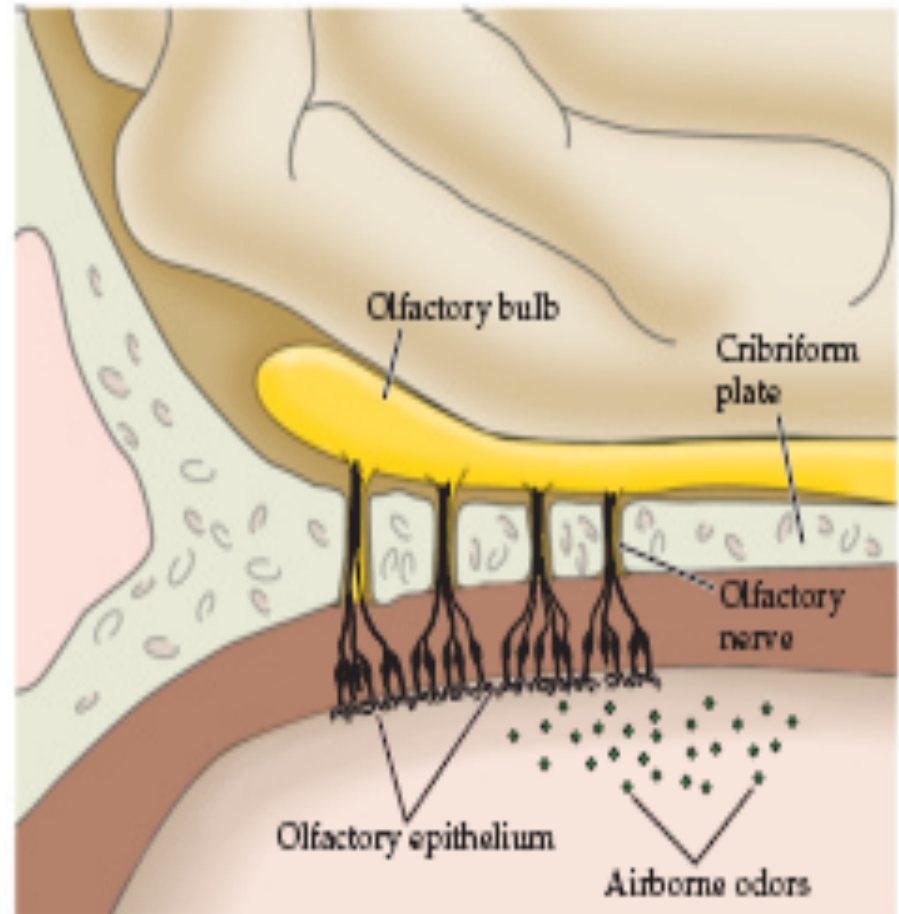


# Olfactory Tract

(A)



(B)



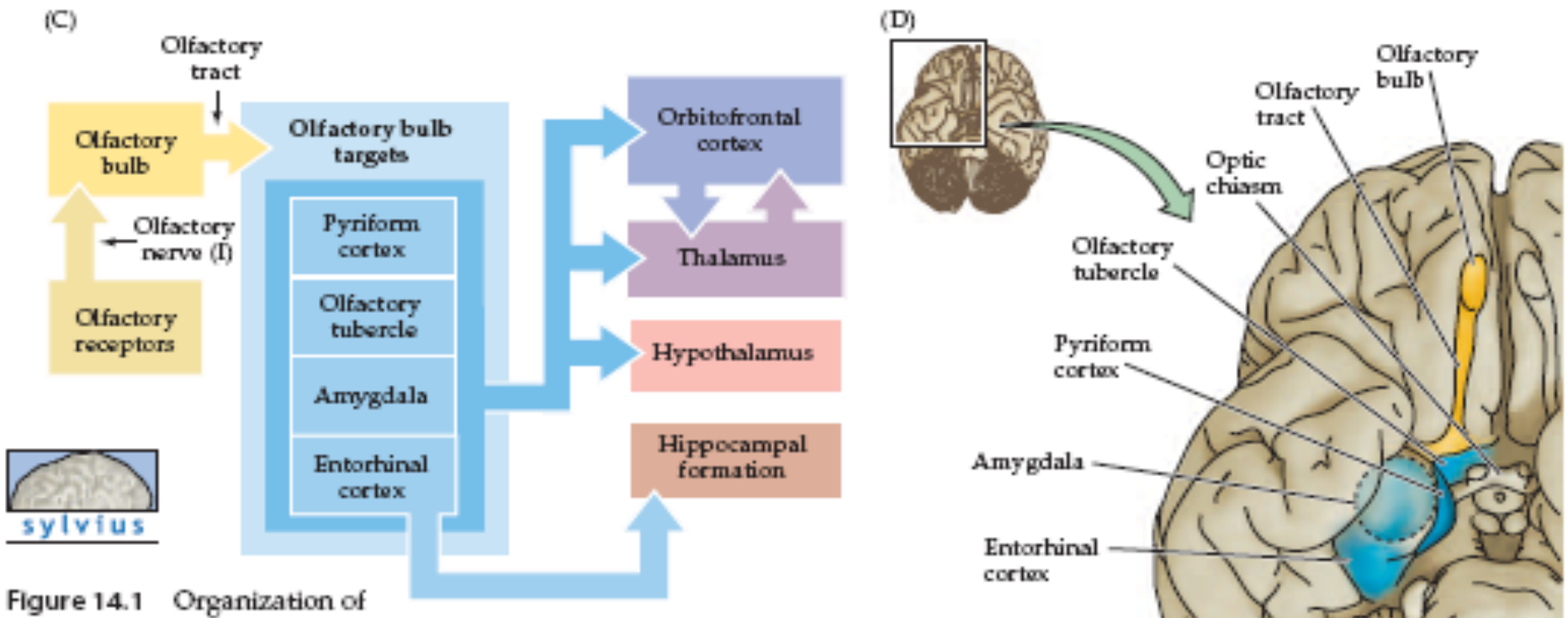
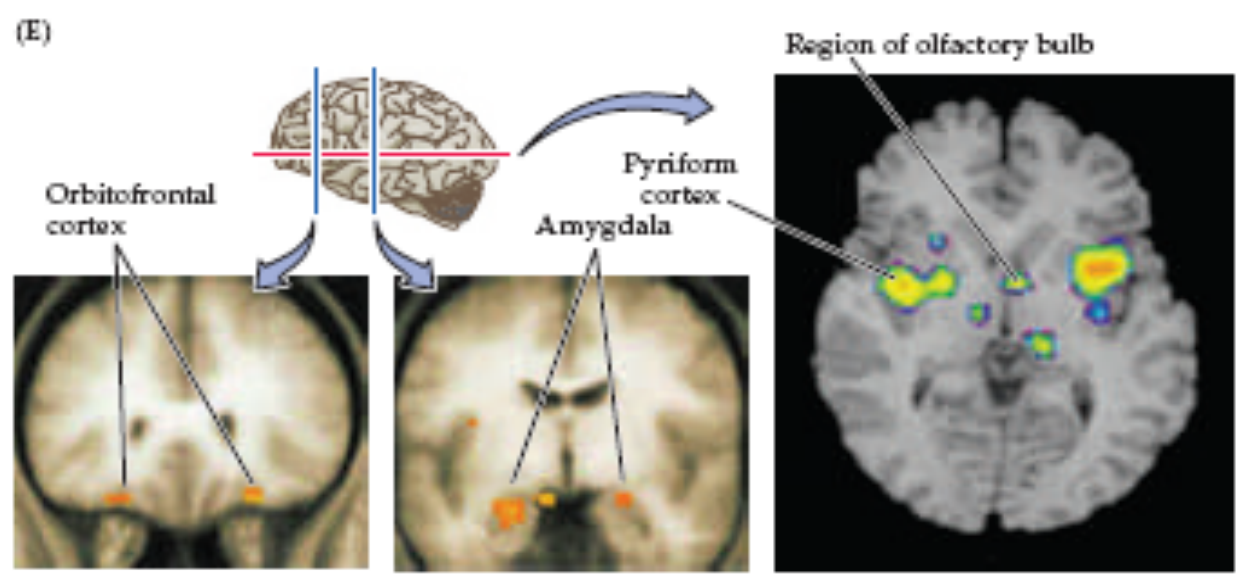
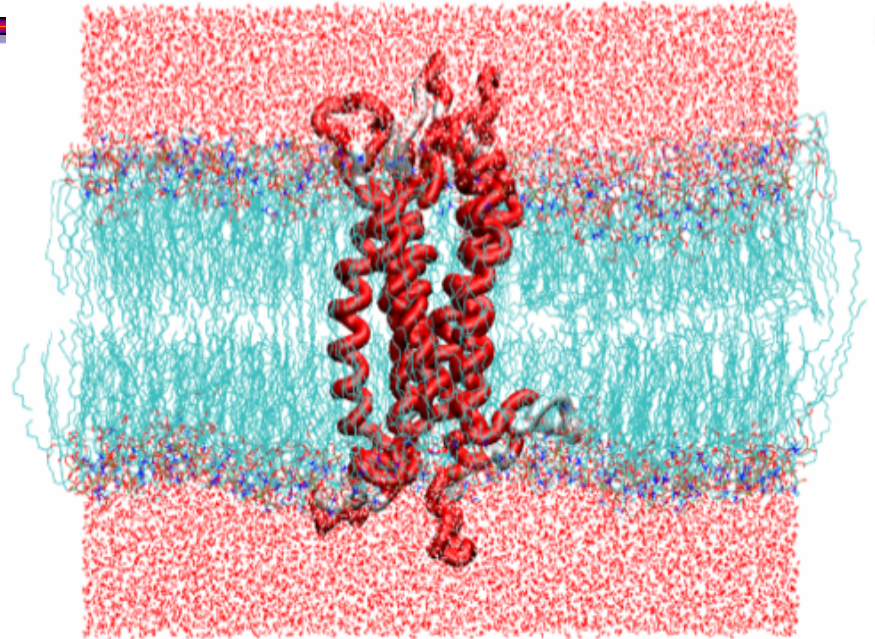


Figure 14.1 Organization of the human olfactory system. (A) Peripheral and central components of the primary olfactory pathway. (B) Enlargement of region boxed in (A) showing the relationship between the olfactory epithelium (which contains the olfactory receptor neurons) and the olfactory bulb (the central target of olfactory receptor neurons). (C) Diagram of the basic pathways for processing olfactory information. (D) Central components of the olfactory system. (E) fMRI images showing focal activity in the regions of the olfactory bulb, pyriform cortex, and amygdala in a normal human being passively smelling odors. (From Savic et al., 2001.)



# Smelly Substances

- Volatile
- Soluble
- A little bit soluble
- Different threshold
- Depending on the substance,  
for example: methyl mercaptan  
(garlic) is mixed with natural gas





# Features

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- **ADAPTATION:**  
PARTIAL RECEPTOR  
PARTIAL CNS
- **PRIMARY SENSATIONS**  
between 2000 and 4000!
- **ODOR INTENSITY**  
Gradations are wrongly detected  
10-50x the threshold: maximum intensity (500.000x in eyes)

# Features

---

- Anosmia: loss or reduction of smell
- Hyperosmia: increase of smell
- Hyposmia: decrease in olfactory ability
- Dysosmia: smell disorders
- Aglossia: without tongue
- Hypoglossia: smaller tongue
- Dysglossia: alteration of phonemes articulation



# PHYSIOLOGY OF HEARING

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MD Consuelo Borrás

# Outline

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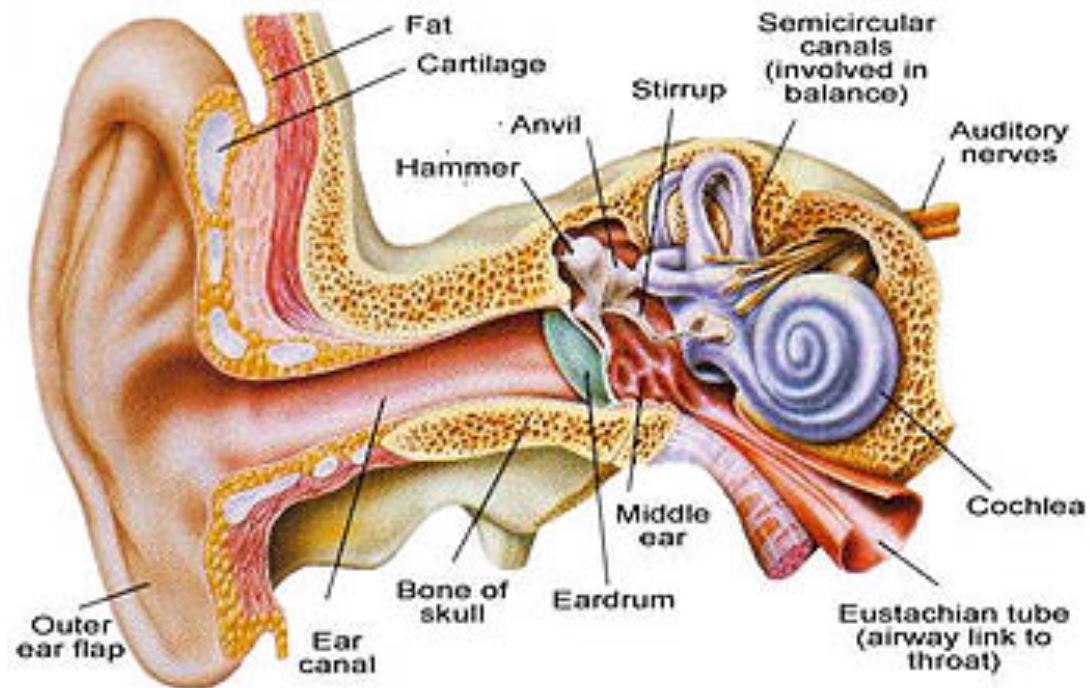
- Introduction
- Structure
- Sound transmission
  - Stapedial reflex
- Tonotopy
- Organ of corti. Mechanism of action
- Auditory pathway

# Introduction

- The organ of hearing is situated in the **cochlea**
  - It perceives sounds from 20-20,000 Hz (wave cycles/sec) frequency and intensity up to 130 dB (traumatism)
  - Whisper 20 dB
  - Conversation 60-65 dB
  - Shout 80-100 dB
  - Hard Rock 110 dB
- (dB: logarithm of the pressure exercised by the sound wave in the eardrum)

# Structure

- Ear:
  - External: eardrum
  - Medium: auditory ossicles
  - Inner: cochlea

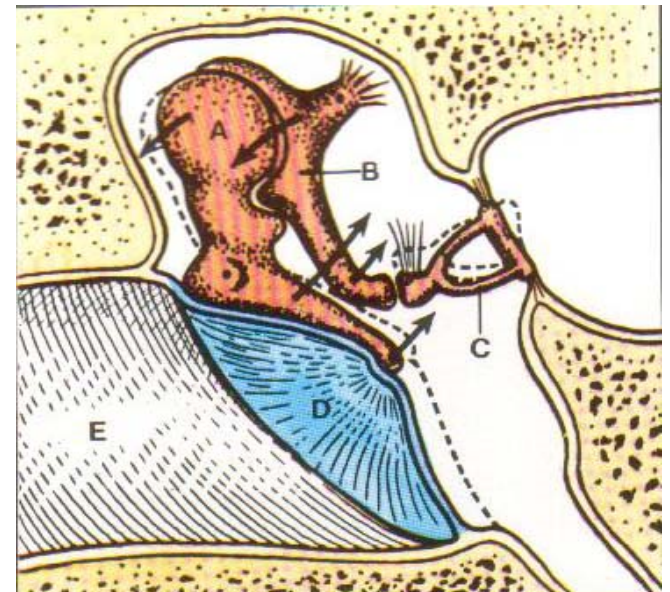


# Sound Transmission

- Sound is transmitted through three means: gas, liquid and solid
- Sound transmission is better:  
solid > liquid > gas
- In the **external ear** the transmission is GASEOUS up to the eardrum, since it becomes SOLID from then on (middle ear).
- In the **middle ear**, the ossicles cause the sound wave to transform into a mechanical vibration.

# Sound Transmission

- In the middle ear sound undergoes an adaptation of his IMPEDANCE (resistance of a material to the passage of an acoustic wave) because it goes from a gaseous medium to a liquid medium in the inner ear.
- In the end, the stirrup hits the oval window and carries the sound to the cochlea.





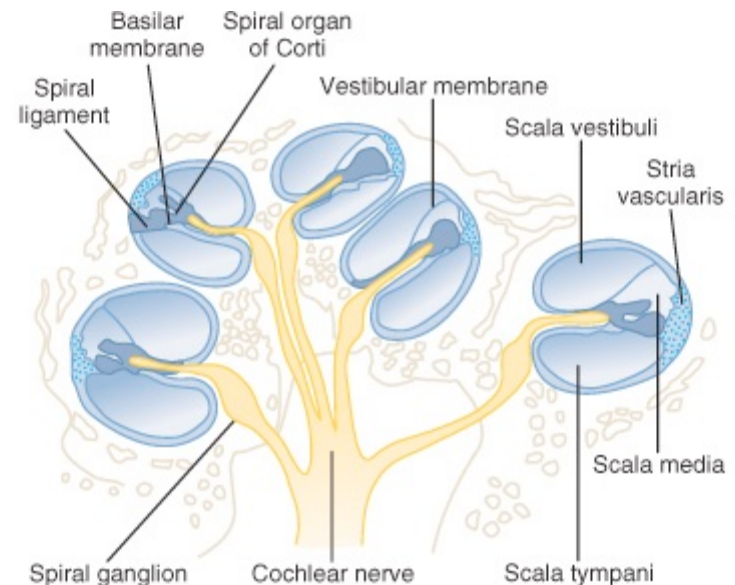
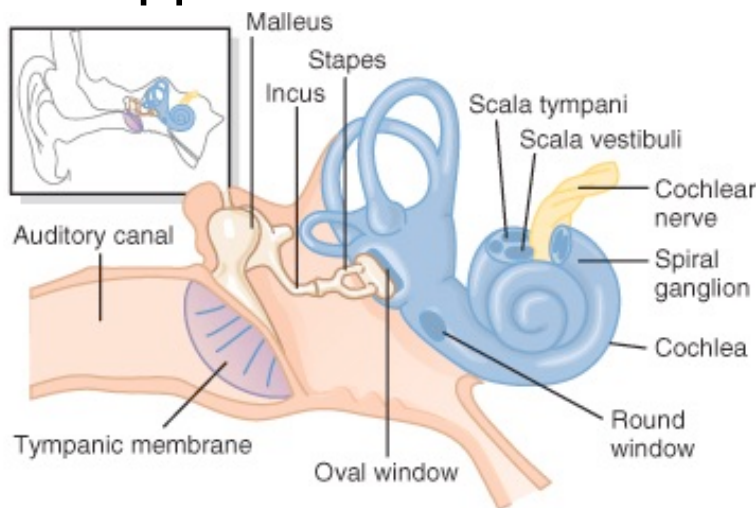
# Stapedial Reflex

- It is the protection the ear has in order to modulate the amount of energy that reaches the inner ear in the sound wave.
- A reflex takes place, in which the stirrup and tensor tympani muscles contract.



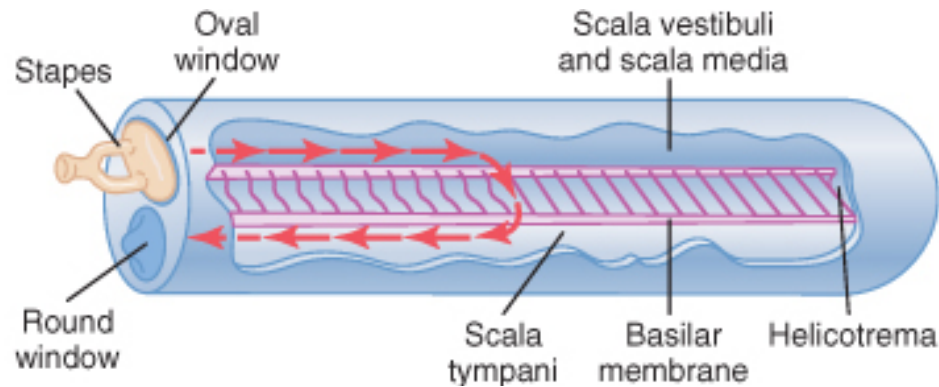
# Sound Transmission

- In the **inner ear**, after going through the oval window, sound goes from liquid to solid medium and produces a fluid wave that moves through the scala vestibuli and makes the basilar membrane vibrate with the organ of Corti.
- The wave advances and returns to the round window in the opposite direction.



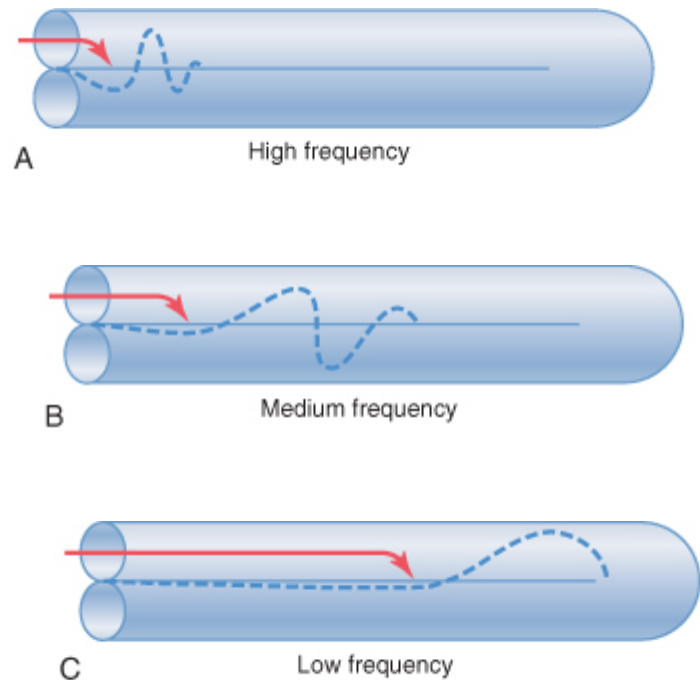
# Sound Transmission

- The round window absorbs the energy of the wave, which disappears.



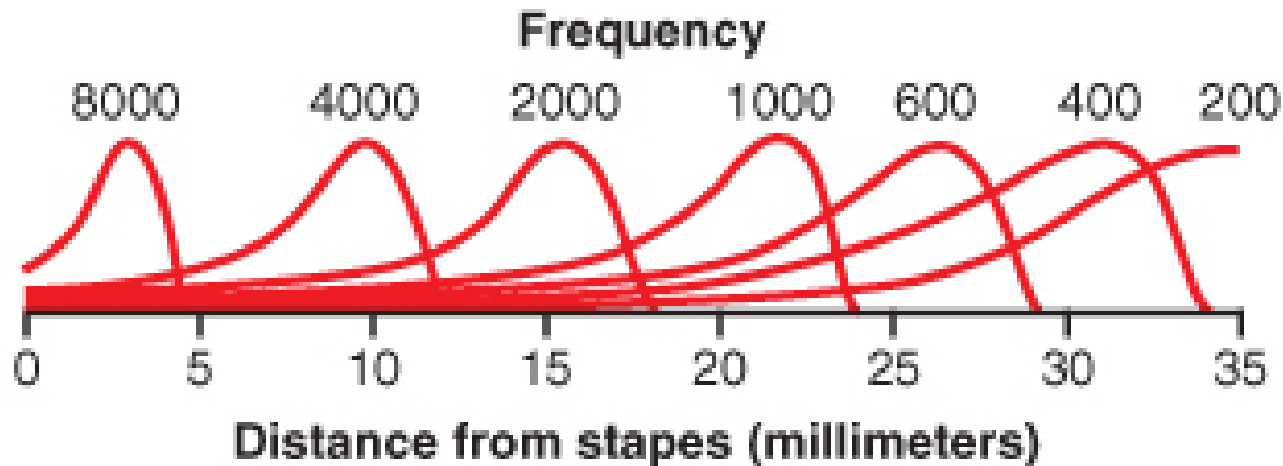
# Tonotopy

- The movement area of the basilar membrane varies according to the sound frequency.
  - High frequency: near the oval window
  - Low frequency: at the end of the cochlea

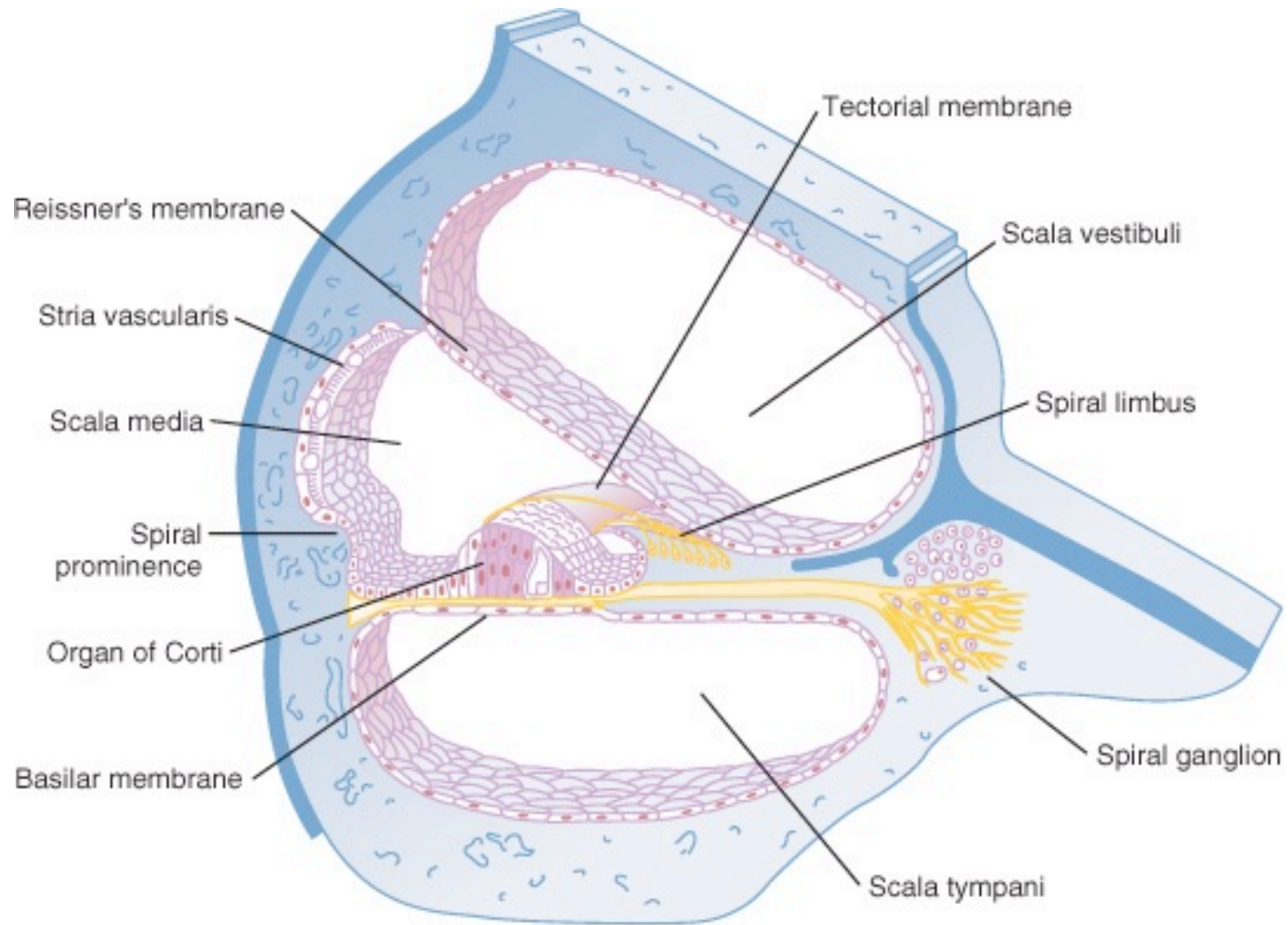


# Tonotopy

- There is a **topographic distribution** of the place of vibration according to the frequency of the sound.

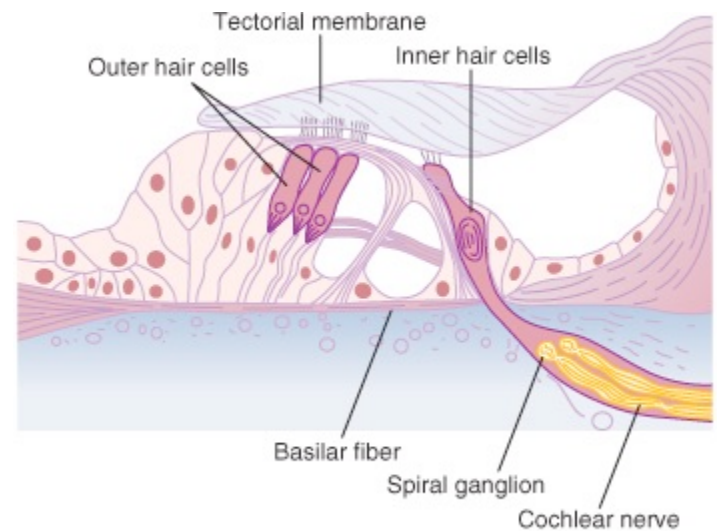


# Organ of Corti



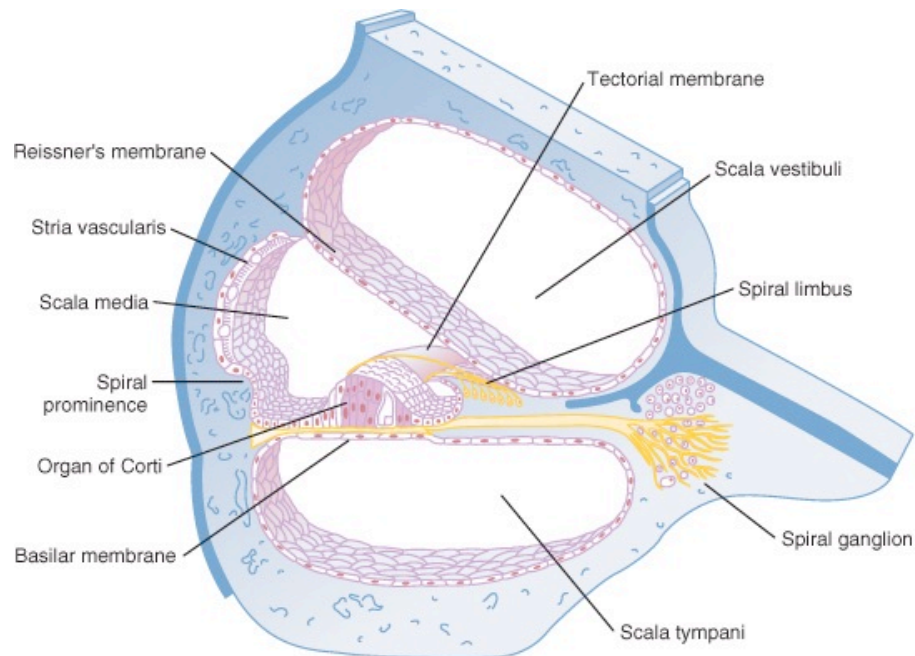
# Organ of Corti

- It has two kinds of cells on the basilar membrane:
  - Outer hair cells: supported by the sustentacular cells or Deiters cells
    - The hairs are embedded in the tectorial membrane (gelatinous structure with calcium salts to increase solidity)
  - Inner hair cells



# Organ of Corti

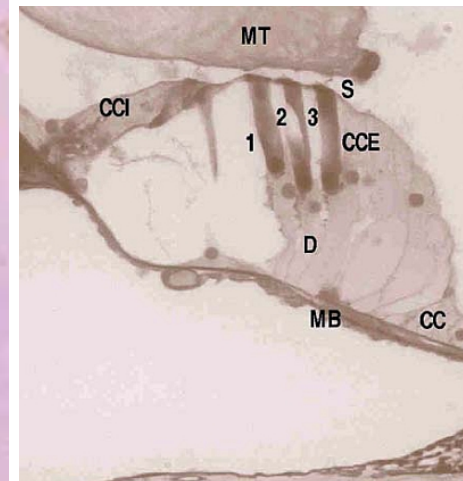
- In the scala vestibuli and scala tympani: **PERILYMPH**
  - Composition similar to the extracellular fluid (+Na<sup>+</sup>, -K<sup>+</sup>)
- In the scala media: **ENDOLYMPH**
  - Composition similar to the intracellular fluid (-Na<sup>+</sup>, +K<sup>+</sup>)
  - Produced by the stria vascularis





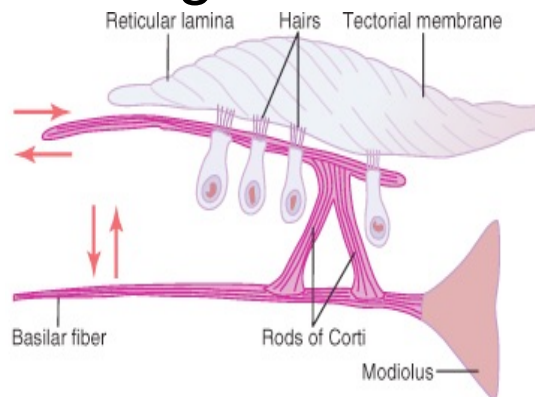
# Organ of Corti. Mechanism of Action

- The inner hair cells have the shape of a bottle, and progressively have longer hairs. The longest hair is known as **STEREOCILUM**.
- When the basilar membrane moves, the stereocilia connected to  $K^+$  channels moves, and they open.  $K^+$  comes in and the cell depolarises. This activates the nerve transmission to the CNS.



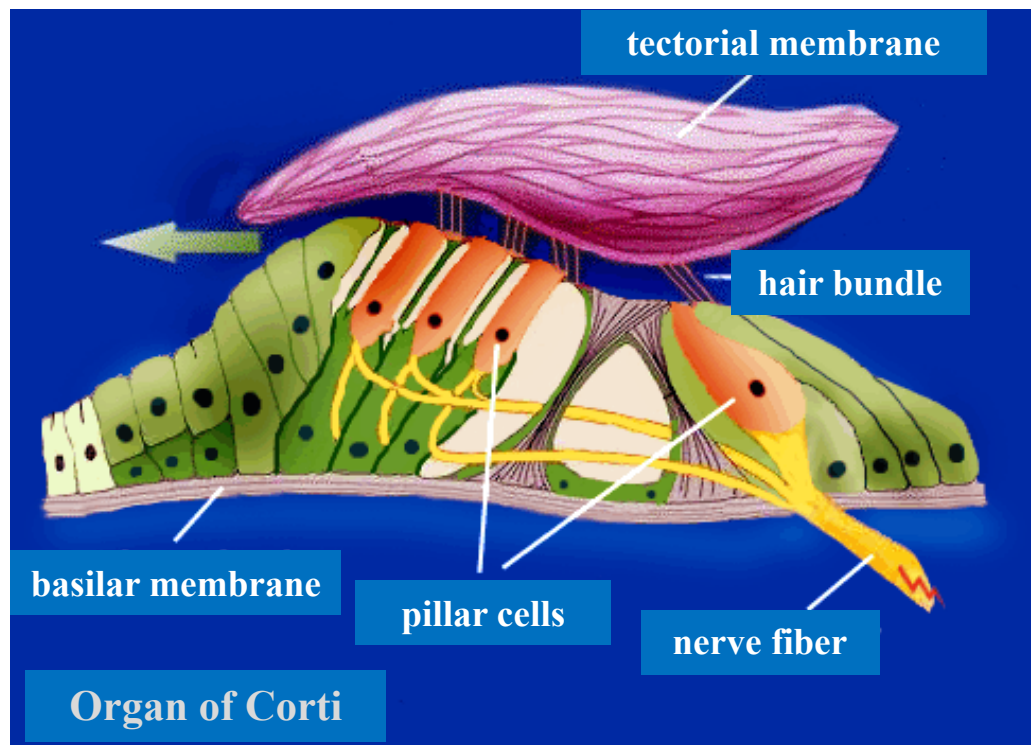
# Organ of Corti. Mechanism of Action

- The outer hair cells also have STEREOCILIA, which are longer than the stereocilia of the inner cells and are imbedded in the tectorial membrane.
- When the basilar membrane moves, the tectorial membrane moves and the stereocilia move (they depolarize).
- When they depolarize, they have contractile capacity due to the fact that they have actin and myosin. Thus they can move the basilar membrane for themselves as well as change the structure of the organ of Corti.



# Organ of Corti. Mechanism of action

- The IHC are the real receptors, the OHC are neuromodulators.



# Outer Hair Cell Innervation

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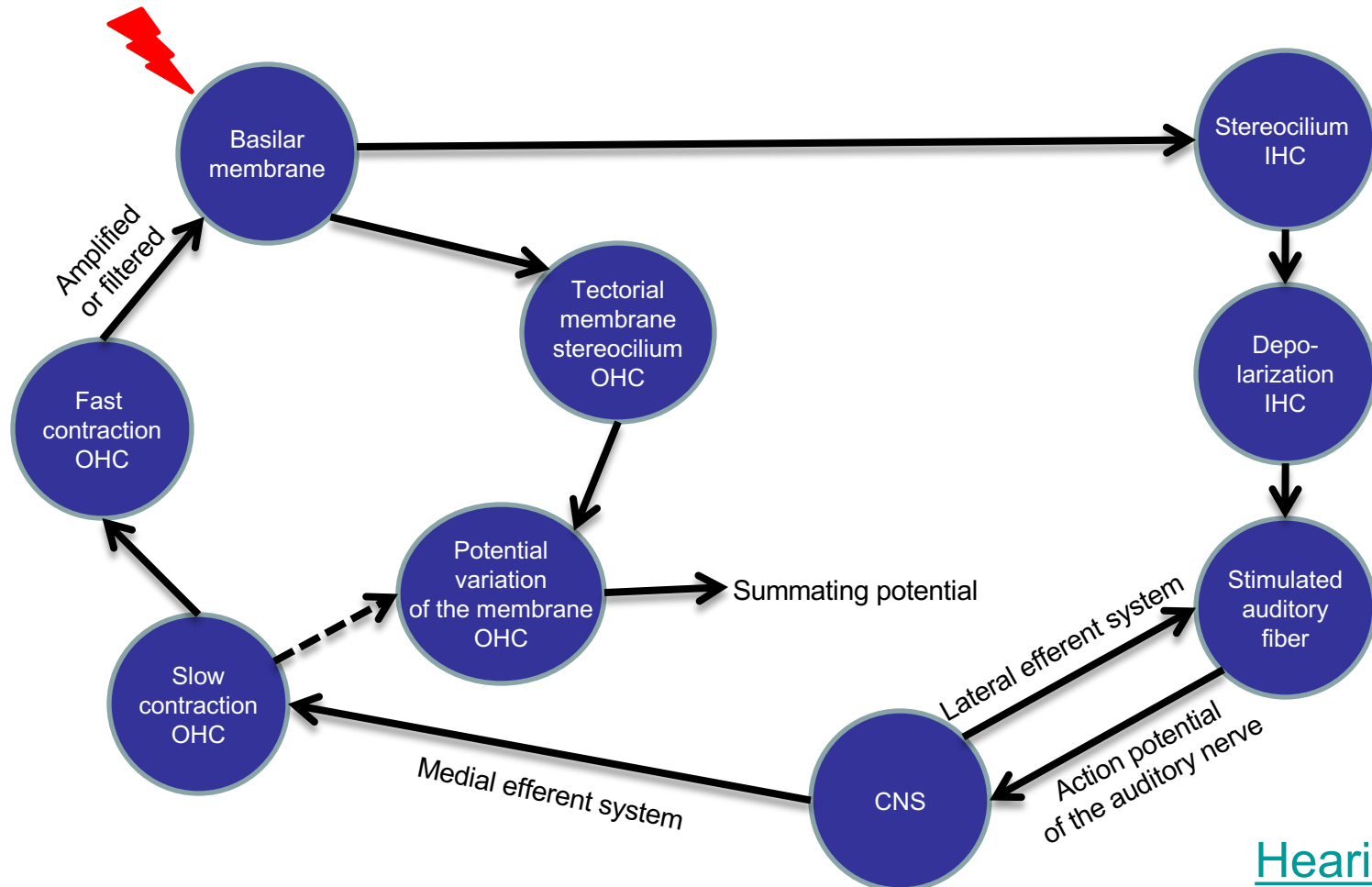
- It comes from upper nerve centers
- Two types of contractions:
  - Fast: amplifies or filters the basilar membrane movement according to whether it is depolarized or hyperpolarized
  - Slow: produced by the CNS, it activates (induced by  $K^+$  or by the increase of permeability to  $Ca^{2+}$ ) or deactivates the basilar membrane (the opposite of hyperpolarization)

# Innervation of the Cochlea

- Three types:
  - **Afferent fibers**: come from the spiral ganglion neurons or Corti. Two types:
    - Bipolar (type I, 95%): innervate the IHC.  
Neurotransmitter: glutamate
    - Pseudopolar (type II, 5%): unmyelinated, innervate the OHC
  - **Efferent fibers**: come from the neurons of the superior olive
    - Lateral (IHC)
    - Medial (OHC)
  - **Perivascular sympathetic fibers**: regulate the vascularization of the organ of Corti

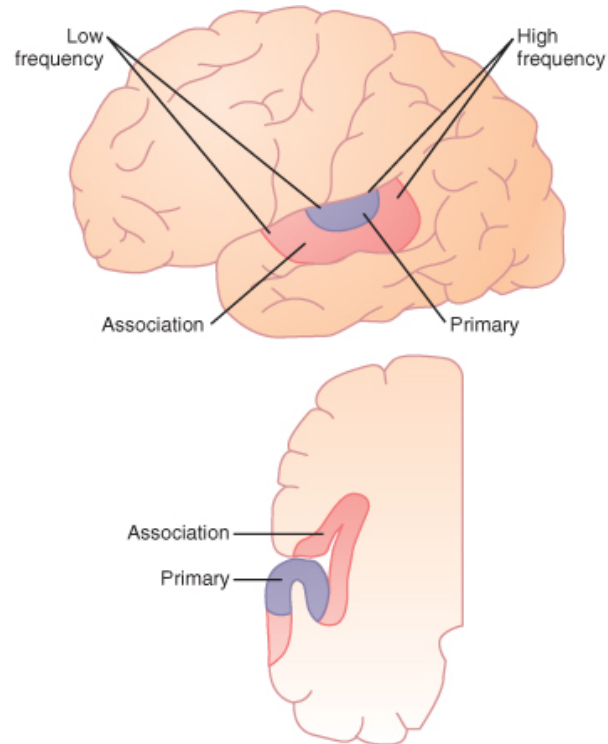
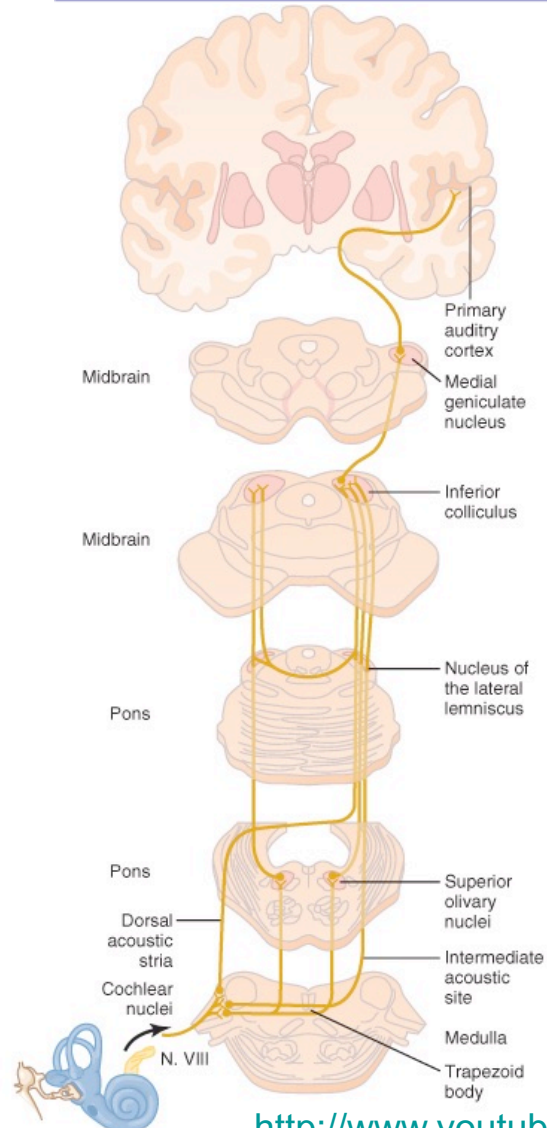
# Cochlear Function

Sound stimulus



Hearing

# Auditory Pathway



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## AUDITORY CORTEX

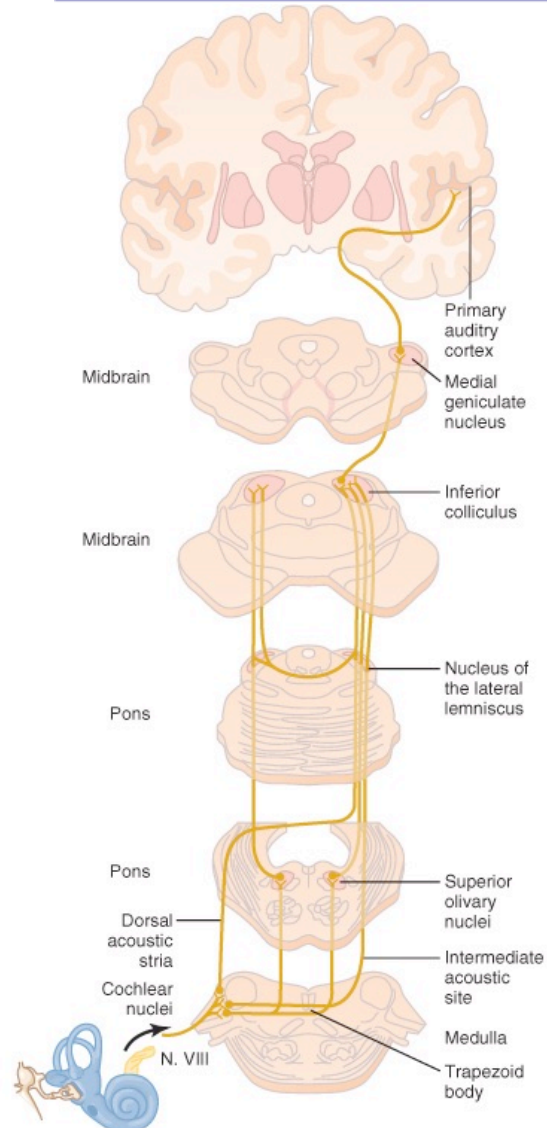
Primary: topographic register

Secondary: auditory association

Basic sounds with no interpretation

<http://www.youtube.com/watch?v=S2r5BT4LQ20&feature=related>

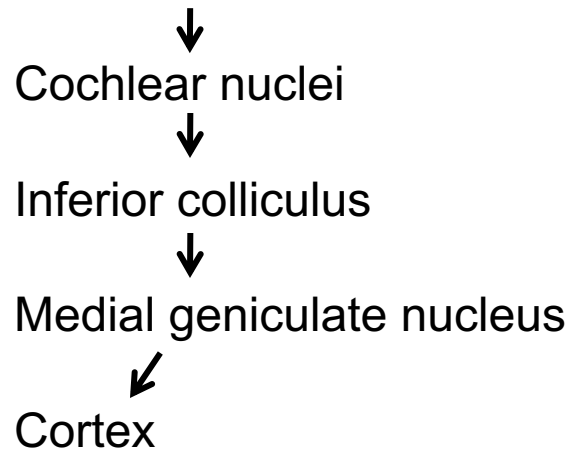
# Auditory Pathway



**SUPERIOR OLIVARY COMPLEX:**  
Sound localization, time it takes to arrive,  
intensity of sound

In the auditory cortex there are suppression  
and summation columns

Analysis of frequency come from:  
Tonotopic maps located in the cochlea







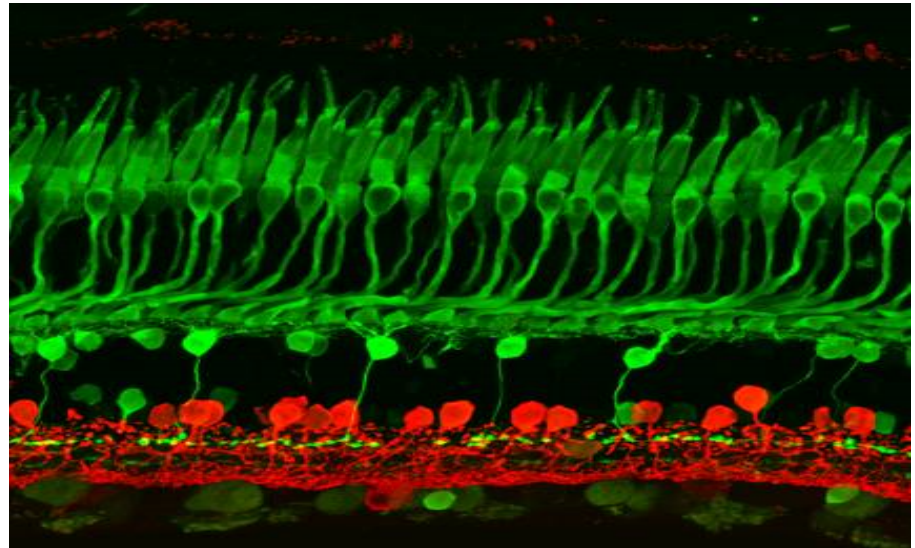
# VISION PHYSIOLOGY



MD Consuelo Borrás

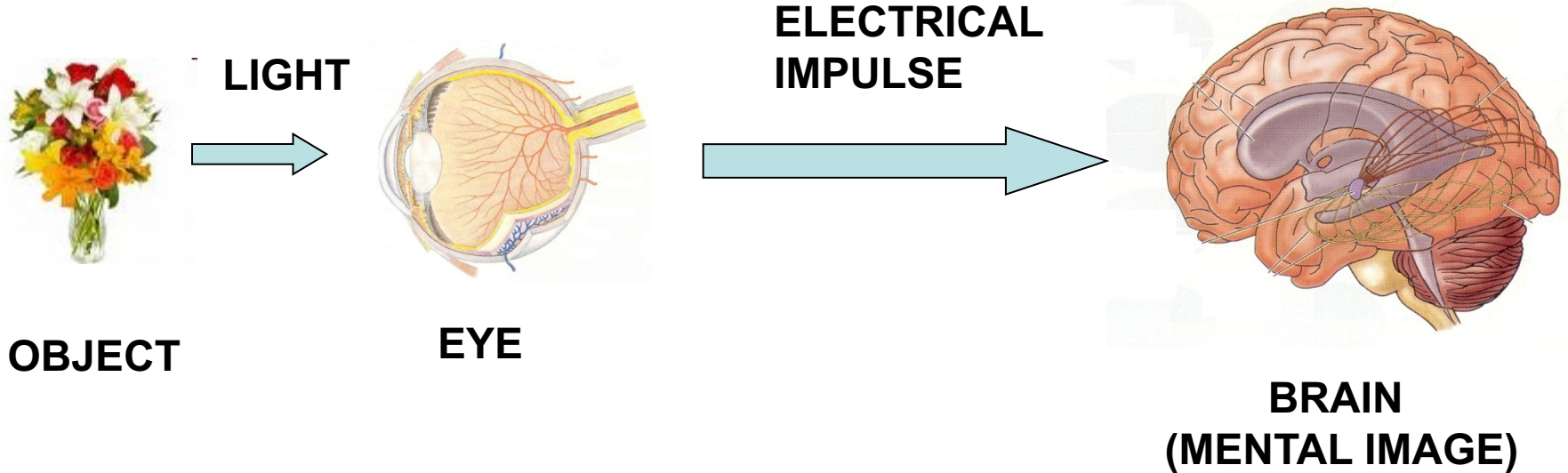
# Outline

- Introduction
- Structure of the eye
  - Outer layer
  - Medial layer
  - Inner layer
- Retina
  - Structure
  - Photochemistry
- Vision pathways

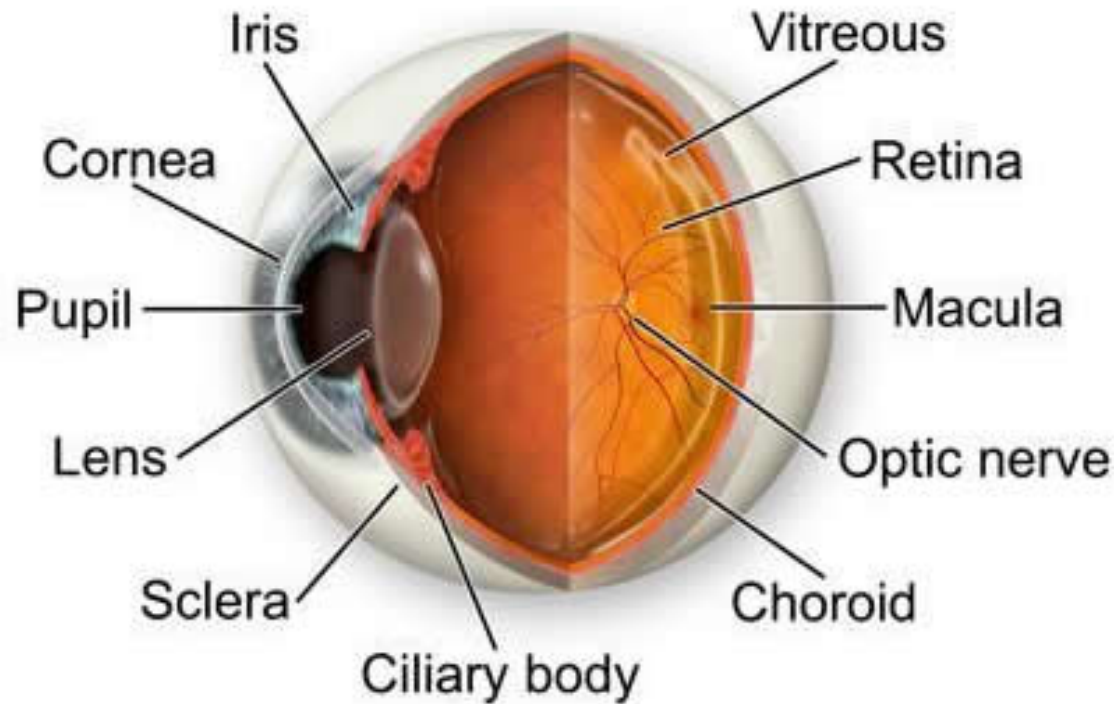


# COMPONENTS OF THE VISUAL PHENOMENON

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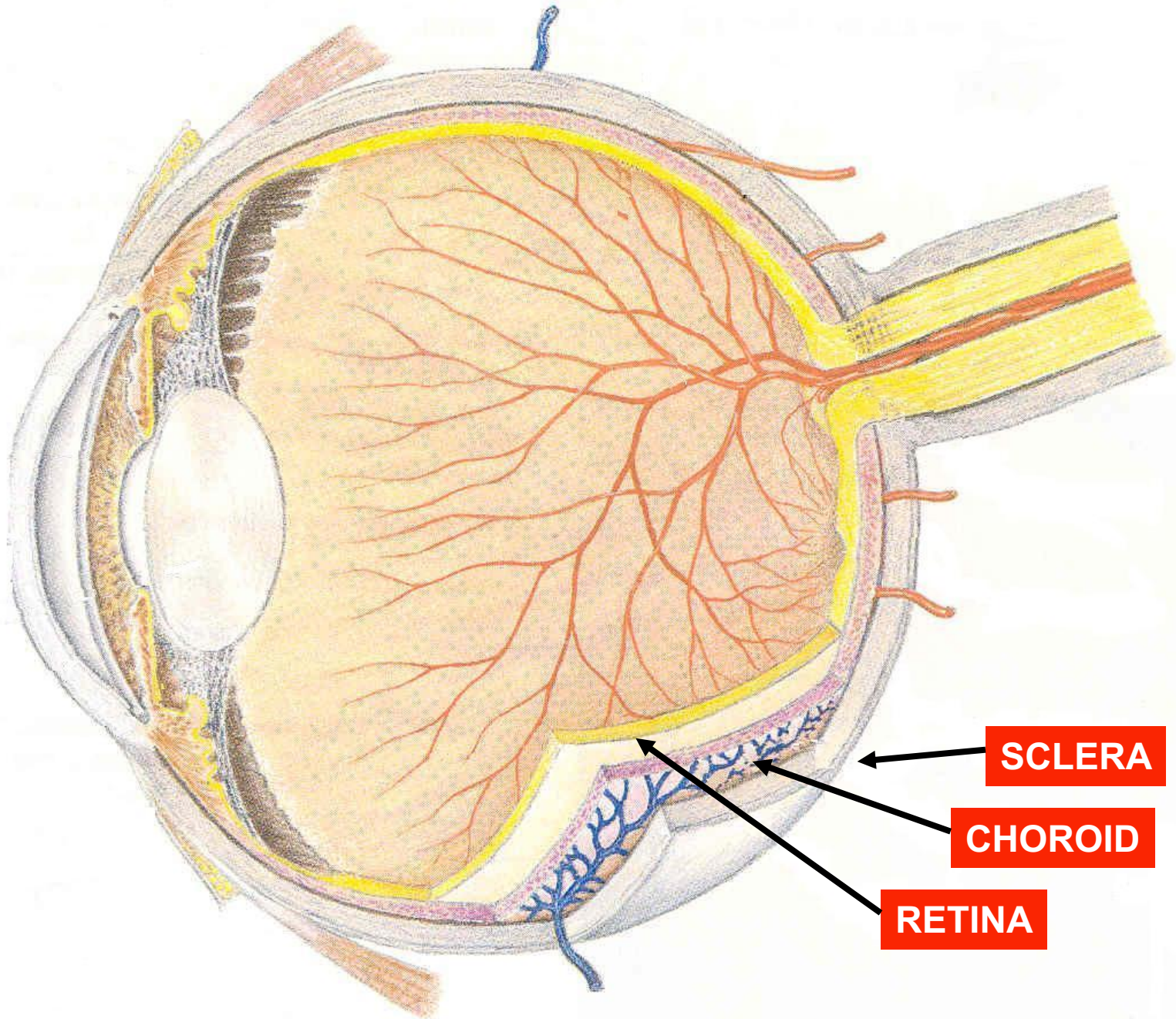
# Structure of the eye



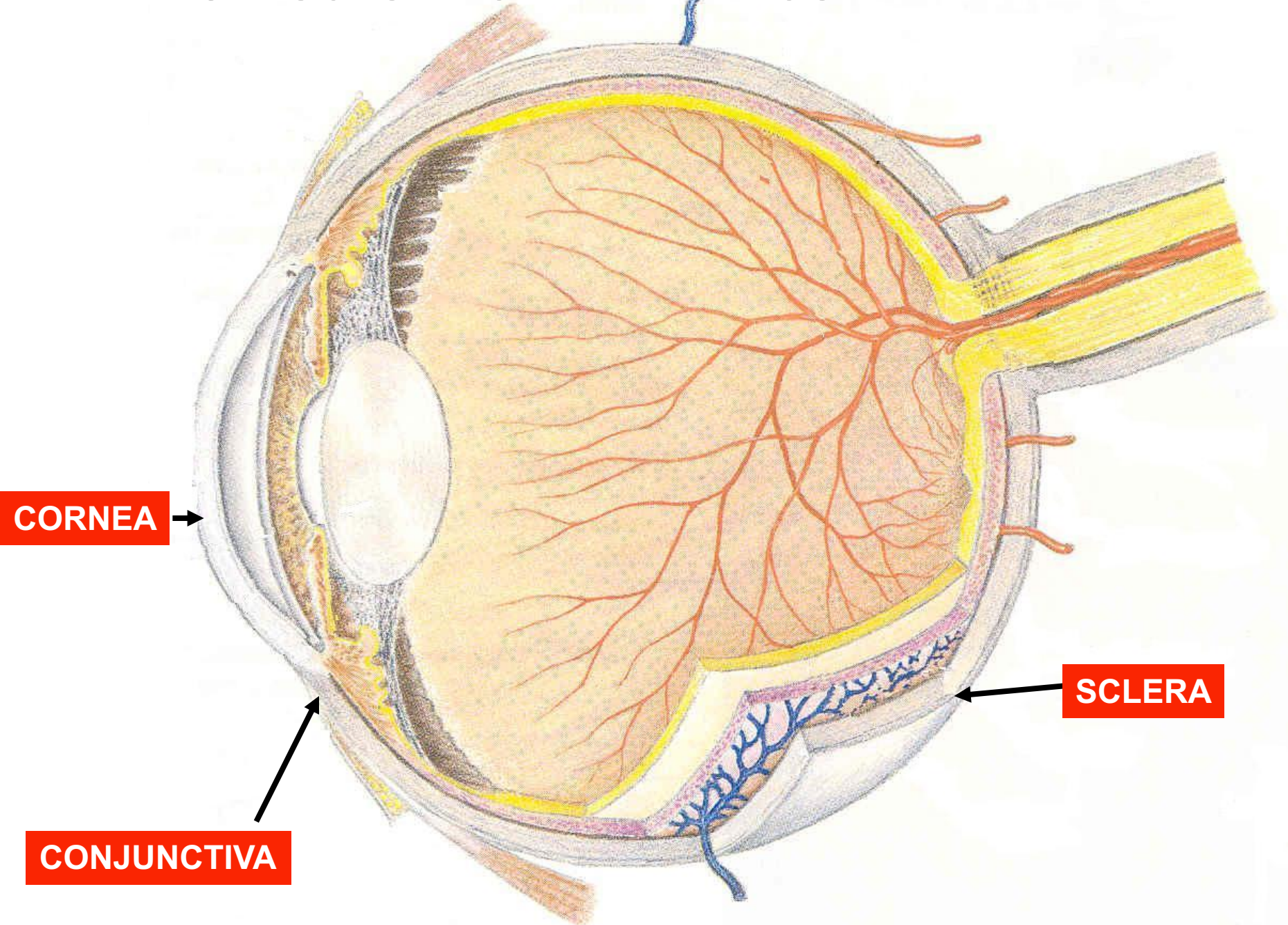
Function:

1. To create sharp images
  2. To generate vision from a small amount of energy
- The photon has a small amount of energy

# STRUCTURE OF THE EYE



# STRUCTURE OF THE EYE: OUTER LAYER

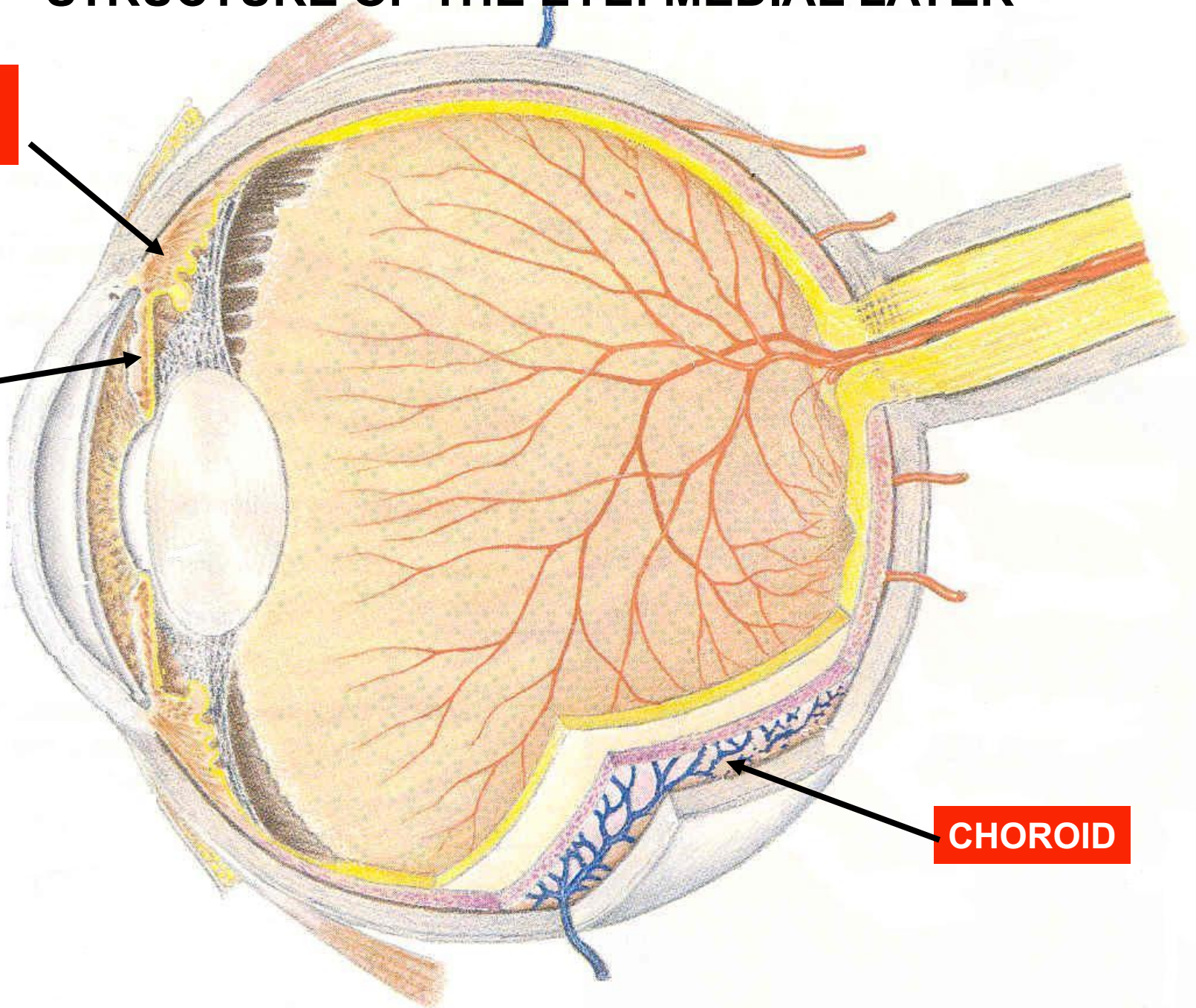


# STRUCTURE OF THE EYE: MEDIAL LAYER

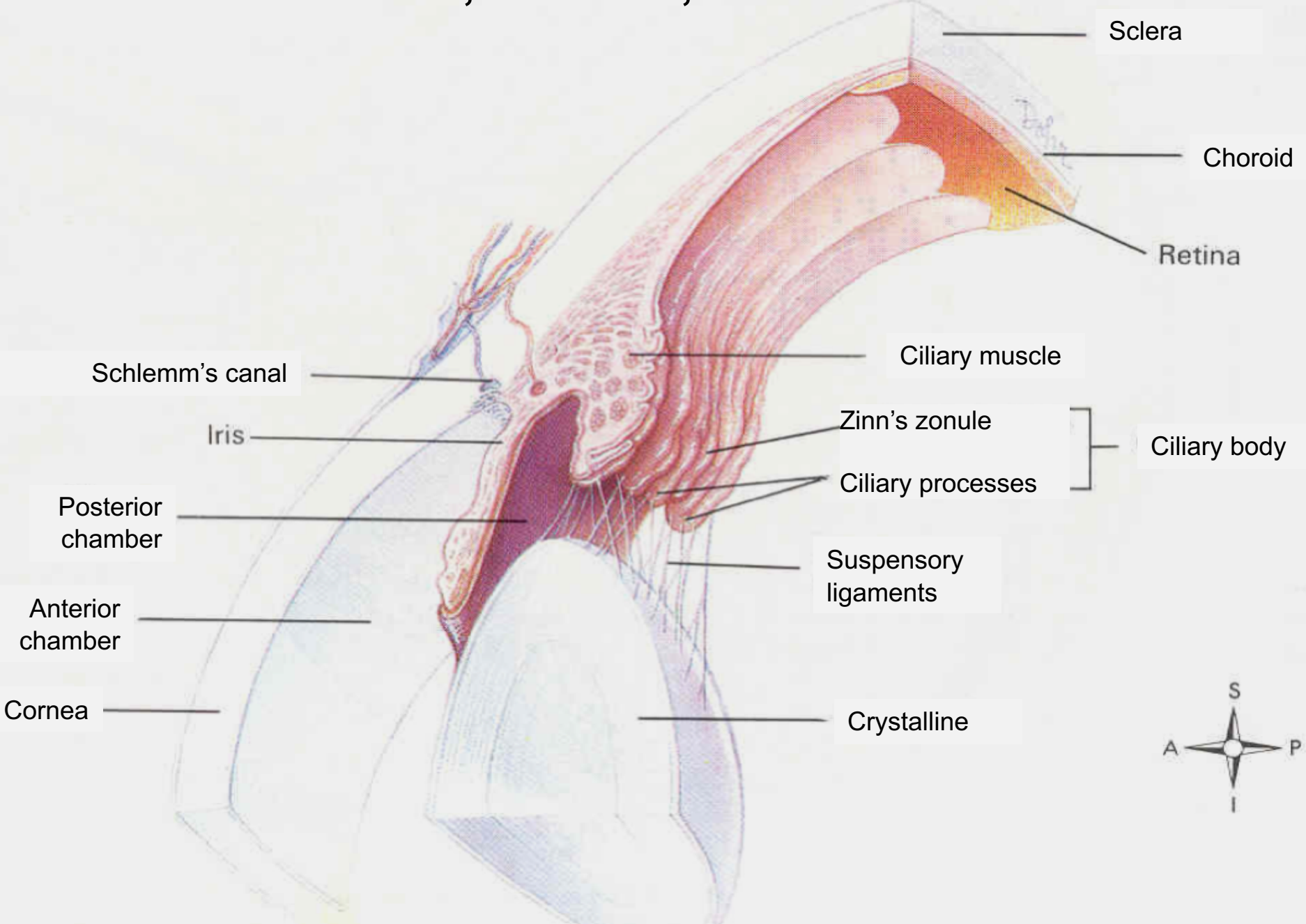
**CILIARY  
BODY**

**IRIS**

**CHOROID**



# CRYSTALLINE, CORNEA, IRIS AND CILIARY BODY

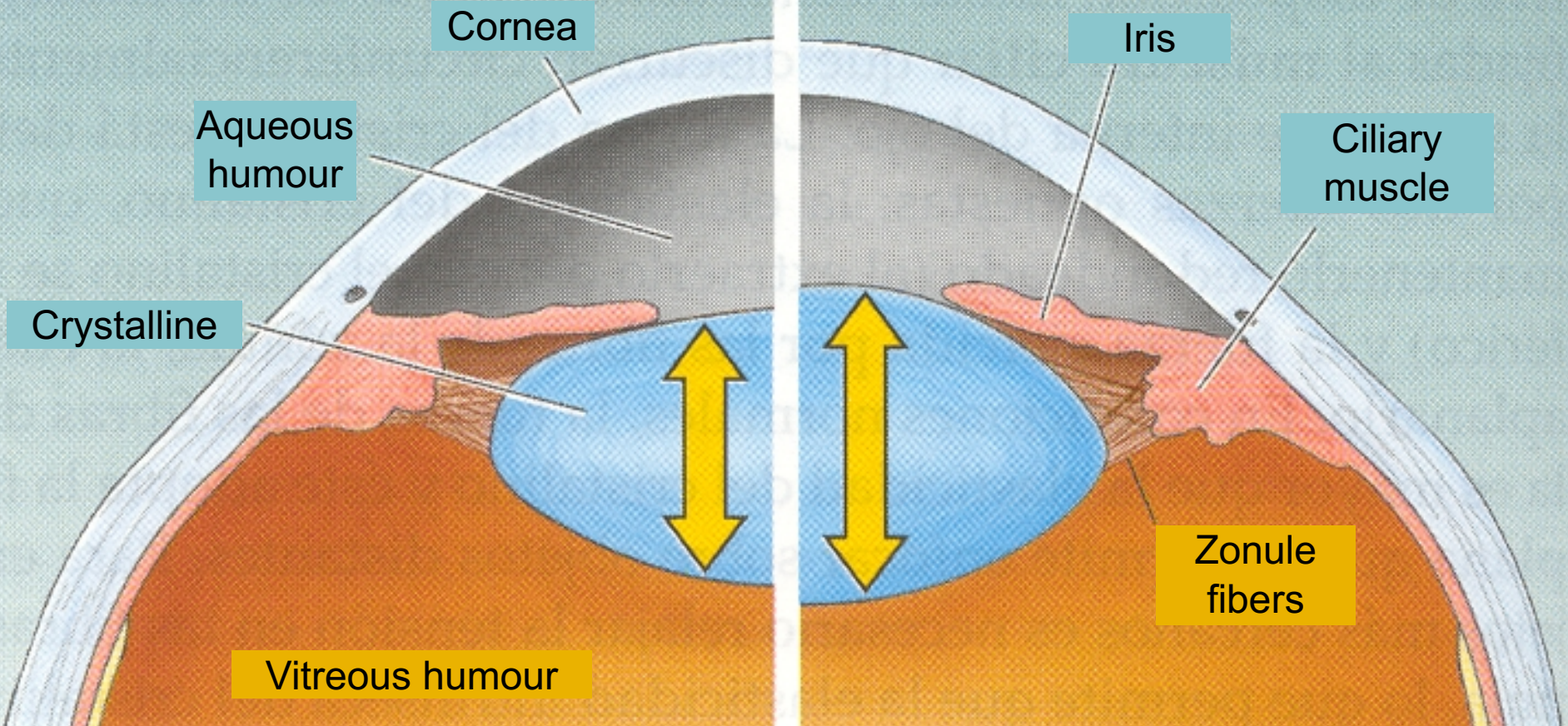




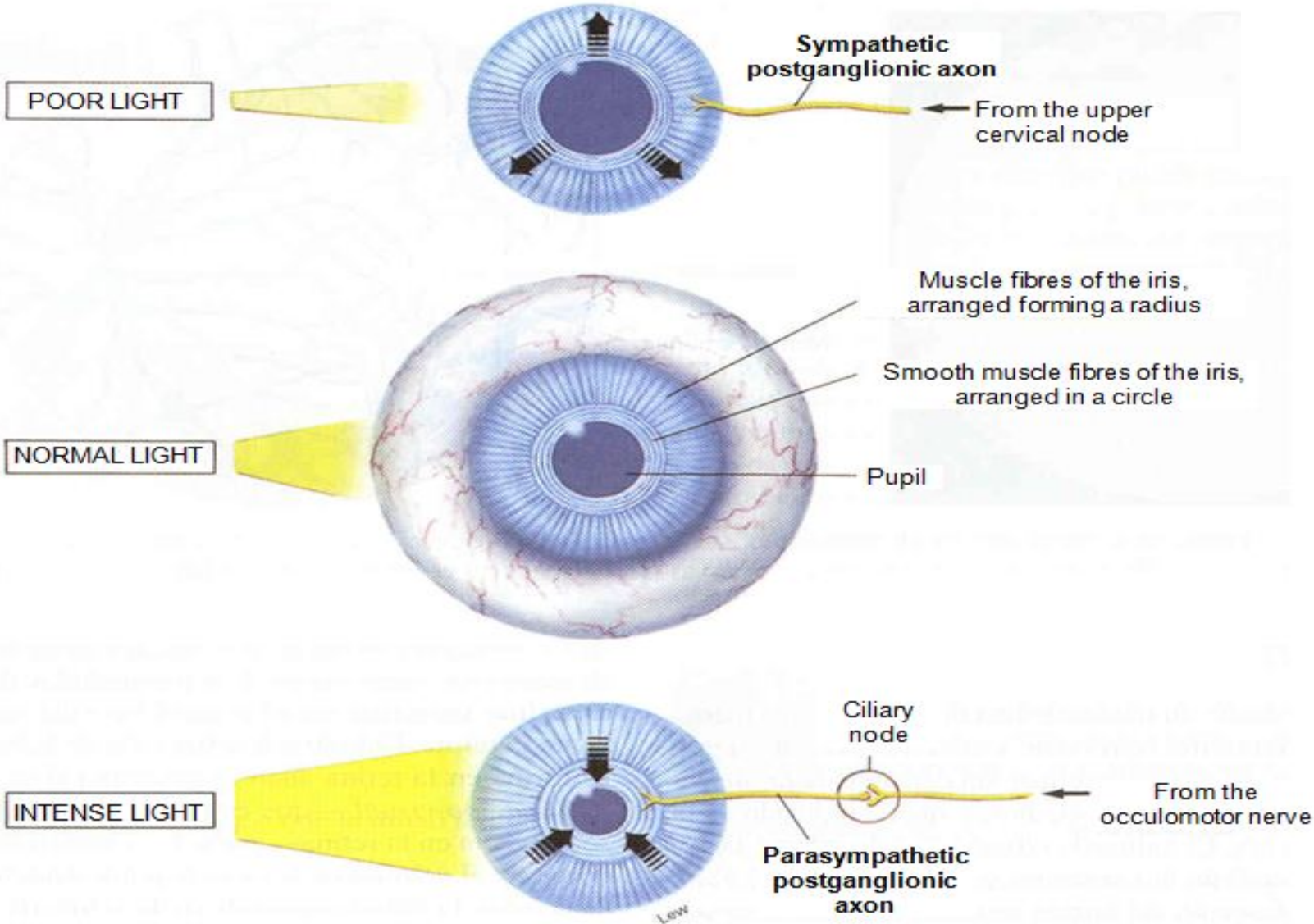
# ACCOMMODATION OF THE CRYSTALLINE

Without accommodation

With accommodation

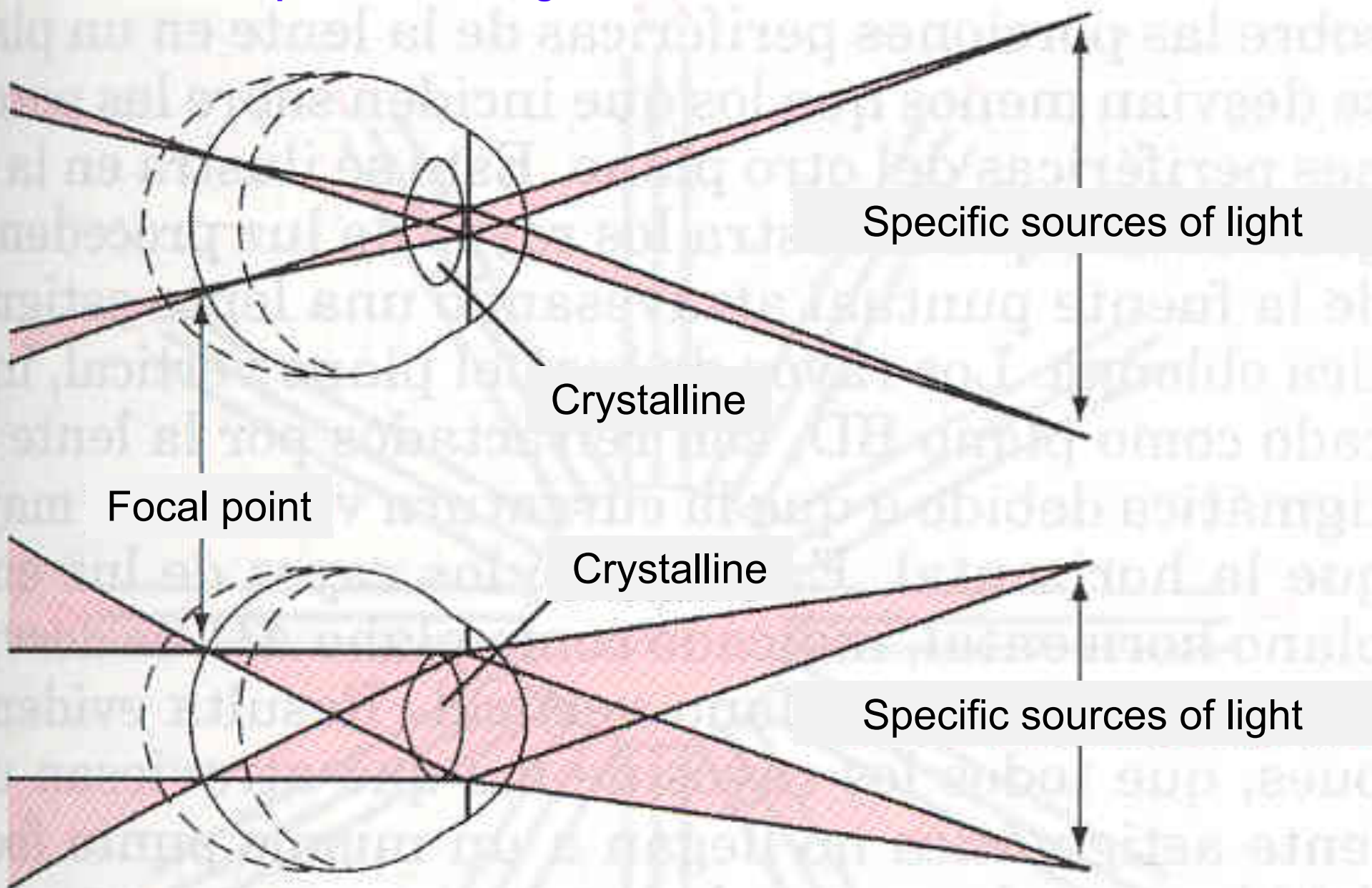


# IRIS: PUPILLARY OPENING CONTROL

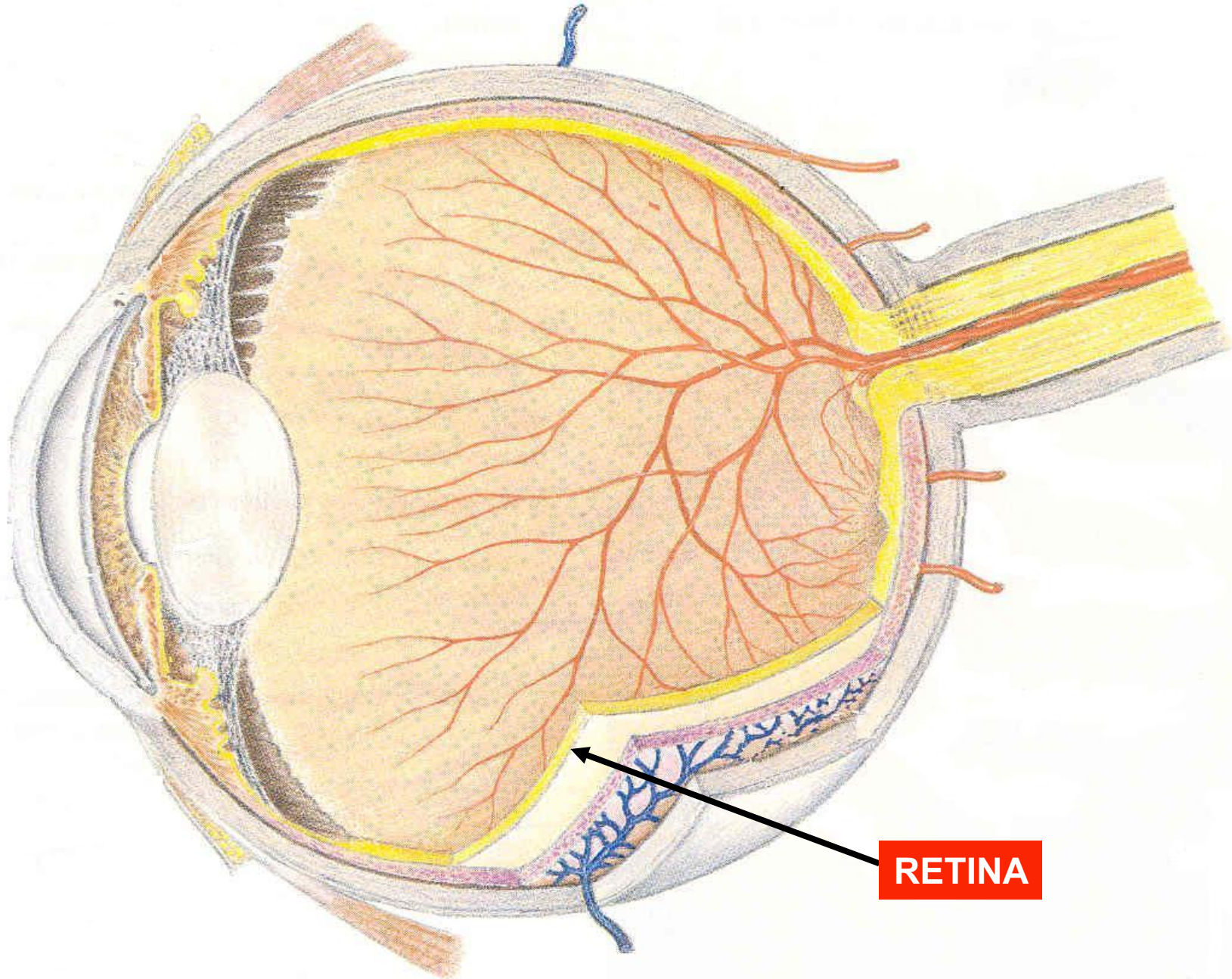


# DEPTH OF THE FOCUS

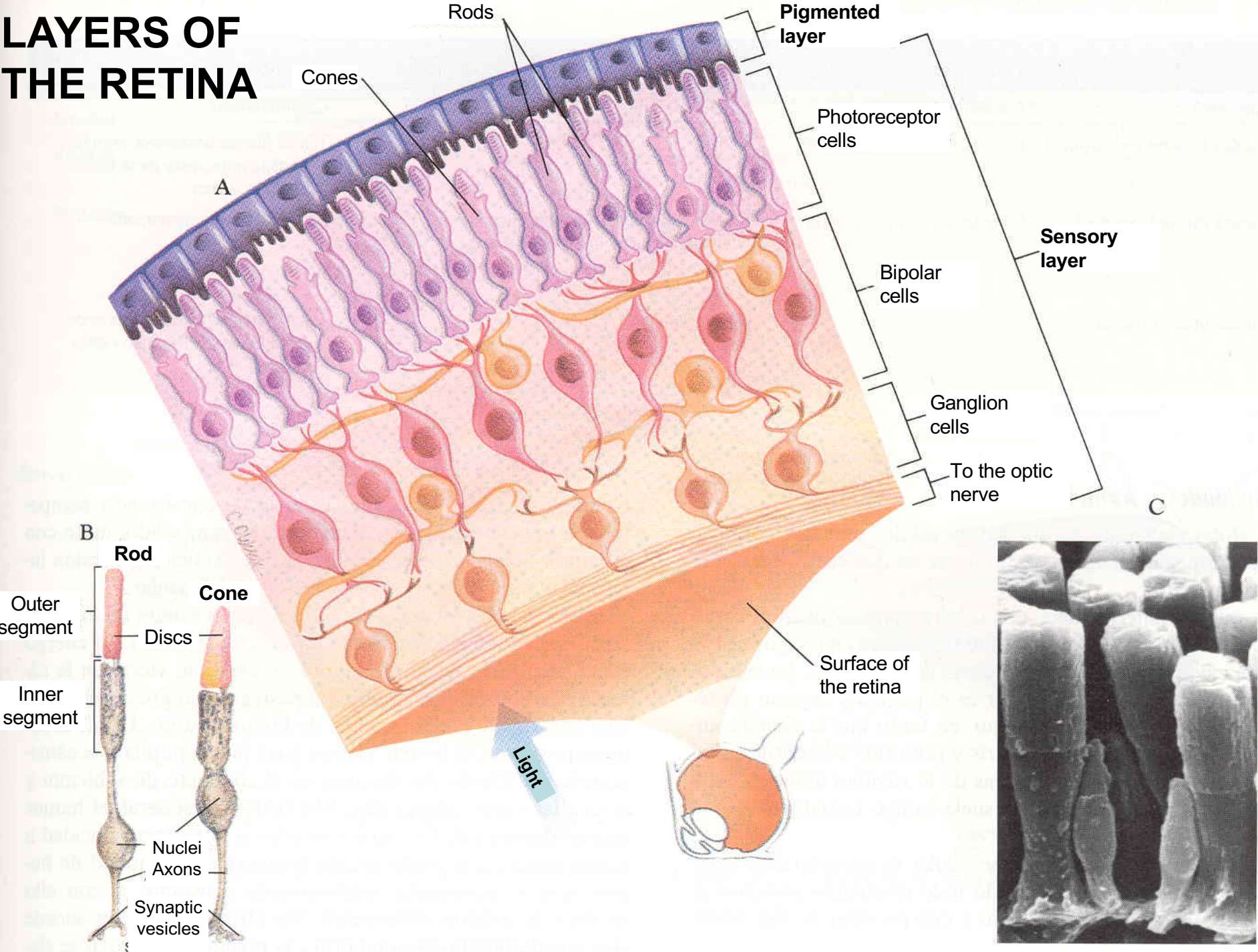
Sharpness of an image, even if it is not focused on the retina



# STRUCTURE OF THE EYE: INNER LAYER

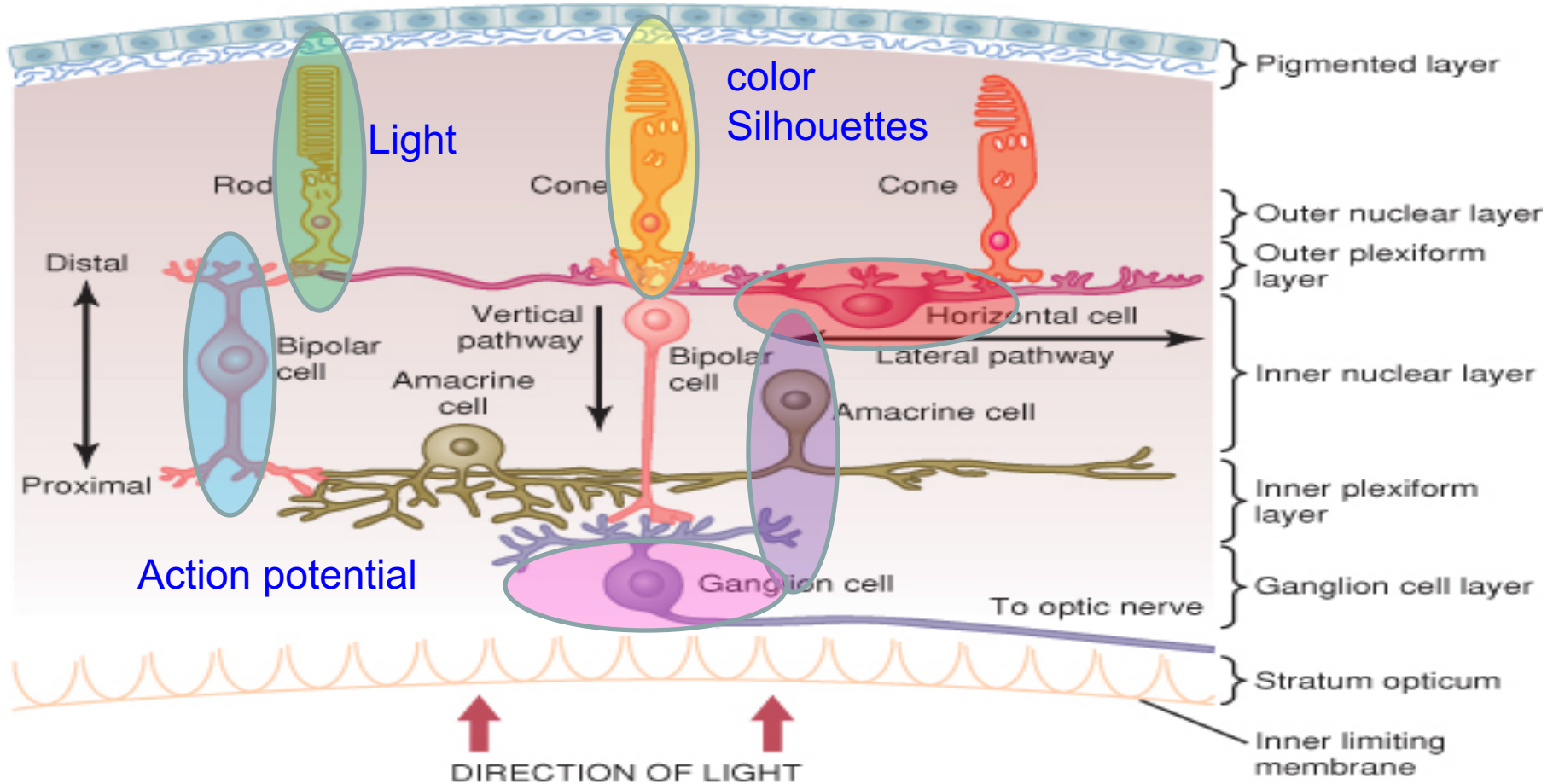


# LAYERS OF THE RETINA

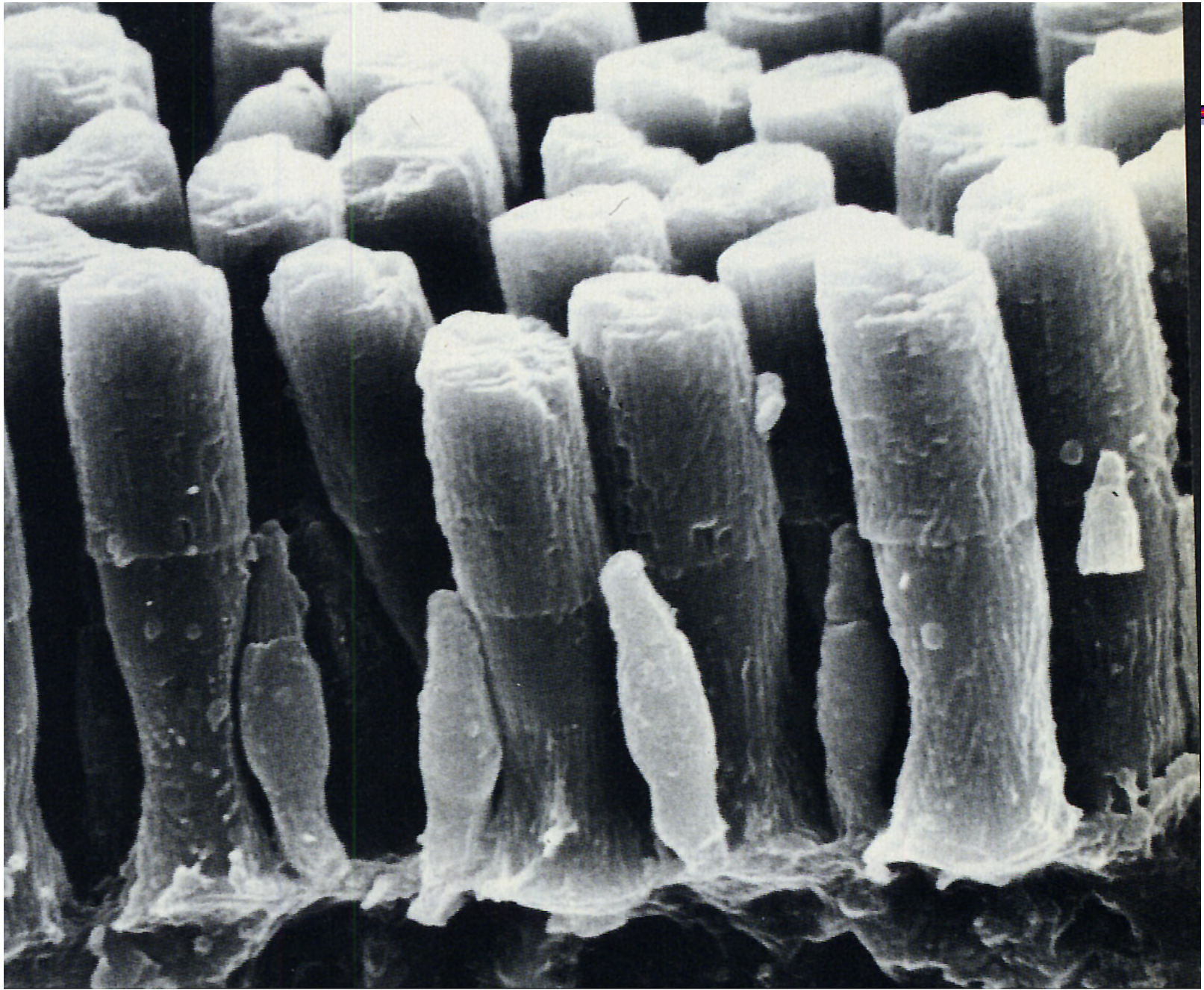


# Retina

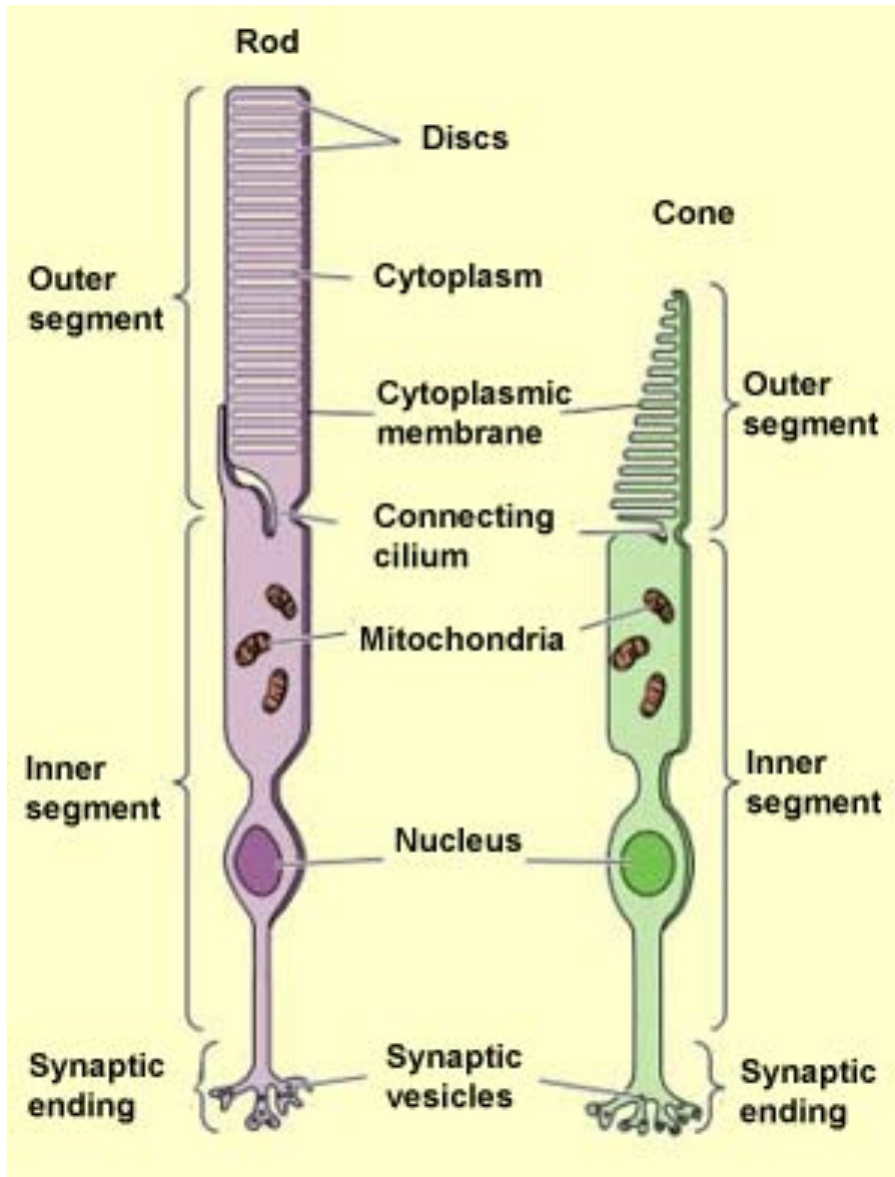
- Part of the eye sensitive to light
- Pigmented epithelium (black): absorbs the light



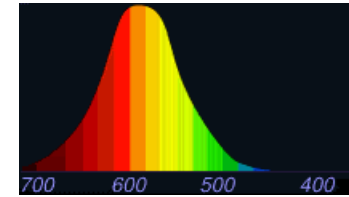
# PHOTORECEPTORS



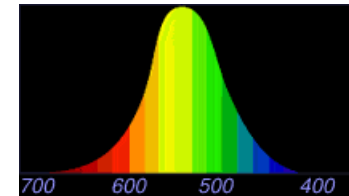
# PHOTORECEPTORS



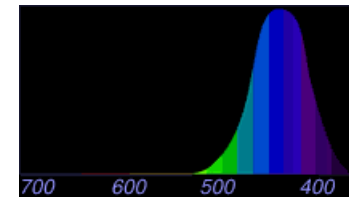
## Color vision



red



green

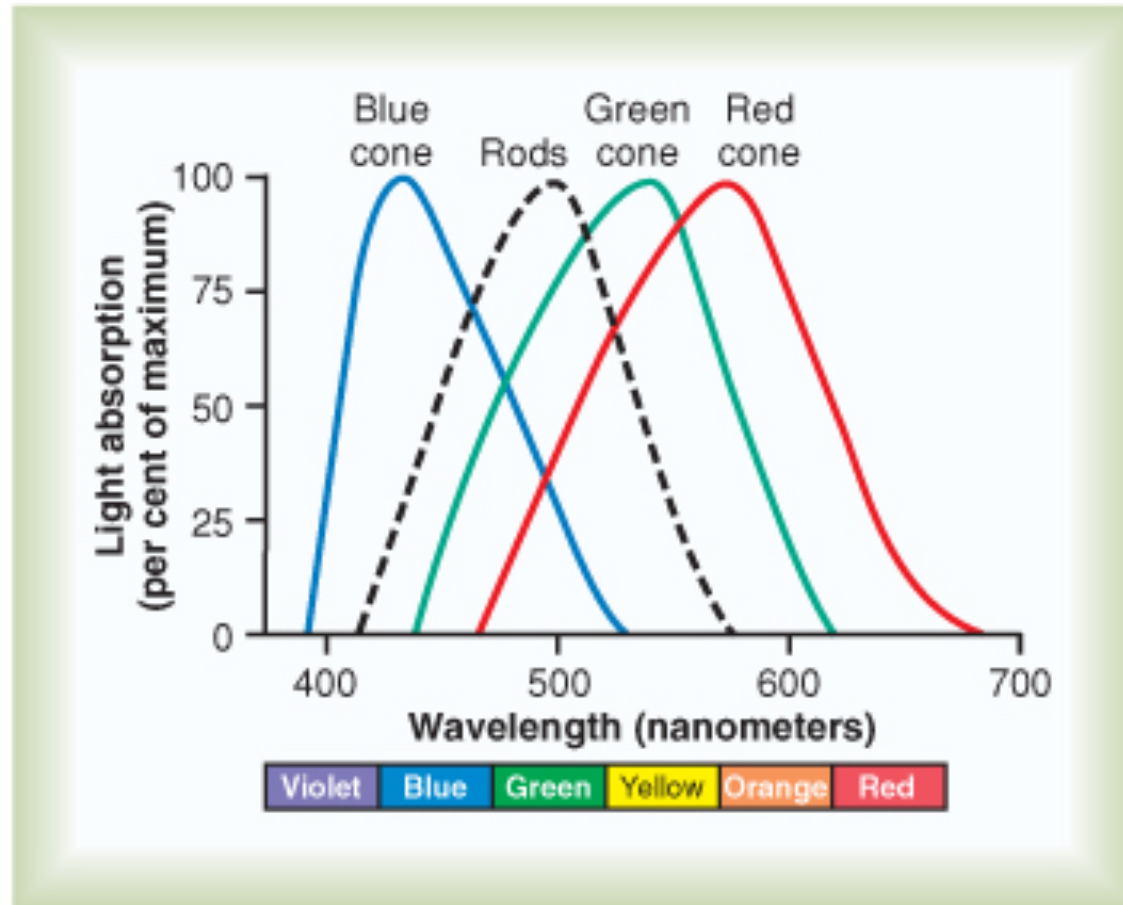


blue

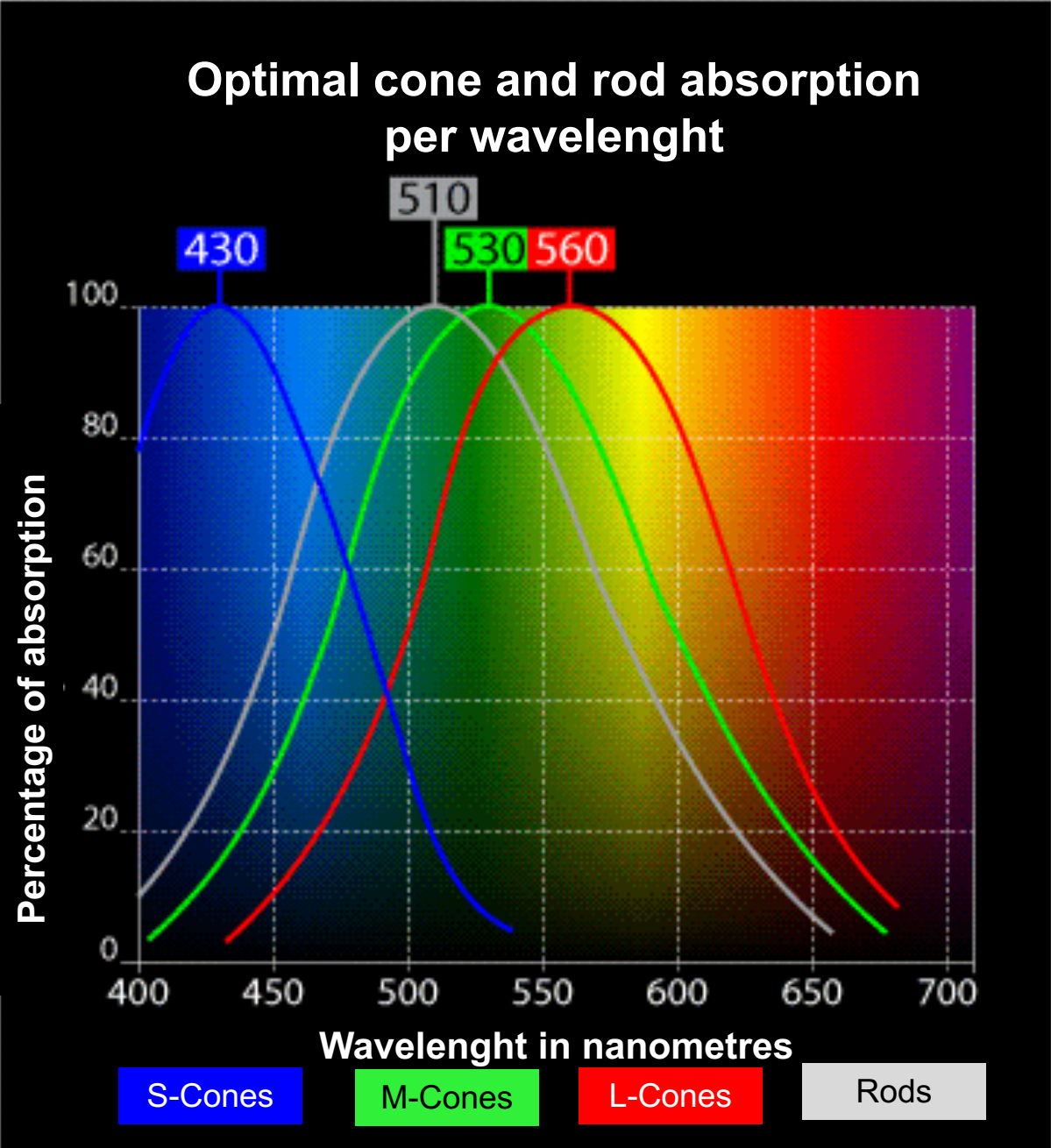
**Black and white vision. Grey tones. Shades and forms.**



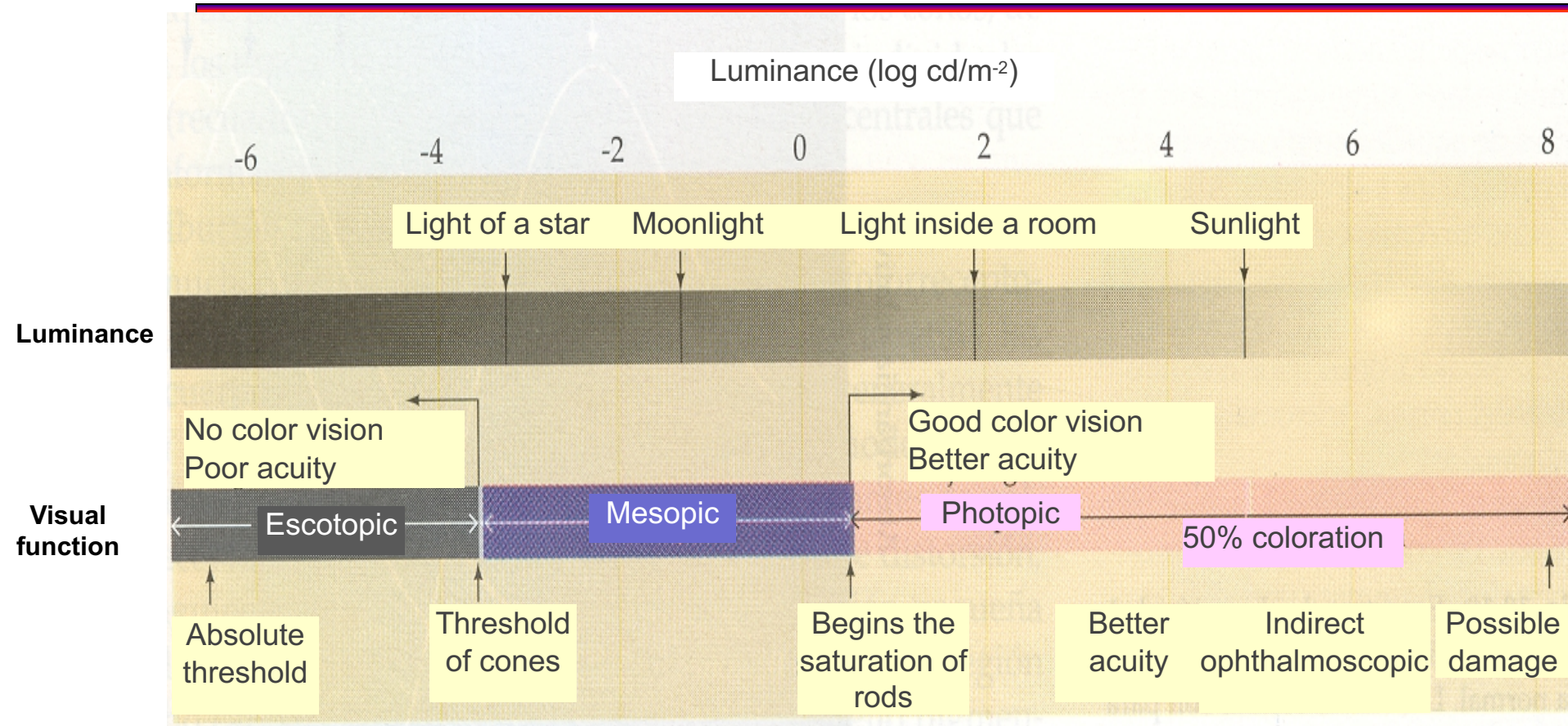
# Cones



# SPECTRUM OF ABSORPTION OF THE PHOTOPIGMENTS

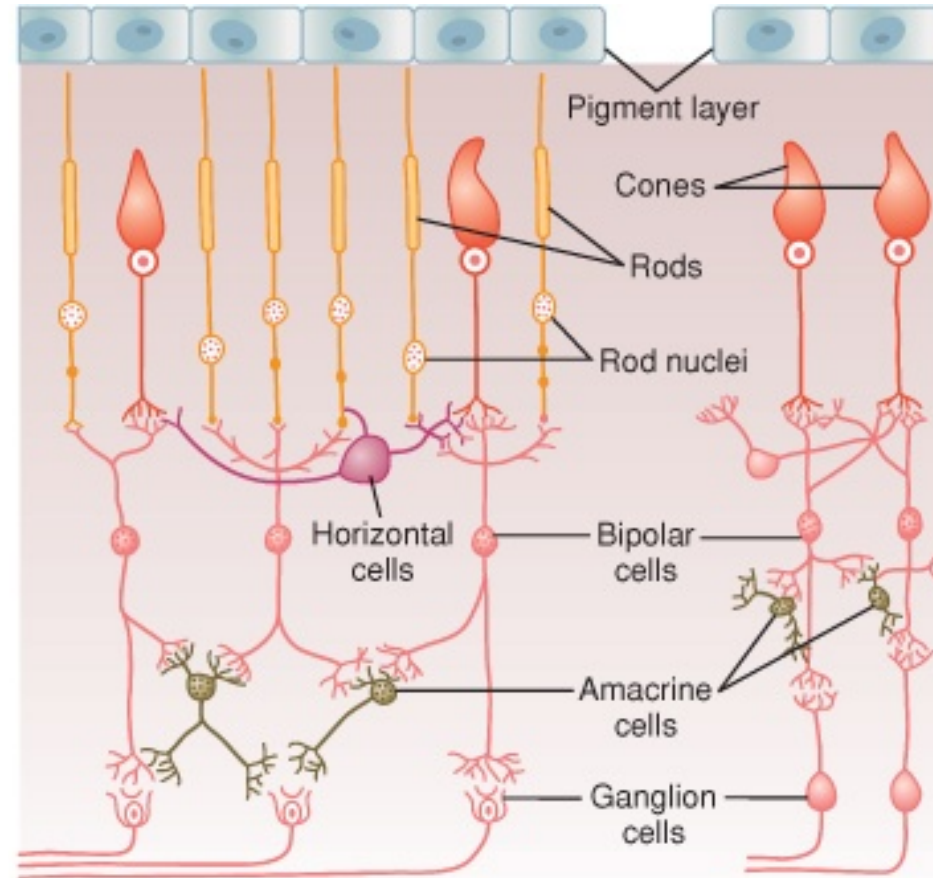
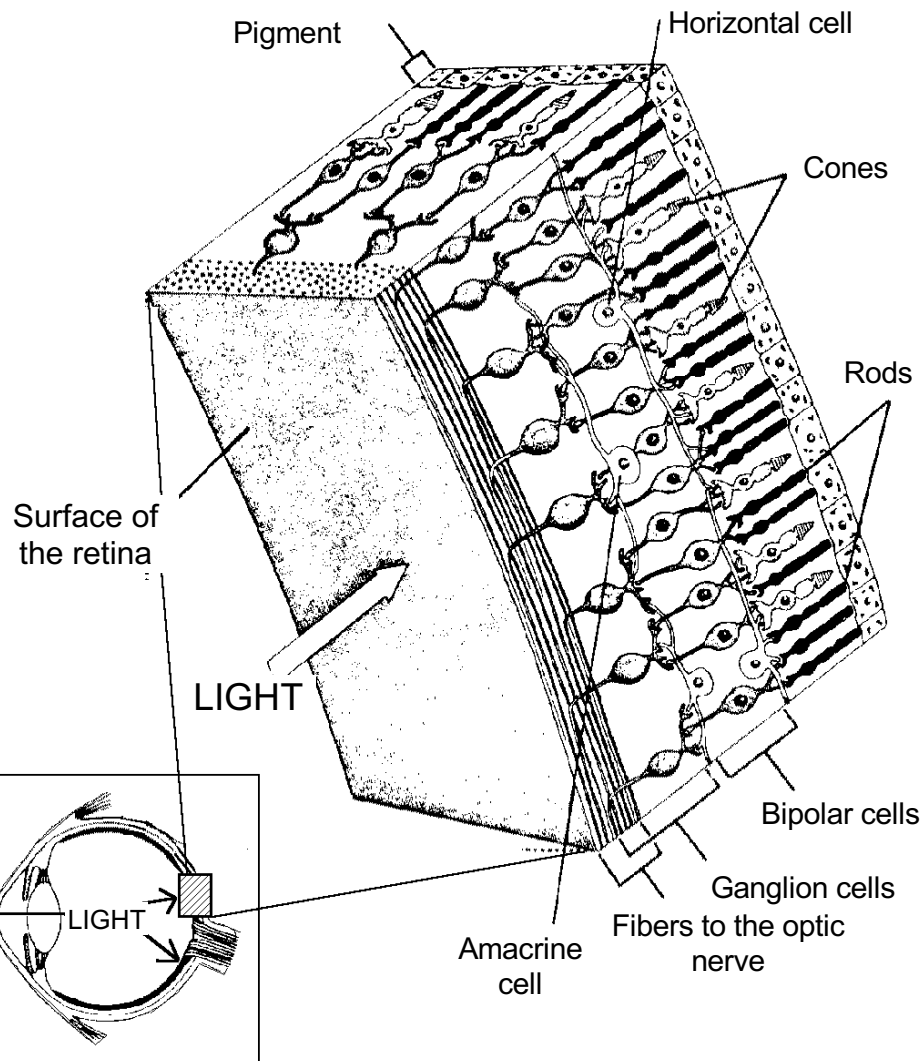


# LUMINANCE FOR THE VISUAL SYSTEM

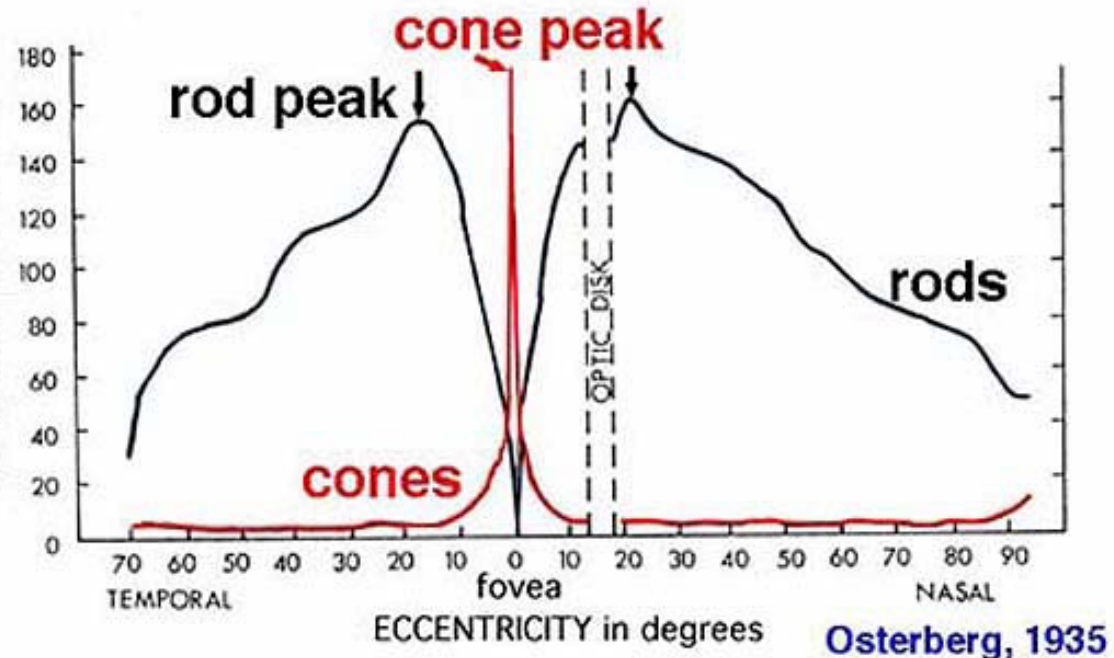
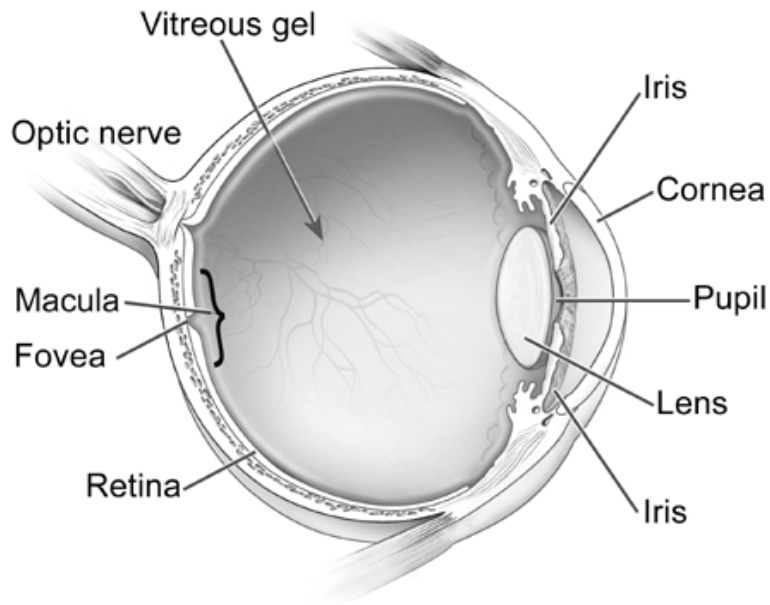


**Luminance:** Amount of light that reaches the eye, and which is therefore the light we see

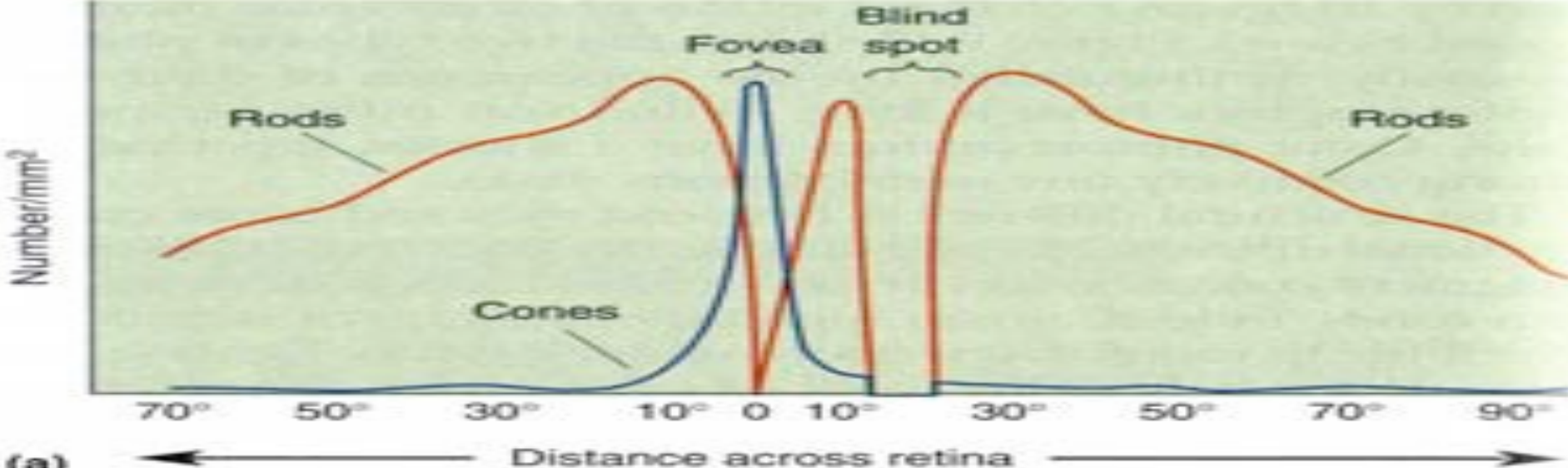
# Retina. Electric Activity



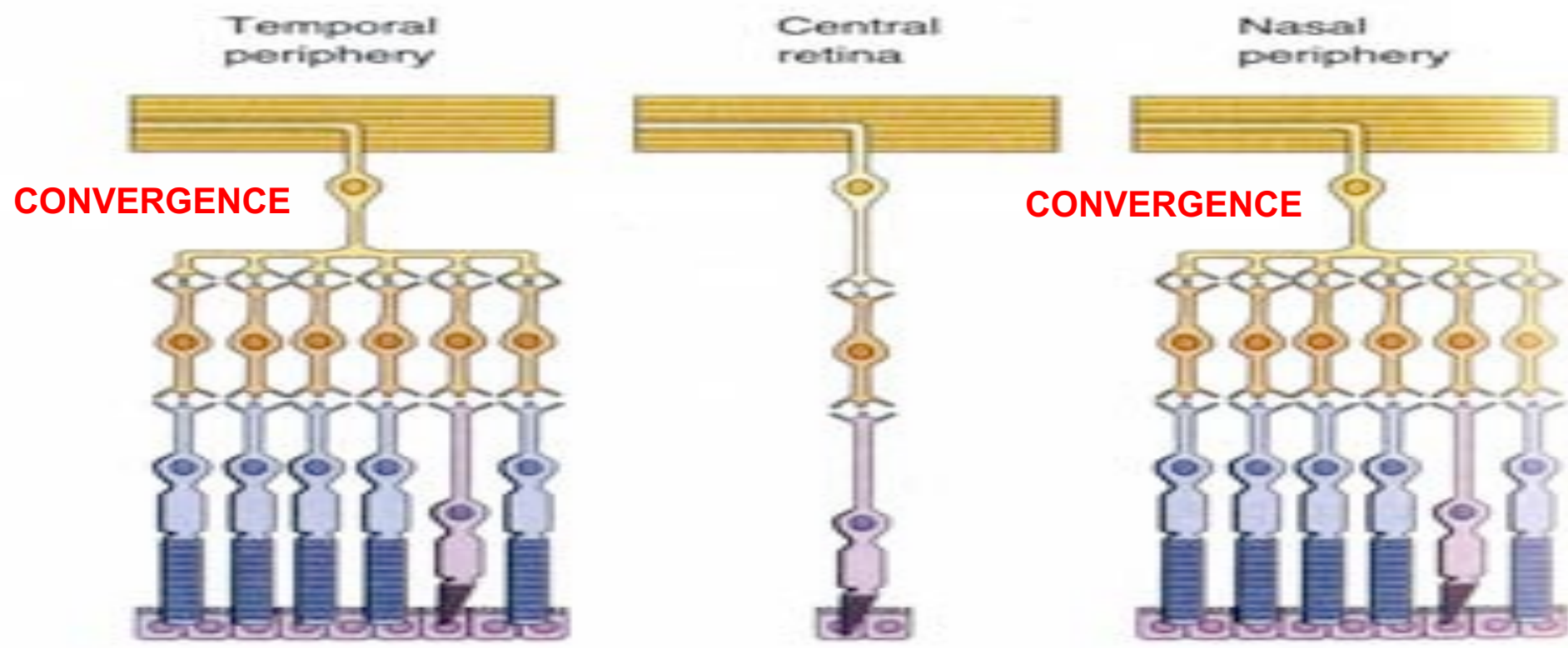
# Retina. Electric activity



**The fovea is the point of the highest visual intensity, where the highest amount of cones is found.**  
**The rods are more numerous around the fovea.**  
**Cones and rods use glutamate as neurotransmitter.**



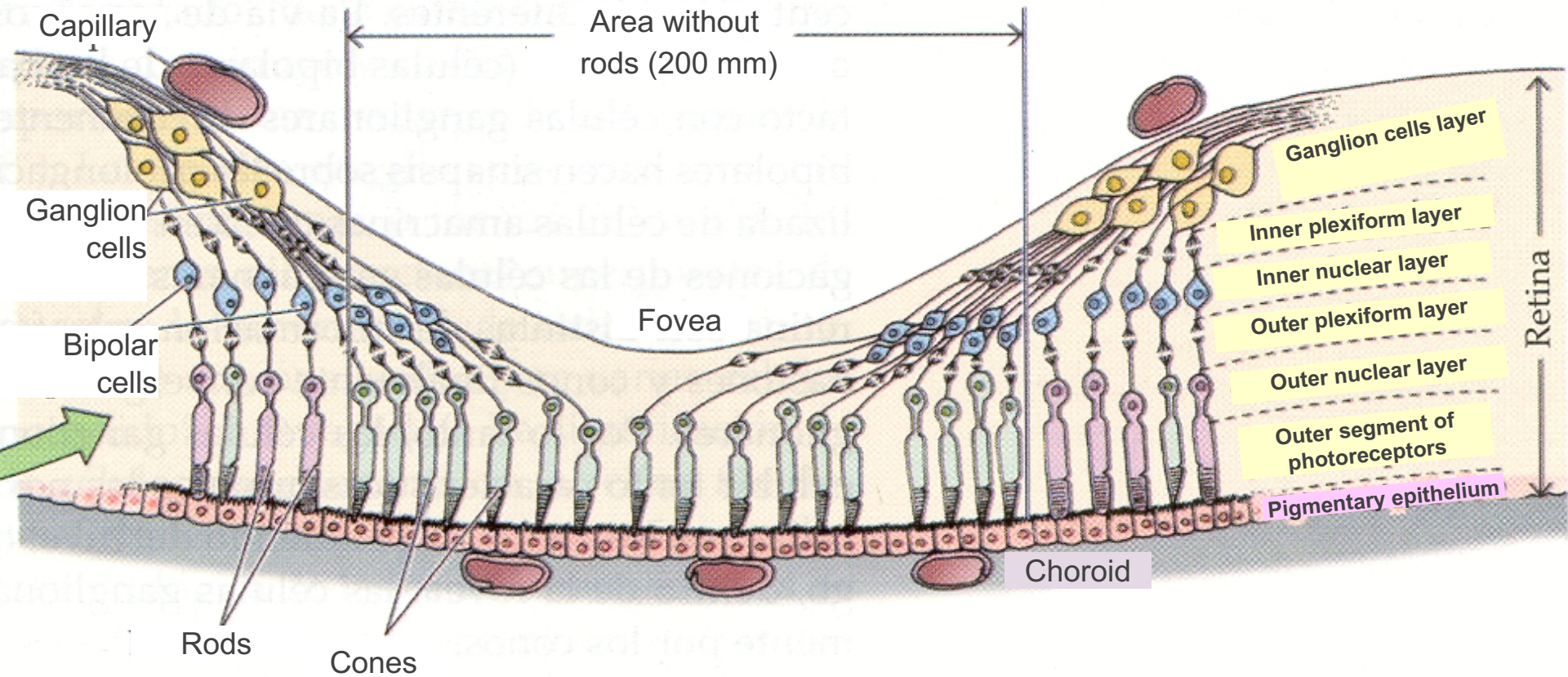
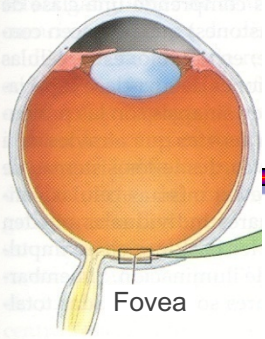
(a)



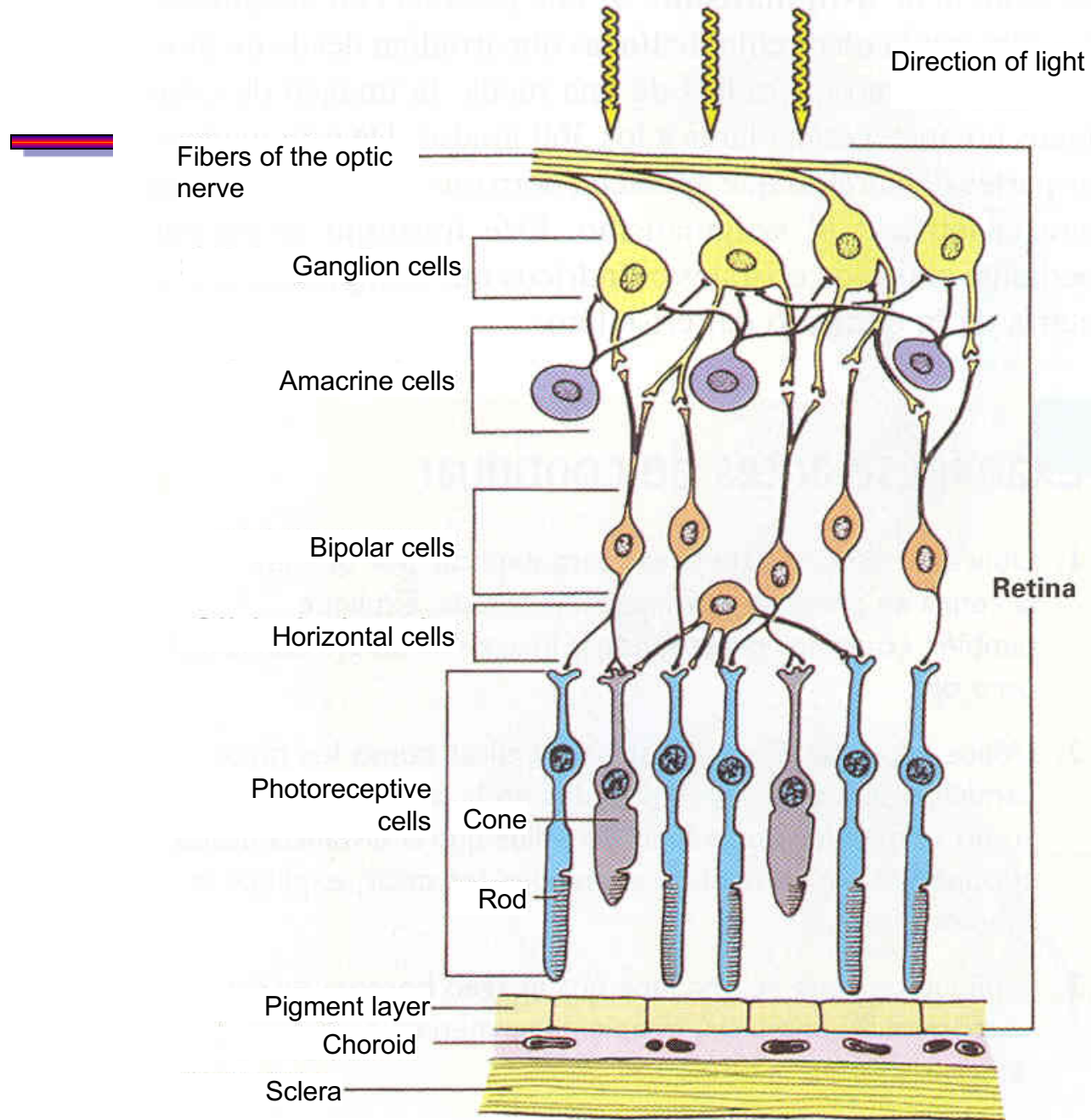
(b)

Peripheral retina      Central retina      Peripheral retina

# DISTRIBUTION OF CONES AND RODS

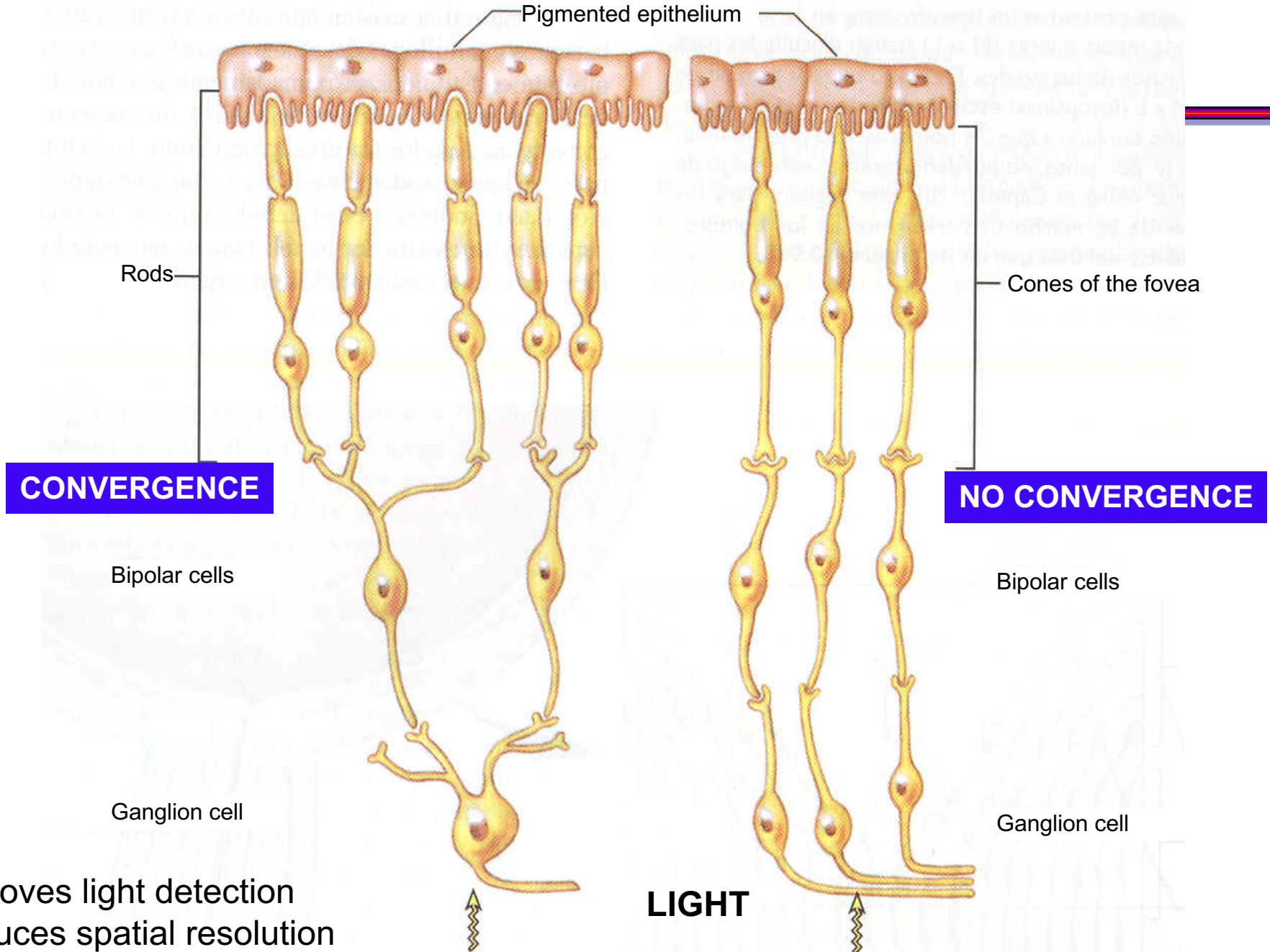


# LAYERS OF THE RETINA

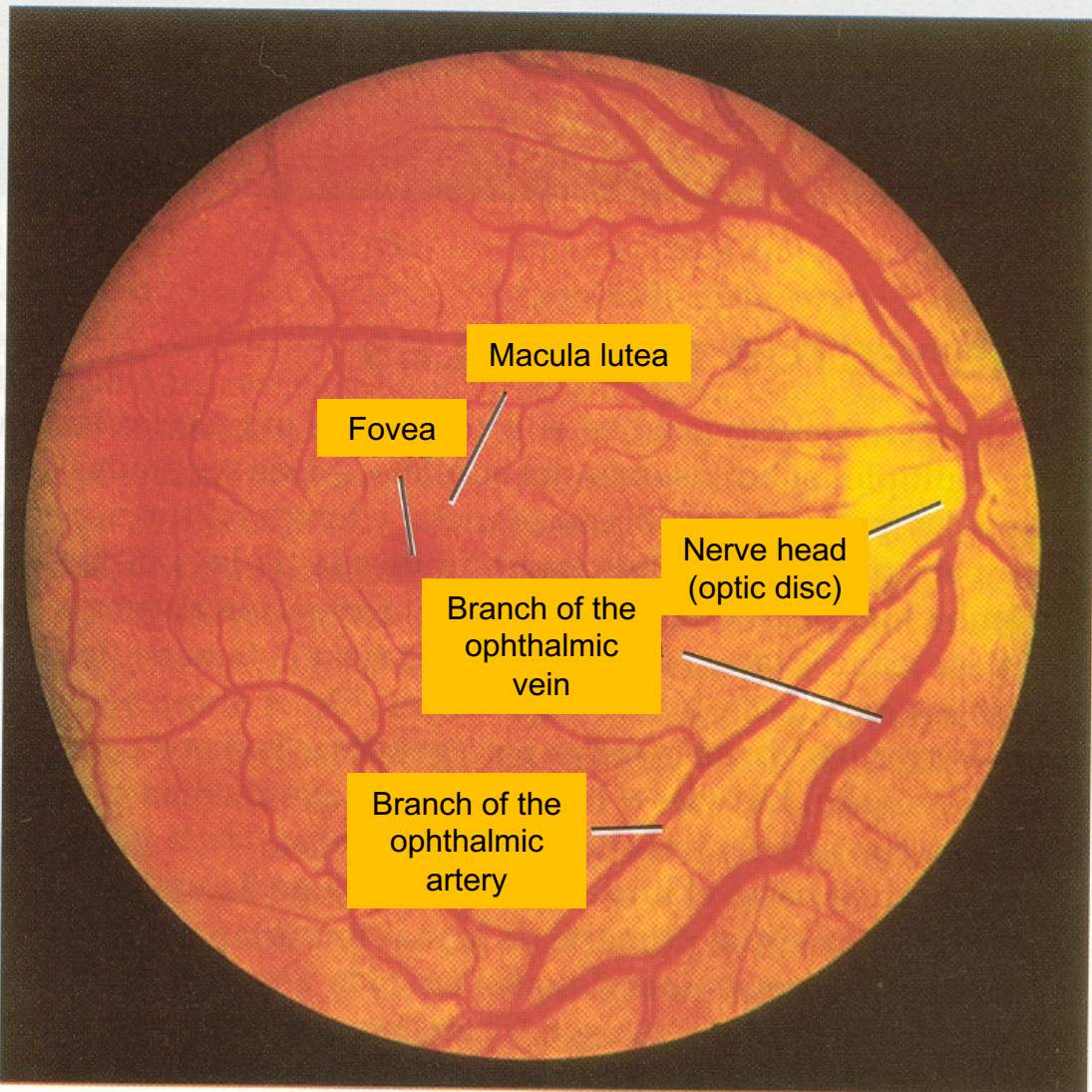




# CONVERGENCE IN THE RETINA



**Figure 11-1.** Retinal surface of the right eye, visualized through an ophthalmoscope. The optic nerve head is the region where the axons of the ganglion cells exit the retina to form the optic nerve; it is also characterized by the respective entrance and exit of arteries and ophthalmic veins that irrigate the retina. The macula lutea can be observed as a pale yellow area in the center of the optic axis (the nerve head is nasally located); the macula is the region where the retina has the highest visual acuity. The fovea is a small depression (around 1,5 mm of diameter) located at the center of the macula.



STRYER, L. (1986) Cyclic GMP cascade of vision. *Annu. Rev. Neurosci.* 9: 87-119.

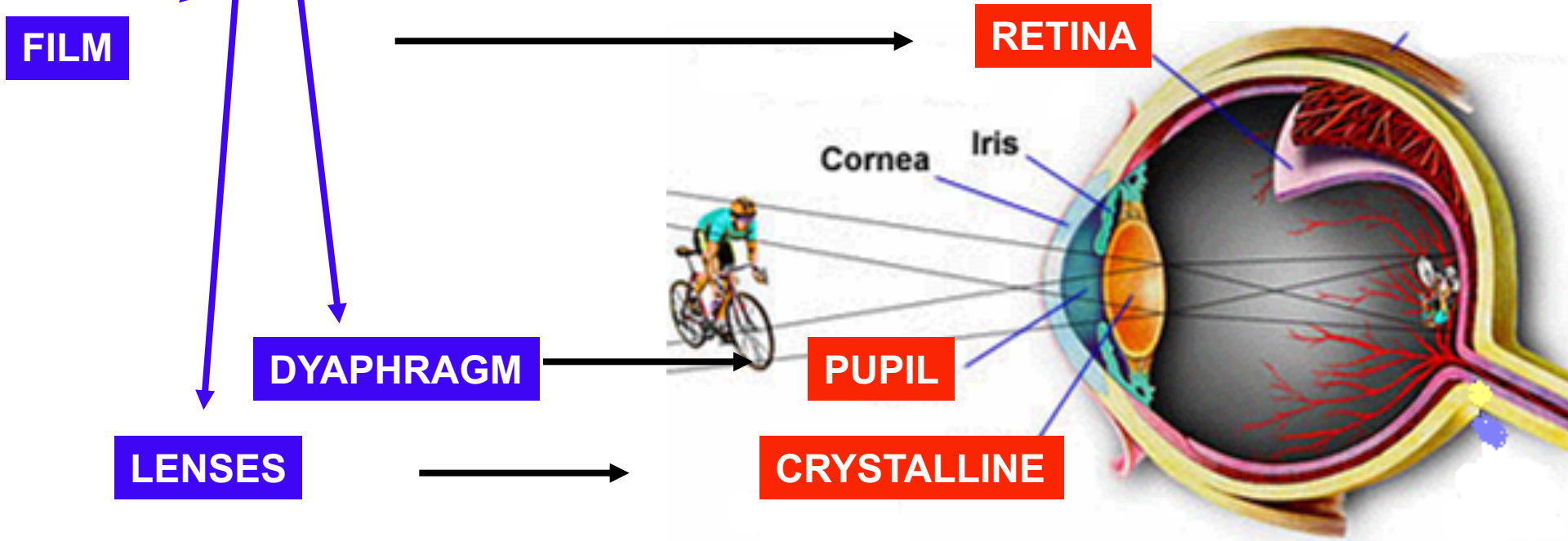
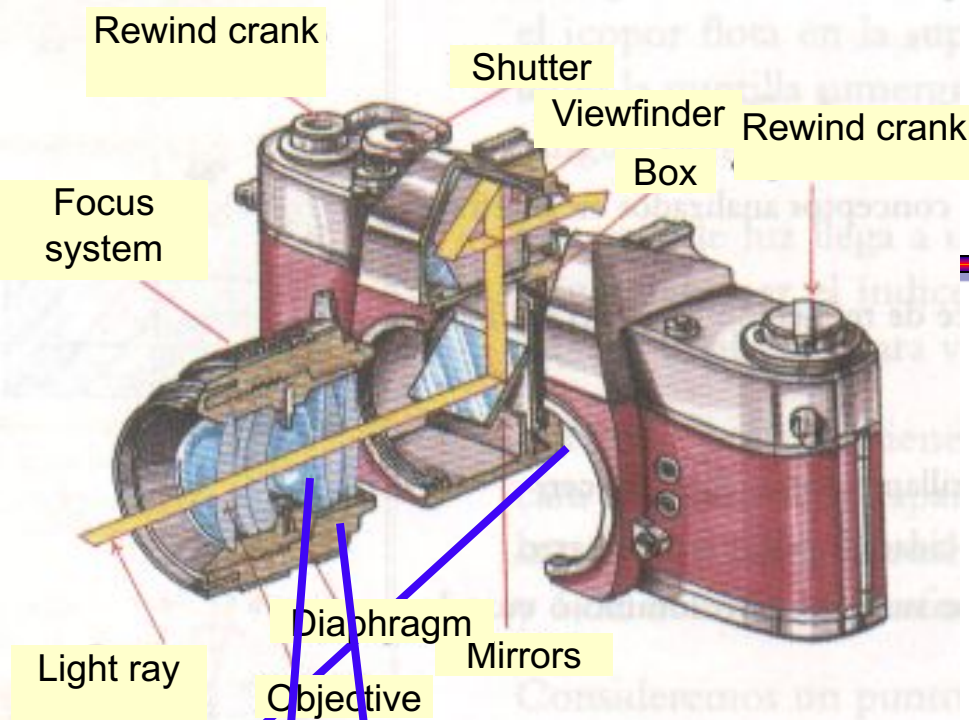
*Articulos originales importantes*

BAYLOR, D. A., M. G. F. FUORTES AND P. M. O'BRYAN (1971) Receptive fields of cones in the retina of the turtle. *J. Physiol. (Lond.)* 214: 265-294.

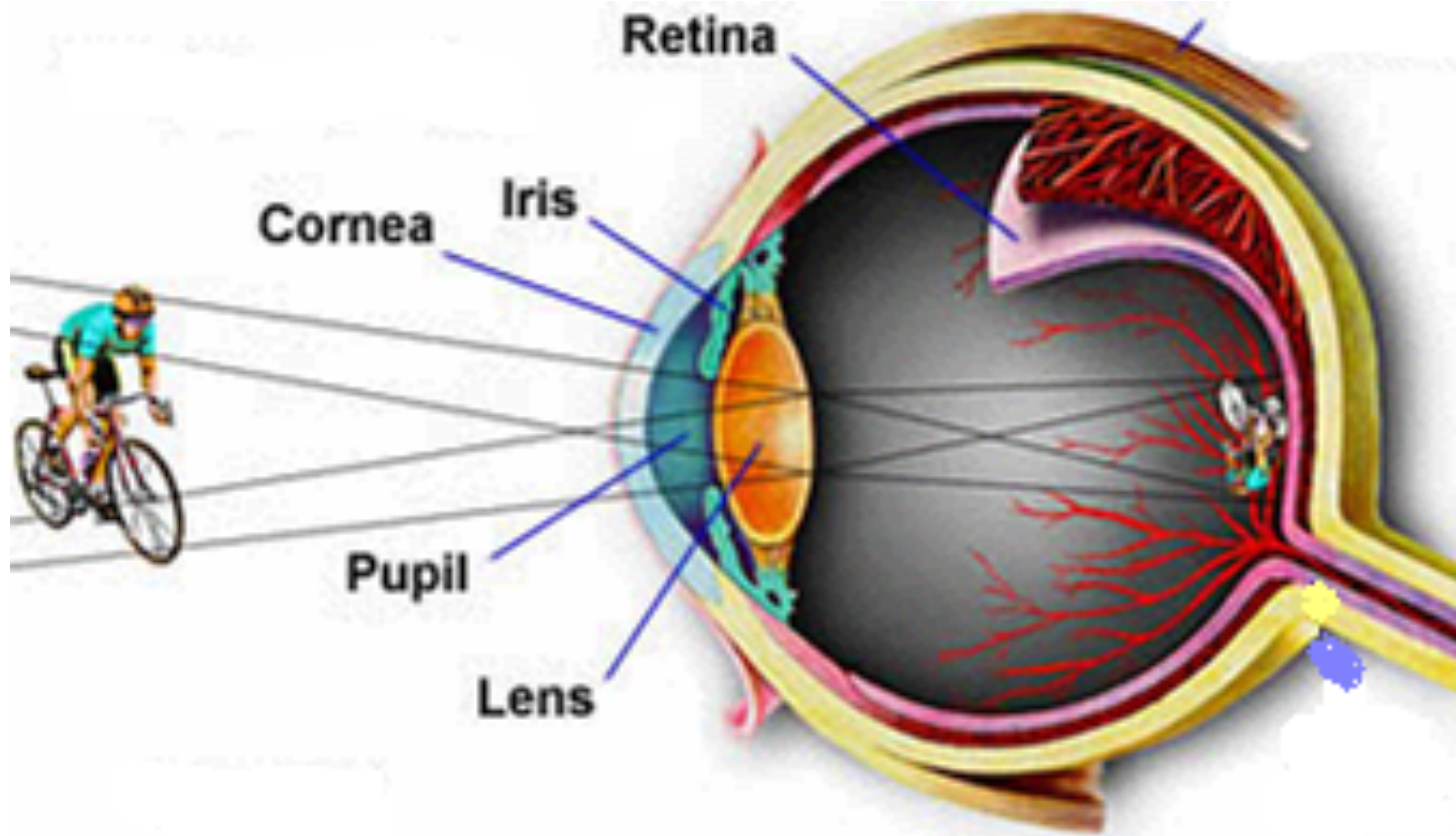
relativa  
la cañ  
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...la vision normal:derada de la integrad



# OPTICS OF THE EYE



# SYSTEM OF LENSES



## MEDIUM

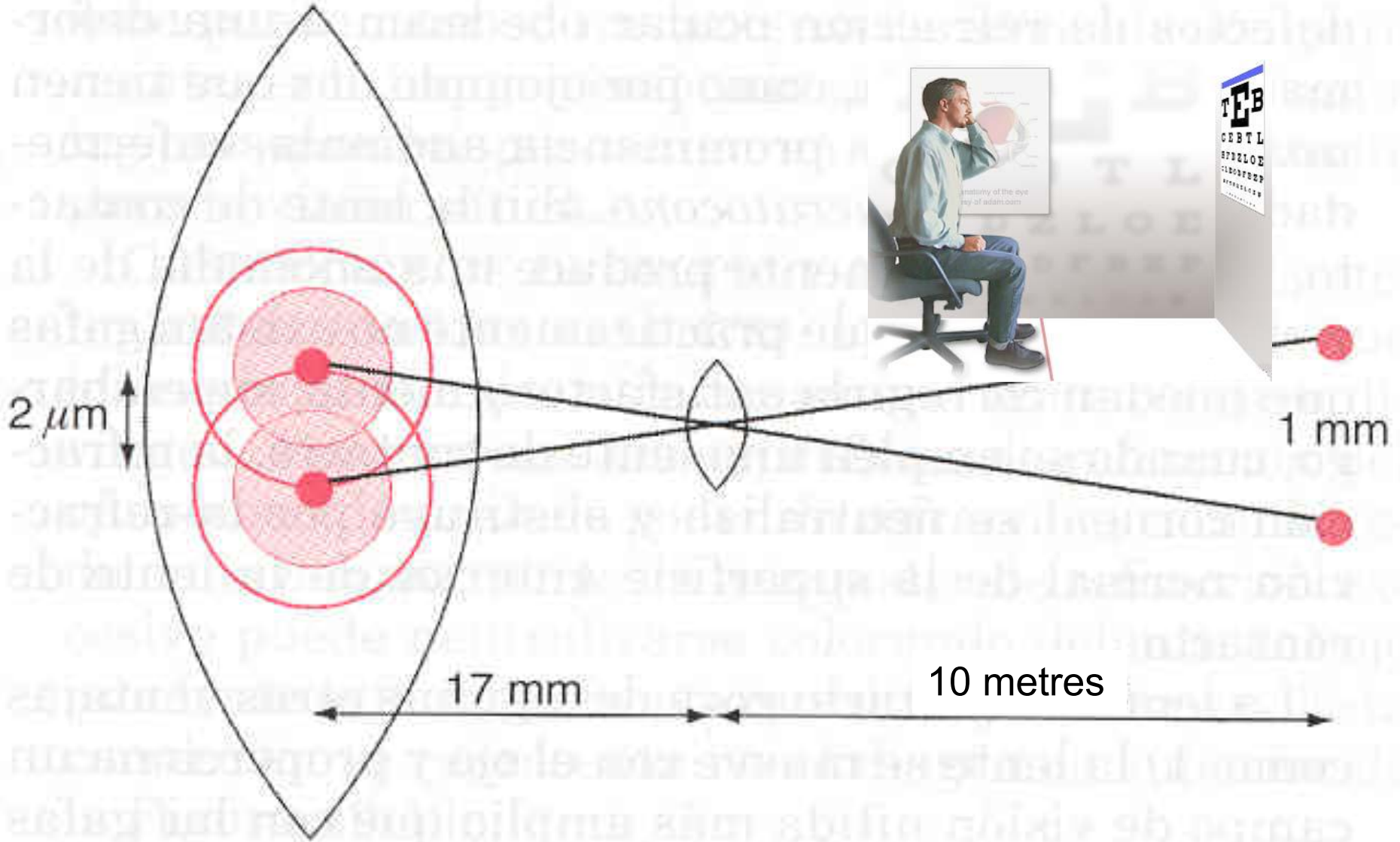
Air – Cornea  
Cornea – Aqueous humour  
A. humour – Crystalline  
Crystalline – Vitreous humour

## REFRACTION

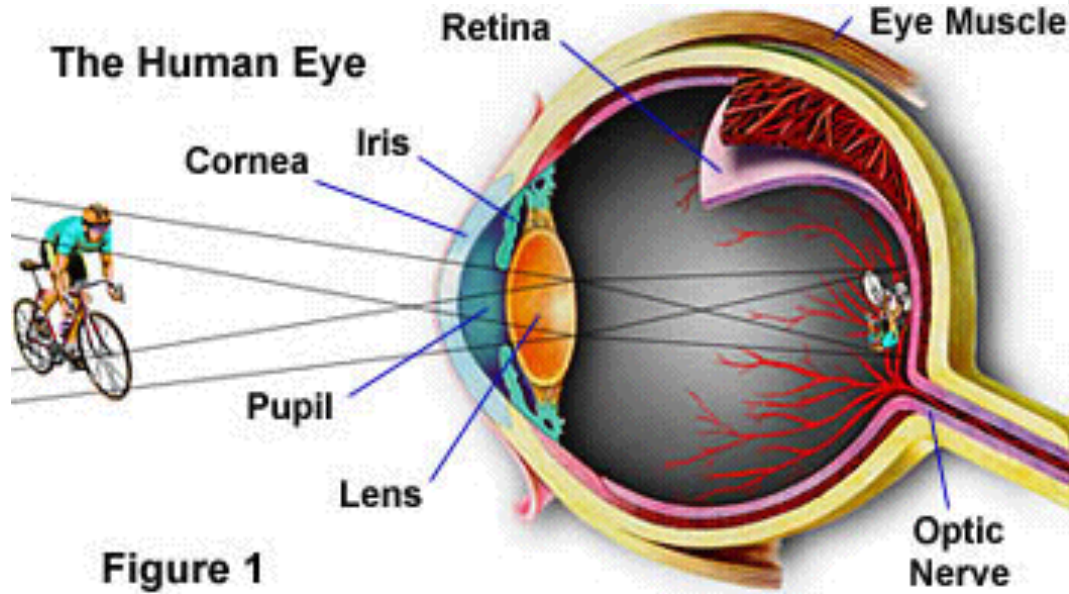
1 – 1.38  
1.38 – 1.33  
1.33 – 1.40  
1.40 – 1.34

# VISUAL ACUITY

ABILITY OF PERCEIVING AN OBJECT IN DETAIL

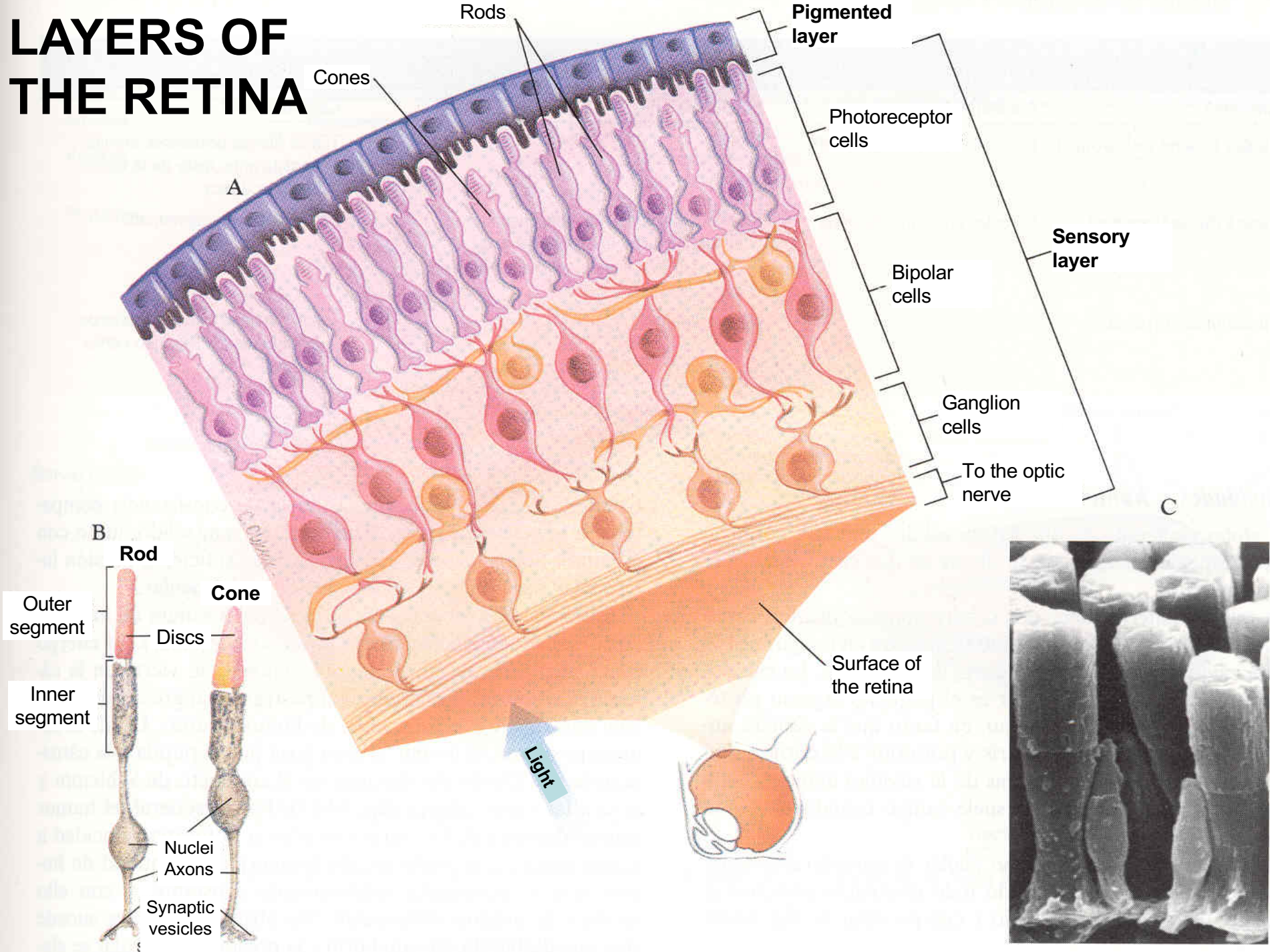


# Transduction of the visual signal



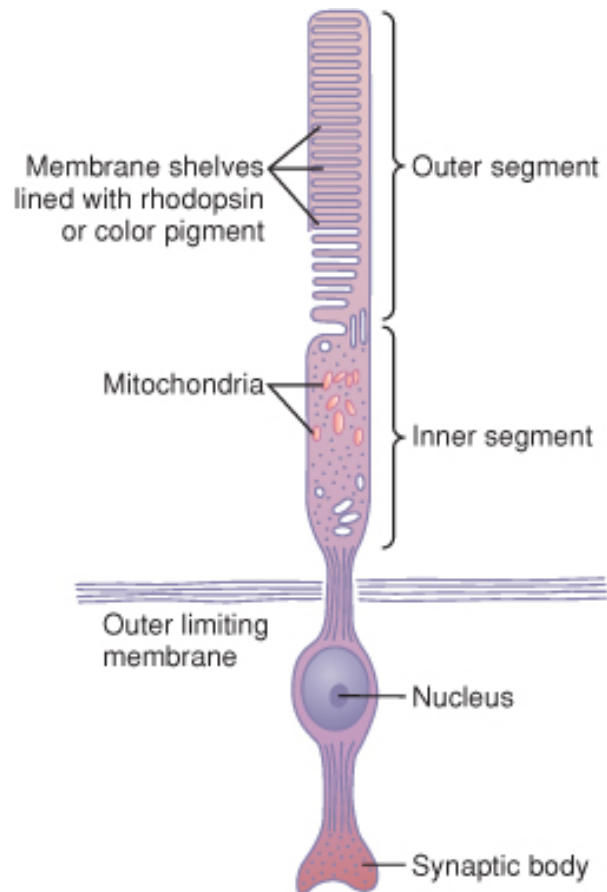
- It is the process through which the incoming light becomes a nervous signal that can reach the brain.
- The photoreceptors transform light into a biological signal through structural changes in proteins and membranes.

# LAYERS OF THE RETINA

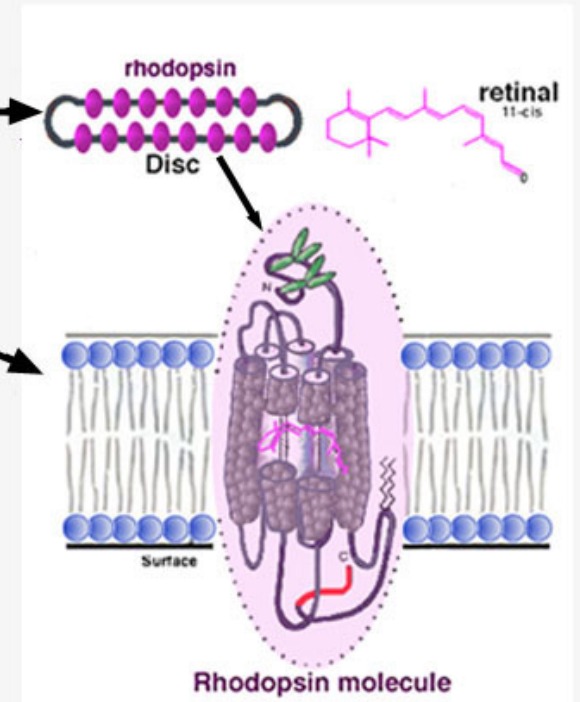




# Rods



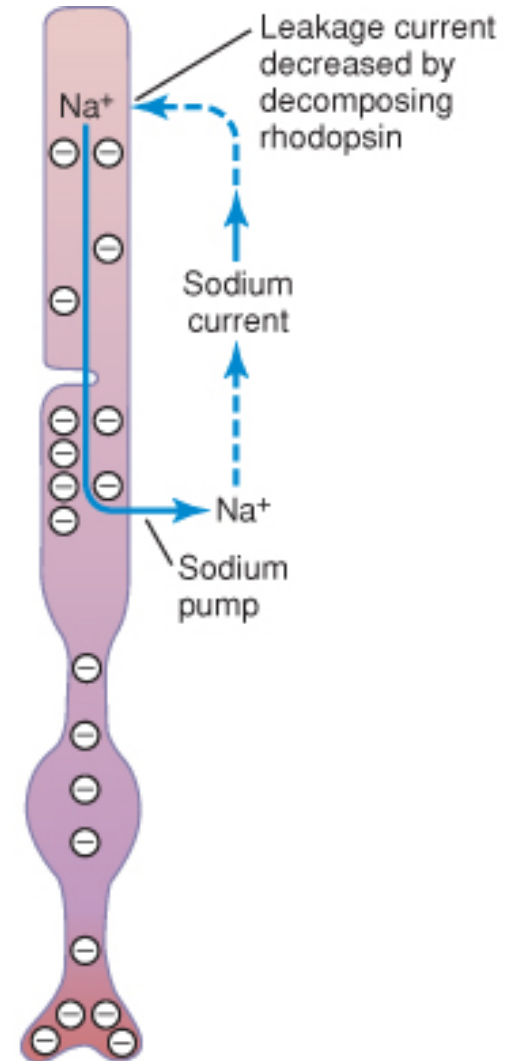
**outer segment**



*Fig 8. Schematic diagram of Rhodopsin in the outer segment discs.*

# Rods

- **DARKNESS:** in the membrane of the external segment there are outflows channels of  $\text{Na}^+$ 
  - $\text{Na}^+$  enters and is pumped from the internal segment to the external segment.
- **LIGHT:** the  $\text{Na}^+$  channels of the external segment are closed, it is **hyperpolarised** and this implies the stimulation of the receptor.



# Mechanism

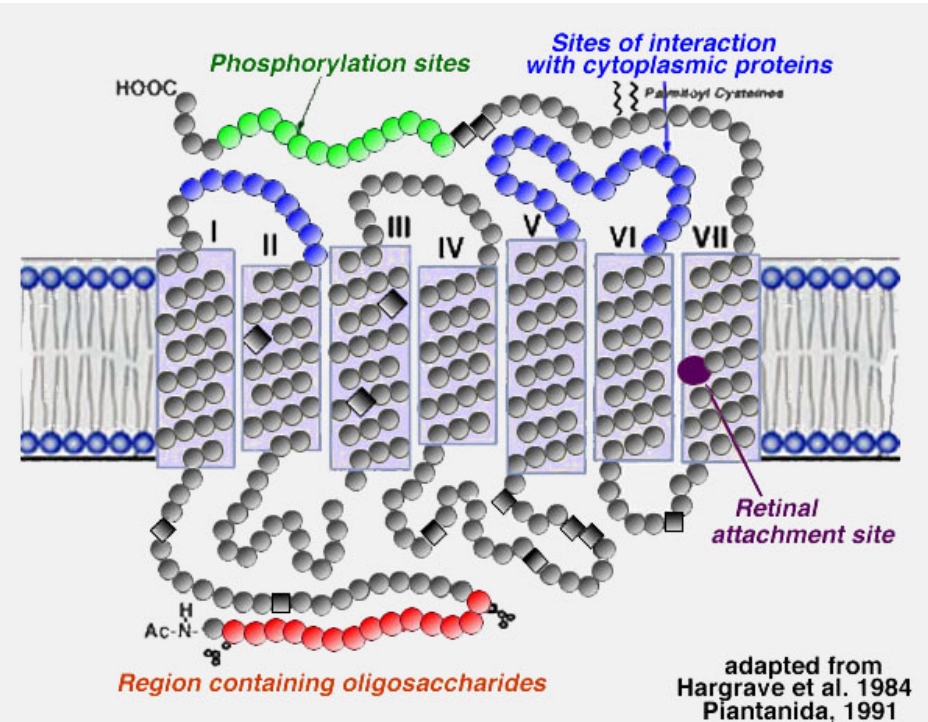
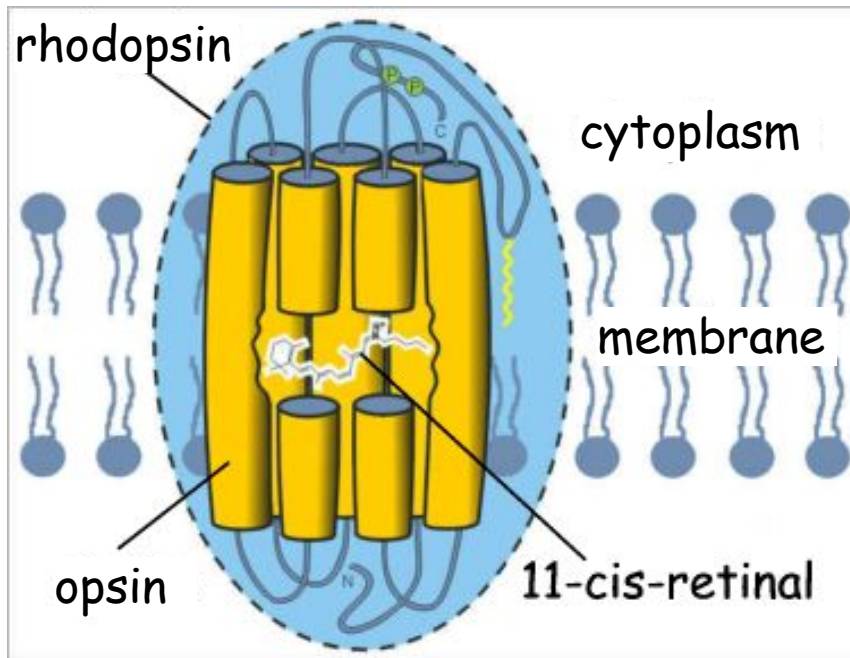
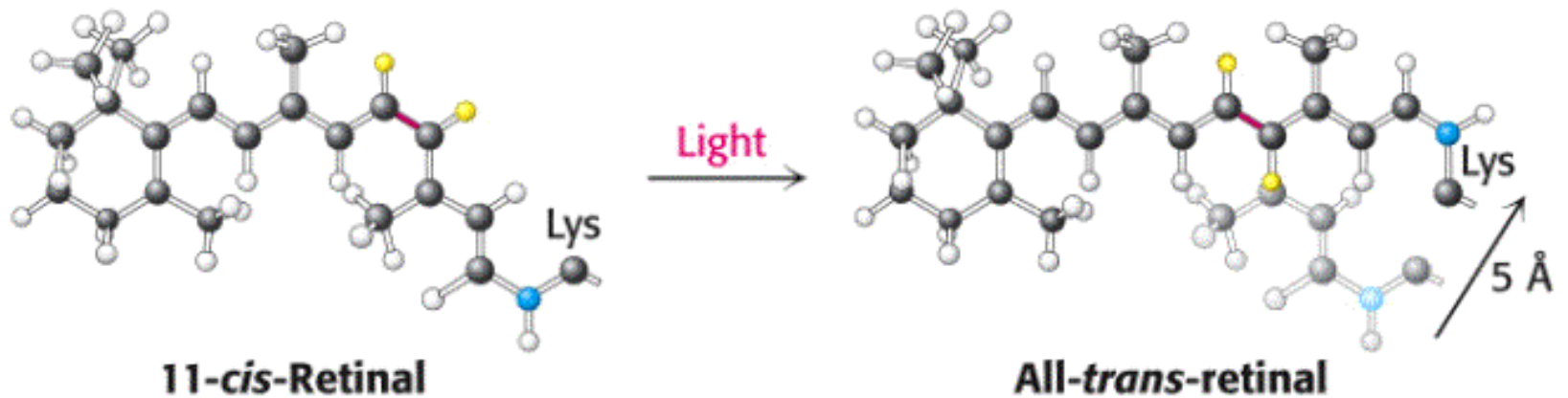
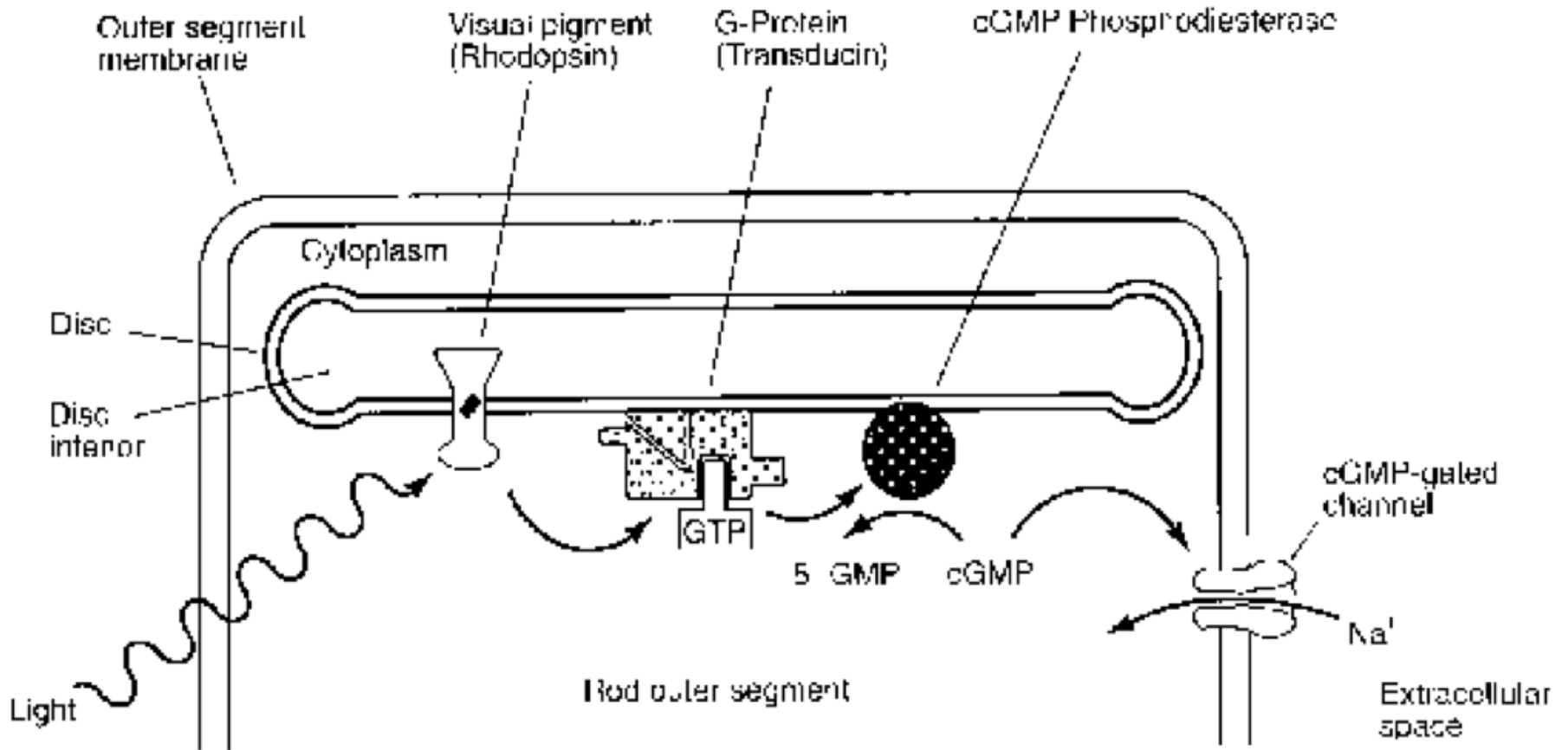


Fig. 9. Structural model of rhodopsin showing seven transmembrane components and the attachment site for retinal.

# Mechanism



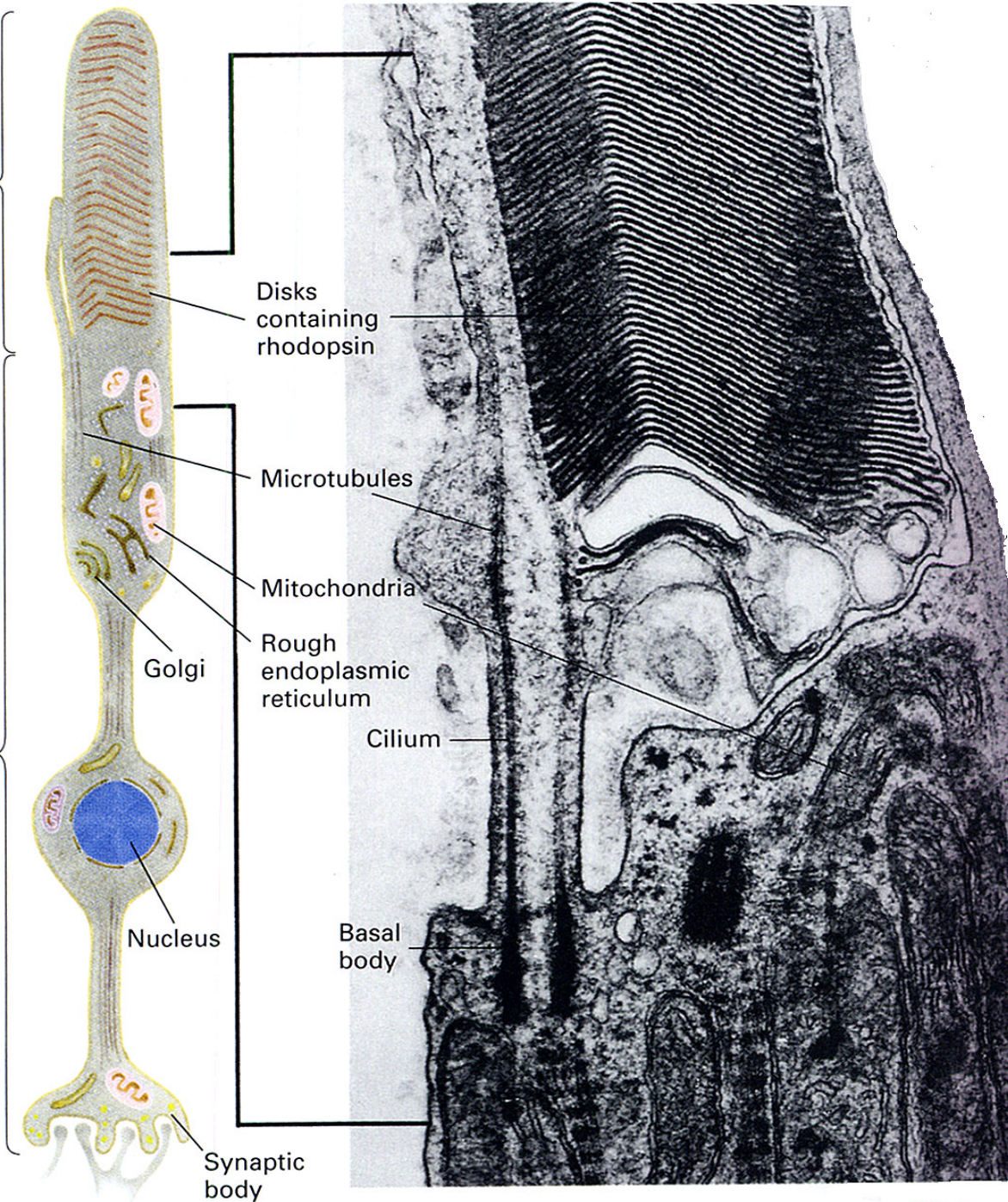
# Mechanism (Photochemistry of Vision)



# PHOTOPIGMENT: RHODOPSIN

Outer  
segment

Inner  
segment



Disks  
containing  
rhodopsin

Microtubules

Mitochondria

Rough  
endoplasmic  
reticulum

Cilium

Basal  
body

Golgi

Nucleus

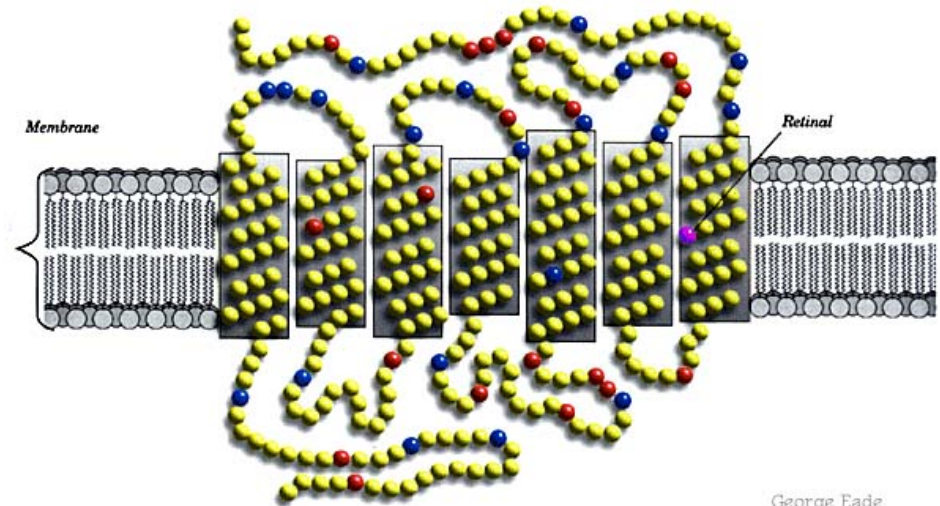
Synaptic  
body

Human rod cell

0.5  $\mu$ m

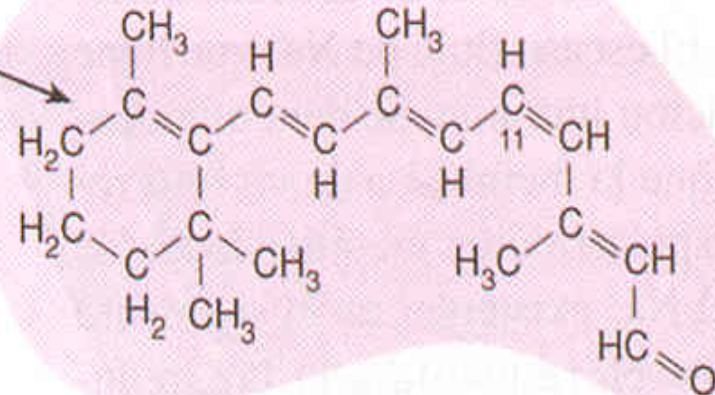
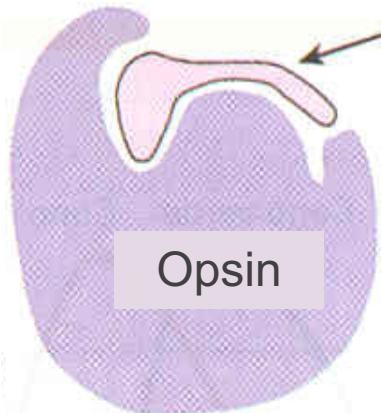
# Photopigment Vertebrates: Rhodopsin

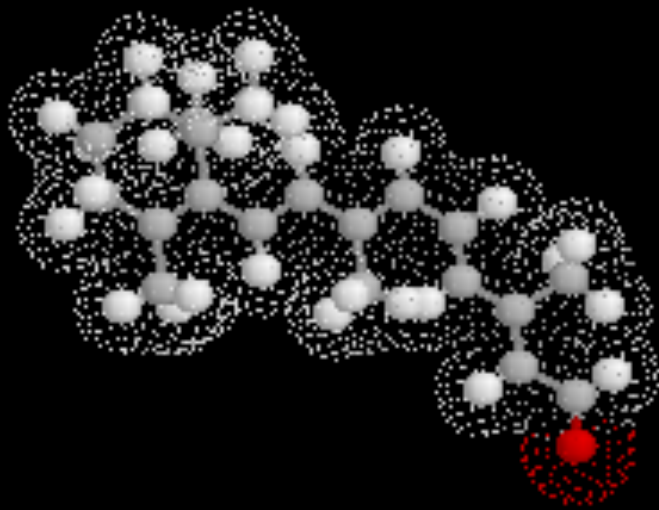
- Opsin
- 11-cis-retinal



George Eade

11-cis-retinal





MDL

11-cis-retinal



MDL

all-trans-retinal

**Light isomerizes the 11-cis-retinal  
into all-trans-retinal.**

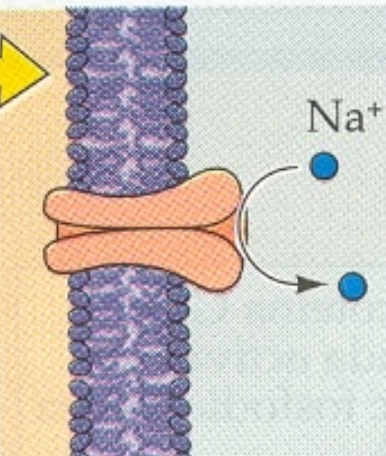
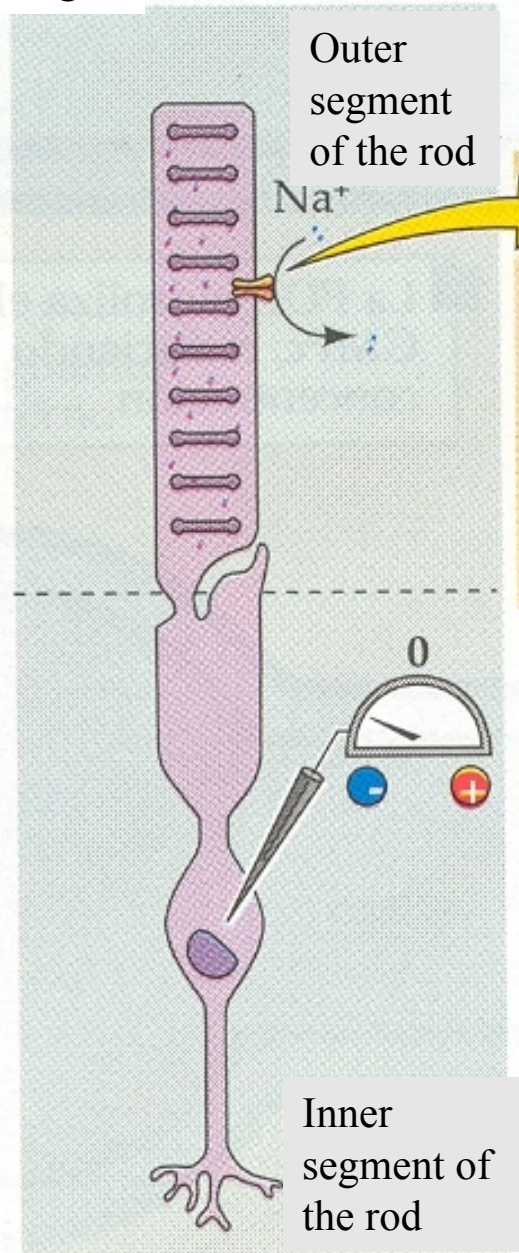
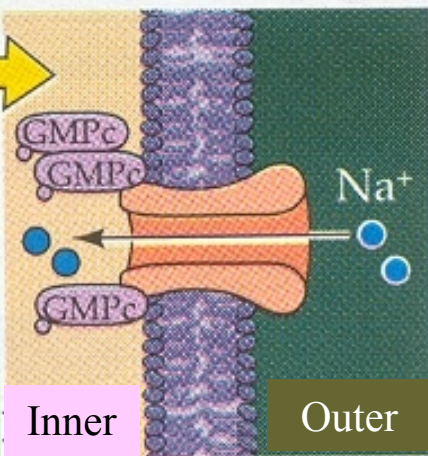
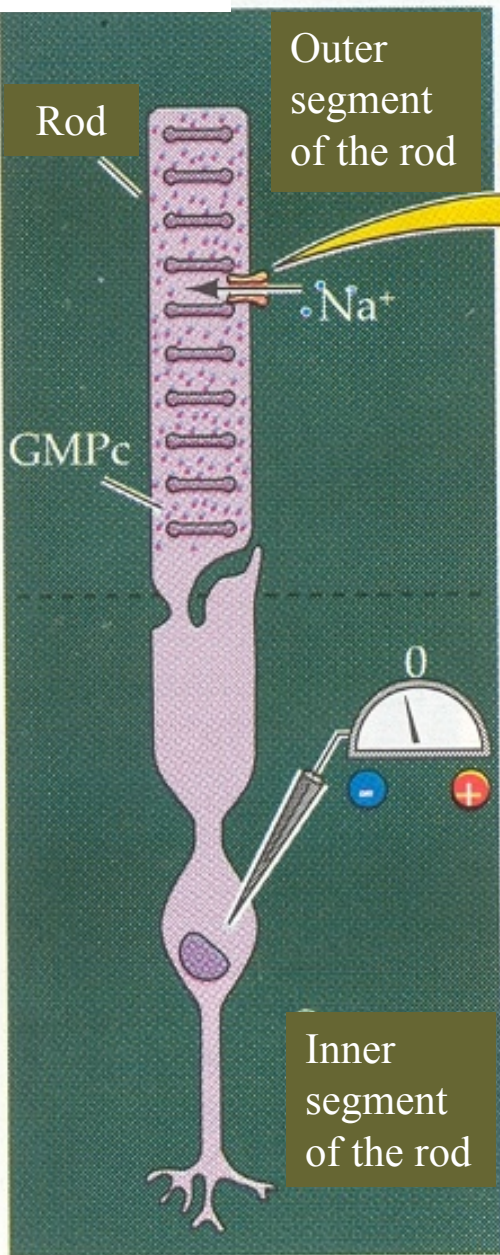




# PHOTOTRANSDUCTION

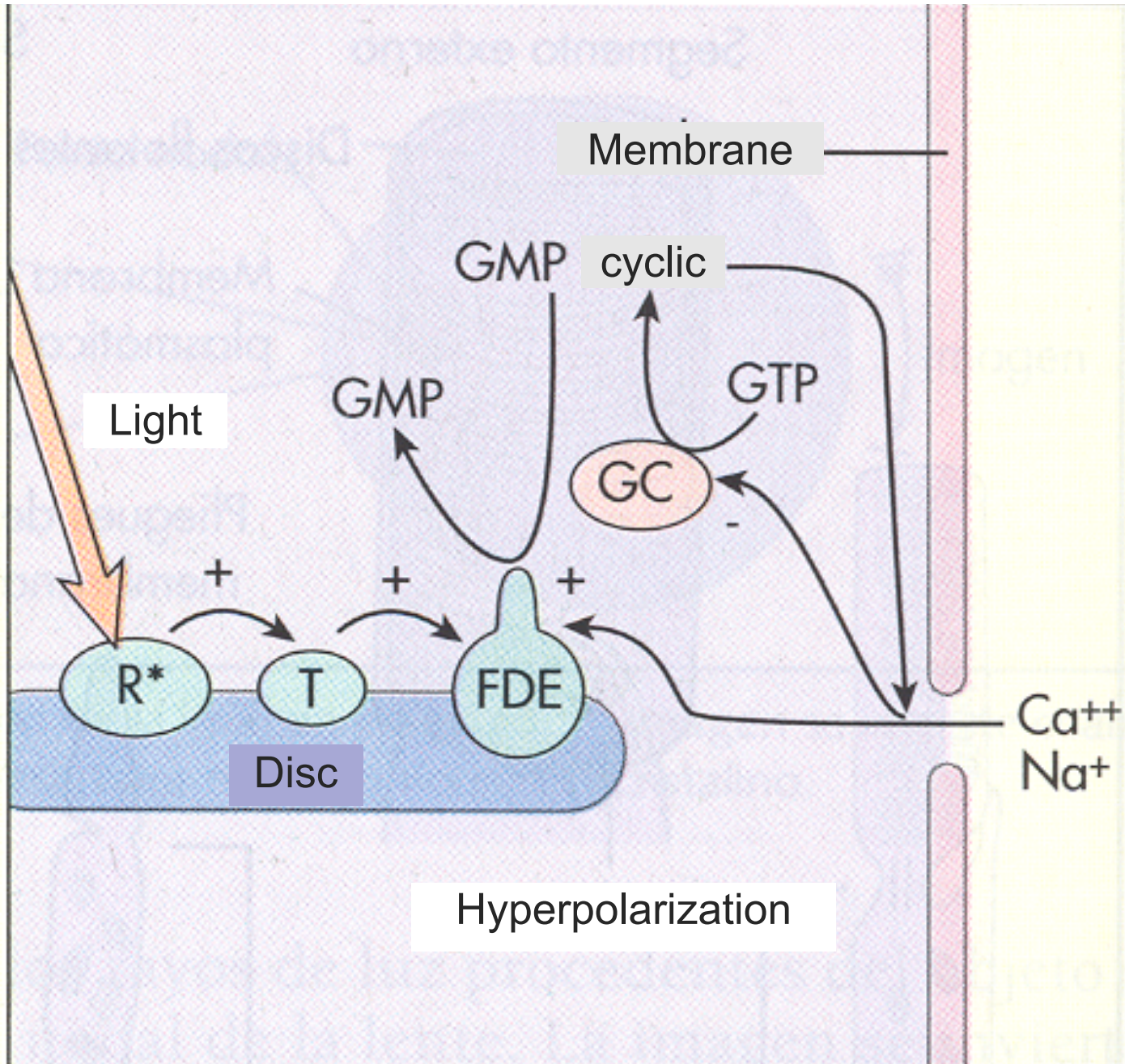
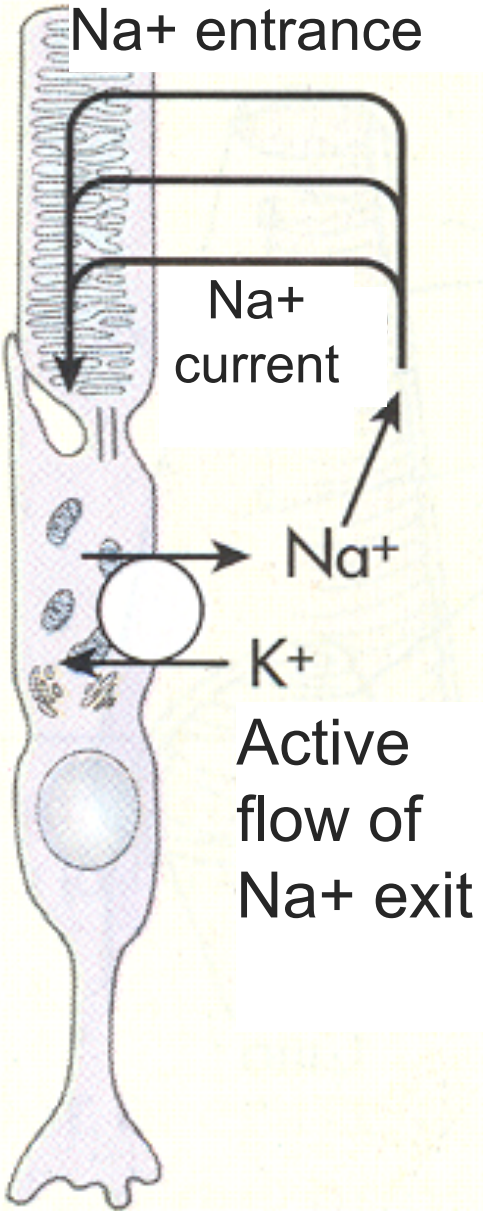
Darkness

Light

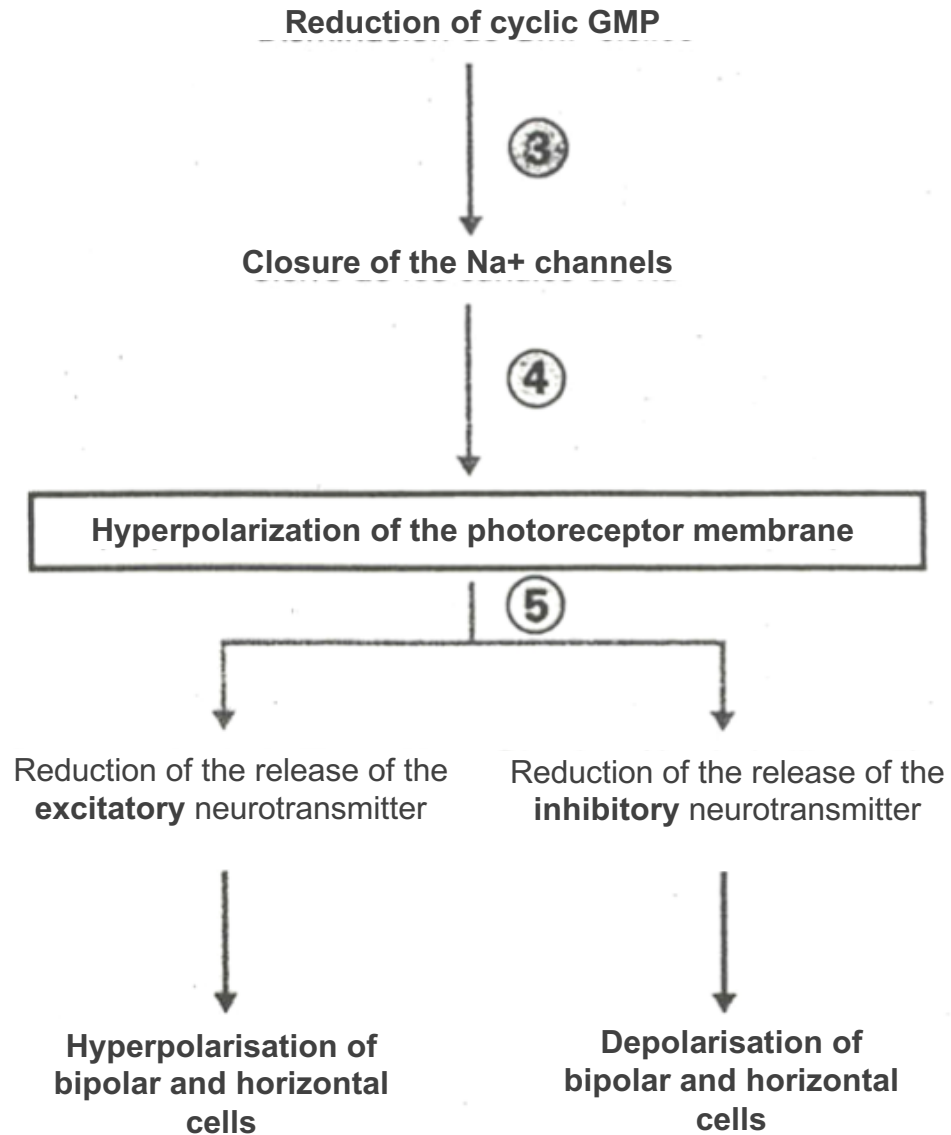
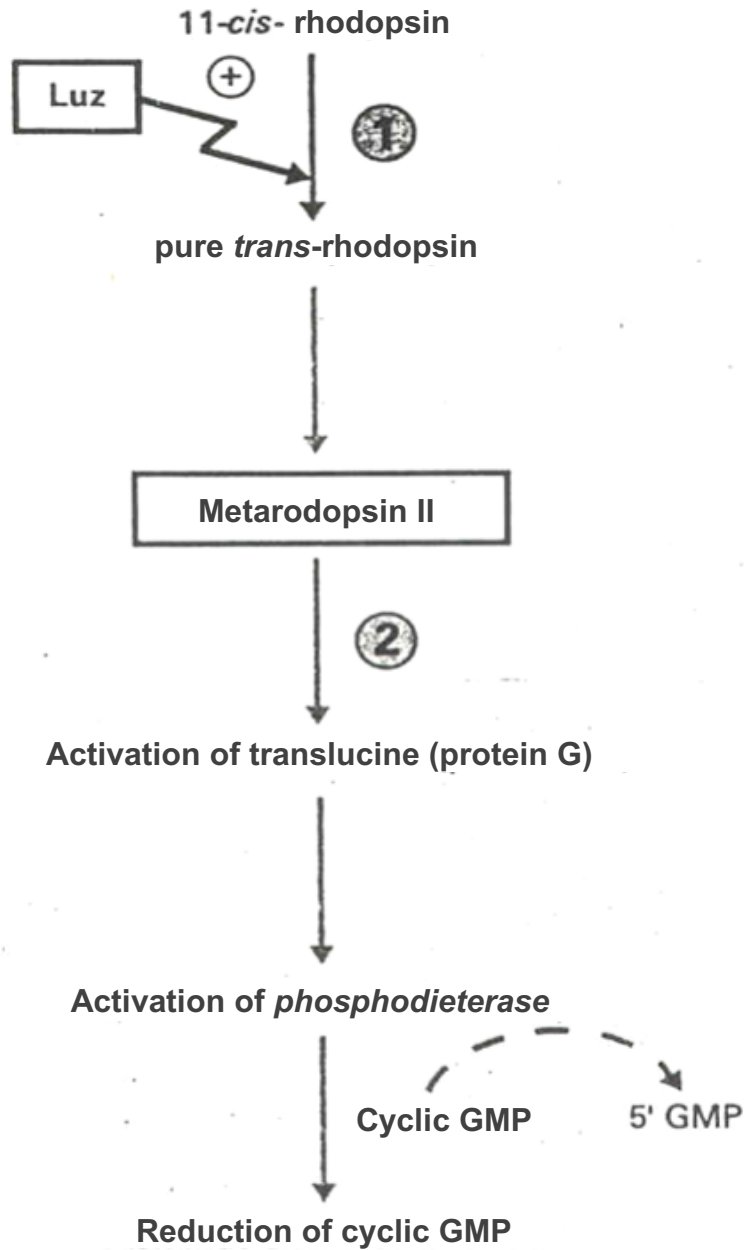


# PHOTOTRANSDUCTION

Passive flow of  $\text{Na}^+$  entrance

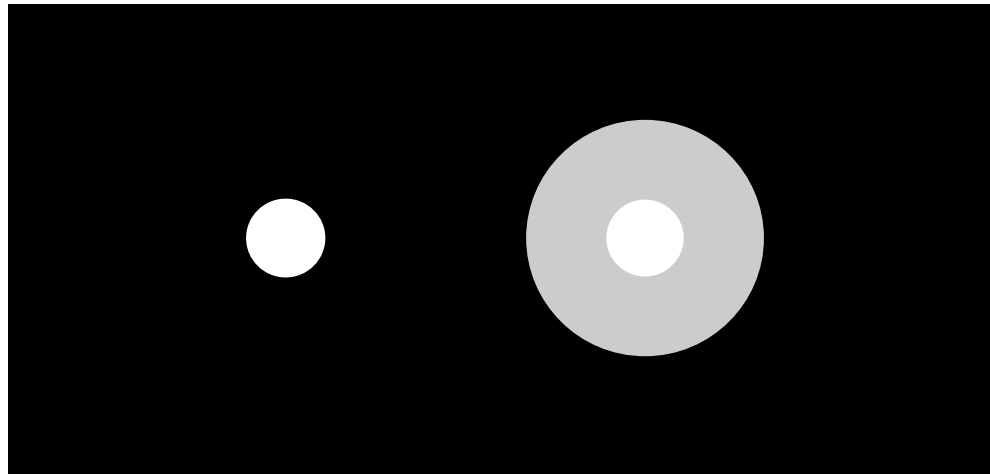


# STEPS IN PHOTORECEPTION

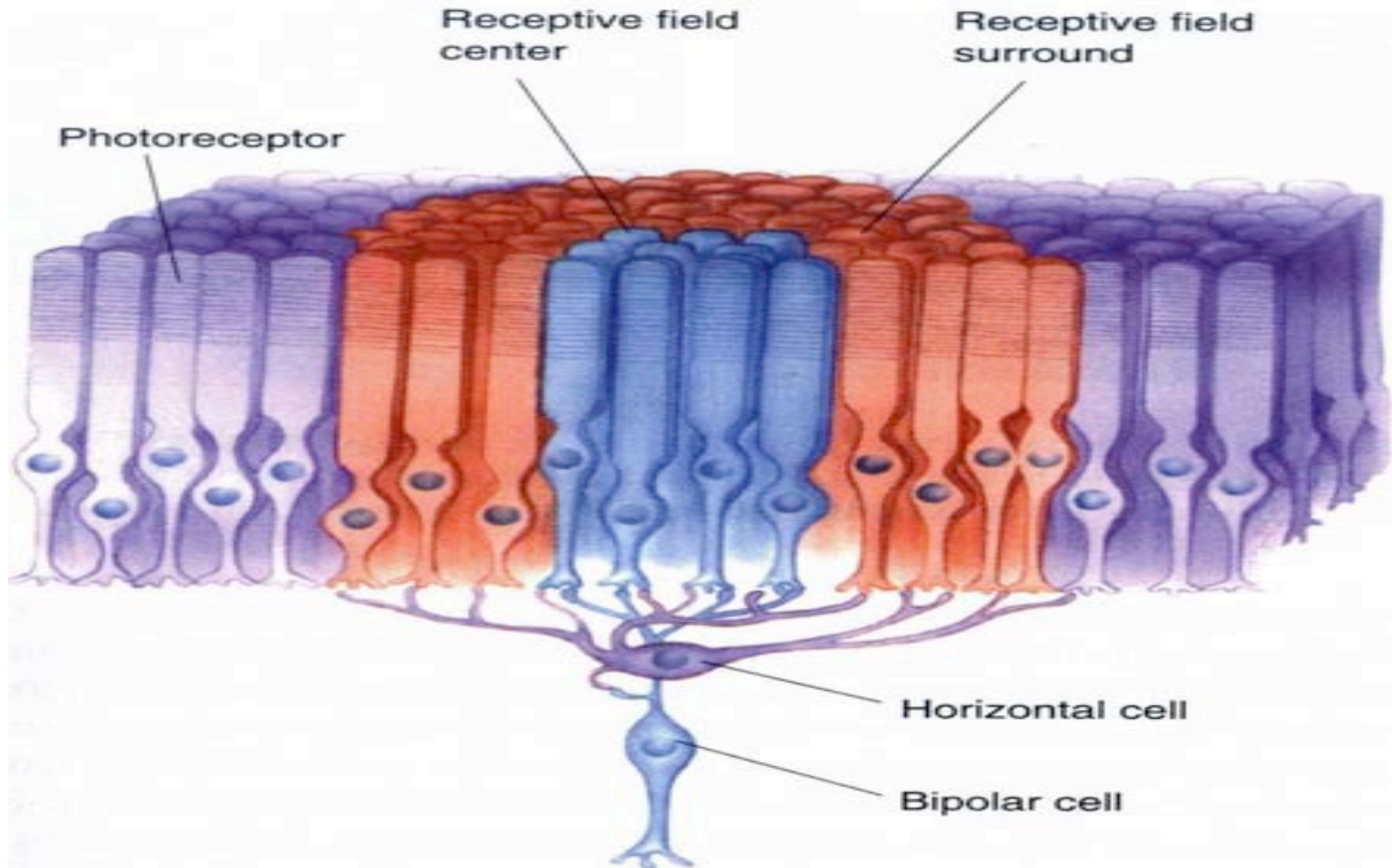


# ON-OFF Pathways

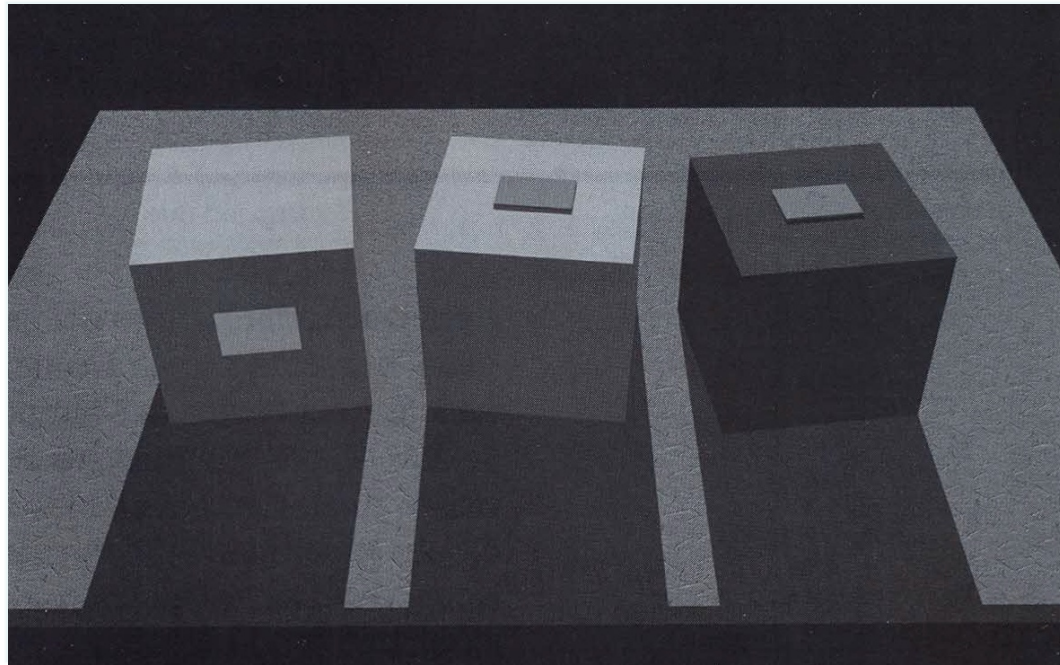
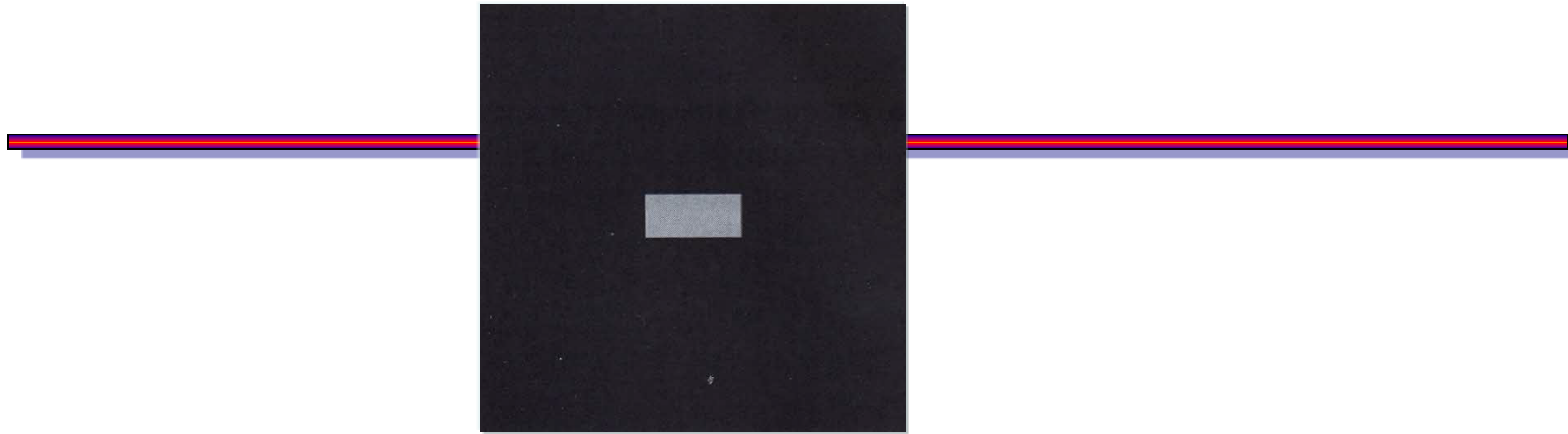
- The retina produces contrasts from the photoreceptor itself, through the so-called on-off pathways.



# Contrast

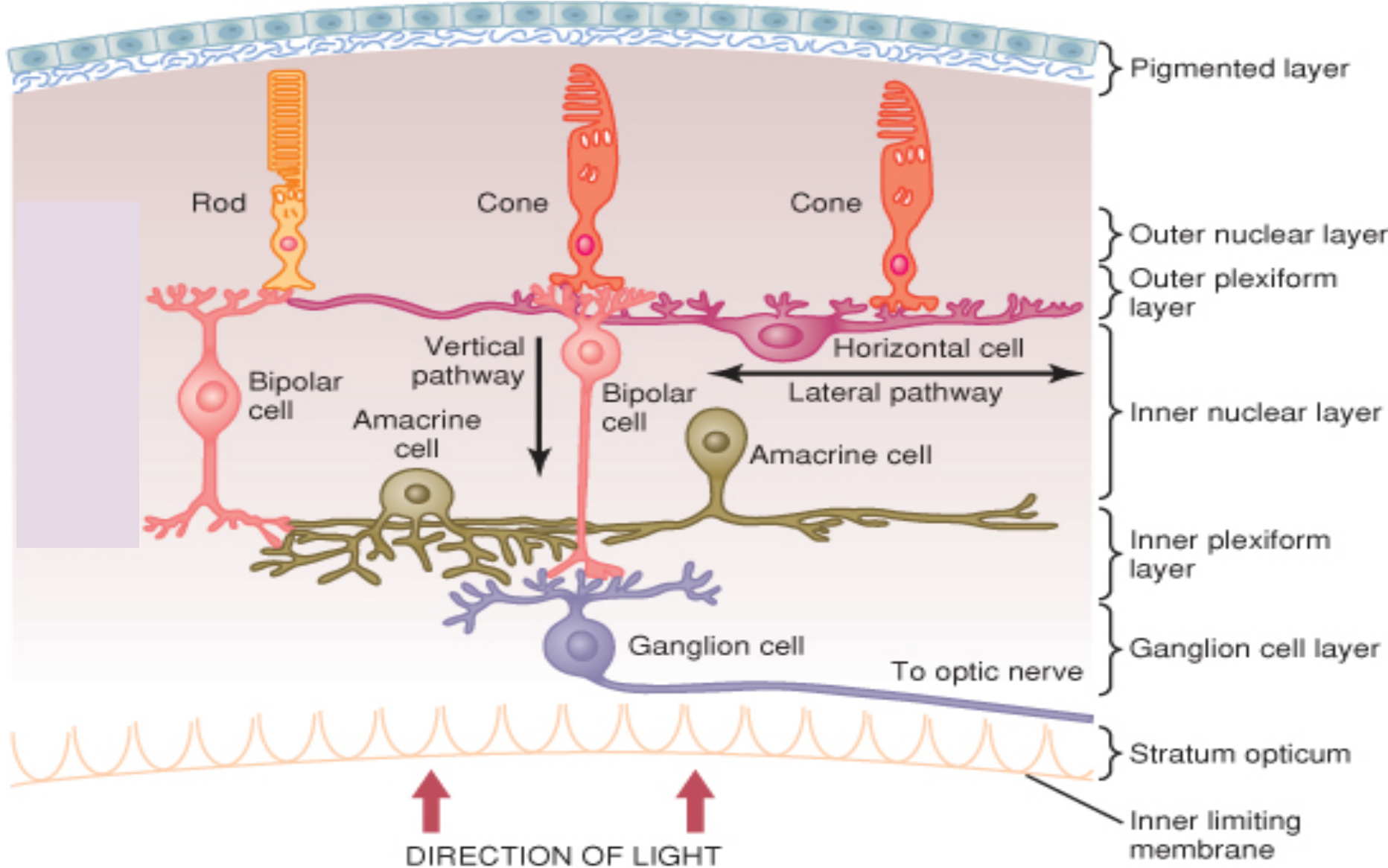


# DISCRIMINATION OF LIGHT INTENSITY (BRIGHTNESS)



How do receptors decipher light intensity?

# STRUCTURE OF THE RETINA



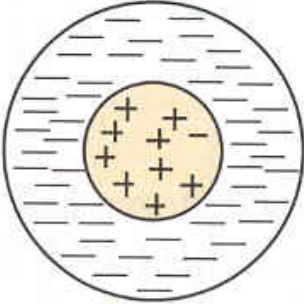


**Receptive field:** area of the retina under the influence of a receptor

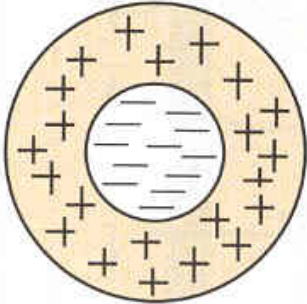
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ON-centre

A



OFF-centre

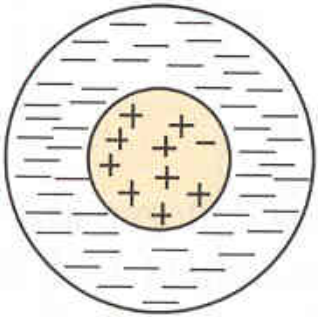


**Receptive field:** area of the retina under the influence of a receptor

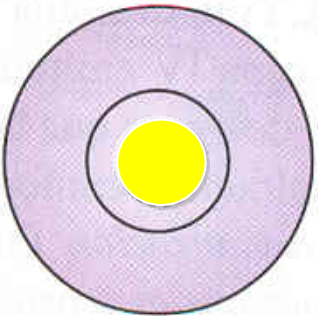
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ON-centre

A

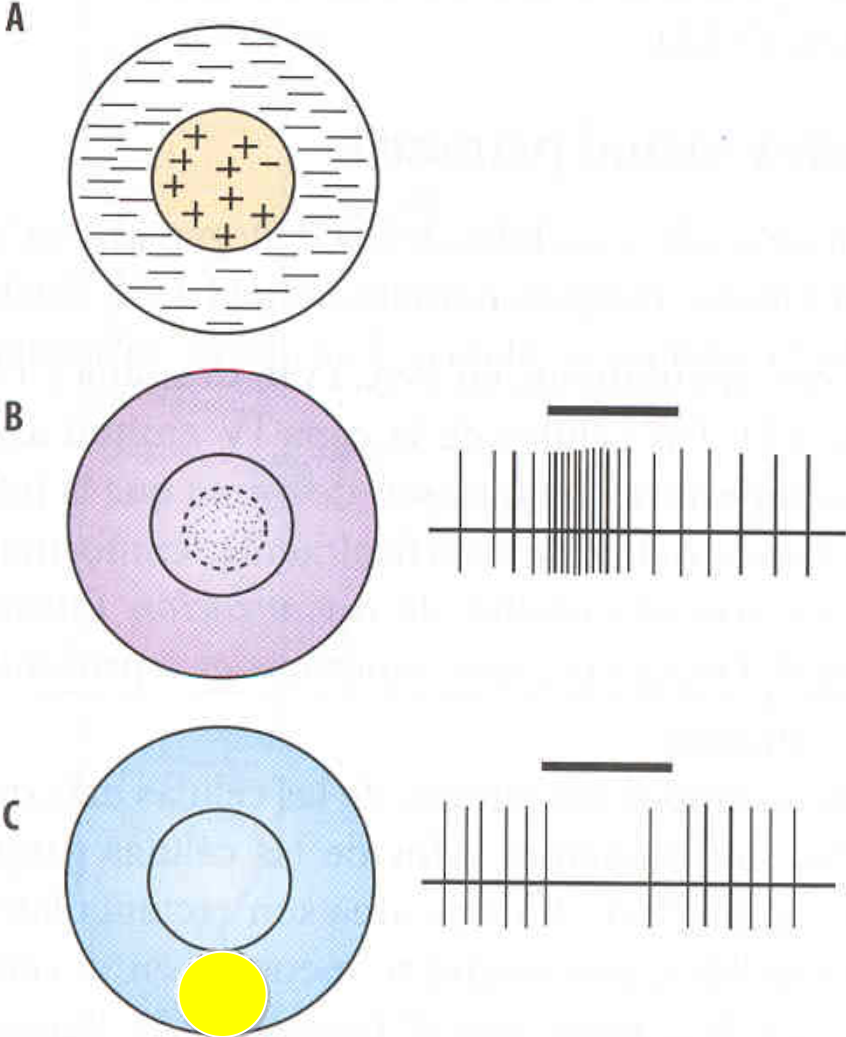


B



# Receptive field: area of the retina under the influence of a receptor

ON-centre

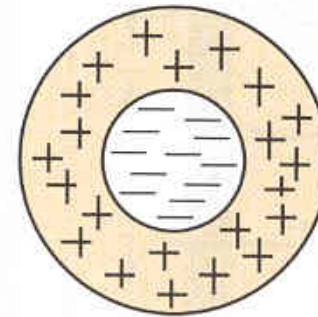
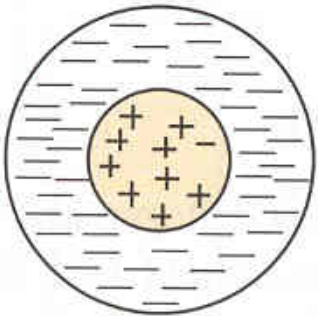


**Receptive field:** area of the retina under the influence of a receptor

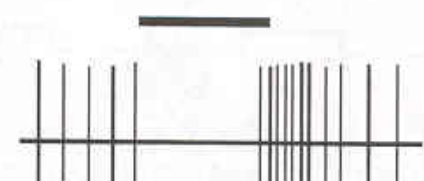
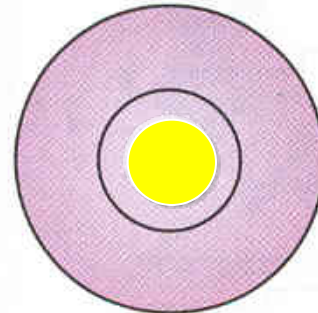
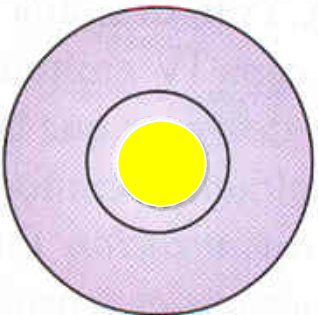
ON-center

OFF-center

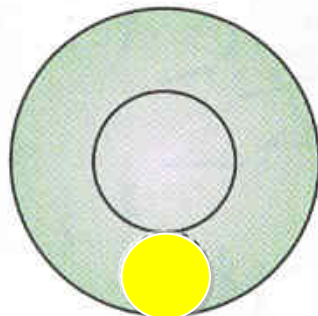
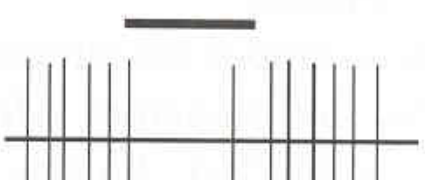
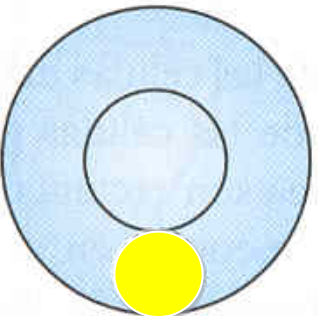
A



B



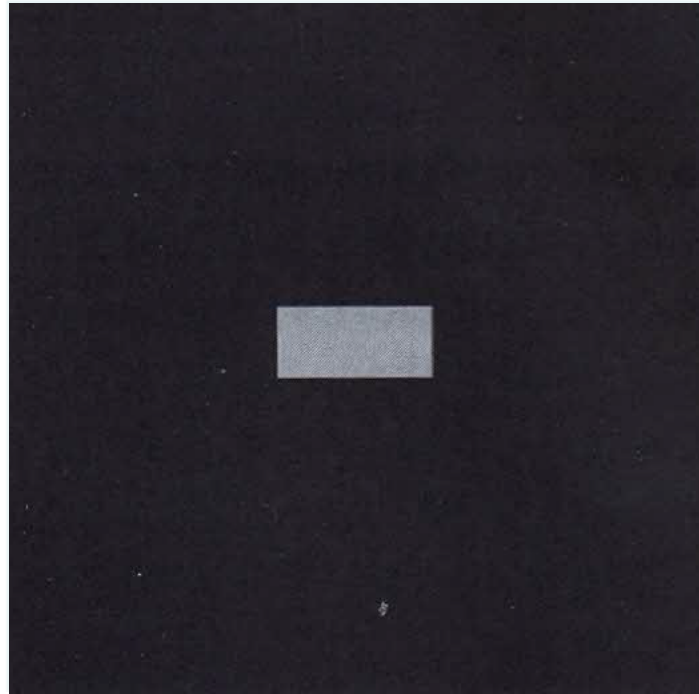
C



# DISCRIMINATION OF LIGHT INTENSITY (CONTRAST)

The interpretation depends on the background

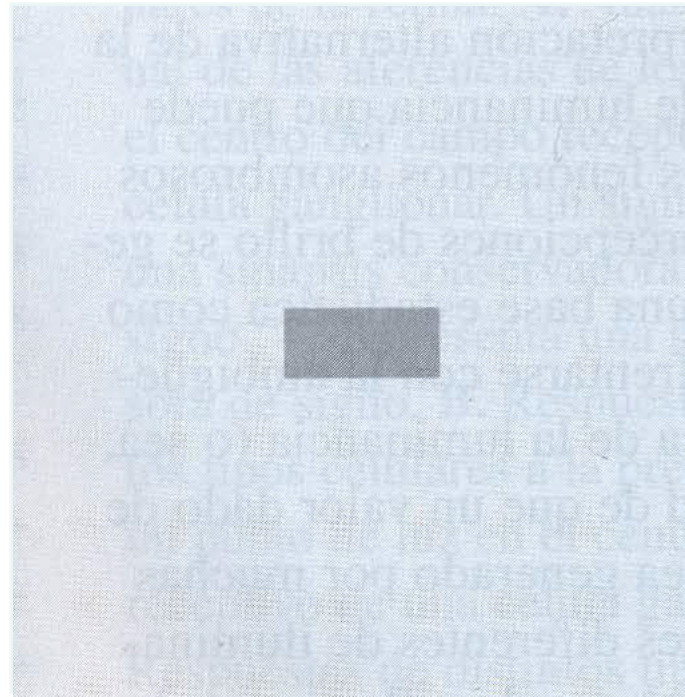
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# DISCRIMINATION OF LIGHT INTENSITY (CONTRAST)

The interpretation depends on the background

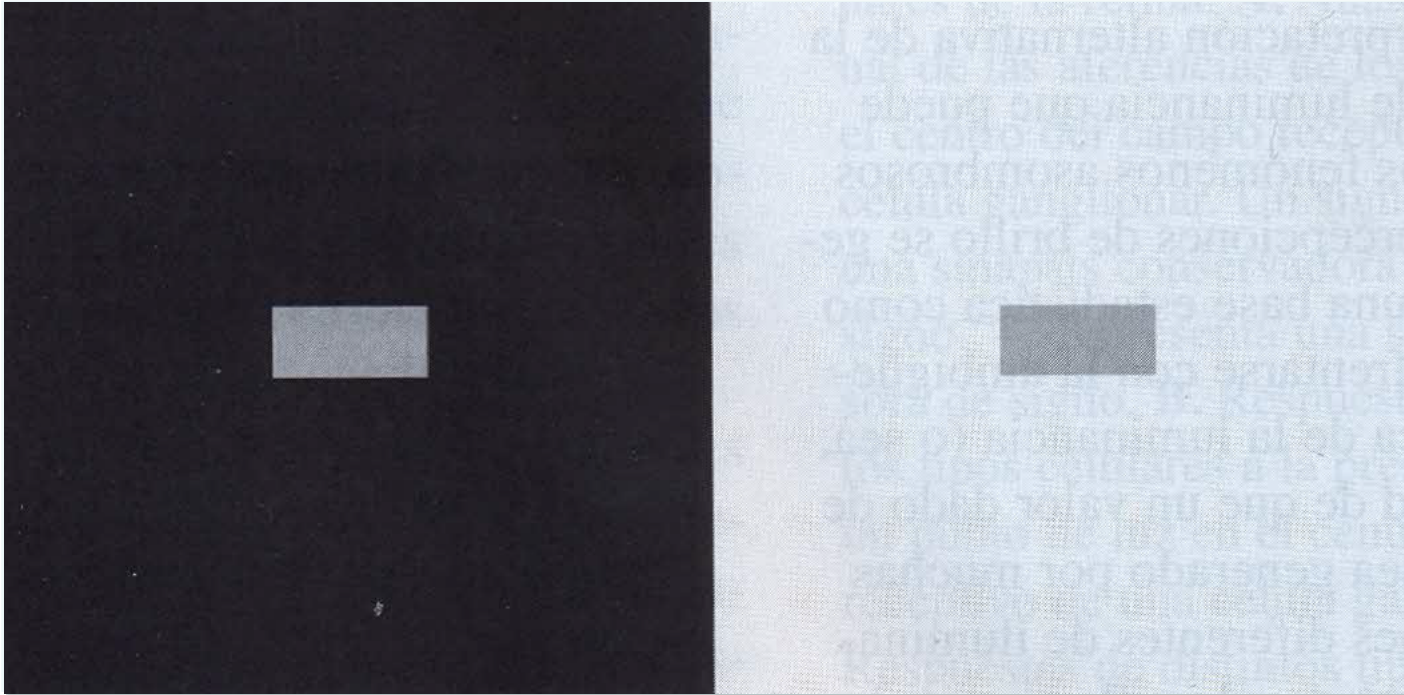
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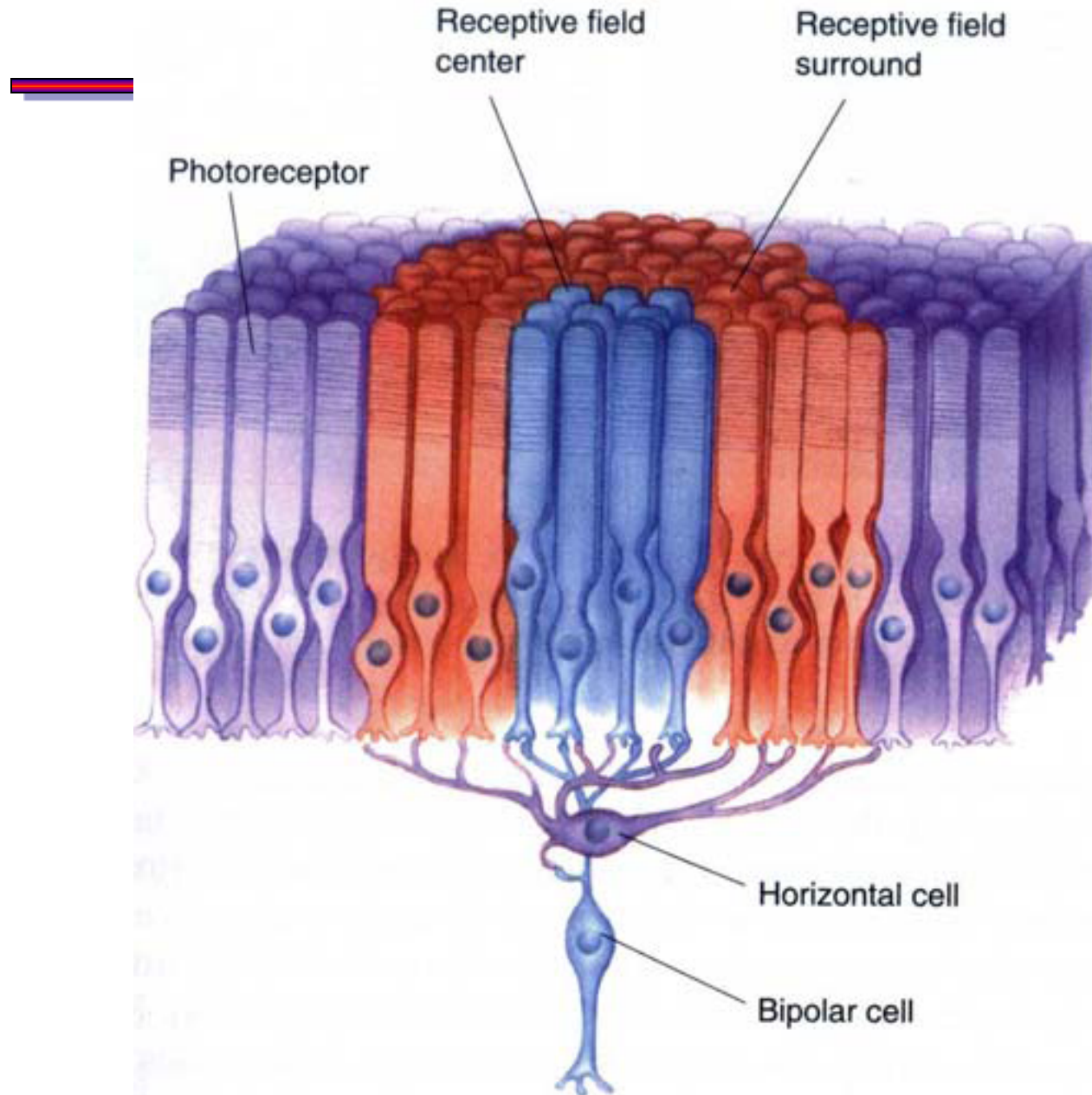
# DISCRIMINATION OF LIGHT INTENSITY (CONTRAST)

The interpretation depends on the background

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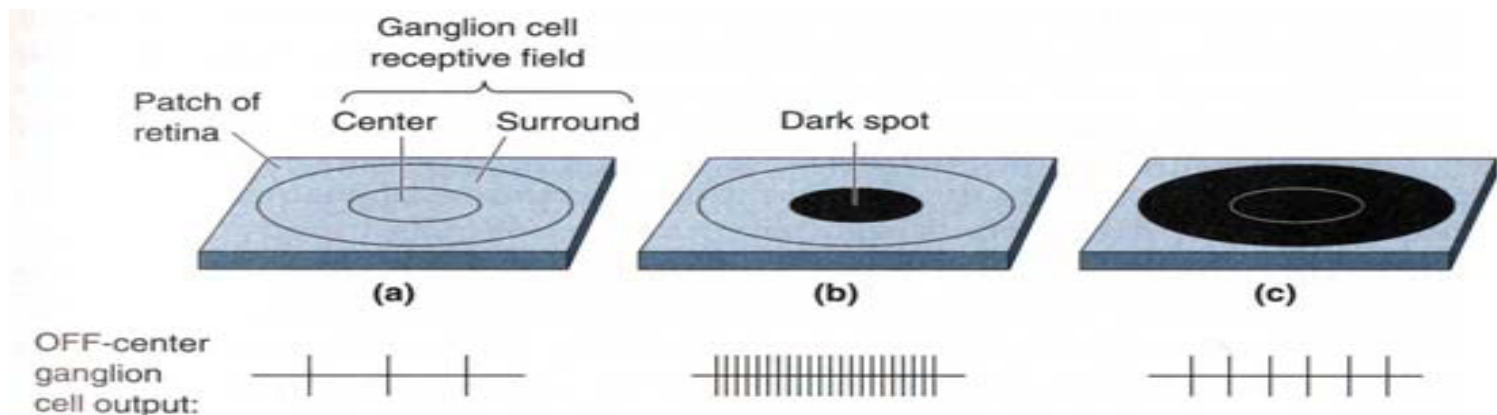
# STRUCTURE OF THE RECEPTIVE FIELD





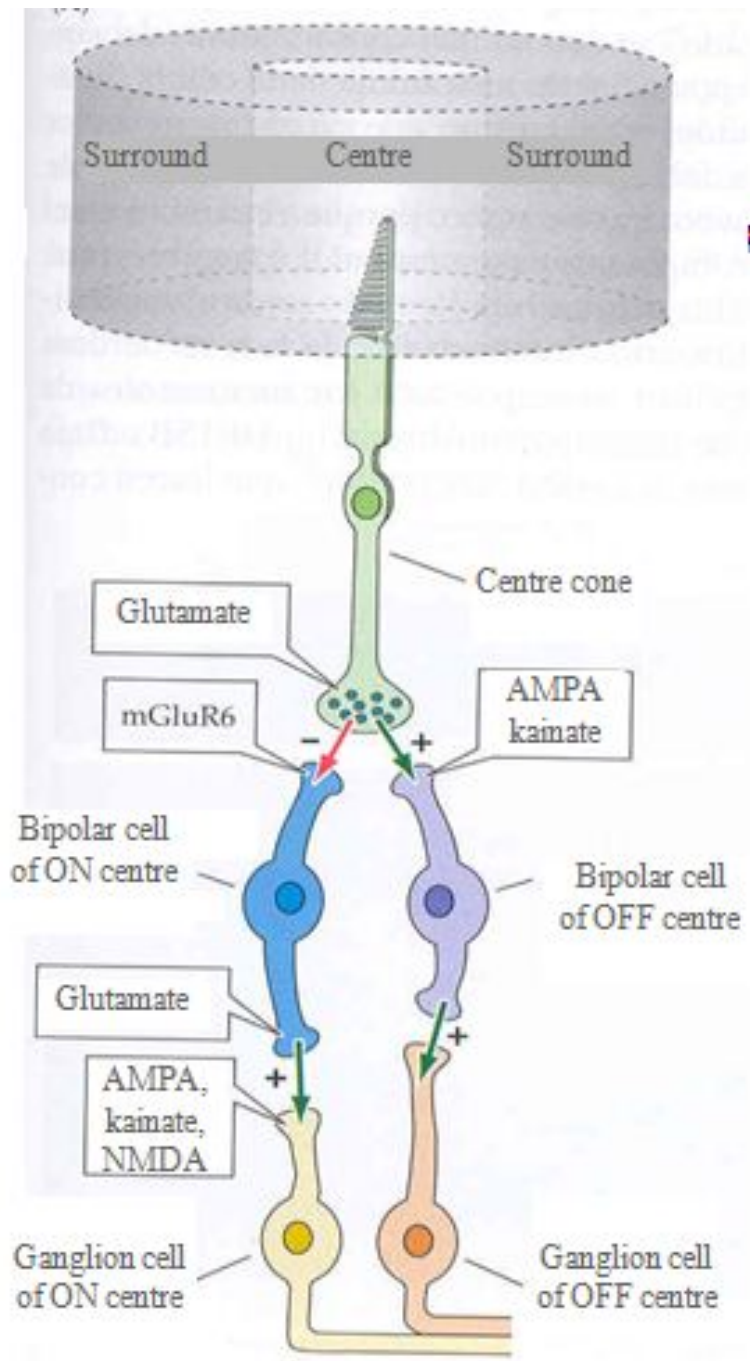
# Field of retinal receptors

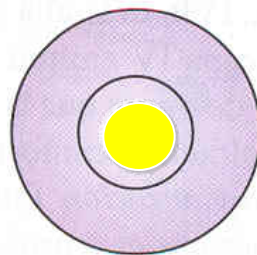
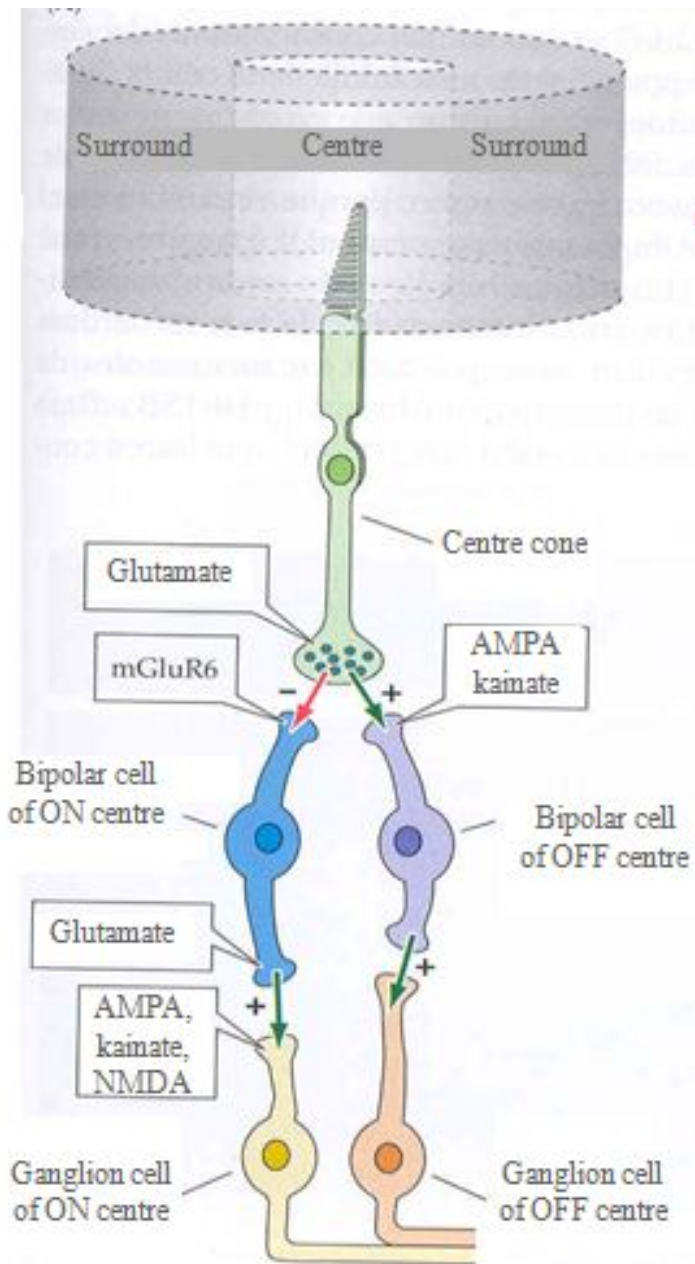
- The ganglion cells (x, cones; y, rods) create circular receptive fields
  - Of ON-center: action potential when light passes through an ON-center
  - Of OFF-center: action potential when darkness passes through an OFF-center
- Both light and darkness supply information. It all depends on the creation of contrasts.



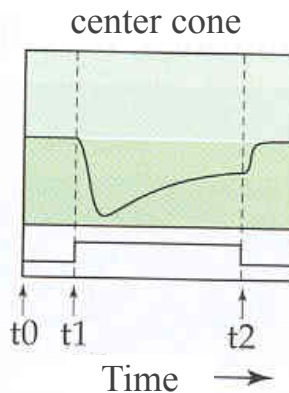
**Figure 9.23**

**A center-surround ganglion cell receptive field.** (a, b) An OFF-center ganglion cell responds with a barrage of action potentials when a dark spot is imaged on its receptive field center. (c) If the spot is enlarged to include the receptive field surround, the response is greatly reduced.

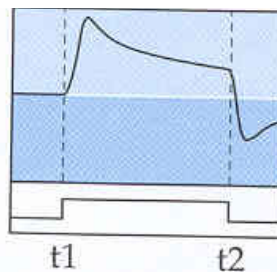




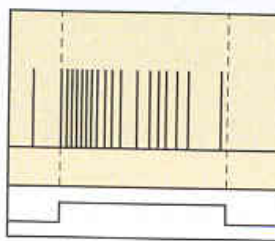
**ON**

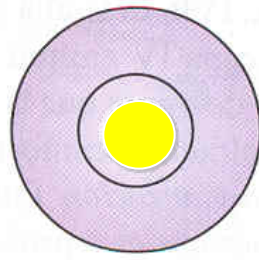


Bipolar cell of ON-centre

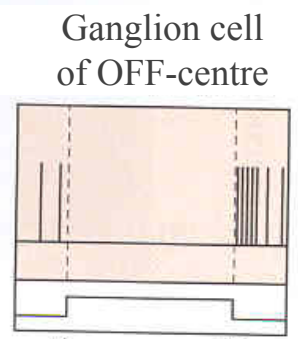
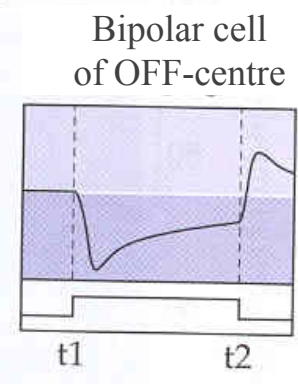
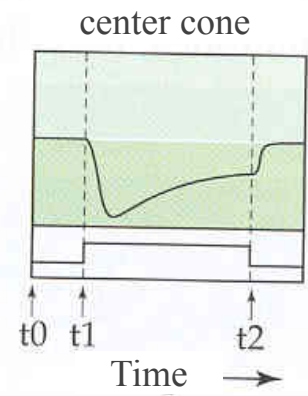
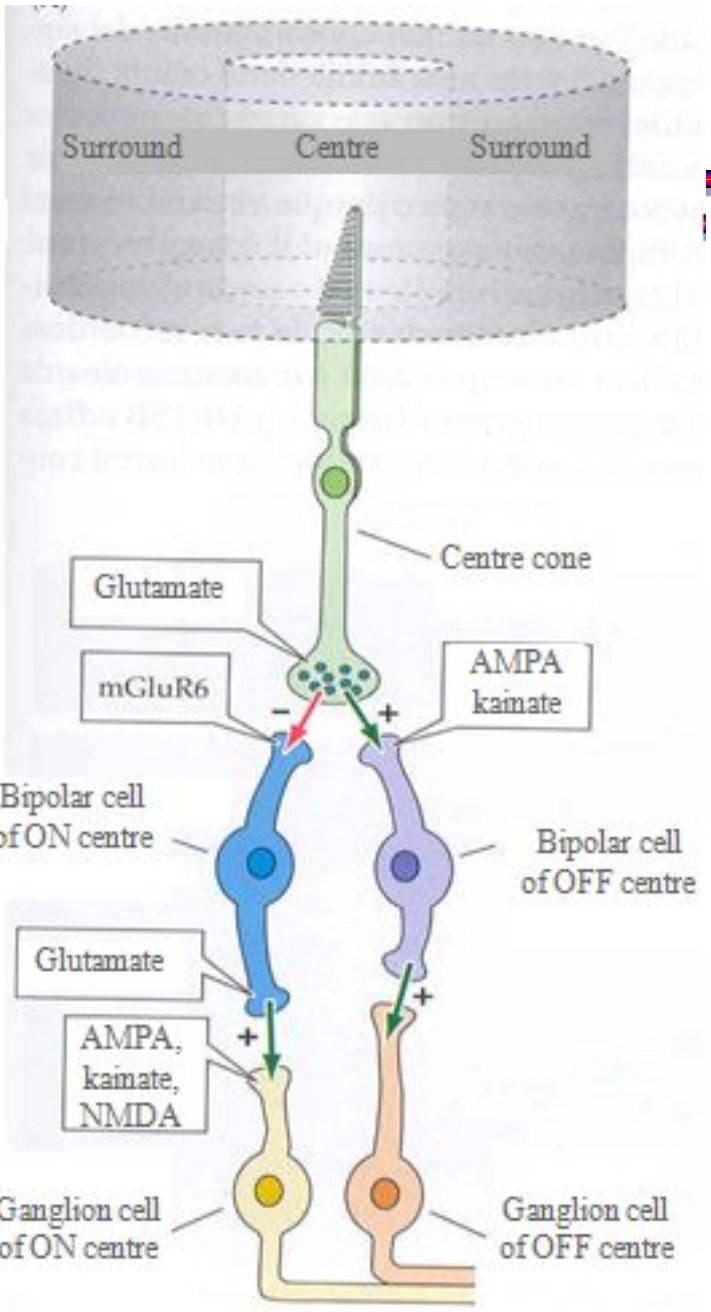


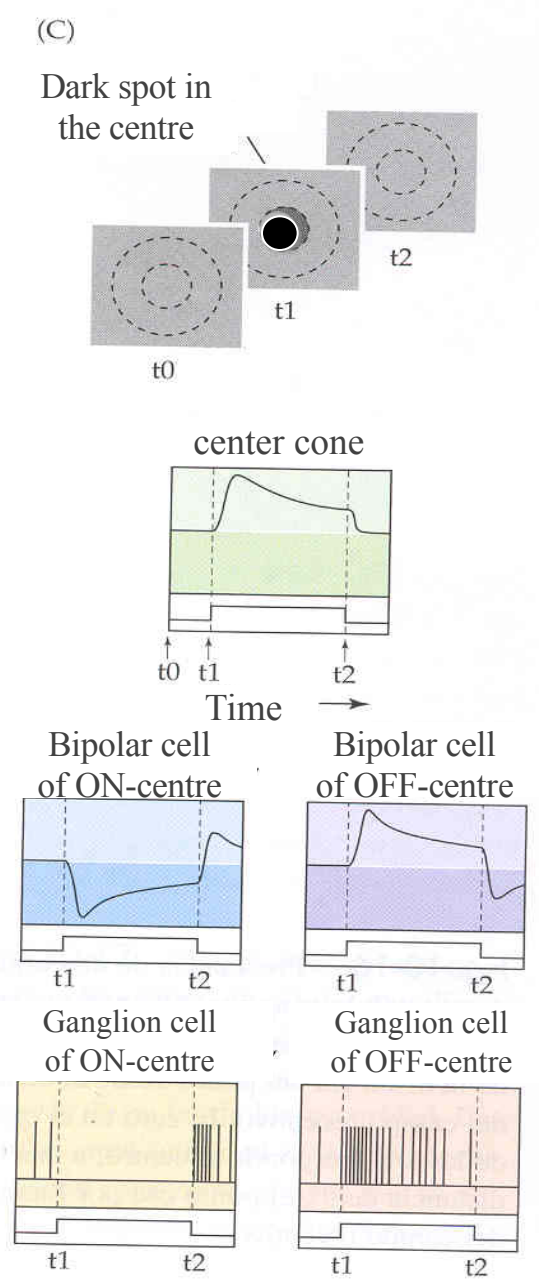
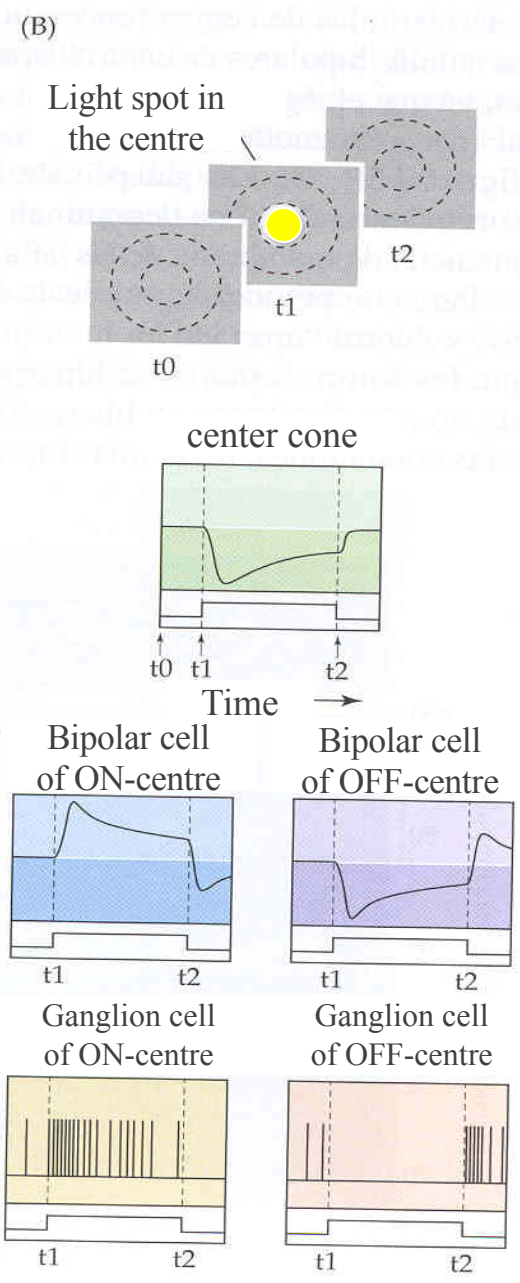
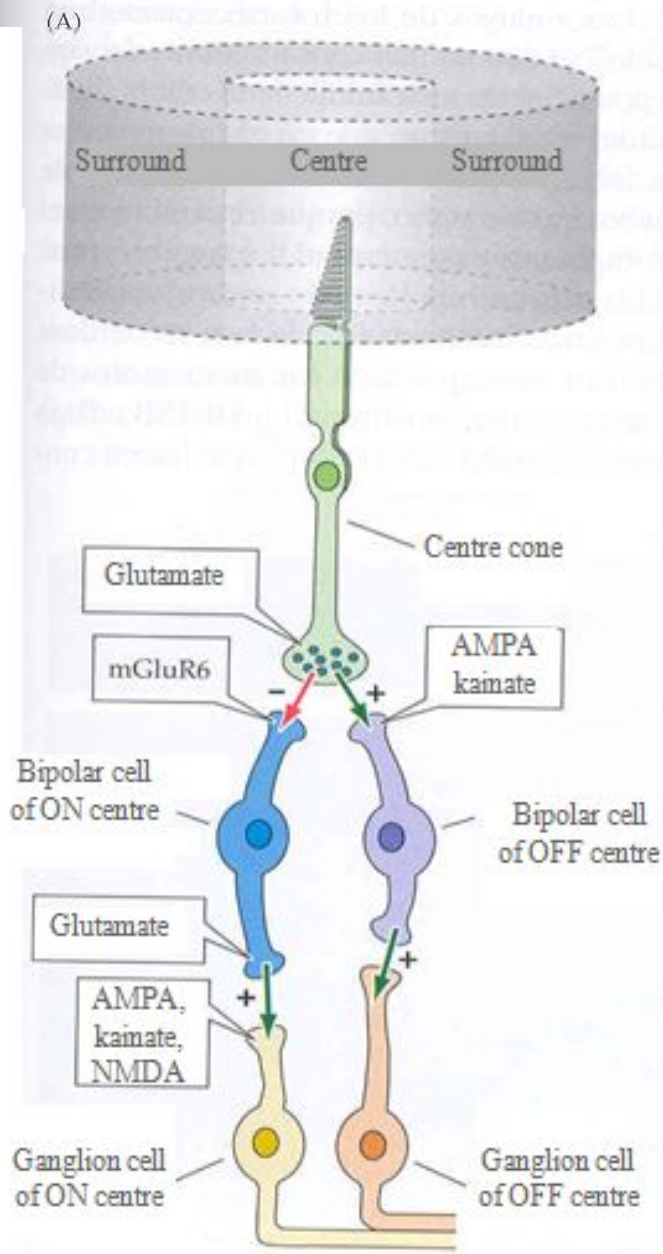
Ganglion cell of ON-centre

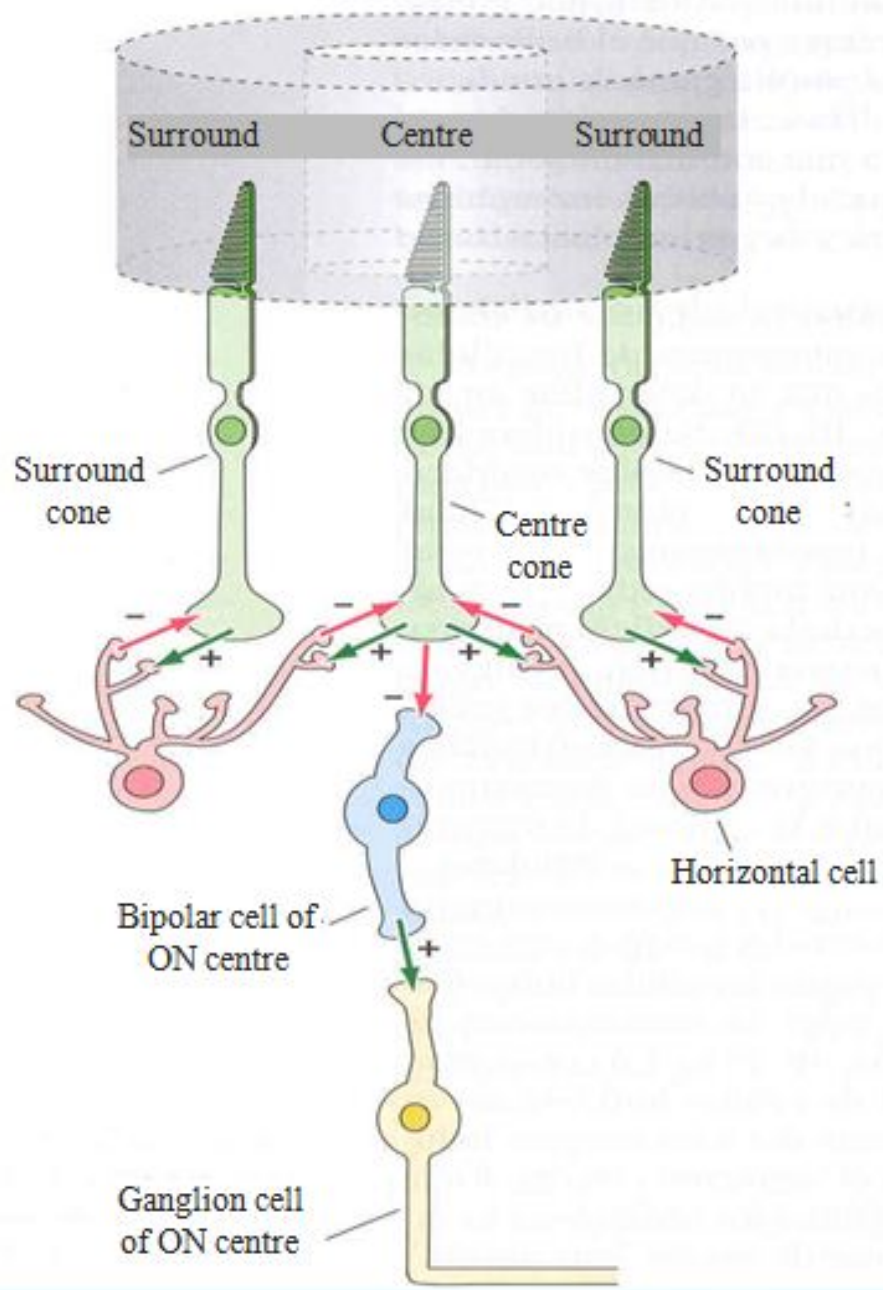


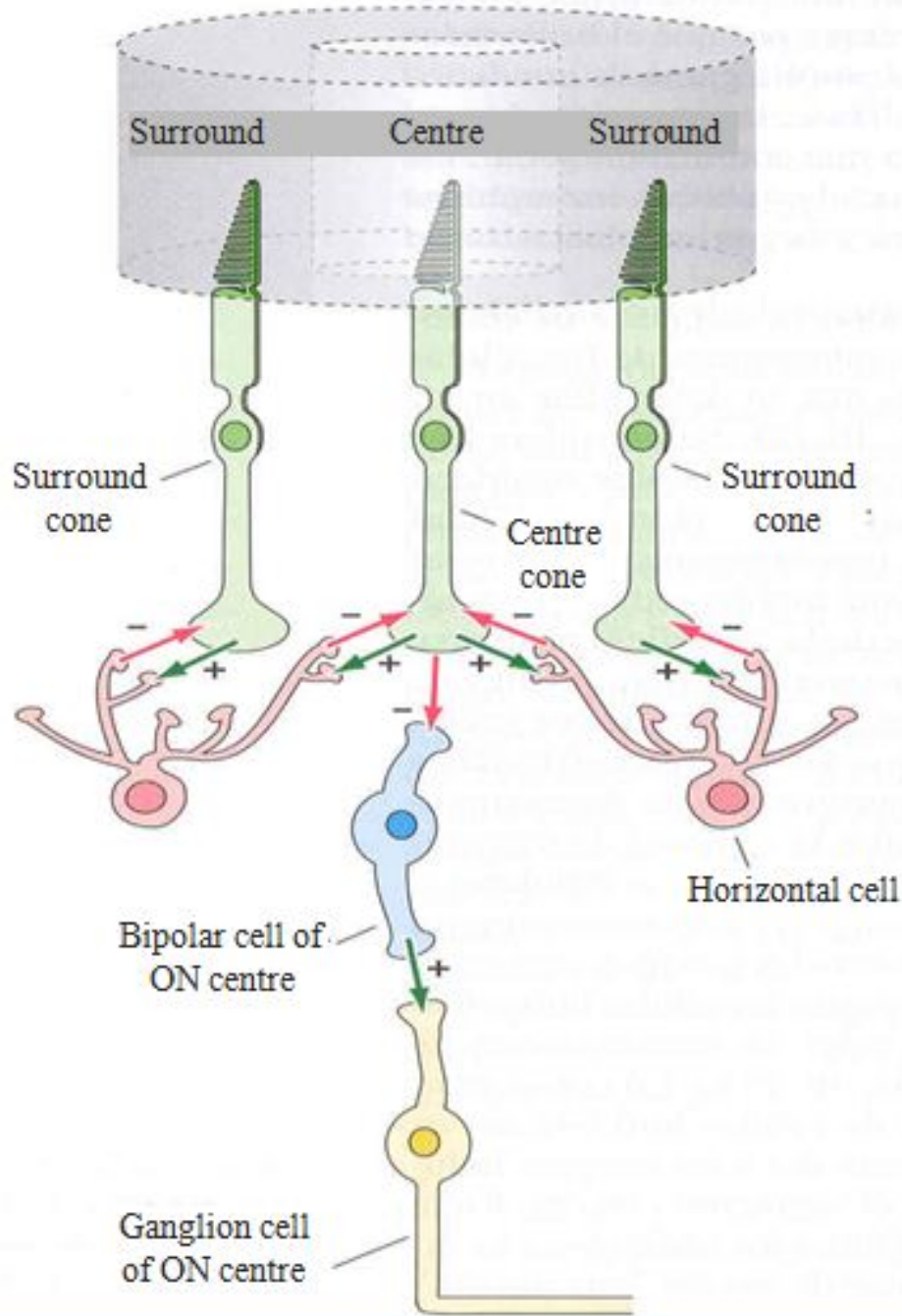


**OFF**

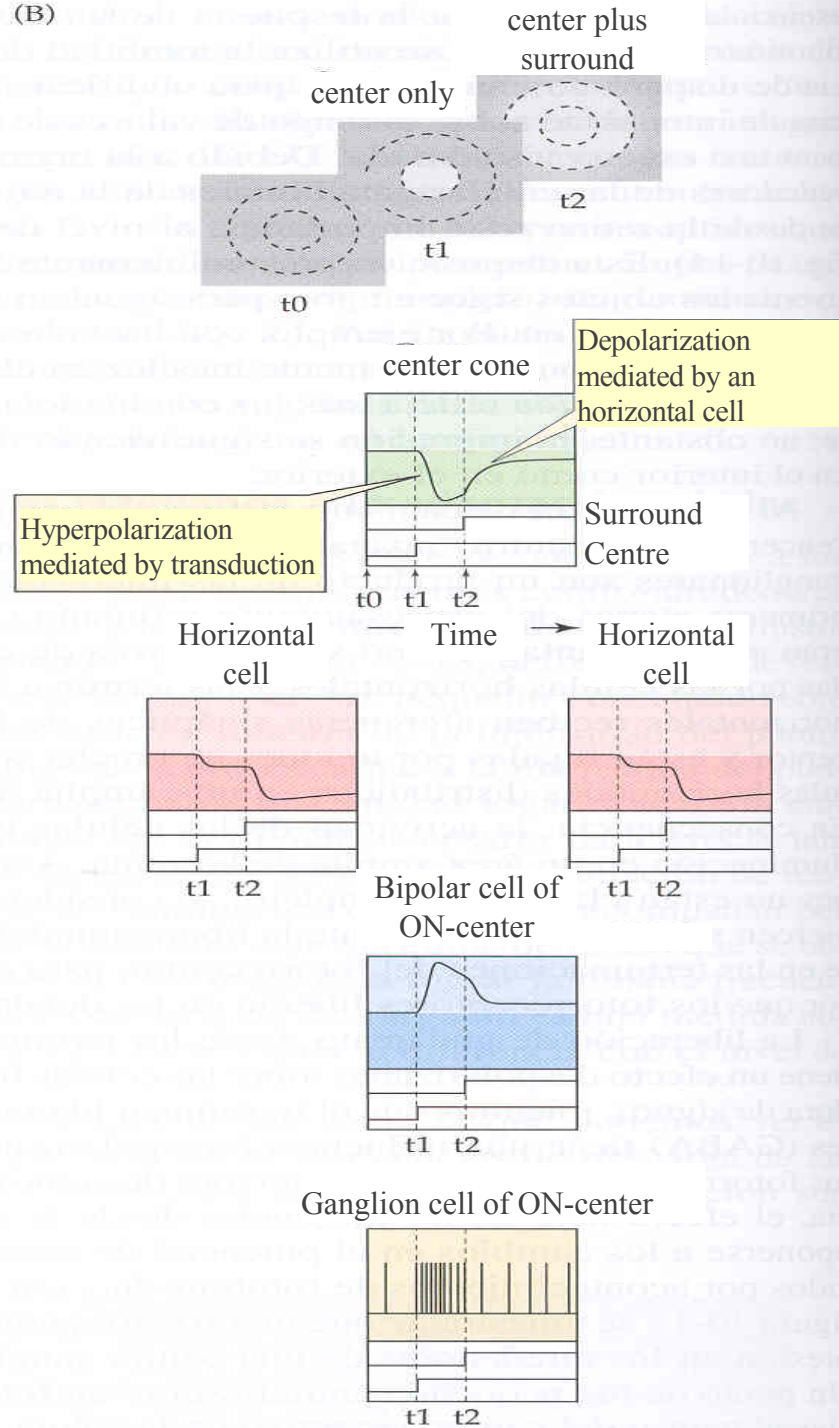






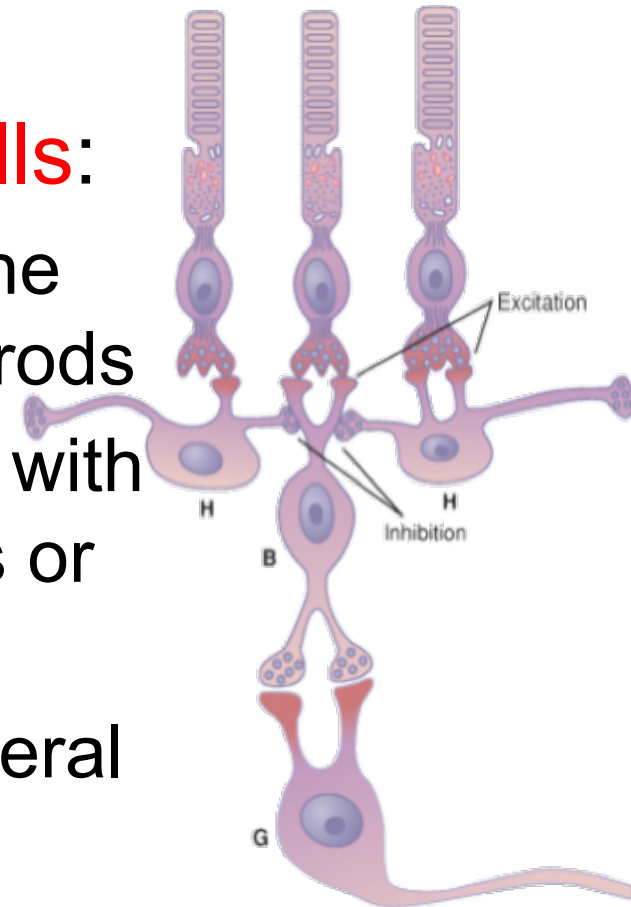


(B)



# ON-OFF Pathways

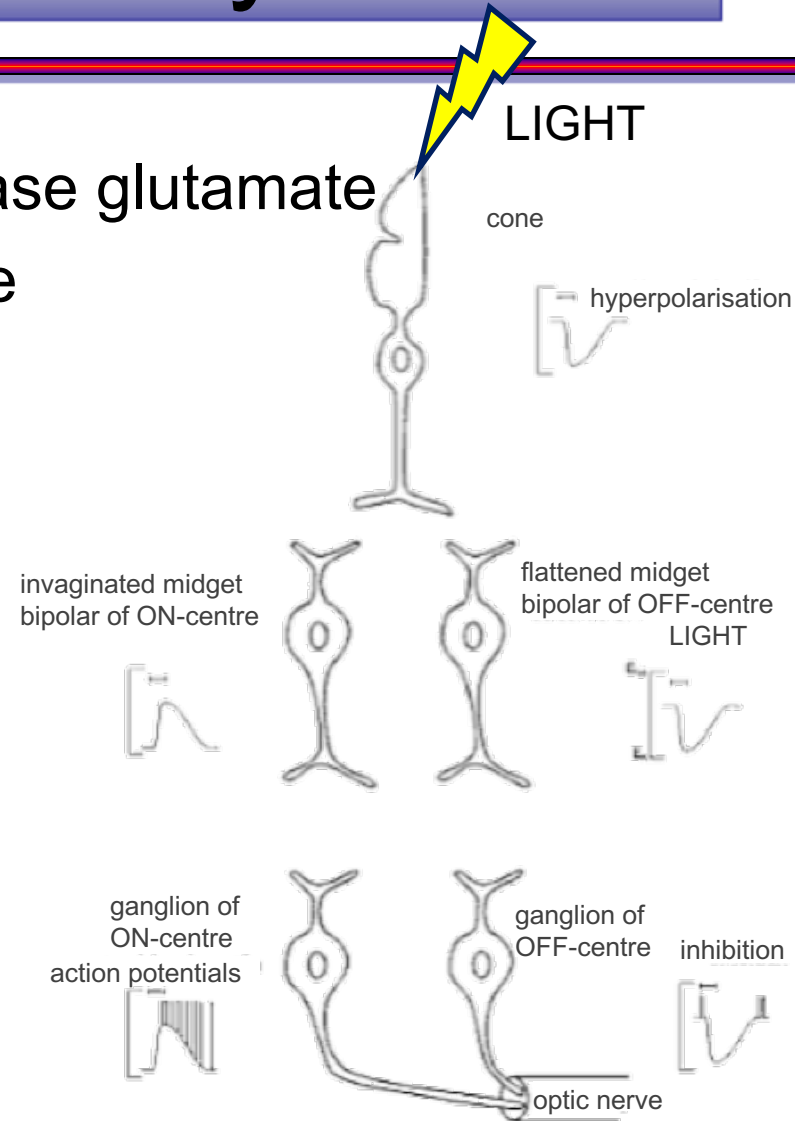
- The **horizontal cells** send inhibitory signals to the bipolar cells
- There are two kind of **bipolar cells**:
  - Depolarizing: it depolarizes with the release of glutamate by cones or rods
  - Hyperpolarizing: it hyperpolarizes with the release of glutamate by cones or rods
  - Complementary mechanism of lateral inhibition (more discriminatory)



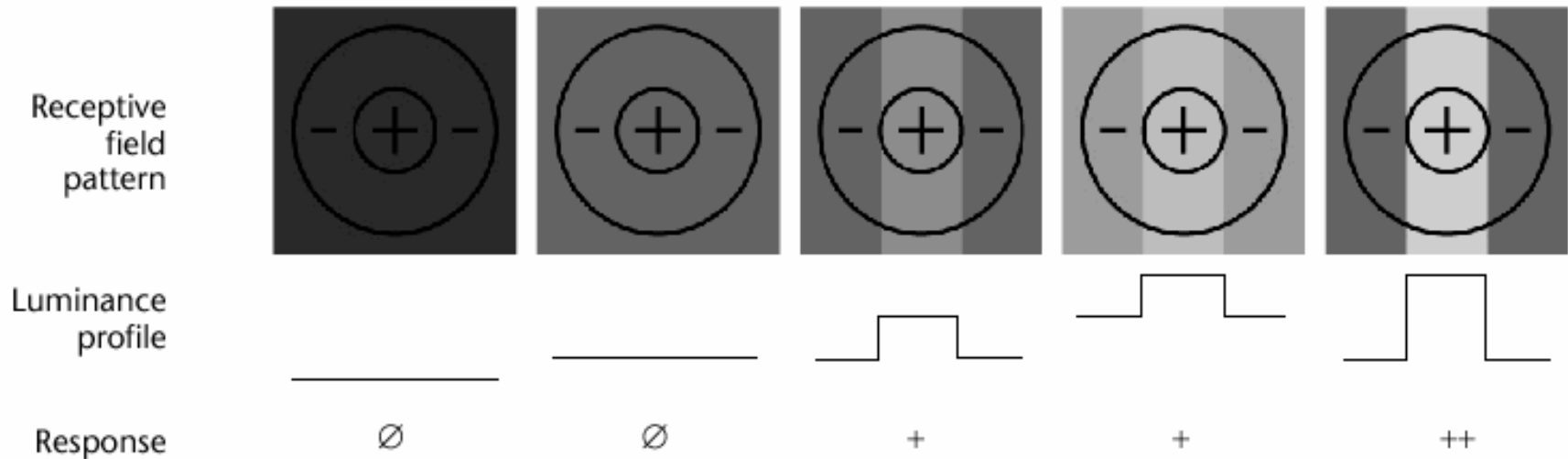


# ON-OFF Pathways

- In the dark, the photoreceptors release glutamate
- Two types of receptors for glutamate in the bipolar cells:
  - ✓ On: hyperpolarization (in the dark)
  - ✓ Off: depolarization (in the dark)
- When light comes in contact, the glutamate is reduced, the ON cells are depolarized and the OFF cells are hyperpolarized.
- The more light there is, there is proportionally more on depolarization.

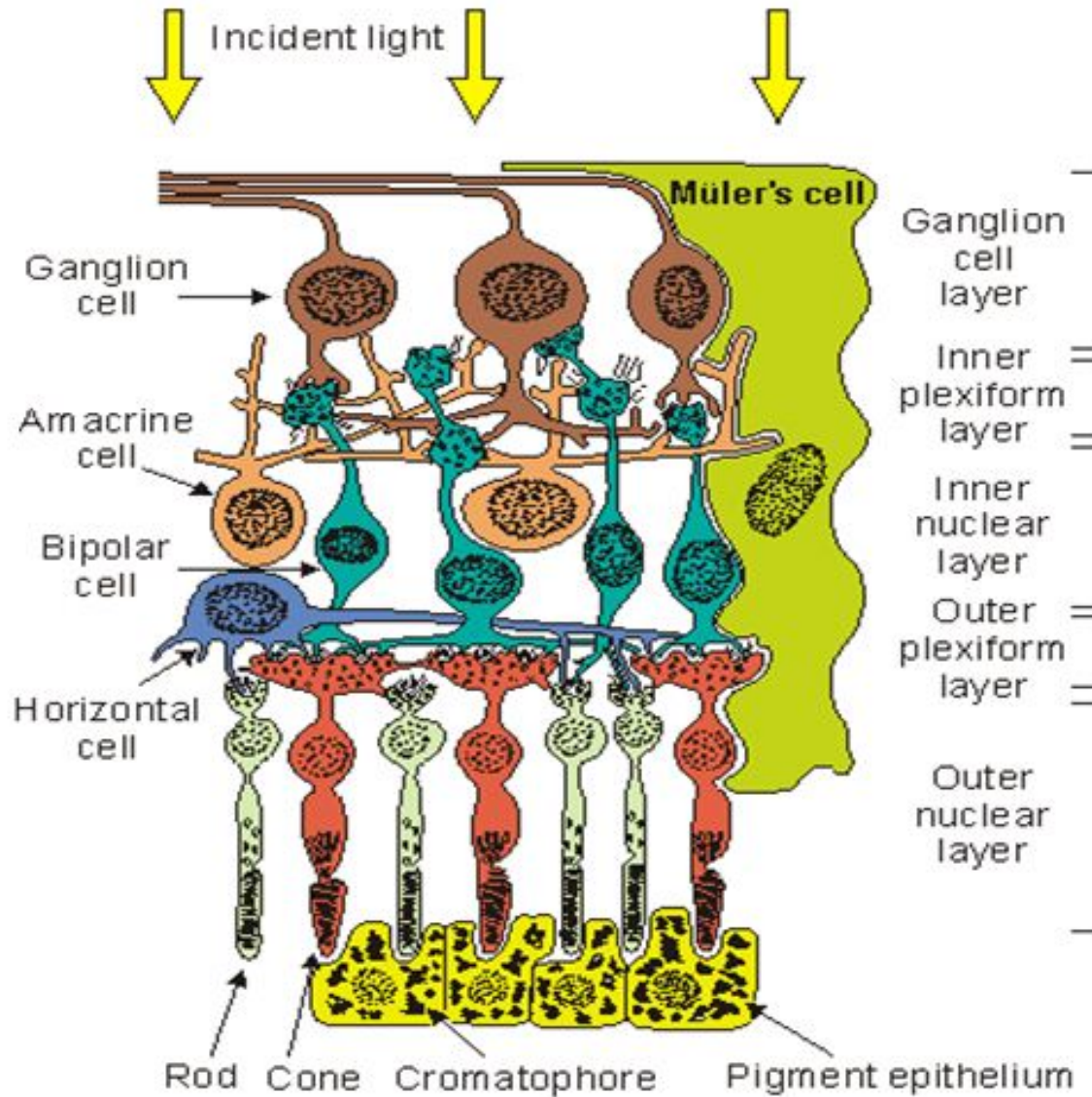


# ON-OFF Pathways

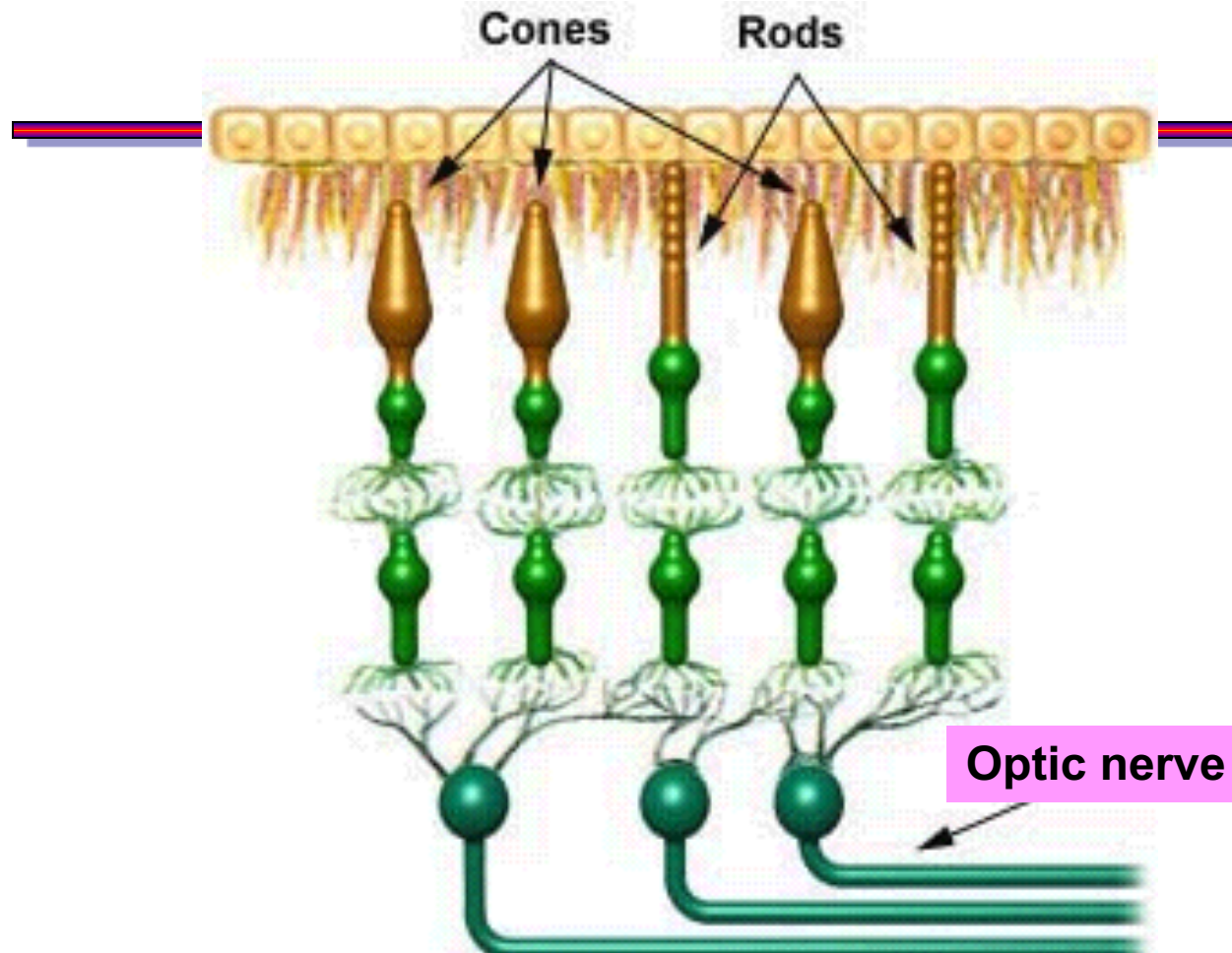


- When the bipolar cells depolarize, **action potentials** are produced in the ON ganglion cells and the signal is transmitted.
- The action potentials are only produced in the ganglion cells. Up to that point, they are electric synapses.

# STRUCTURE OF THE RETINA



# ACTION POTENTIALS

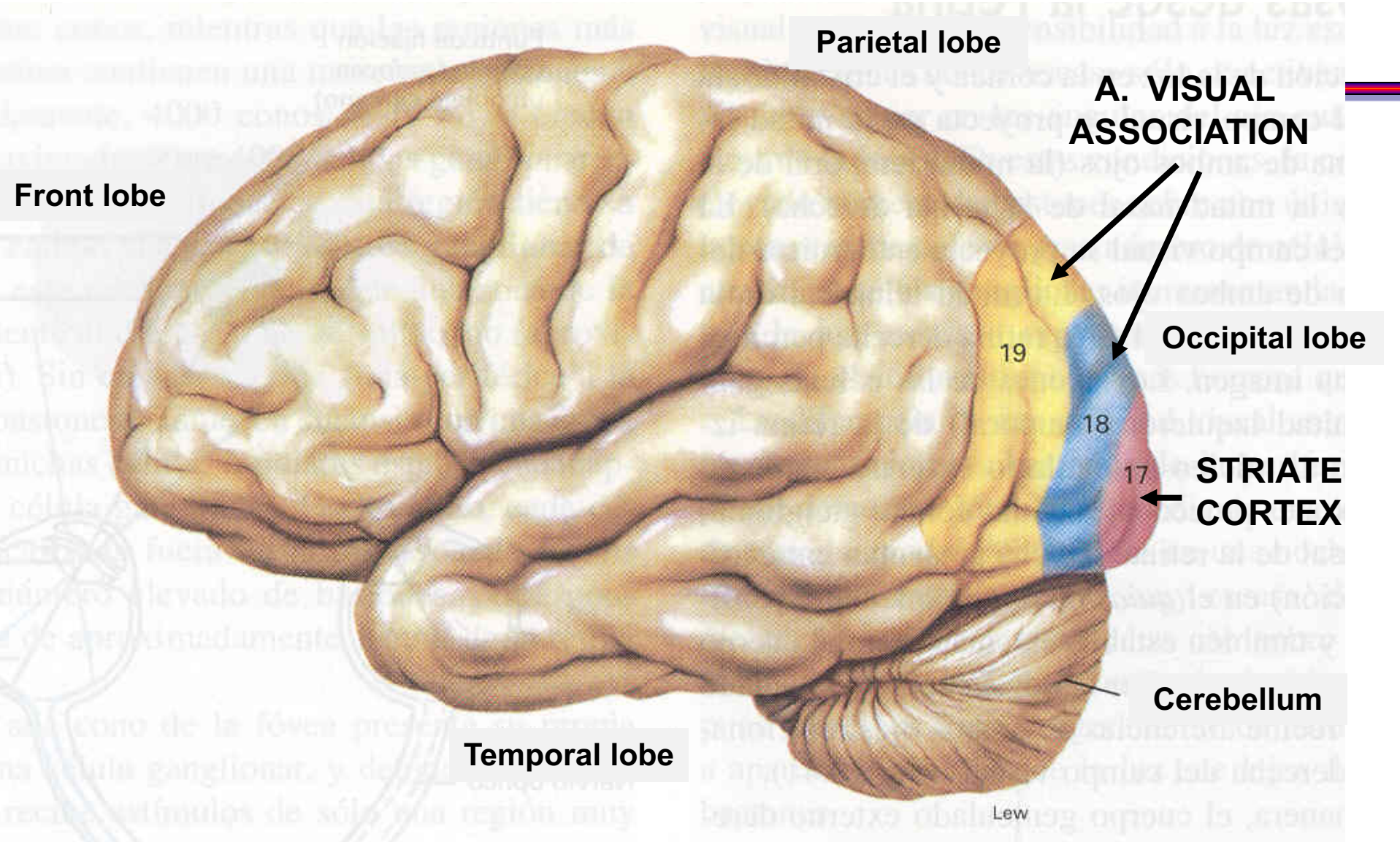


The action potentials initiate in the ganglion cells and are transmitted to the brain by the optic nerve.

# Retina. Electric Activity

---

- **Electrotonic conduction**: the neurons of the retina (except for the ganglion cells) transmit a direct flow of electric current (not action potentials) from the excitatory point up to the exit synapses.
- This allows the **layered conduction** of the signal potential (it is not “all or nothing”).



Parietal lobe

A. VISUAL ASSOCIATION

Front lobe

Occipital lobe

19

18

STRIATE CORTEX

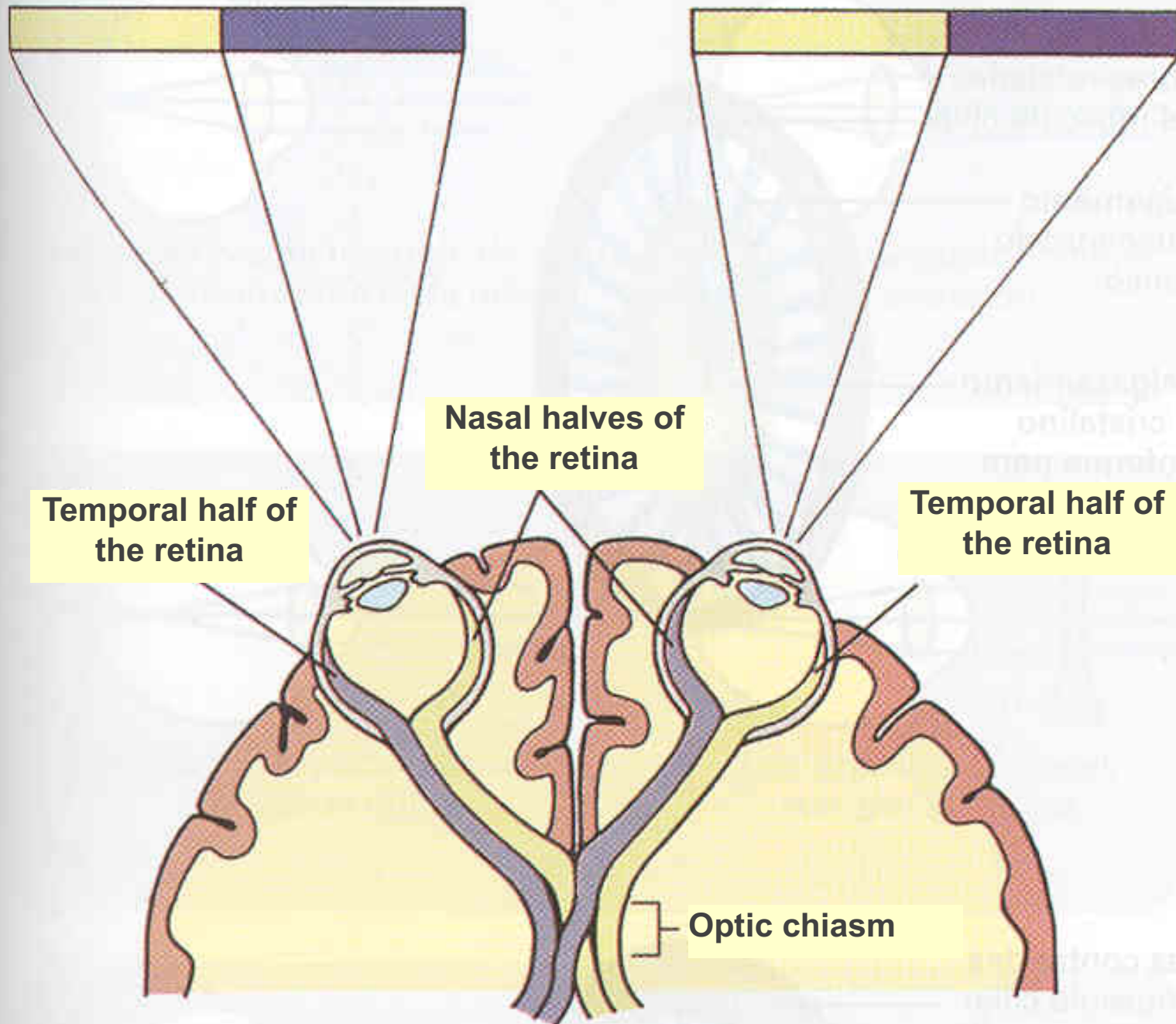
17

Cerebellum

Temporal lobe

Lew

# FIELDS OF VISION



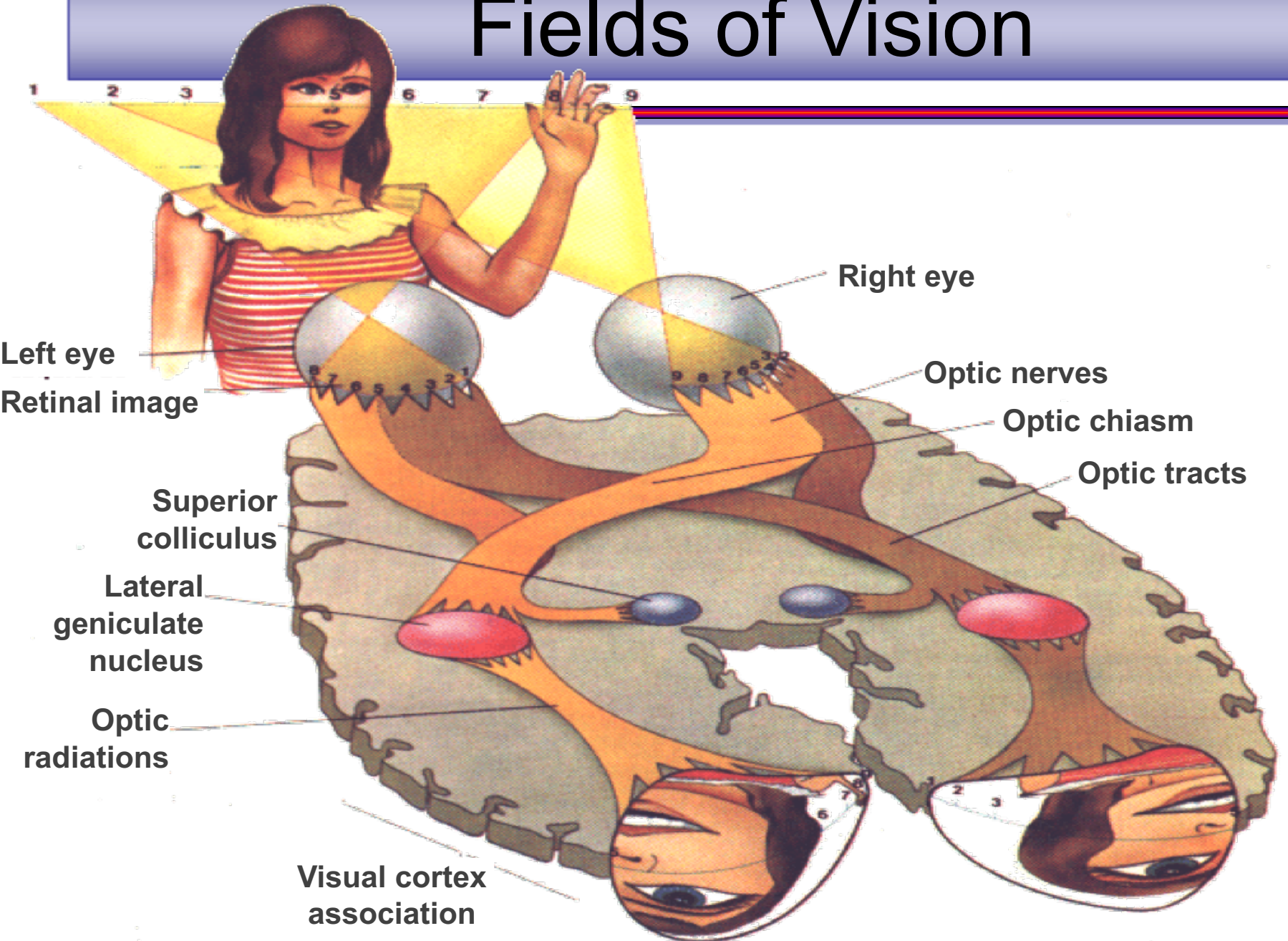
Temporal half of the retina

Nasal halves of the retina

Temporal half of the retina

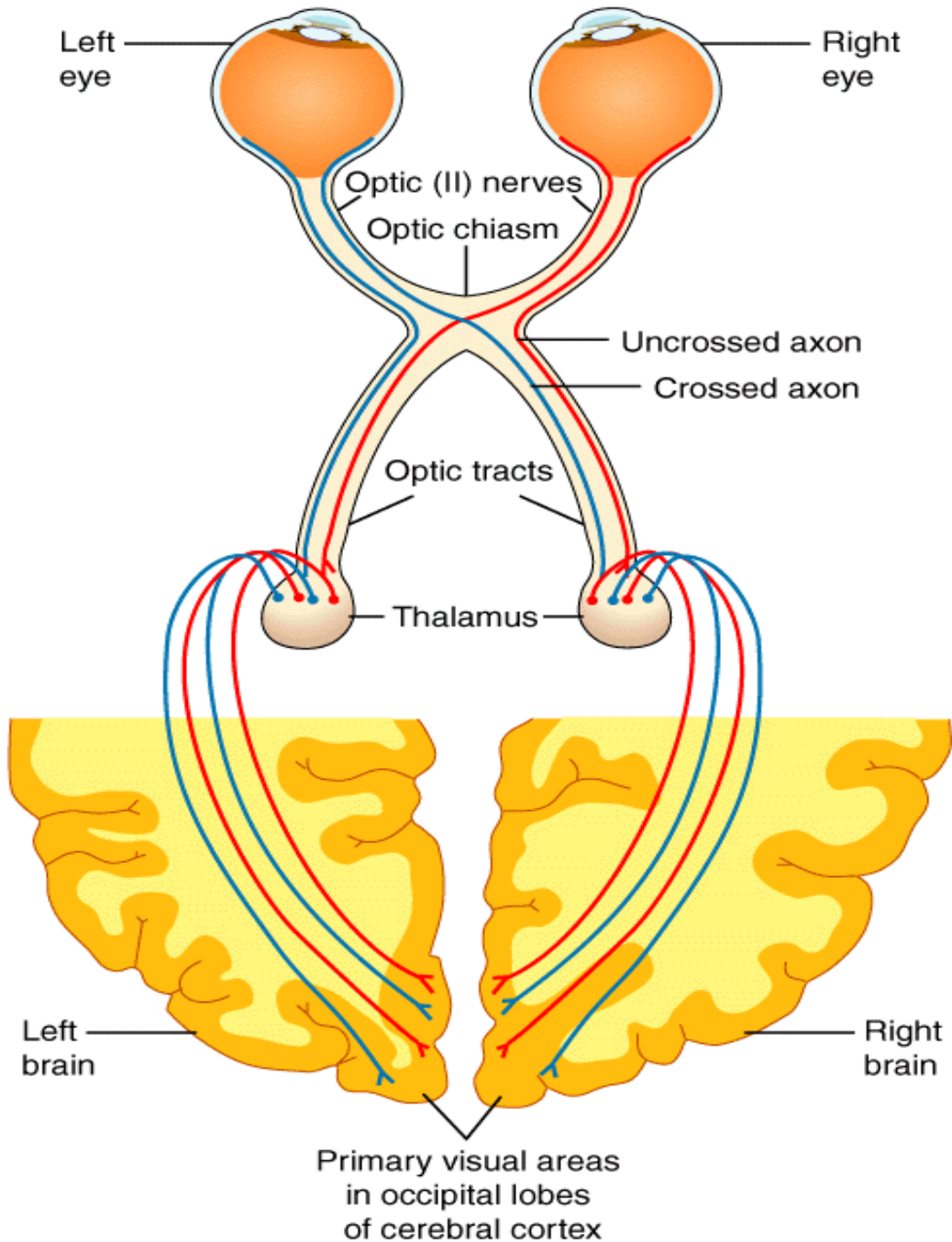
Optic chiasm

# Fields of Vision

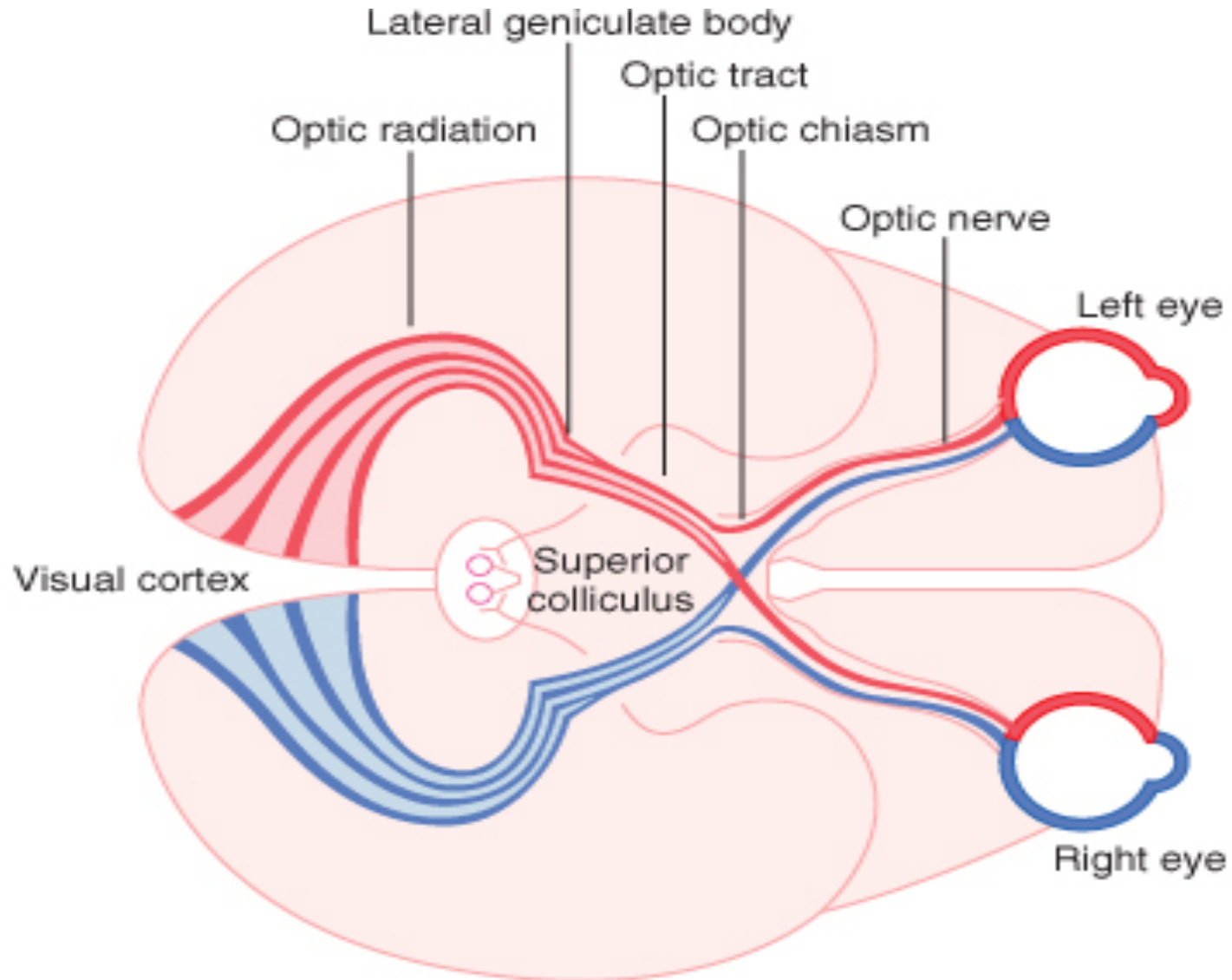




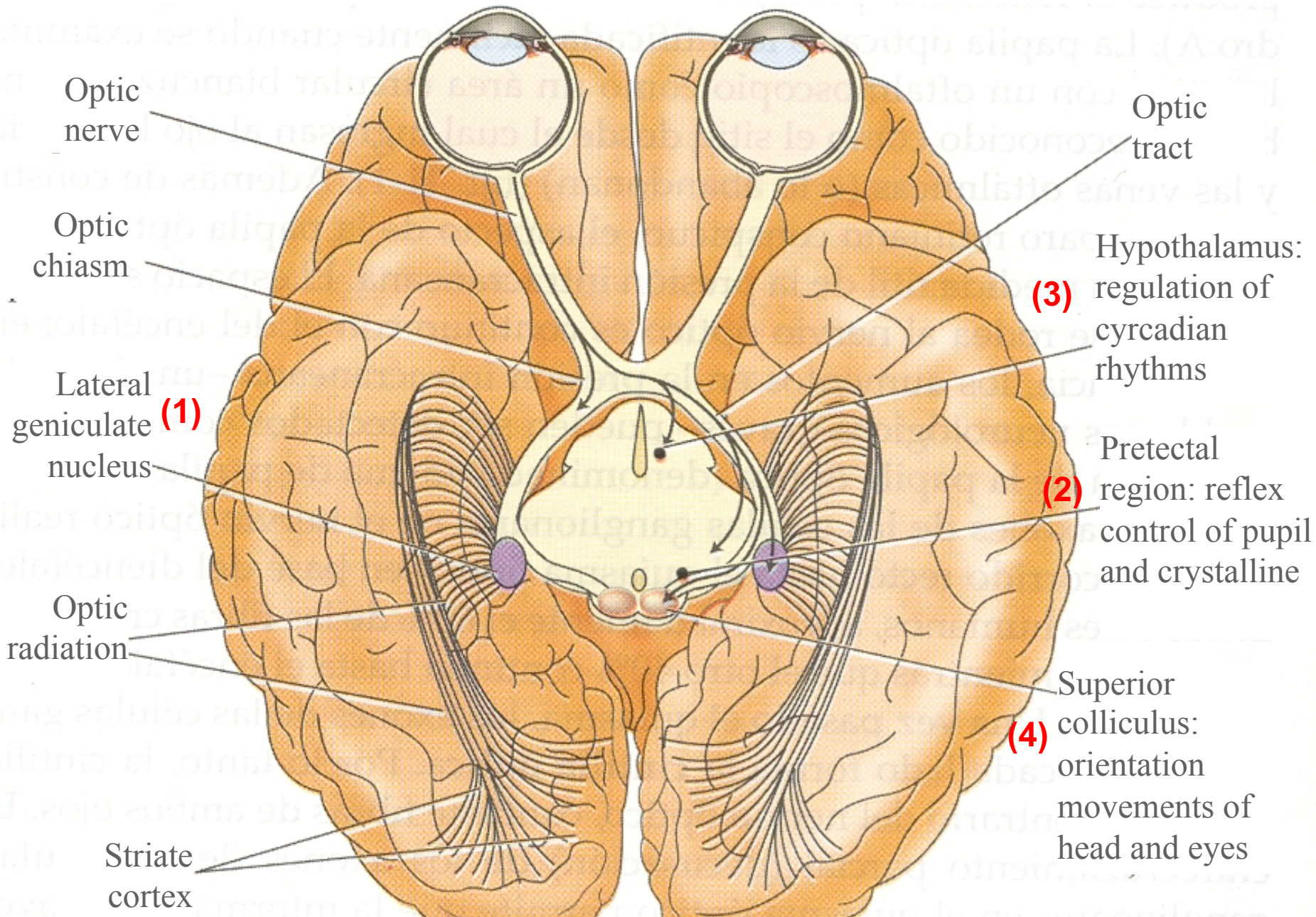
# VISION PATHWAYS



# Vision pathways



# TARGET STRUCTURES OF GANGLION AXONS



# CAMPIMETRIC DEFECTS DUE TO DAMAGE OF THE VISUAL PATHWAY

## Vision field

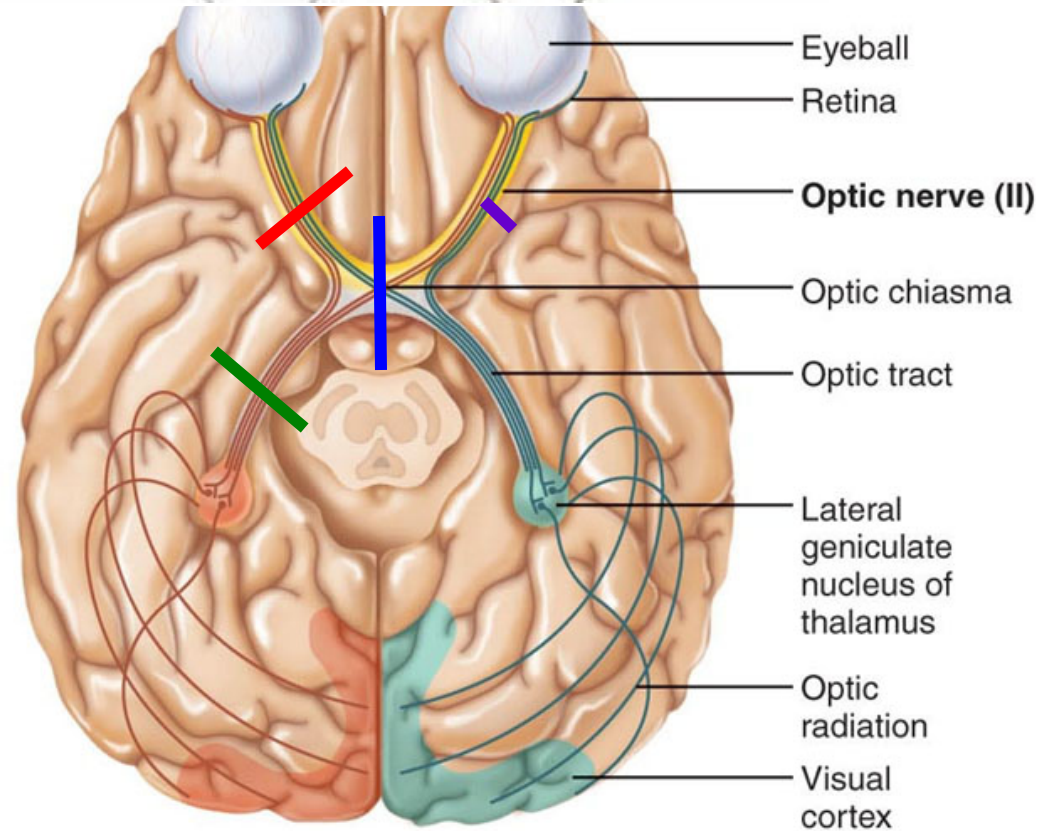


1. Section of the left optic nerve

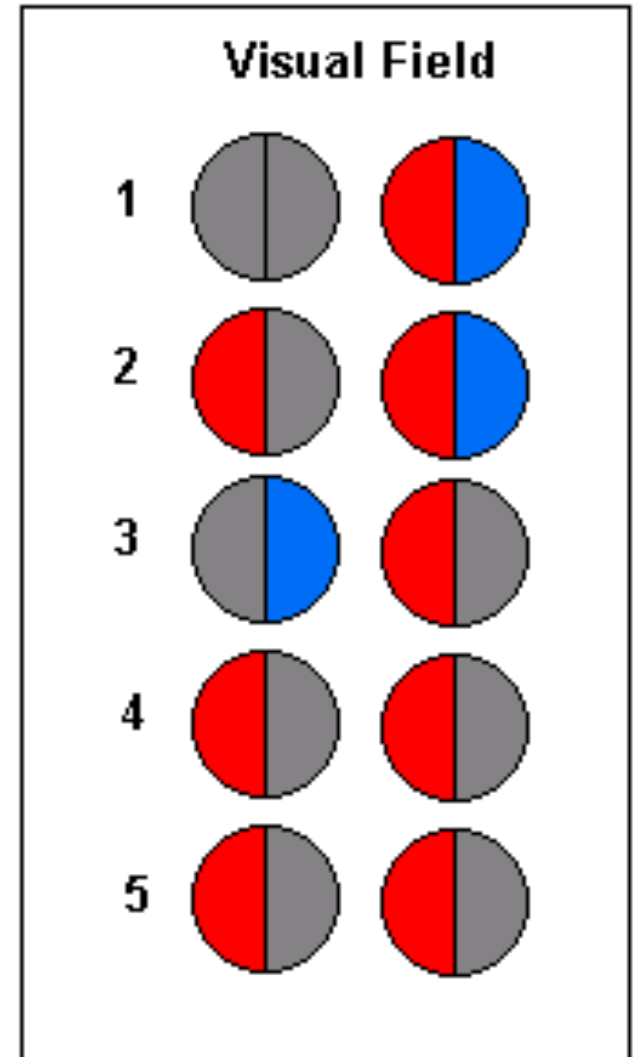
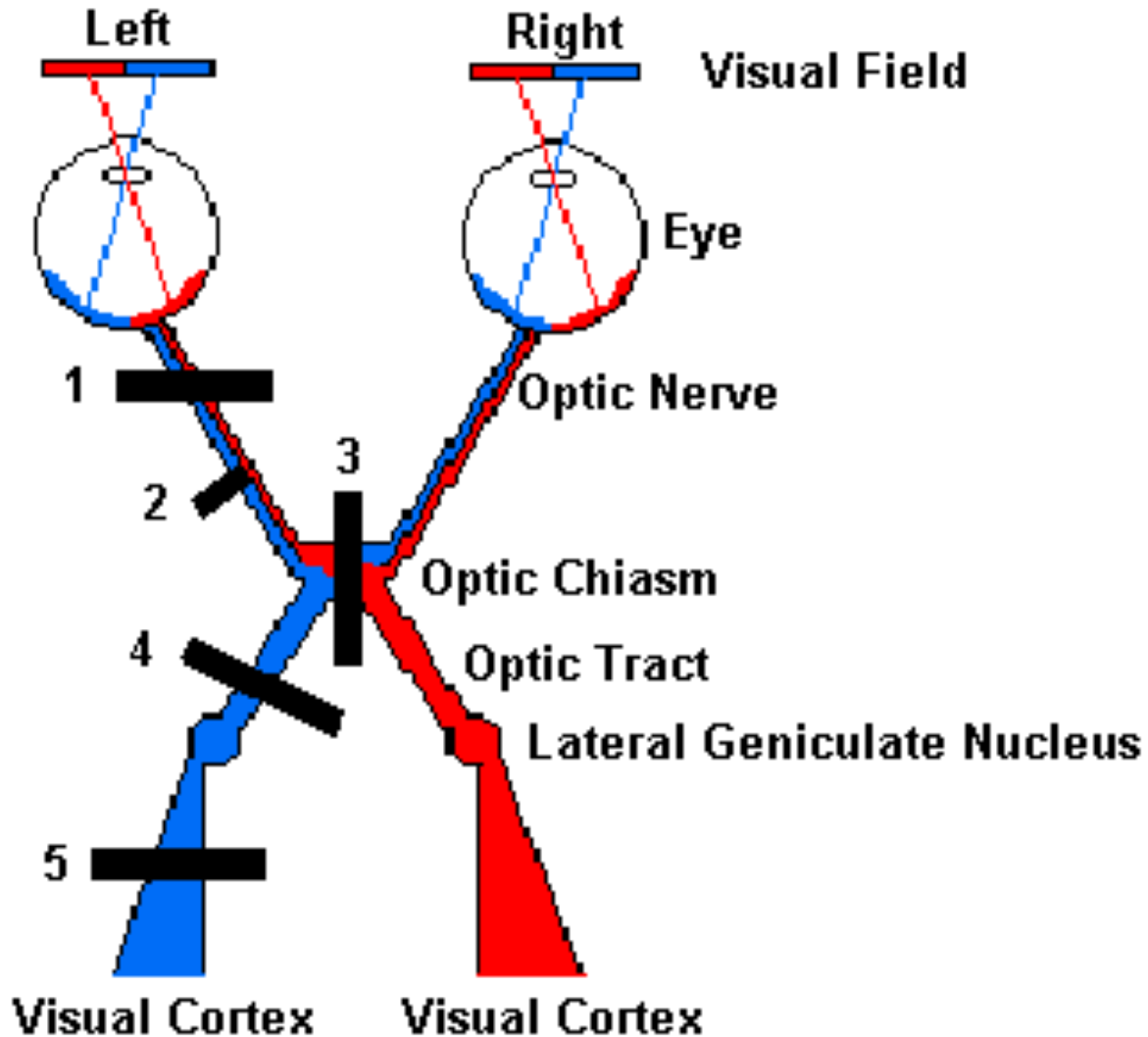
2. Section of the left optic tract

3. Section of the optic chiasm

4. Section of fibers external to the right optic nerve

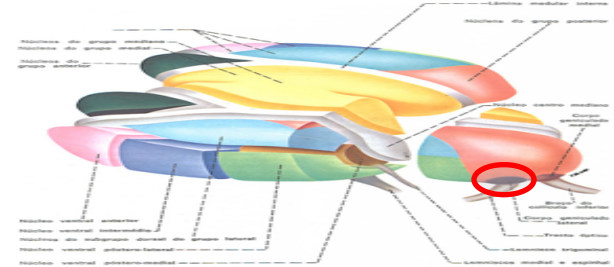


# Vision pathways





# Lateral geniculate nucleus



- Two basic types of neurons:

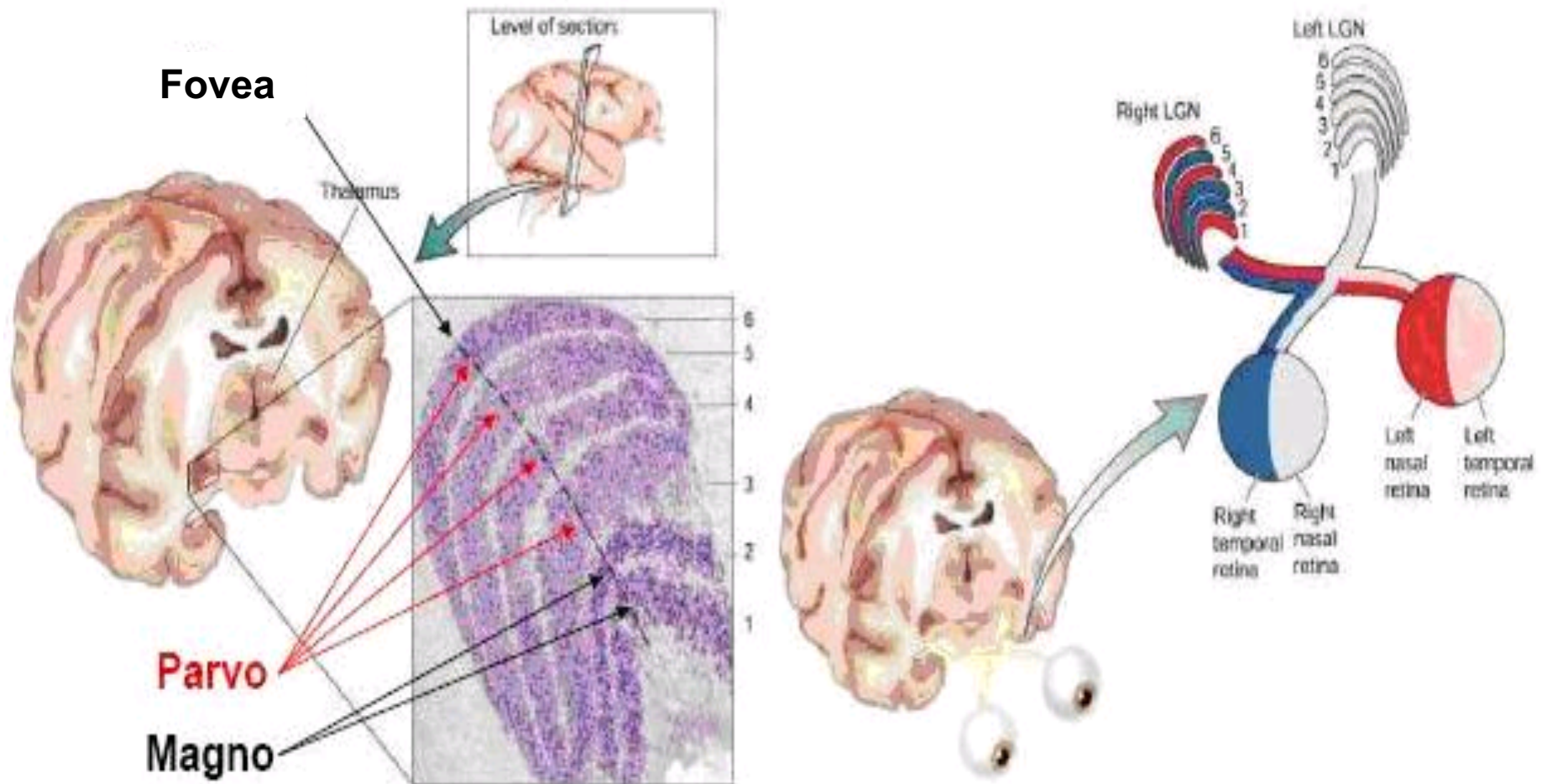
- **Main**

- **Parvocellular**: color and visual acuity (cones)
    - **Magnocellular**: black and white vision (rods) and movement. Little detail.

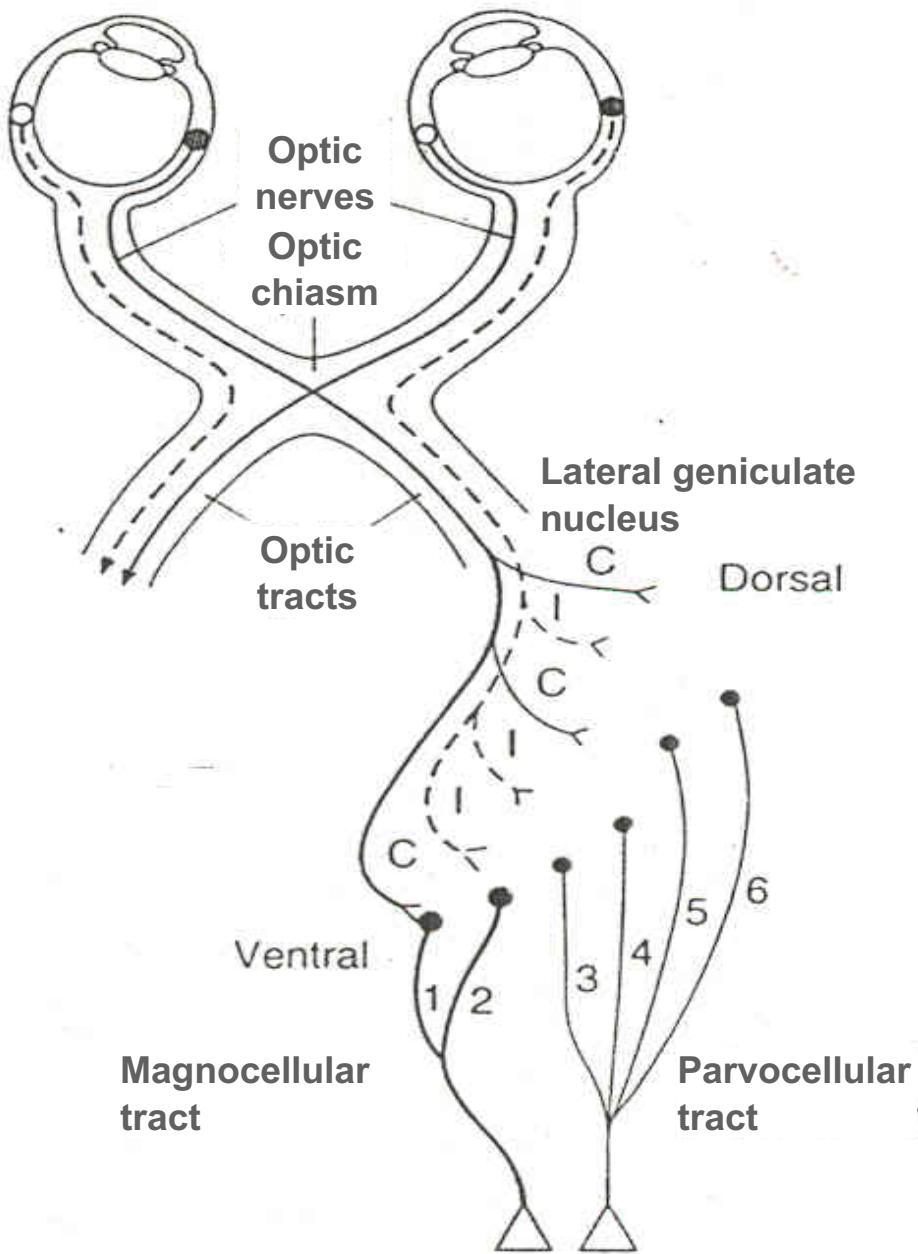
- **Interneurons**: communicate the different layers of the lateral geniculate nucleus and non-retinal signals (colliculi) in order to integrate what we see:

- The geniculate nucleus has 6 cellular layers: magnocellular in the 1<sup>st</sup> and 2<sup>nd</sup> layer and parvocellular in the remaining 4.
    - 70% of the information the lateral geniculate nucleus processes comes from the fovea (the rest comes from colliculi and lateral cortex and makes up what we see).
    - Organizes visual information and movement.

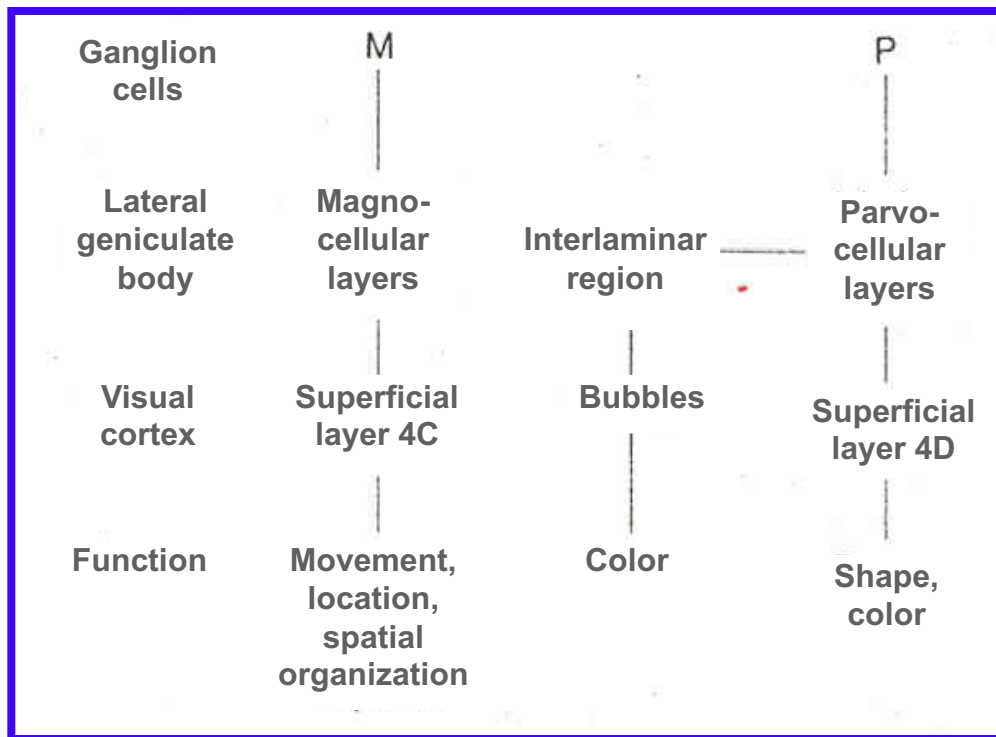
# Lateral geniculate nucleus





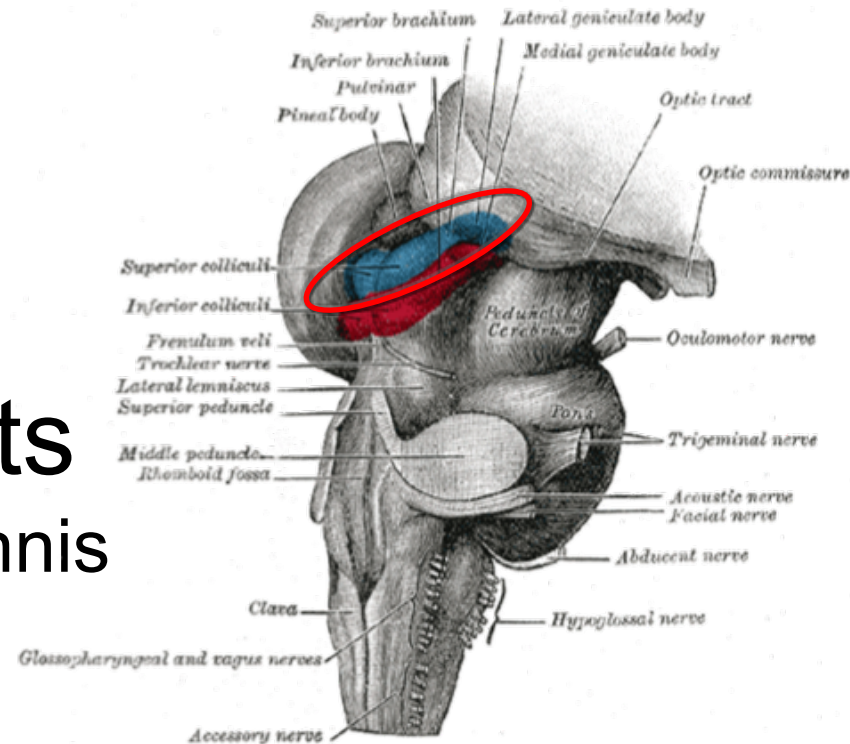


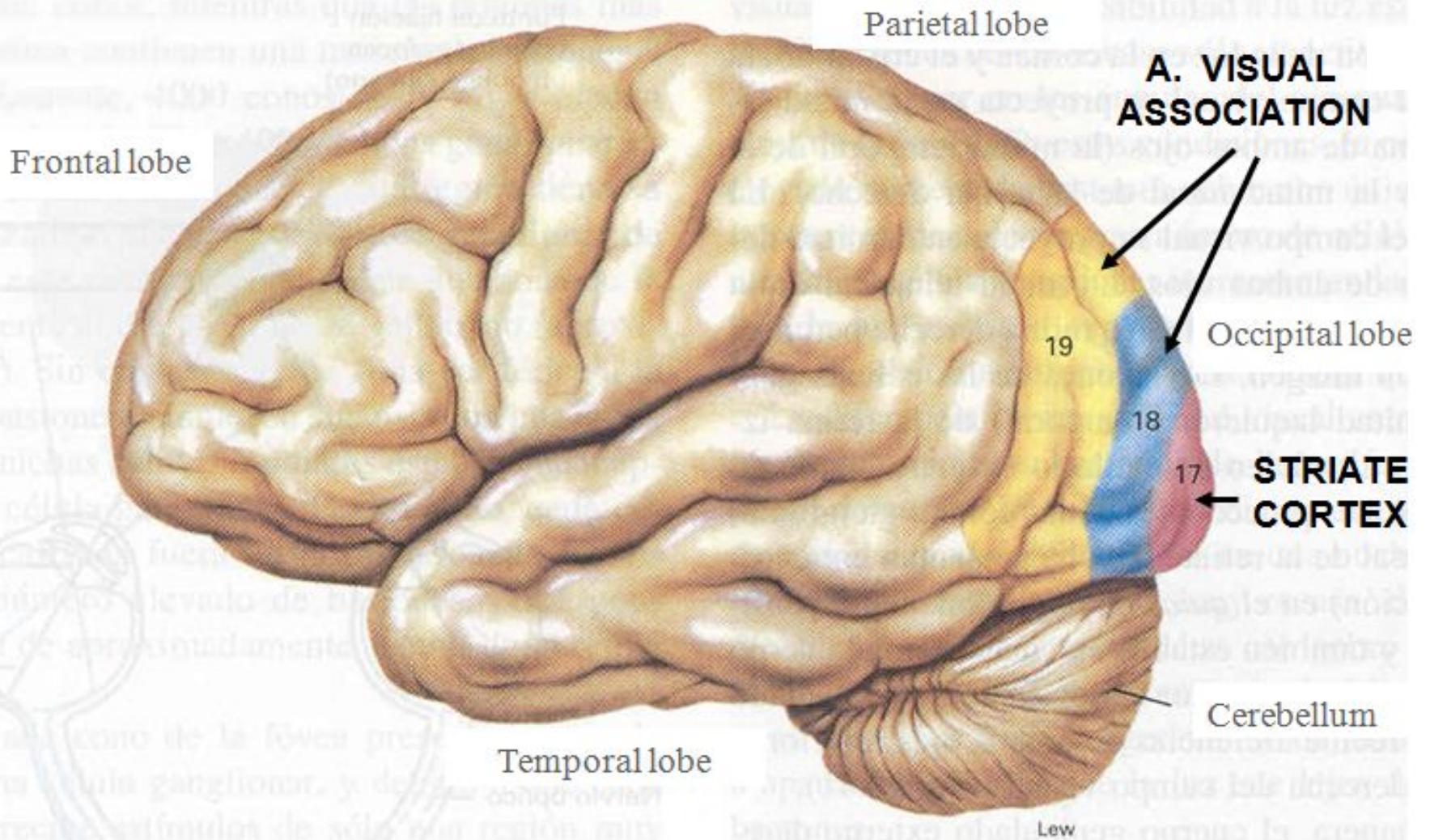
Primary visual cortex (area 17)



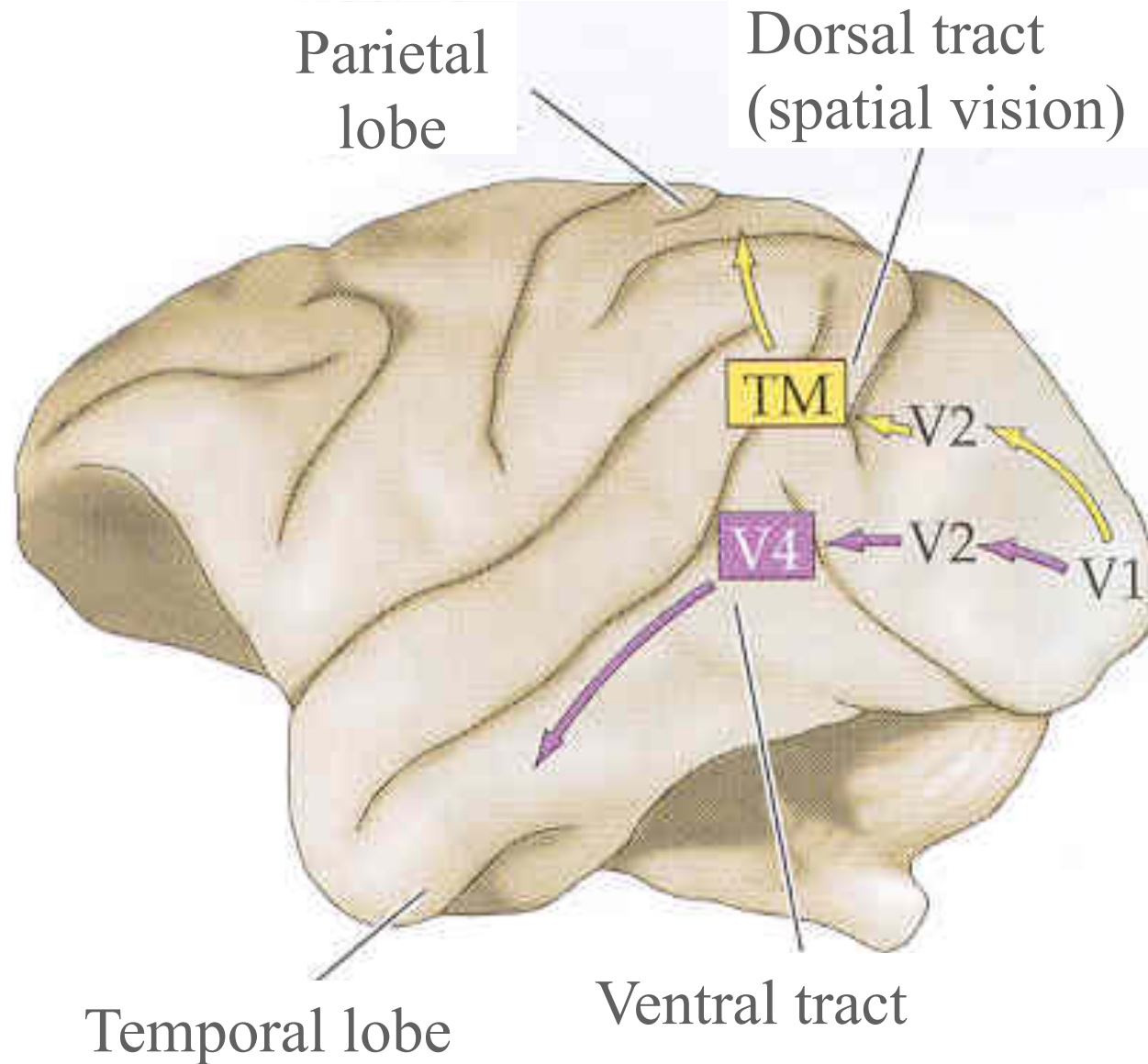
# Colliculus

- It is responsible for the coordination of the eye movements, especially the saccadic movements (for instance, watching a tennis game)





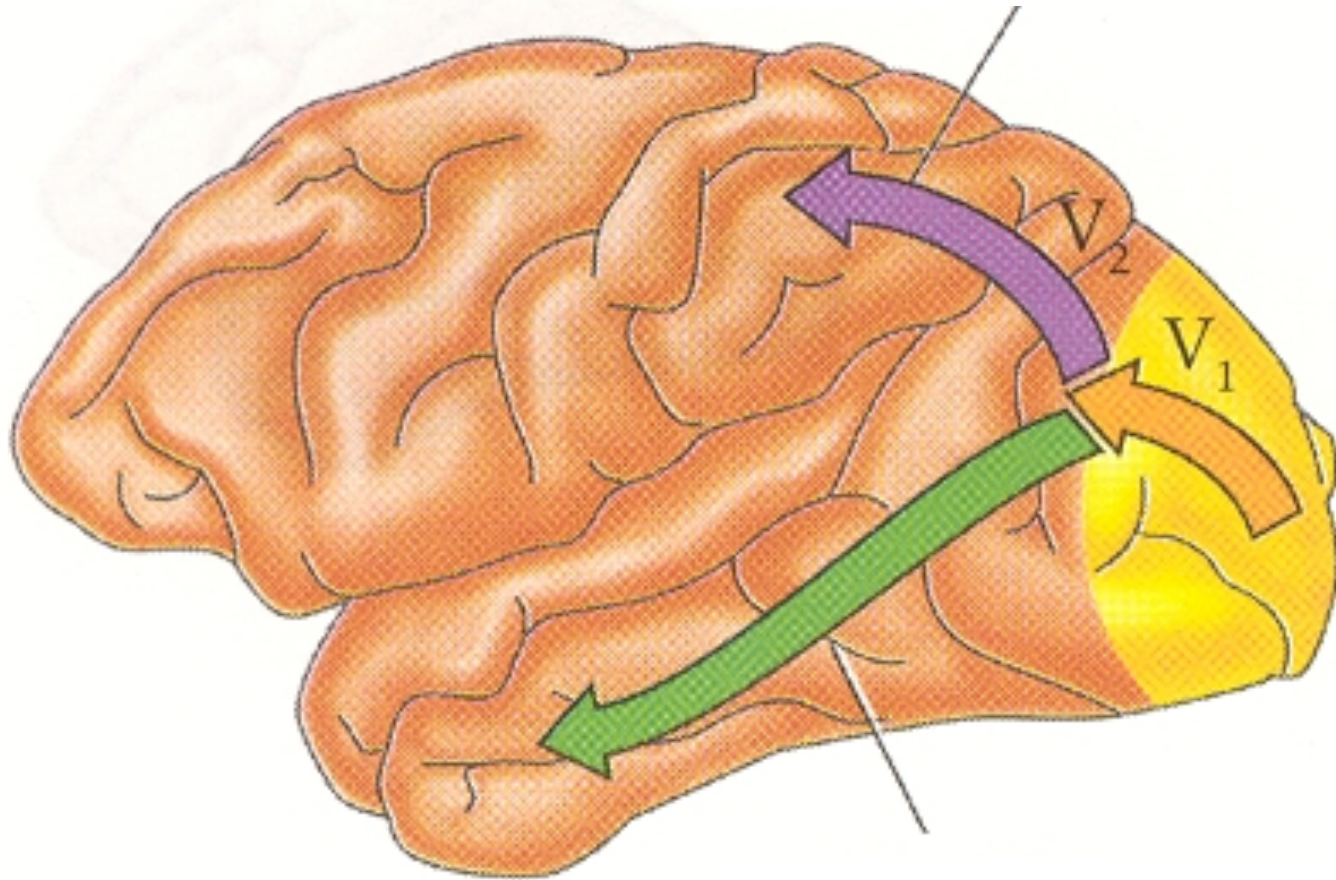
# EXTRASTRIATE VISUAL AREAS



# EXTRASTRIATE VISUAL AREAS

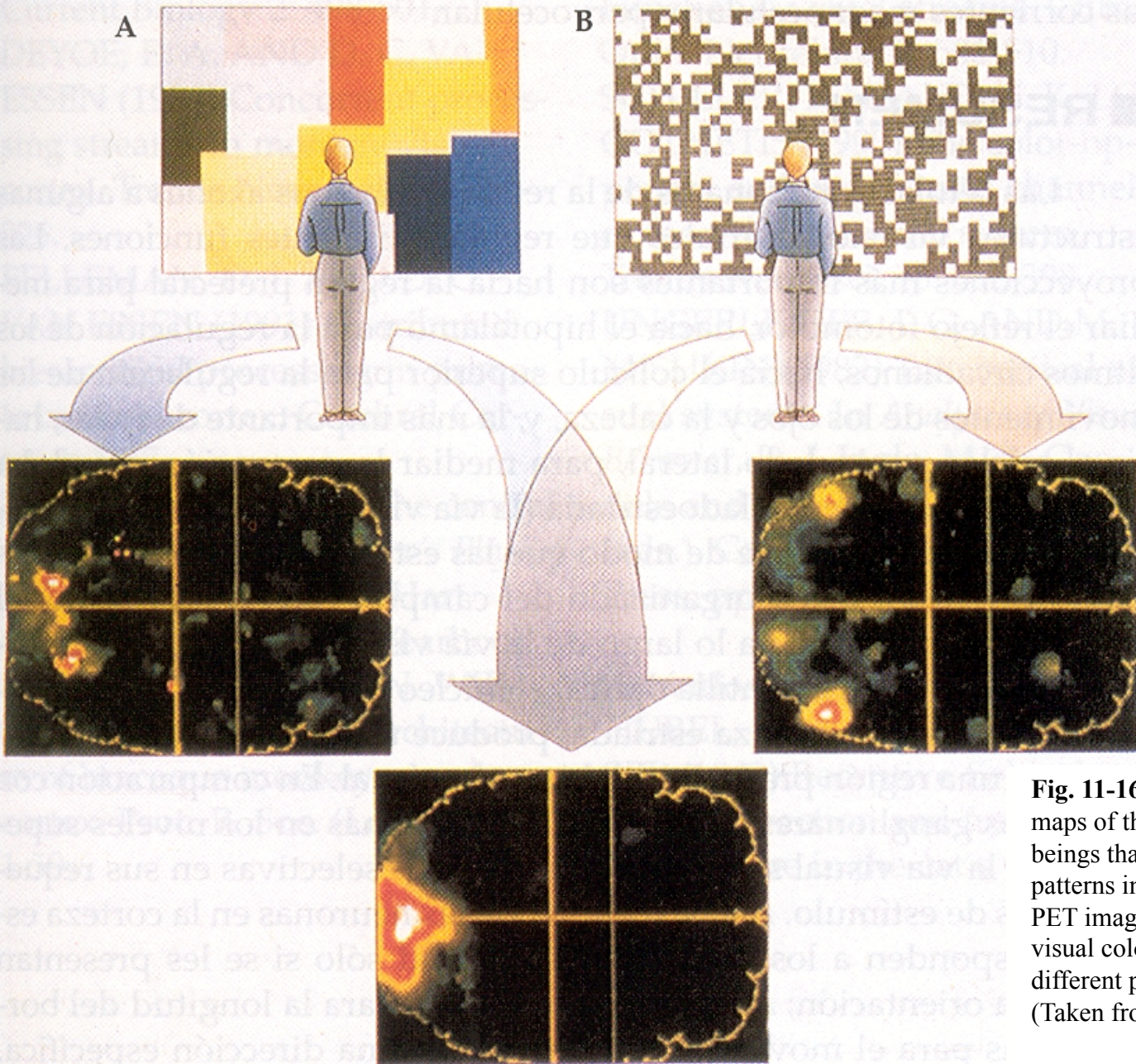
**DORSAL TRACT**

Spatial vision  
tract



**VENTRAL TRACT**

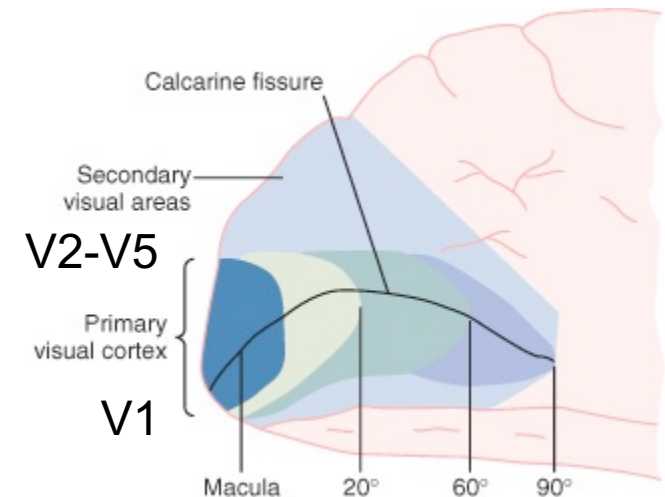
Object recognition  
tract



**Fig. 11-16.** Comparison of the functional maps of the extrastriate cortex in human beings that see color patterns (A) and patterns in movement (B). These horizontal PET images (Box E, Ch. 1) show that the visual color and movement stimuli activate different parts of the extrastriate cortex. (Taken from Zeki, 1990.)

# Visual cortex

- There are at least 12 different visual cortices:
- **V1 (color), V2 (movement), V3 (movement), V4 (color and complex shapes), V5 (movement)** are the best-known
- The main neurons emit axons that form the optic or Gratiolet's radiation, that reaches the visual cortex (occipital)

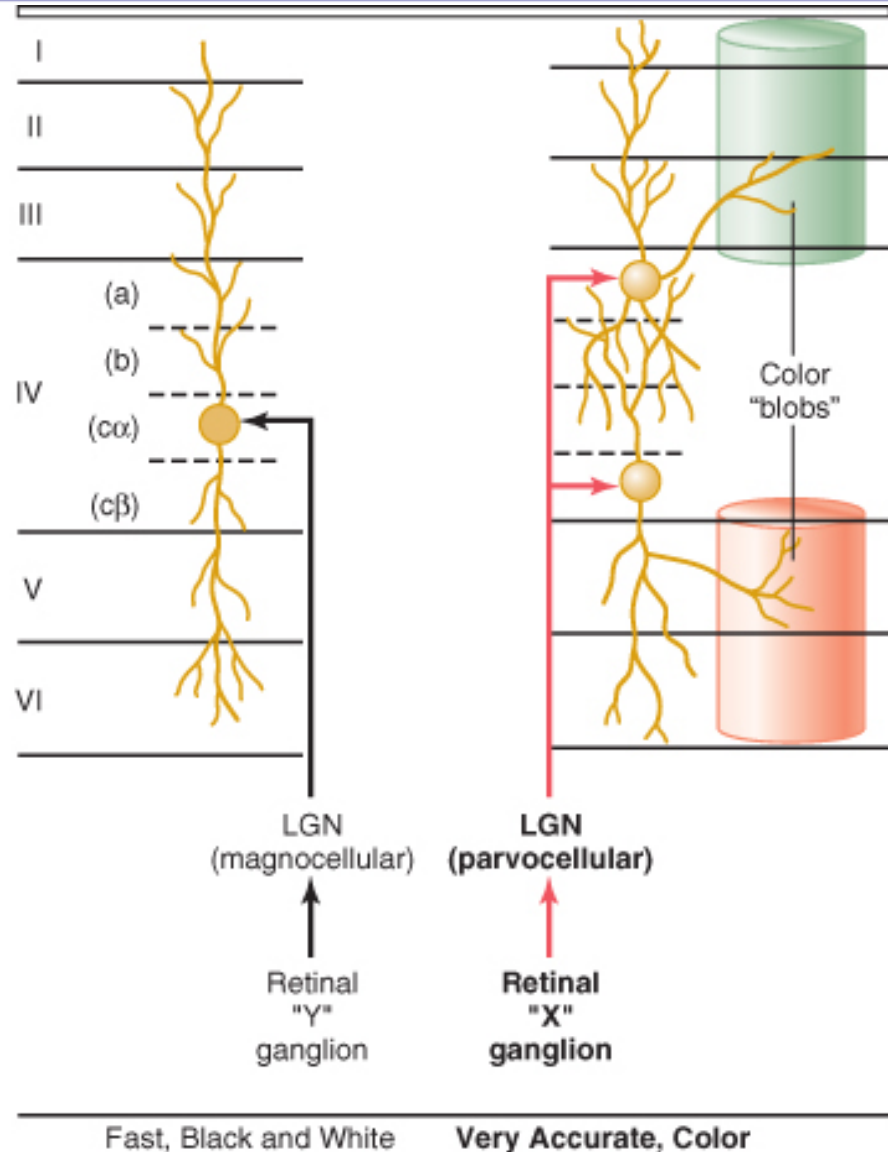


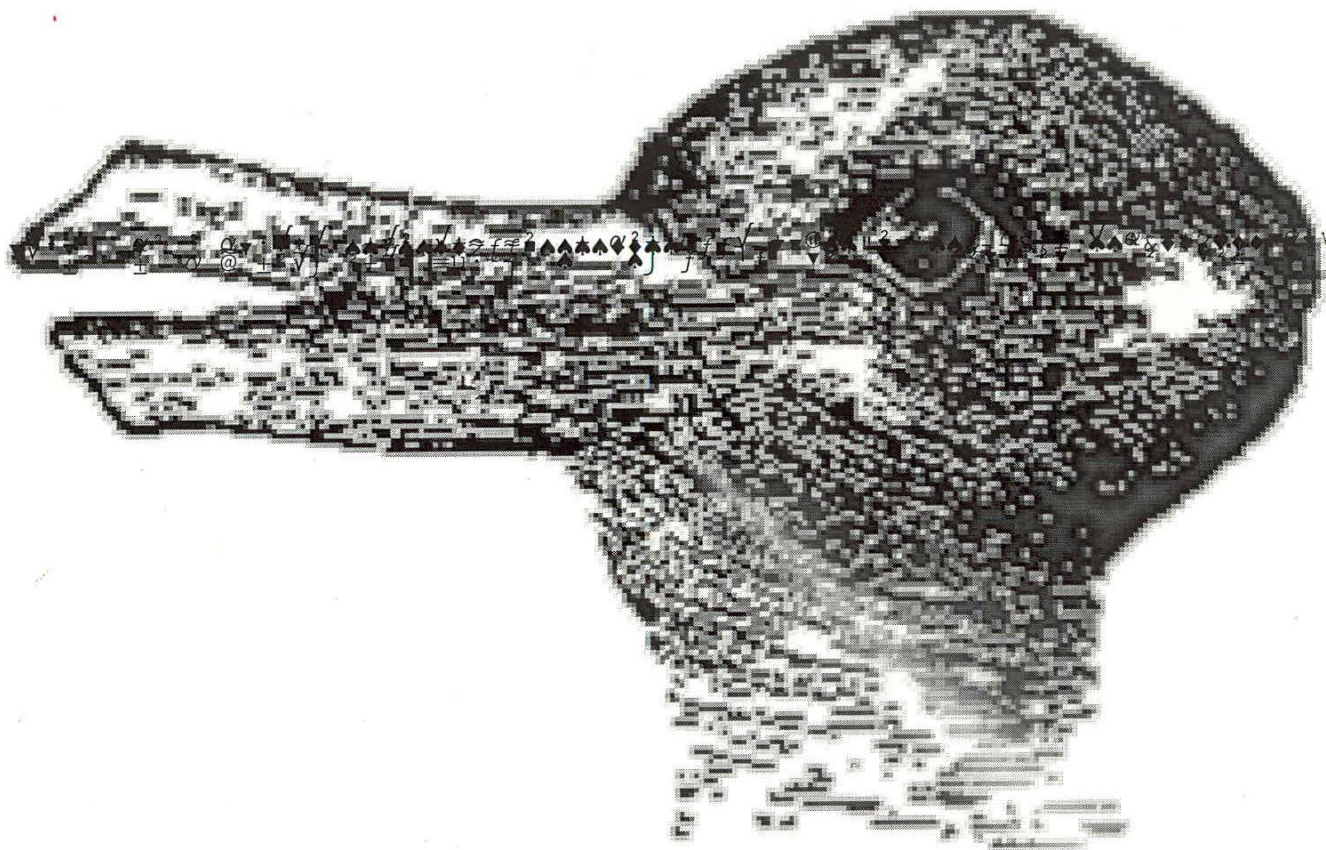


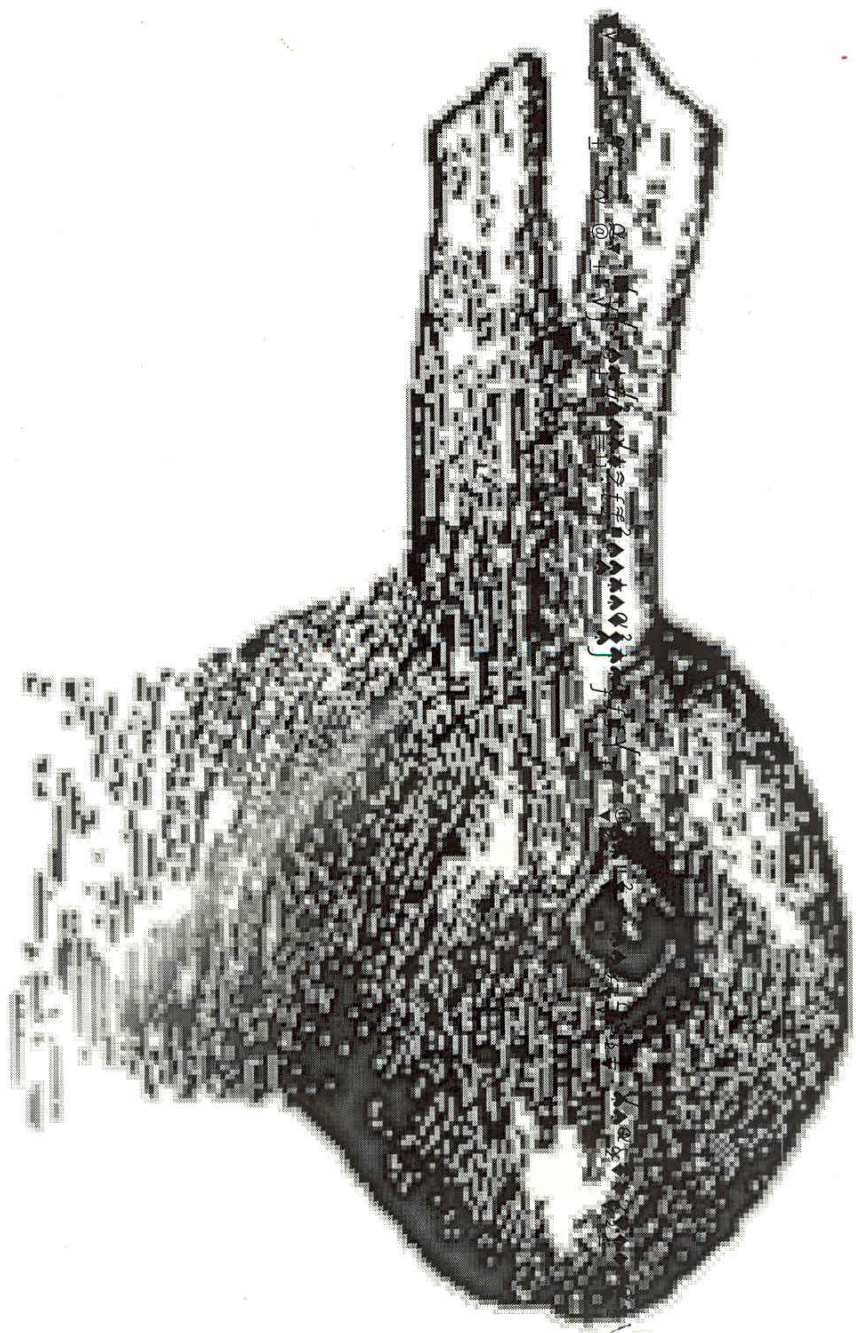


# Laminar structure of the primary visual cortex

- “Blobs”: color
- “Interblobs”: no color
- Orientation: they are activated with movement (depending on the movement, some activate more than others)
- Ocular dominance: for the right or left eye









# MOTOR REFLEXES MUSCLE TONE AND POSTURE

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MD Consuelo Borrás

# Outline

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- Reflexes
- Monosynaptic reflex
  - Structure of the neuromuscular bundle
  - Function of the neuromuscular bundle
  - Gamma motor neurons
- Inverse myotatic reflex
- Muscle tone
- Polysynaptic reflex. Flexor reflex

# Reflexes

---

- Automatic responses triggered by various stimuli, that integrate in different parts of the Central Nervous System and that occur in a practically identical form if those stimuli have the same characteristics every time they are applied.

# Reflexes: Components

---

- **Sensory receptor**
- **Sensory neuron** that contains the **afferent fibers**, which may or may not synapse directly with the
- **Motor neuron**, from which the **efferent fibers** that carry the “response” up to the effector leave.
- The **effector** can be a skeletal muscle.

# Reflexes: Types

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- **Monosynaptic:** The only monosynaptic reflex in the organism is the myotatic reflex, also called stretch or traction reflex.
- **Polysynaptic:** The remaining reflexes.



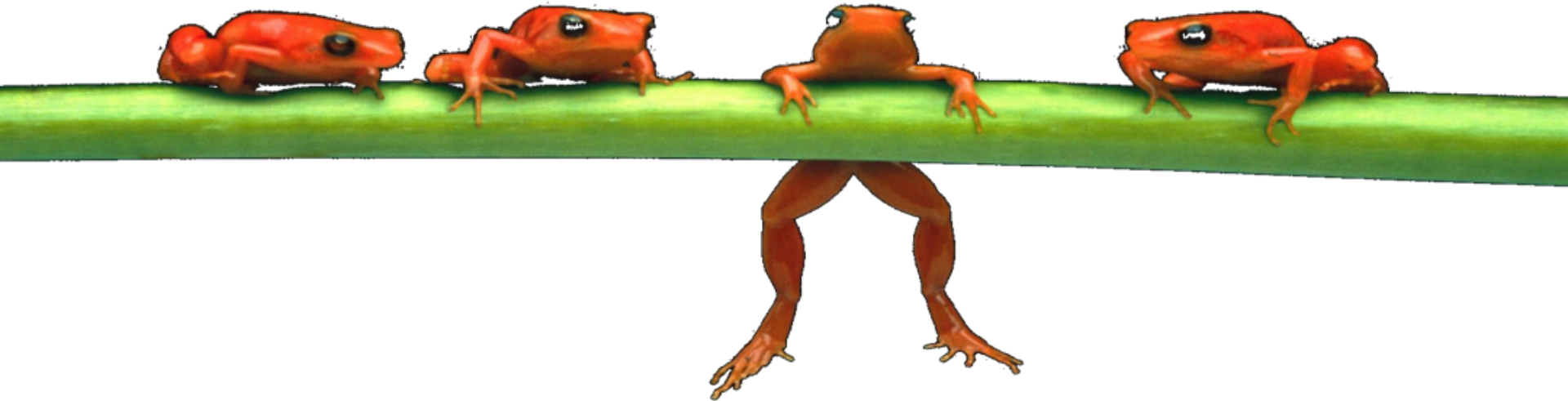
# Reflexes: Physiological Properties

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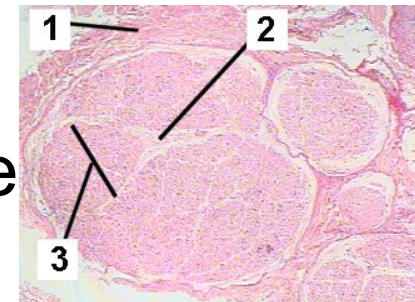
- Polarized spreading
- Latent period
- Existence of the central excitatory and inhibitory states
- Specificity of the stimulus
- Modification of the responses according to the sensory experience
  - Habituation
  - Sensitization

# Monosynaptic Reflex

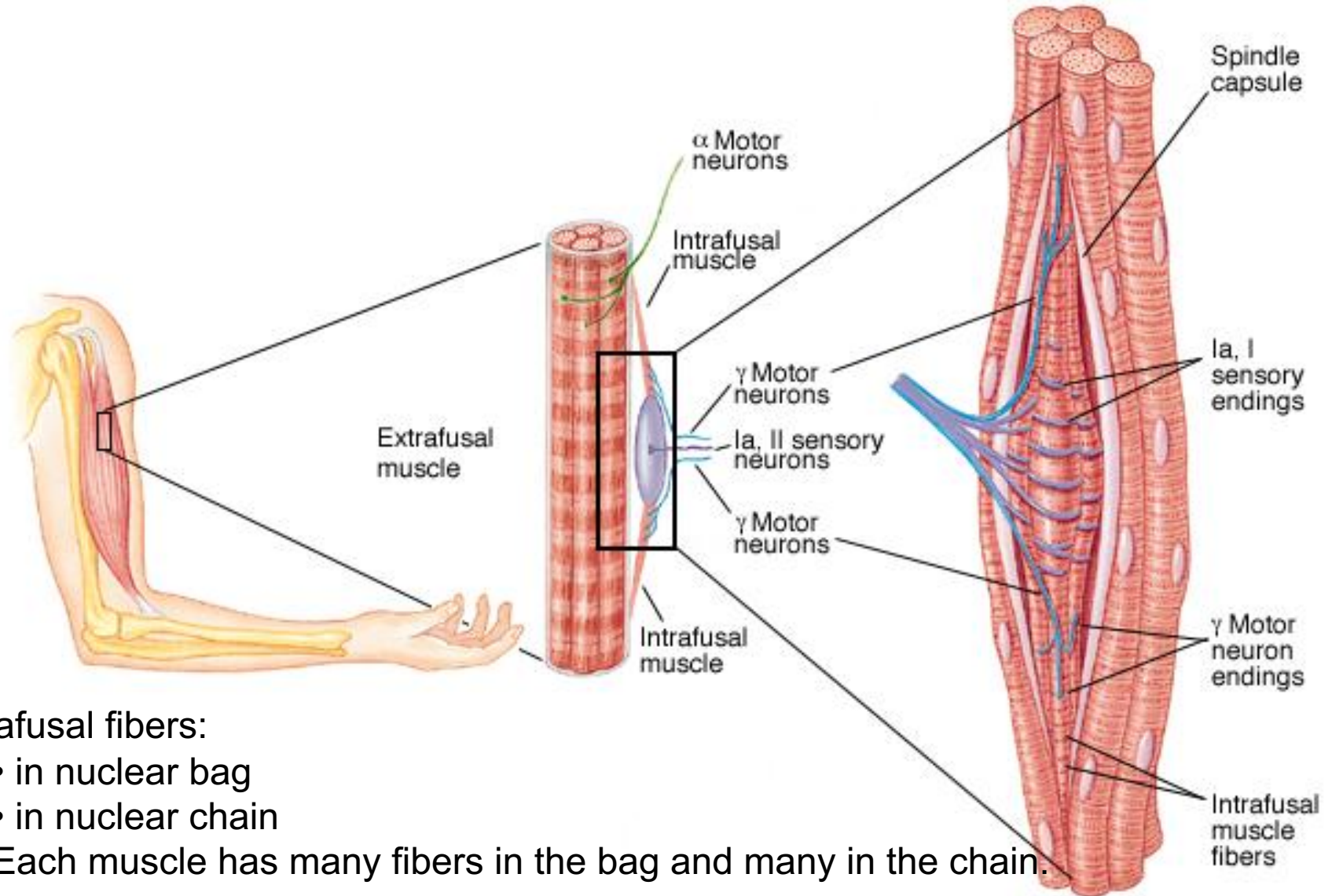
- It is the simplest motor mechanism
- It is also called myotactic or stretch reflex



- Its cause are stretching receptors:  
**NEUROMUSCULAR BUNDLES**
- It is located parallel to the muscle bundle



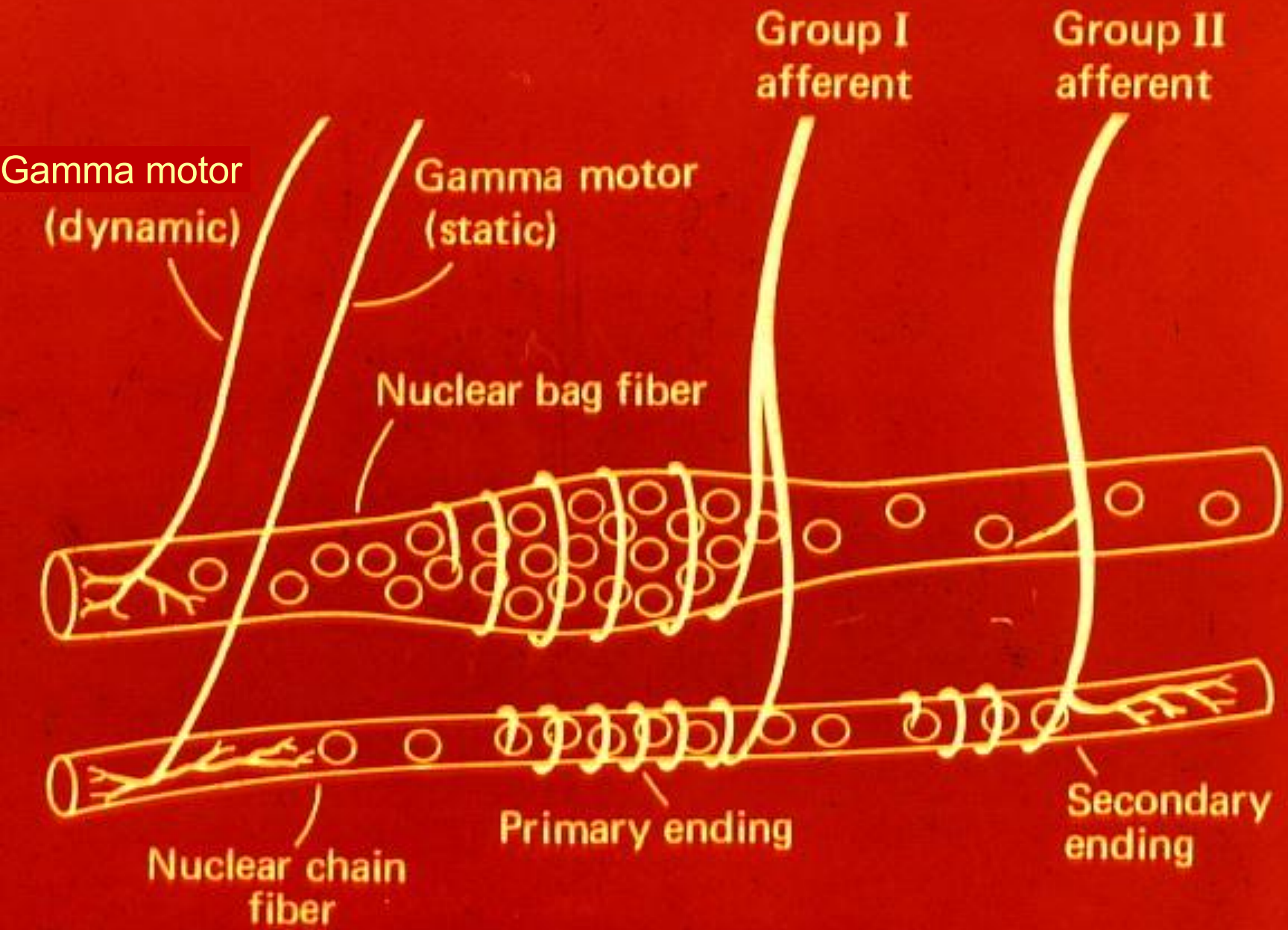
# Structure of the Neuromuscular Bundle



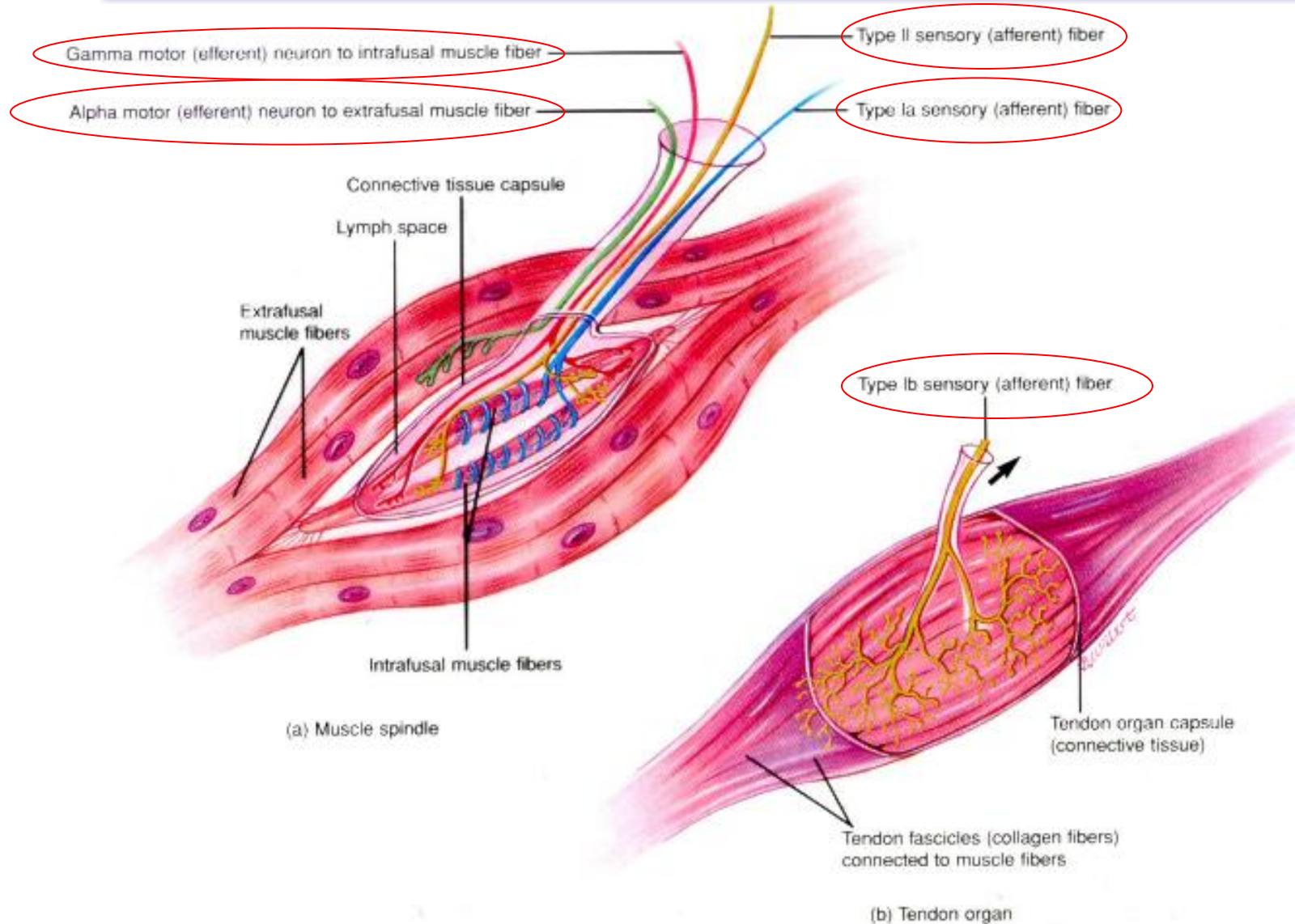
- Intrafusal fibers:

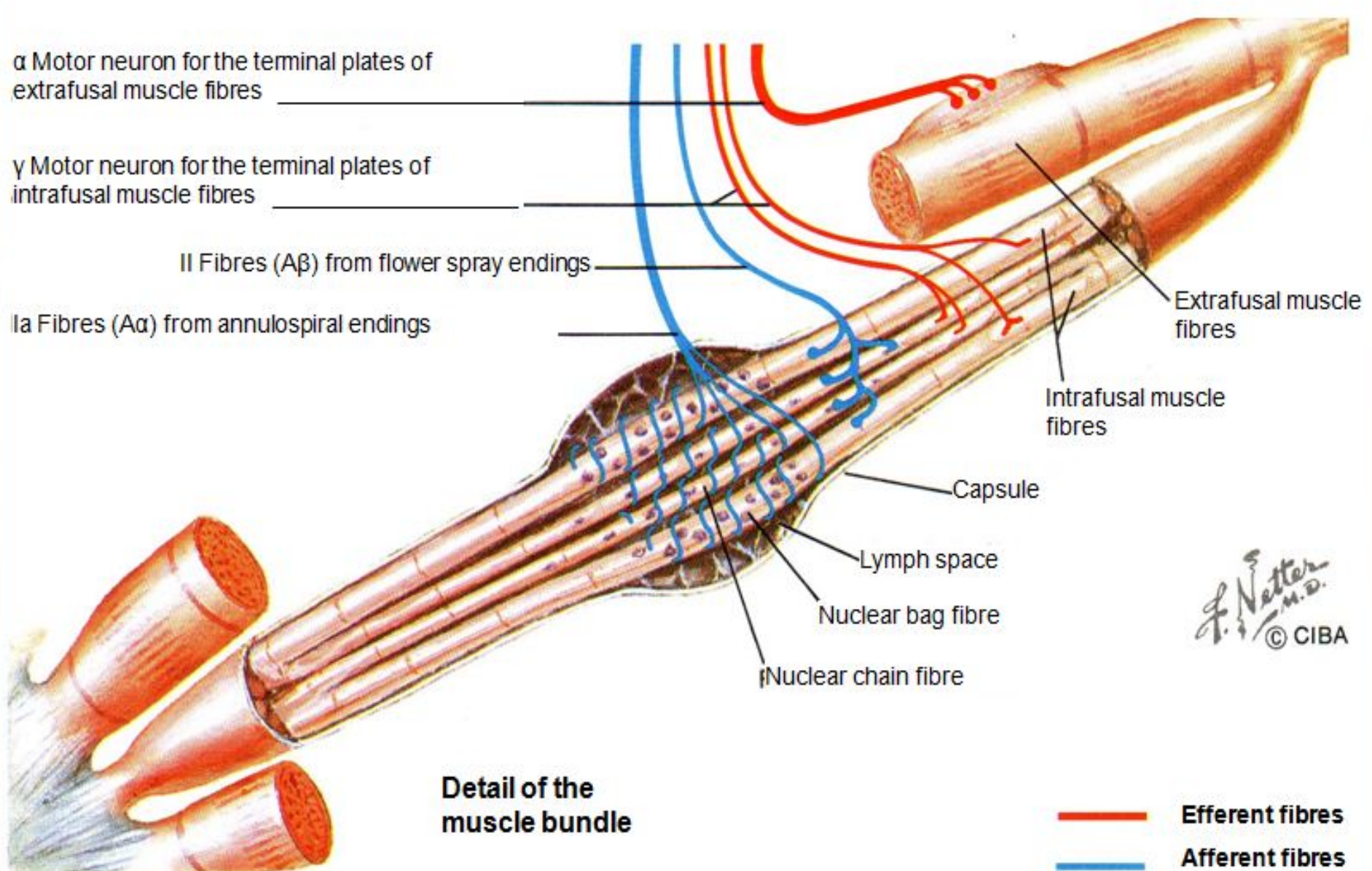
- in nuclear bag
- in nuclear chain

Each muscle has many fibers in the bag and many in the chain.



# Innervation of the Neuromuscular Bundle





*F. Netter*  
 M.D.  
 © CIBA

## Muscle and articular receptors

$\alpha$  motor neurons to the terminal  
extrafusal plates of the striated muscle

$\gamma$  motor neurons to the terminal  
extrafusal plates of the striated muscle

Ia ( $A\alpha$ ) from annulospiral endings  
(proprioception)

II ( $A\beta$ ) from flower spray  
endings(proprioception); from  
paciniform corpuscles (pressure) and  
from Pacinian corpuscles (pressure)

III ( $A\delta$ ) fibres from free nerve terminals  
and some specialized terminals (pain  
and some degree of pressure)

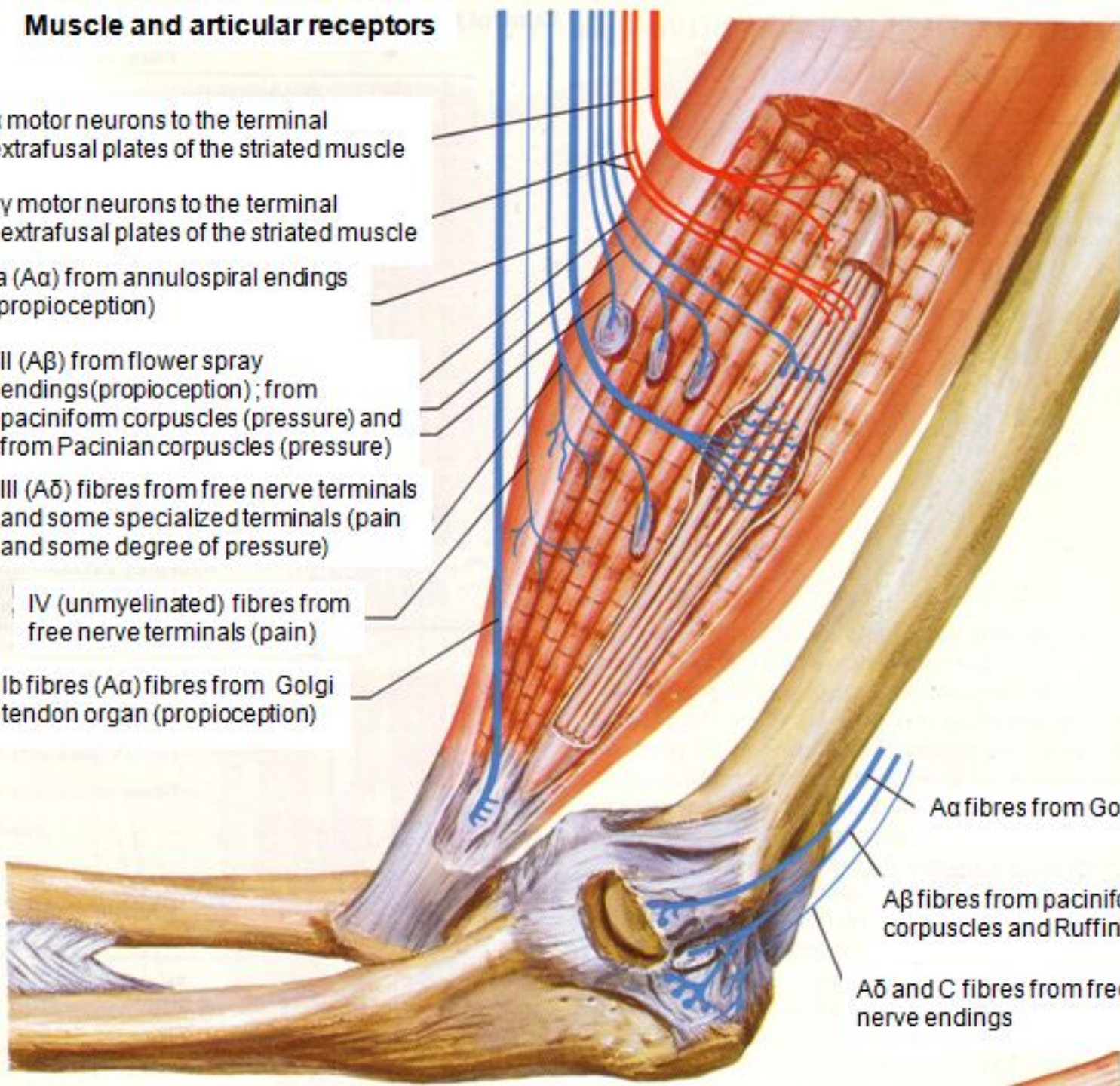
IV (unmyelinated) fibres from  
free nerve terminals (pain)

Ib fibres ( $A\alpha$ ) fibres from Golgi  
tendon organ (proprioception)

$A\alpha$  fibres from Golgi endings

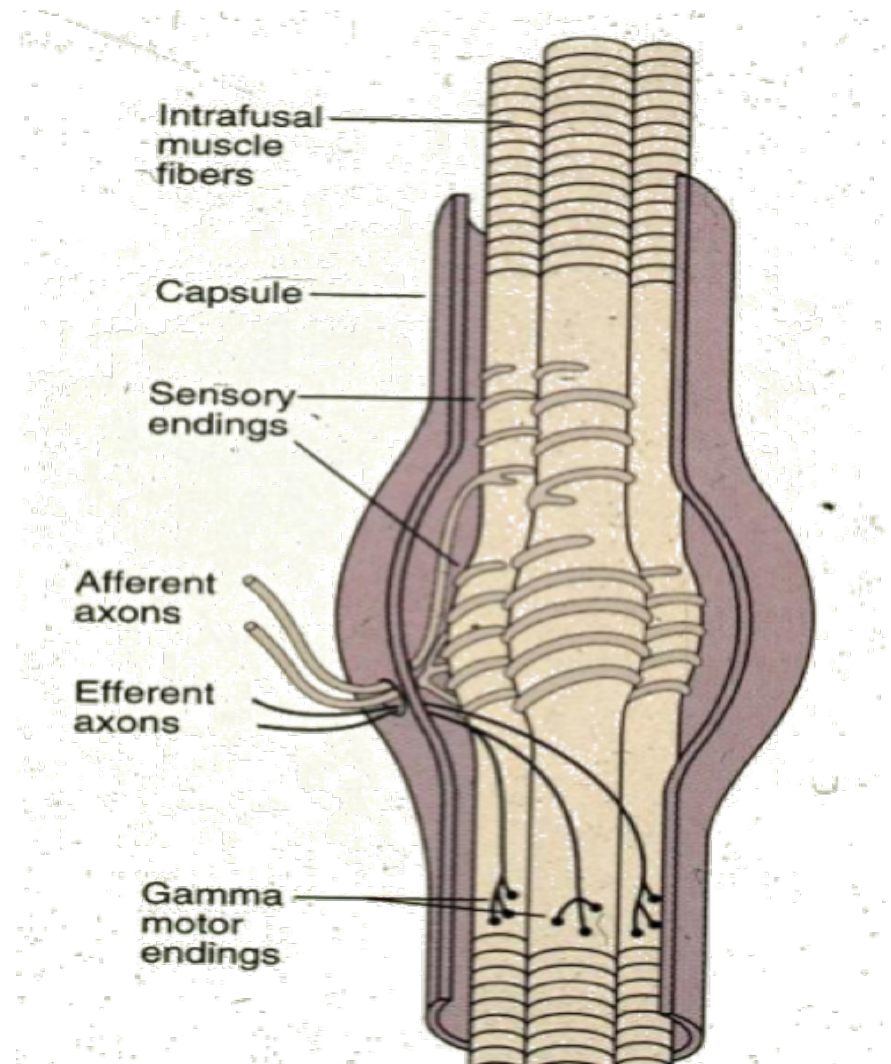
$A\beta$  fibres from paciniform  
corpuscles and Ruffini endings

$A\delta$  and C fibres from free  
nerve endings



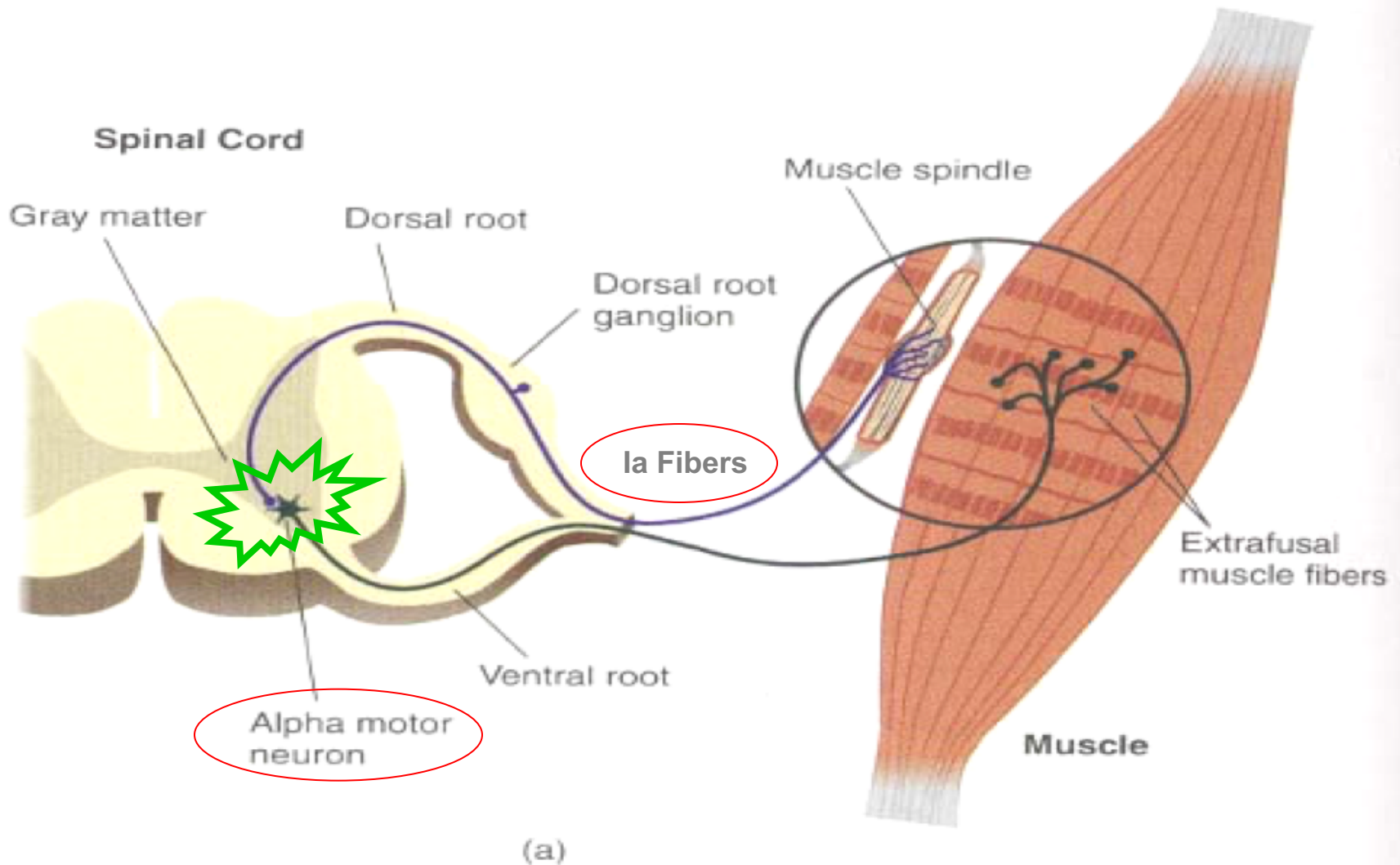
# Function of the Neuromuscular Bundle

- Muscle stretch → activation of the neuromuscular bundle due to stretching → sending of afferent signals



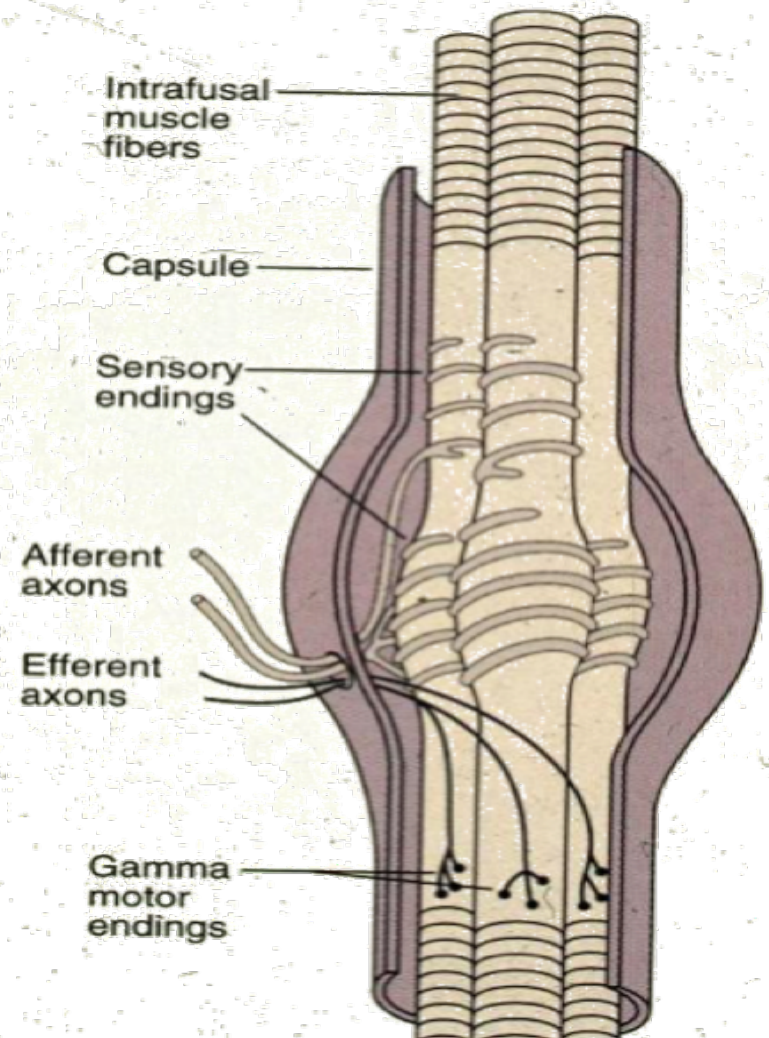
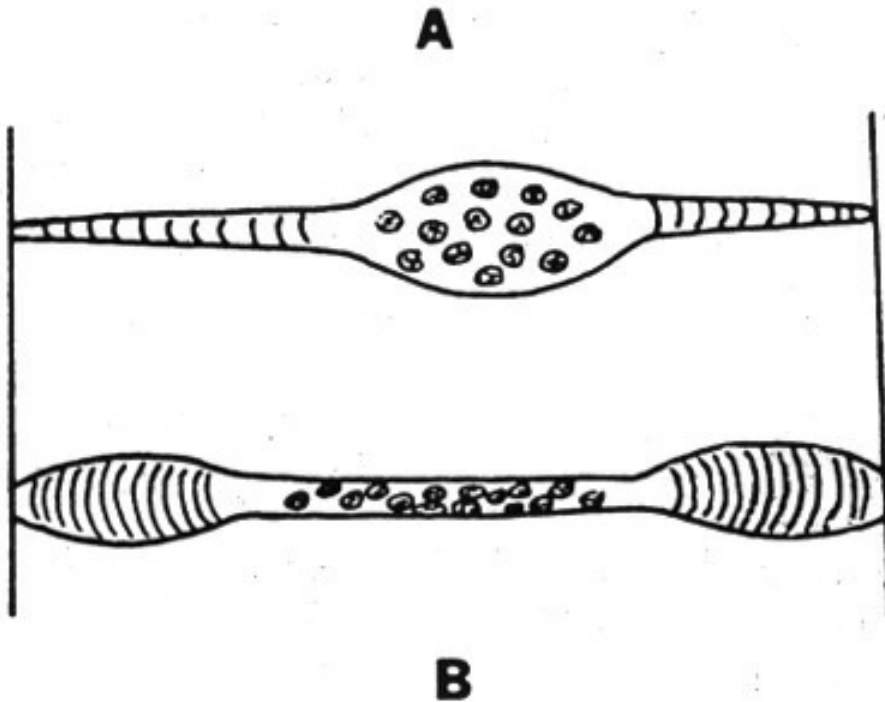


# Function of the Neuromuscular Bundle

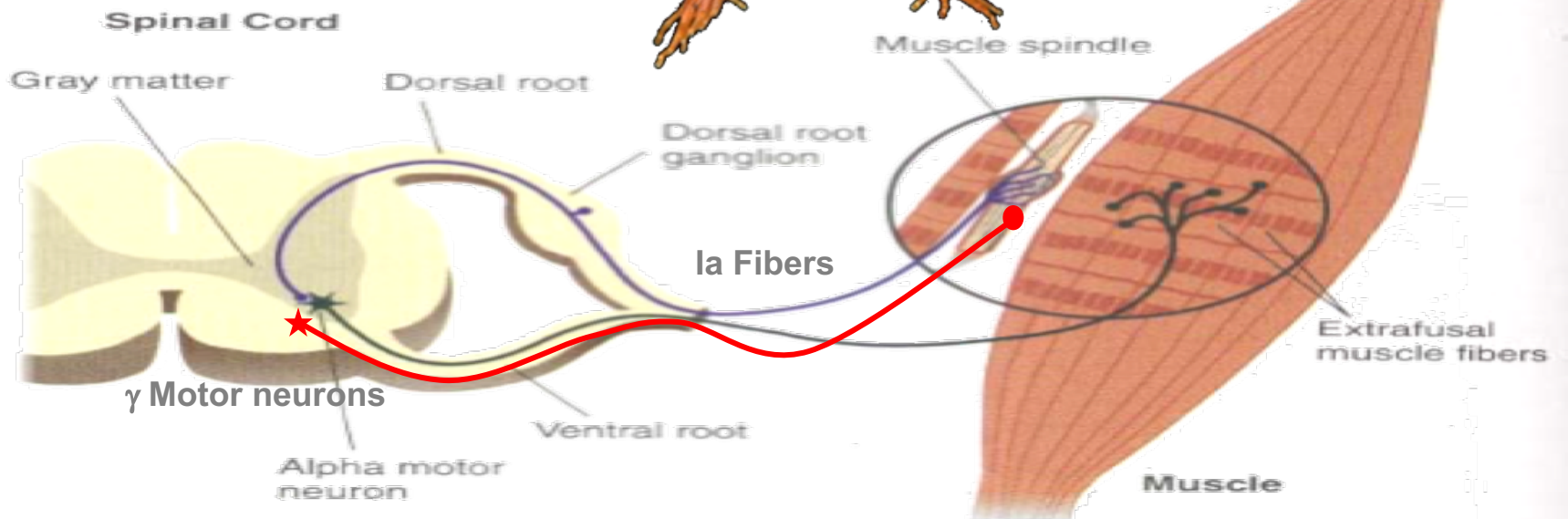
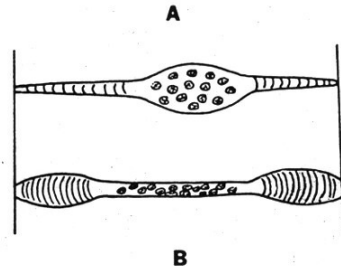


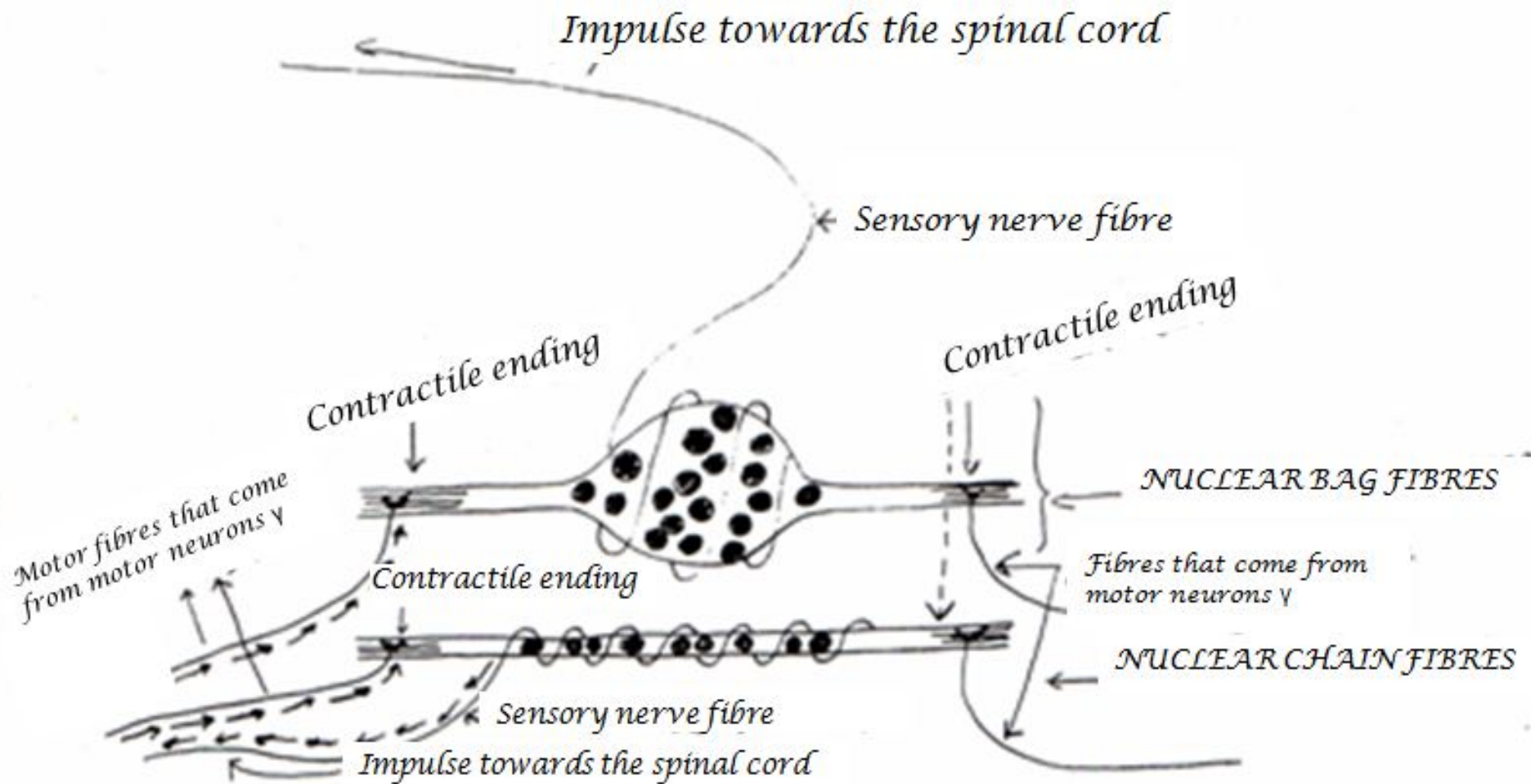
# Gamma Motor Neurons

- Motor neurons  $\gamma$



# Gamma Motor Neurons





OUTLINE OF THE MUSCLE  
BUNDLE STRUCTURE AND  
INNERVATION

# Inverse Myotatic Reflex

- Golgi tendon organ → tension receptors

- Afferent fibres

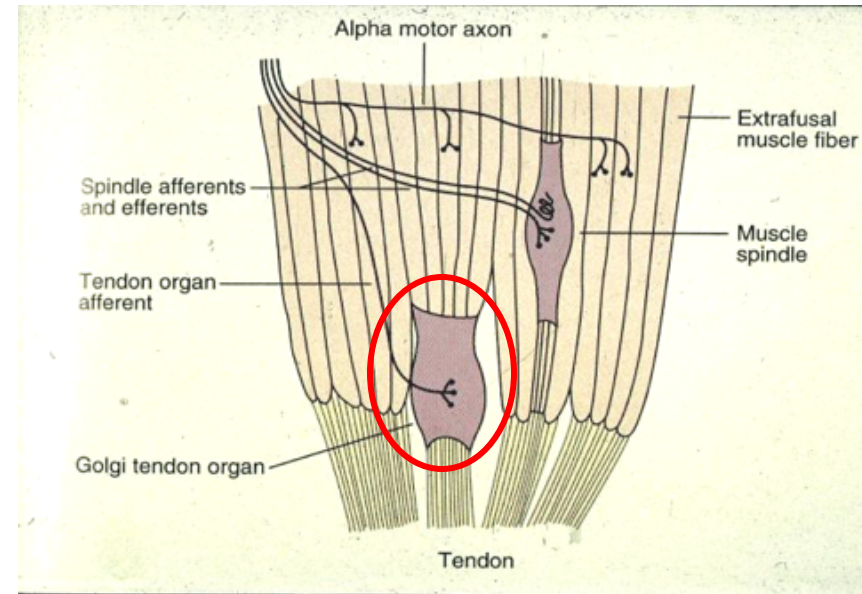
Ib → dorsal roots →

interneuron synapses →

motor neuron inhibitory

synapses  $\alpha$  → muscle relaxation

Defense mechanism of the tendon



# Muscle Tone

---

- Permanent semi-contraction state of the skeletal muscle fibre
- Permanent contraction of the muscles that give the human body its characteristic position, opposed to the passive modifications of such position
- We regulate our muscle tone according to the physical exercise we want to do
- The gamma motor neurons maintain the muscle tone

# Muscle Tone: Characteristics

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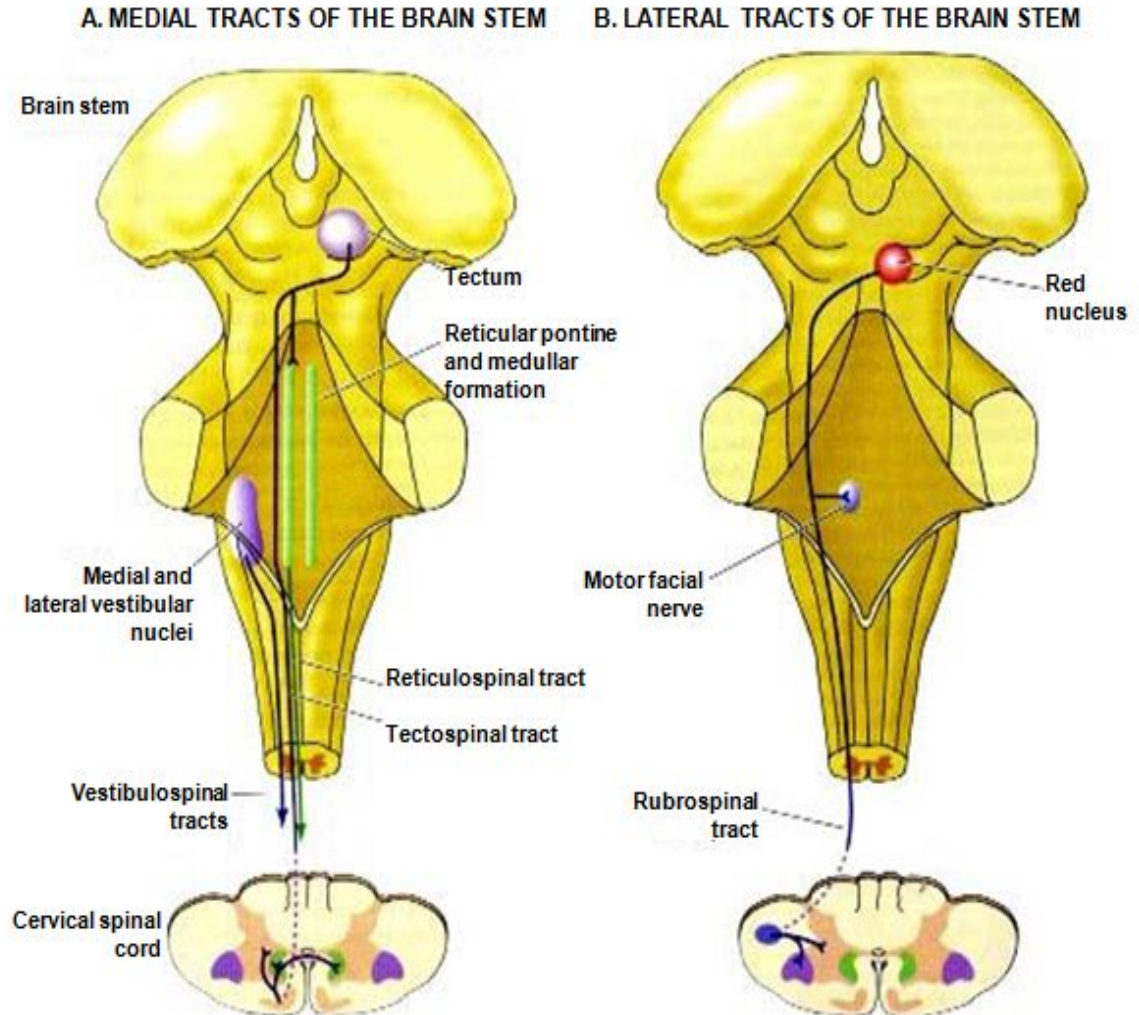
- a) Does not generate movement.
- b) Is slowly achieved.
- c) Prevents the feeling of fatigue.
- d) Is lasting.
- e) Requires little energy for the maintenance of the tonic contraction.





# Regulation of Muscle Tone

- CENTRAL
  - Reticular formation
  - Vestibular nuclei
  - Red nucleus
  - Tectum
  - Cerebral cortex



# Hypotonia

Hypotonia

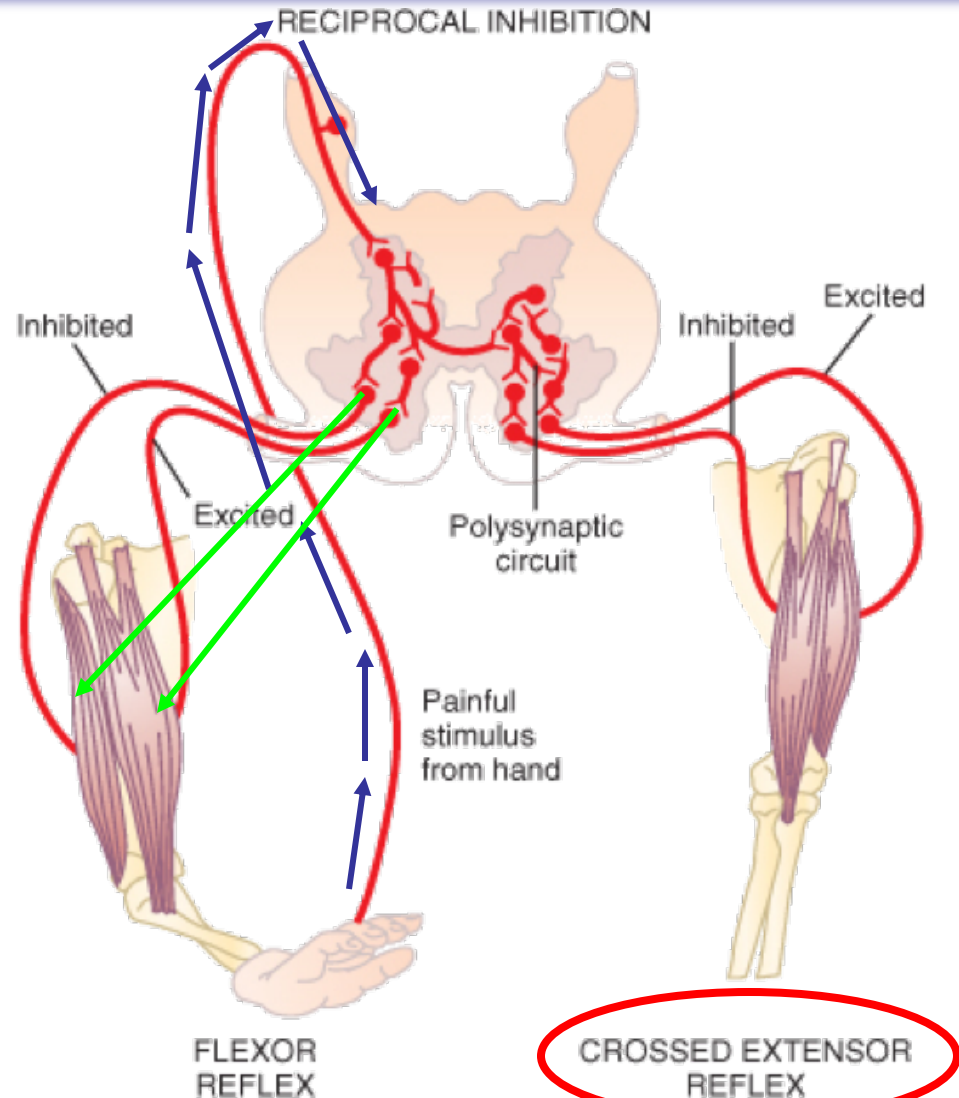


# Hypertonia



# Polysynaptic Reflexes: Flexor and Extensor

- More than one neuron activates in order to produce movement (these reflexes do generate a complex and coordinate movement)



# Reflexes

---

- All reflexes are involuntary movements
- They implicate the spinal cord but do not reach the cortex
- Muscle tone is the only controllable reflex (although it is equally involuntary)
- Spinal injury, spinal roots section, lack of myelin → lack of reflexes

# Exploration of Infant Reflexes

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- <http://www.youtube.com/watch?v=0nnnc1wJcjk>

# Mechanisms of Regulation of the Postural Activity



Dra. Consuelo Borrás

# Script

---

- Position
  - features
  - elements
  - postural reflexes
- Balance
  - structures
- Ciliated cells. Mechanism of action
- Vestibular pathways



# Position

---

- Type of reflex that keeps the body with respect to space
- It consists of 4 basic elements:
  - Vision (photoreceptor)
  - Head position (balance). Labyrinth
  - Muscle proprioception
  - Ligaments proprioception
- It is built on muscle tone

# Postural Reflexes

---

- **Support reactions.** Ensure the maintenance of posture “at rest”. Example: If a dog is held in the air and it touches the ground, the legs, which were limp and half bent, now get stiff. Proprioceptors and exteroceptors are involved.

# Postural Reflexes

---

- Static adaptation reactions. When the body or any part thereof deviate from the characteristic posture, these reflexes result in a change in the distribution of muscle tone to fit the new situation.  
Example: adaptation to load. If we put a load on a dog and then increase it without abruptness it will increase the tone of support.

# Postural Reflexes

- **Righting reflexes.** They are the reflexes that allow the position to be acquired when the animal is in a position that is not the position of the characteristic feature.
- A. Righting labyrinthine: A dog suspended in the air in a position straightens the head though we deprive him of visual information with a dark sack.
- B. Righting neck: When the head is straightened, the animal is lying on one side of the body as a result of reflexes acting on it, twisting the neck makes both the chest and lower back and pelvis adopt vertical position. This reflex is caused by initial excitation of proprioceptors located in the neck.

# Postural Reflexes

## **Acceleration or statokinetic reflexes**

- Help maintain the balance of movement and displacement.
- A. Reflex of linear acceleration. If we have a cat in the air grabbed by the pelvis and it sharply goes down, we observe that its front legs are extended and the fingers are separated.
- B. Reflex of angular acceleration. Rotational movements cause reactions in the muscles of the eyes called nystagmus. There are reactions in the muscles of the trunk and neck.

# Postural Reflexes

---

- Allow us to support the position before any disturbance.
- **POSITIVE REACTION OF SUPPORT:** Increase of the muscular tone where the gravity center moves.
- **STEP REACTION:** increase of the surface of sustentation.

# Postural Reflexes

---

**CERVICAL TONIC REFLEX:** The lower jaw goes down to protect the neck. Usually accompanied by protection movements of top members.

**Reflex of spinal vestibule:**

- Place the body in a fetal position (protecting the body with the back).  
Position of greater protection of our body.

# “Learned Reflexes”

- Automated movements that are not involuntary reflexes



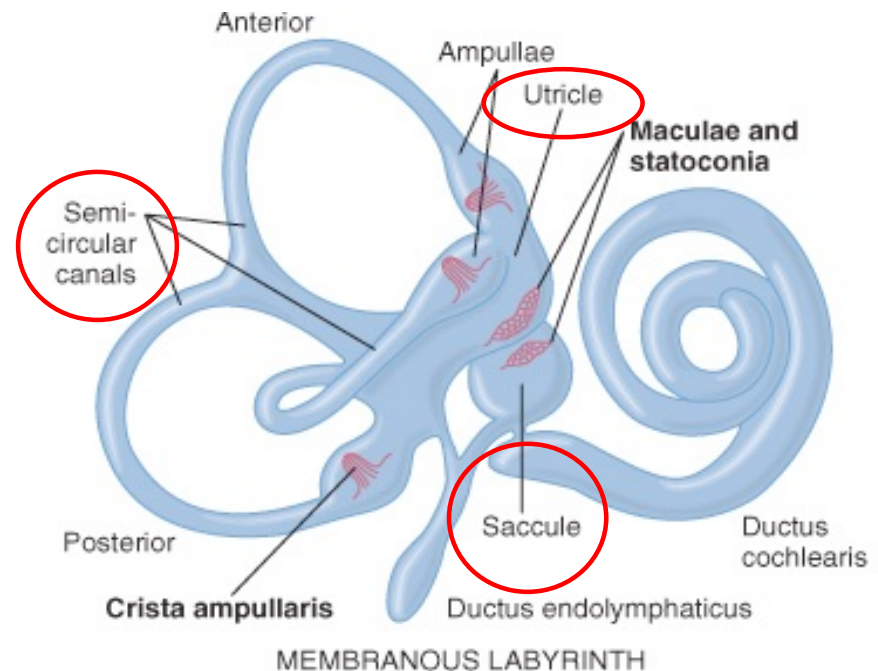


# Equilibrium

- Balance is the most important sense of all
- The vestibular apparatus reports the position of the head in space and must be taken into account:
  1. The important position of the head has a clear priority over the others.
  2. The head position is the most important factor because it determines the position of the other body parts.
  3. The straightening always starts with the head and then following this, the other parts of the body.
- It is located in the membranous labyrinth next to the cochlea
- Includes:
  - semicircular canals
  - utricle and saccule

# Equilibrium Structures

The **semicircular canals** are responsible for the information on the angular acceleration of the head's rotation  
The **utricle** and **sacculle** are responsible for maintaining information about the head and body in the space.



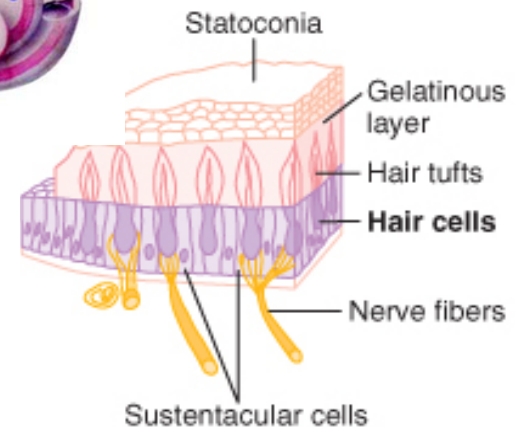
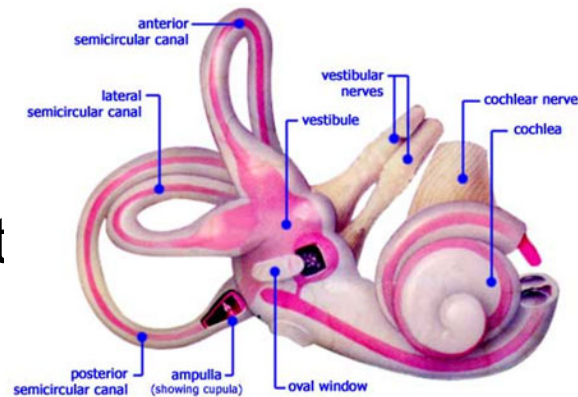
# Equilibrium Structures

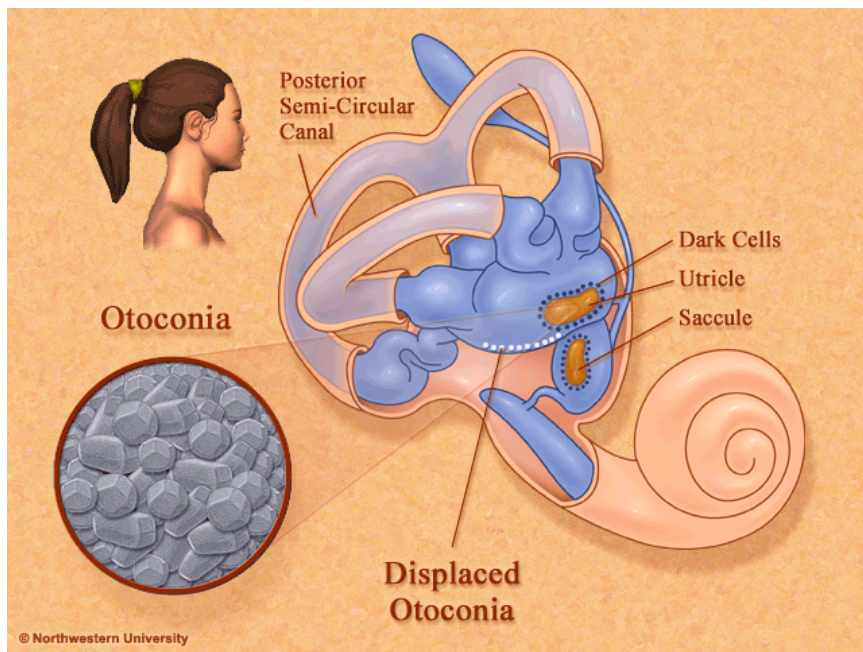
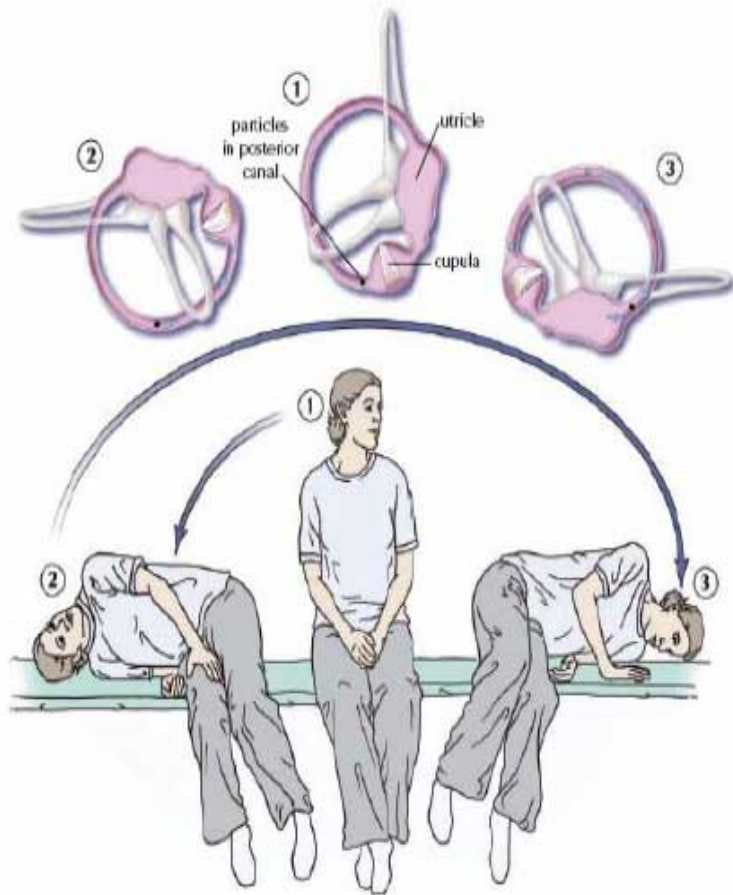
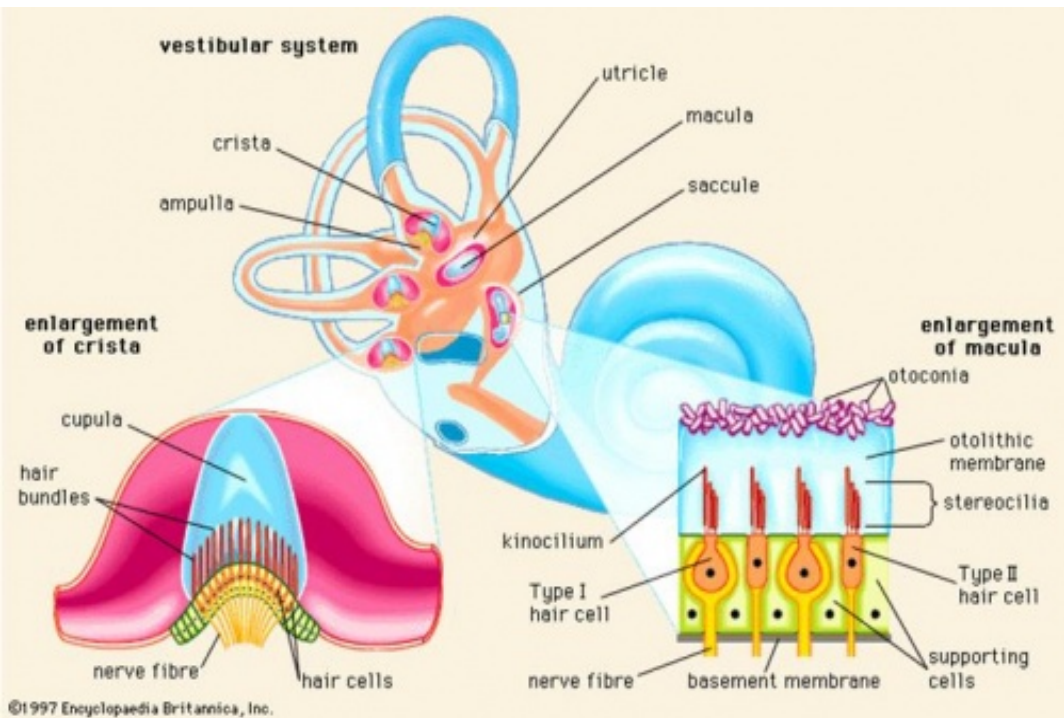
**Macules:** sensory organs of the utricle and saccule to detect the orientation of the head relative to gravity.

In the **utricle** it is in horizontal position, and this is important to determine the position of the head when it is in vertical position.

In the saccule it is in vertical position, and this is important to determine the head position when it is in horizontal position.

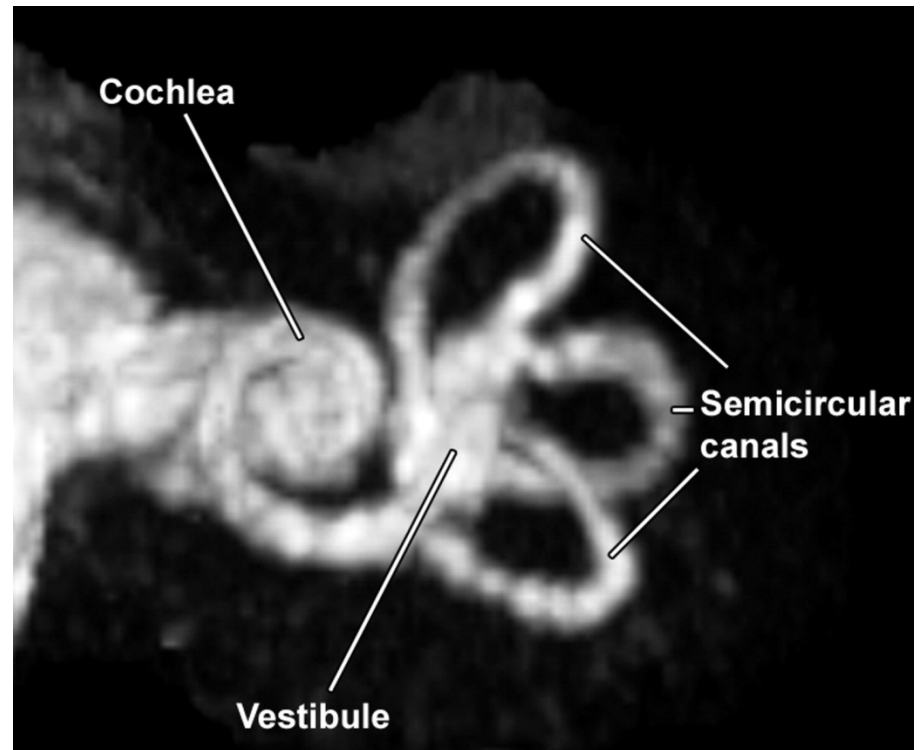
It contains ciliary cells.





# Vestibular Duct

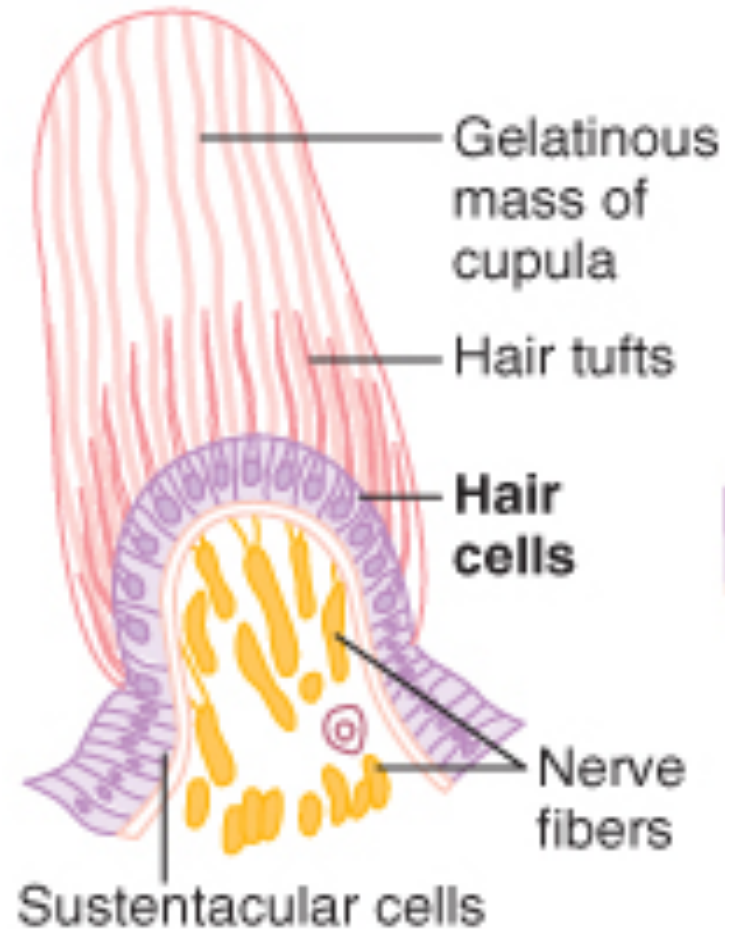
- Vestibular ducts are oriented so as to represent the three planes of space.
- Each duct has an expansion called **blister** and are bathed in endolymph.



# Equilibrium Structures

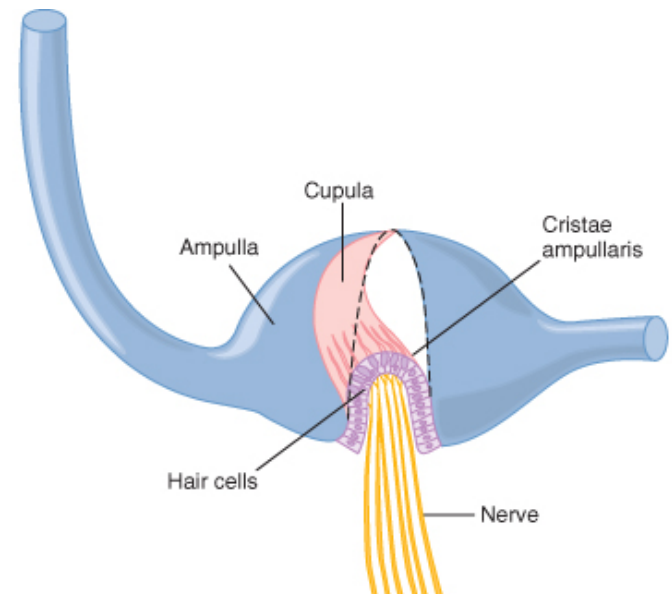
**Ampullary crests:**  
semicircular canals  
sense organs.  
Similar to macules  
but more elongated.

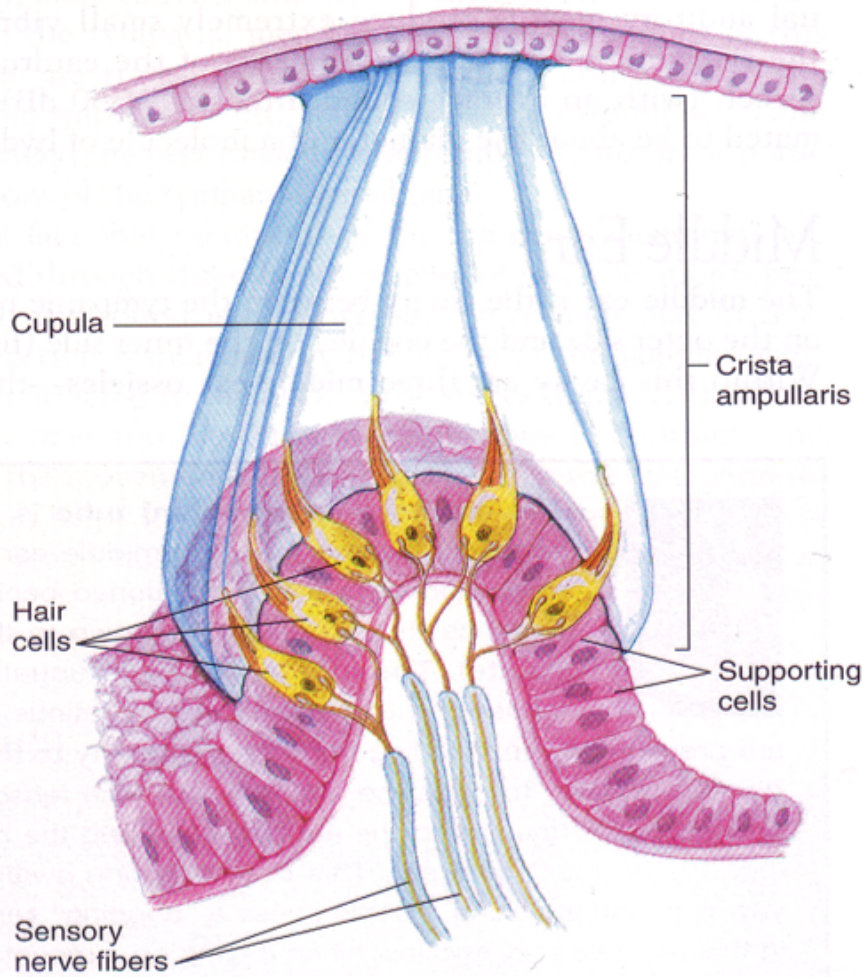
Contains ciliary cells



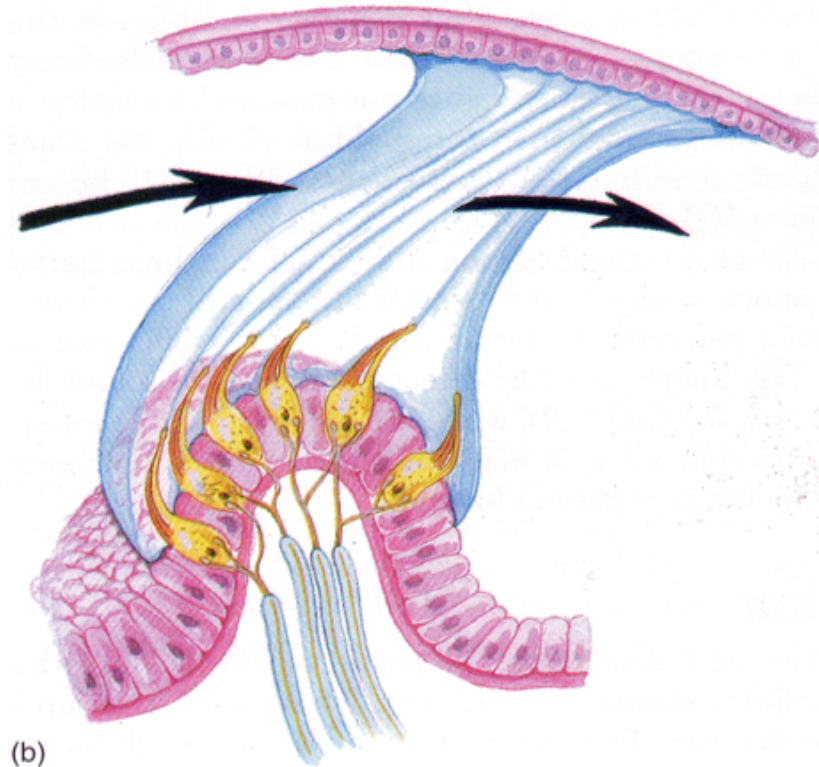
# Vestibular Duct

- The dome is a gelatinous mass above the tope.
  - The rotation of the head to one side or another dome tilts to one side (depolarization) or other (hyperpolarization).
- Rotation Change  
-Change of velocity







(a)

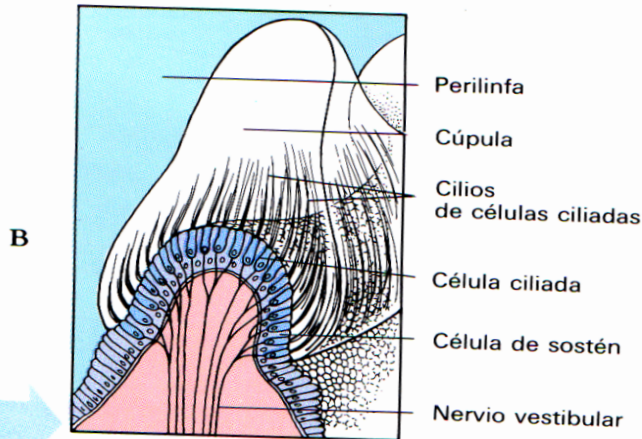
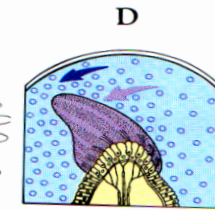
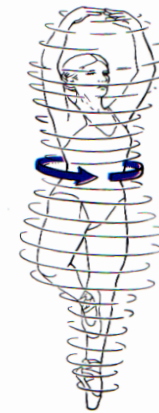
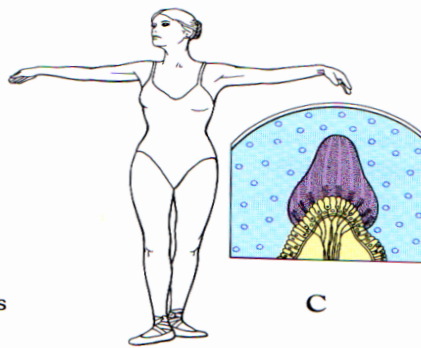
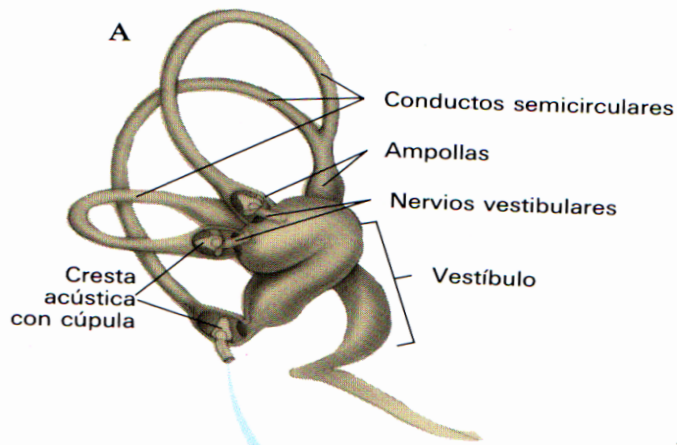


(b)

**Figure 10.16** The cupula and hair cells within the semicircular canals. (a) Shown here, the structures are at rest or at a constant velocity. (b) Here, movement of the endolymph during rotation causes the cupula to bend, thus stimulating the hair cells.  

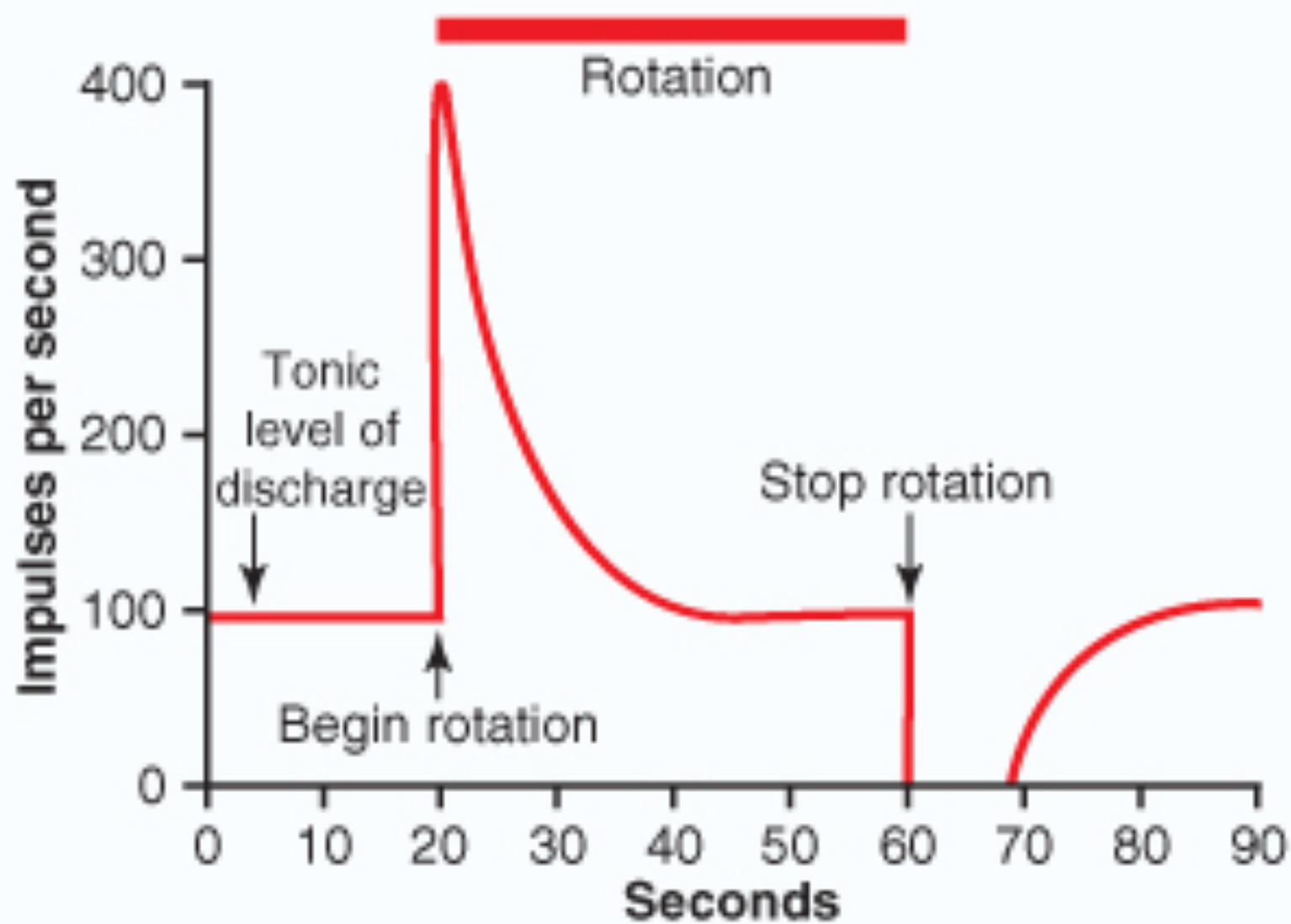
Source: Stuart Ira Fox. *Human Physiology*. 6<sup>th</sup> ed. WCB. McGraw-Hill. Boston





**FIGURA 14-8 Estructura y función de la cresta acústica.** A, Conductos semicirculares que muestran la situación de la cresta acústica en las ampollas. B, Ampliación de cresta acústica y cúpula. C, Cuando una persona está en reposo, la cresta acústica no se mueve. D y E, Cuando una persona empieza a dar vueltas, la cresta acústica es desplazada por la endolinfa en sentido opuesto al del giro.

## Structure and function of the acoustic crest



# Ciliary Cells

- Recipient cells
- They have stereocilia and one longer than the others: KINOCILIUM
- They are connected by filaments. The movement of a cilium moves them all



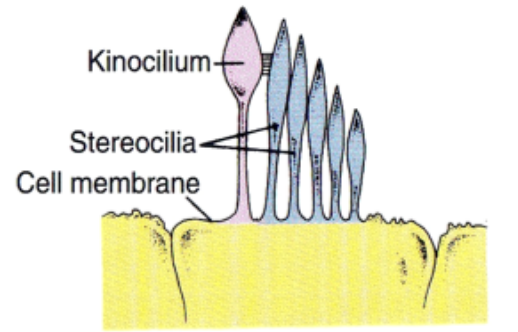
# Ciliary Cells

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- KINOCILIUM movement towards its end, stimulates the receptor, open potassium channels, depolarizes the cell and sends signals through the nerve fibers.
- KINOCILIUM movement towards its other end, closes potassium channels, it hyperpolarizes the cell and stops sending signals through the nerve fibers.

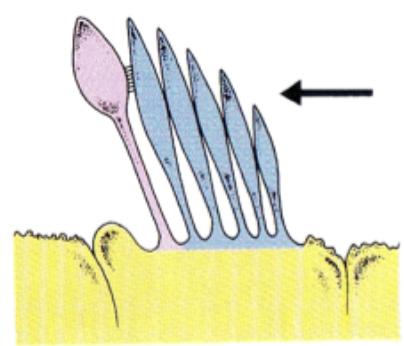


(a)



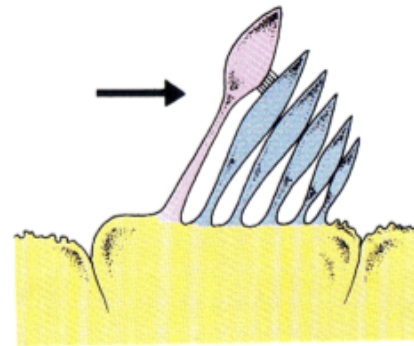
(b)

At rest




(c)

Stimulated

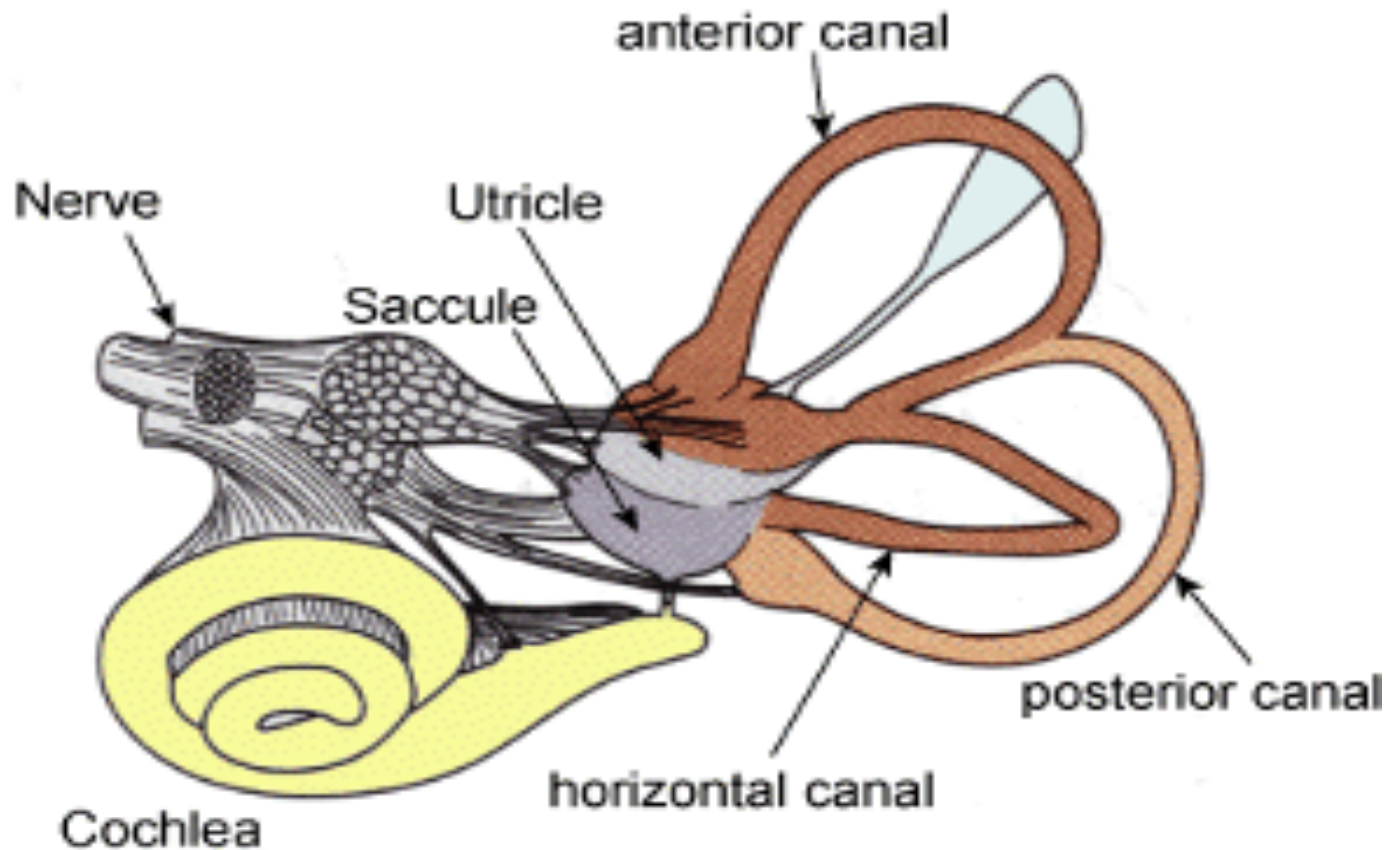


(d)

Inhibited

**Figure 10.14** Sensory hair cells within the vestibular apparatus. (a) A scanning electron photograph of a kinocilium and stereocilia. (b) Each sensory hair cell contains a single kinocilium and several stereocilia. (c) When stereocilia are displaced toward the kinocilium (arrow), the cell membrane is depressed and the sensory neuron innervating the hair cell is stimulated. (d) When the stereocilia are bent in the opposite direction, away from the kinocilium, the sensory neuron is inhibited. 

# Vestibular Pathways



# Role of the Bulb and Protuberance

---

- If we disconnect the bulb and the protuberance of the superior nerve centers, the animal is in a rigidity state called decerebrate rigidity or mindless animal.
- The animal stays with the legs extended, head dorsally flexed (extended), raised tail and trunk in opisthotonos. It supports the body against gravity.

# Role of the Bulb and Protuberance

- Elimination of inhibitory influences (on motoneurons g) of the extensor tone, from the uppermost parts of the N. S. and otherwise facilitating influences conservation (on motoneurons g) bulb and protuberance works on the tone of the extensors. Preserves the labyrinth tonic reflexes (by changing position of the animal varies the stiffness of place and intensity) and tonic neck (changes in stiffness, the changed position of the head relative to the whole body). There is also a direct activation of alpha motor neurons, which depend on the action on these neurons and belong to the vestibular nucleus, which exert their action through the spinal vestibule. Any other way can also provide alpha motoneurons.



# Role of the Midbrain

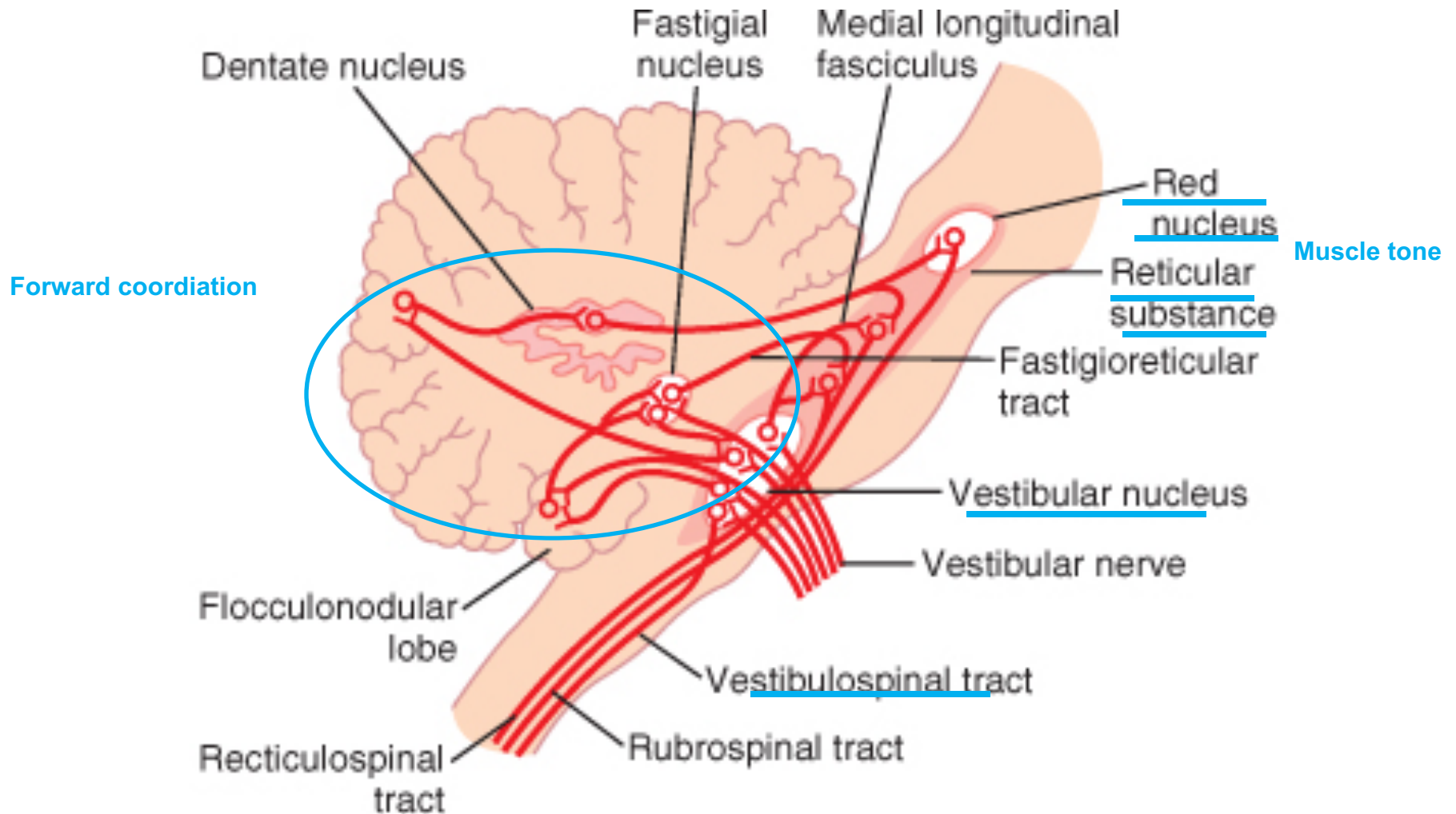
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- If we cut the N. S. at the top of the midbrain (high decerebration) the animal retains righting reflexes. The stiffness that occurs in these cases occurs when the animal is making moves.

# Role of the Cerebellum and Cortex

- Decorticated and mindless animals have few postural reflexes, but much of the postural activity can be kept in them. The role of cerebral cortex and cerebellum in motor control will be discussed later.
- It is necessary to comment that in higher animals like primates, or even more, men, the consequences of motor decortication are worse. And it is that animals are more superior since they have a degree of greater “encephalization” or “telencephalization”, this is because the cerebral cortex is highly developed and has taken on sensory and motor functions, in the case of lower animals those are carried out by lower areas.

# Role of the Cerebellum

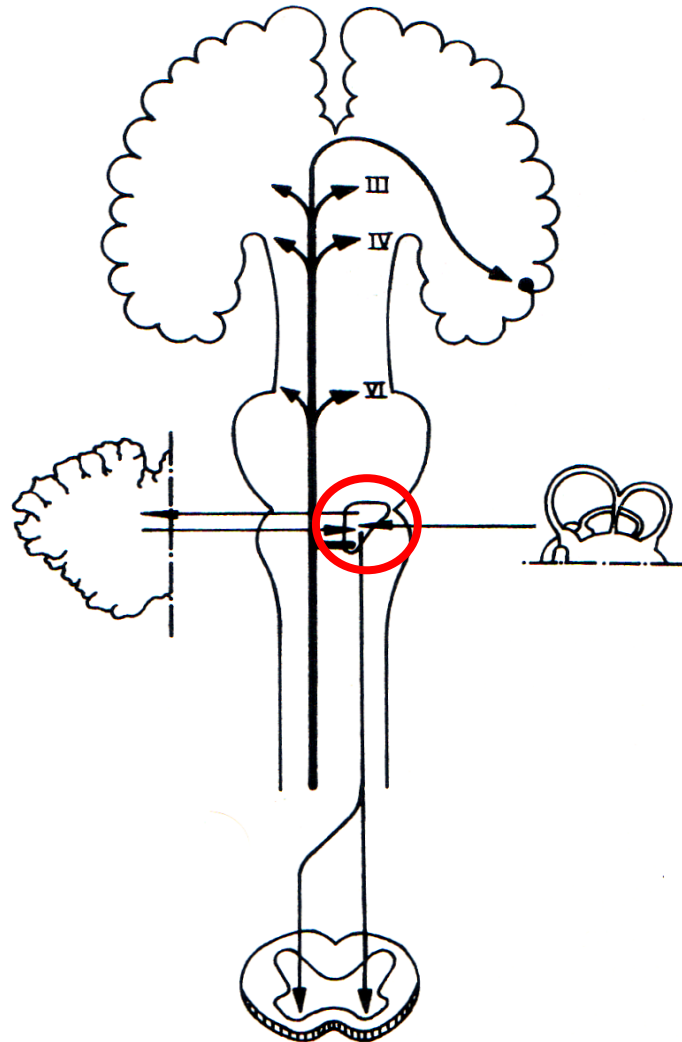


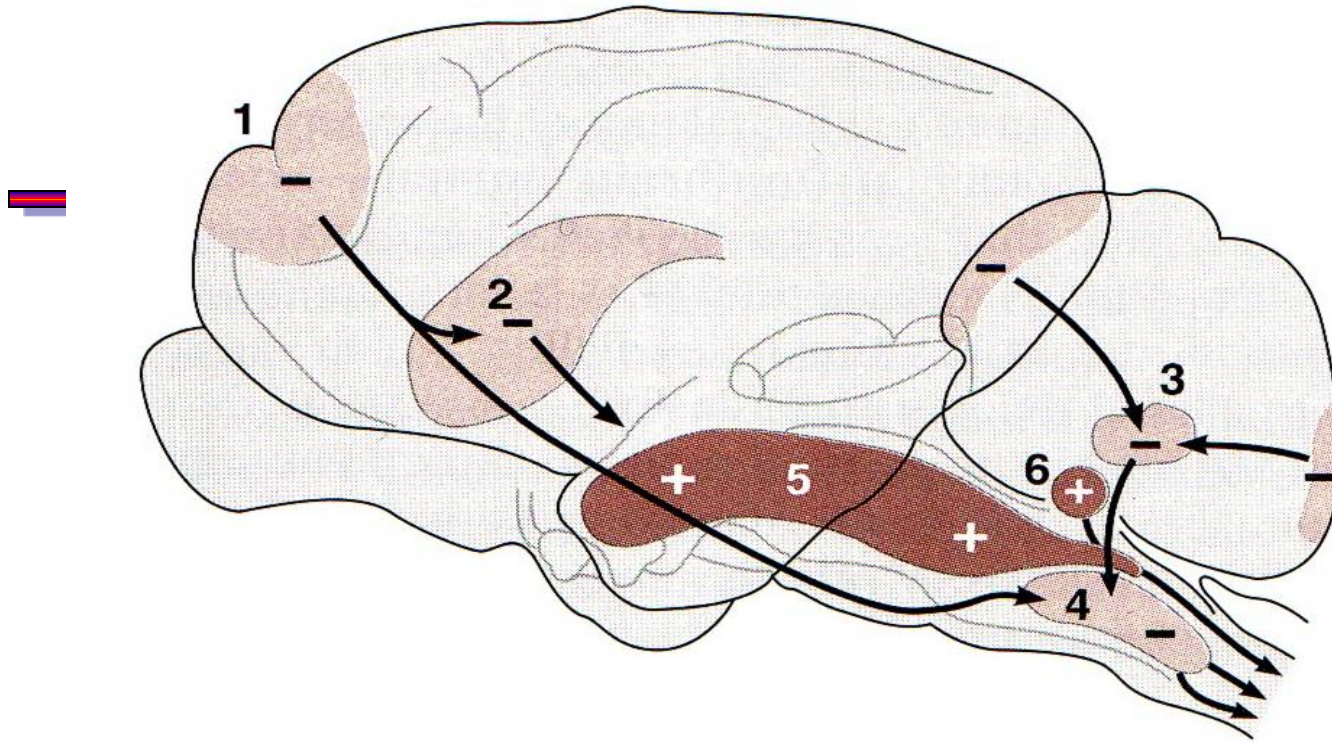
[http://www.dailymotion.com/video/x6y8ko\\_el-equilibrio\\_school](http://www.dailymotion.com/video/x6y8ko_el-equilibrio_school)

<http://www.youtube.com/watch?v=wBe43MKdKGM>

# Relation cerebellum – vestibular nucleus (brainstem) – vestibular apparatus

---





**Figure 12–6.** Areas in the cat brain where stimulation produces facilitation (plus signs) or inhibition (minus signs) of stretch reflexes. 1, motor cortex; 2, basal ganglia; 3, cerebellum; 4, reticular inhibitory area; 5, reticular facilitatory area; 6, vestibular nuclei. (Reproduced, with permission, from Lindsley DB, Schreiner LH, Magoun HW: An electromyographic study of spasticity. *J Neurophysiol* 1949;12:197.)

Source: Ganong, F. W. *Review of Medical Physiology*. Lange Medical Books/McGraw-Hill. 2001. New York



# VOLUNTARY MOTOR CONTROL (I)

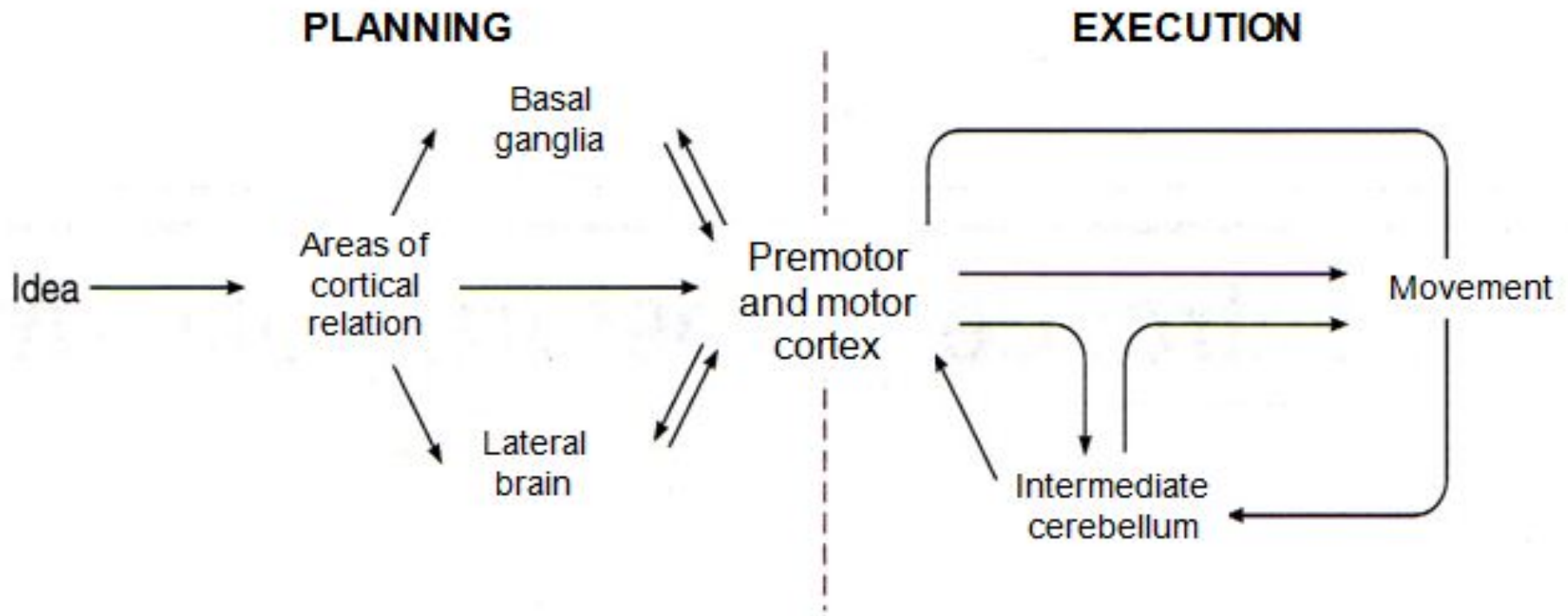
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# Outline

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- Motor cortex
  - Primary
  - Premotor area
  - Supplementary premotor area
- Nerve tracts
  - Pyramidal
- Spinal areas of motor control
- Brainstem



**Figure 12-1.** Voluntary movement control.



# MOTOR CORTEX

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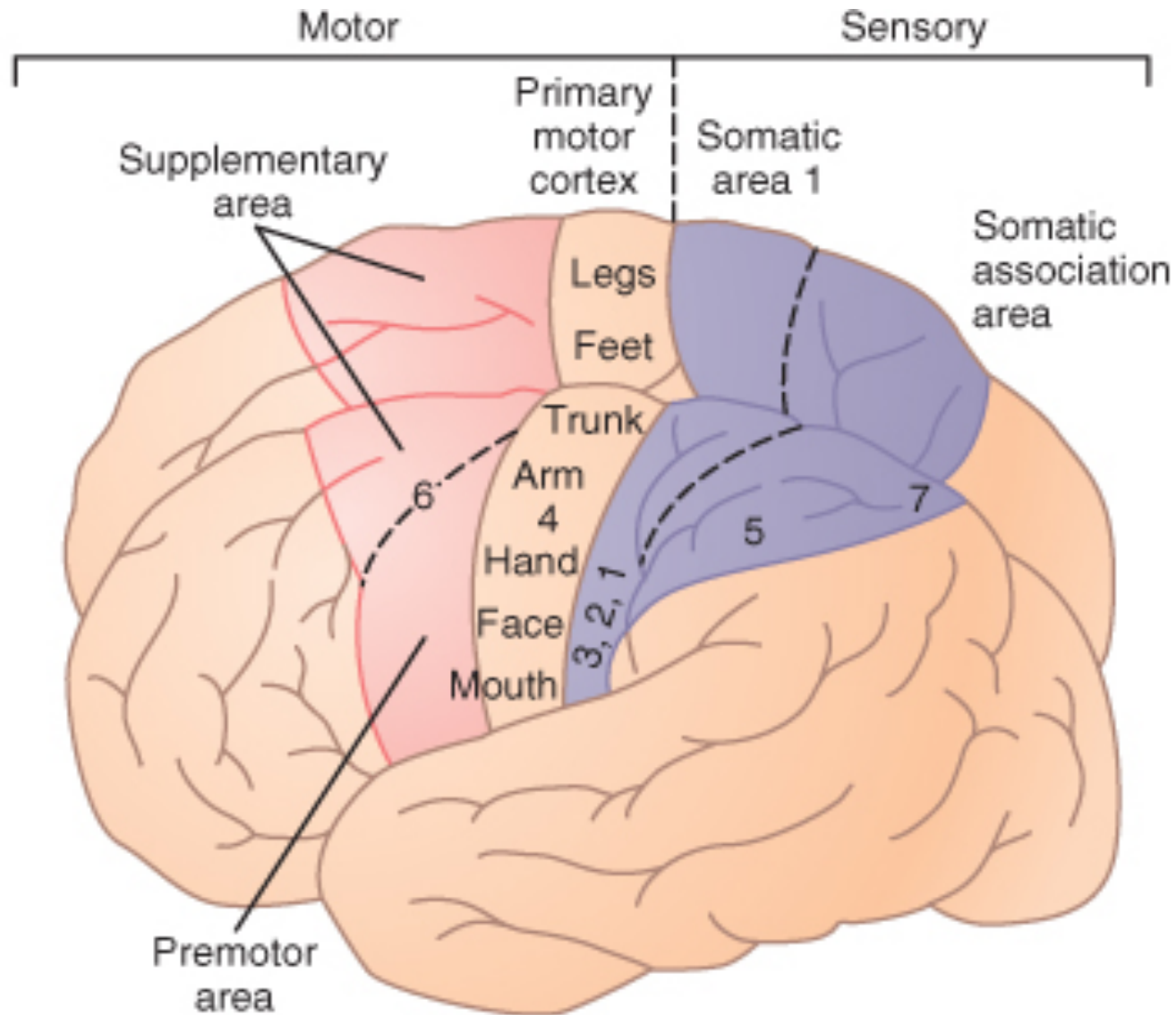
- PLASTICITY
- REPRESENTATION OF DIFFERENT BODY PARTS
- COLUMN-SHAPED ORGANIZATION

# Neuron Organization in Motor Cortex

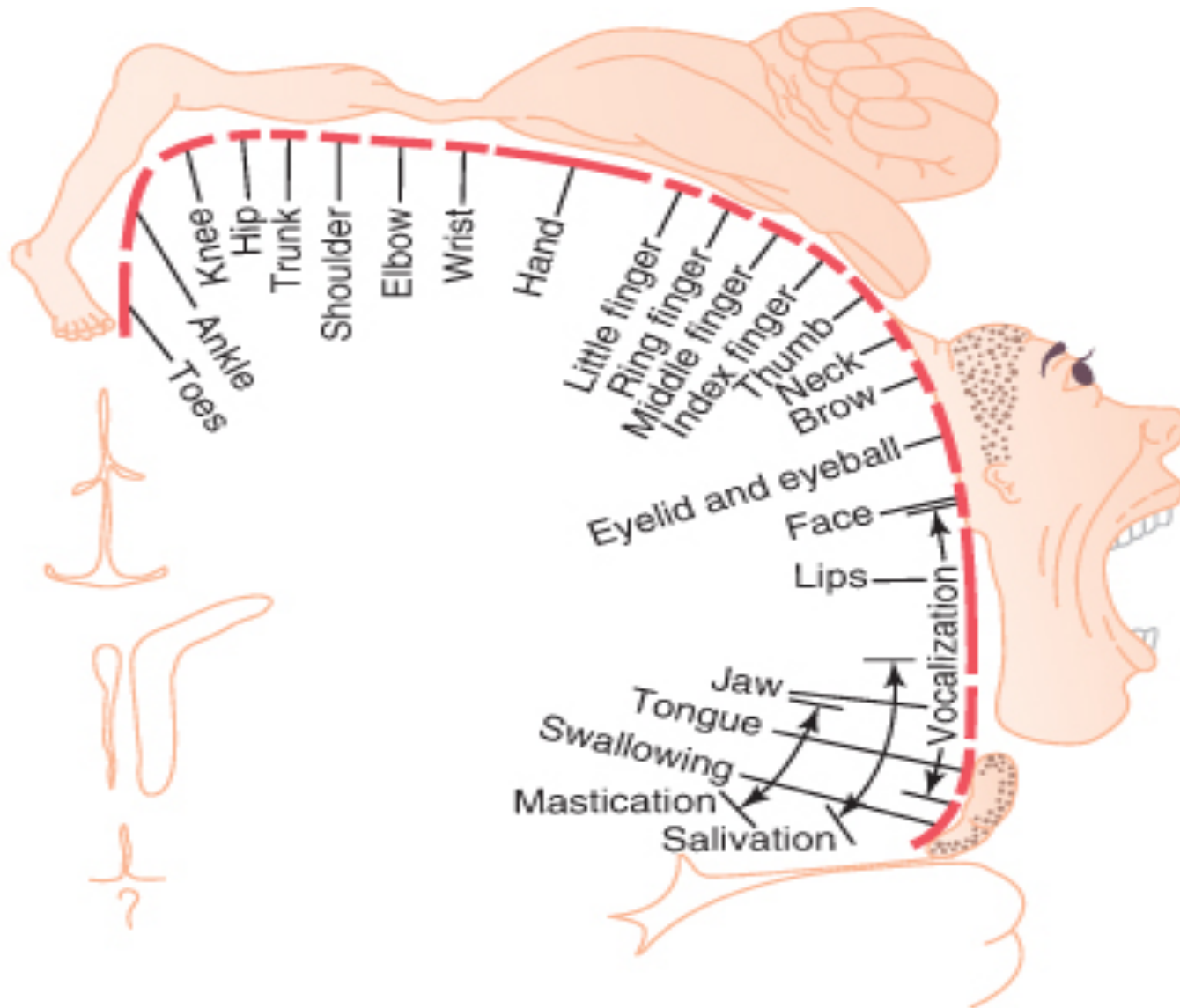
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- Organized in vertical cell columns
- Integrated system, amplifier
- Dynamic neurons/Static neurons
- The somatosensory feedback of the motor cortex helps control the accuracy of muscle contraction.

# Motor Cortex

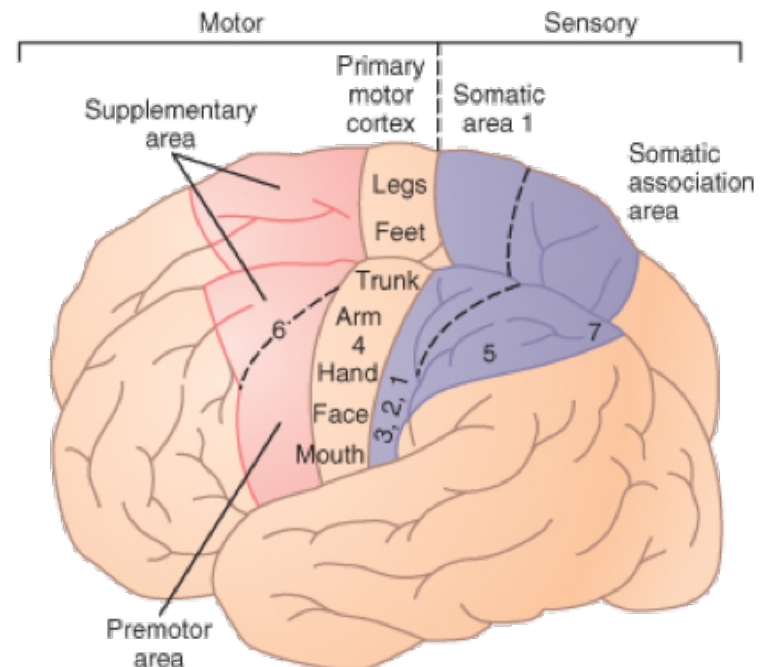


# Primary Motor Cortex



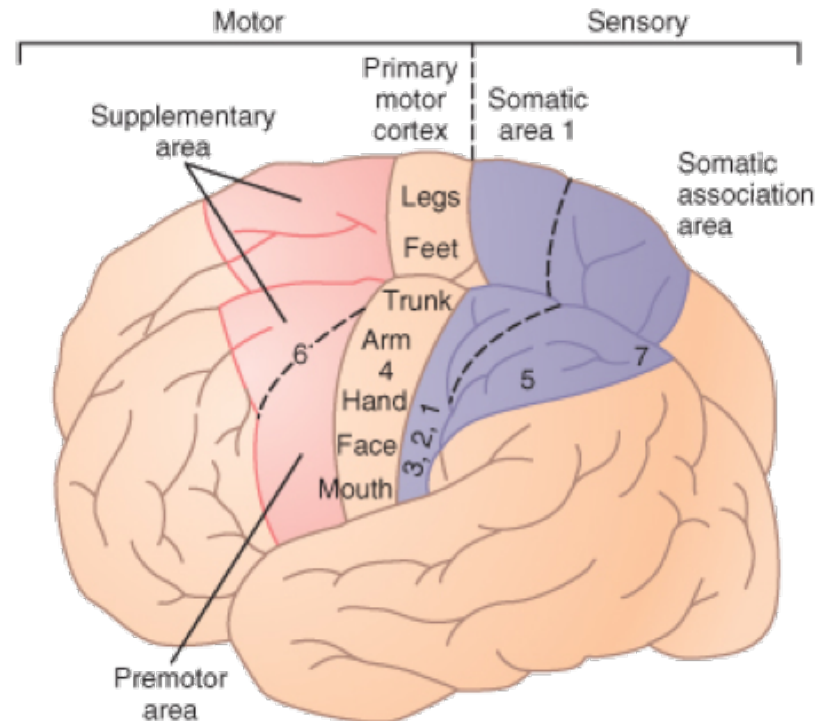
# Premotor Area

- Postural base for the execution of voluntary movements.
- Signals to basal ganglia, thalamus and primary motor cortex.

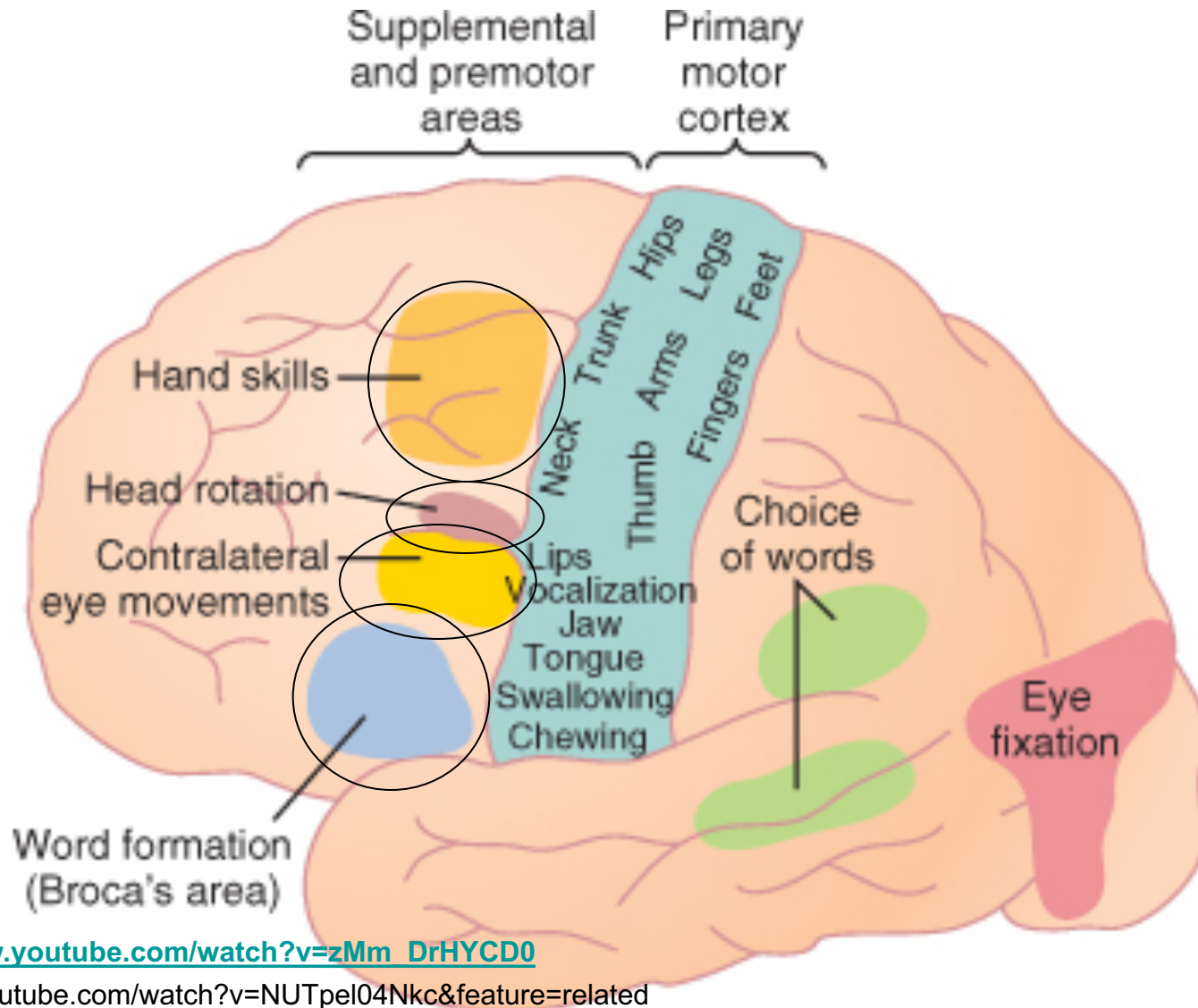


# Supplementary Premotor Area

- Programming of motor sequences.
- Acts in consonance with the premotor area and primary motor cortex.



# Specialized Areas



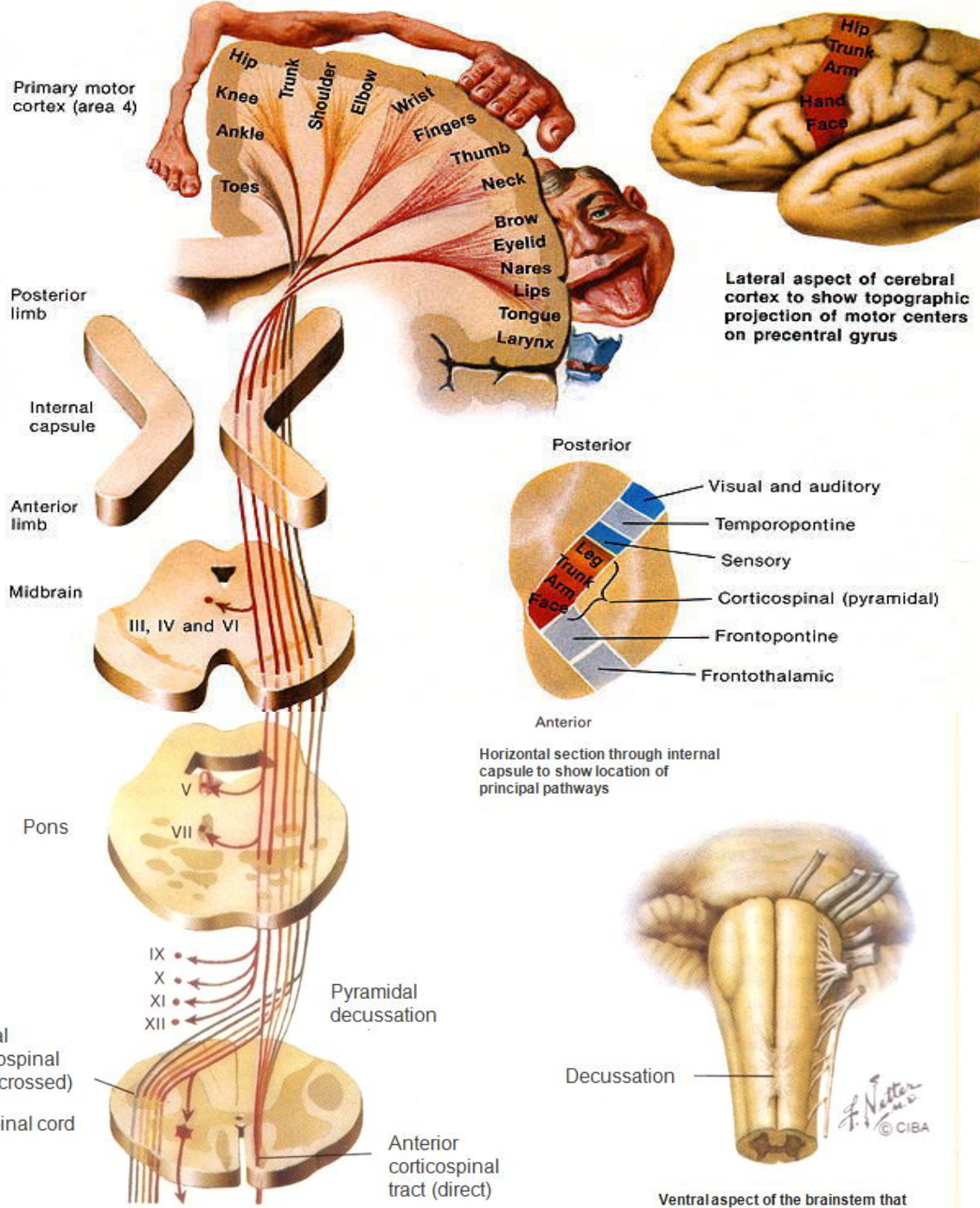
# Signal Transmission

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- Cortex → corticospinal fascicle → spinal cord
- Secondary tracts:
  - Basal ganglia
  - Cerebellum
  - Brainstem nuclei

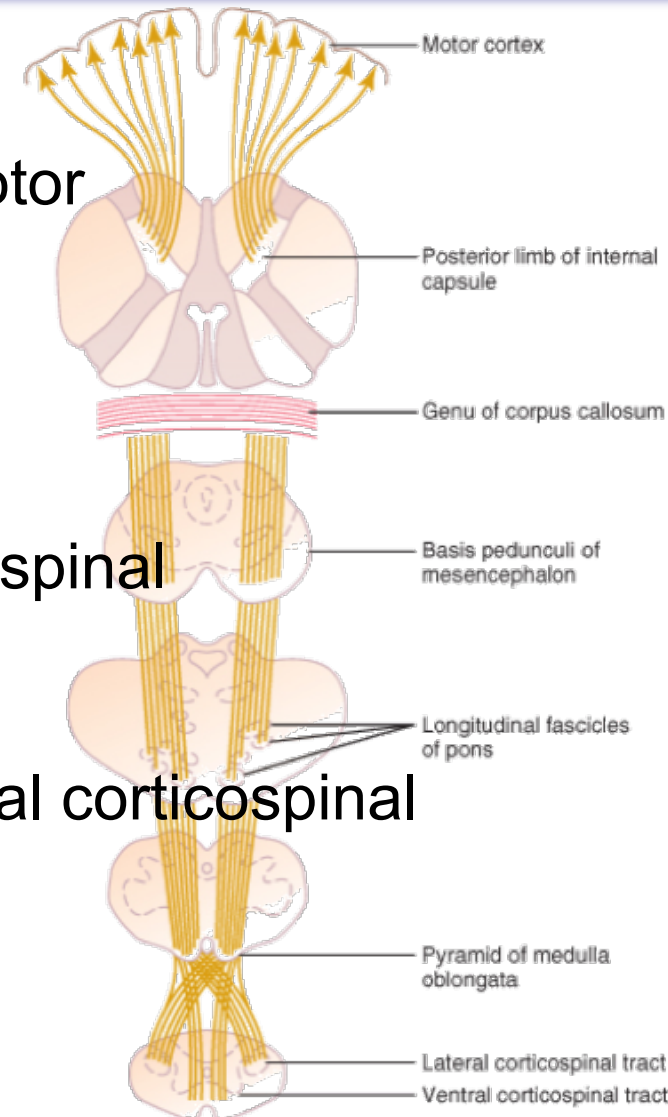


# Corticospinal tract (pyramidal)

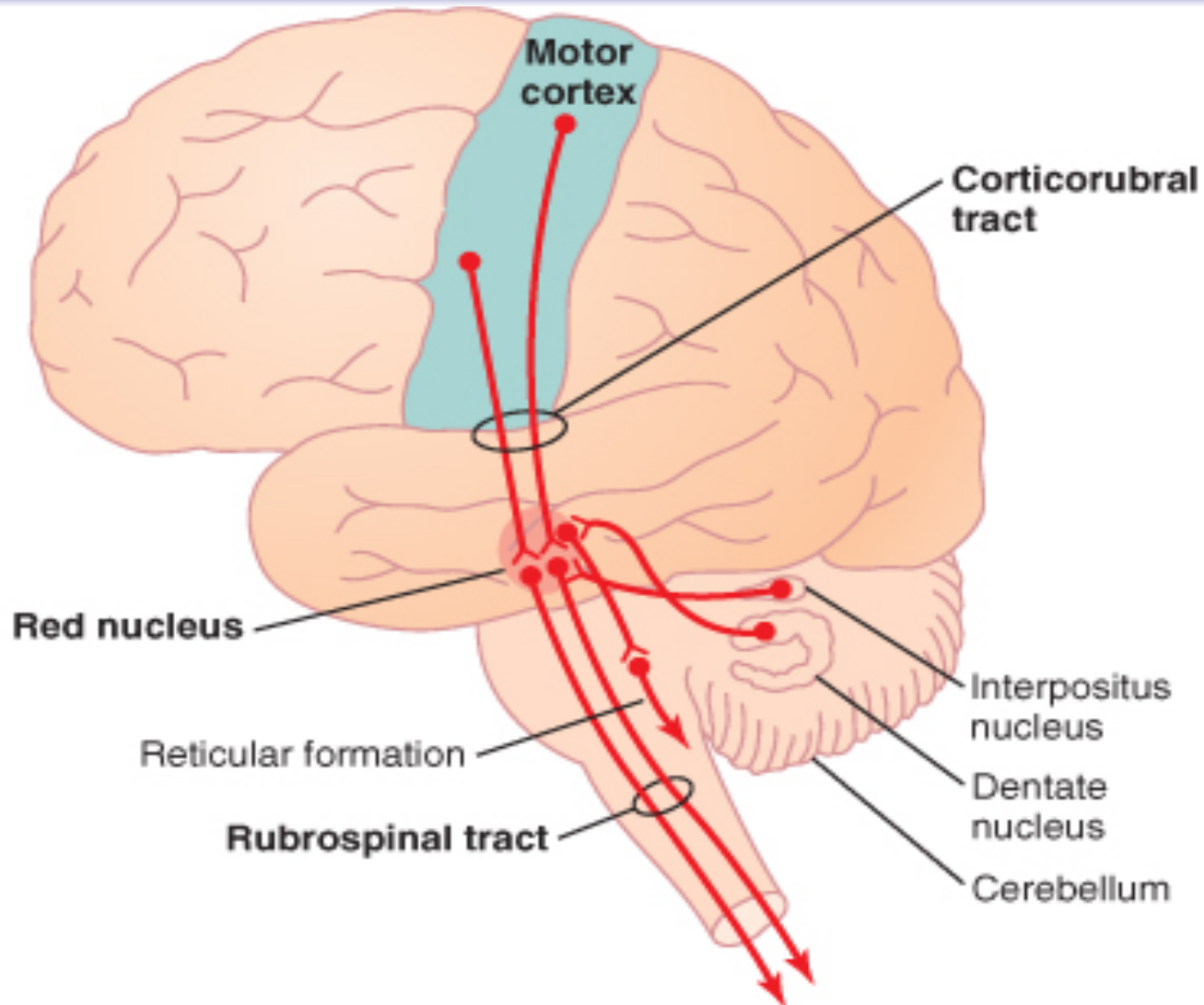


# Corticospinal Fascicle: Pyramidal Tract

- Is born
  - 30% primary motor cortex
  - 30% premotor and supplementary motor
  - 40% somatosensory areas
- Inner capsule (basal ganglia)
- Pyramids of the medulla oblongata (brainstem)
- Cross to the opposite side: lateral corticospinal fascicles of the spinal cord (80%)
  - Interneurons, sensory, motoneurons
- DO NOT cross to the opposite side: lateral corticospinal ventral fascicles of the spinal cord (20%)
  - cross on the neck or thorax
  - postural movements



# Red Nucleus

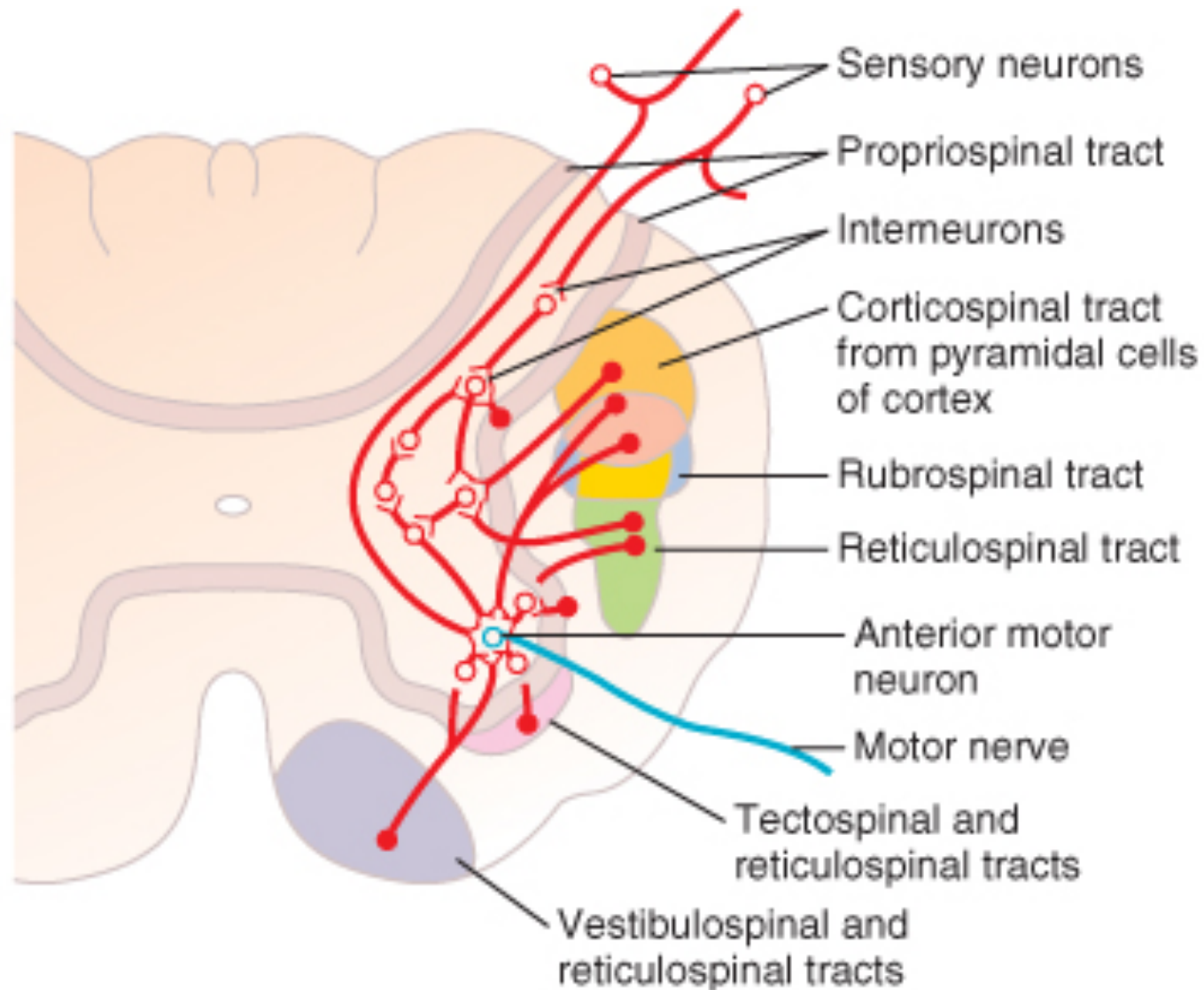


# Function of the Corticorubrospinal System

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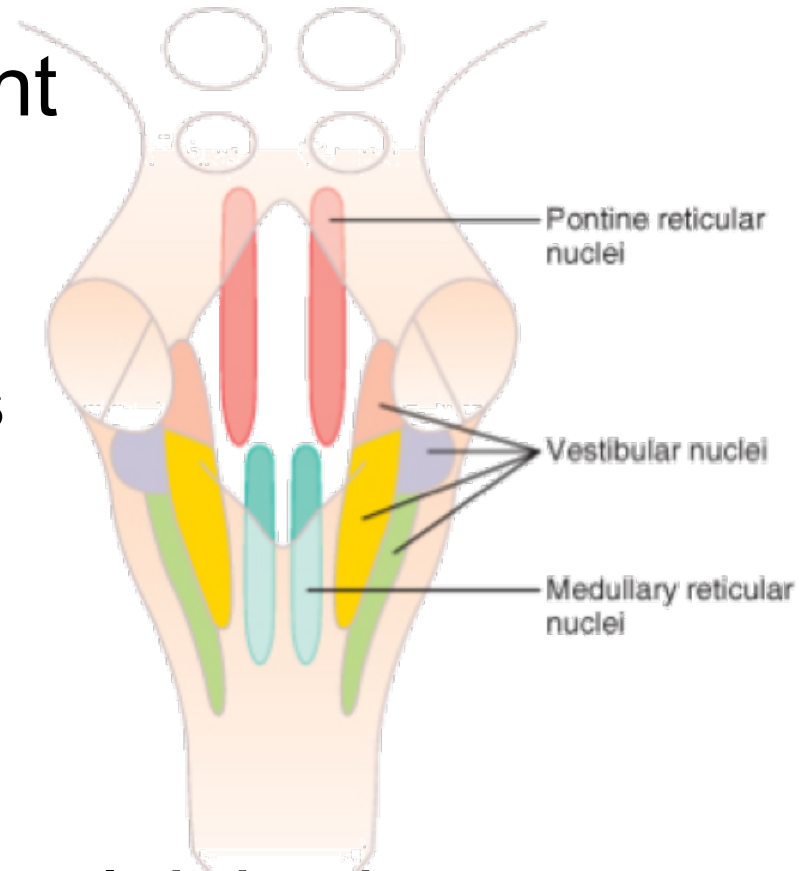
- There is a somatographic representation but it is less accurate
- No fine movements (hands, fingers)
- Gross movements: wrist

# Spinal Areas of Motor Control



# Brainstem

- Face and head movement
- Control of:
  - Breathing
  - Cardiovascular apparatus
  - Digestive (partial)
  - Stereotyped movements
  - Balance
  - Eye movements
- Vestibular and reticular nuclei: body support against gravity, balance and movement of the body as a whole





# VOLUNTARY MOTOR CONTROL (II)

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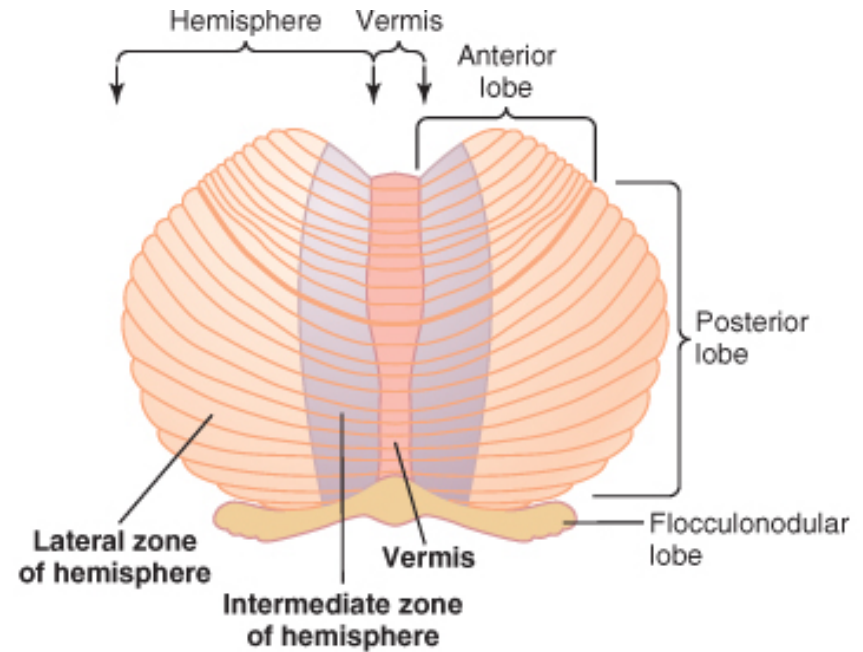
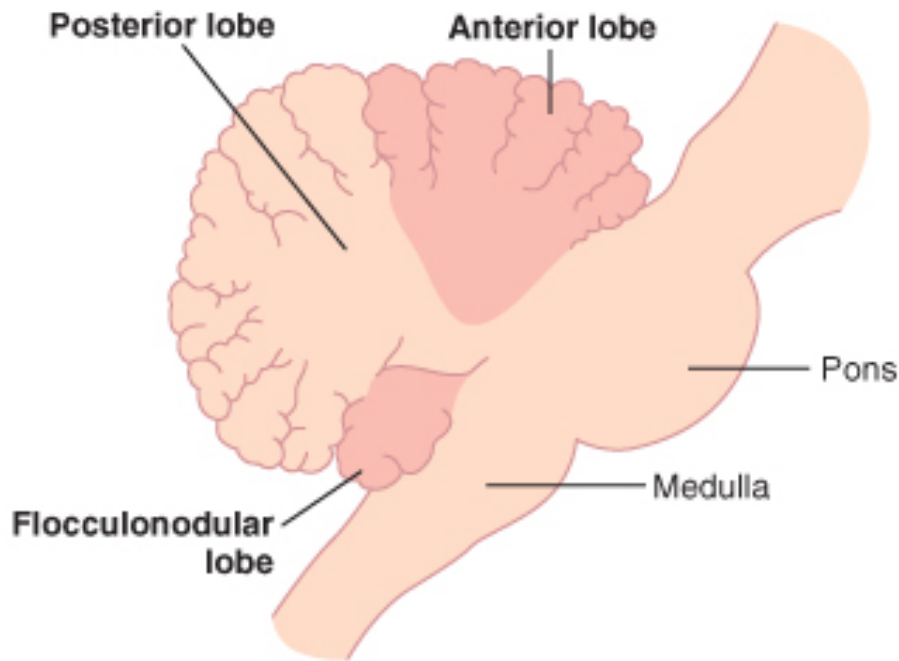
# Outline

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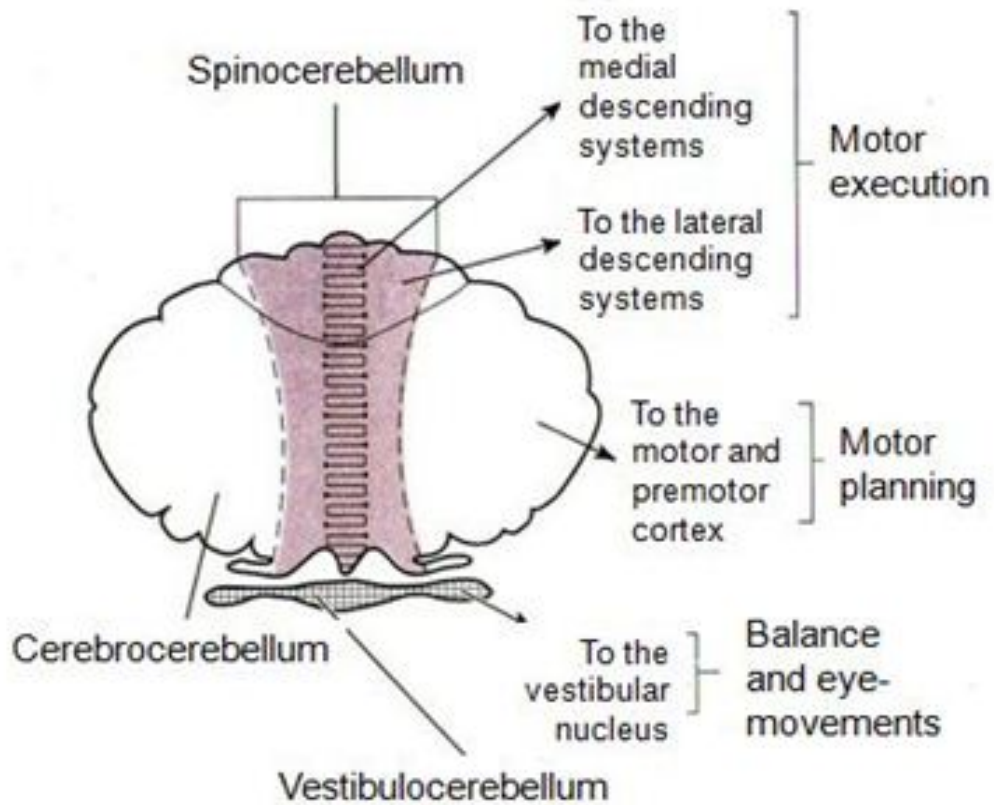
- The cerebellum and its motor functions
- Neuronal circuit of the cerebellum
  - Entry tracts
  - Exit tracts
- Cerebellar cortex
- Basal ganglia
  - Putamen circuit
  - Caudate circuit



# Cerebellum



- It is involved in the coordination of movement, not in its production.



**Figure 12-16.** Functional divisions of the cerebellum. (Modified from ER, Schwartz JH, Jessell TM [eds.]: *Principle of Neural Science*, 4<sup>th</sup> ed. McGraw-Hill, 2000.)

# Cerebellum

---

- Temporal coordination of motor activities
- Smooth and quick transition from one muscle movement to the next
- Regulation of the muscle contraction intensity
- Control of instant interactions between agonist and antagonist muscle groups

# Structures Related to Coordination and Motor Adjustment

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## a) Peripheral sensory receptors

- muscle bundles
- Golgi tendon organ
- articular receptors (Pacini corpuscles, Ruffini's end organs and receptors similar to Golgi tendon organs)
- vestibular apparatus
- sight and hearing

## Structures Related to Coordination and Motor Adjustment

**b) Nerve tracts that “connect to cerebellum and receptors”**

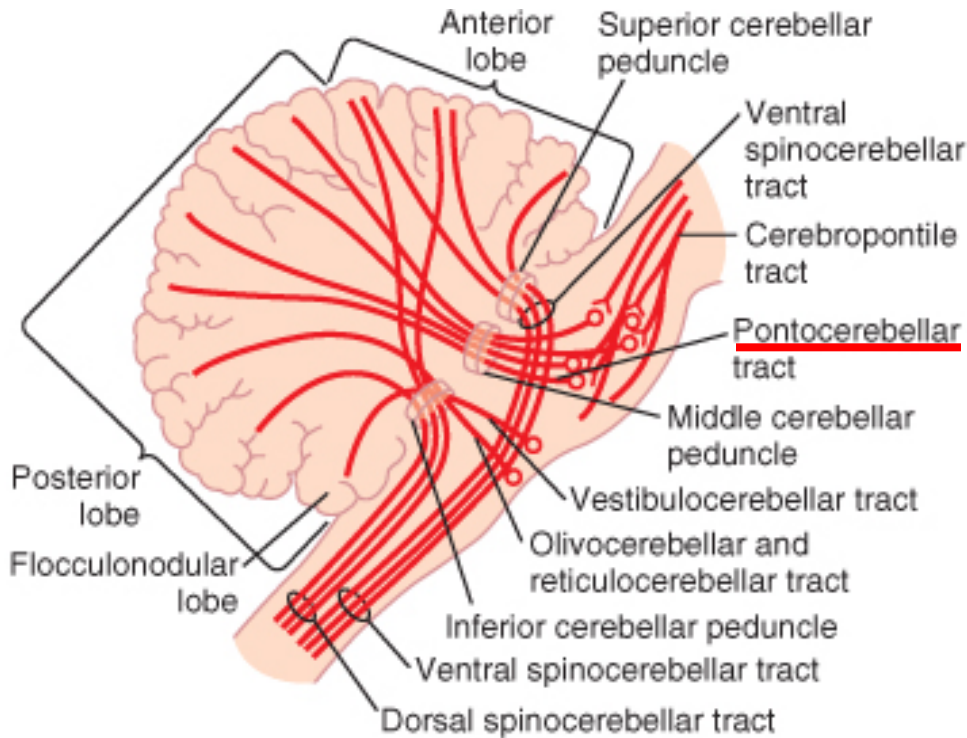
1) General somatic afferences

Direct: fascicles or spinocerebellar, dorsal, ventral, rostral, cuneocerebellar and trigeminocerebellar tracts

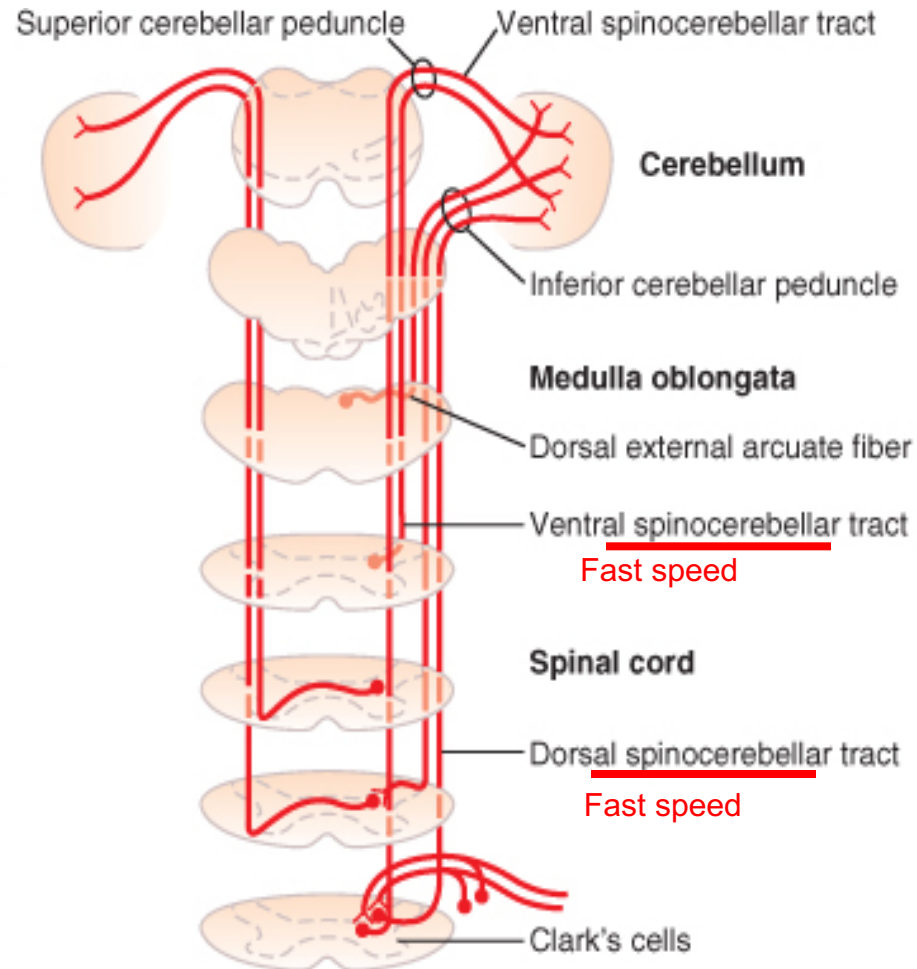
Indirect: spinoreticulocerebellar and spinolivocerebellar tract

2) Afferences from other vestibular (vestibular-cerebellar tract), auditory and visual sensory modes

# Neuronal Circuit of the Cerebellum



Afferent tracts from other portions of the brainstem



Peripheral afferent tracts

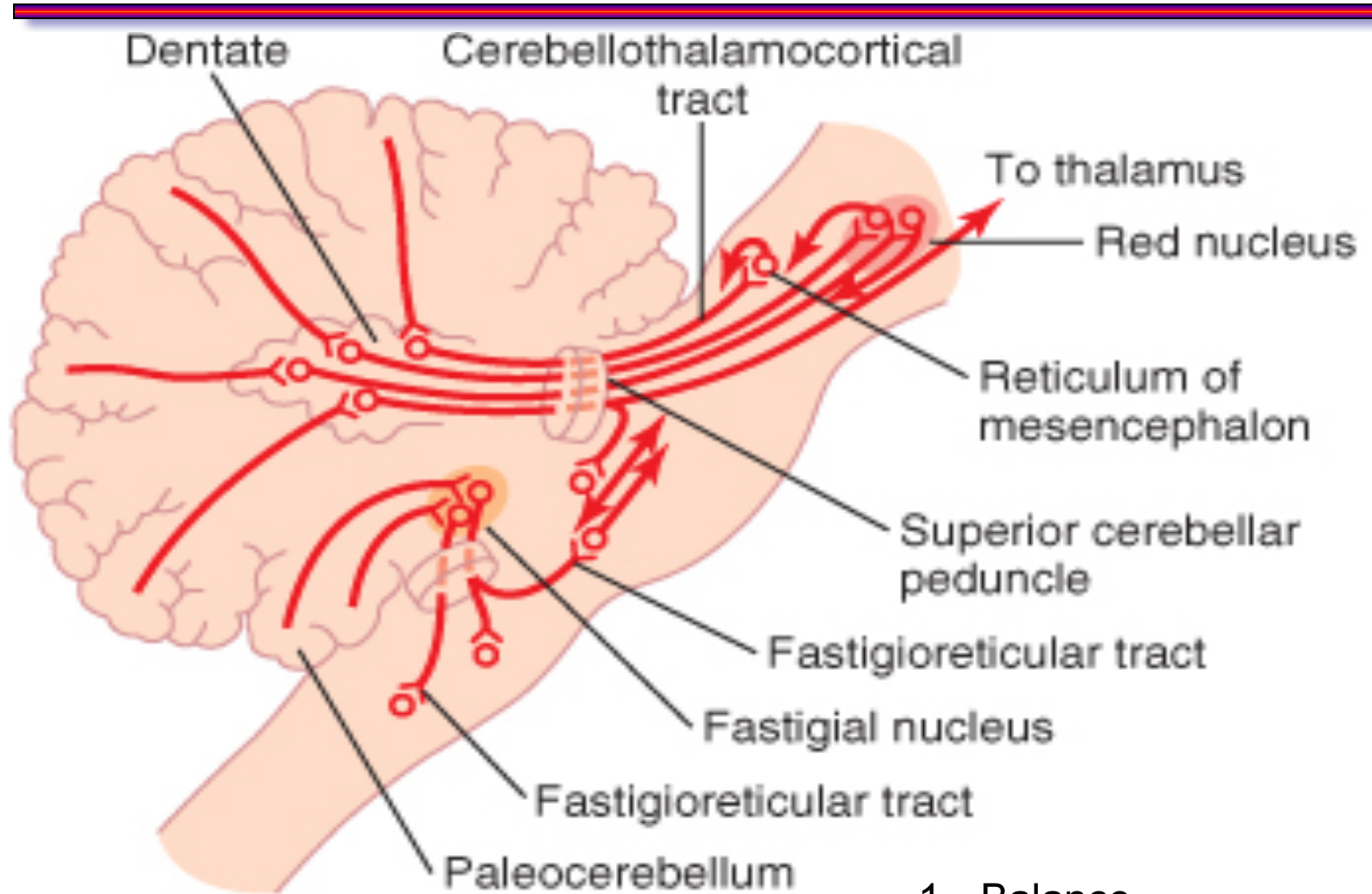
# Structures Related to Coordination and Motor Adjustment

## **b) Nerve tracts that “connect to cerebellum and receptors”**

### 1) Efferences

- from the cerebellar cortex to the brain cortex, going through the dentate nucleus (cerebellum) and ventral lateral and ventral anterior thalamic nuclei
- from the middle line of the cerebellum up to the medulla oblongata and pons
- up to the basal ganglia, after passing through the thalamus
- towards the red nucleus

# Neuronal Circuit of the Cerebellum



Efferent tracts

1. Balance
2. Coordination
3. Agonist/antagonist

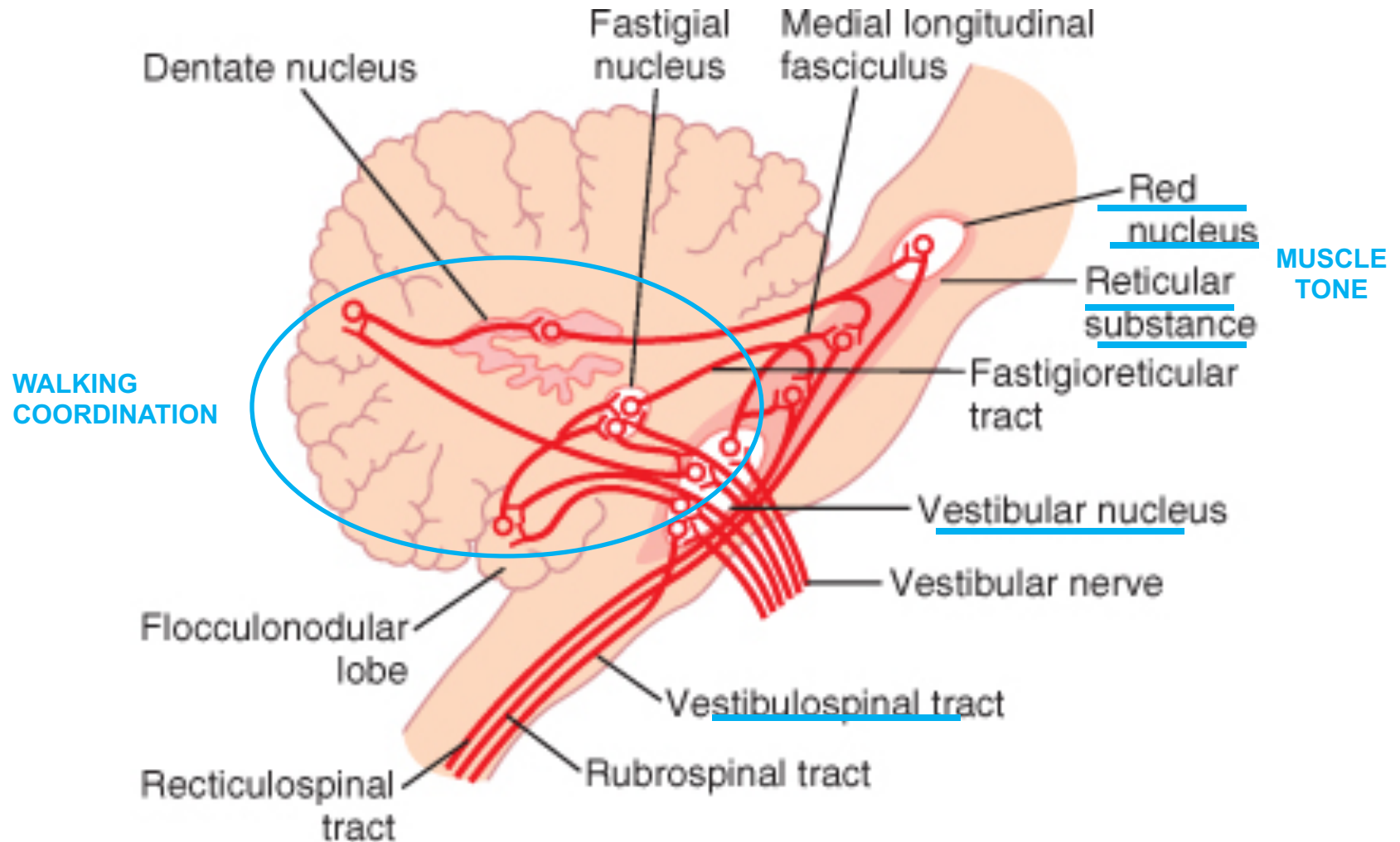


# Structures Related to Coordination and Motor Adjustment

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- a) peripheral sensory receptors**
- b) nerve tracts that “connect to cerebellum and receptors”**
- c) cerebral motor cortex**
- d) tracts that connect the cerebral cortex to the cerebellum**

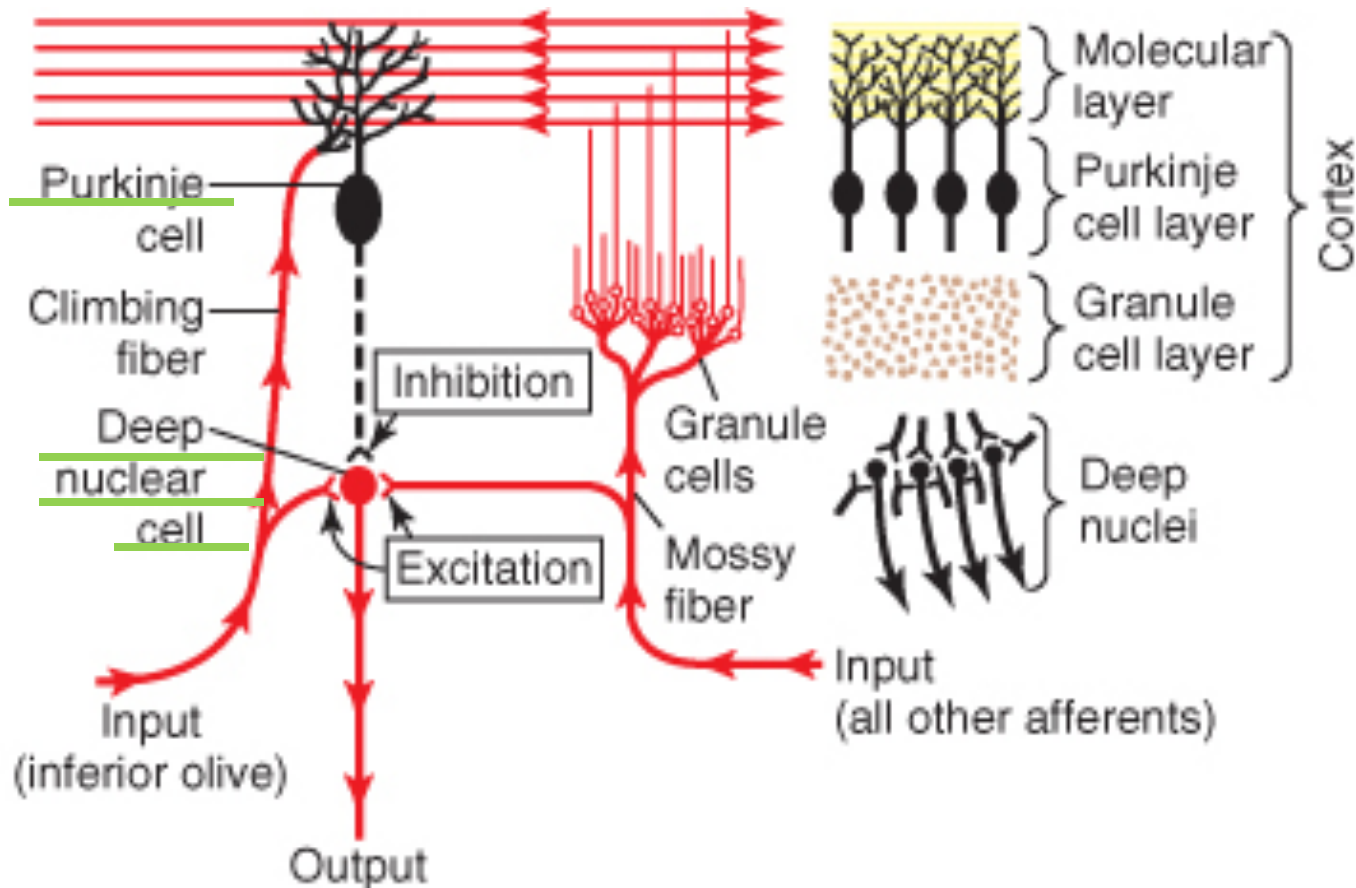
# Vestibular Tracts



[http://www.dailymotion.com/video/x6y8ko\\_el-equilibrio\\_school](http://www.dailymotion.com/video/x6y8ko_el-equilibrio_school)

<http://www.youtube.com/watch?v=wBe43MKdKGM>

# Cerebellar Cortex



# Cerebellum Injury

- hypermetria
- intentional trembling
- reduction of the ability to orderly transition from one kind of movement to the other
- the cerebellar patient may present scanning speech, characterized by the difficulty to pronounce coherent or sequenced phonemes
- <http://www.youtube.com/watch?v=5eBwn22Bnio>
- <http://www.youtube.com/watch?v=DYP2hkkE9fQ>

# Role of the Cerebellum on the Motor Coordination and Adjustment

---

- a) Receives information about a series of movements that the person wants to make, **from the brain structures related to the programming and execution of movements.**
- b) **Receives information from the peripheral receptors about the state of each body part displaced as a consequence of movement.**

## **Role of the Cerebellum on Motor Coordination and Adjustment**

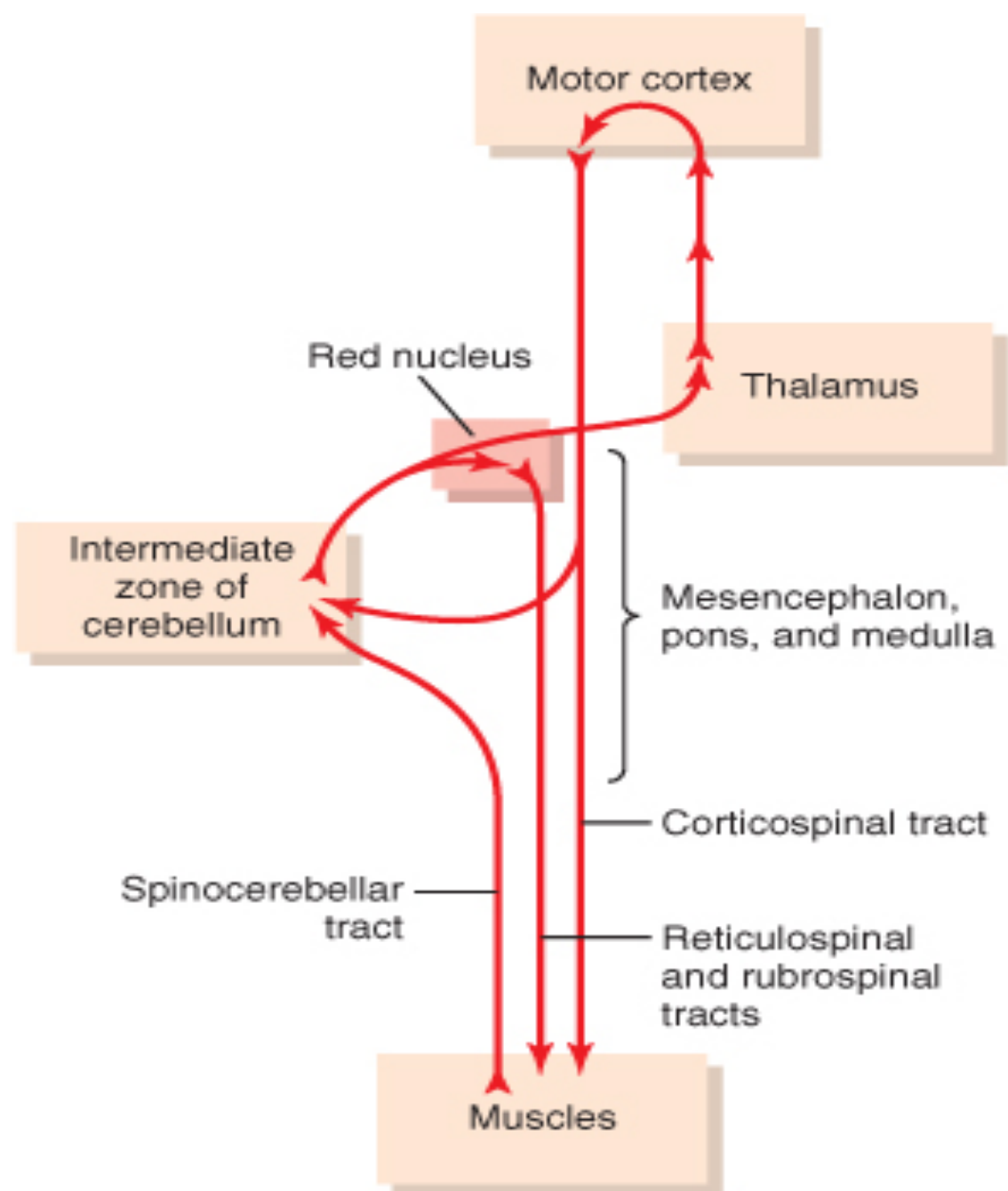
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**c) Compares what was achieved by the movement with what was expected to achieve according to the motor orders from the motor cortex. This comparison process will allow the cerebellum to send corrective signs to the motor brain cortex in order to adequately adjust motor orders from the said cortex to the movement the person wants to execute.**

# Role of the Cerebellum on Motor Coordination and Adjustment

---

The existence of direct feedback circuits between the motor cortex and the cerebellum, as well as feedback circuits where signals from the periphery to the cerebellum intervene allow the **participation of the cerebellum in the cortical motor control**. The cerebellar control of the cortical motor function through the aforesaid feedback circuits allows the brain to exercise two functions: **shock-absorption and prediction**. The first function is manifested by the avoidance of the previously mentioned dysmetria, which was responsible for the intentional trembling; the second function is manifested by the prediction of the temporal evolution of the movements of different body parts.



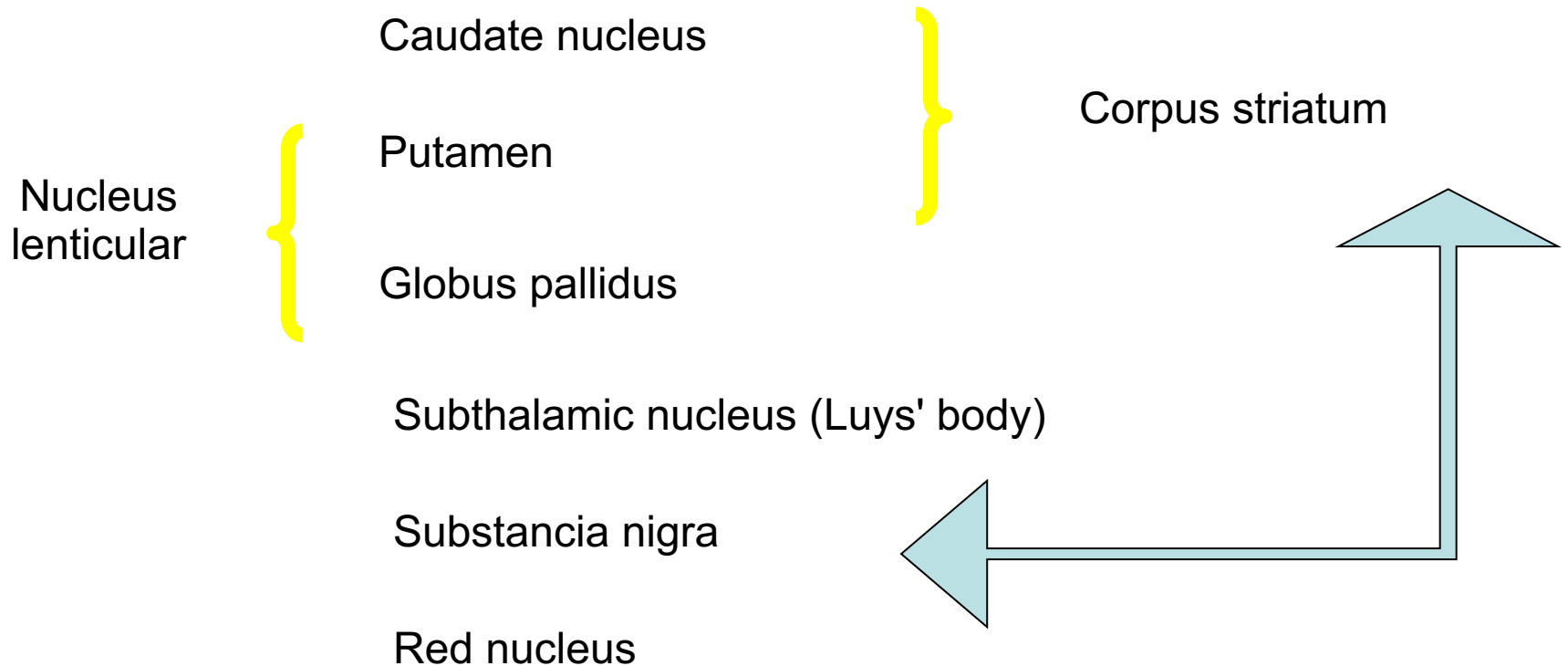


# Basal Ganglia

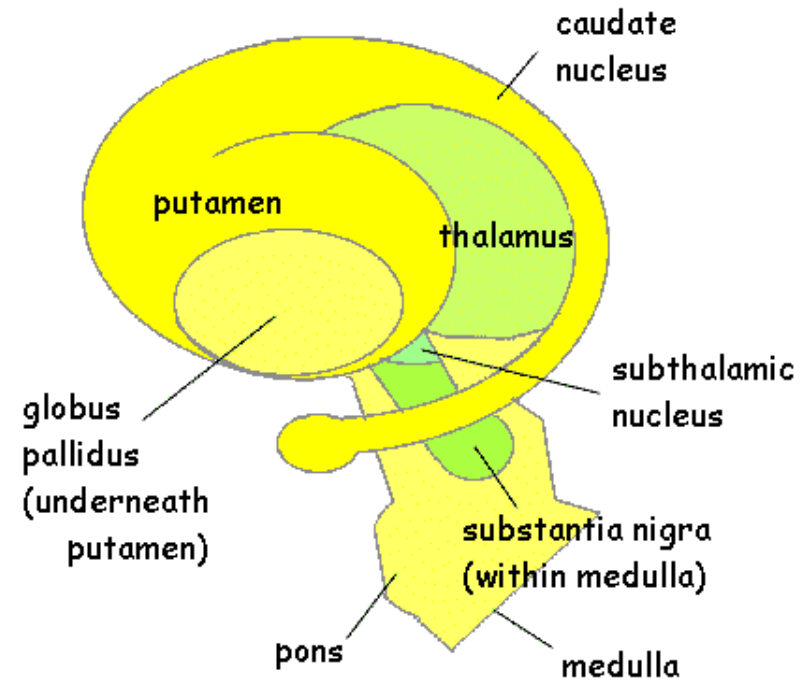
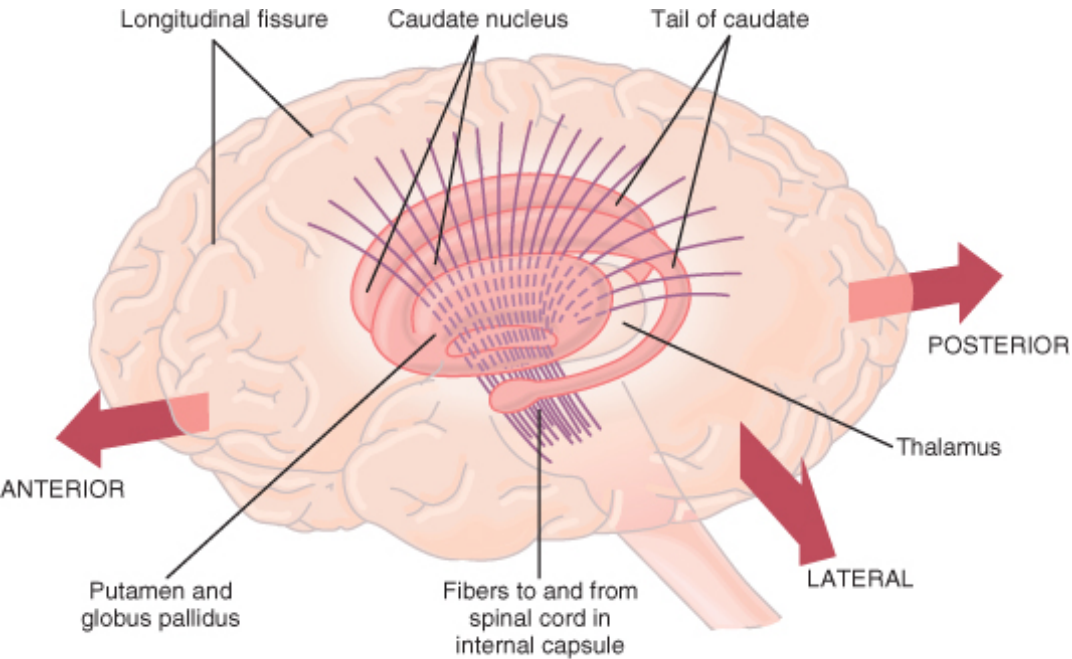
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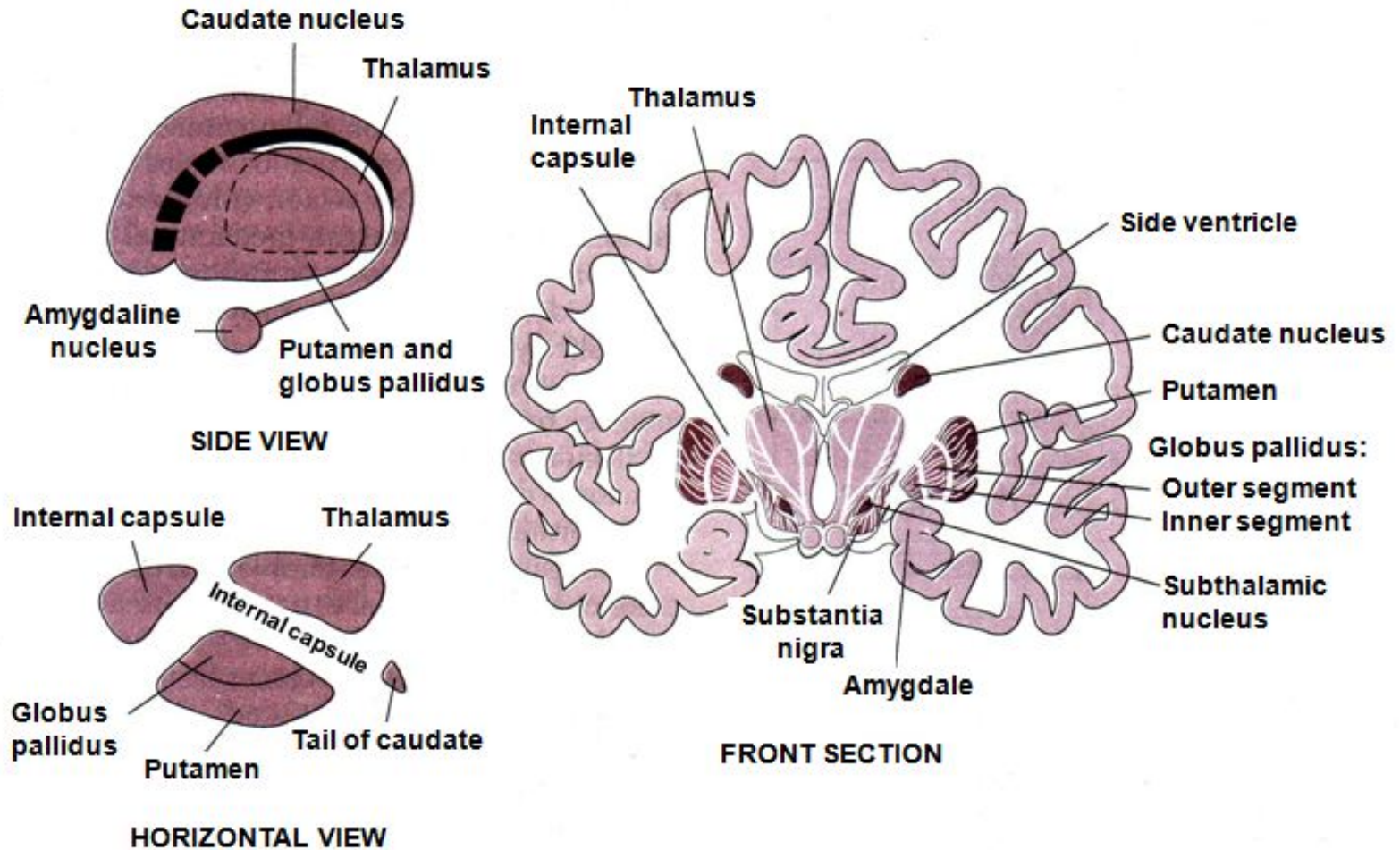
- They plan and control complex patterns of movement.
- They regulate relative intensities of each movement, its direction, and the ordering of parallel and successive movements for the execution of a complex movement.

# BASAL GANGLIA



# Basal Ganglia

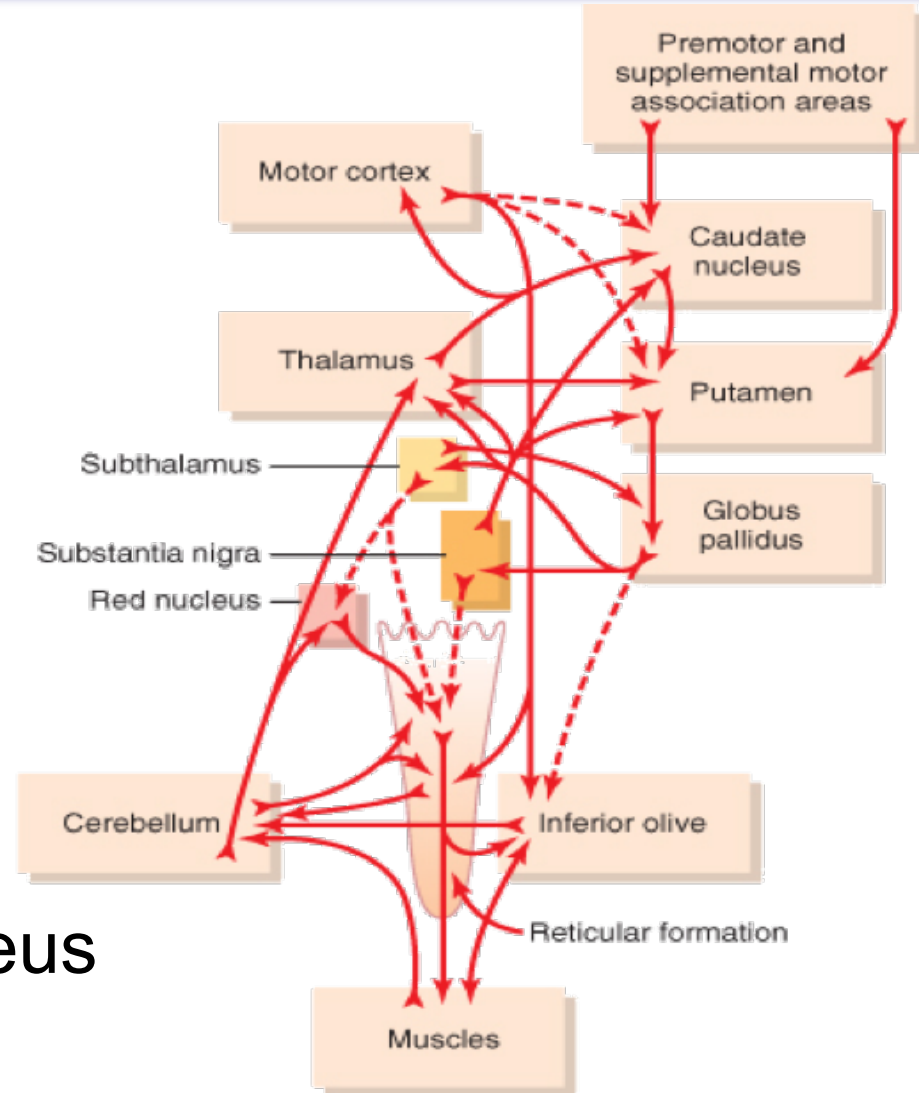




**Figure 12-9.** Basal ganglia.

# Basal Ganglia

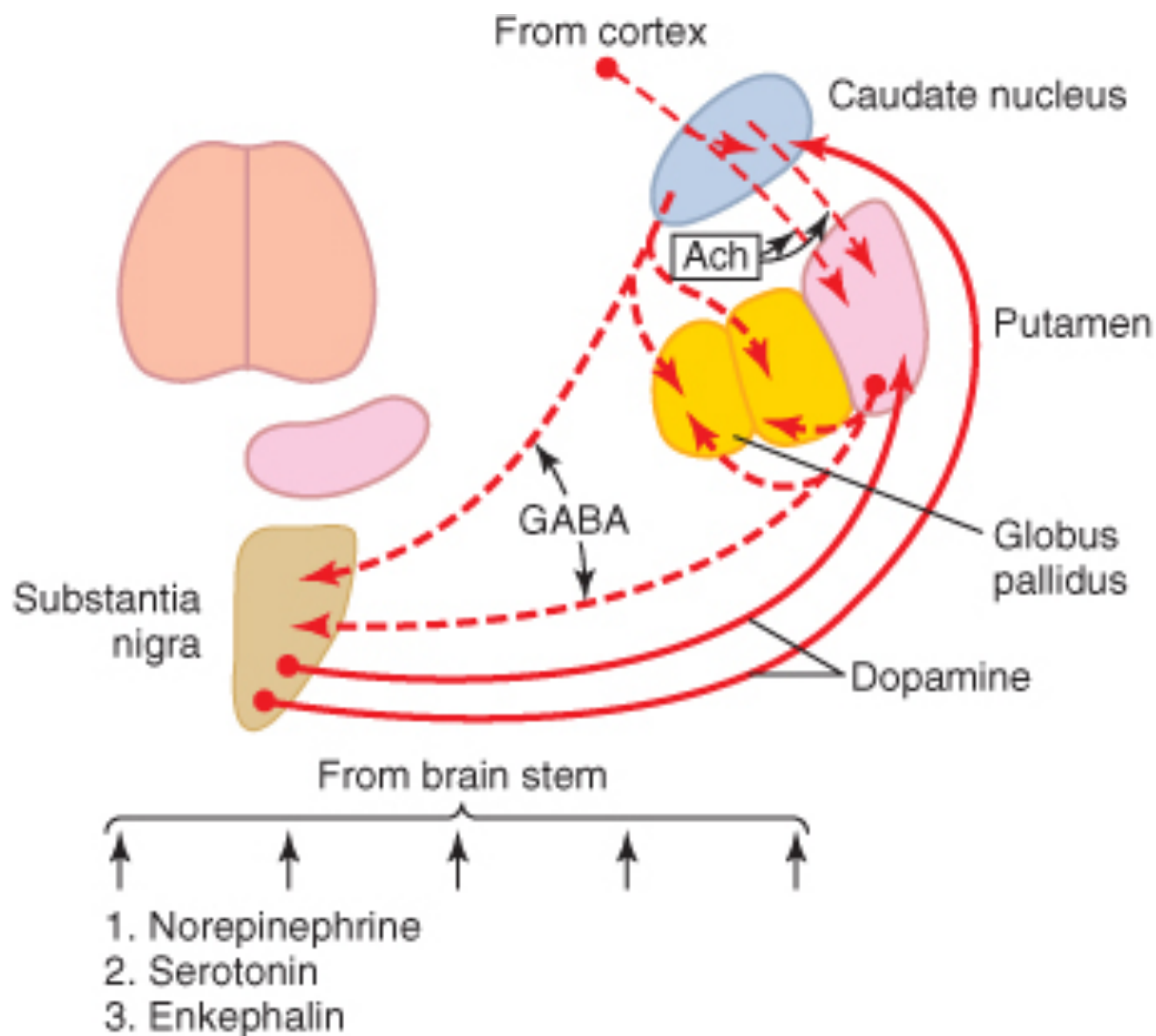
- Controls complex patterns of motor activity:
  - Putamen
  - Caudate nucleus
  - Globus pallidus
  - Substantia nigra
  - Subthalamic nucleus

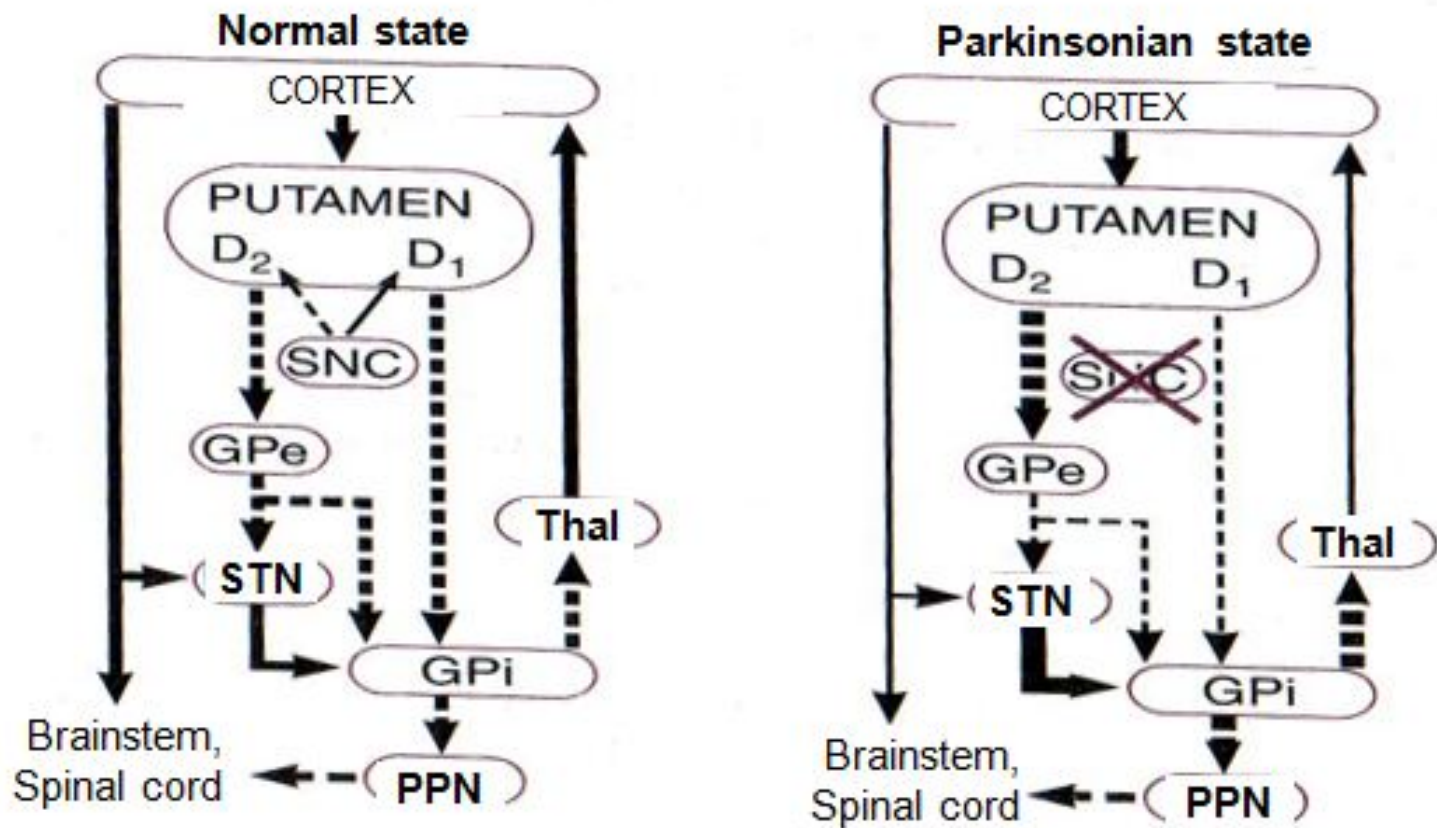


# Basal Ganglia

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- Putamen: complex patterns of motor activity: writing letters, cutting paper with scissors...
- Caudate nucleus: cognitive control of motor activity: adequate reaction to a given stimulus
- Injuries: Parkinson disease, Huntington disease





**Figure 12-11.** Circuit from the basal ganglia, thalamus and cortex in Parkinson's disease. The arrows indicate excitatory outputs and the dotted arrows indicate inhibitory outputs. The strength of each output is indicated with the width of the arrow. GPe, external segment of the globus pallidus; GPi, internal segment of the globus pallidus; SNc, compact part of substantia nigra; STN, subthalamic nucleus; PPN, peduncle-pontine nucleus; Thal, thalamus. See text for further detail. Modified from Grafton SC, DeLong M: Tracing the brain circuitry with functional imaging. *Nat Med* 1997; 3: 602.)



# Neuroplasticity

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- <http://www.youtube.com/watch?v=qLziFMF4DHA>