Chapter 6 中樞及周邊神經系統

6-1　神經系統的組成

6-2　大腦

6-3　間腦

6-4　腦幹

6-5　小腦

✓6-6　脊髓(p.186-189)

✓ 6-7　周邊神經系統(p.192-193)

Chapter 8 感覺

✓ 8-1 感覺接受器

✓ 8-2 體感覺

✓ 8-3 視覺

✓ 8-4 聽覺

✓ 8-5 平衡覺

✓ 8-6 嗅覺

✓ 8-7 味覺

Sensory Physiology

- **Information from periphery to CNS (Afferent=input)**

  --External environment: Sensory

  --Internal environment: Visceral afferent

- **Sensory Systems**

  1. Somatosensory system (General senses)

  --***Somatic*** — sensations of the skin

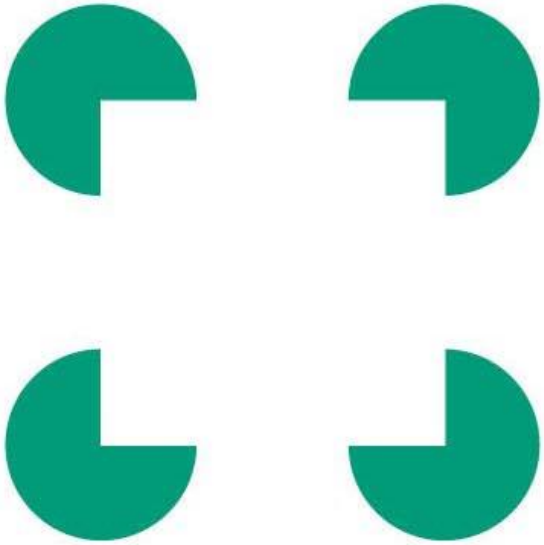
  --***Proprioception*** — perception of limb and body positions

  2. Special senses: Vision, Hearing, Equilibrium, Taste and Smell

Fallibility of Perception

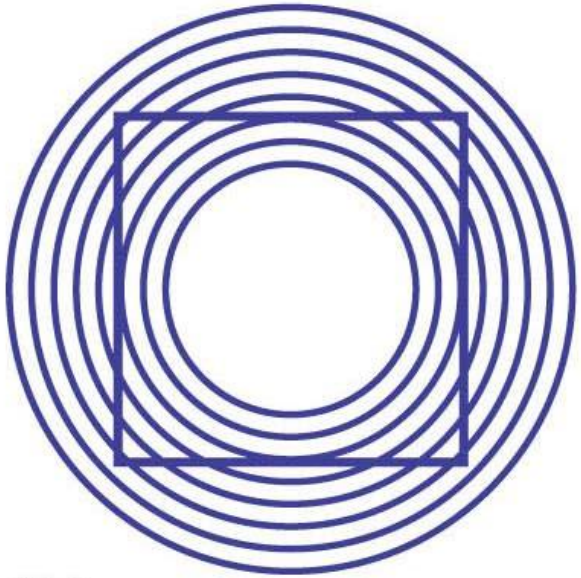
Conscious Interpretation of External World

知覺(認知)無法反應真實



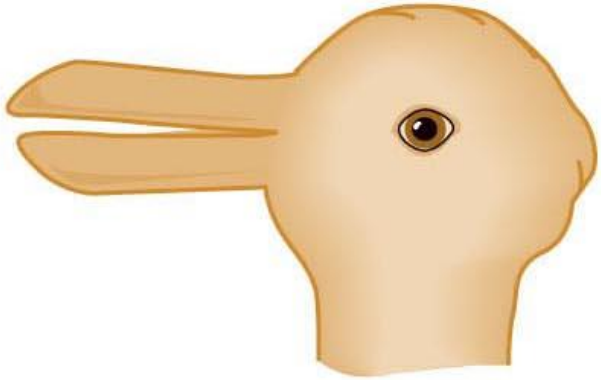
(a)

Do you see a square ?



(b)

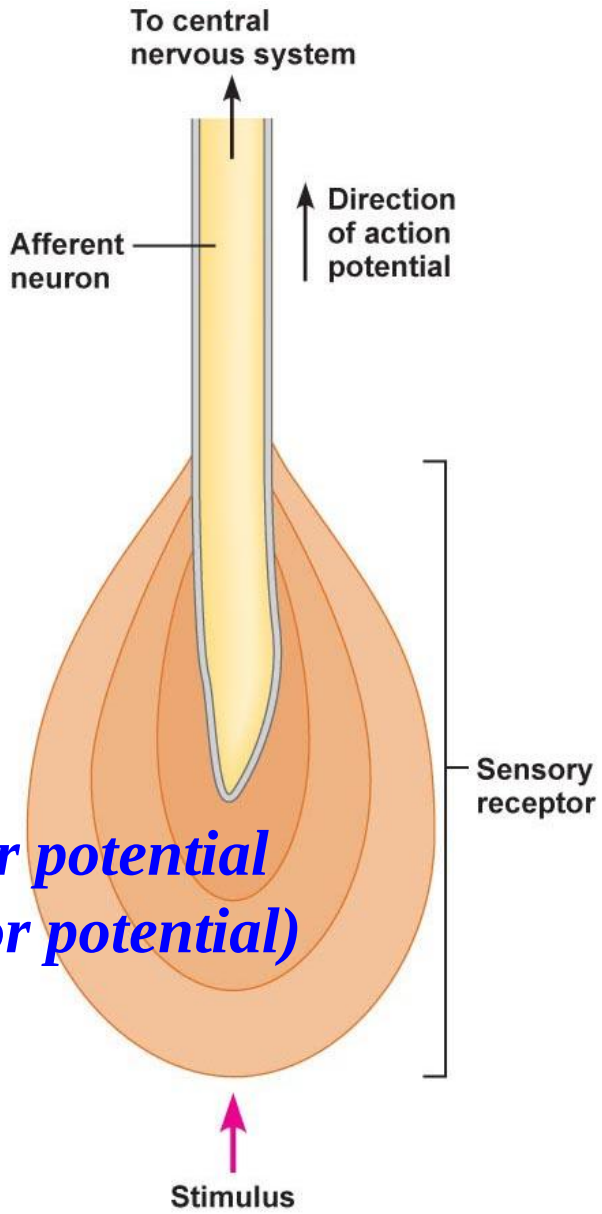
Are the sides of the square straight ?



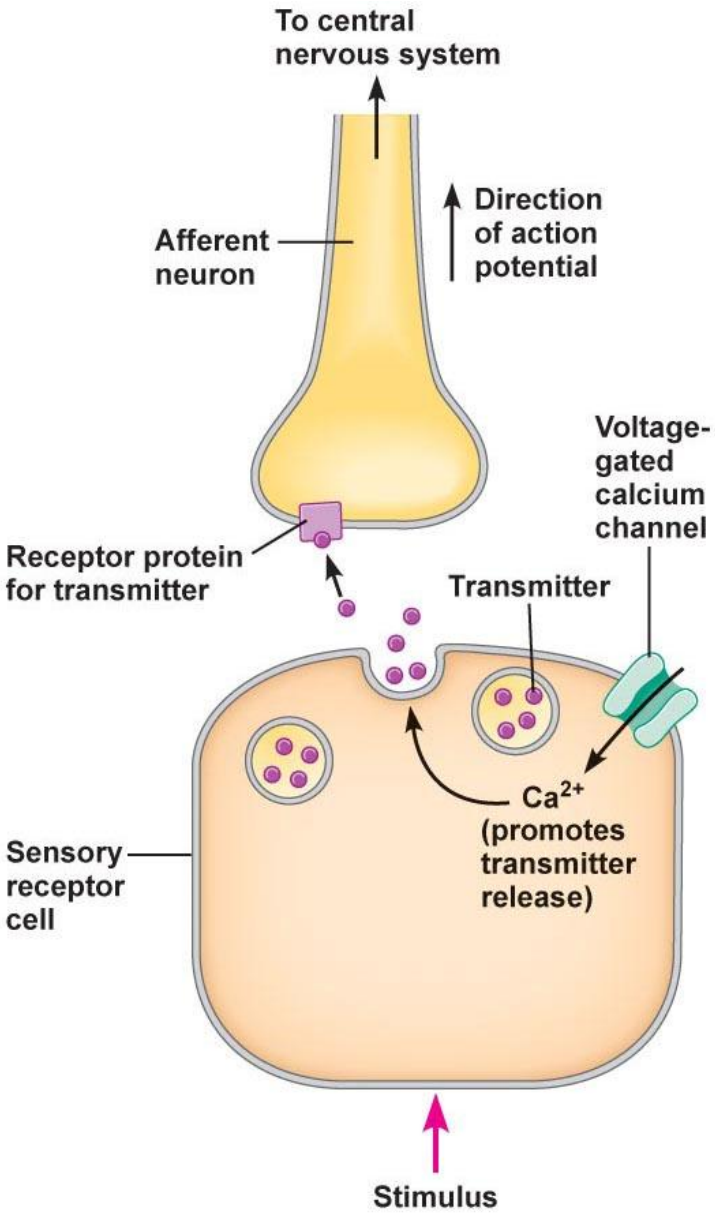
(c)

Duck or rabbit ?

Sensory Receptors



Receptor potential (generator potential)



Specialized nerve ending* or *separate cell

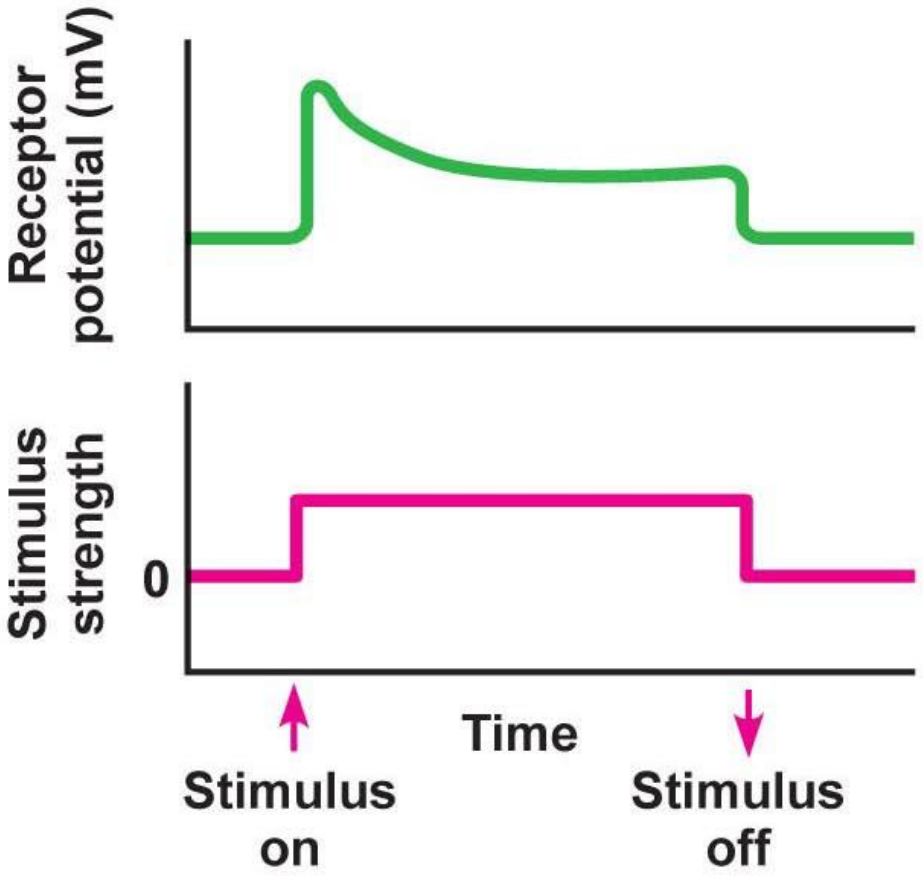
that detects a sensory stimulus

Sensory Receptor Characteristics

Receptor class	Sensation/visceral information	Modality
Photoreceptors	Vision	Photons of light
Chemoreceptors	Taste	Chemicals dissolved in saliva
	Smell	Chemicals dissolved in mucus
	Pain	Chemicals in extracellular fluid
	Blood oxygen	Oxygen dissolved in plasma
	Blood pH	Free hydrogen ions in plasma
Thermoreceptors		
Warm receptors	Warmth	Increase in temperatures between 30°C and 43°C
Cold receptors	Cold	Decrease in temperatures between 35°C and 20°C
Mechanoreceptors		
Baroreceptors	Blood pressure	Stretch of specific blood vessel walls
Osmoreceptors	Osmolarity of extracellular fluid	Swelling (stretch) of receptor cells
Hair cells	Sound	Sound waves
	Balance and equilibrium	Acceleration

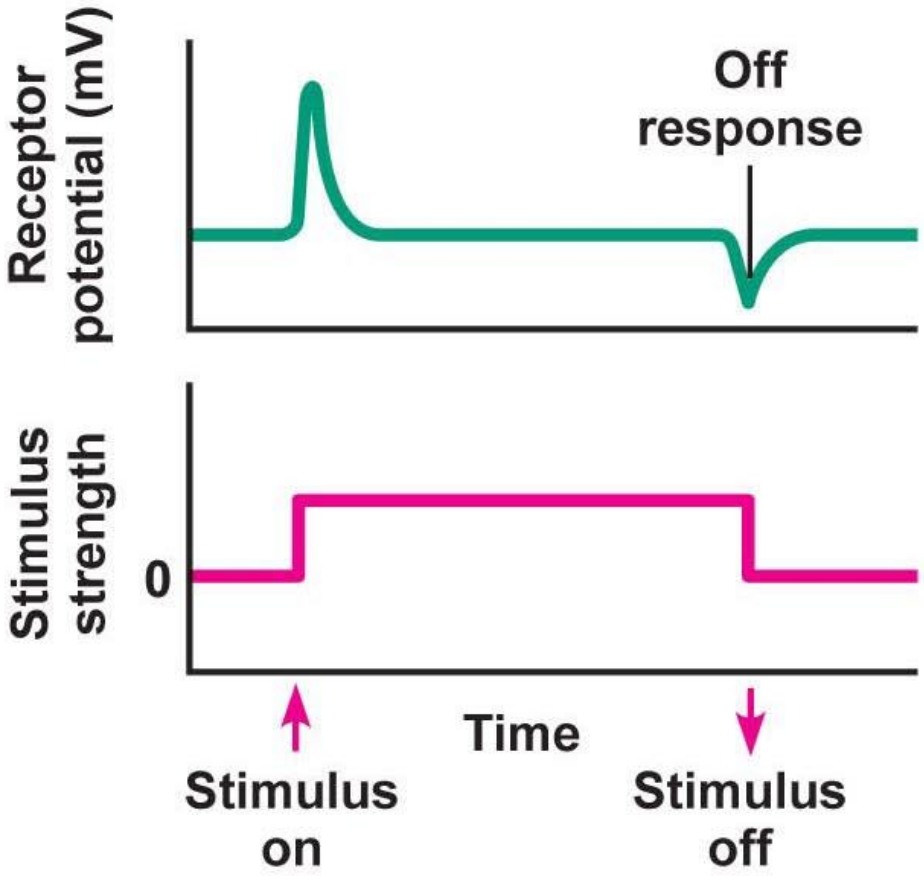
- ***Nociceptors:*** Pain receptors that depolarize when tissues are damaged
  - --Stimuli can include heat, cold, pressure, or chemicals
  - --Glutamate and substance P are the main neurotransmitters
  - --Perception of pain can be enhanced by emotions and expectations
  - --Pain reduction depends on endogenous opioids

Slow vs. Fast Adaptation



(a) Slowly adapting receptors

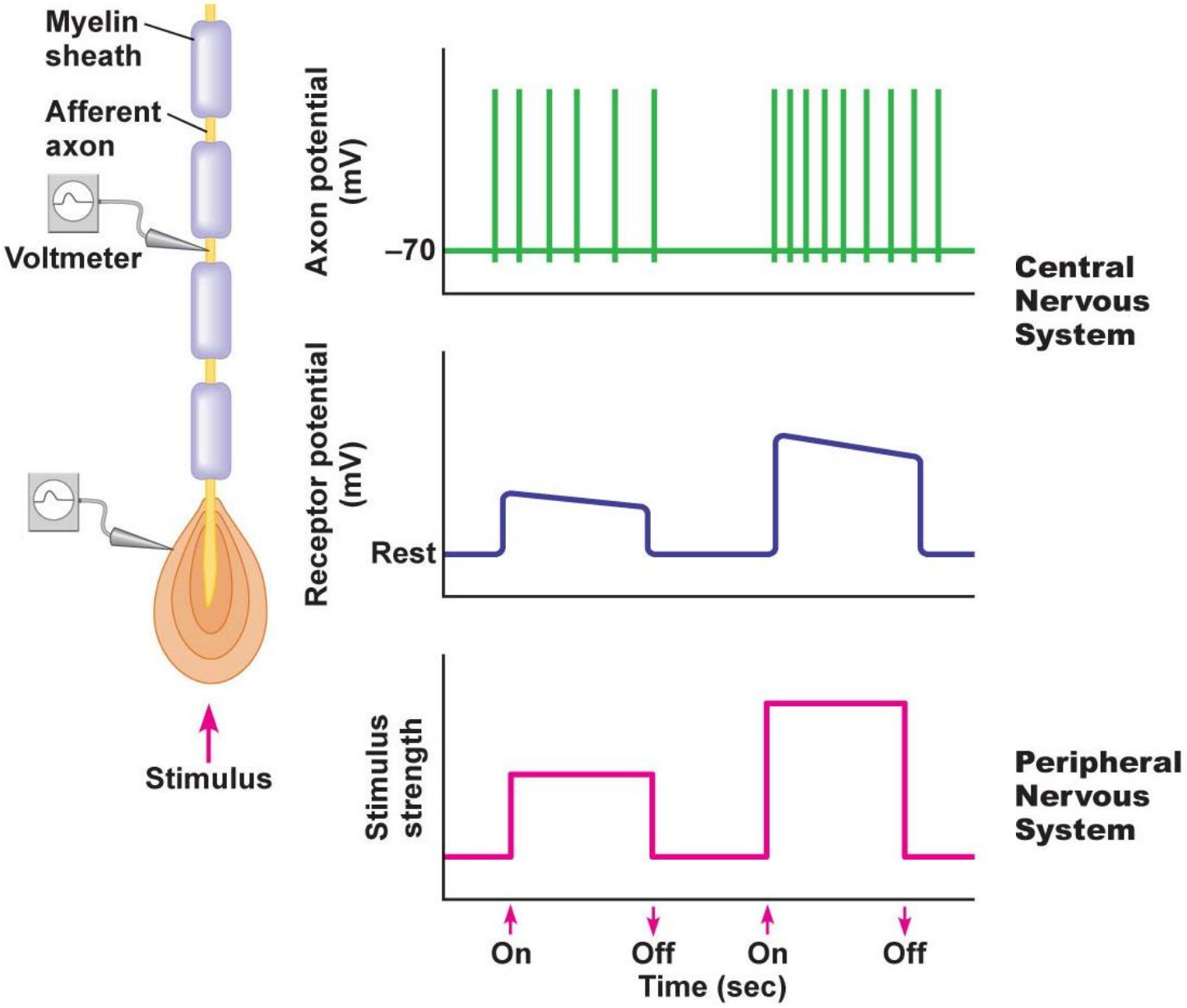
Tonic receptor

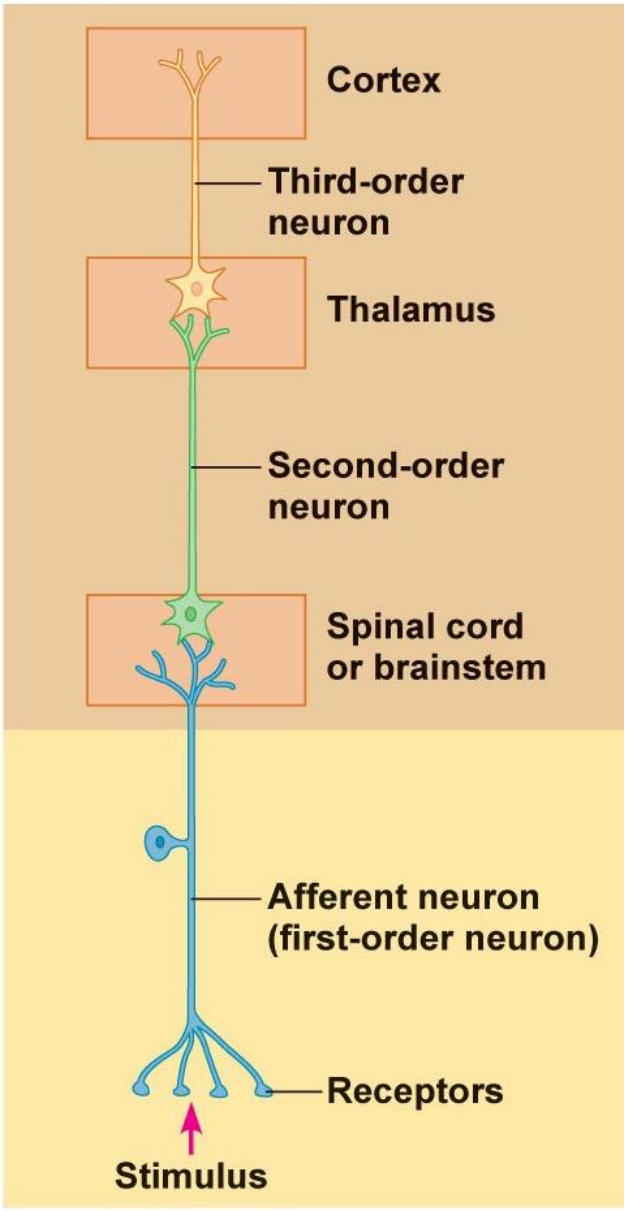


(b) Rapidly adapting receptors

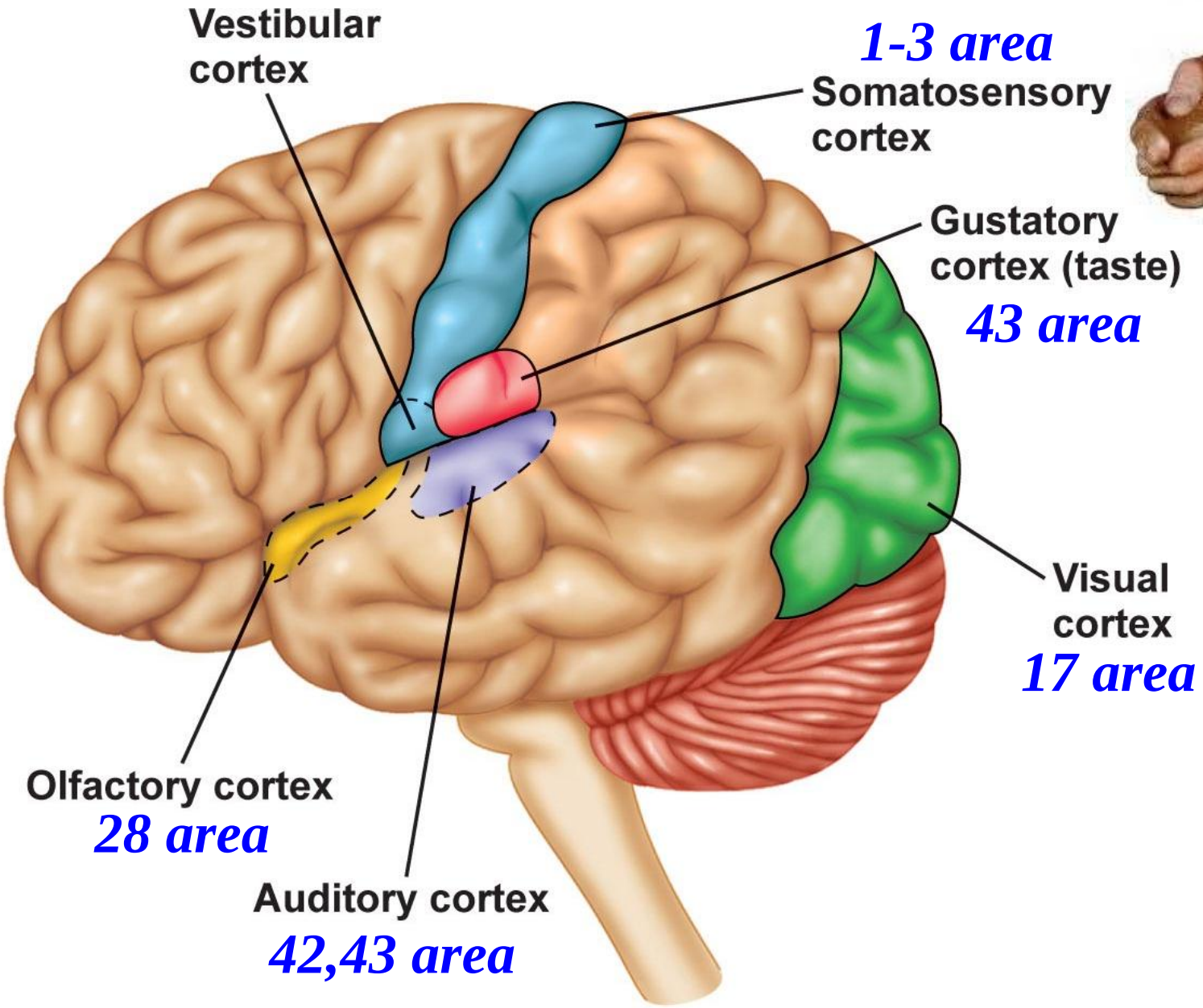
Phasic receptor

General Sensory Pathway





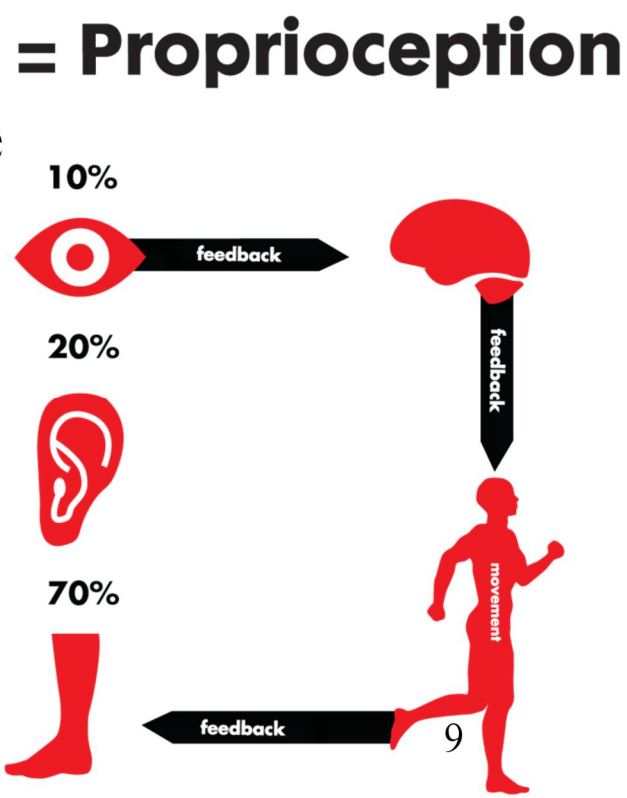
Cortical Sensory Areas



Somatosensory System

=General Senses

- **Somatic Sensations**
  1. ***Somesthetic sensations* (皮膚感覺)**
     --Associated with skin
  2. ***Proprioception* (本體=動力感覺)**
     --Awareness of body's position in space



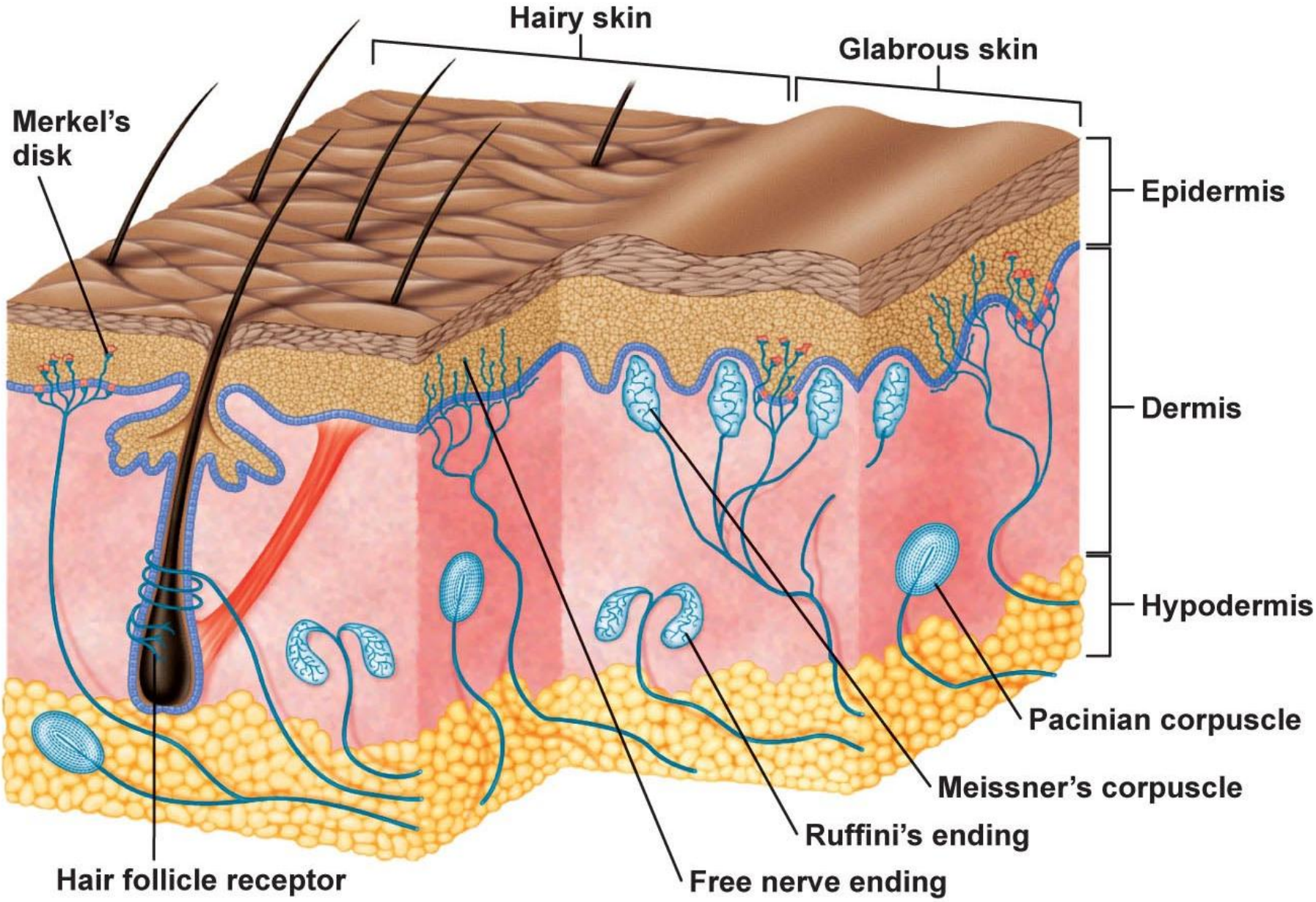
- **Somatosensory Receptors**
  1. ***Mechanoreceptors***
  2. ***Thermoreceptors***
  3. ***Nociceptors***

Types of Skin Receptors

Receptor class	Type	Associated afferent type	Location	Receptive field size	Adaptation	Modality
Mechanoreceptors	Free nerve ending	A-delta, C	Superficial, all skin	Small	Slow	Light touch
	Merkel's disk 麥氏	A-beta	Superficial, all skin	Small	Slow	Pressure
	Pacinian corpuscle	A-beta	Deep, all skin	Large	Rapid	Vibration *fast*
	Meissner's corpuscle	A-beta	Superficial, glabrous skin	Small	Rapid	Vibration *slow*
	Hair follicle receptor	A-beta	Superficial, hairy skin	Small	Rapid	Bending of hair
	Ruffini's ending 路氏	A-beta	Deep, hairy skin	Large	Slow	Pressure *warmth*
Thermoreceptors	Warm receptors (free nerve endings)	C	Superficial, all skin	Small	Rapid	Increase in skin temperature
	Cold receptors =Krause=麥氏	A-delta	Superficial, all skin	Small	Rapid	Decrease in skin temperature
Nociceptors	Mechanical (free nerve endings)	A-delta	Superficial, all skin	Large	Slow	Intense mechanical stimulus
	Thermal (free nerve endings)	A-delta	Superficial, all skin	Small	Rapid	Intense hot or cold stimulus
	Polymodal (free nerve endings)	C	Superficial, all skin	Large	Slow	Intense mechanical or thermal stimulus; specific chemicals

Receptive field = 每一感覺R能偵測的特定區域

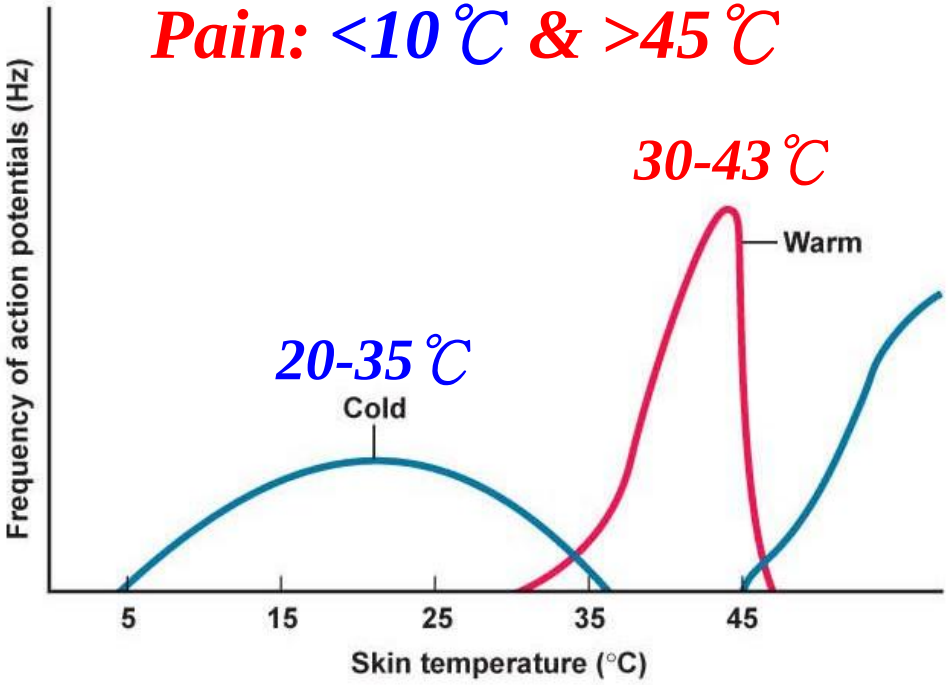
Mechanoreceptors of Skin



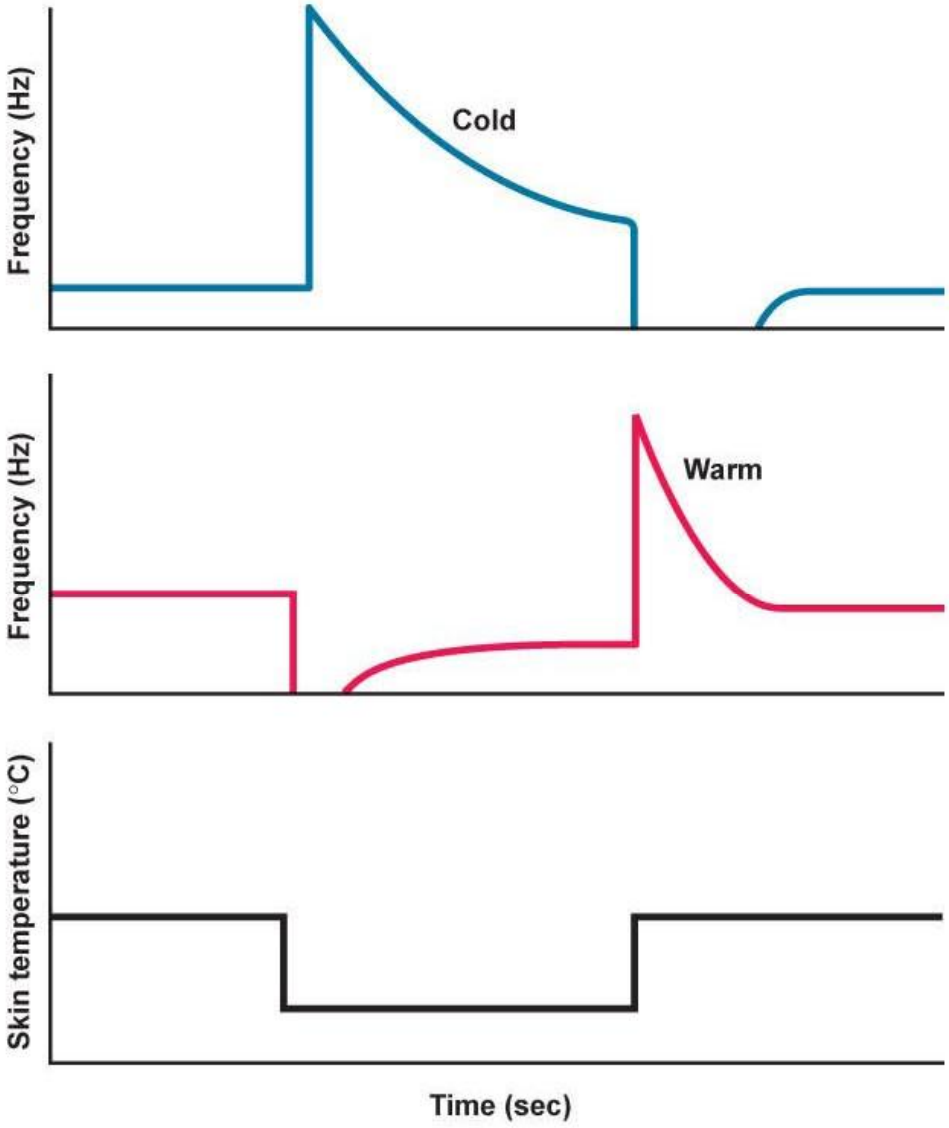
Thermoreceptor Responses

➢ ***Free nerve endings***

Pain: <10℃ & >45℃

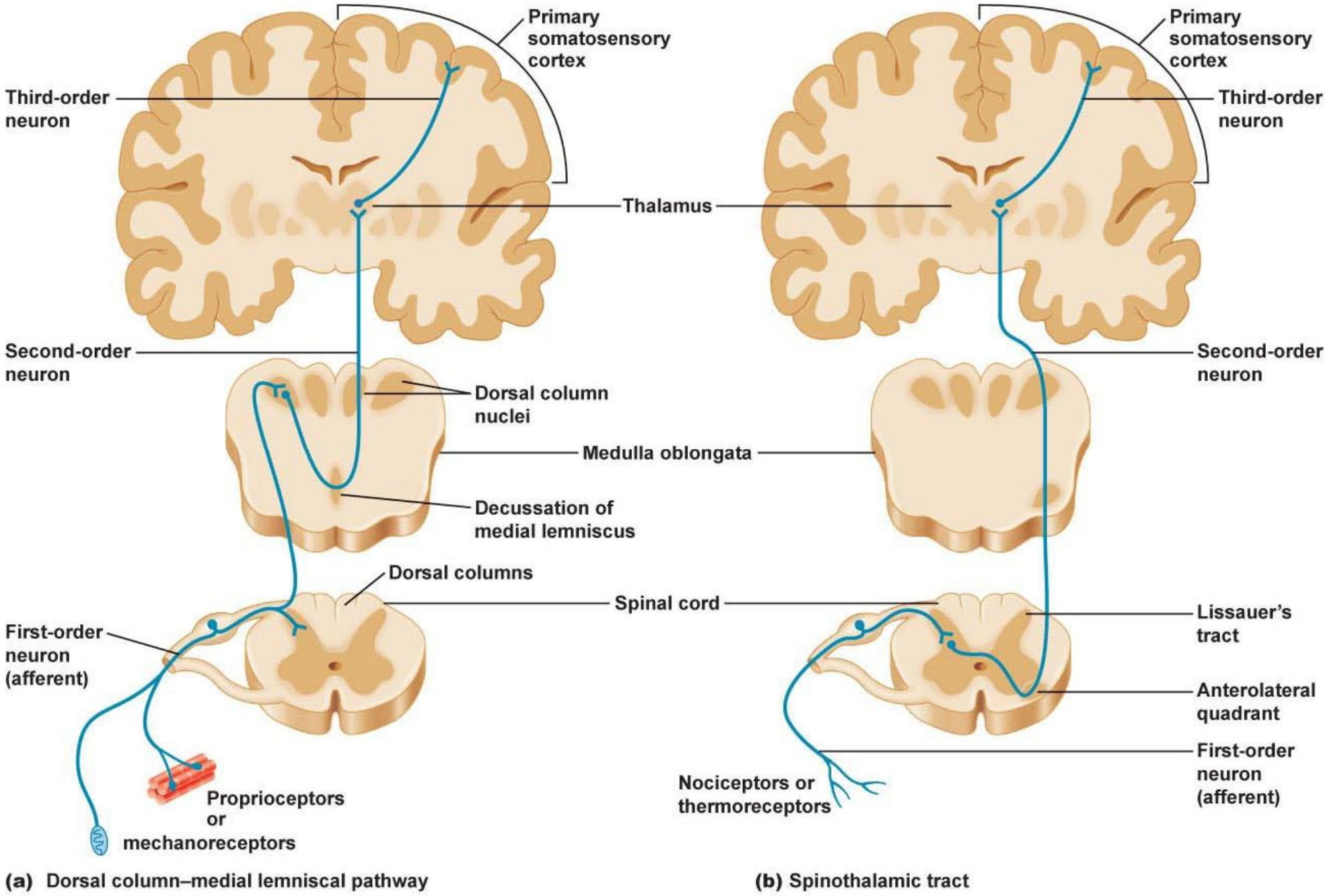


(a) Response of thermoreceptors to static temperature



(b) Response of thermoreceptors to changes in temperature

Somatosensory Pathways



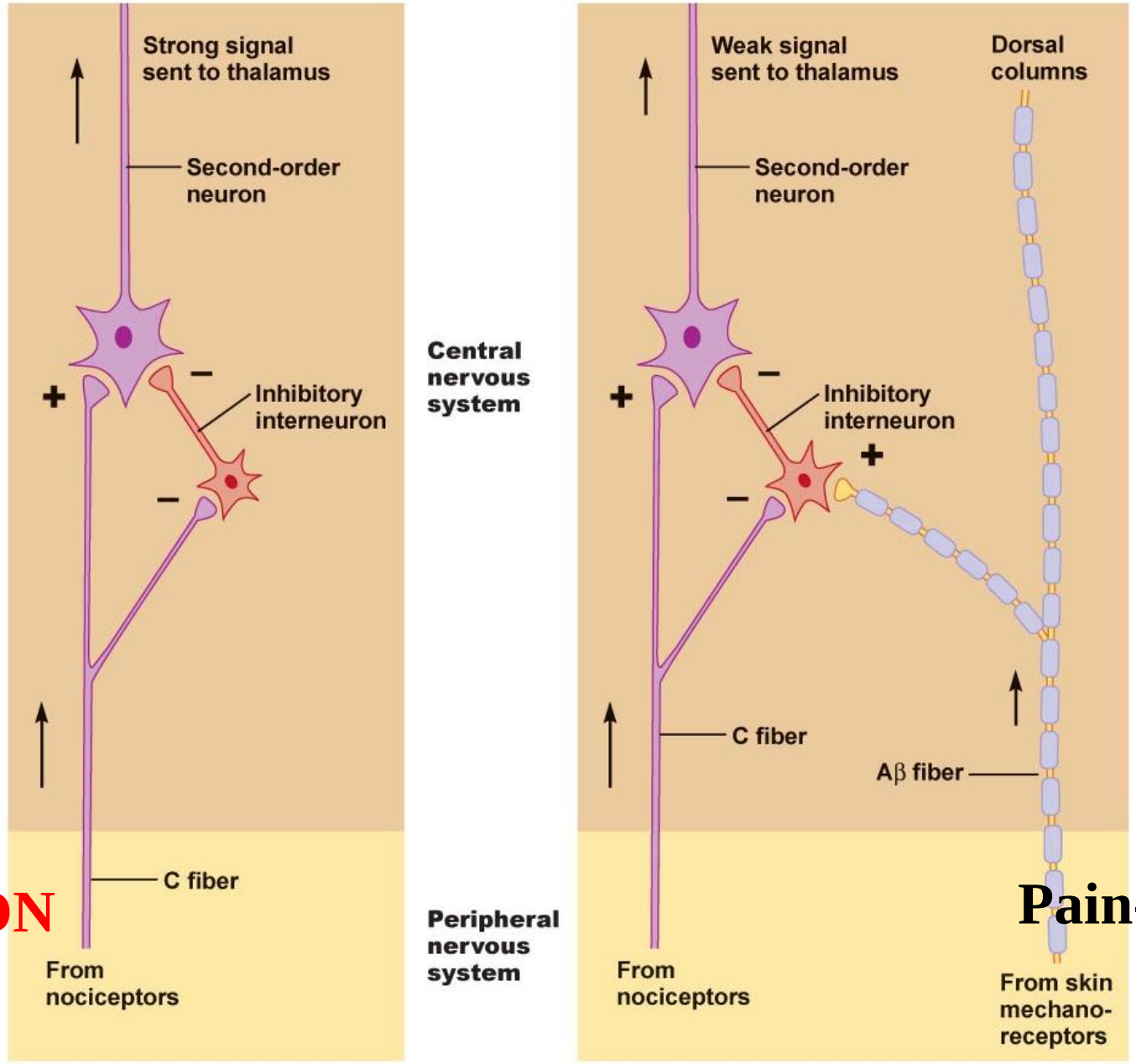
Nociceptors & Pain Response

- **Free nerve endings**: ***A delta (fast pain) or C fibers (slow pain)***
- **Classes: *Mechanical, Thermal and Polymodal***
- Sensation produced by tissue-damaging stimulus or stimulus that can potentially cause tissue damage
- Pain elicits sensation, autonomic responses, and emotional responses
- Pain perception depends on past experiences
- Chemicals activating nociceptors: ***Potassium, Histamine, Prostaglandins, Bradykinin and Serotonin***

Pain Pathways

- Afferents for pain
  --***A delta*** or ***C fibers***
- Terminate in ***spinal cord dorsal horn***
- Neurotransmitter of C fibers (maybe A delta) is ***substance P***
- Specific pathways
  --***Spinothalamic tract***
- Nonspecific pathway
  --To reticular formation, hypothalamus, limbic system

Gate-Control Theory of Pain



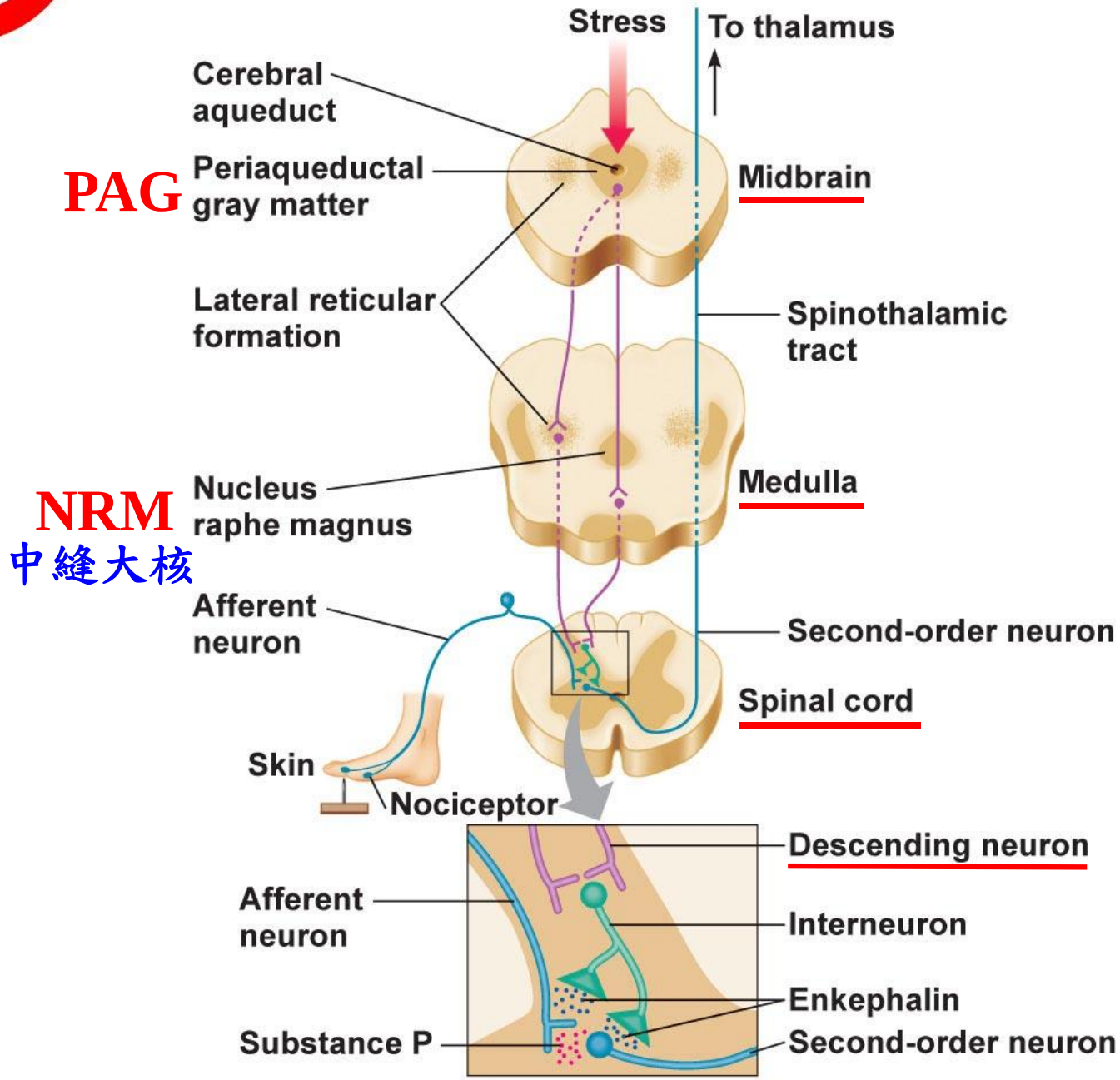
Pain-gate: ON

Pain-gate: OFF

(a) Unmodulated pain

(b) Modulation of pain

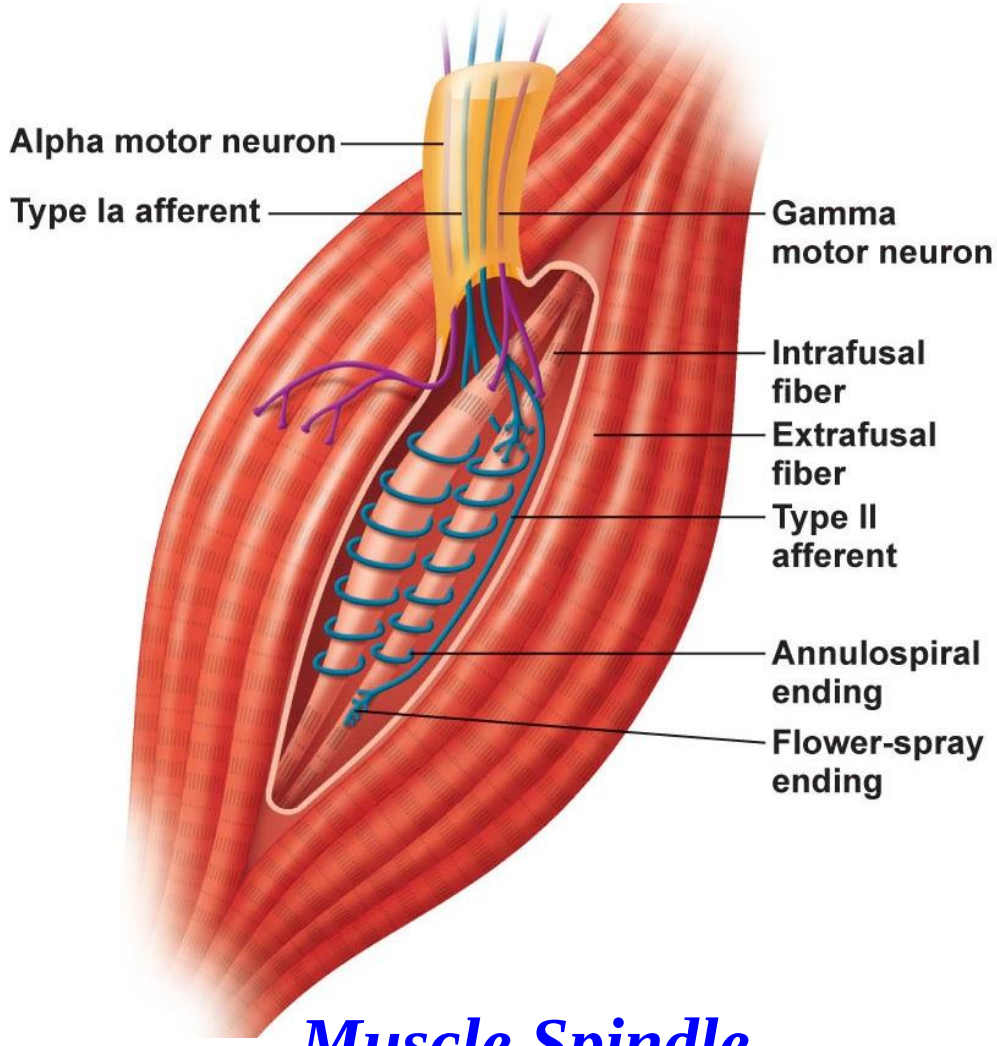
Pain Modulation (Endogenous Analgesia Systems)



Proprioception

Skeletal Muscle Receptors = Proprioceptor

➢ ***Detect changes in muscle length***



Muscle Spindle

➢ **Extrafusal fibers**

--Contractile cells of the muscle

--Responsible for skeletal muscle contraction

--Innervated by alpha motor neurons

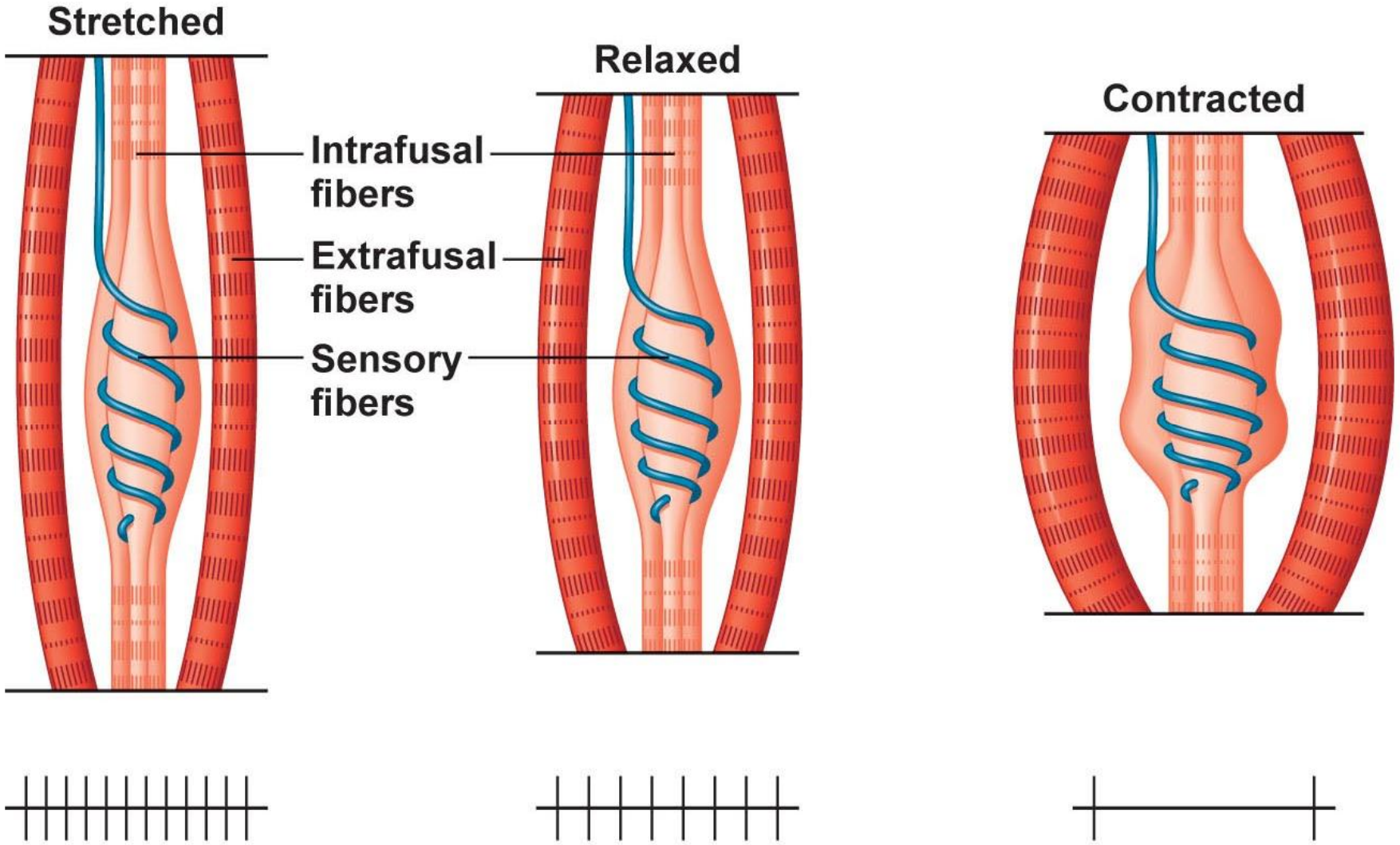
➢ **Intrafusal fibers**

--Contractile cells of the muscle spindle

--Adjust sensitivity of muscle to stretch

--Innervated by gamma motor units

Muscle Spindle Responses

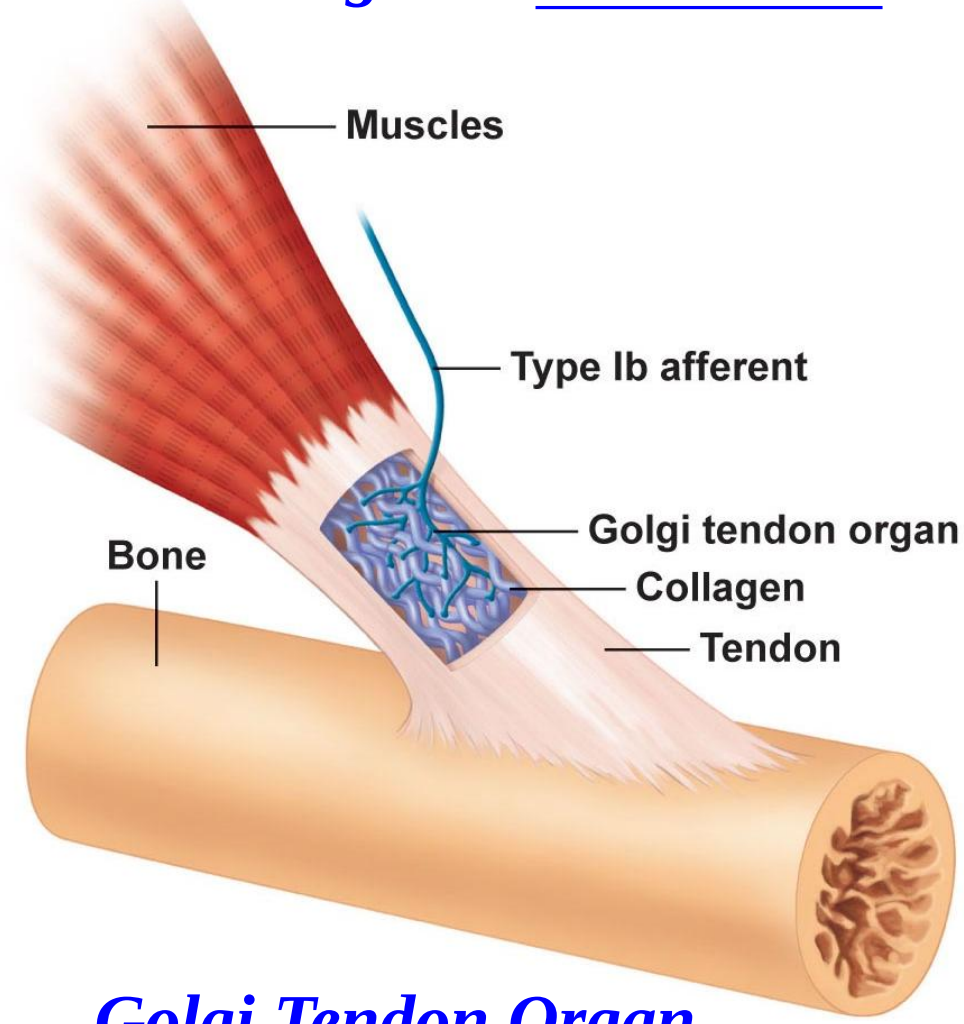


➢ ***Sensitivity can be adjusted by action of intrafusal fibers***

Proprioception

Skeletal Muscle Receptors = Proprioceptor

- ***Detect changes in muscle tone***



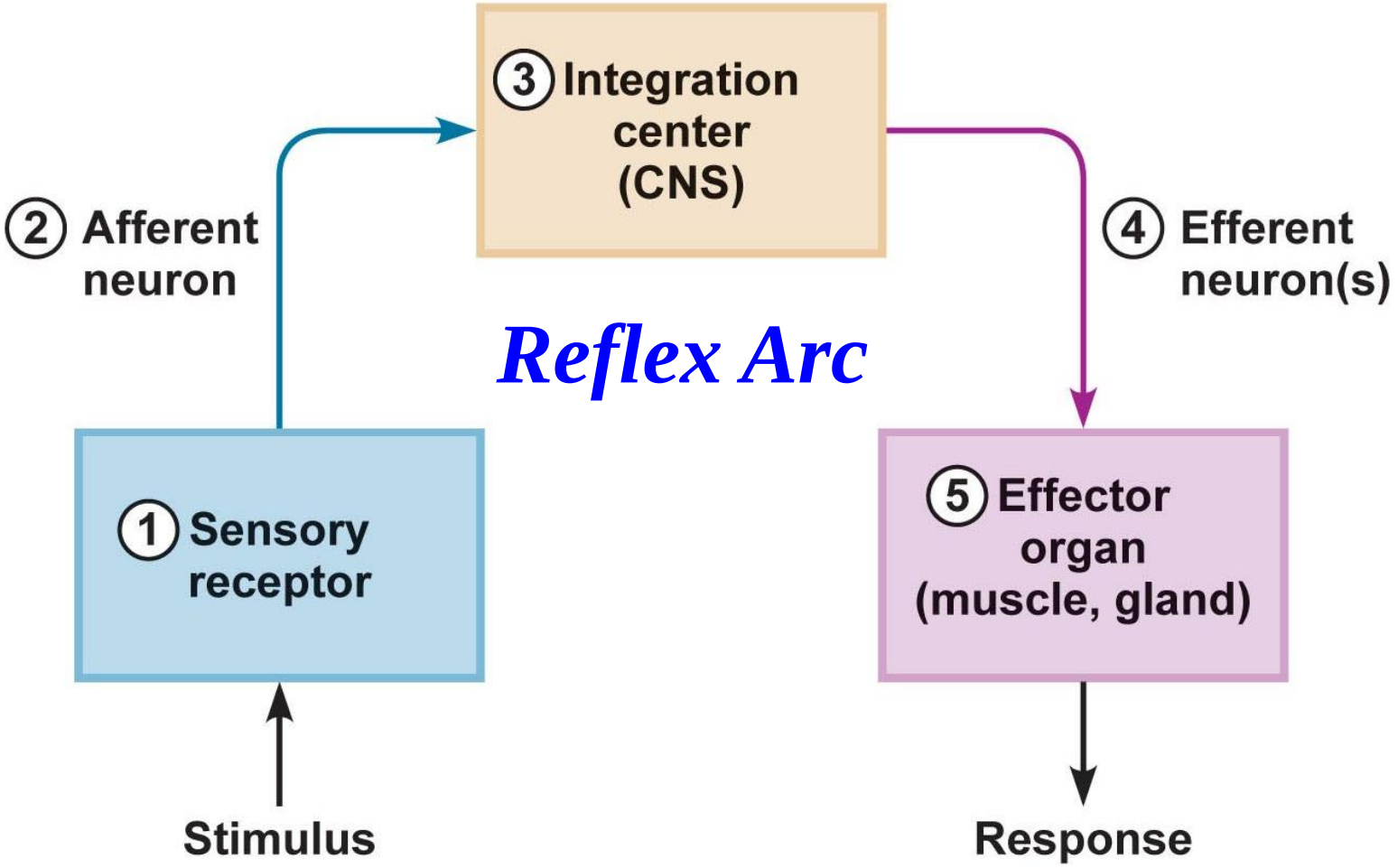
Golgi Tendon Organ

- ***Sensory capsules within tendons***
- ***Tendon stretch activates GTO***
- ***Reflex inhibition of muscle via Type Ib afferent neurons***
- ***Protection against overactivity of muscle***

Integrated CNS Functions:

Reflexes

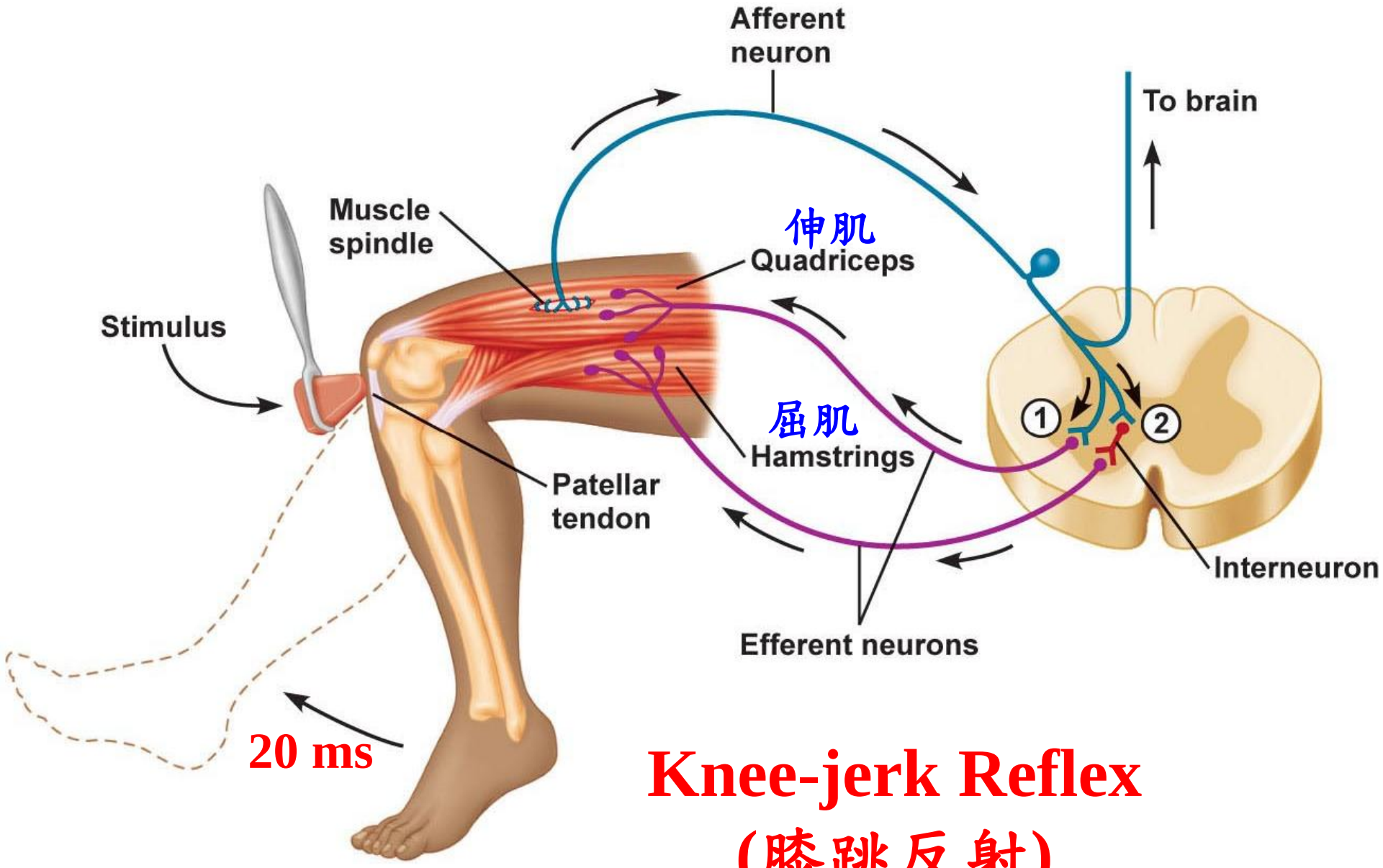
- *Stretch reflex*
- *Withdrawal and crossed-extensor reflexes*



Classes of Reflexes

Basis of classification	Classes	Example
Level of neural processing	Spinal	Muscle spindle stretch reflex
	Cranial	Pupillary reflex
Efferent division controlling effector	Somatic *(ske. m.)*	Muscle spindle stretch reflex
	Autonomic	Baroreceptor reflex to control blood pressure
Developmental pattern	Innate	Muscle spindle stretch reflex
	Conditioned *(learned)*	Salivation reflex of Pavlov's dogs
Number of synapses in the pathway	Monosynaptic	Muscle spindle stretch reflex
	Polysynaptic	All other reflexes

Stretch Reflex

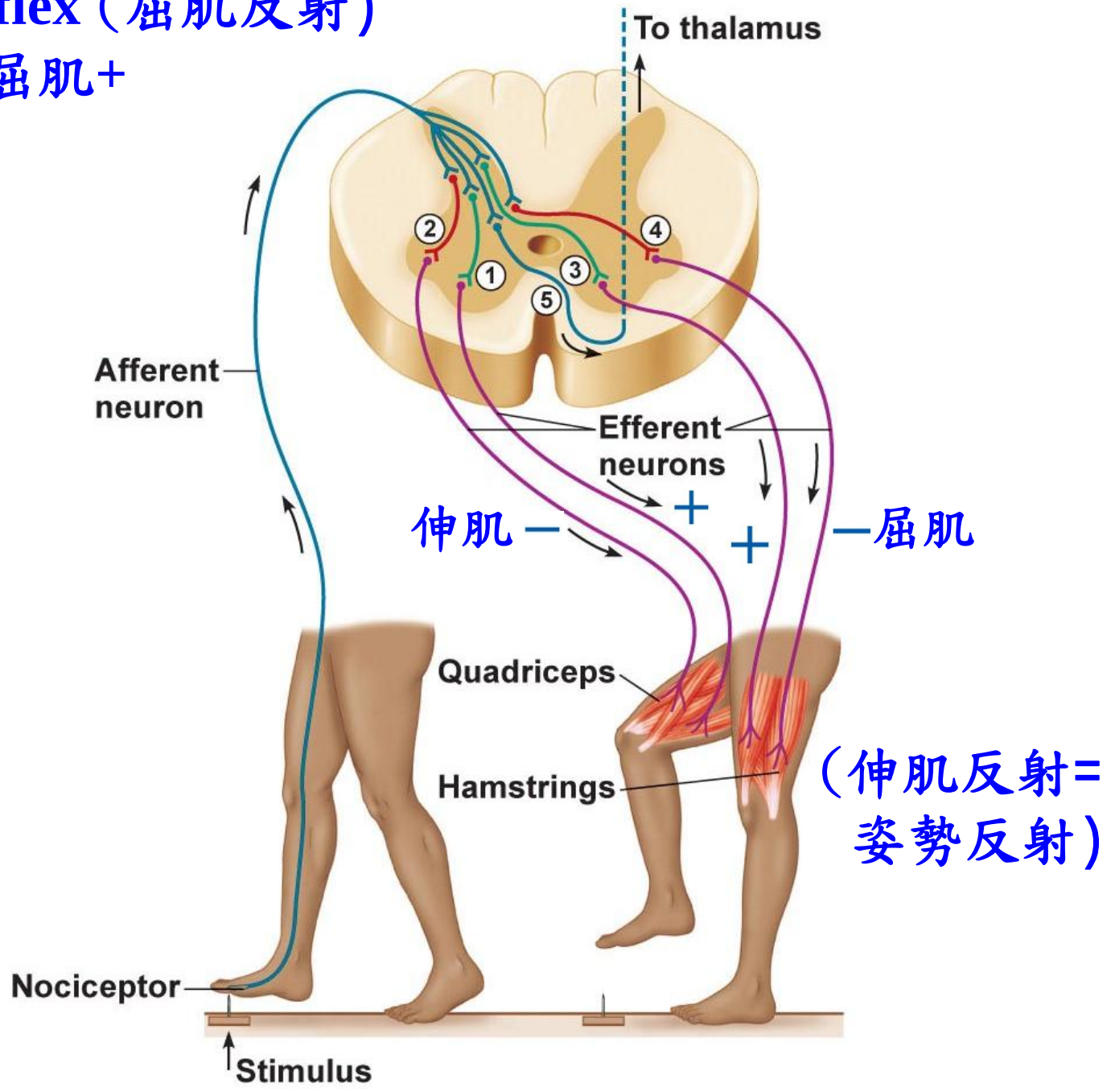


Knee-jerk Reflex
(膝跳反射)

Withdrawal and Crossed-Extensor Reflexes

=Flexor reflex（屈肌反射）

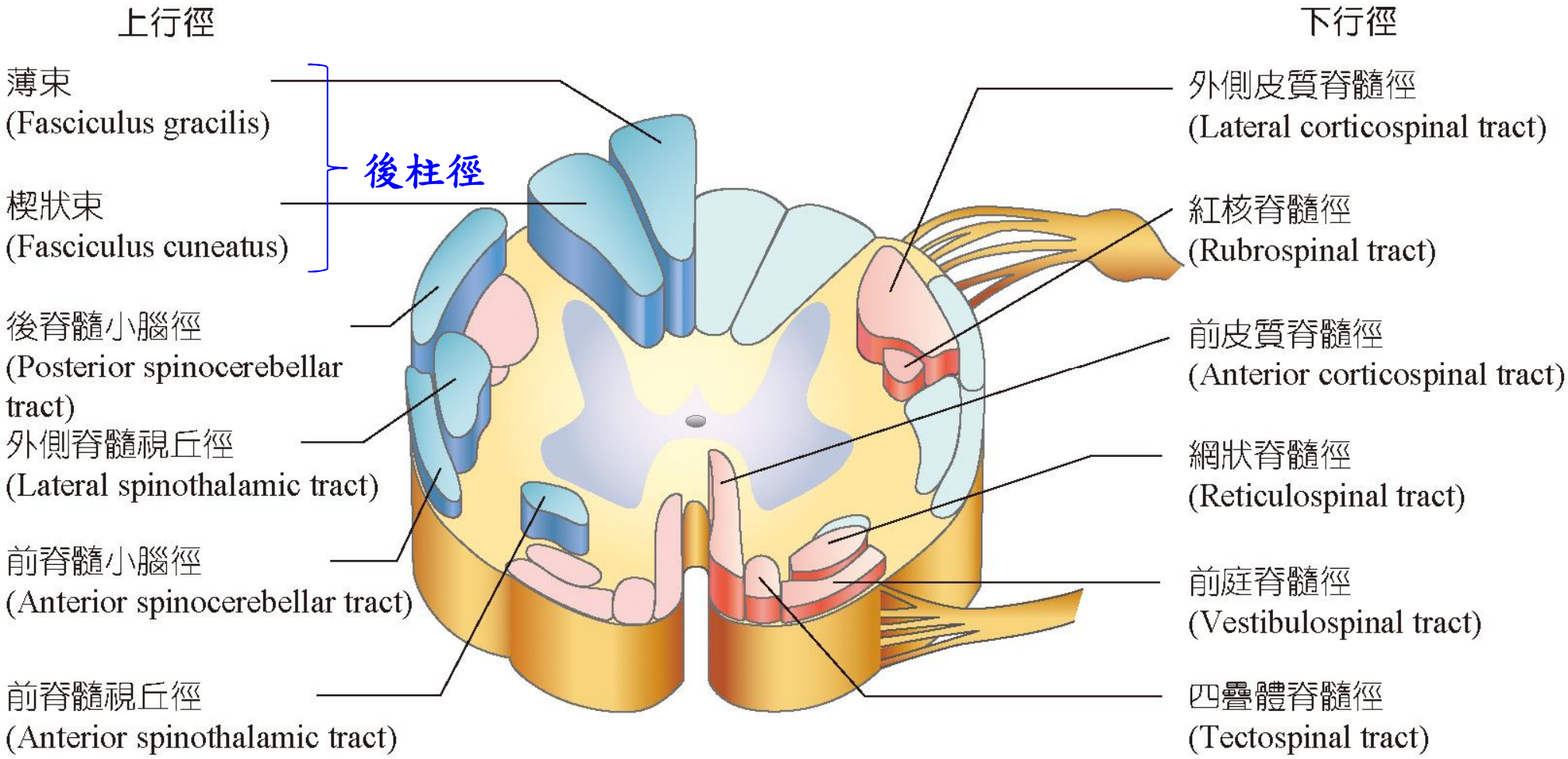
=伸肌- & 屈肌+



Spinal Cord Tracts

Ascending Tracts (Sensory pathway)

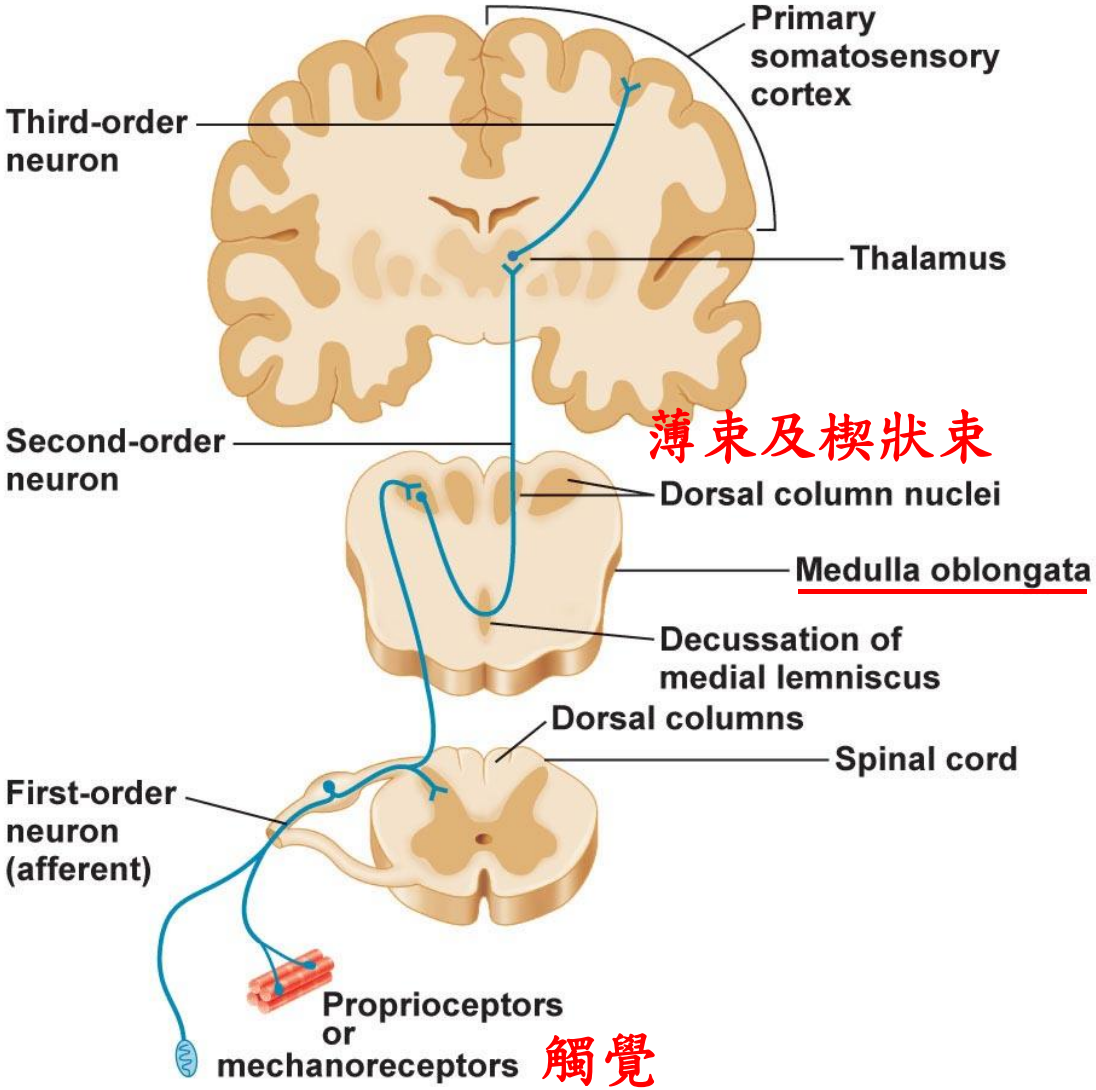
Descending Tracts (Motor Pathway)

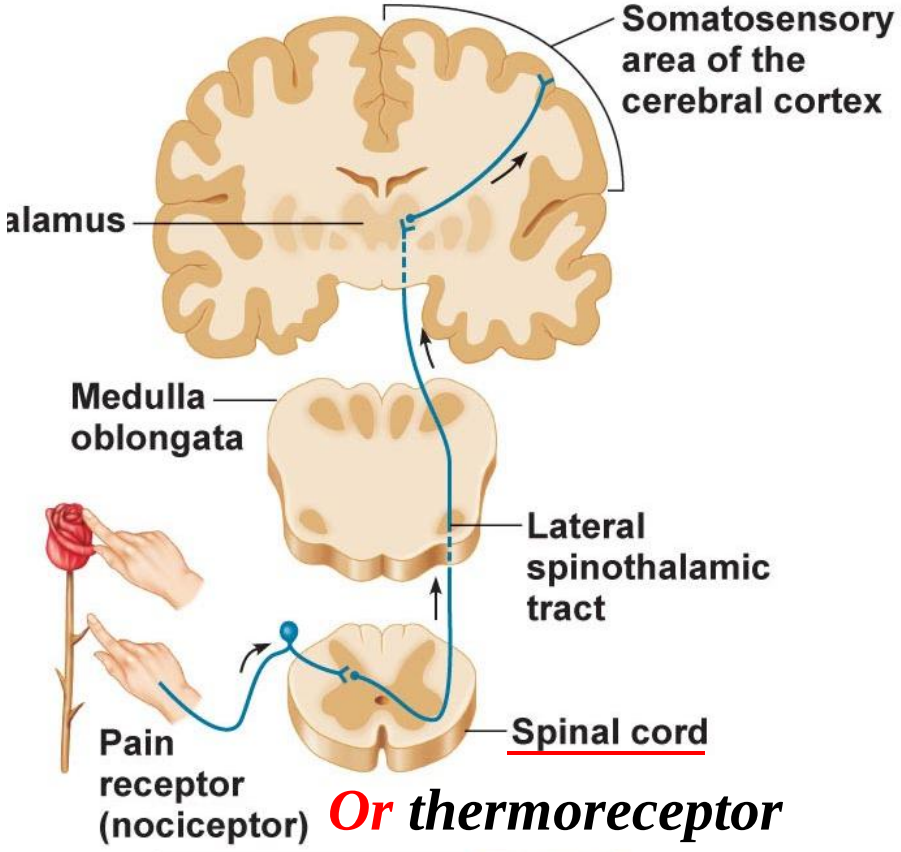


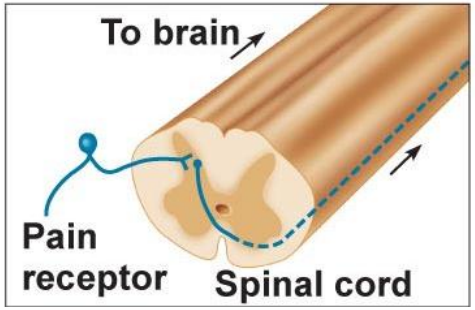
Ascending Tracts of Spinal Cord

上行徑	位置	起點	終點	功能
脊髓視丘徑路				
前脊髓視丘徑 (Anterior spinothalamic tract)	前索	脊髓灰質的後角，但交叉到對側	視丘，最後傳到大腦皮質	傳導粗略觸覺及壓力感覺
外側脊髓視丘徑 (Lateral spinothalamic tract)	側索	脊髓灰質的後角，但交叉到對側	視丘，最後傳到大腦皮質	傳導痛覺及溫度覺至大腦皮質
後柱徑路				
薄束及楔狀束 (Fasciculus gracilis and fasciculus cuneatus)	後索	周邊的傳入神經元，上行於同側脊髓中，在延腦交叉	延腦的薄核及楔狀核，最後到視丘，然後到大腦皮質	傳導由皮膚、肌肉、肌腱及關節來的輕觸、精確壓力及身體動作的感覺衝動
脊髓小腦徑路				
後脊髓小腦徑 (Posterior spinocerebellar tract)	側索	脊髓的灰質後角，不交叉	小腦	傳導身體的感覺衝動至同側小腦；協調肌肉收縮
前脊髓小腦徑 (Anterior spinocerebellar tract)	側索	脊髓的灰質後角，有些纖維交叉，有些不交叉	小腦	傳導身體兩側的感覺衝動至小腦；協調肌肉收縮

Ascending Tracts of Spinal Cord





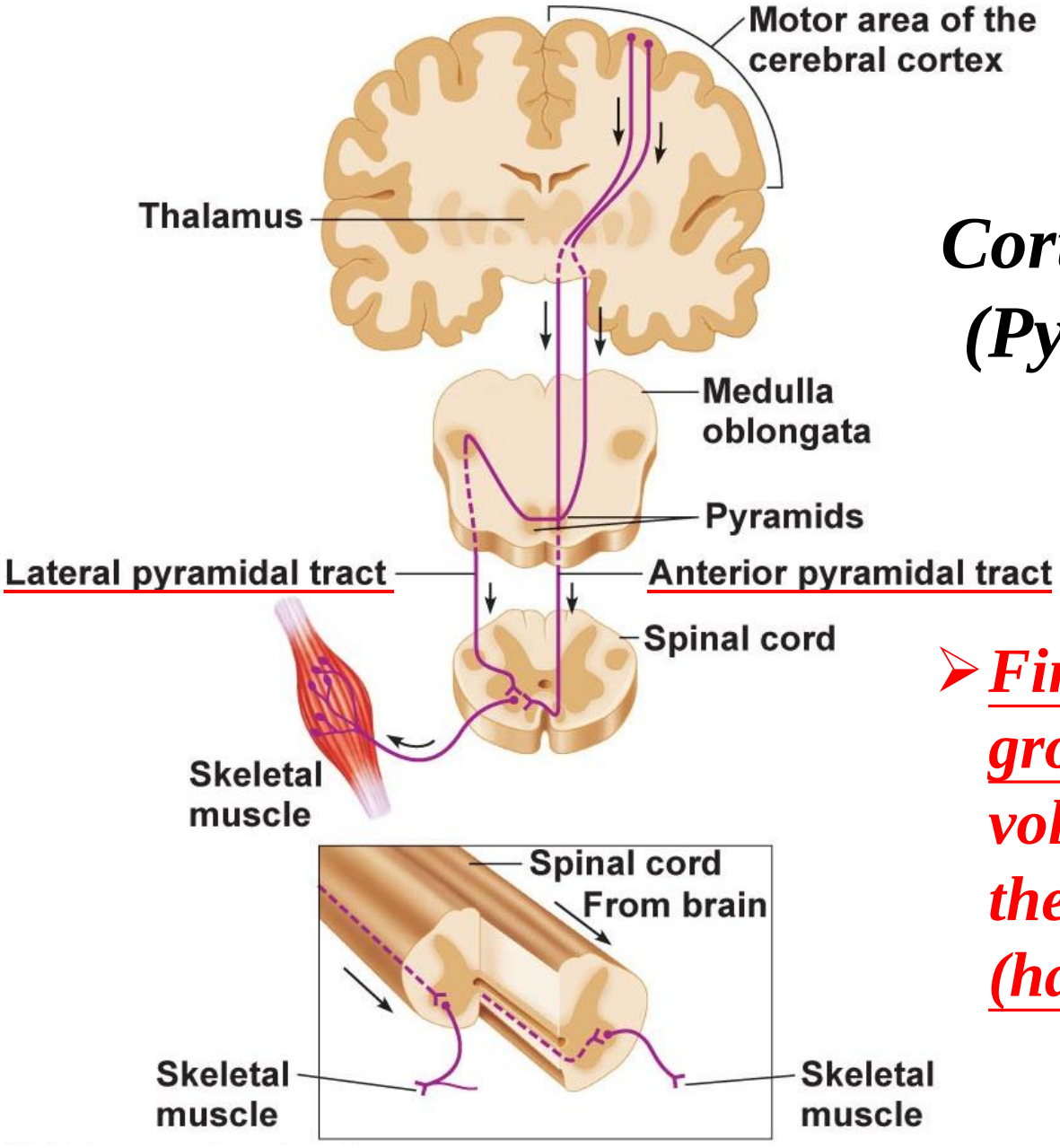


Desending Tracts of Spinal Cord

上運動神經元控制骨骼肌的路徑

下行徑	位置	起源	功能
錐體徑			
外側皮質脊髓徑 (Lateral corticospinal tract)	脊髓外側柱	大腦皮質	控制對側肌肉的精細動作（佔80%），在延腦交叉
前皮質脊髓徑 (Anterior corticospinal tract)	脊髓前柱	大腦皮質	控制對側肌肉的精細動作（佔20%），在脊髓交叉
錐體外徑	由腦幹發出，大部分受黑質-紋狀體(運動)路徑控制		
紅核脊髓徑 (Rubrospinal tract)	脊髓外側柱	紅核（中腦）	維持對側肌肉的張力及姿勢，負責軀幹的姿態維持
四疊體脊髓徑 (Tectospinal tract)	脊髓前柱	小腦上丘（中腦）	維持對側頭部肌肉的動作
前庭脊髓徑 (Vestibulospinal tract)	脊髓前柱	前庭核（延腦）	維持同側肌肉的張力及姿勢，負責軀幹的姿態維持
網狀脊髓徑 (Reticulospinal tract)	脊髓前柱及側柱前半	網狀結構（延腦及橋腦）	控制骨骼肌的活動

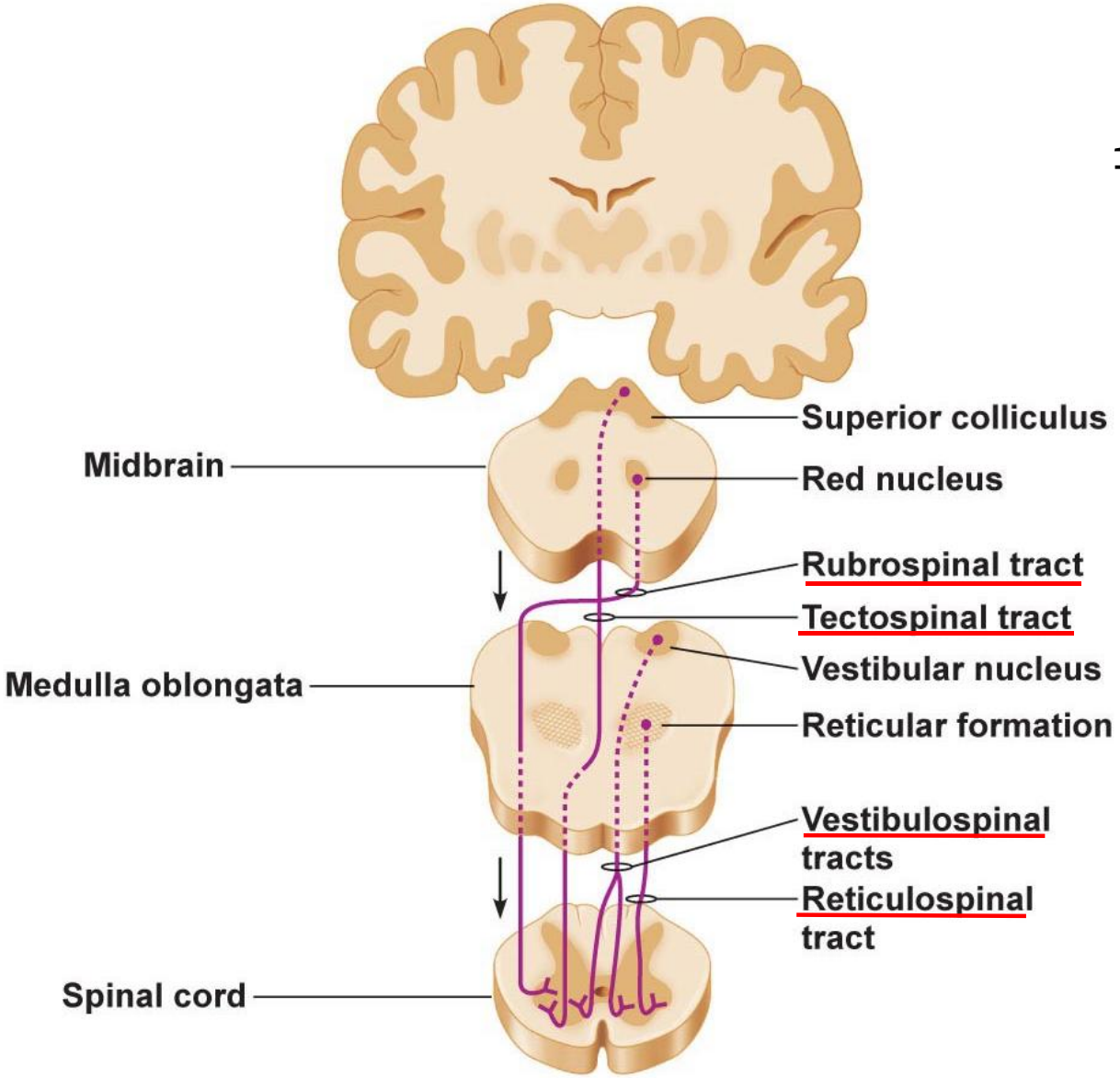
Desending Tracts of Spinal Cord



Corticospinal Tract (Pyramidal Tract)

- ***Fine control (smaller groups of muscles) of voluntary movement of the distal extremities (hands and fingers)***

Desending Tracts of Spinal Cord

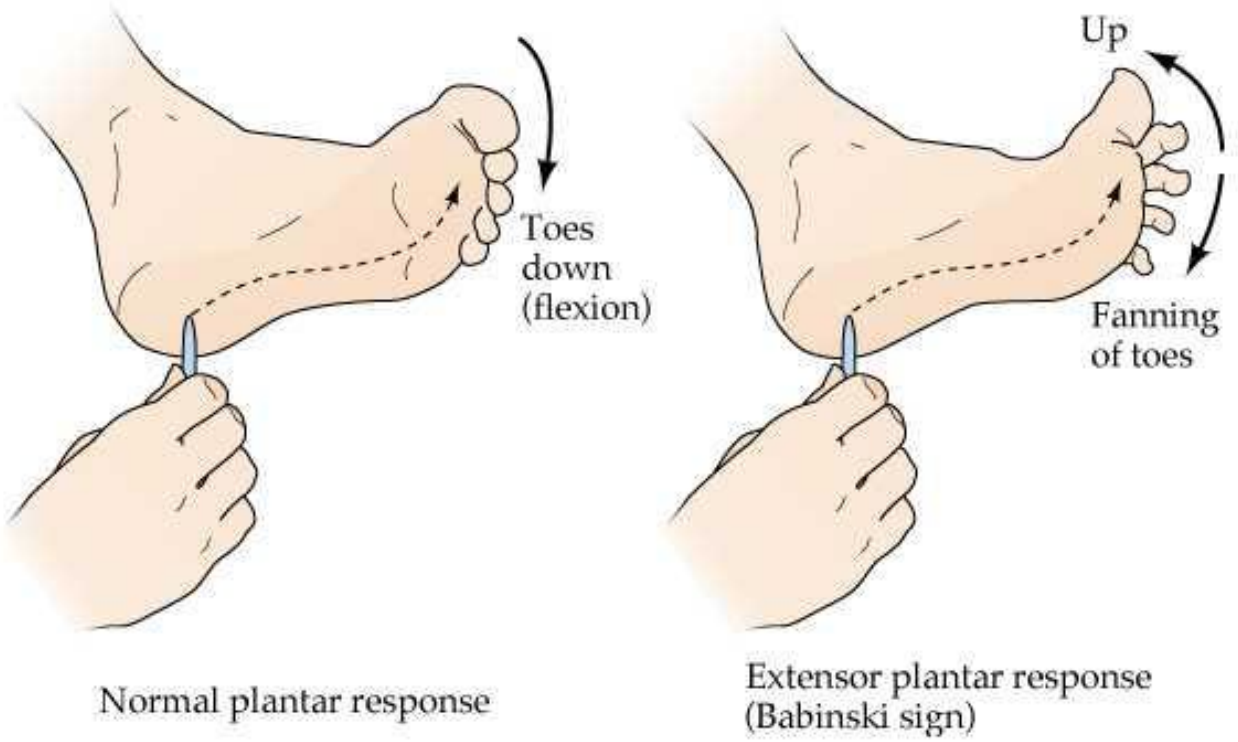


Extrapyramidal Tract

- ***Supportive voluntary movement of the trunk, neck and proximal extremities***
- ***Controlling large groups of muscles to maintain posture and balance***
- ***Extrapyramidal symptoms (EPS)***
  黑質-紋狀體(DA↓)路徑→ similar to PD's symptoms

Clinical Application:

Pyramidal Tract Damage



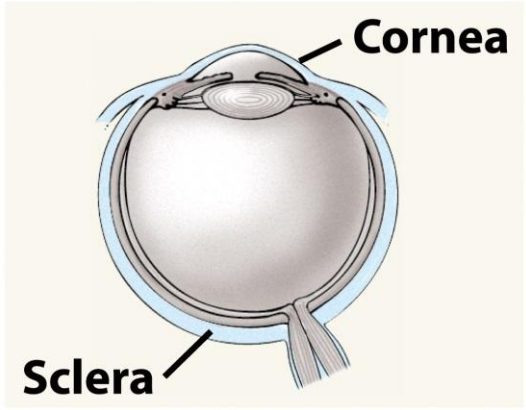
Normal plantar response

Extensor plantar response
(Babinski sign)

Babinski Reflex

Vision
Anatomy of the Eye

Fibrous tunic



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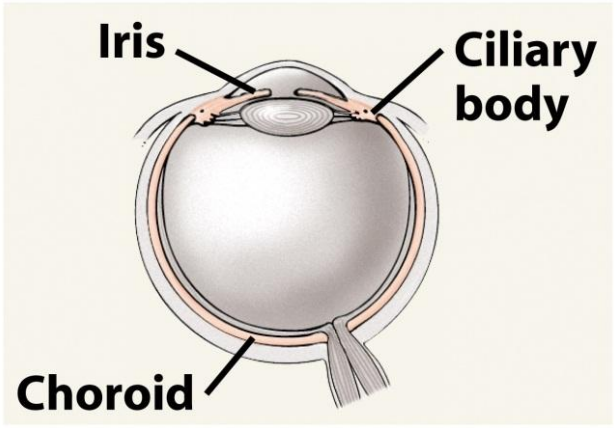
Vascular tunic



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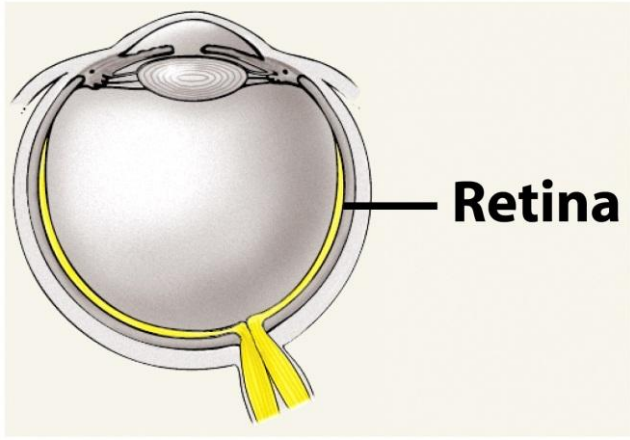
Retina



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Fibrous Tunic (outer layer)

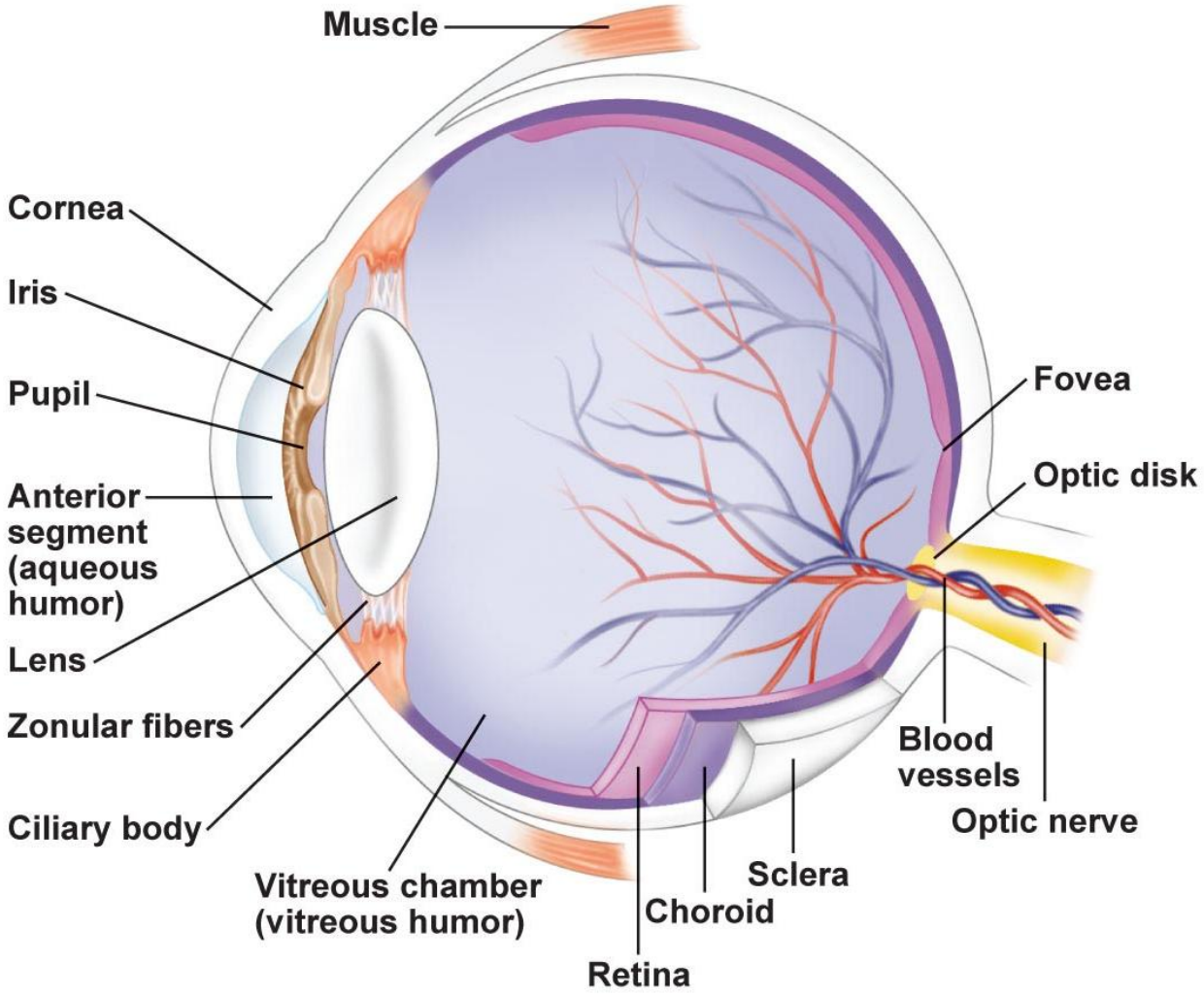
Vascular Tunic (middle layer)

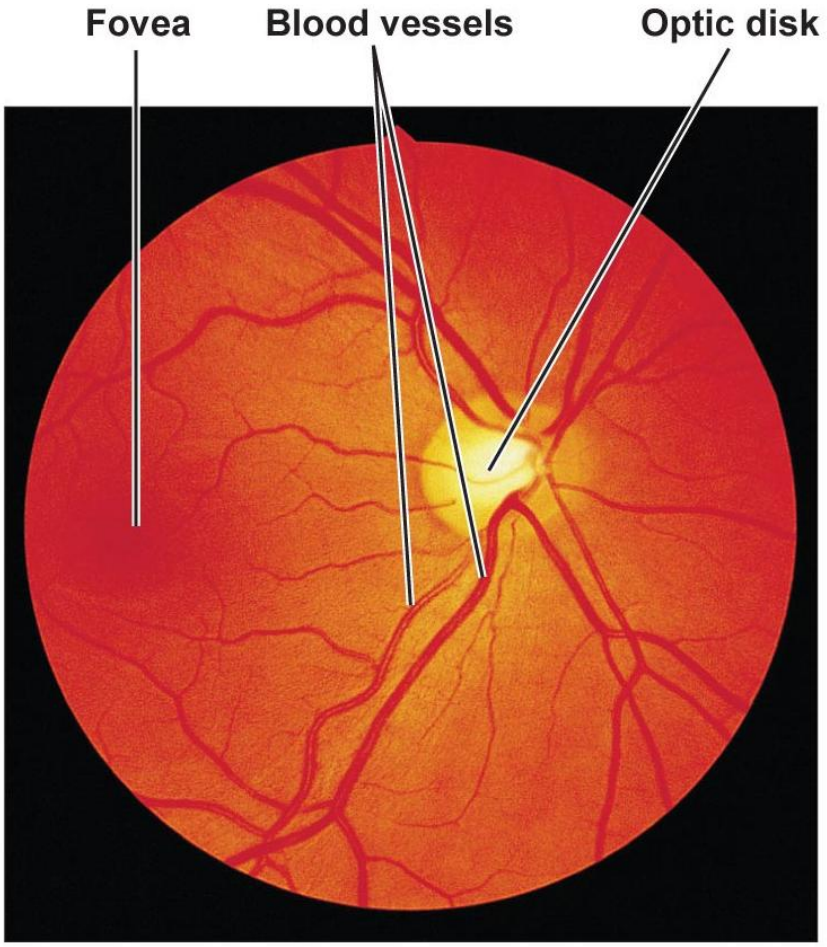
Nervous Tunic (inner layer)

Anatomy of the Eye

Tunic and Structure	Location	Composition	Function
Fibrous tunic	Outer layer of eyeball	Avascular connective tissue	Gives shape to the eyeball
Sclera	Posterior outer layer; white of the eye	Tightly bound elastic and collagen fibers	Supports and protects the eyeball
Cornea	Anterior surface of eyeball	Tightly packed dense connective tissue—transparent and convex	Transmits and refracts light
Vascular tunic (uvea)	Middle layer of eyeball	Highly vascular pigmented tissue	Supplies blood; prevents reflection
Choroid	Middle layer in posterior portion of eyeball	Vascular layer	Supplies blood to eyeball
Ciliary body	Anterior portion of vascular tunic	Smooth muscle fibers and glandular epithelium	Supports the lens through suspensory ligament and determines its thickness; secretes aqueous humor
Iris	Anterior portion of vascular tunic; continuous with ciliary body	Pigment cells and smooth muscle fibers	Regulates the diameter of the pupil, and hence the amount of light entering the vitreous chamber
Internal tunic	Inner layer of eyeball	Tightly packed photoreceptors, neurons, blood vessels, and connective tissue	Provides location and support for rods and cones
Retina	Principal portion of internal tunic	Photoreceptor neurons (rods and cones), bipolar neurons, and ganglion neurons	Photoreception; transmits impulses
Lens (not part of any tunic)	Between posterior and vitreous chambers; supported by suspensory ligament of ciliary body	Tightly arranged protein fibers; transparent	Refracts light and focuses onto fovea centralis

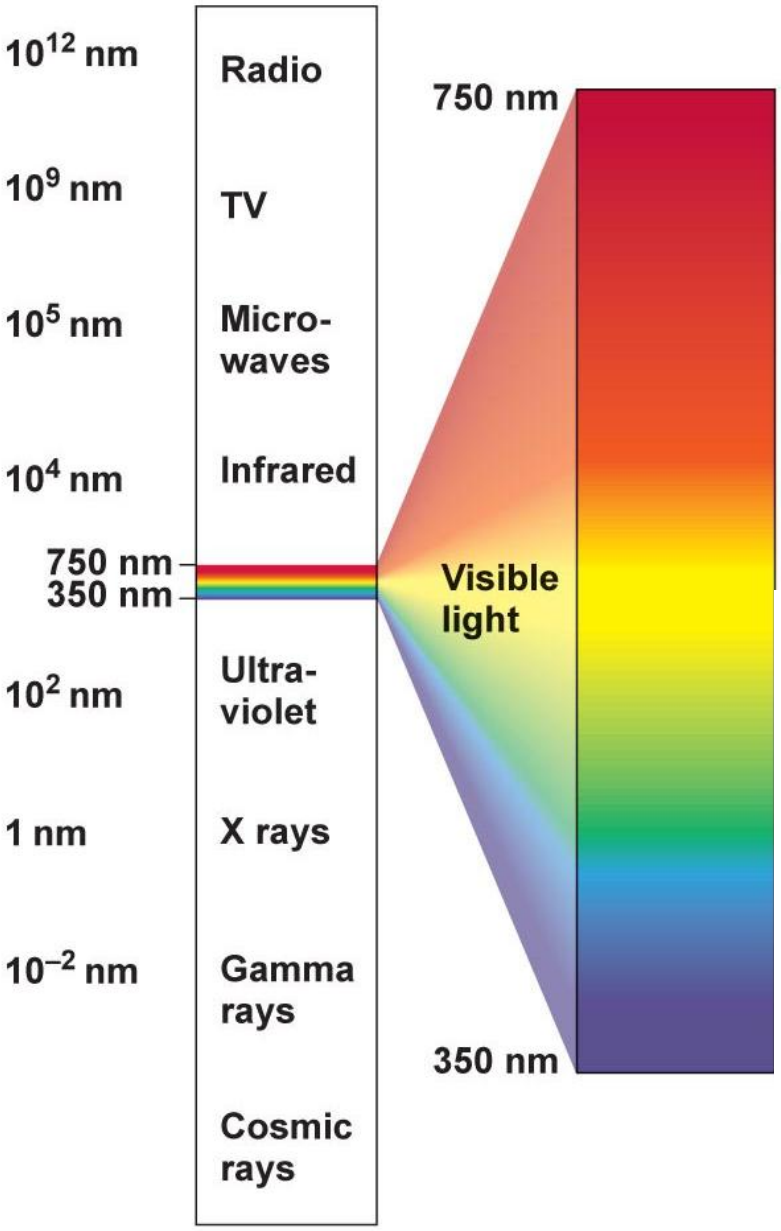
Anatomy of the Eye





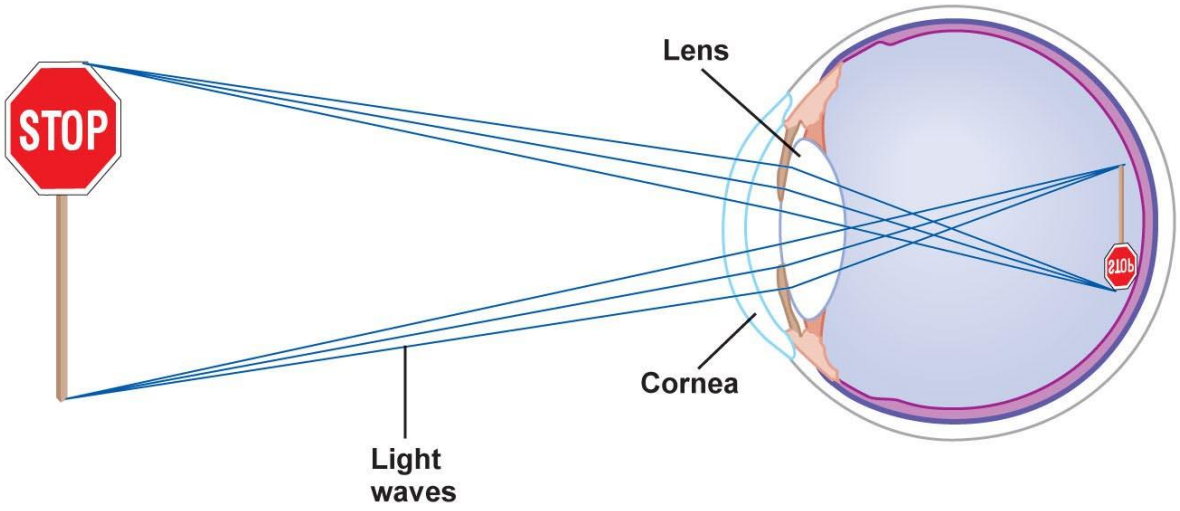
(b) Retina: Ophthalmoscope

Light Waves



Electromagnetic Spectrum

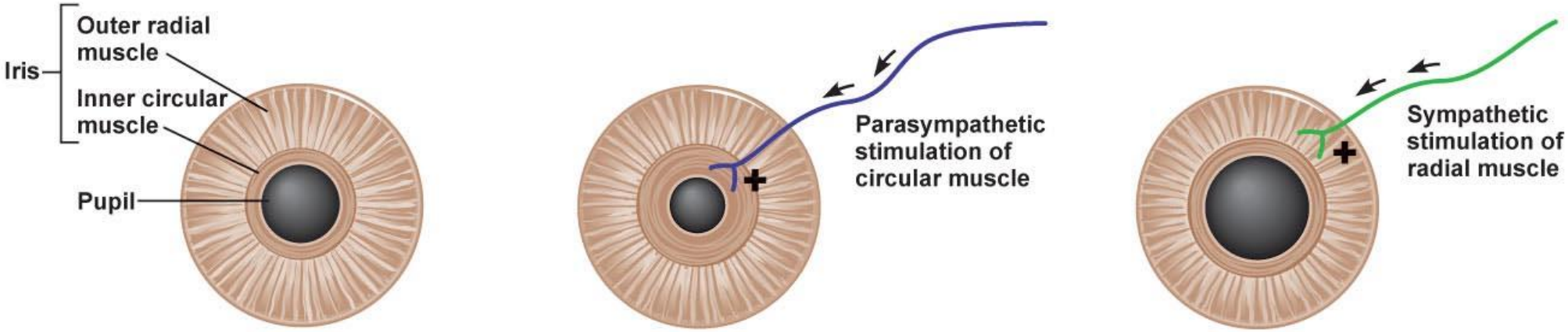
- Transduce light energy into nerve impulses (**photoreceptor cells**)
- Only a limited part of the electromagnetic spectrum can excite **photoreceptors**



Light Refraction by Eye

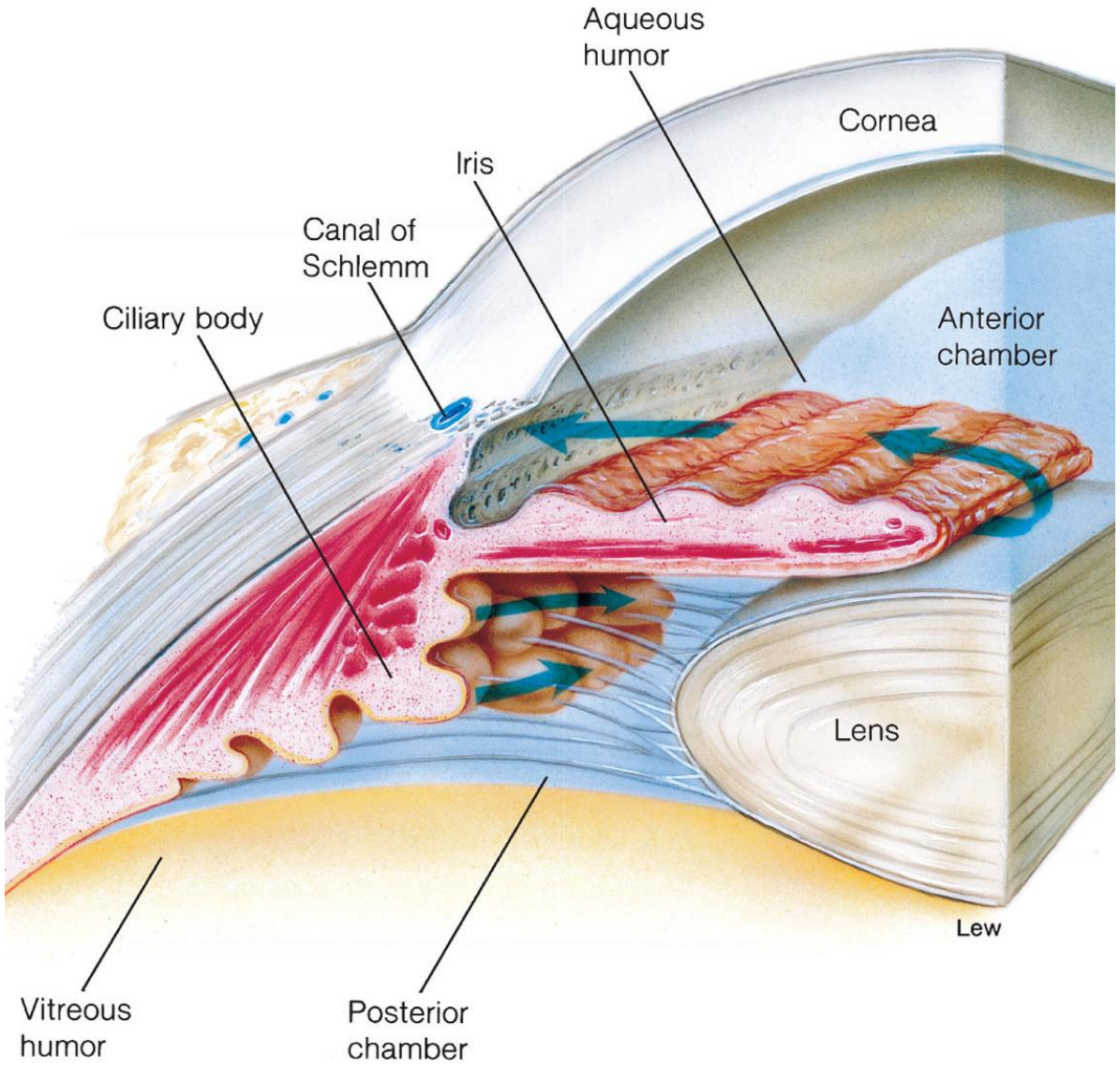
Pupil and Iris

- Size of **pupil** regulates the amount of light entering eye
- **Iris** consists of two layers of smooth muscle
  - --**Inner circular muscle**—constrictor
  - --**Outer radial muscle**—dilator
  - --Hole opening in center—pupil



(a) Anatomy of iris and pupil (b) Pupillary constriction (c) Pupillary dilation

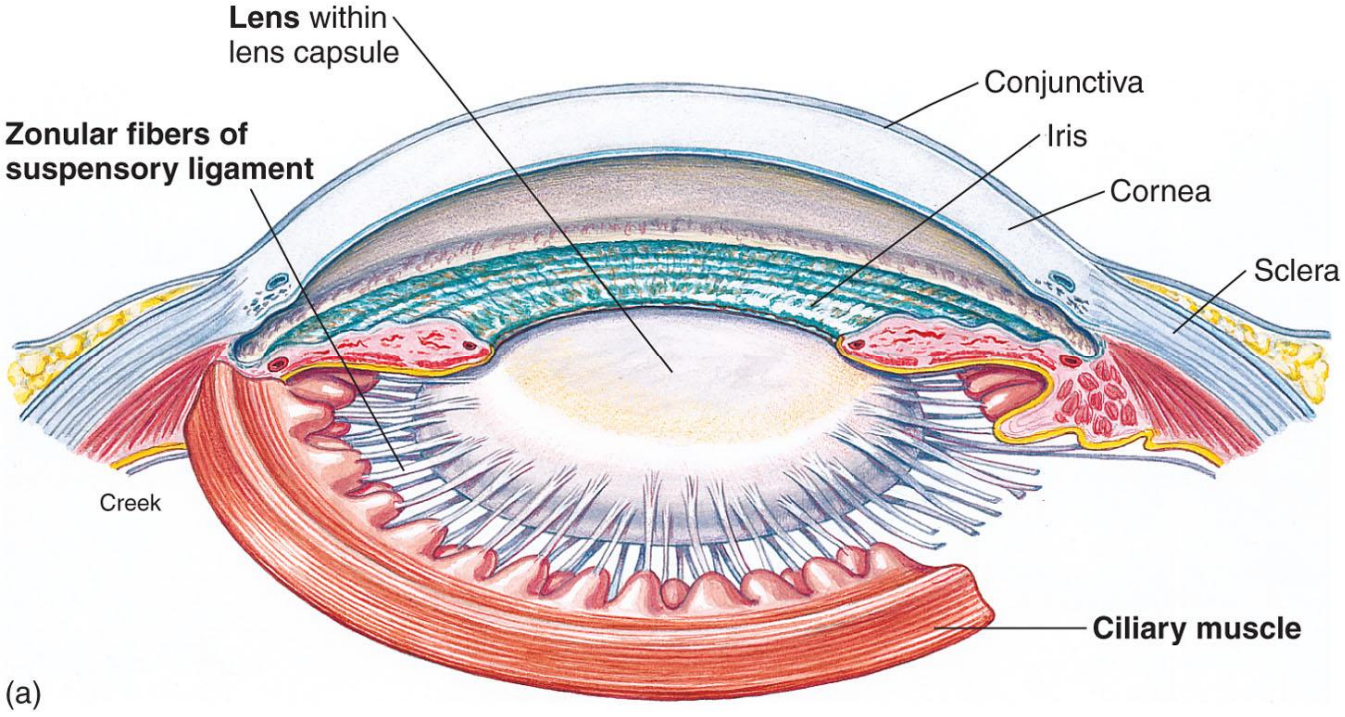
Aqueous Humor

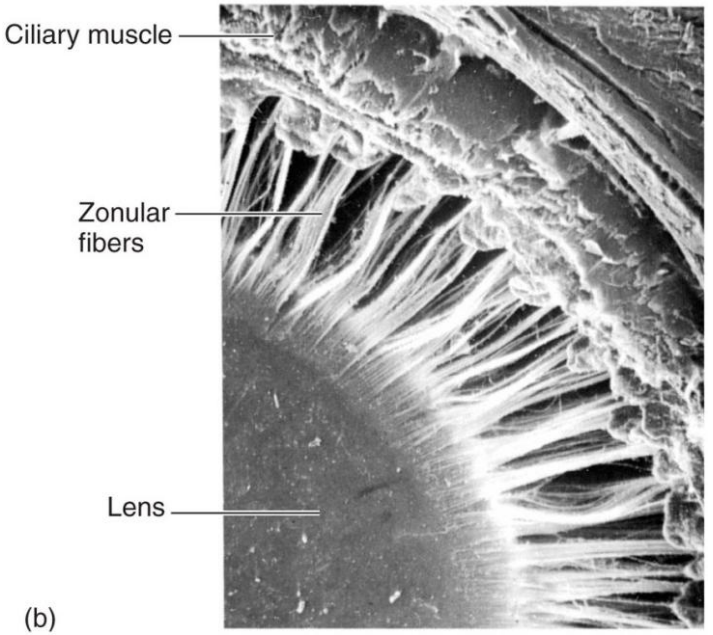


- Fills anterior chamber
- Secreted by **ciliary bodies** to provide nourishment to lens and cornea
- Constant IOP **(15±3 mmHg)**
- Drains into **scleral venous sinus**
- Inadequate drainage leads to **glaucoma (>20-25 mmHg)**

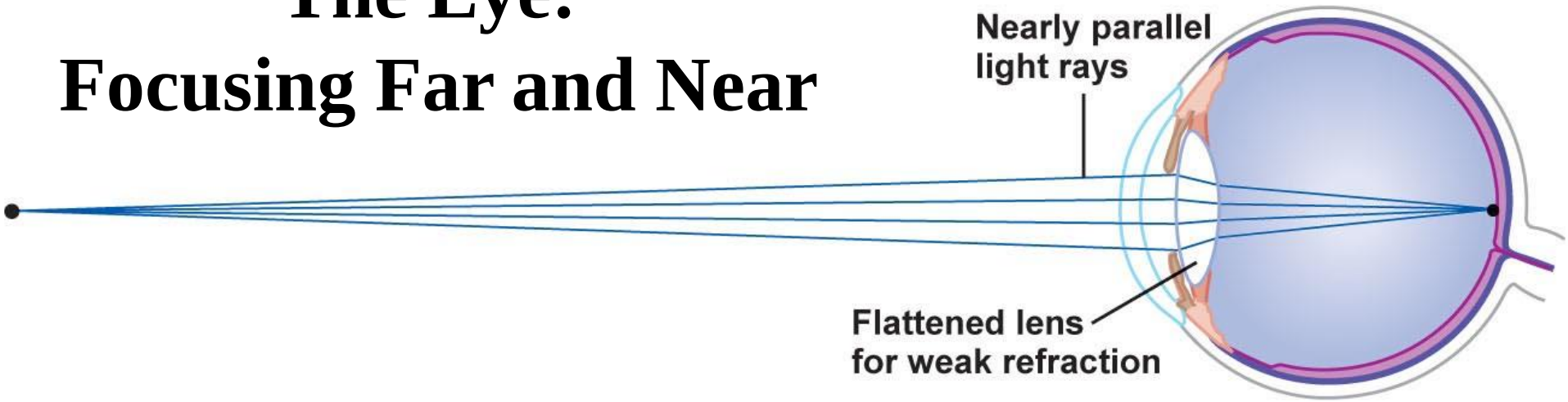
Lens

- Three main parts: the lens capsule, the lens epithelium, and the lens fibers
- Suspended from **suspensory ligaments**
- Attached to muscles called **ciliary bodies**



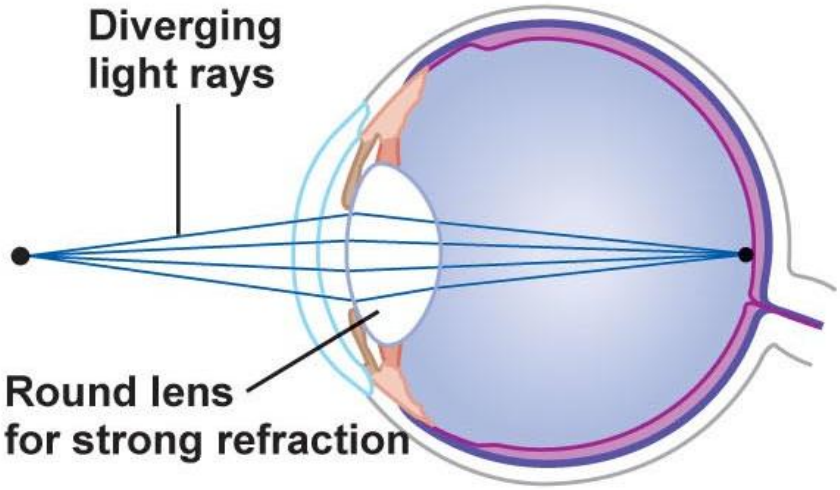


The Eye: Focusing Far and Near



(a) Viewing a distant object

>6 m

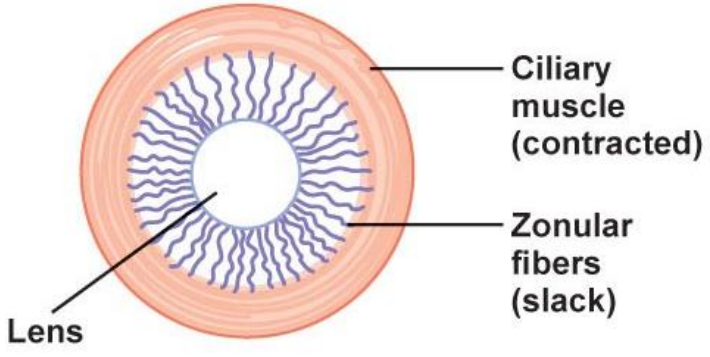


(b) Viewing a near object

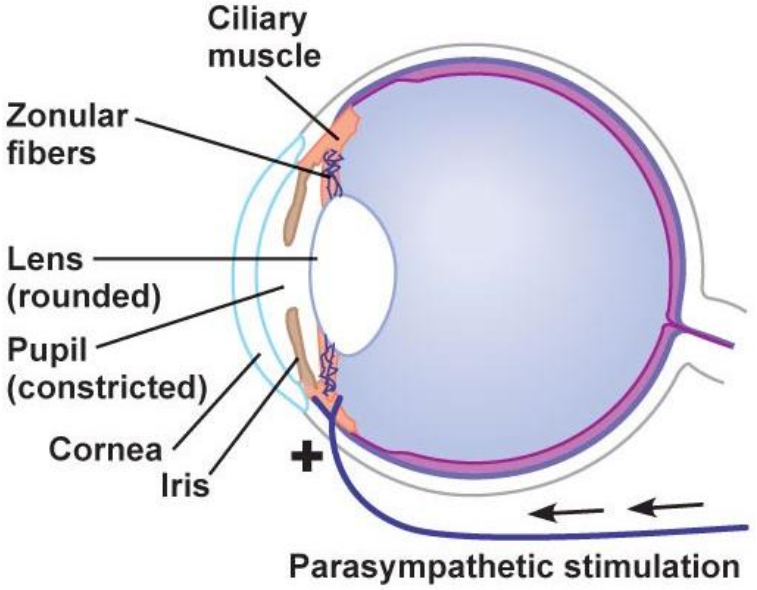
<6 m

Lens Accommodation

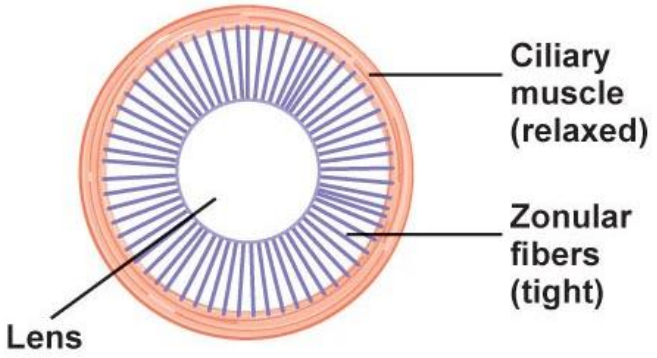
- Increasing lens curvature in order to focus on **near objects**
- Mechanisms
  - --Under **parasympathetic** control
  - --**Ciliary muscle contracts**
  - --**Decreased tension on zonular fibers**
  - --Lens becomes **rounder (refractive index increases)**



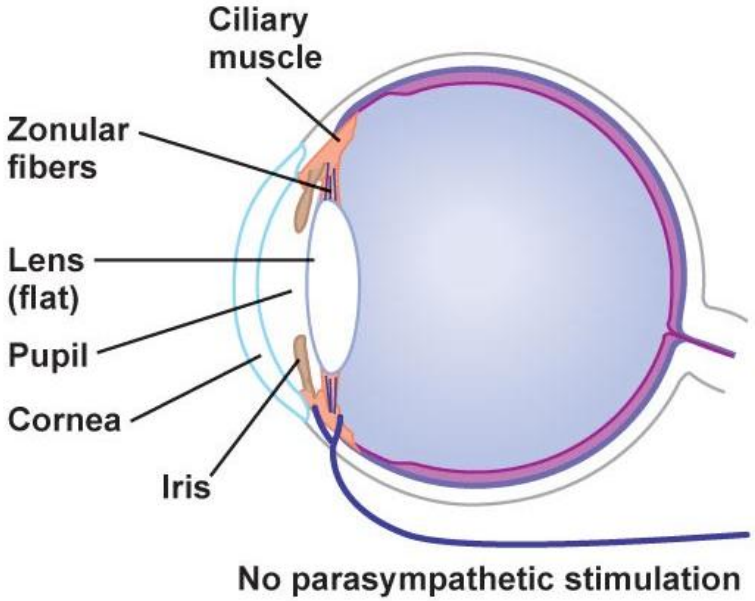
(b) Accommodation for near vision



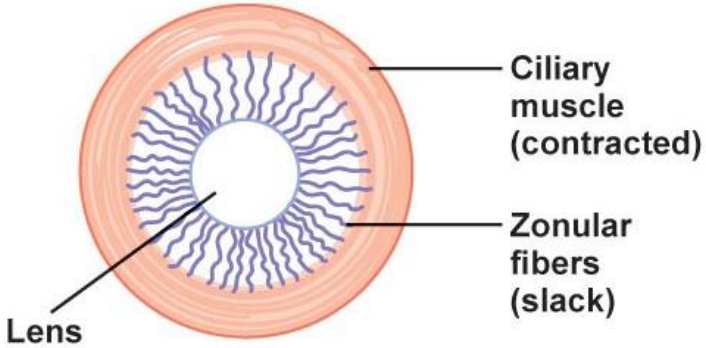
Lens Accommodation



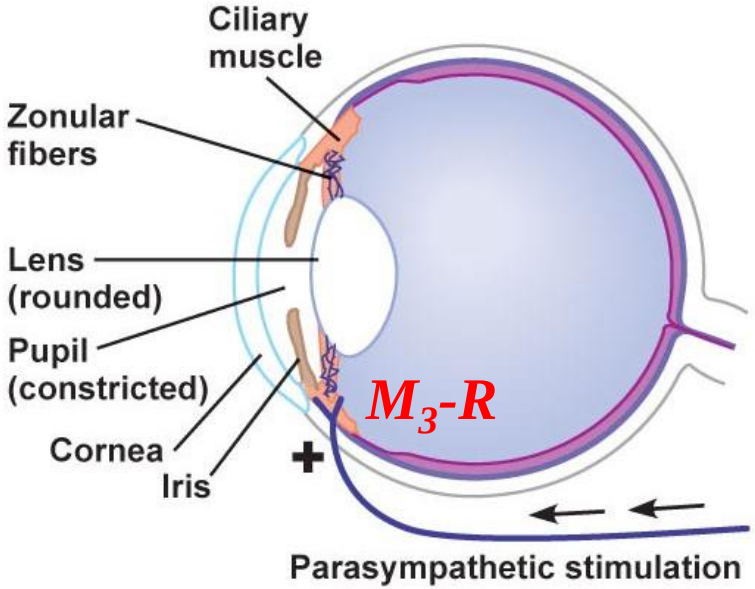
(a) Far vision of distant objects



No parasympathetic stimulation



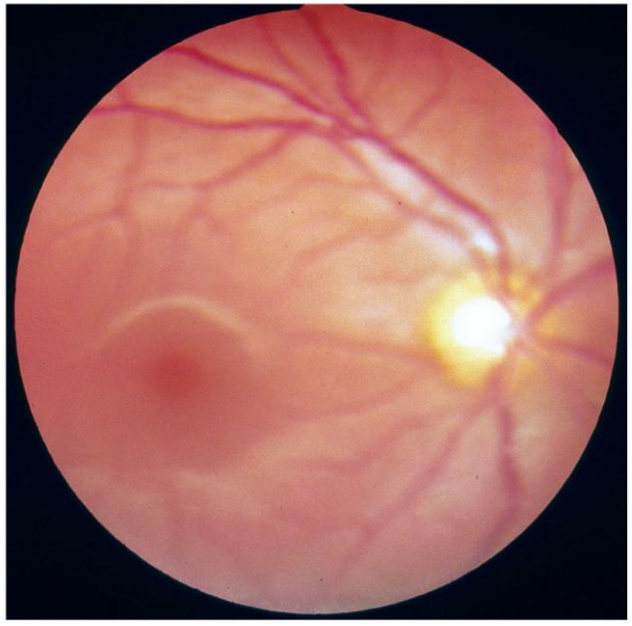
(b) Accommodation for near vision

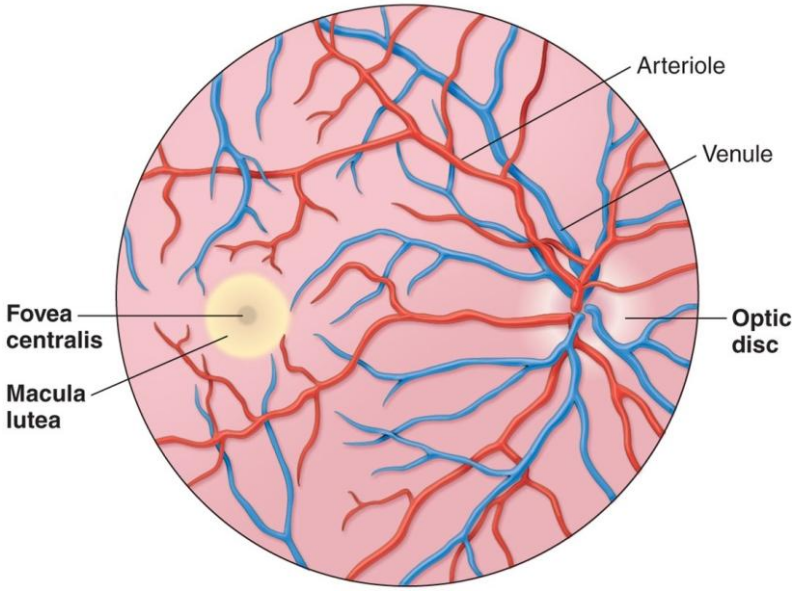


Parasympathetic stimulation

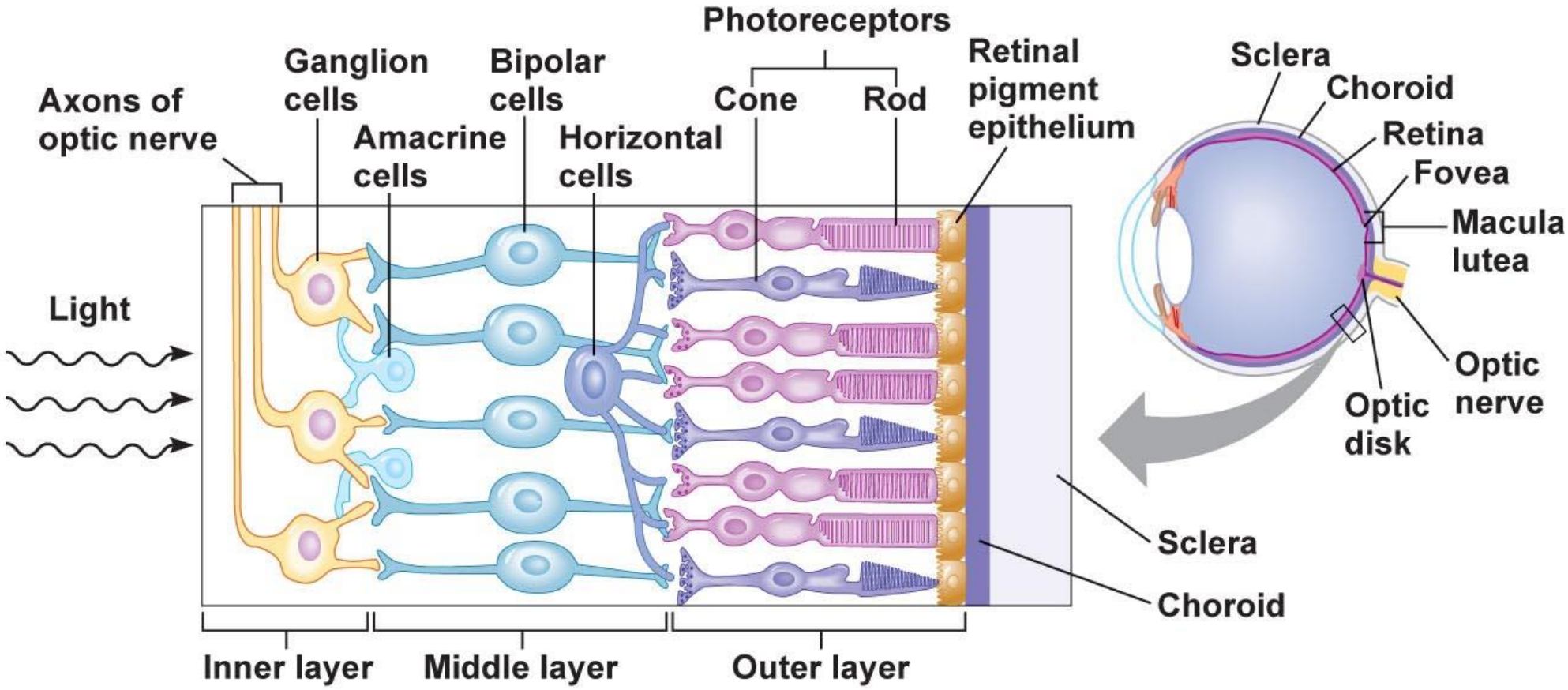
Retina

- Neural tissue contains **photoreceptors**
- Three layers: ***Outer—photoreceptors; Middle—bipolar cells and Inner—ganglion cells***
- Neuron axons in the retina are gathered at a point called the **optic disc** (**blind spot**)
- Blood vessels also enter here



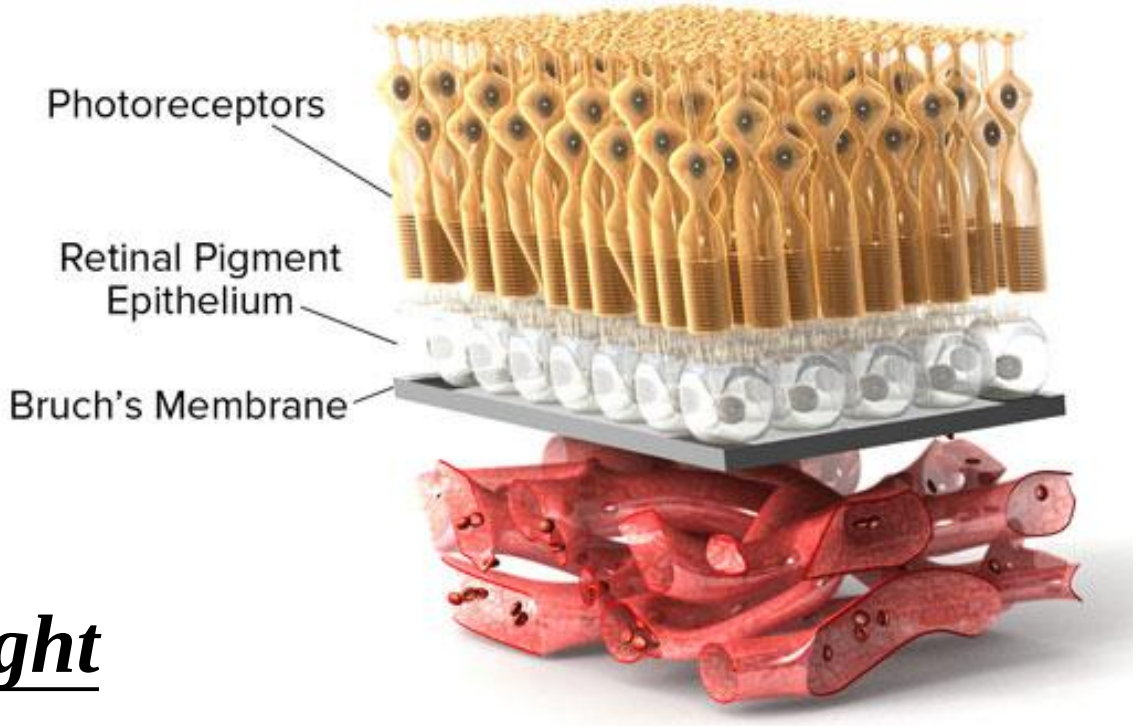


Anatomy of the Retina

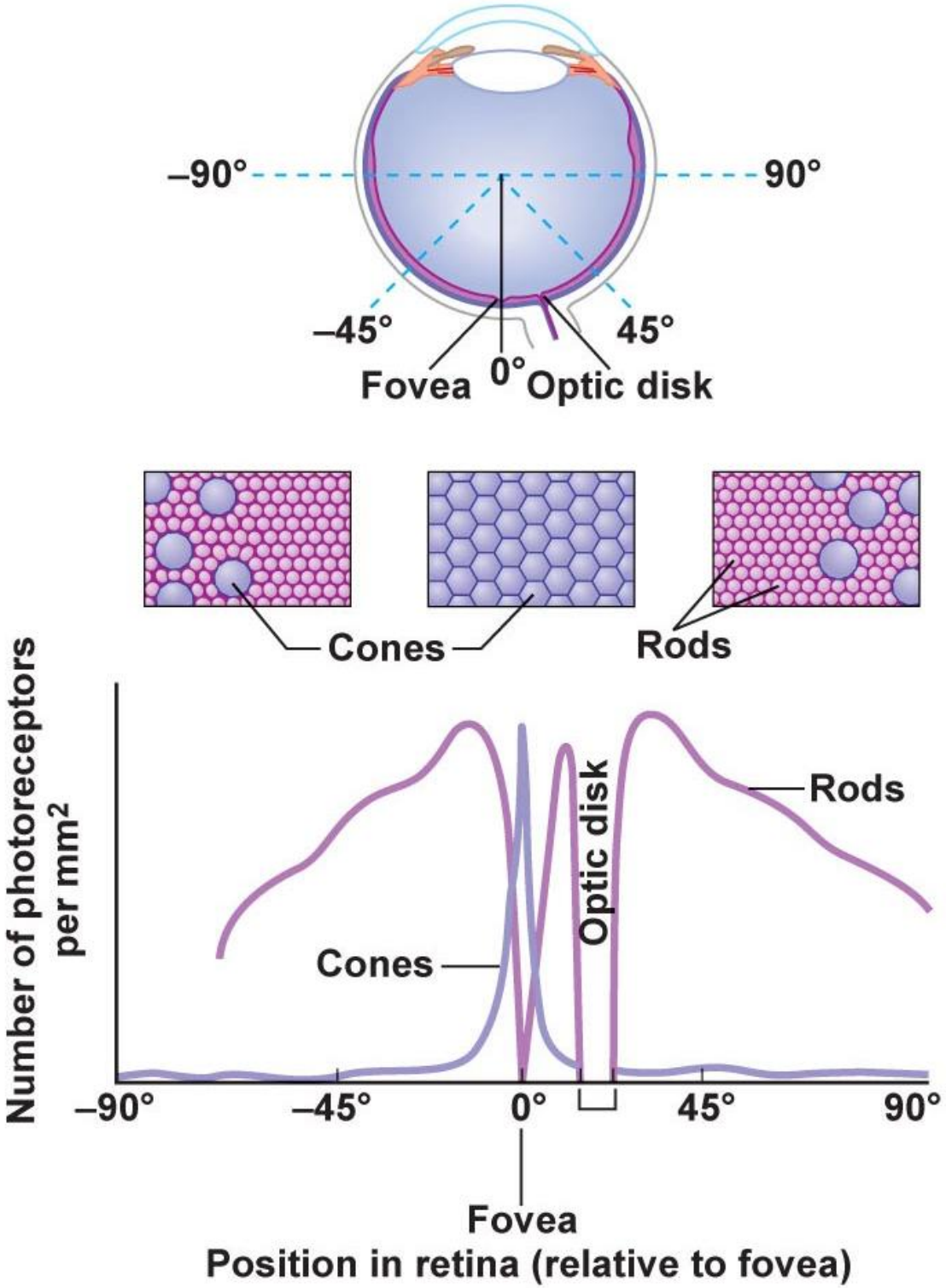


Retinal Pigment Epithelium (RPE)

- Located under the rods and cones
- **Help vision** by:
  - ***--Phagocytizing shed outer discs***
  - ***--Absorbing scattered light***
  - ***--Delivering nutrients to rods and cones***
  - ***--Suppressing immune attack in retina***
  - ***--Participating in visual cycle of retina***
  - ***--Stabilizing ionic concentrations in area***

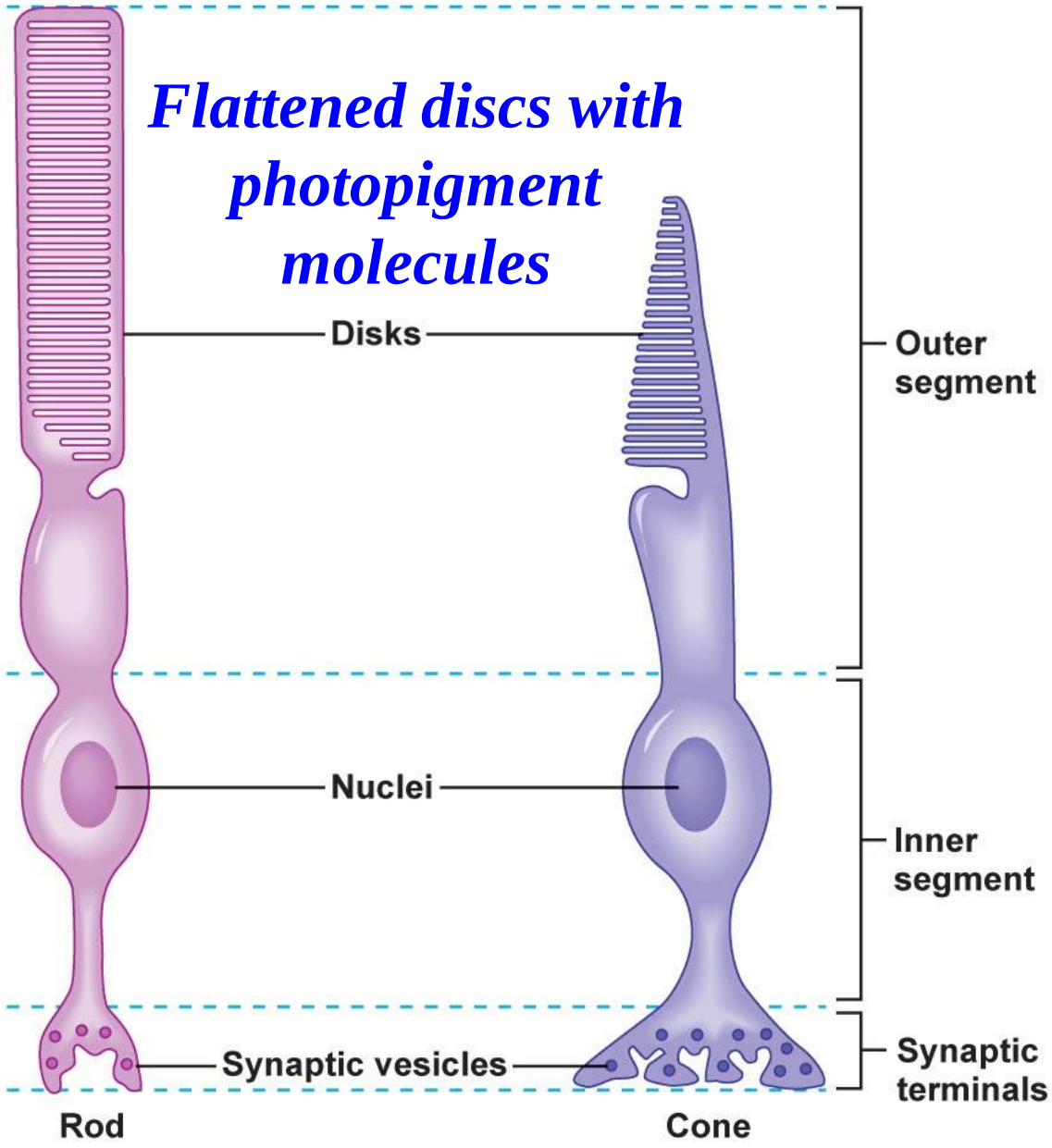


Rod and Cone Distribution



- **Fovea centralis**: vision is best at one point in the retina
  - --Each cone has a 1:1 relationship with a ganglion cell which allows **great visual acuity**
- Convergence of lots of rods onto a single ganglion cell increases **light sensitivity**

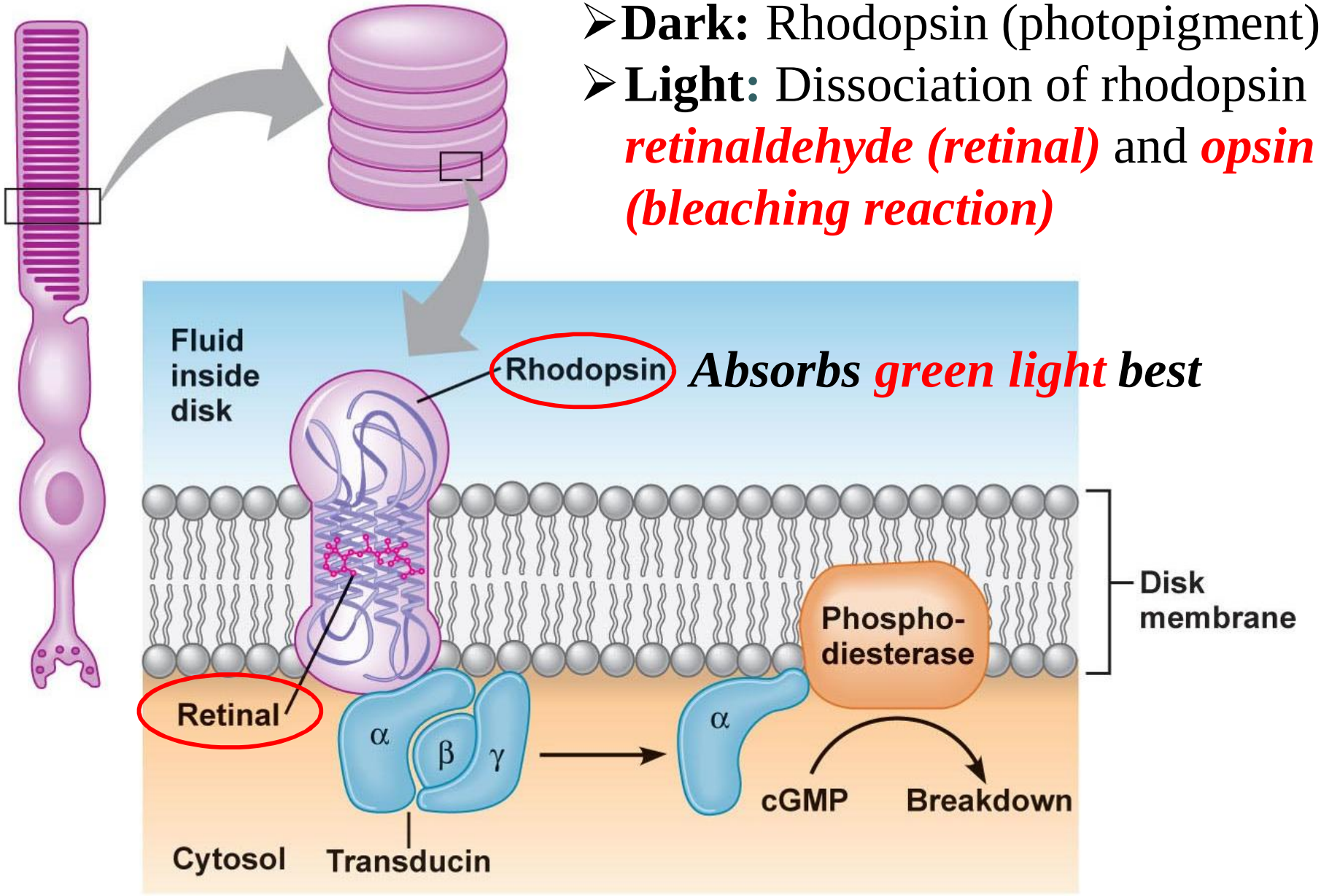
Anatomy of Rods and Cones



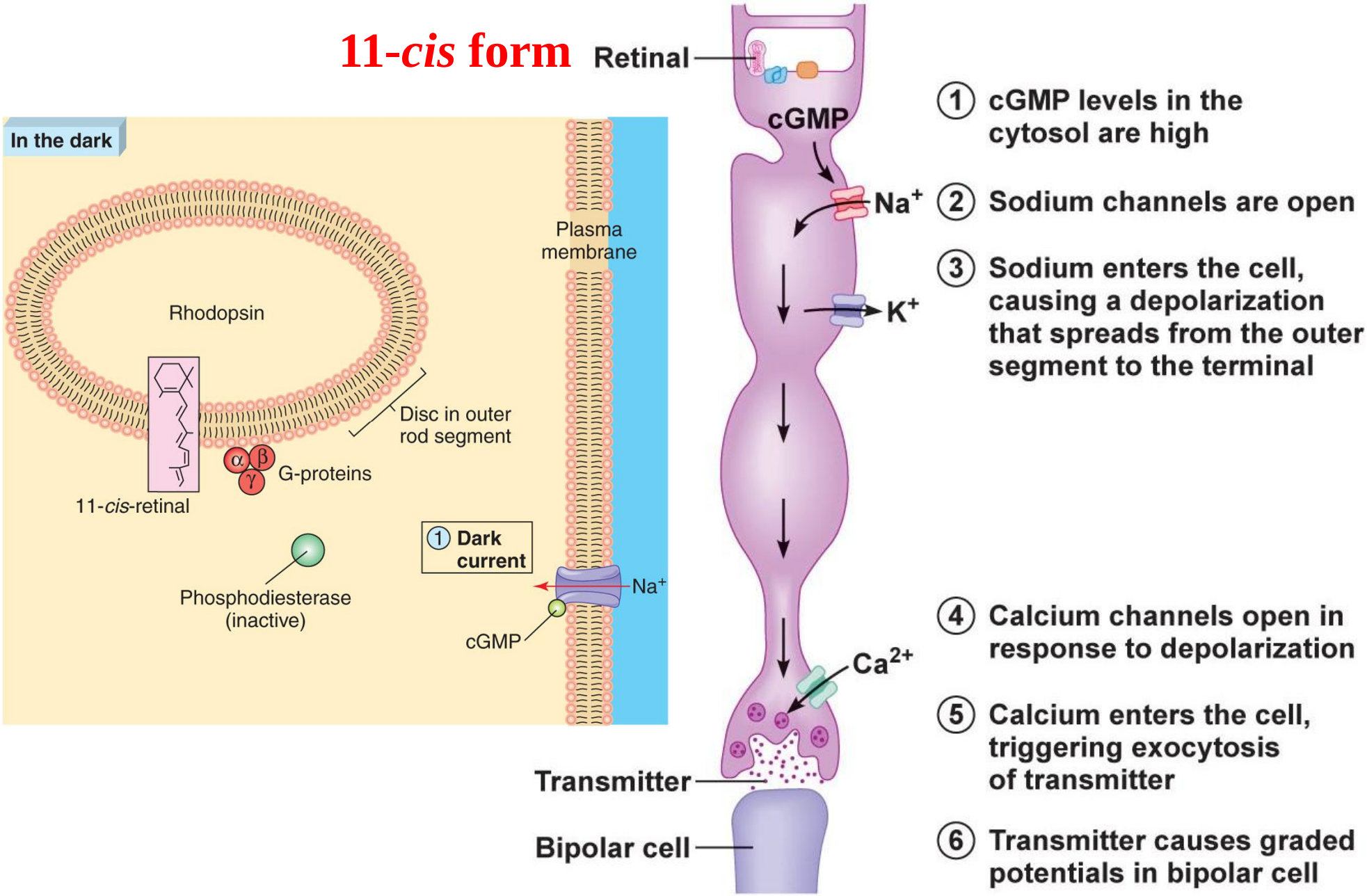
- **Consist of:** ***Outer and Inner segment***
- **Function of rods and cones:** ***Conversion of light energy to nerve signals (Phototransduction)***
- **Four photopigments**
  - **--Each has** ***retinal*** **and** ***opsin***
- **Four different opsins**
  - **--One for the rods (*black and white vision*)**
  - **--Three for the cones (*color vision*)**

Components of Rods

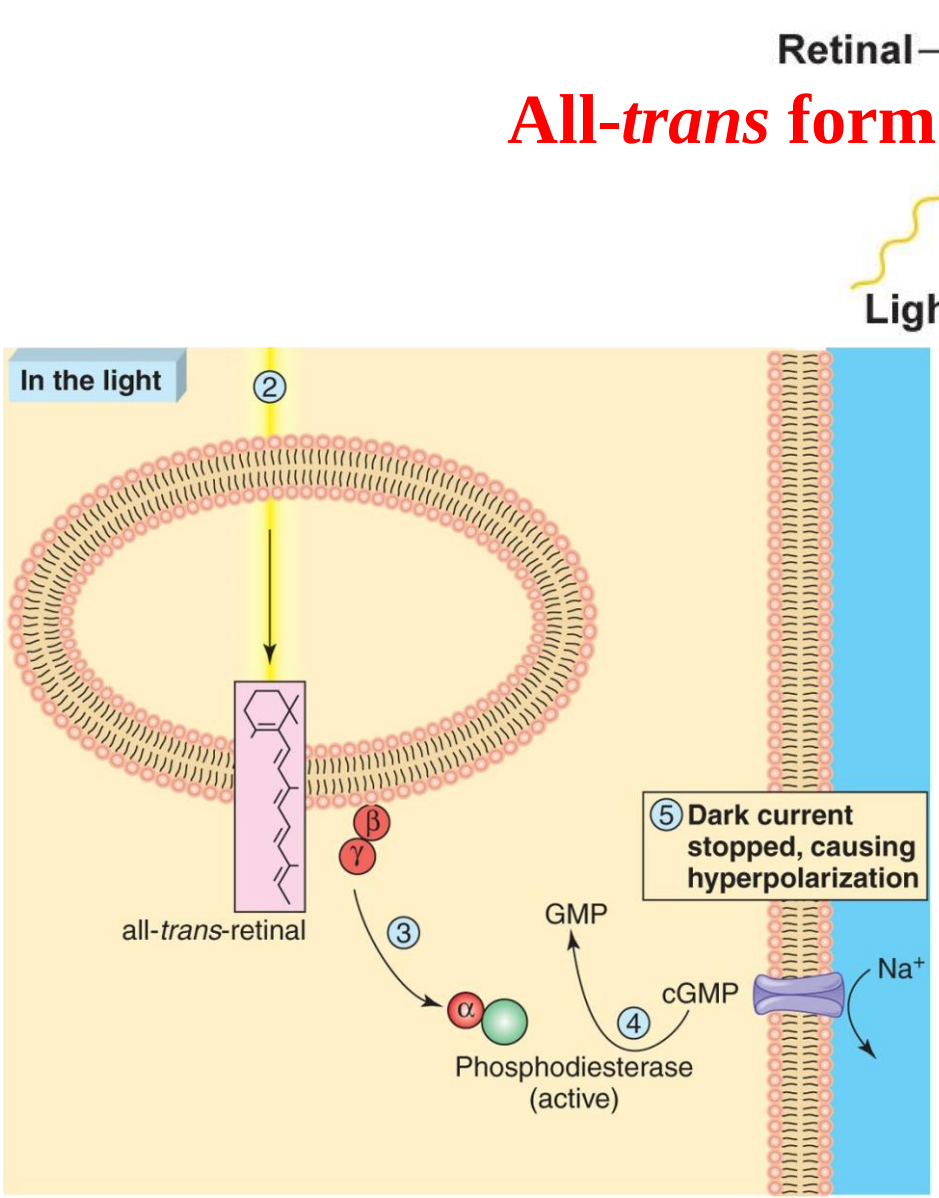
- **Dark:** Rhodopsin (photopigment)
- **Light:** Dissociation of rhodopsin ***retinaldehyde (retinal)*** and ***opsin (bleaching reaction)***

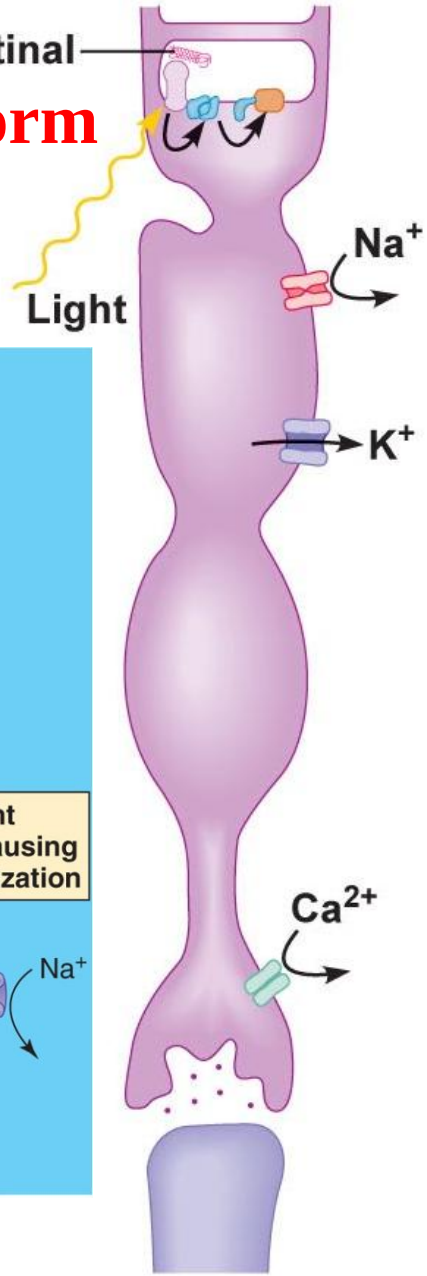


Phototransduction of Rods: Dark



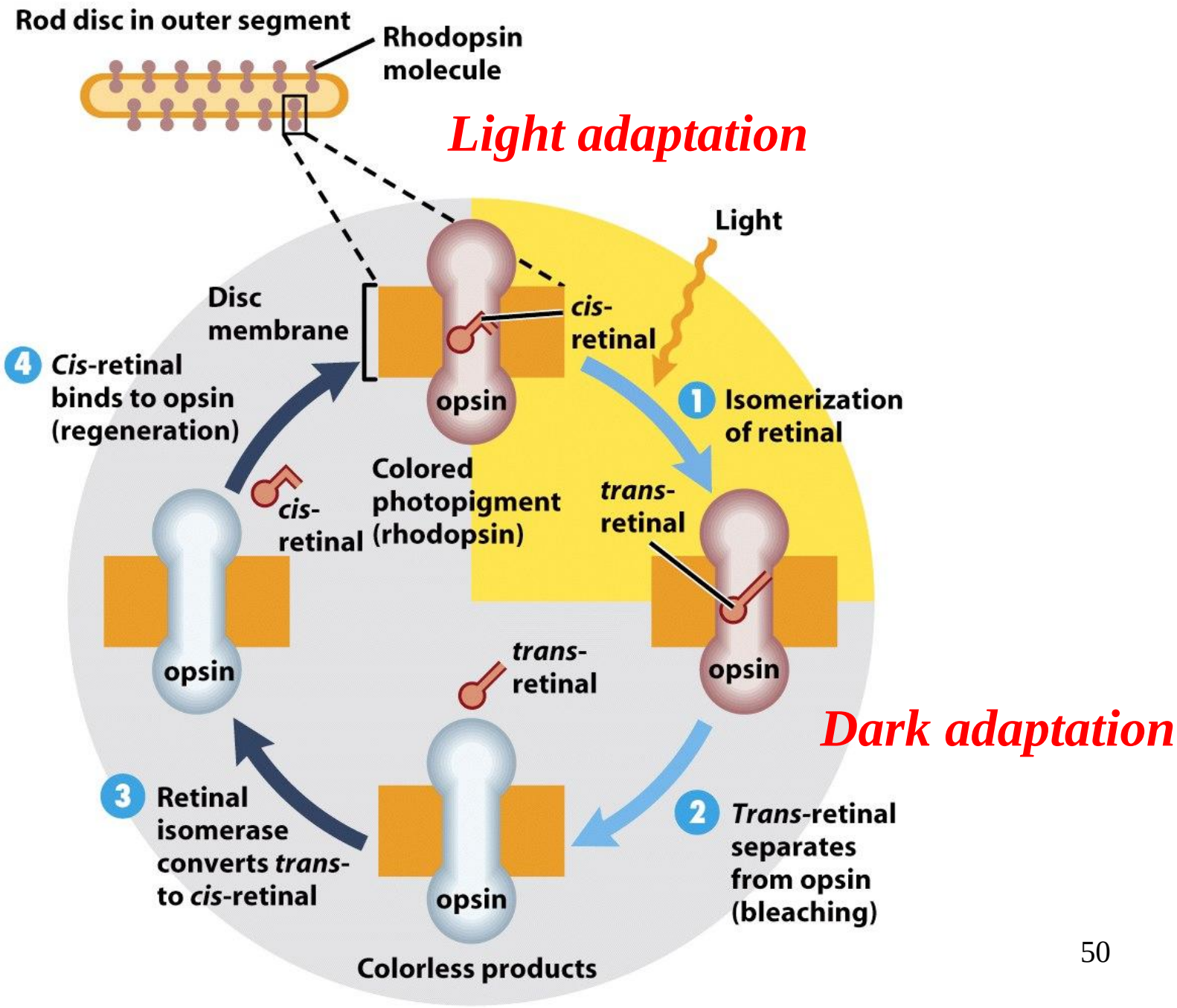
Phototransduction of Rods: Light



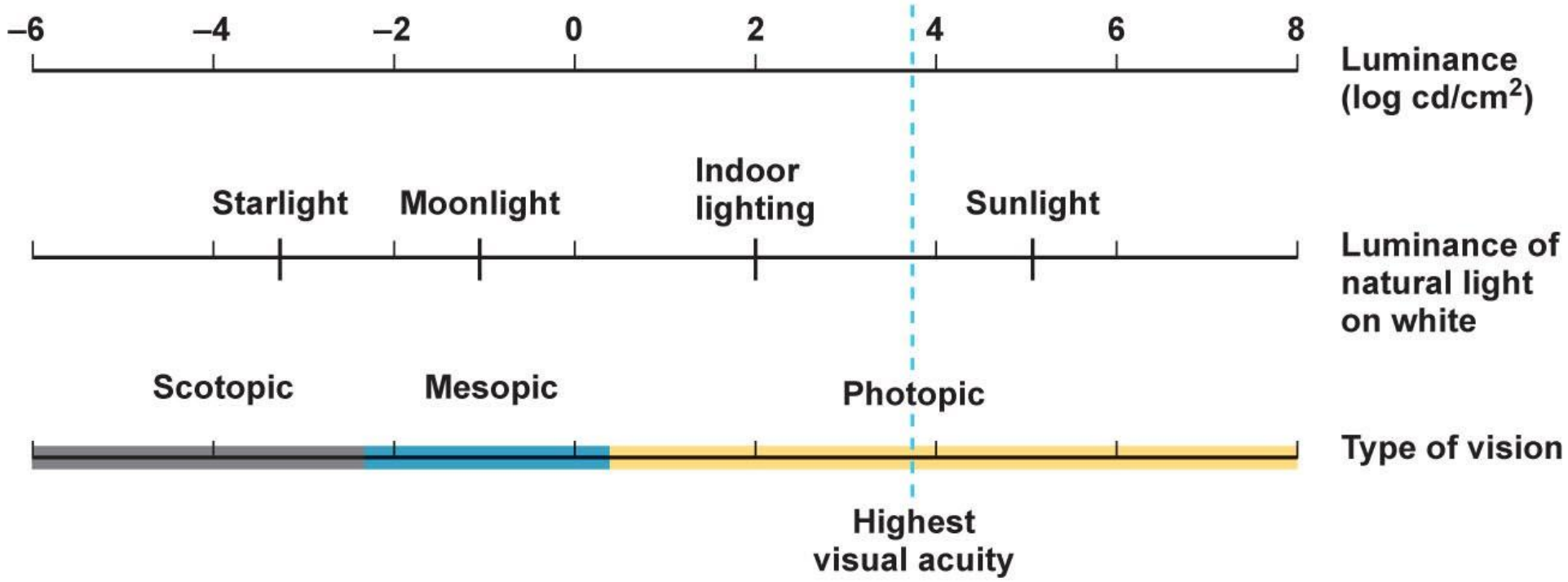


1. Light is absorbed by photopigment
2. Retinal and opsin dissociate
3. Transducin is activated
4. Phosphodiesterase is activated
5. cGMP levels in cytosol decrease
6. Sodium channels close
7. With less sodium entering the cell, the cell hyperpolarizes
8. Calcium channels close
9. Transmitter release is decreased
10. Graded potential in bipolar cell gets smaller

Visual Cycle of Retinal

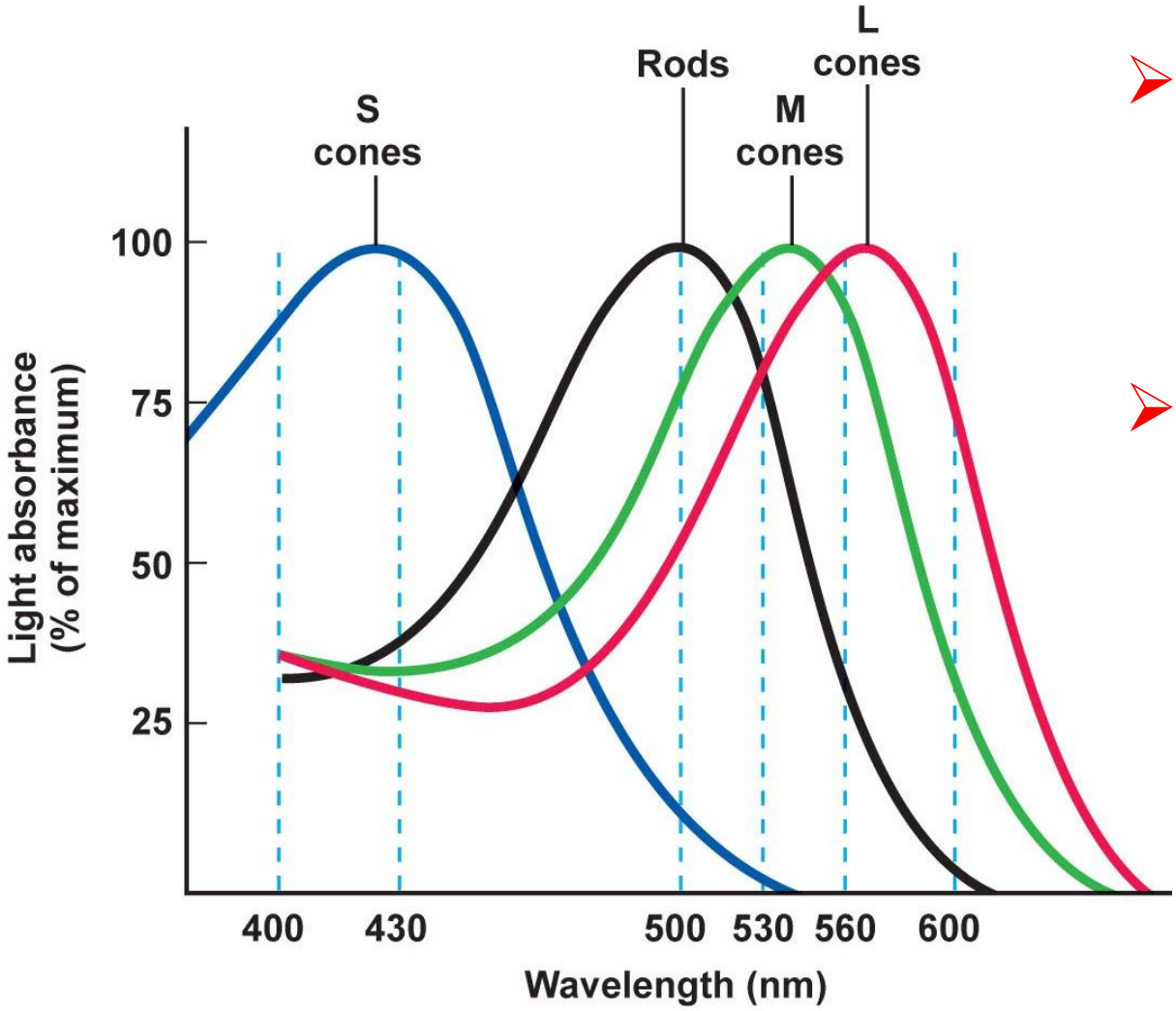


Rod and Cone Sensitivity



- ***<u>Scotopic</u> vision: rods***
- ***Mesopic vision: rods and cones***
- ***<u>Photopic</u> vision: cones***

Absorbance Spectra of Rods & Cones



- ***Rods** are **high sensitive to light** (**black and white vision—500 nm**), but **lower visual acuity***
- ***Cones** are less sensitive to light, but allow **color vision** and **greater visual acuity***

3 types of cones

- ✓***Blue**—responds best to **420 nm***
- ✓***Green**—responds best to **530 nm***
- ✓***Red**—responds best to **560 nm***

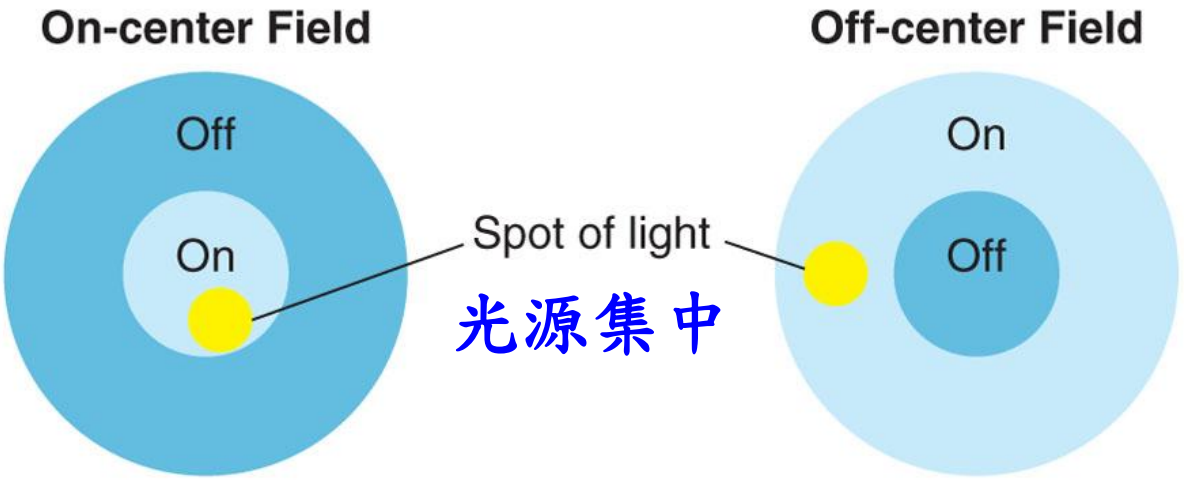
Characteristics of Rods & Cones

	Rods	Cones
Types of vision	Black and white; night (dim light)	Color; day (bright light)
Sensitivity to light	High	Low
Abundance	100 million per retina	3 million per retina
Visual acuity	Low	High
Site of greatest concentration	Periphery of retina	Fovea
Degree of convergence with bipolar cells	High	Low

Neural Processing in the Retina

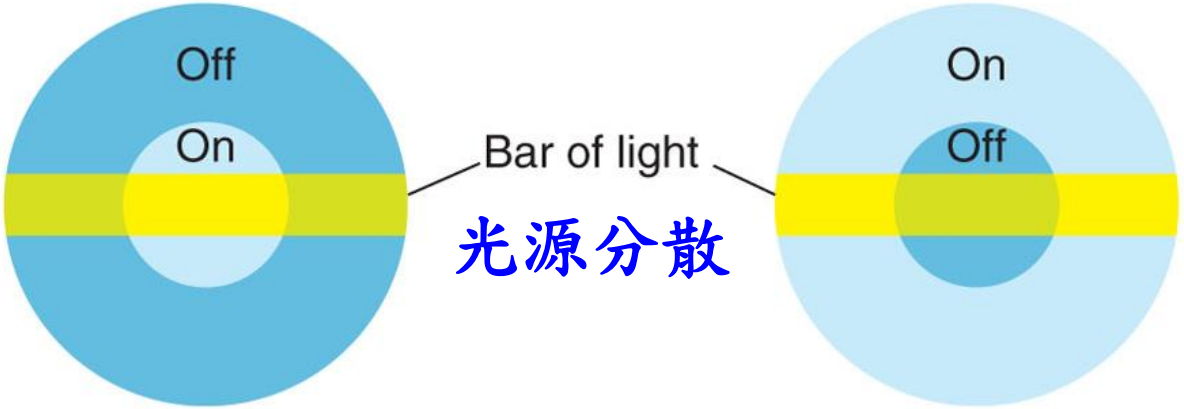
- Transmitter released from rods and cones
- Communicates with bipolar neurons
  - --**More NT** in **dark**
  - --Some inhibitory, some excitatory
  - --**Graded potentials** only (some hyperpolarizations=IPSP, some depolarizations=EPSP)
- Bipolar cells synapse with ganglion cells
  - --Some excitatory, others inhibitory
- Ganglion cell is first cell in pathway to generate **action potentials**
  - --Axons of ganglion cells = **cranial nerve II**
  - --Convergence of excitation and inhibition gives **complex receptive fields (On-center or Off-center field)**

Ganglion Cell Receptive Fields



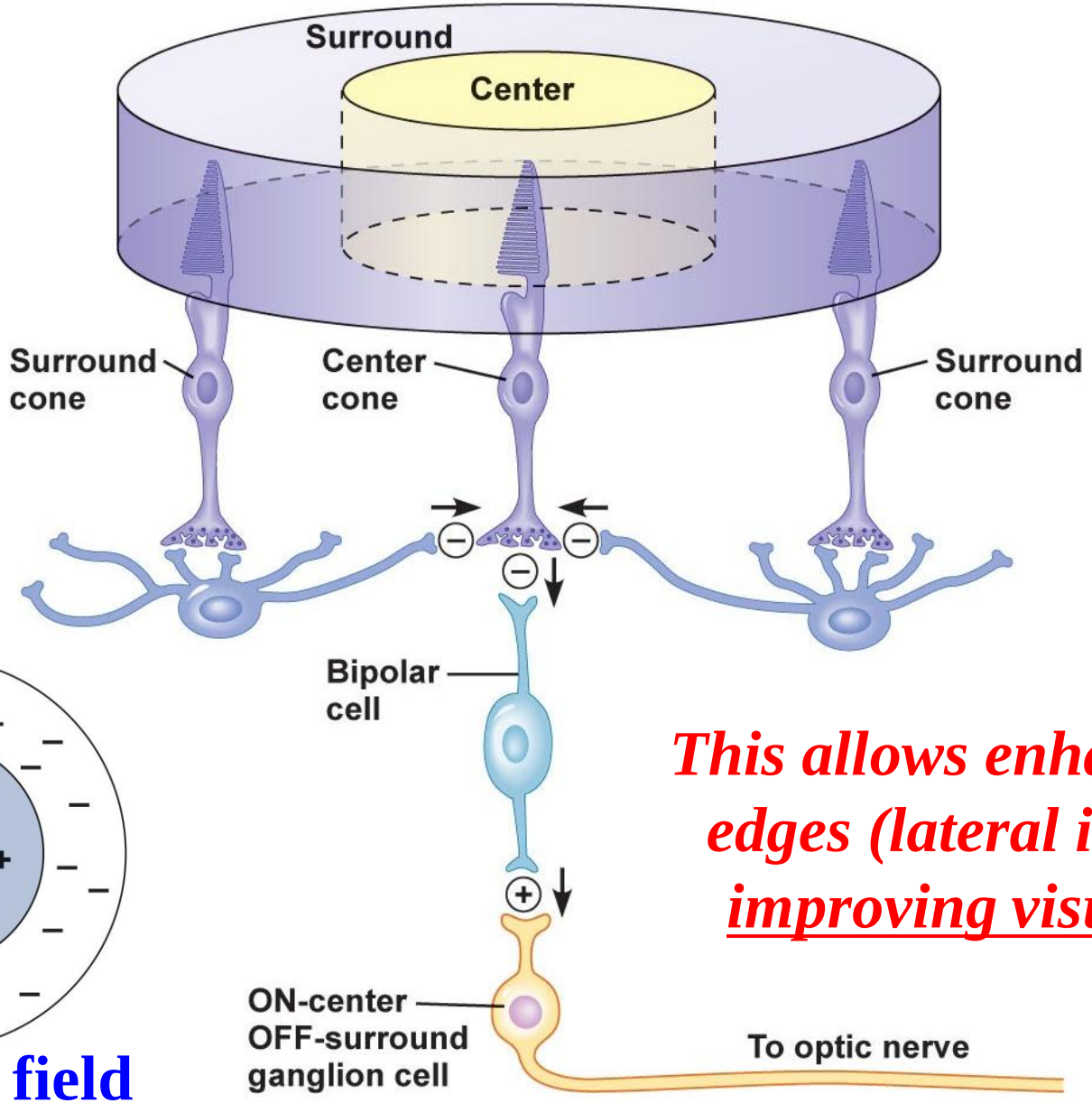
Light on center stimulates, light on surround inhibits, ganglion cell

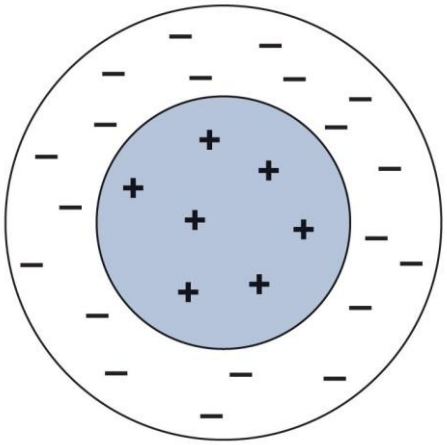
Light on center inhibits, light on surround stimulates, ganglion cell



Light across both center and surround is less effective at stimulating ganglion cell

Receptive Fields of Ganglion Cells



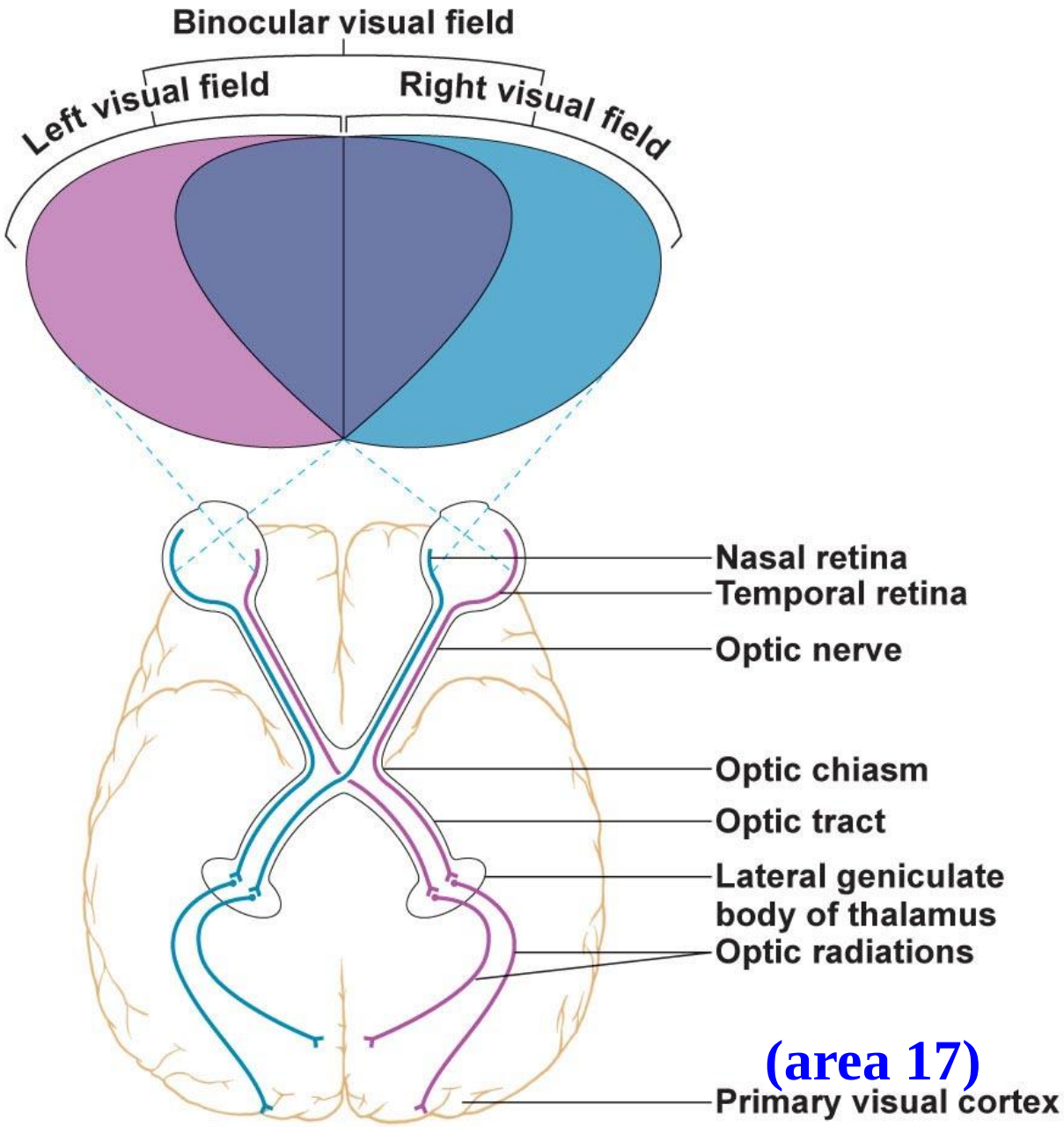


On-center field

This allows enhancement of edges (lateral inhibition), improving visual clarity

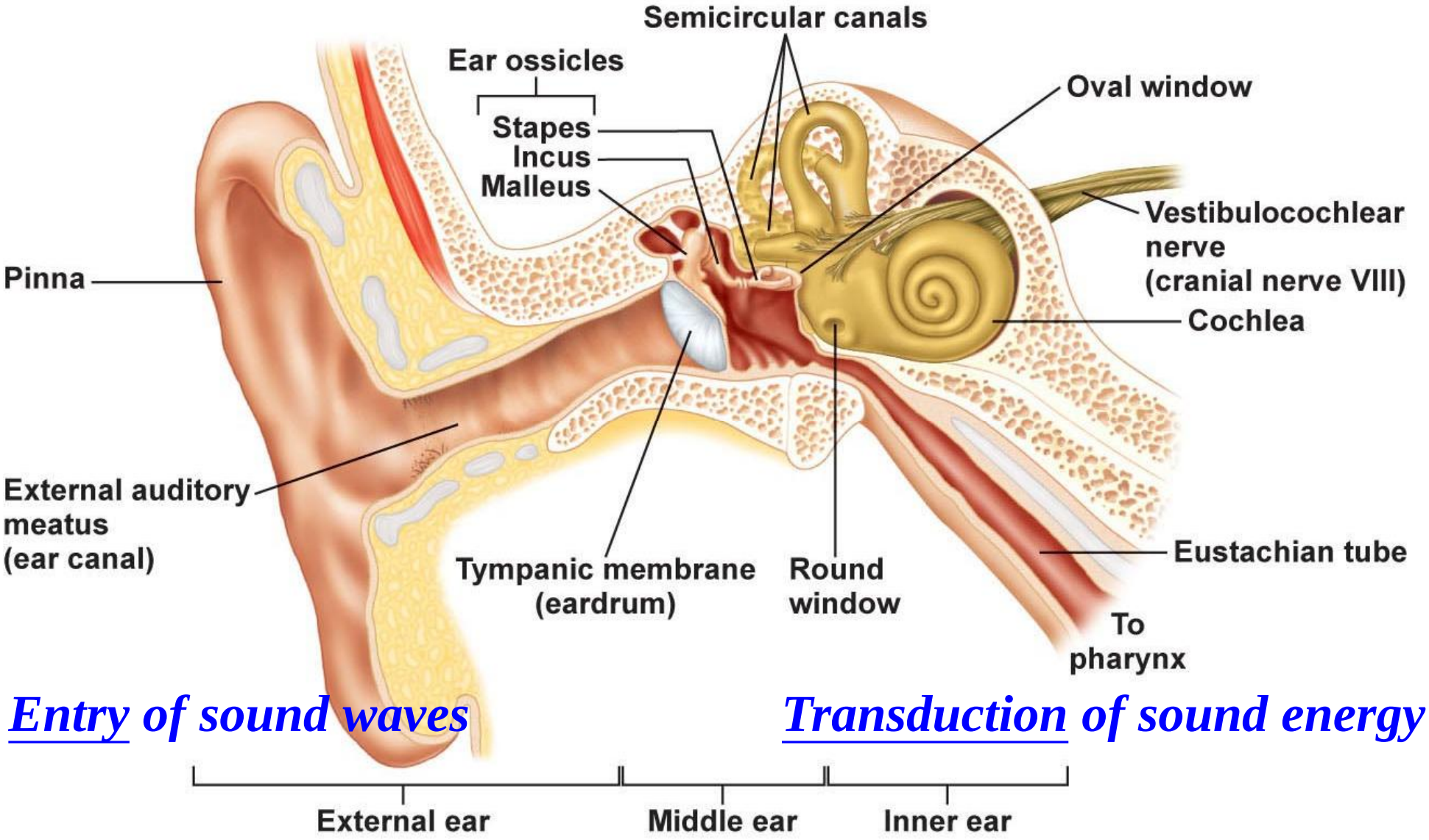
Visual Pathway

- **Ganglion Cells**
  - --***Optic nerve***
  - --***Optic chiasm***
  - --***Optic tract***
- ***LGB*** synapses
- ***Optic radiations***
- ***Visual cortex*** synapses (70-80%)
- ***Superior colliculus*** of the midbrain synapses (20-30%): helps with eye and body movements
- Right visual field to left cortex; vice versa



結構（按字母順序）	位置	功能
水樣液	位於角膜和水晶體之間的前面腔室	持續形成的乾淨水樣液，並提供養分給角膜和水晶體
雙極細胞	視網膜神經細胞的中間層	在視網膜處理光刺激時是很重要的
盲點	在視網膜上稍微不在正中點，視神經離開處；缺乏光感受器（又稱作視神經盤）	視神經和血管的穿過路線
脈絡層	眼睛的中間層	含有色素的可以避免光線在眼睛中散射；包含血管提供視網膜養分；前方特化成睫狀體和虹膜
睫狀體	脈絡層前方特化的構造；形成包在水晶外圍的一個環	製造水樣液以及內含有睫狀肌
睫狀肌	睫狀體組成中的環狀肌肉；藉由懸韌帶連接到水晶體上	對調節作用很重要
視錐細胞	視網膜最外層的光感受器	負責高敏銳度、顏色，和白天視覺
角膜	眼睛前方乾淨的最外層	幫助提供大量的眼睛折射能力
中央窩	視網膜的正中心處	最大敏銳度的地方
神經節細胞	視網膜的內層神經細胞	在視網膜處理光刺激時是很重要的；形成視神經
虹膜	在水樣液中可見的含色素環狀肌肉	藉由不同的收縮來改變瞳孔的大小；負責形成眼睛的顏色
水晶體	位在水樣液和玻璃狀液之間；藉由懸韌帶和睫狀肌相連	當適應作用時提供不同的折射能力
黃斑	包在中央窩外圍的區域	因為富含視錐細胞所以有高度的敏銳度
視神經盤	（見盲點）	
視神經	每一隻眼睛離開視神經盤（盲點）處	傳遞到腦部視覺傳遞路徑的第一部分
瞳孔	前方虹膜中心的圓型開口	允許不同的光線量進入眼睛
視網膜	眼睛的最內層	包含光感受器（視桿和視錐細胞）
視桿細胞	視網膜最外層的光感受器	負責高敏感性，黑和白，夜晚的視覺
鞏膜	眼睛堅固的外層	保護的結締組織外膜，形成眼睛可見的白色部分，前方特化成角膜
懸韌帶	懸在睫狀肌和水晶體中間	在調節作用中很重要
玻璃狀液	位於水晶體和視網膜中間	半流動狀，果凍狀的物質可以幫助維持眼睛球狀構造

Hearing & Equilibrium
Anatomy of the Ear



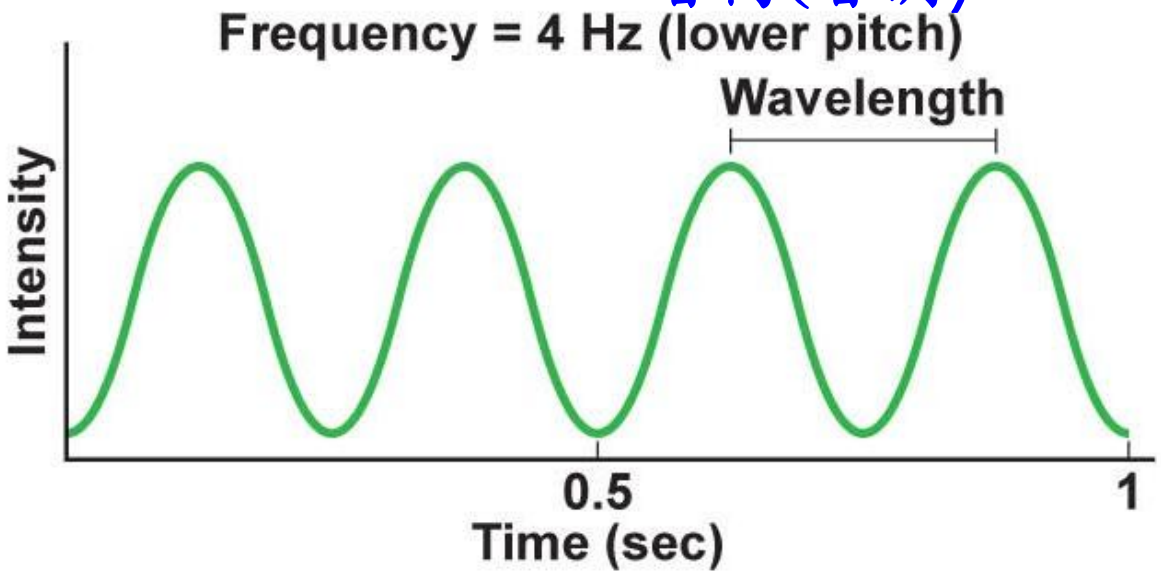
Entry of sound waves

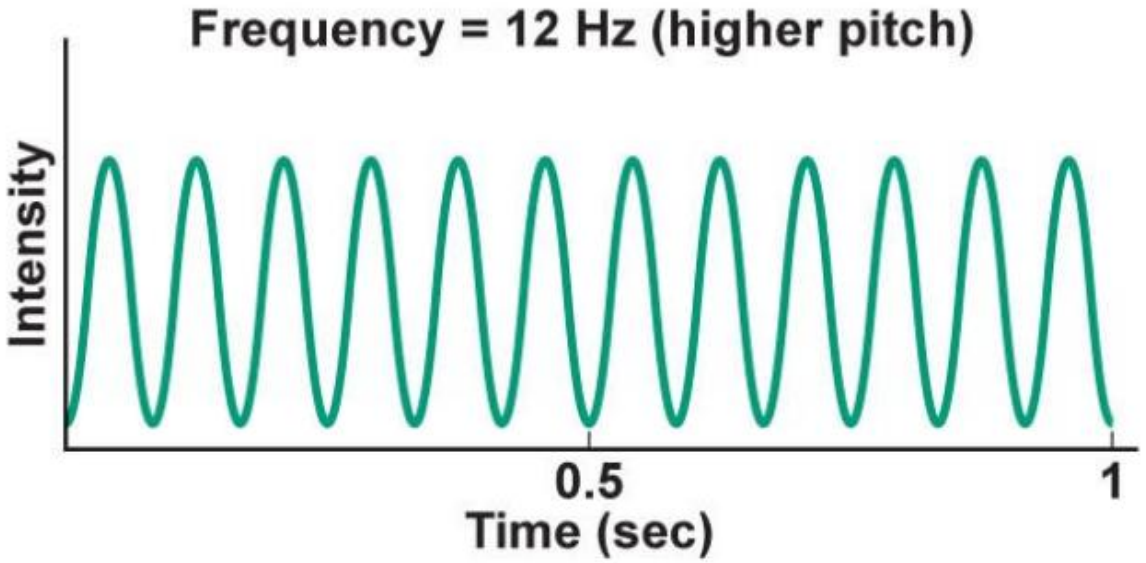
Transduction of sound energy

Amplification of sound waves

Properties of Sound Waves

音高(音調)



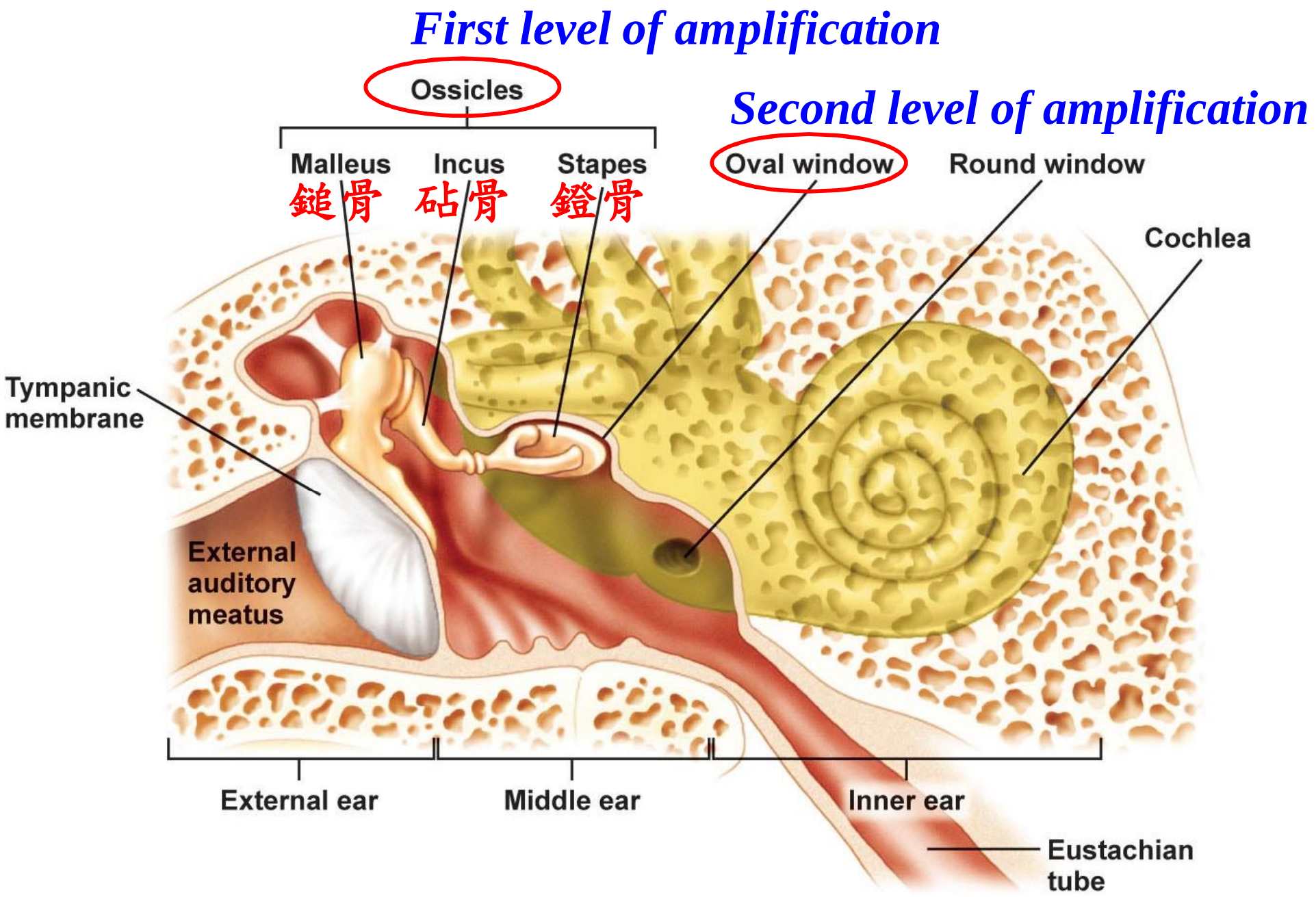


Characterized by:

--**Frequency**, measured in hertz (**Hz**). Higher frequencies have higher pitches (Human range is **20–20,000 Hz**)

--**Intensity** (**loudness**), measured in decibels (**dB**)

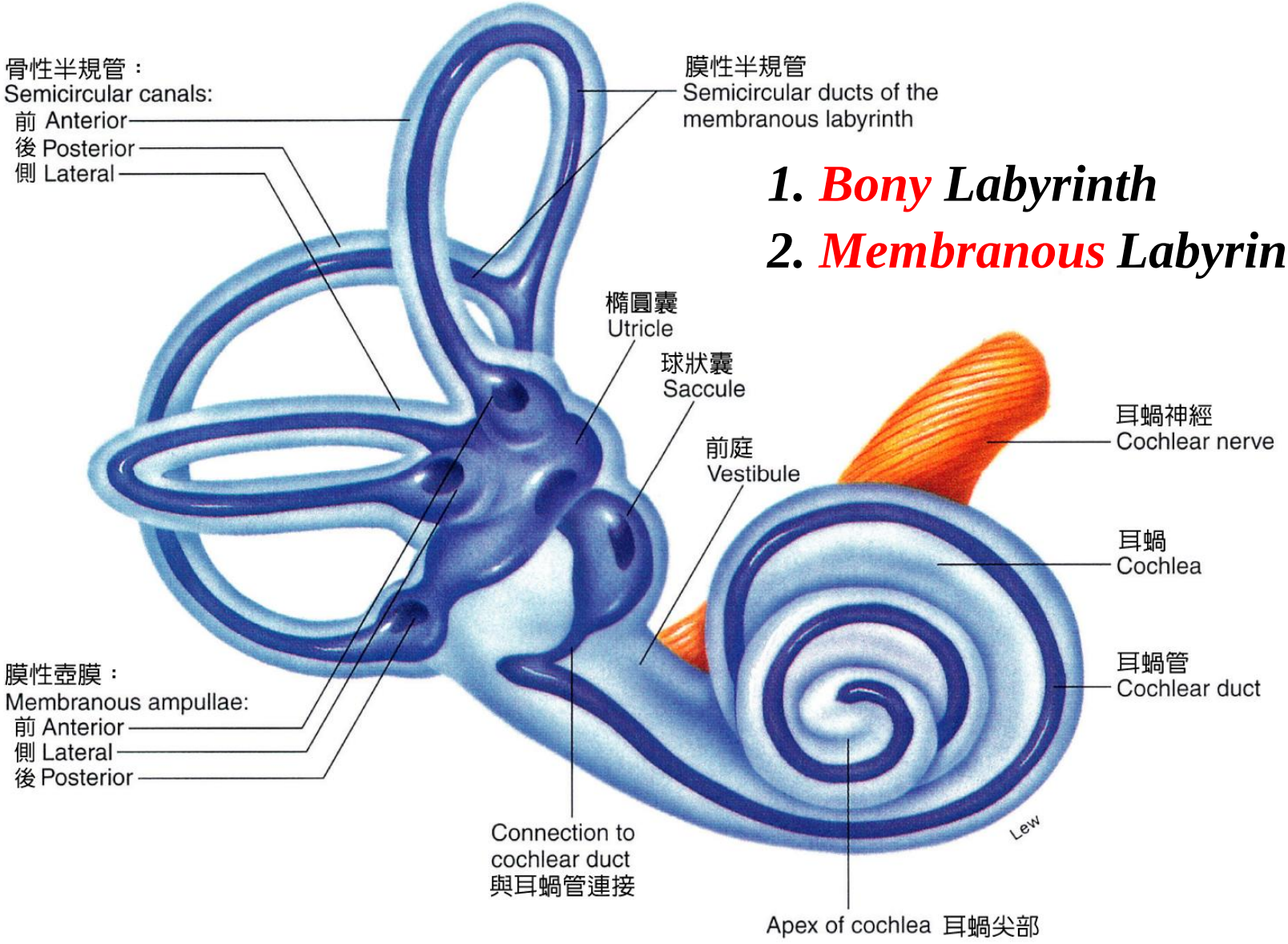
Anatomy of Middle Ear



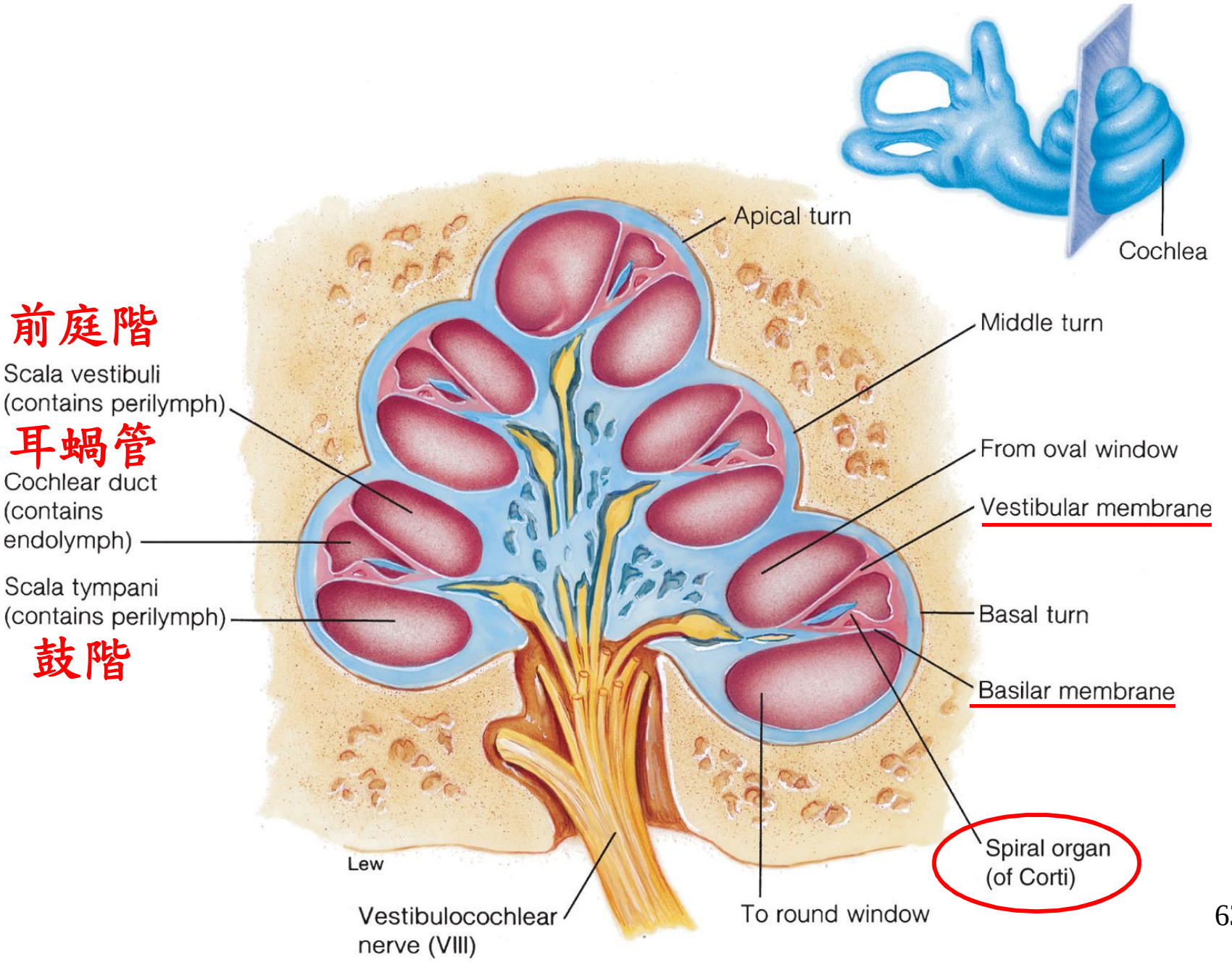
Signal Transduction of Sound Waves

✓*Conversion of sound energy to action potentials*

✓*Occurs in cochlea of inner ear (Labyrinth)*

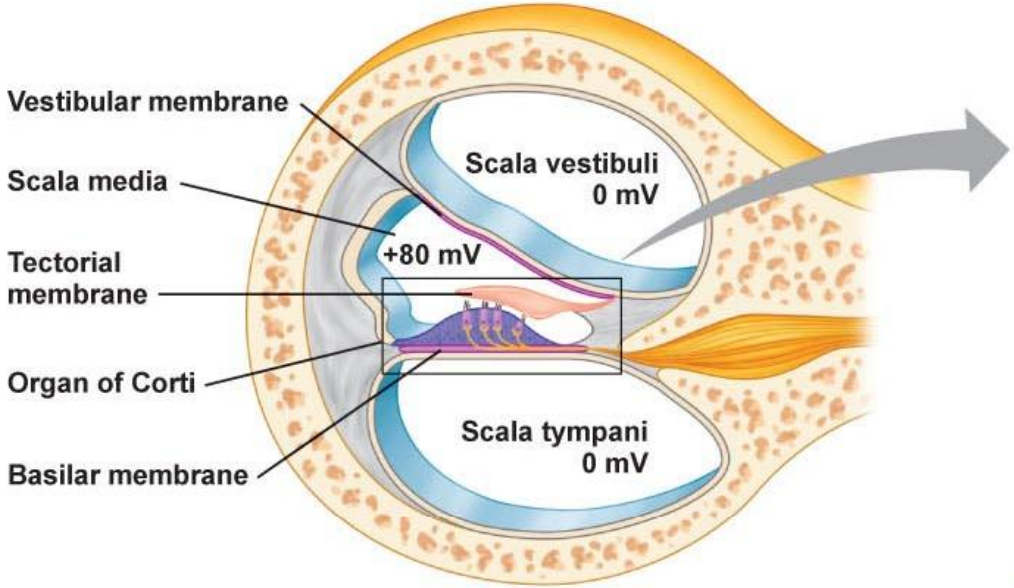


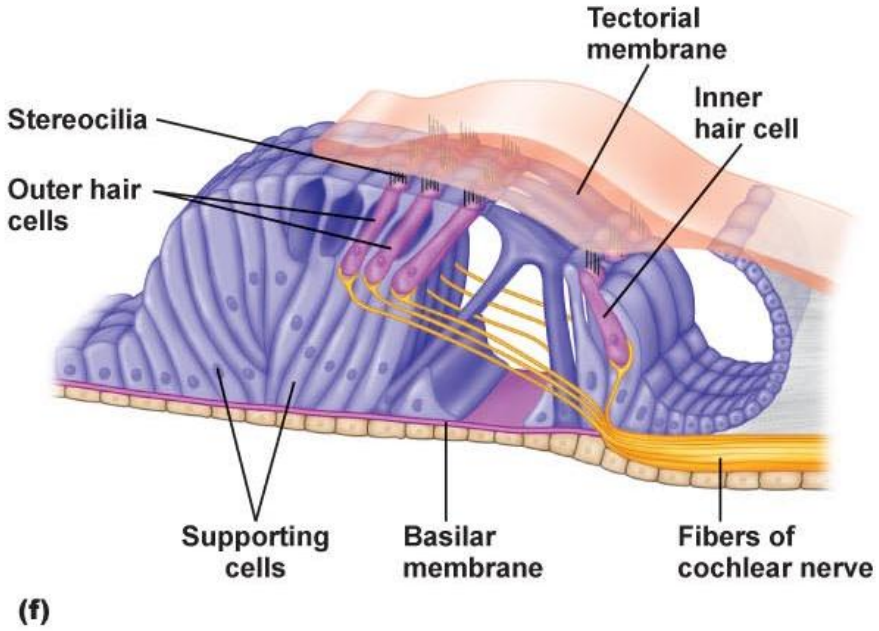
Sound Transduction: Cochlea



Functional Anatomy of Cochlea

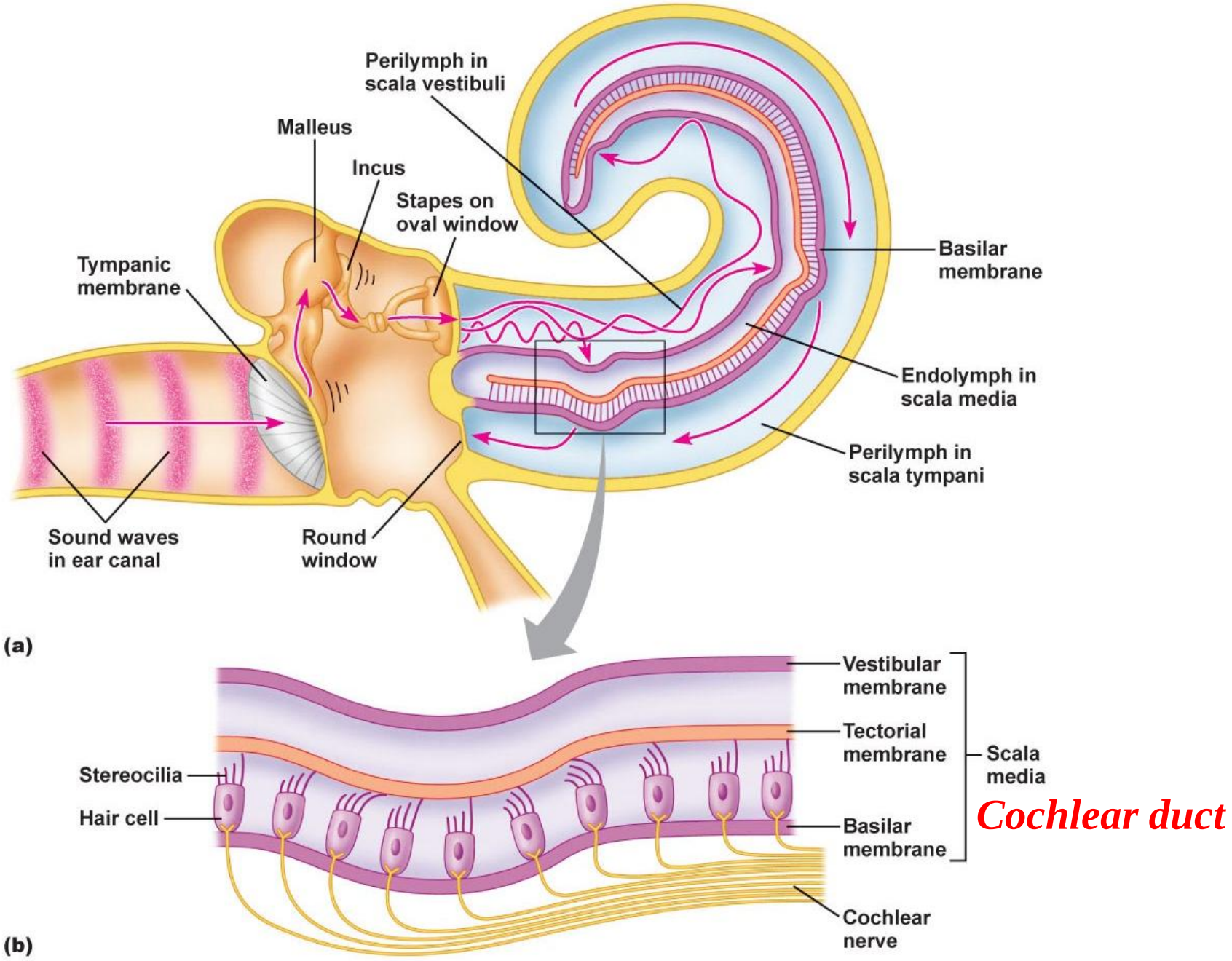
Hair Cells of the Organ of Corti





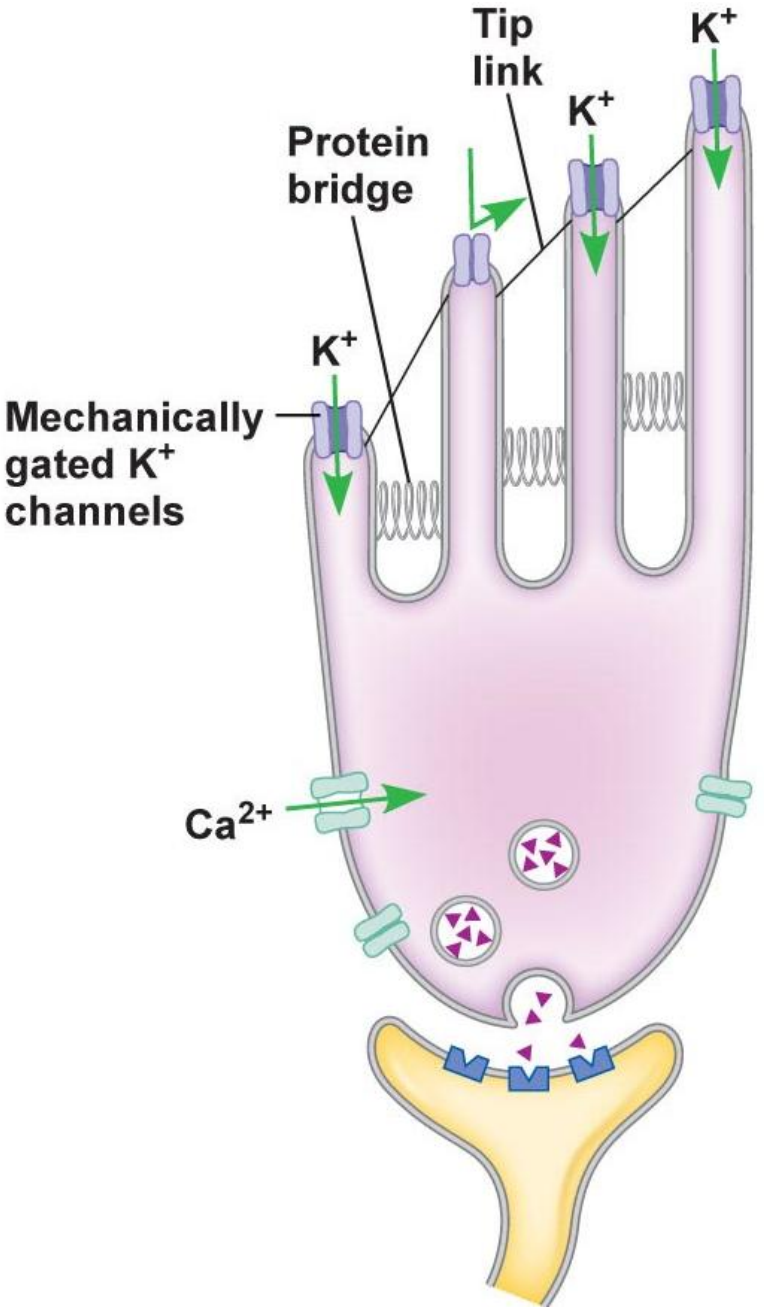
- Receptor cells for sound
- Stereocilia
  - --Tips embedded in tectorial membrane
  - --Oriented short to tall
- Surrounded by endolymph (**high K^+**)

Inner Hair Cells: Sound Conduction

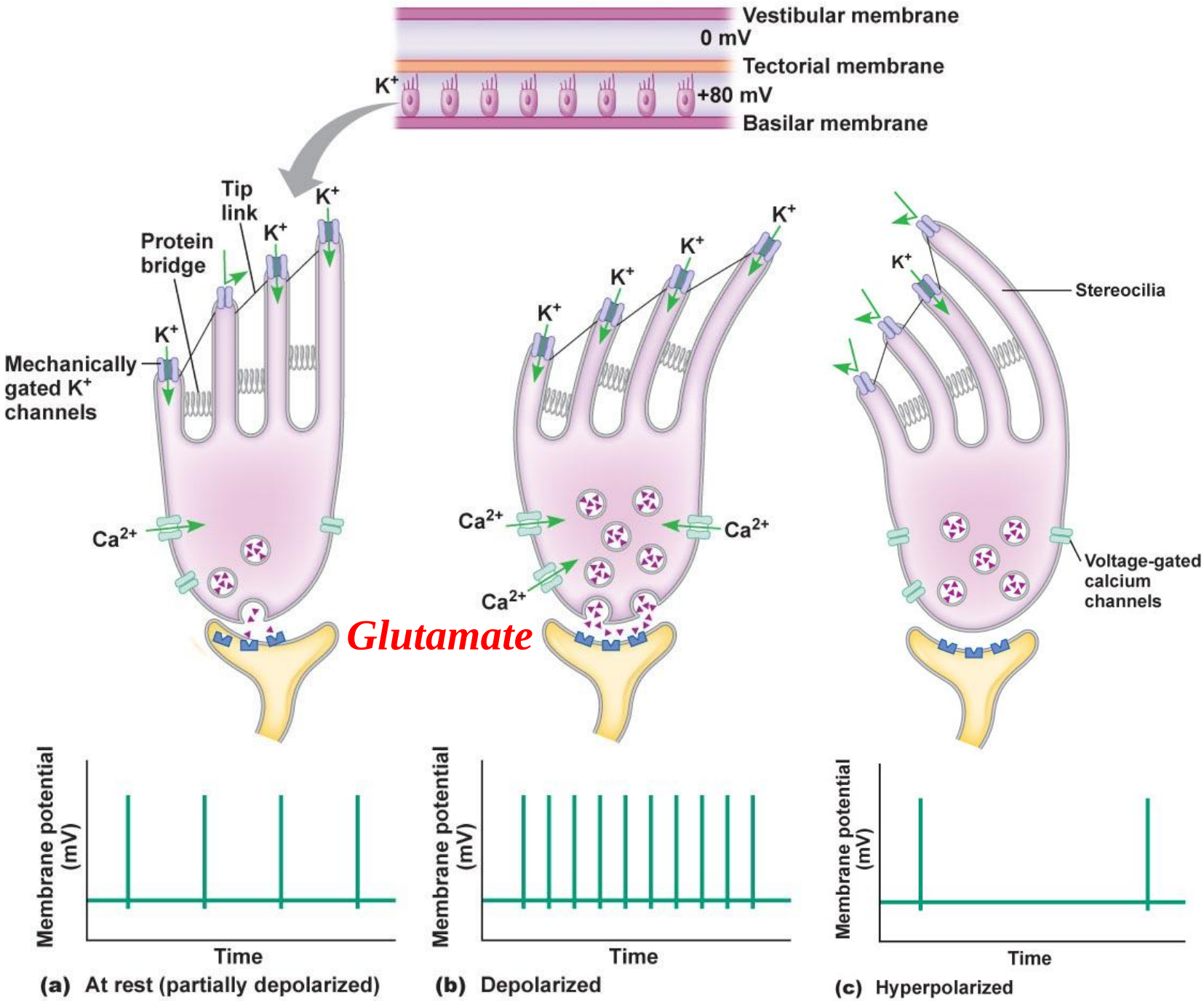


Mechanism of Sound Transduction

- Stereocilia of hair cells connected by protein bridges
- Mechanical stress moves protein bridges, causing the opening or closing of cation channels
- Cation channels allow cations, especially **potassium**, to move through
- Potassium high in endolymph; therefore enters cell causing **depolarization**



Hair Cells: Sound Transduction



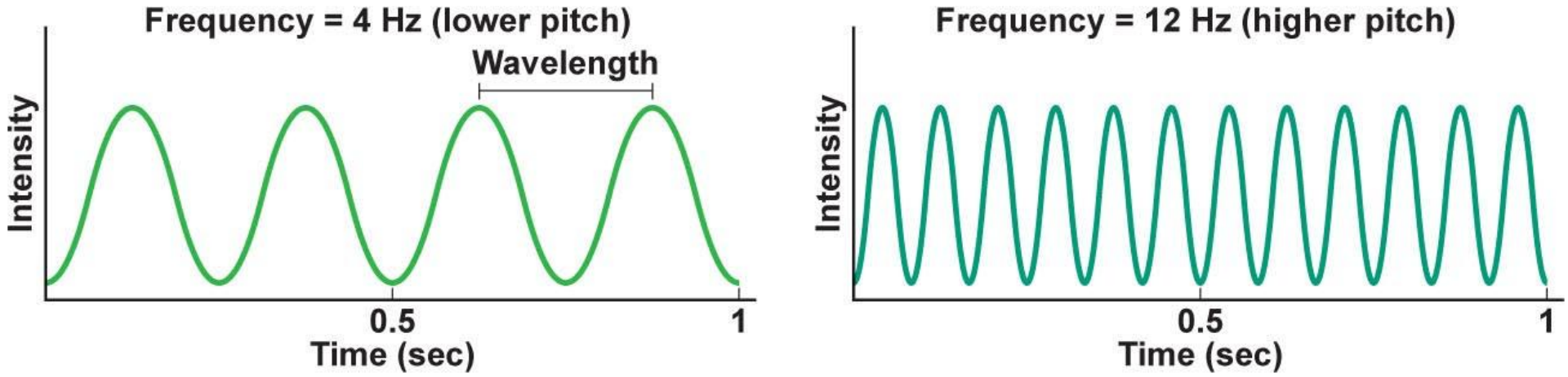
Coding for the Qualities of Sound

- ***Intensity (dB) coding = loudness*** **(強度=響度)**

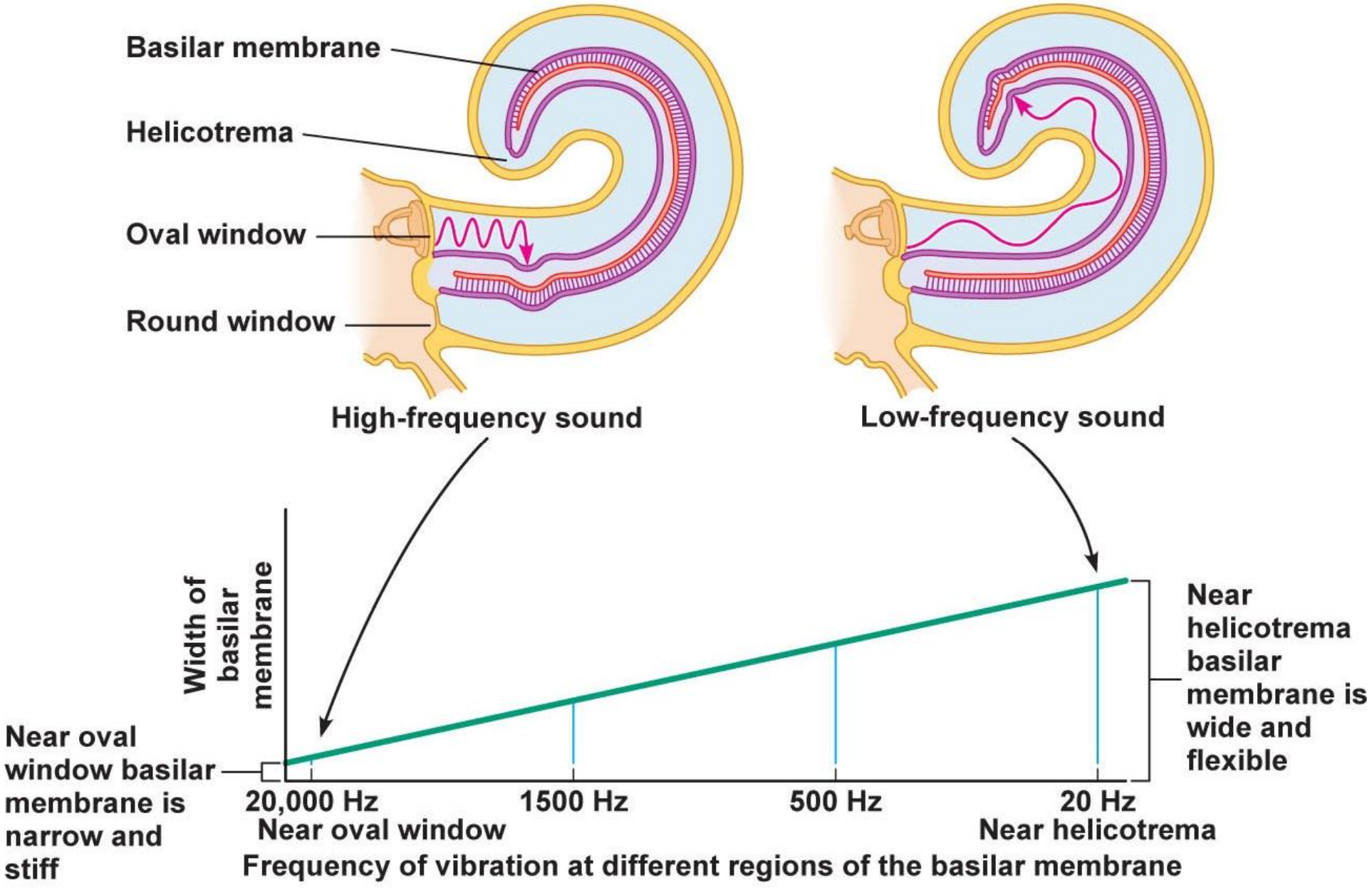
  --**Amplitude** is coded by the degree of deflection and opening of ion channels in stereocilia

- ***Frequency (Hz) coding = pitch*** **(音頻=音調)**

  --Coded by where on the basilar membrane the deflection occurs

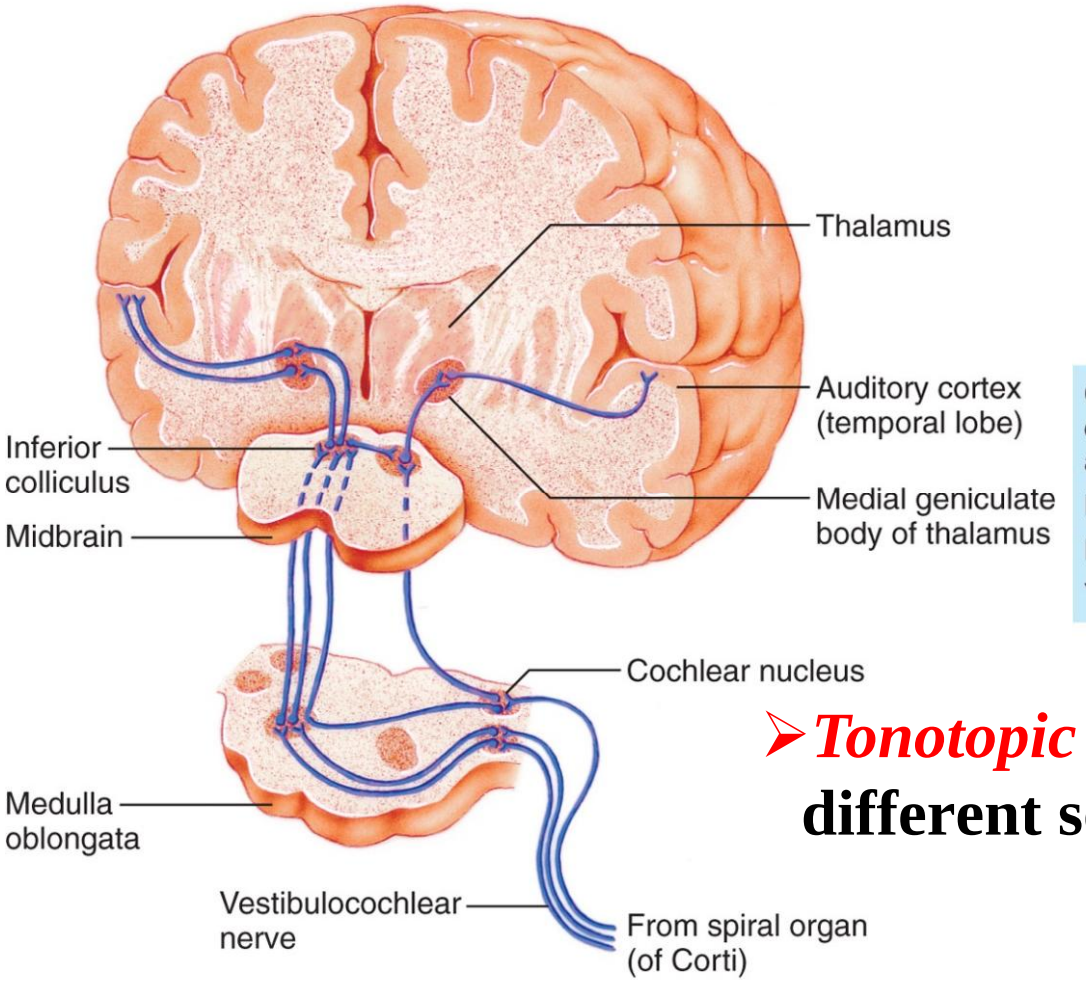


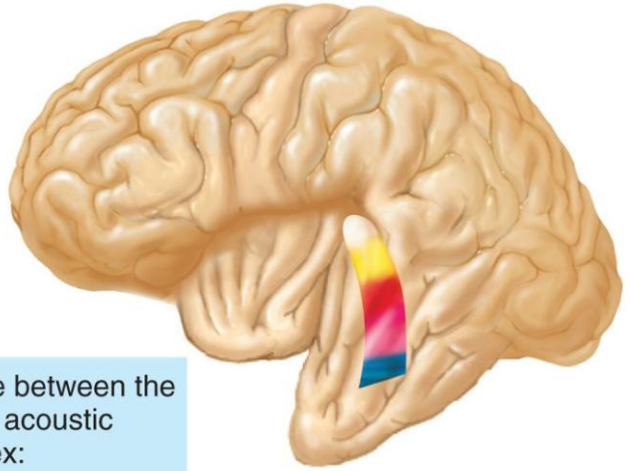
Sound Frequency Coding



Neural Pathways for Sound

Vestibulocochlear nerve →Medulla oblongata →Inferior colliculus of midbrain → Medial geniculate nucleus of thalamus →Auditory cortex of temporal lobe





Correspondence between the cochlea and the acoustic area of the cortex:

Blue—low tones

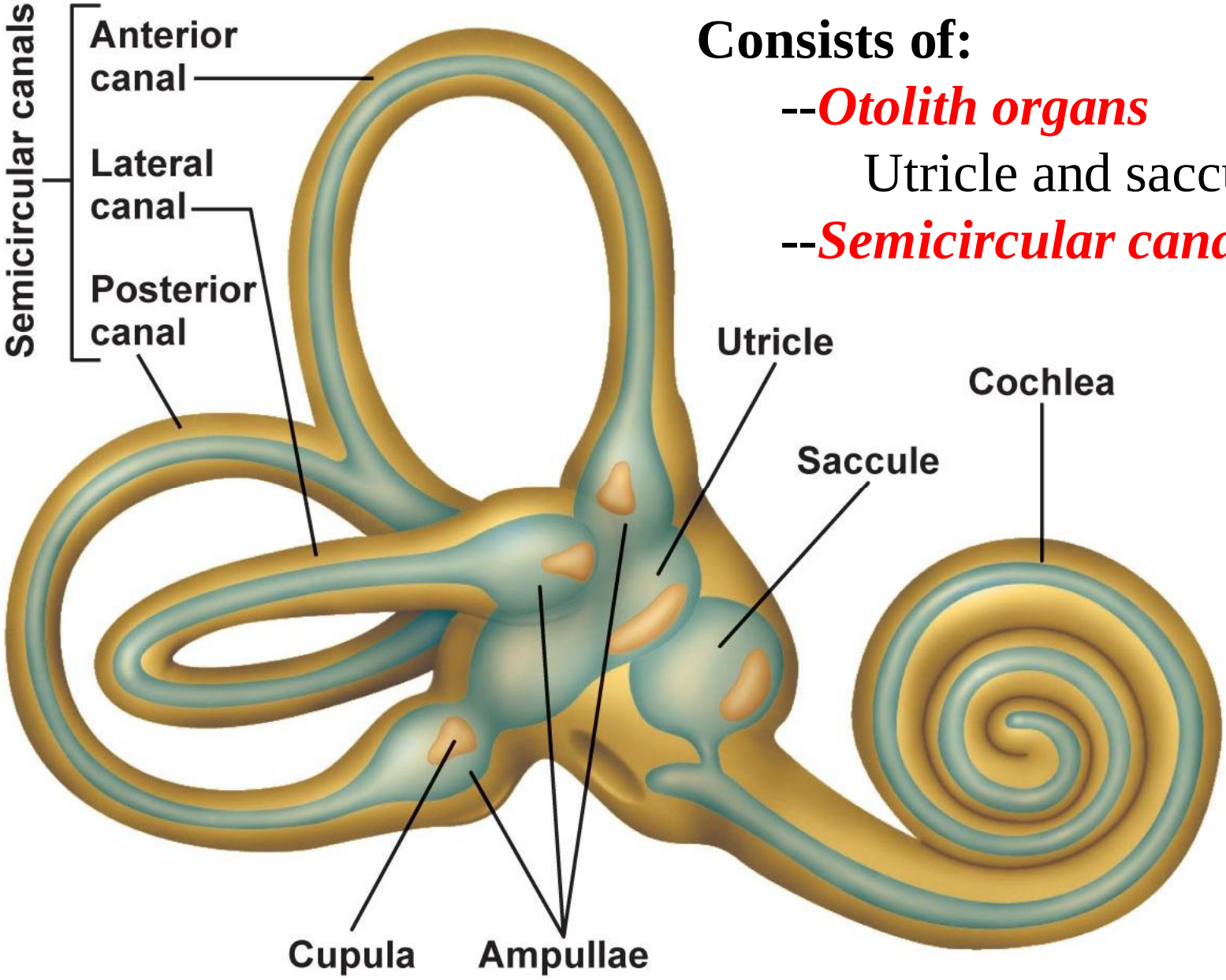
Red—medium tones

Yellow—high tones

➢ ***Tonotopic*** **= areas represent different sound frequencies**

Inner Ear and Equilibrium

Vestibular Apparatus



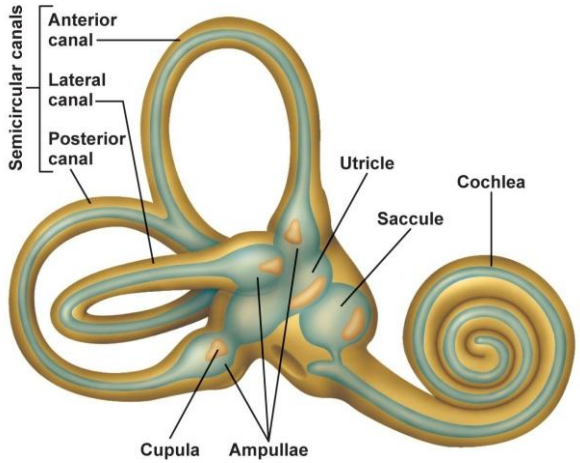
Consists of:

--***Otolith organs***

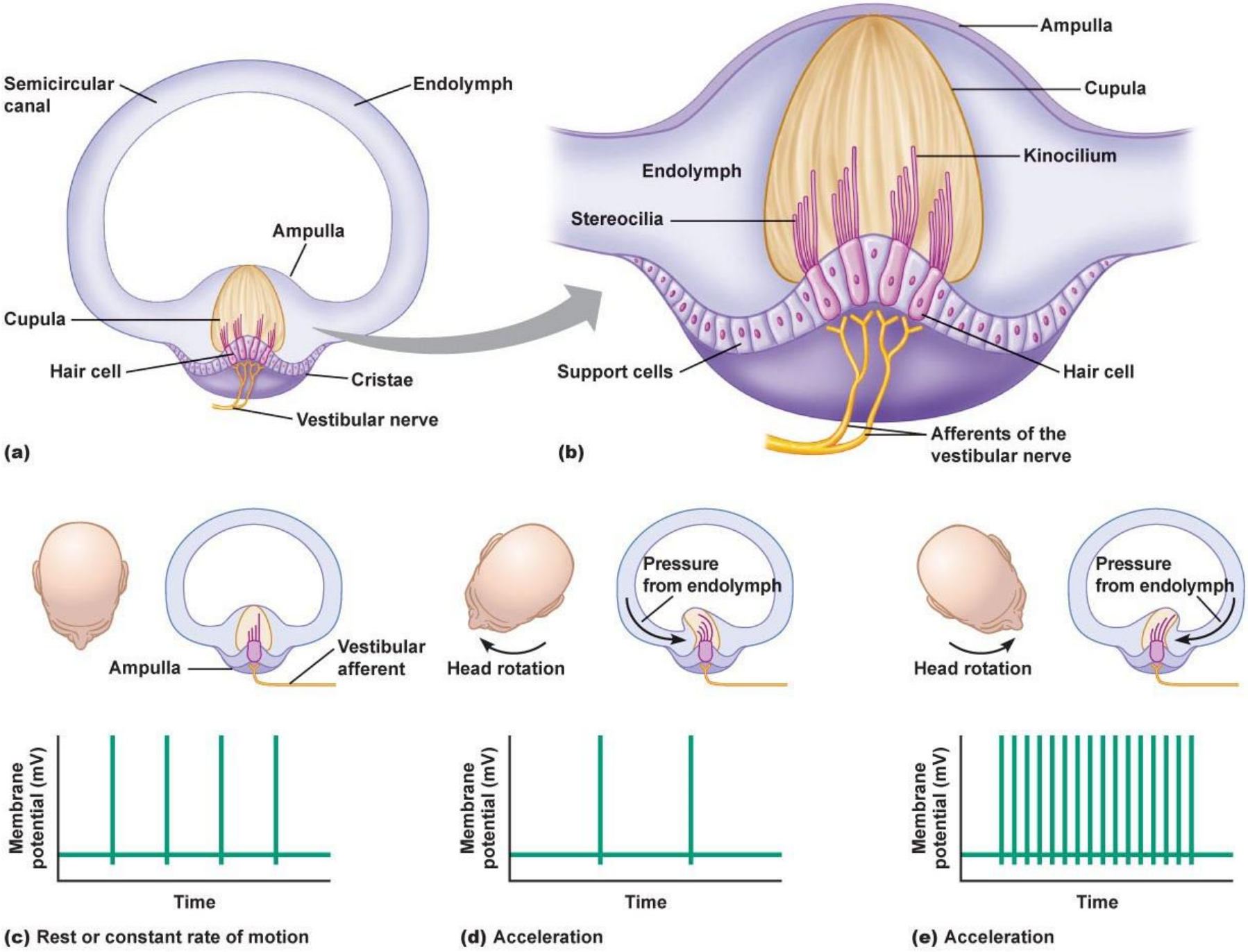
Utricle and saccule

--***Semicircular canal***

Semicircular Canals
Transduction of Rotation



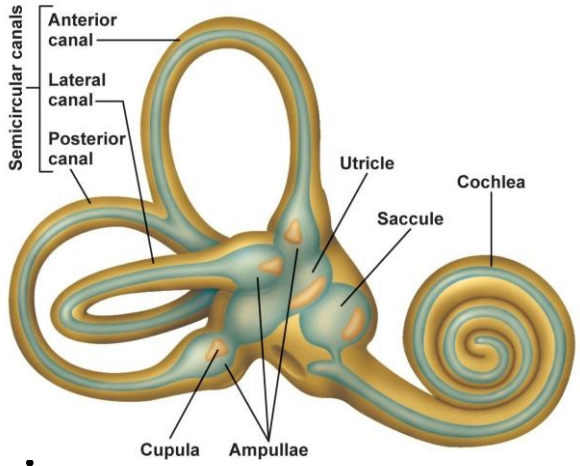
- **Three semicircular canals oriented perpendicular to each other**
  - ***1. Anterior canal***
    - --Detect movement of **head up or down**
  - ***2. Posterior canal***
    - --Detect movement of **head up and down to the side**
  - ***3. Lateral canal***
    - --Detect movement of **head from side to side**
- **Receptor cells = hair cells**
  - --Located in **ampulla**



➢ ***Rotation*** ***makes the endolymph circulate, pushing the cupula and bending the hair cells***

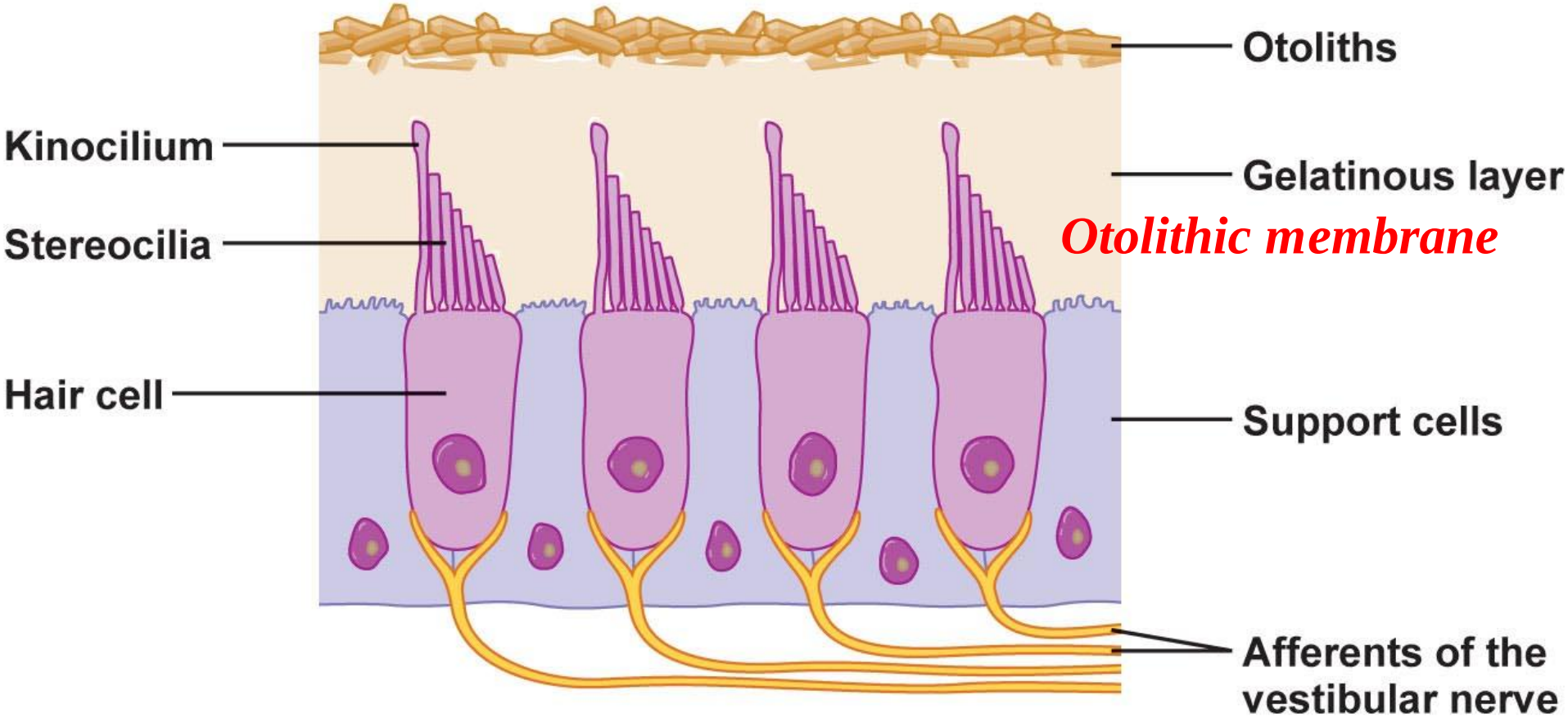
Utricle and Saccule

Transduction of Linear Acceleration



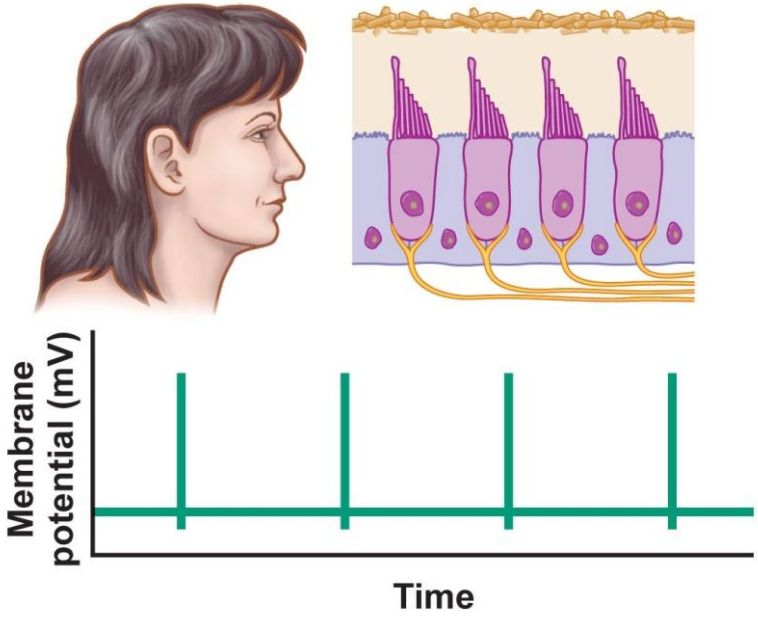
- **Bulges between semicircular canals and cochlea**
- **Oriented to detect linear acceleration**
  - --***Utricle***—detects forward and backward motion (**horizontal**)
  - --***Saccule***—detects up and down motion (**vertical**)
- **Receptor cells = hair cells**
  - Located in gelatinous material (**otolithic membrane**) covered by otoliths

Anatomy of Utricle and Saccule

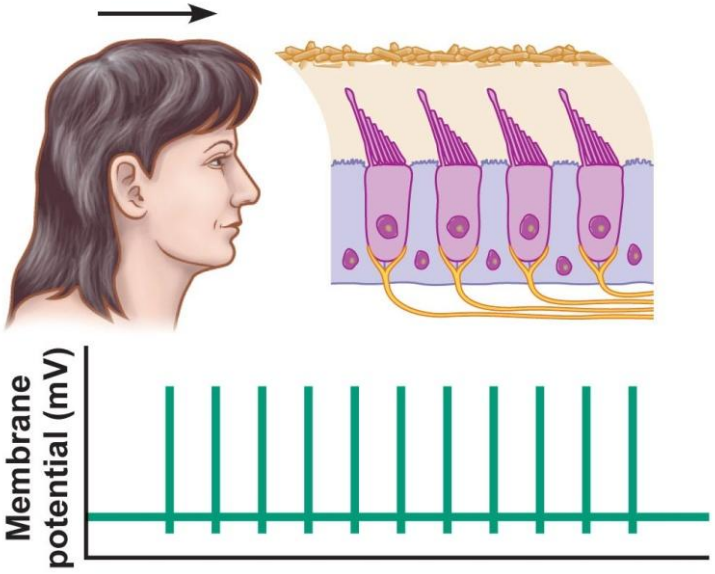


- Specialized epithelium called the **macula** houses <u>hair cells</u>

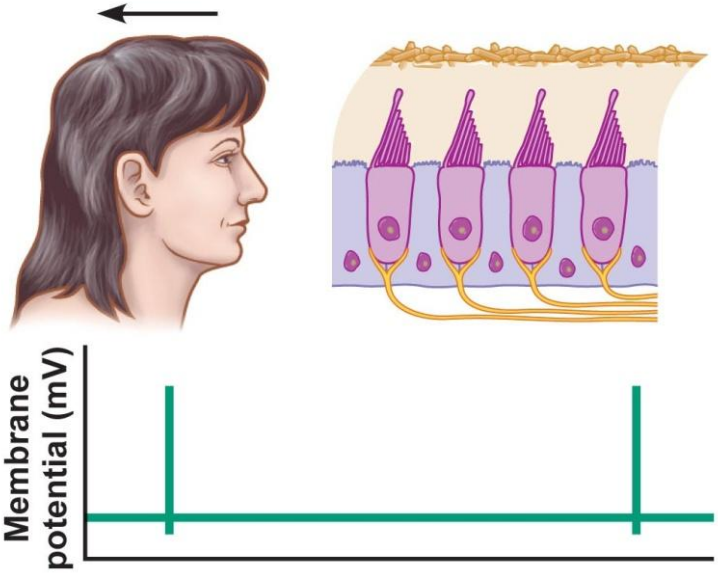
Coding for Linear Acceleration



(b) Rest or constant motion



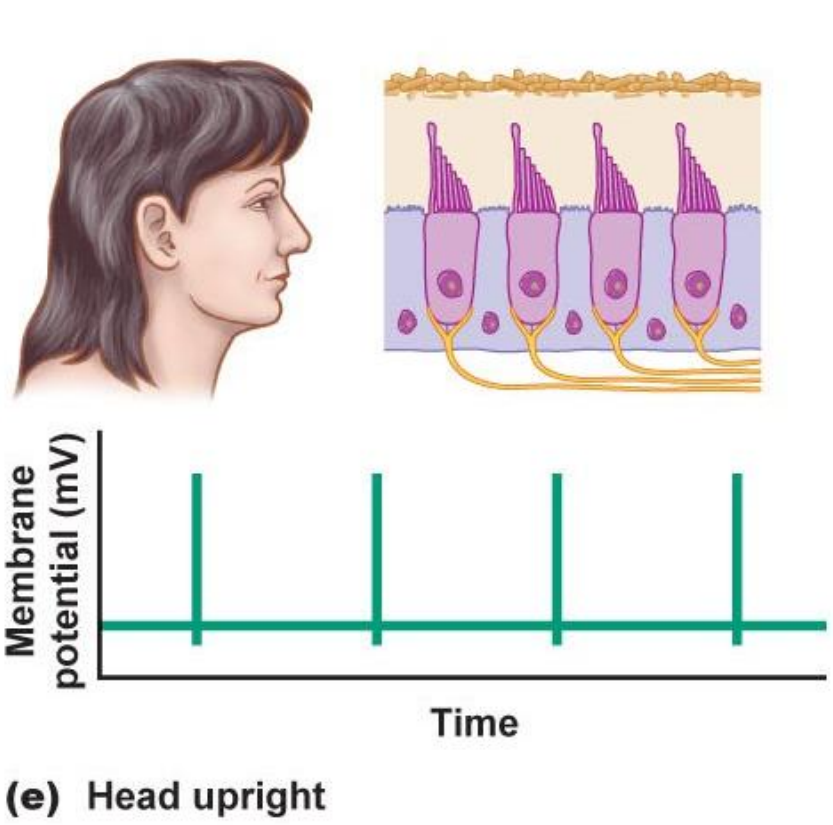
(c) Forward acceleration



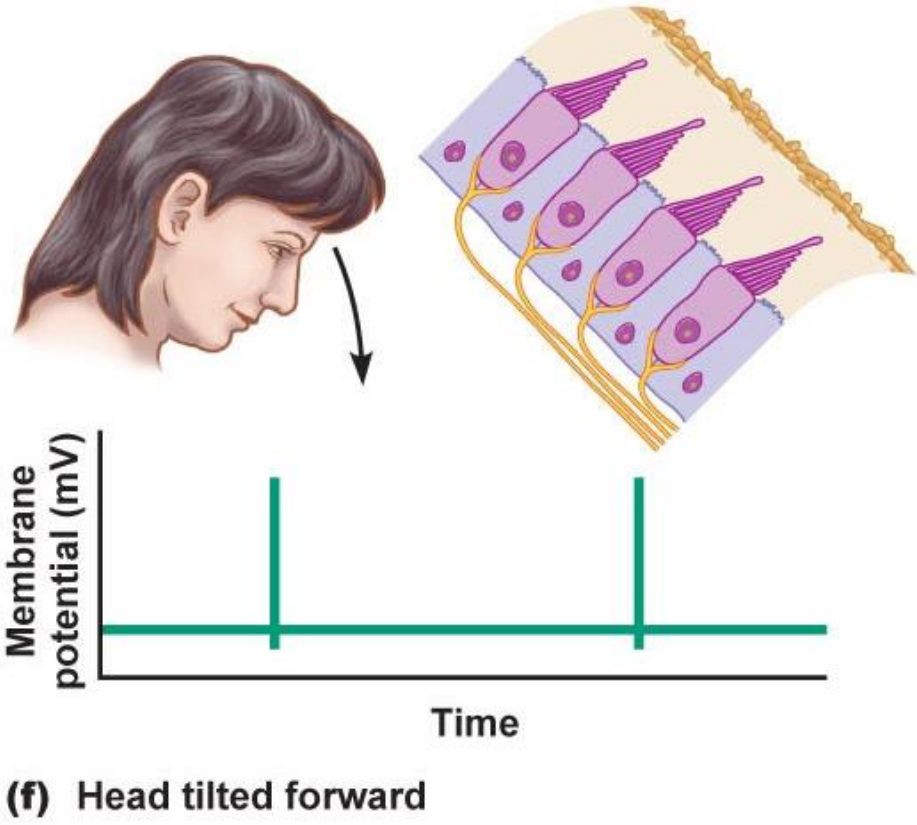
(d) Backward acceleration

Horizontal Acceleration

Coding for Head Tilting

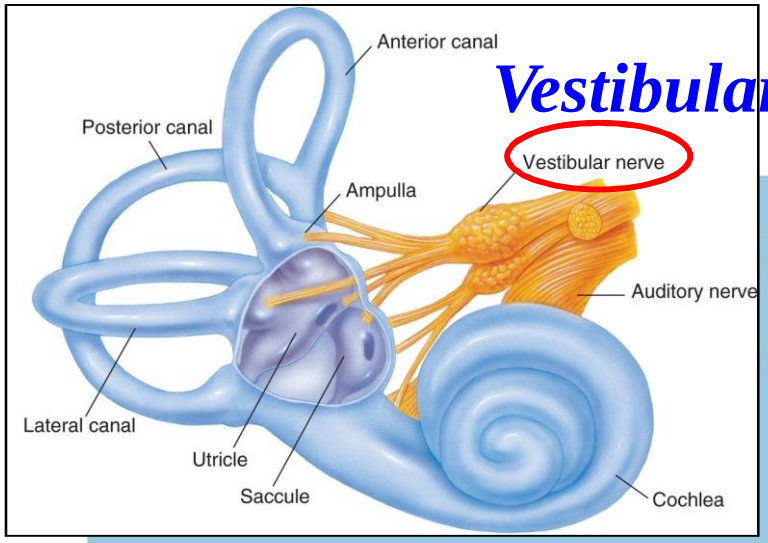


(e) Head upright



(f) Head tilted forward

Neural Pathways for Equilibrium



Vestibular nerve

Vestibular afferents

Vestibular nuclei (brainstem)

Sensory systems

Cerebellum

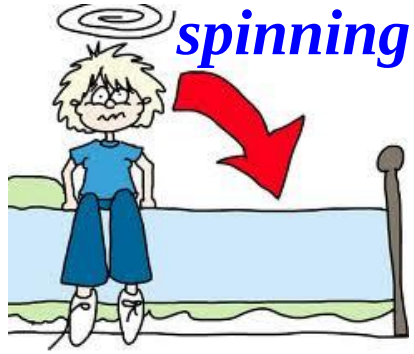
Cortex

Eye movements

Balance and equilibrium

Perception

Clinical Application: Vertigo



- A sensation of spinning while stationary ***(dysfunction of the vestibular apparatus in the inner ear)***
- It is commonly associated with vomiting or nausea, unsteadiness, and excessive perspiration
- **Three types of vertigo:**
  1. **Objective–** the patient has the sensation that objects in the environment are moving
  2. **Subjective–** patient feels as if he or she is moving
  3. **Pseudovertigo–** intensive sensation of rotation inside the patient's head
- **Benign paroxysmal positional vertigo (BPPV:** the most common cause; mechanical malfunction of the inner ear**), Vestibular migraine, Ménière's disease, Vestibular neuritis (**viral infection of the inner ear**), Motion sickness** and **Alcoholic beverages**

構造（structure）	位置（location）	功能（function）
外耳（External ear）		**收集和傳遞聲波至中耳**
耳殼（pinna; ear）	位於頭部兩側由皮膚覆蓋的軟骨構造	收集聲波並將其導引至耳道中，同時負責定位聲音來源方向
外耳道（external auditory meatus; earcanal）	由外部經過顳骨到達鼓膜的通道	導引聲波至鼓膜，覆有過濾作用的細毛，並會分泌耳蠟以黏附外來的微粒
鼓膜（tympanic membrane; eardrum）	將外耳及中耳分開之薄膜構造	受聲波撞擊後產生同步震動，使中耳的骨質結構隨之振動
中耳（Middle ear）		**將鼓膜的震動傳遞至耳蝸中的液體並在此過程中加強聲波能量**
鎚骨（Malleus）、砧骨（incus）、鐙骨（stapes）	一連串可移動的骨頭，延伸至中耳空腔，鎚骨連接至鼓膜，而鐙骨連接至卵圓窗	與鼓膜同步震動，並啟動耳蝸的外淋巴液以相同頻率產生波狀移動
內耳：耳蝸（inner ear；cochlea）		**內含形成聽覺所需的感覺系統**
卵圓窗（oval window）	位於耳蝸入口處的薄膜，將中耳及前庭階分開	與相連的鐙骨形成同步震動，卵圓窗的震動會啟動耳蝸中的外淋巴液移動
前庭階（scala vestibular）	位於耳蝸入口處的薄膜，呈現蝸牛形狀的管路系統，且深埋於顳骨內耳蝸的較低部分	內含外淋巴液，會因中耳骨震動引起的卵圓窗移動影響，而造成外淋巴液的移動
鼓階（scala vestibular）		
耳蝸管（Cochlear duct, scala media）	位於耳蝸的上部部分與下部部分中間，通過耳蝸中心的末梢封閉管路系統	包含有基底膜（Basilar membrane）以及柯蒂氏器（organ of Corti）
基底膜（Basilar membrane）	構成耳蝸管的底部表面	隨著外淋巴液的移動產生同步震動，連帶與柯蒂氏器（organ of Corti）形成聽覺器官
柯蒂氏器（organ of Corti）	遍布於基底膜全範圍表面上	帶有毛髮細胞，為聲音的受器，當耳蝸內的淋巴液體流動，將使毛髮細胞彎曲並且產生受器電位
耳蝸覆膜（Tectorial membrane）	為固定不動的膜狀組織，懸掛於柯蒂氏器上，而受器的毛髮細胞的纖毛包埋於膜狀組織中	當震動而位移的基底膜相對於固定的耳蝸覆膜產生相對位置移動時，使包埋於耳蝸覆膜的毛髮細胞的纖毛彎曲，並且產生受器電位
圓窗（Round window）	將中耳與耳蝸的上部部分與下部部分隔開的薄膜	與外淋巴液體流動產生同步位移，分散耳蝸內的壓力，而不會造成聲音知覺
內耳：前庭器（Inner Ear: Vestibular Apparatus）		**包含負責平衡以及提供有關維持身體姿勢、平衡所需資訊的感覺系統**
半規管（Semicircular canals）	三個半規管在空間上排列成三個彼此垂直的平面，位於耳蝸附近	偵測旋轉動作或是角加速度或是減速
橢圓囊（Utricle）	位於耳蝸及半規管之間的骨質空腔中的囊狀構造	可偵測頭部 (1) 垂直方向狀態之改變；(2) 水平方向的加速及減速
小囊（Saccule）	位於橢圓囊旁	偵測頭部 (1) 水平方向狀態之改變；(2) 垂直方向的加速及減速

Taste (Gustation)

●**舌乳頭(papillae)**：舌頭表面凸起構造

Taste depends on chemicals in food binding to chemoreceptors

1. 葉狀乳頭(foliate papillae)：

具有味蕾，多分佈於舌頭**後兩側**部位(via **CN IX**) 。

2. 絲狀乳頭(filiform papillae)：

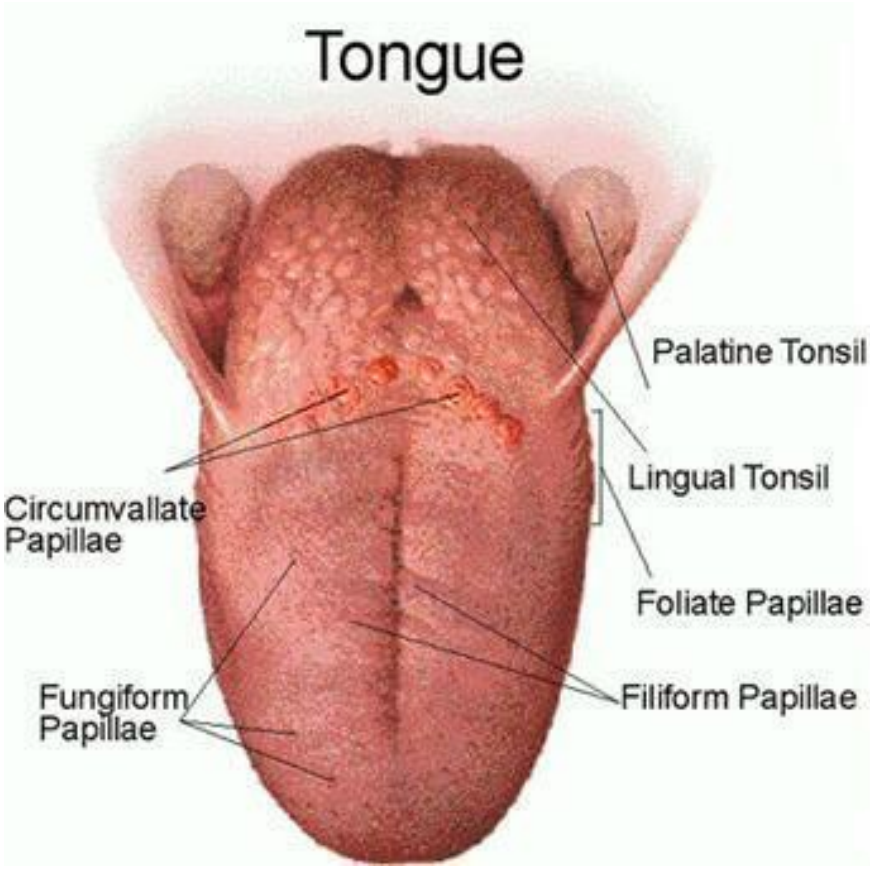
數目最多，**不含味蕾**，多分佈於舌頭前2/3的部位。

3. 蕈狀乳頭(fungiform papillae)：

具有味蕾，多分佈於**舌頭前2/3**部位(via **CN VII**)。

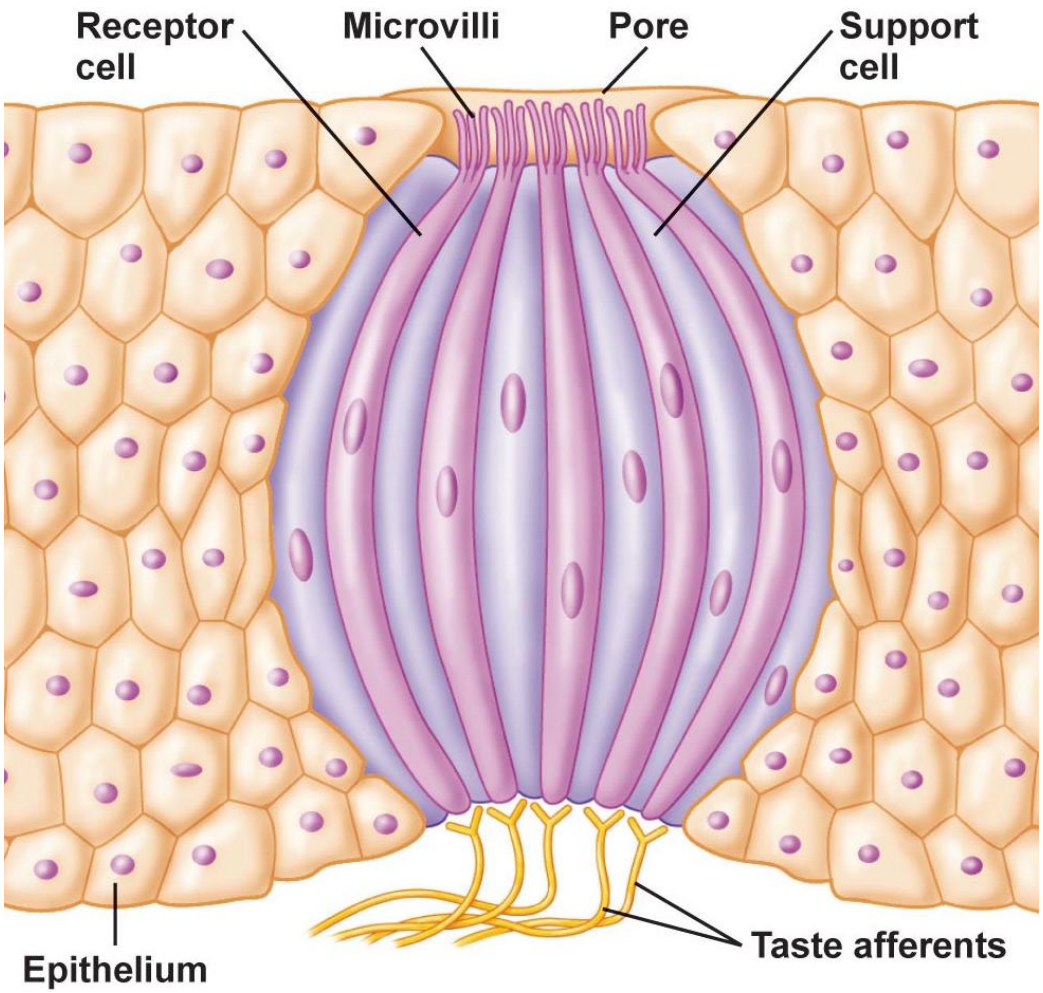
4. 輪狀乳頭(circumvallate papillae)：

為最大的一種，呈圓形，約8~12個，於**舌根部呈V字型**分佈，有味蕾於其側溝中(via **CN IX**) 。

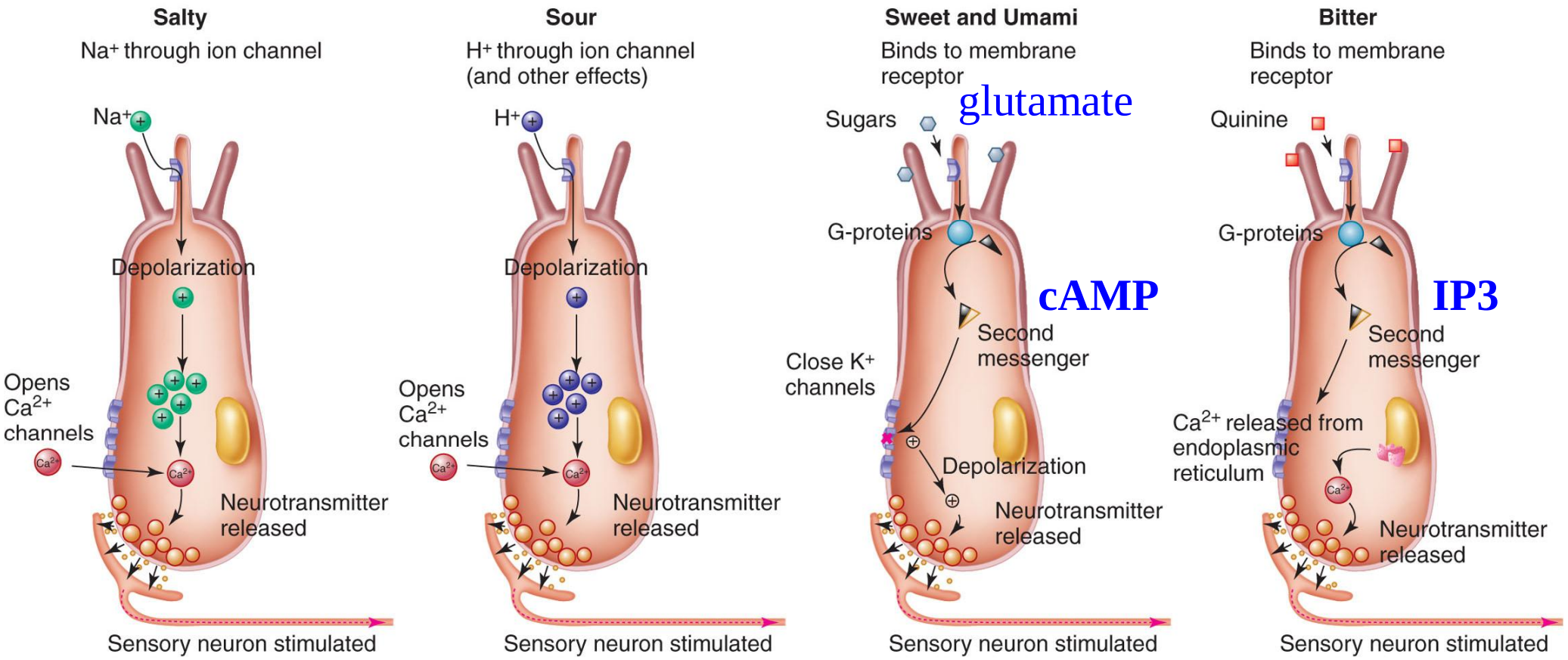


Taste Buds

- **Over 10,000 taste buds**
  - --***Tongue*** (CN VII and IX)
  - --***Pharynx*** (CN X)
- Pore exposed to ***saliva*** in mouth
- **50–150 taste receptors cells per bud + support cells**
  - --Modified epithelial cells
  - --Microvilli respond to tastants (chemicals)

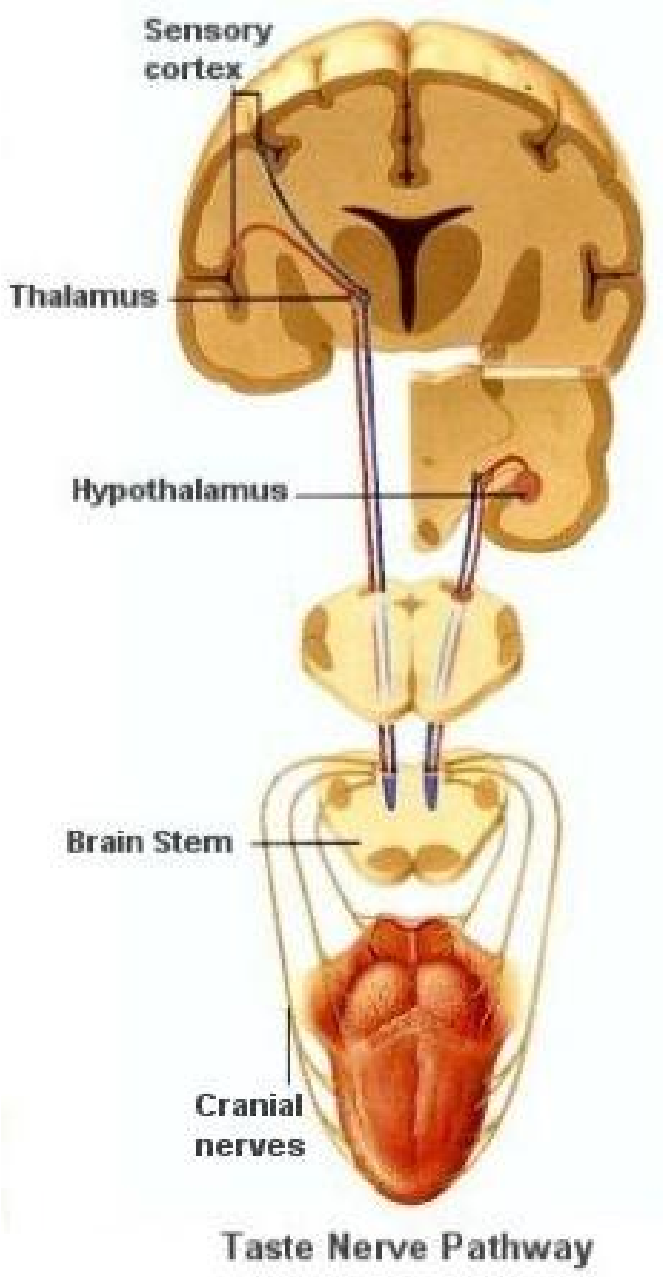


Signal Transduction in Five Primary Tastes



Neural Pathway for Taste

- Sensory neurons = CN **VII, IX**, and **X**
- Terminate in brainstem gustatory nucleus
- Second-order neurons to thalamus
- Third-order neurons to gustatory cortex (area 43) in parietal lobe near mouth region of somatosensory cortex



Smell (Olfaction)

Olfaction depends on chemicals in air which bind to chemoreceptors in olfactory epithelium

- Located in **nasal cavity**
- Three cell types

  1. Supporting cells

  --Secrete **mucus**

  --Oxidize hydrophobic volatile odors

  2. Basal stem cells

  --**Precursor cells** for new receptor cells

  2. Receptor cells

  --**Neurons** that respond to odorants

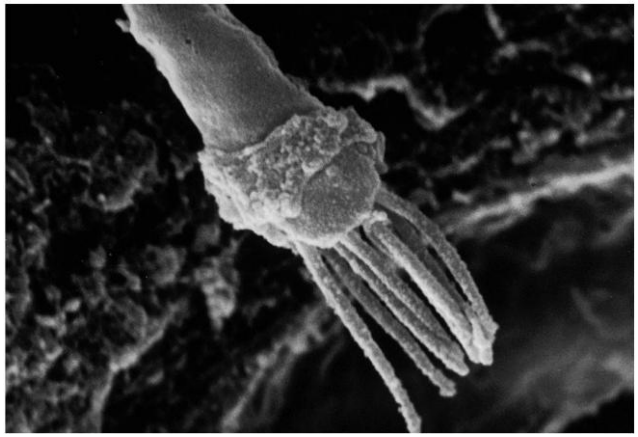
- Olfactory receptor cells are **bipolar neurons** which are replaced continuously
- **Cilia** project into mucus

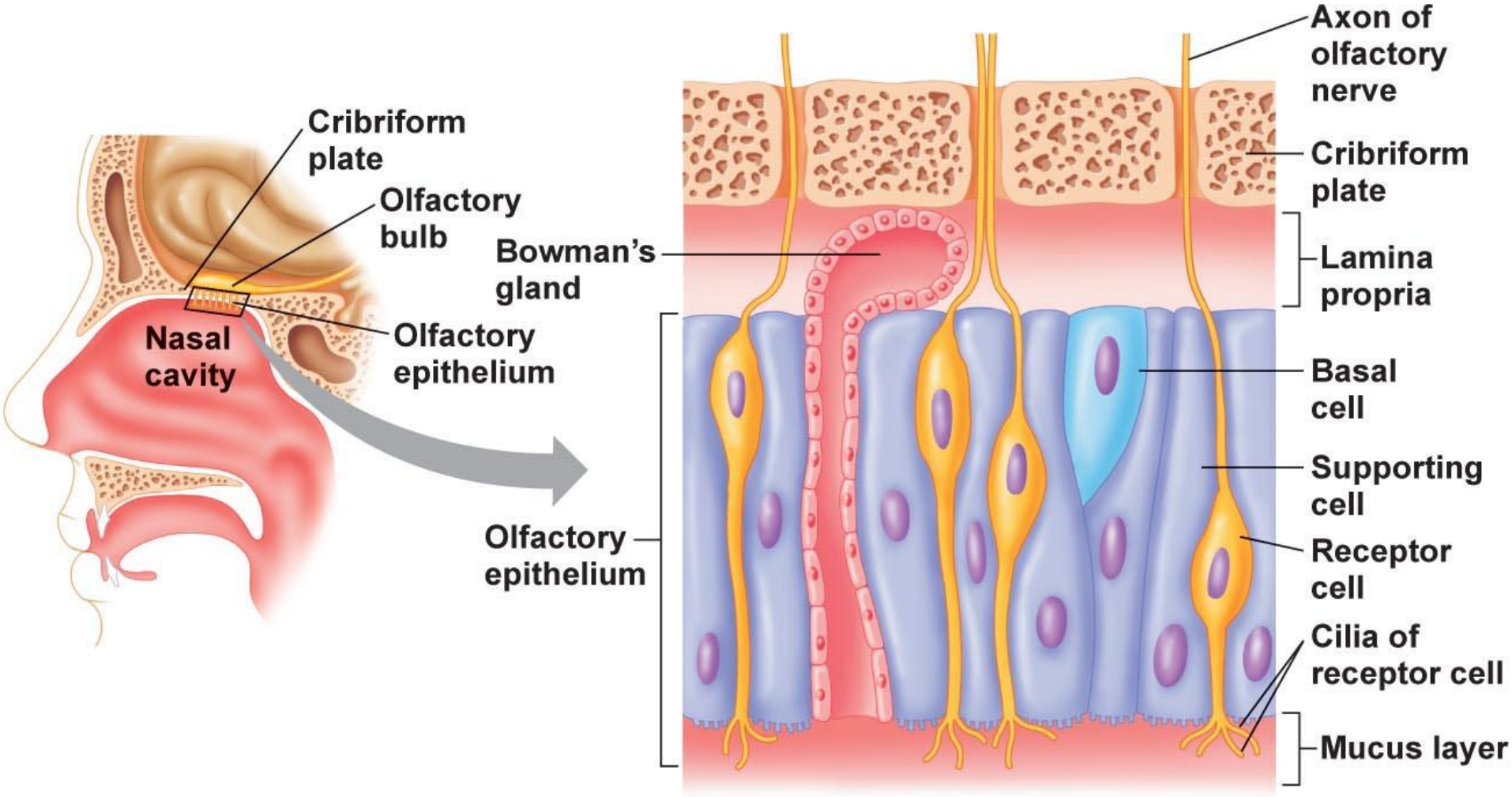
  --Have **chemoreceptors**
- Olfactory binding proteins

  --Located in mucus

  --Transport odorants to receptors

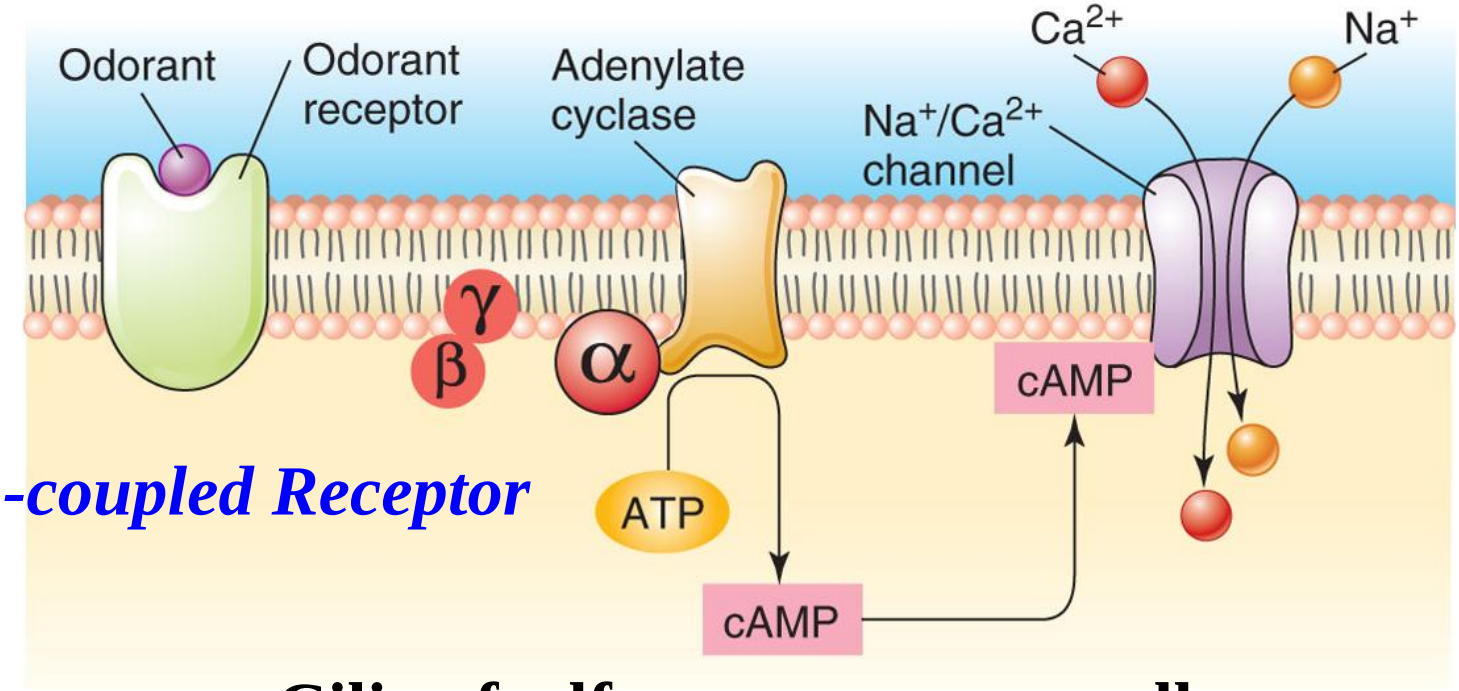
Olfactory Epithelium: Receptor Cells





Signal Transduction in Smell

- **Air-borne chemical must dissolve in mucus**
- **Chemical (odorant) binds to specific receptor**
  - ***--Activates G protein called G_{olf}***
  - ***--Activates adenylate cyclase → cAMP***
  - ***--cAMP directly binds cation channels, opening them***
  - ***--Na^+ and Ca^{2+} enter cell → depolarization***



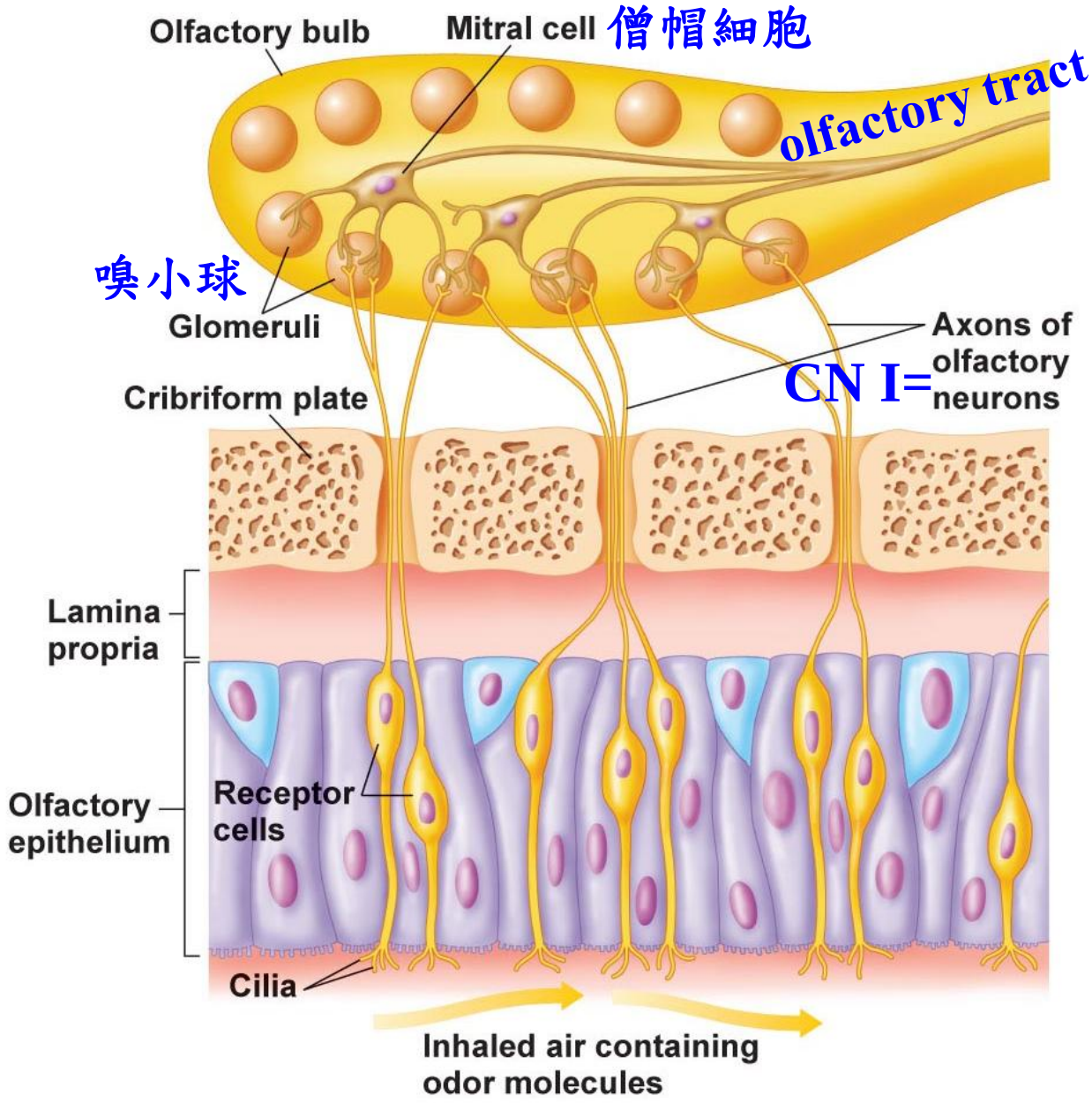
G protein-coupled Receptor

Cilia of olfactory receptor cell

Neural Pathway for Olfaction

- Olfactory neurons are **unmyelinated (CN I)** and synapse on a **glomerulus** in the olfactory bulb
  --Each type of olfactory receptor synapses on a particular glomerulus

- Neurons from the olfactory bulb synapse on the prefrontal cortex, **medial temporal lobes**, hippocampus, and amygdala



自己

你明明很喜歡一個人，卻沒有表白的勇氣。

你明明很希望告訴某個討厭的傢伙再也別來煩你，
卻從來不敢如此痛快淋漓。

你明明很不願意買下那件店員拚命推薦的襯衫，
卻又擔心他會以怨恨的眼光看你。

於是你心裡想的和實際去做的往往風馬牛不相及，就像你
明明愛吃漢堡，卻老是莫名其妙地點了薯條。
因為你總是擔心別人的反應。

別人的反應都只是你的虛擬而已。
你真正在應付的不是別人，是你那顆混亂不安的心。

一如站在一面鏡子前，不管是正對或背對，
呈現的只是個人的鏡象。

你面對或逃避的，終究只是自己