Introduction:

Chapter 6

Part I

Visceral afferents carry subconscious input whereas, sensory afferents carry conscious input:

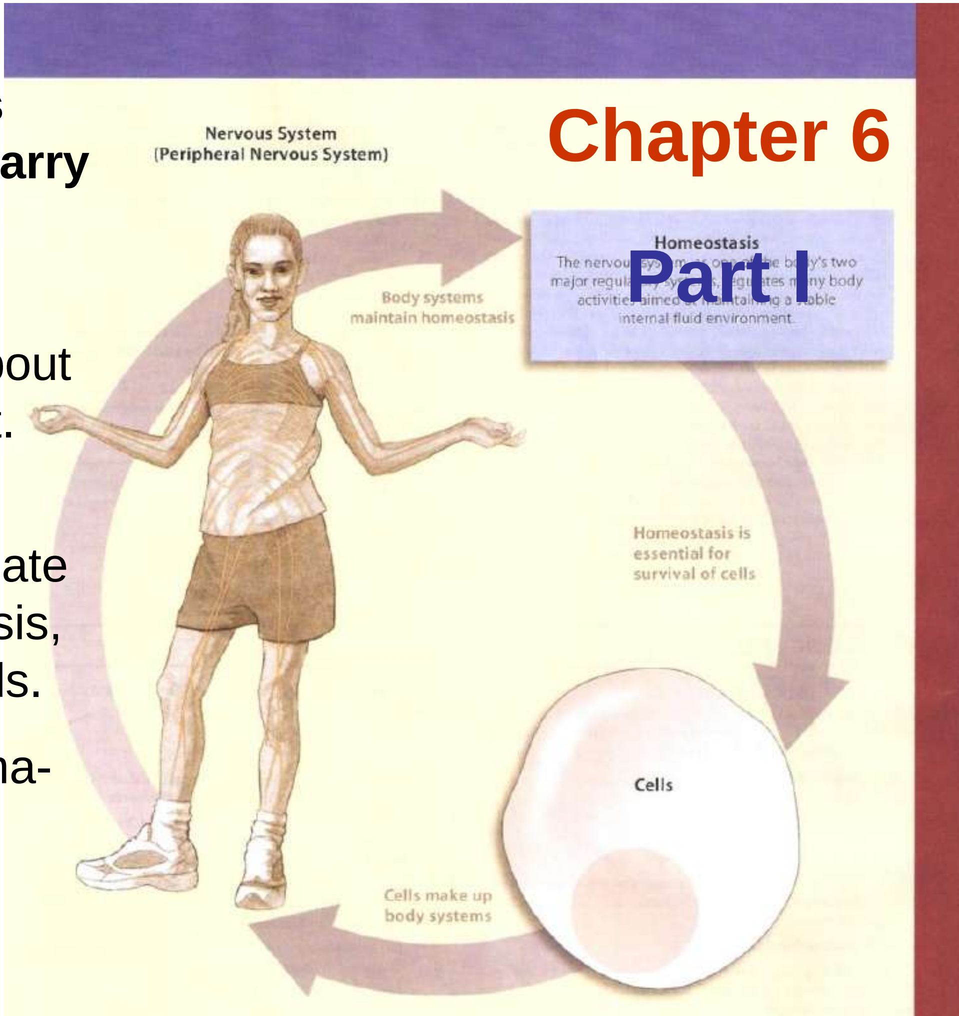
- The afferent division of the peripheral nervous system sends information about the internal and external environment.
- The internal afferent information is essential for determining the appropriate afferent output to maintain homeostasis, e.g. BP and Co_2 concentration in fluids.
- Sensory afferent carry sensory information and reach the level of conscious awareness, it is categorized to :

1. **Somatic sensation** (body sense):

   (a) Somesthetic sensation from the skin.

   (b) Proprioception from muscles, joints, skin and inner ear.

2. **Special senses**



The nervous system, one of the two major regulatory systems of the body, consists of the central nervous system (CNS), composed of the brain and spinal cord, and the **peripheral nervous system (PNS),** composed of the afferent and efferent fibers that relay signals between the CNS and periphery (other parts of the body).

The **afferent division** of the peripheral nervous system detects, encodes, and transmits peripheral signals to the CNS for processing. It is the communication link by which the CNS is informed about the internal and external environment. This input to the controlling centers of the CNS is essential in maintaining homeostasis. To make appropriate adjustments, the CNS has to "know" what is going on. Afferent input is also used to plan for voluntary actions unrelated to homeostasis.

ORGANIZATION OF THE NERVOUS SYSTEM

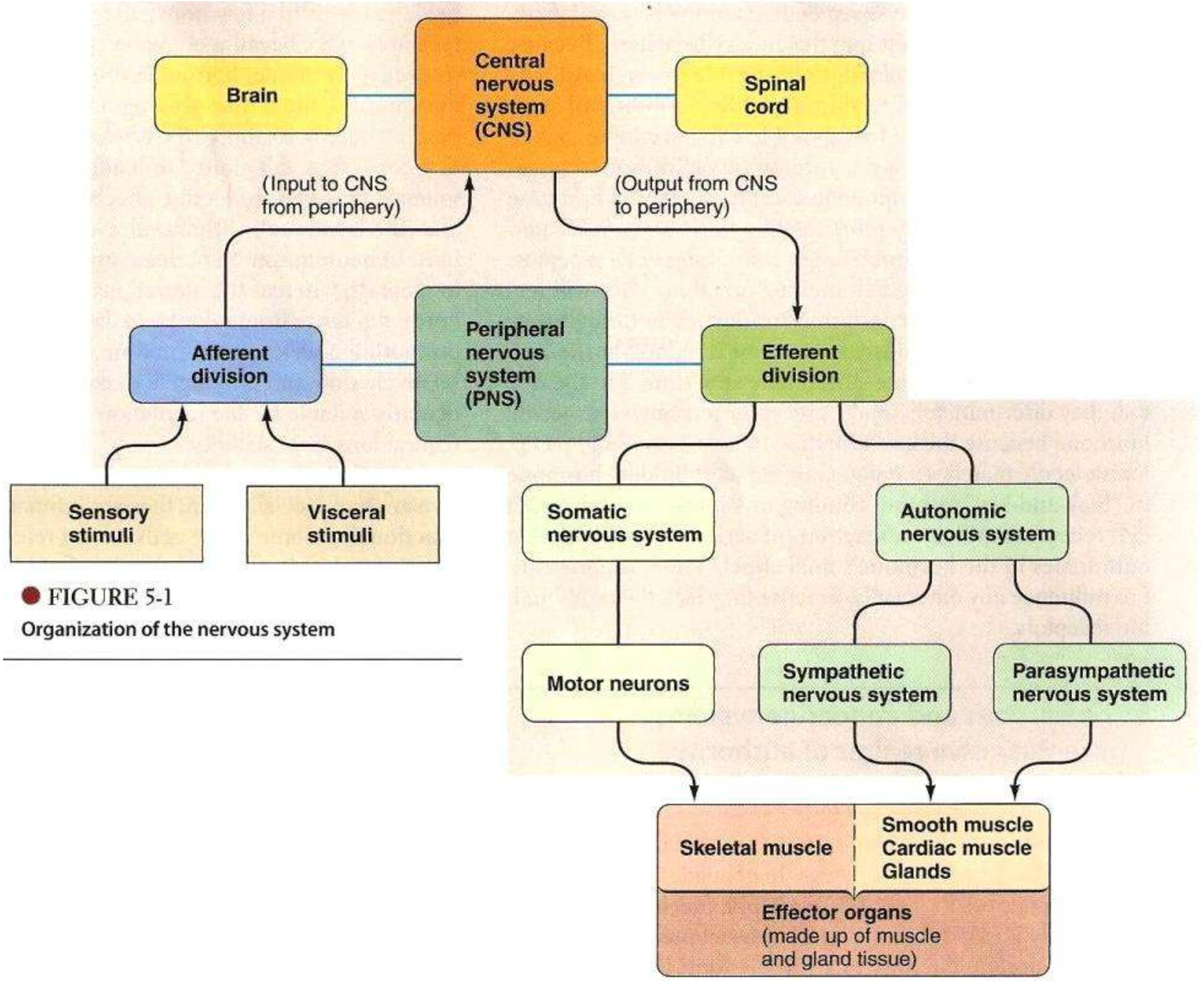


FIGURE 5-1
Organization of the nervous system

Perception is the conscious awareness of surrounding derived from interpretation of sensory input

- **Is the world as we perceive it, reality** ***??***

Samples

NO, for several reasons:

1. Human have limited ability receptors, so they can detect some energy forms e.g. sound, colors, shapes, textures, smells, tastes and temperature, **but** not informed of magnetic forces, polarized, light waves, radio waves, X-rays .. etc.
2. The afferent pathways are not high-fidelity دقة recorders; some features of stimuli are accentuated تؤكد and others are suppressed or ignored.
3. The cerebral cortex comparing the sensory input with other incoming information, e.g. sifting out تمييز a friends words.

- The cortex often fills in or distorts the information to abstract a logical perception Fig. 6-1 & 6-2

➢ Thus our perception do not replicate reality.

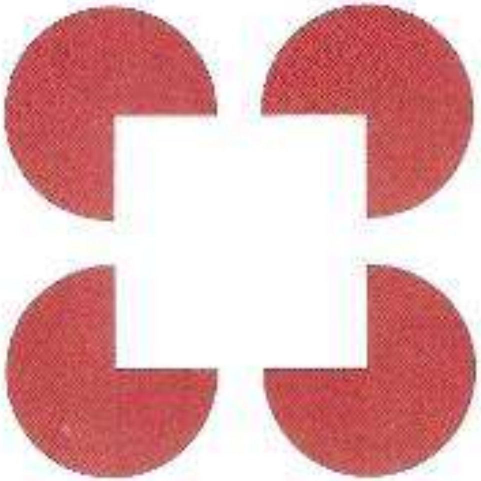


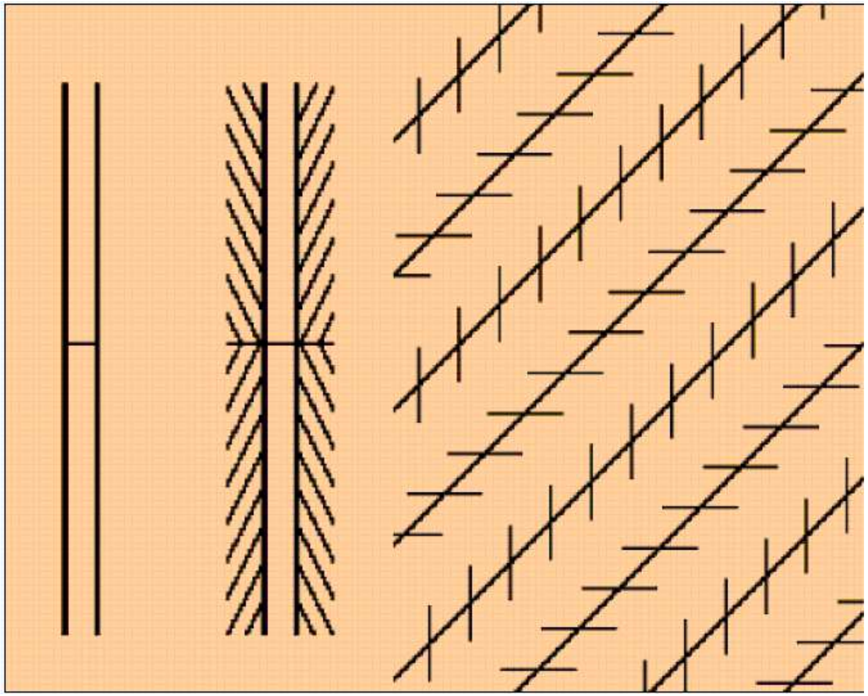
FIGURE 6-1

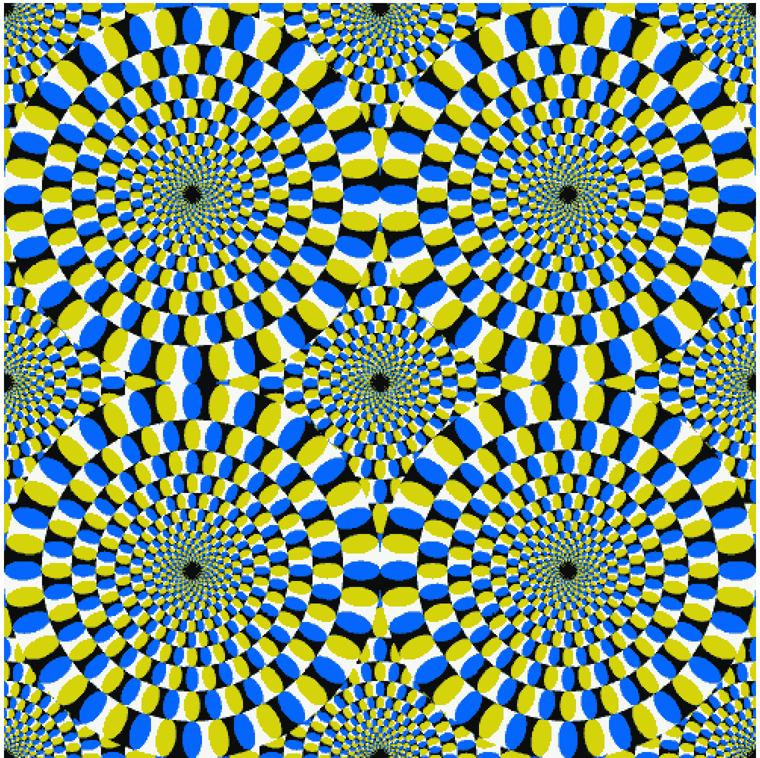
Do you "see" a white square that is not really there?

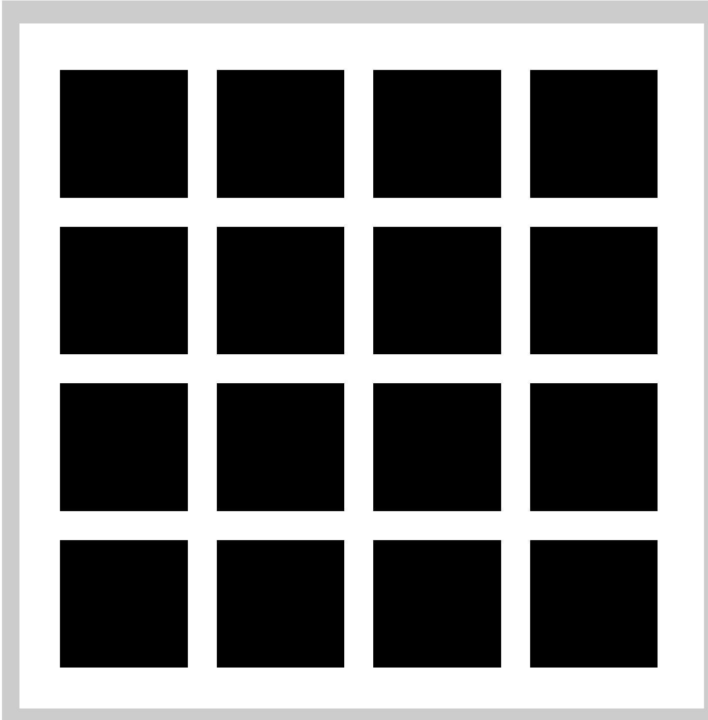
FIGURE 6-2

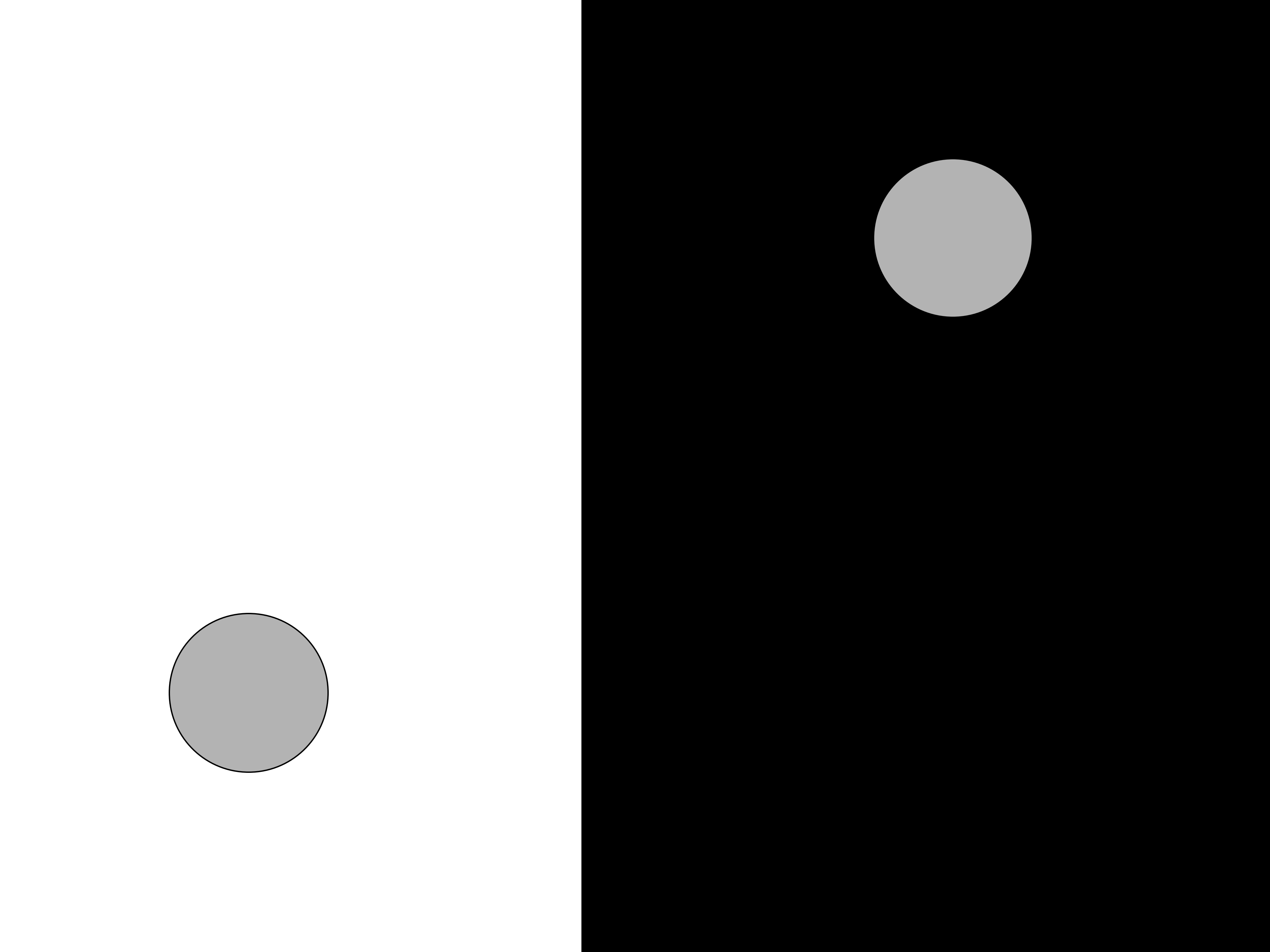
Variable perceptions from the same visual input

Do you see two faces in profile, or a wineglass?









RECEPTOR PHYSIOLOGY

- **A stimulus:**

  - Is a change detectable by the body.

  - Exist in a variety of energy forms.

  - Detected by the receptors.

- **Receptors:** convert the energy forms into electrical signals (action potentials) in a process called ***Transduction.***

Receptors have different sensitivities to various stimuli

- Each type of receptors has its adequate stimulus (with some exceptions e.g. "sees stars").

Receptor types according to their adequate stimulus:

- ***Photoreceptors.***
- ***Mechanoreceptors.***
- ***Thermoreceptors.***
- ***Osmoreceptors.***
- ***Nociceptors (pain receptors).***

- Some sensations are compound sensations, e.g. wetness comes from touch, pressure and thermal receptor input.

Uses for information detected by receptors

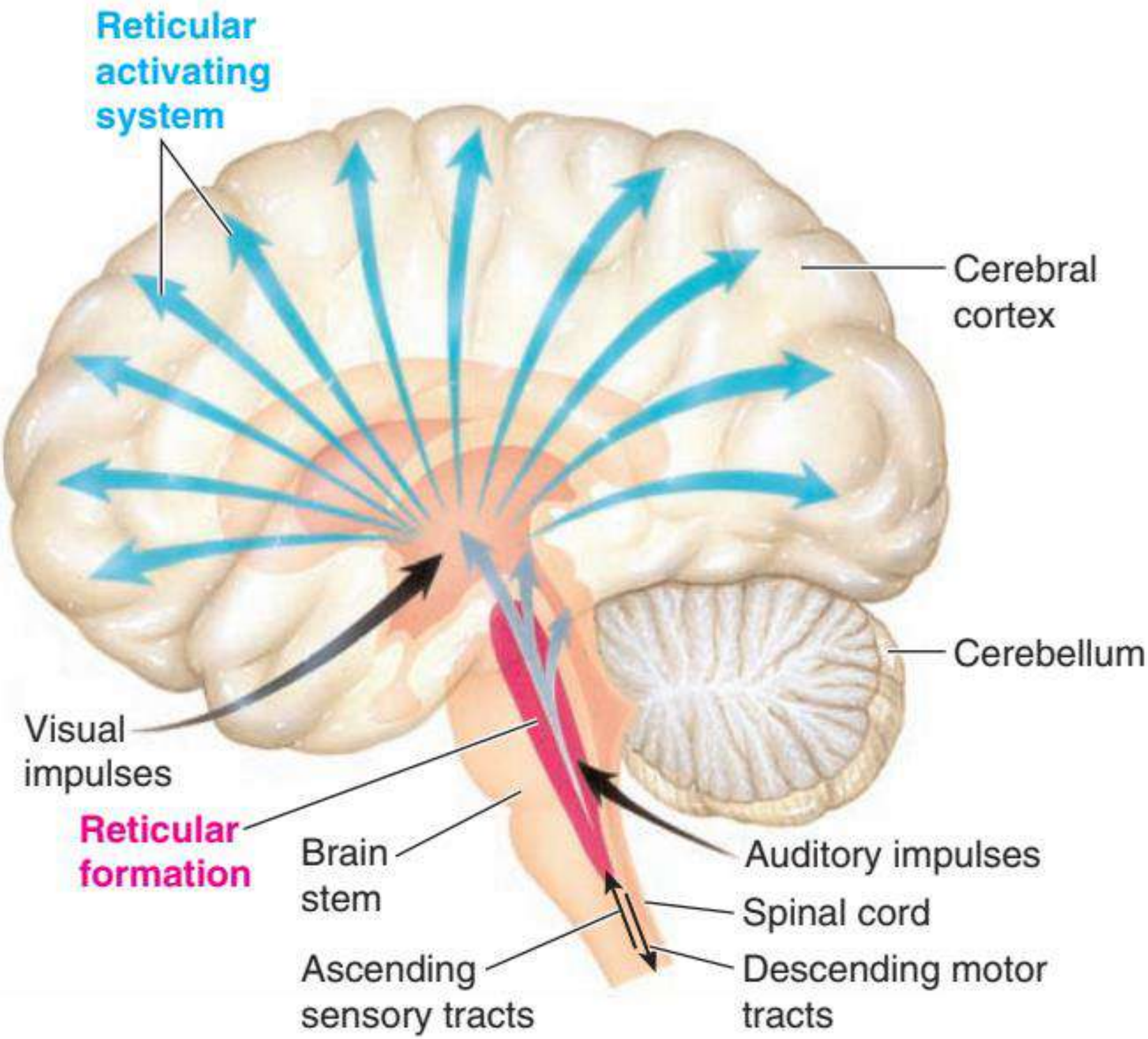
- **First,** afferent input is essential for the control of efferent output.
- **Second,** processing of sensory input by Reticular activating system (**RAS**), in the brain stem is critical for cortical arousal and consciousness.
- **Third,** central processing of sensory information gives rise to our perception of the world around us.
- **Fourth,** selected information delivered to the CNS may be stored for future reference.
- **Finally,** sensory stimuli can have a profound impact our emotions,

  e.g. - The smell of just-baked apple pie.

  - The sight of a love one.
  - The hearing bad news.

Well, gladden, sadden, arouse, calm, anger, frighten, ..etc.

- **How adequate stimuli initiate action potential** ***???***


Reticular activating system
Cerebral cortex
Cerebellum
Visual impulses
Reticular formation
Brain stem
Auditory impulses
Spinal cord
Ascending sensory tracts
Descending motor tracts

A stimulus alters receptors permeability, leading to a graded receptor potential

- A receptor may be either: (1)a specialized ending of the afferent neuron, or (2) a separate cell closely associated with the peripheral ending of the neuron.
- Stimulation of a receptor alters its membrane permeability, usually by opening a nonselective small ions channels.
- The predominant effect is an inward flux of **Na^+**, because it has the greater electrochemical driving force then others, So it depolarizes the receptor membrane except in the photoreceptors, which hyperpolarized upon stimulation.
- The local depolarizing charge in potential is known as:
  - Generator potential in a specialized ending of afferent neurons, or as
  - Receptor potential in a separate receptor cells.

Both are graded potential and have its properties (Amplitude, duration, refractory period , summation).

Receptor potentials may initiate action potentials in the afferent neuron

- If of sufficient magnitude, a receptor (or generator) potential initiates an action potential in the afferent neuron membrane adjacent to the receptor by triggering the opening of Na^+ channels in this regions

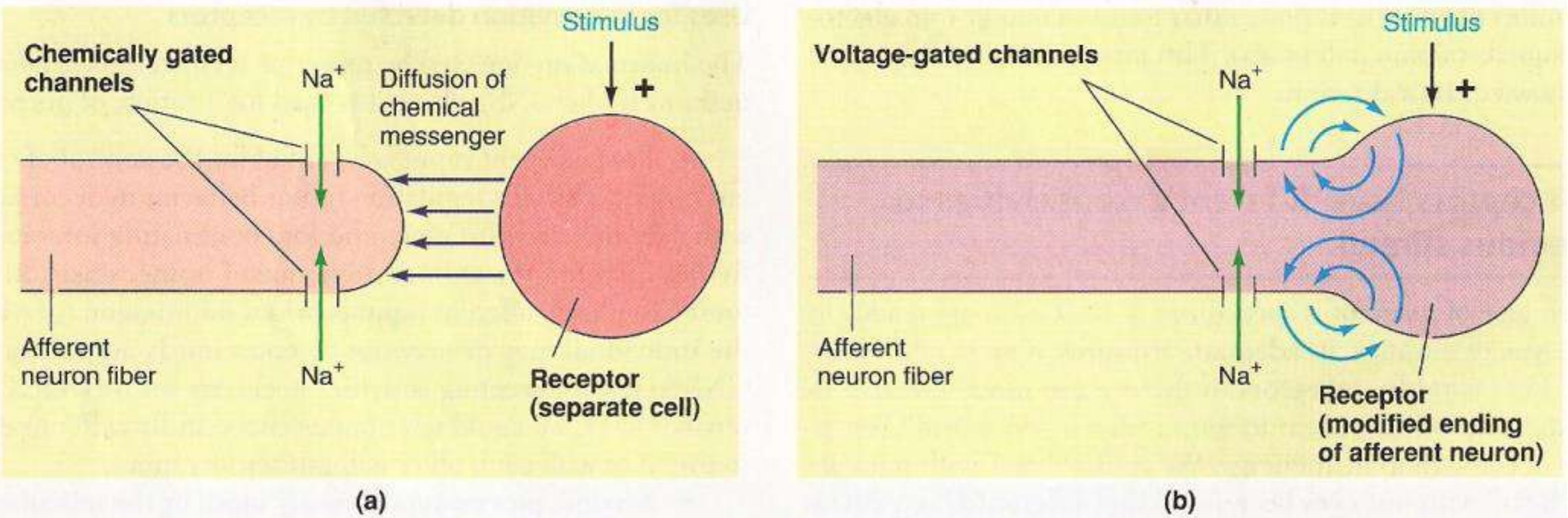


FIGURE 6-3

Conversion of receptor and generator potentials into action potentials

(a) Receptor potential. The chemical messenger released from a separate receptor initiates an action potential in the fiber by opening chemically gated Na^+ channels. (b) Generator potential. The local current flow between the depolarized receptor ending and the afferent fiber initiates an action potential in the fiber by opening voltage-gated Na^+ channels.

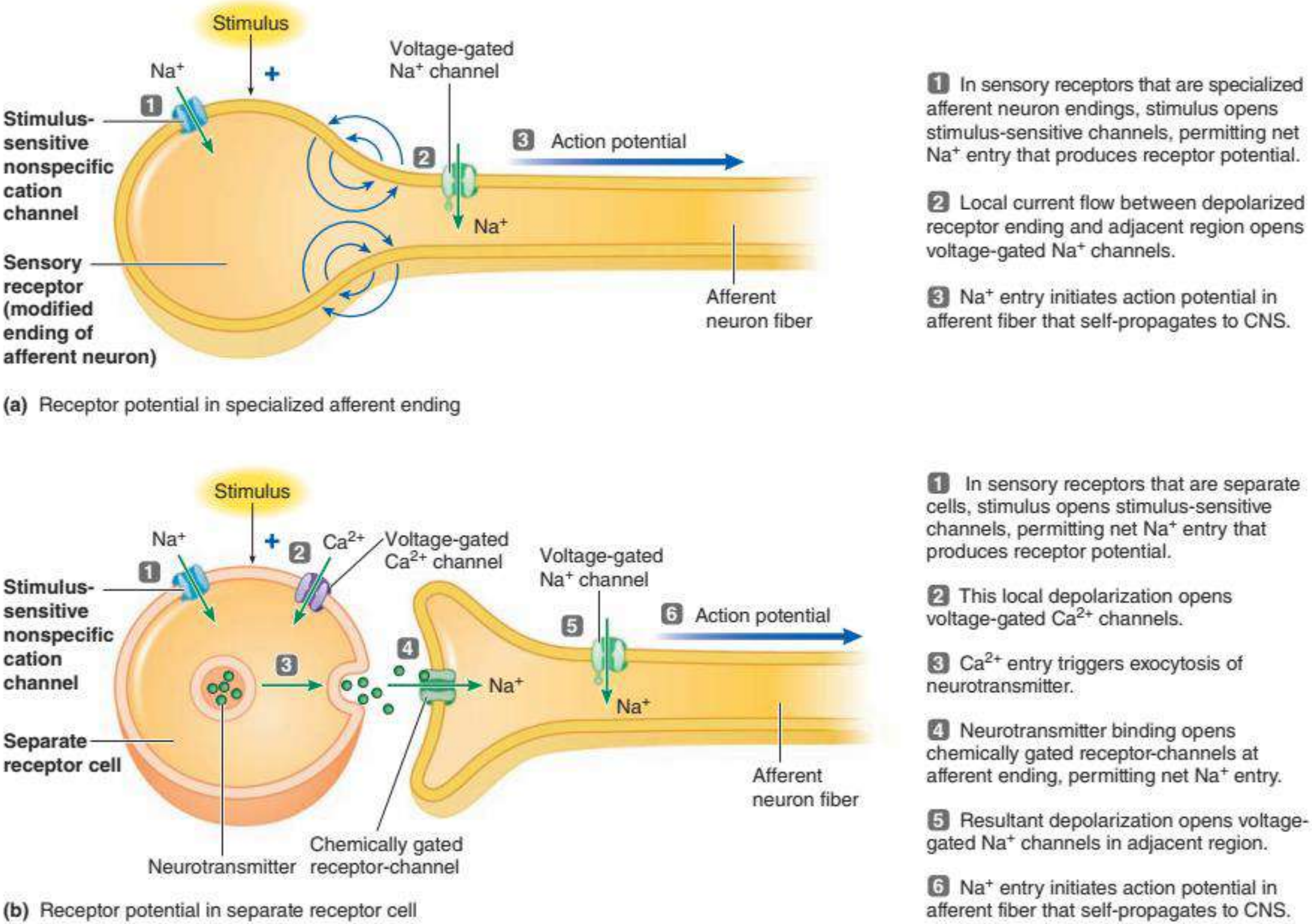


Figure 6-1 Conversion of receptor potential into action potentials. (a) Specialized afferent ending as sensory receptor. Local current flow between a depolarized receptor ending undergoing a receptor potential and the adjacent region initiates an action potential in the afferent fiber by opening voltage-gated Na^+ channels. (b) Separate receptor cell as sensory receptor. The depolarized receptor cell undergoing a receptor potential releases a neurotransmitter that binds with chemically gated channels in the afferent fiber ending. This binding leads to a depolarization that opens voltage-gated Na^+ channels, initiating an action potential in the afferent fiber.

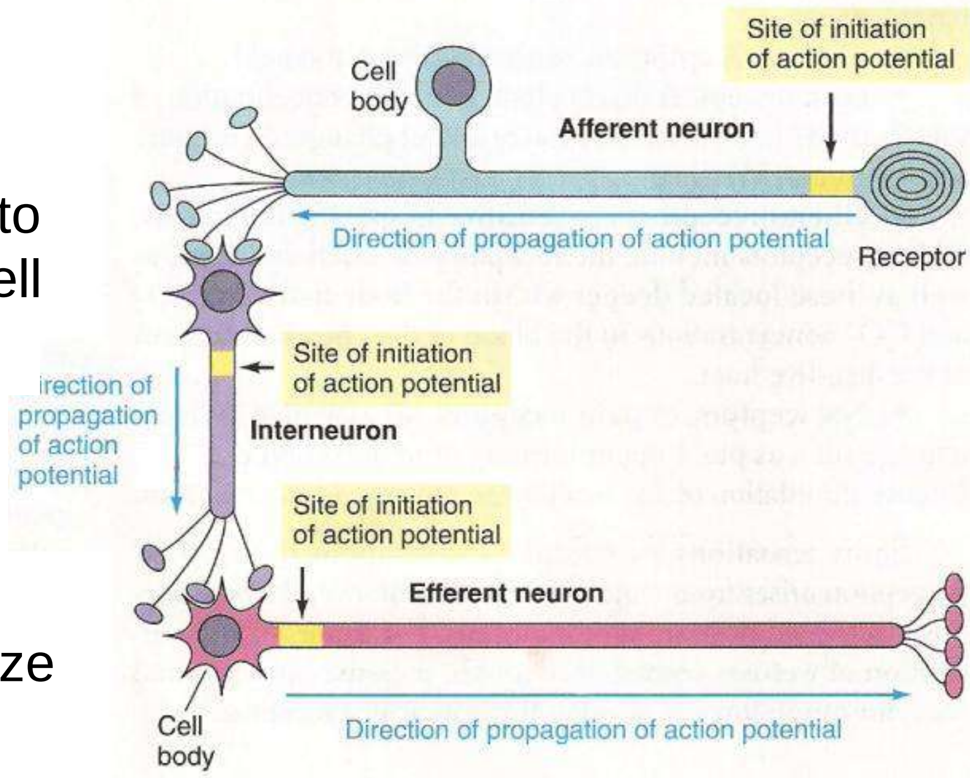
➤In either case, if the magnitude is sufficient to bring the adjacent membrane to threshold, **But where?**

* Action potentials are initiated at the axon hillock located at the beginning of the axon adjacent to the cell body in an <u>efferent neurons and interneurons</u>,

* While in the <u>afferent neurons</u> action potentials are initiated at the peripheral end of an afferent nerve fiber adjacent to the receptor, along distance from the cell body.

•We know, the larger the receptor potential, the greater the frequency of action potentials generated.

•Stimulus strength is reflected by the size of the area stimulated.



● FIGURE 6-4
Comparison of the site of initiation of an action potential in the three types of neurons

Receptor may adapt slowly or rapidly to sustained stimulation

- **Adaptation : a** reduction in receptor potential despite sustained stimulation of the same magnitude.

  The ability to diminish the extent of their depolarization despite sustained stimulus strength.

➢ **Types of receptors according to their speed of adaptation:**

1. Tonic receptors, e.g. tonic receptors in the skeletal system.
2. Phasic receptors, e.g. tactile receptors.

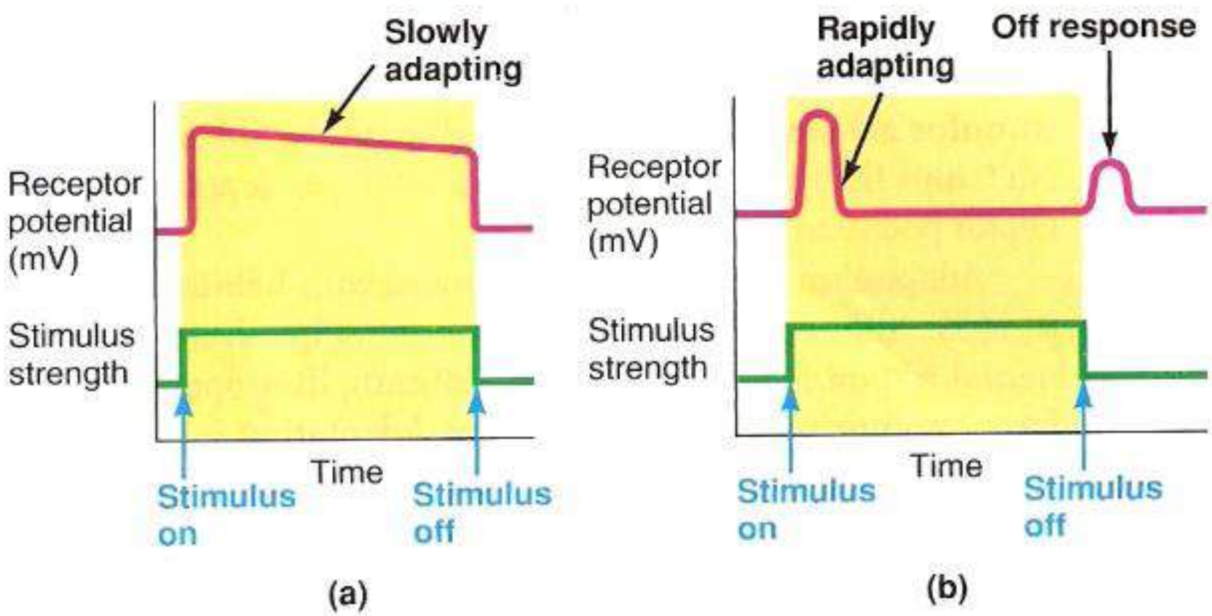


FIGURE 6-5

Tonic and phasic receptors

Mechanisms of adaptation in the pacinian corpuscle

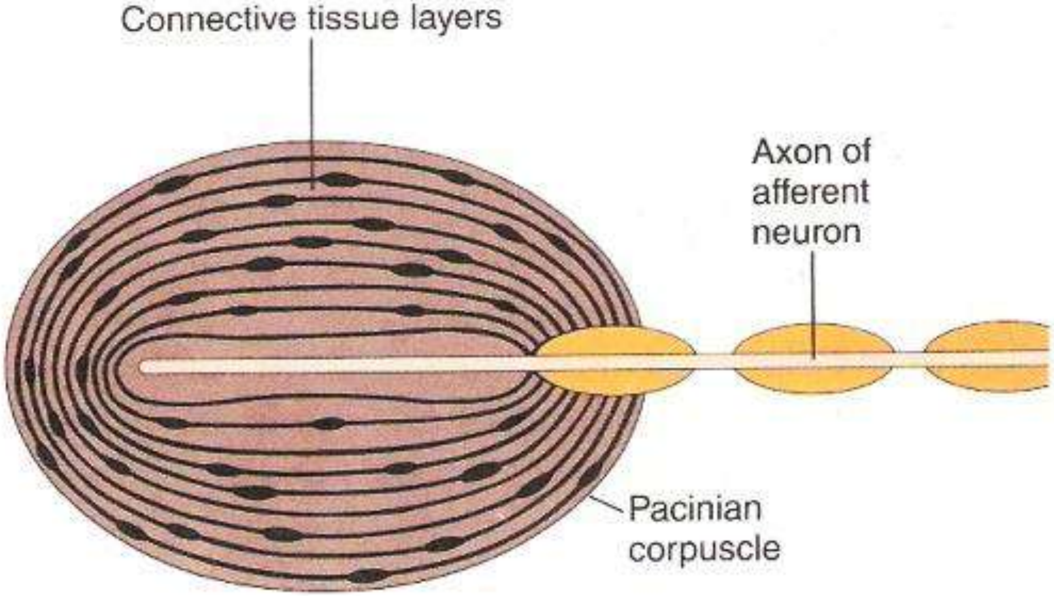
- Pacinian corpuscle is a rapidly adapting skin receptor that detect pressure and vibration.
- Pacinian adaptation involves both:

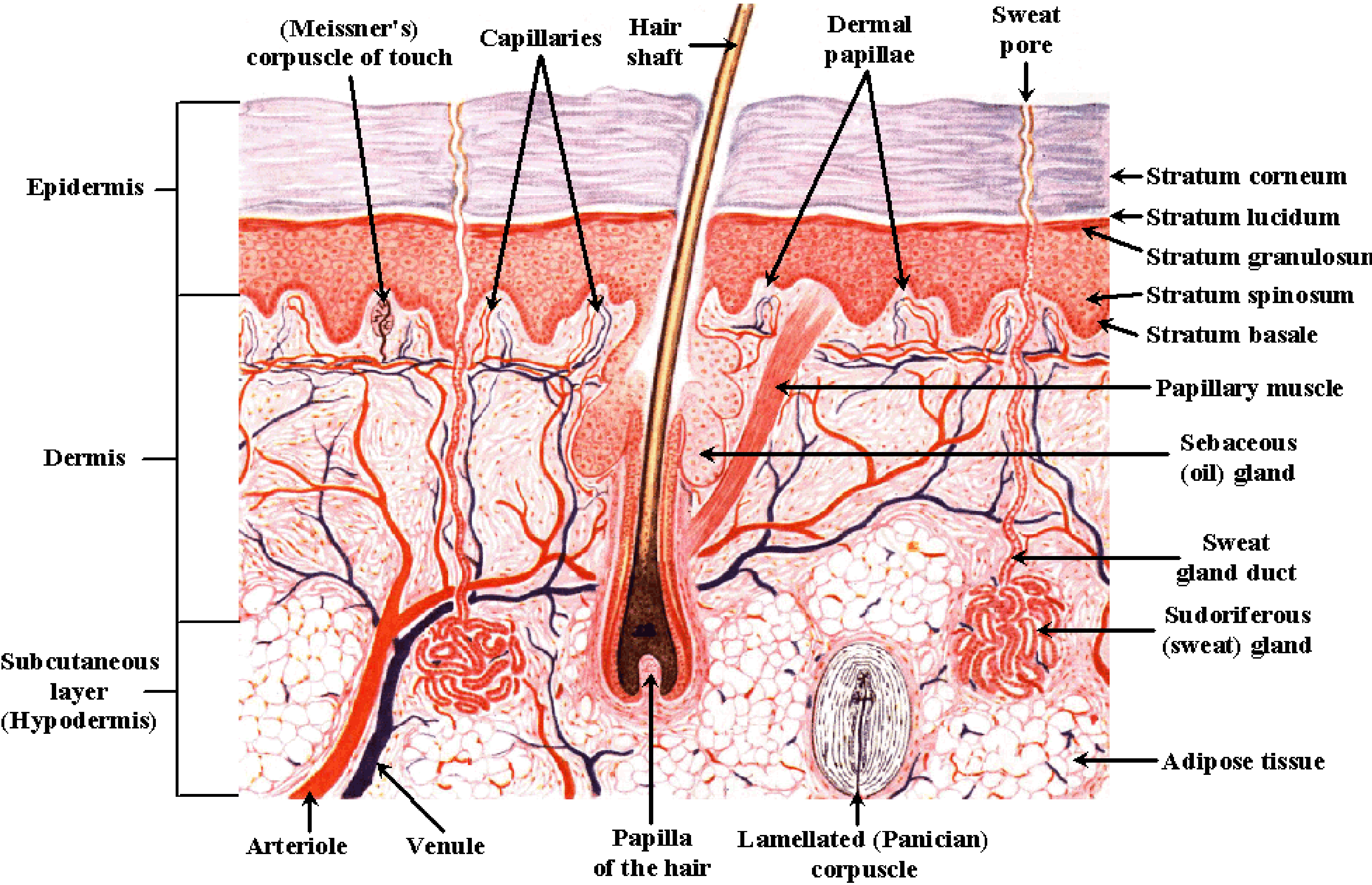
1- Mechanical and

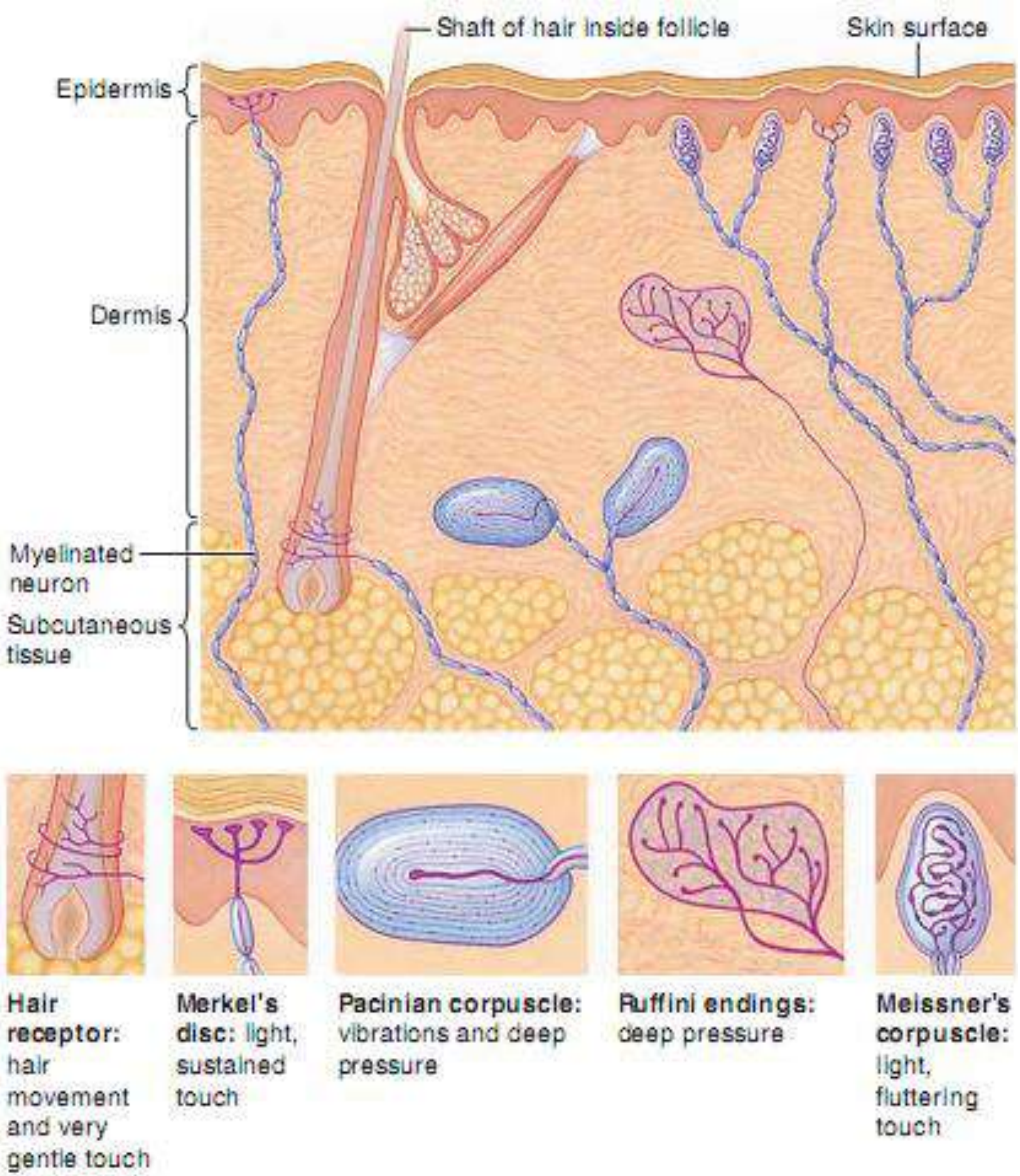
2- Electrochemical components.

● FIGURE 6-6

Pacinian corpuscle
The Pacinian corpuscle consists of concentric layers of connective tissue wrapped around the peripheral terminal of an afferent neuron.




(Meissner's) corpuscle of touch
Capillaries
Hair shaft
Dermal papillae
Sweat pore
Epidermis
Stratum corneum
Stratum lucidum
Stratum granulosum
Stratum spinosum
Stratum basale
Papillary muscle
Dermis
Sebaceous (oil) gland
Sweat gland duct
Sudoriferous (sweat) gland
Subcutaneous layer (Hypodermis)
Adipose tissue
Arteriole
Venule
Papilla of the hair
Lamellated (Panician) corpuscle



• FIGURE 6-5 Tactile receptors in the skin.

Mechanisms of adaptation

1. The mechanical components

- Depends on the physical properties of this receptor, that consists of concentric layers of connective tissue.
- At first, the under layers terminal responds with a receptor potential of a magnitude that reflex the stimulus intensity.
- As the stimulus continues, the pressure energy is dissipated because it causes the receptor layers to slip.

2. The electrochemical components:

- Involves changes in ionic movement across the receptor membrane,
- So, the Na^+ channels slowly inactivated and reduce the Na^+ ions influx.

- **Both involves decreased neuronal responsiveness to repeated stimuli.**
- **Adaptation :** is a receptor adjustment in PNS.
- **Habituation :** involves a modification in synaptic effectiveness of CNS.

Each somatosensory pathway is “labeled” تصيف/تميز according to modality and location

- On reaching the spinal cord, afferent information has two possible destinations:
  1. It may because part of a reflex are, bringing about an appropriate effector response, or
  2. It may be relayed up ward to the brain via ascending pathways for further processing and possible conscious awareness.

- The afferent neuron with its peripheral receptor that first detects the stimulus is known as **first-order sensory neuron.**
- It synapses on a **second-order sensory neuron** either in the spinal cord or the medulla.
- This neuron then synapses on a **third-order sensory neuron** in the thalamus, and so on.
- A particular sensory input is **projected** to a specific region of the cortex, thus different types of incoming information are kept separated within specific labeled lines between the periphery and the cortex.

Even though all informations propagated to CNS via action potentials,

Table 6-1 summarize how the CNS is informed of the ***type*** (**what?**),

location (**where?**) and

intensity (**How much?**) of a stimulus.

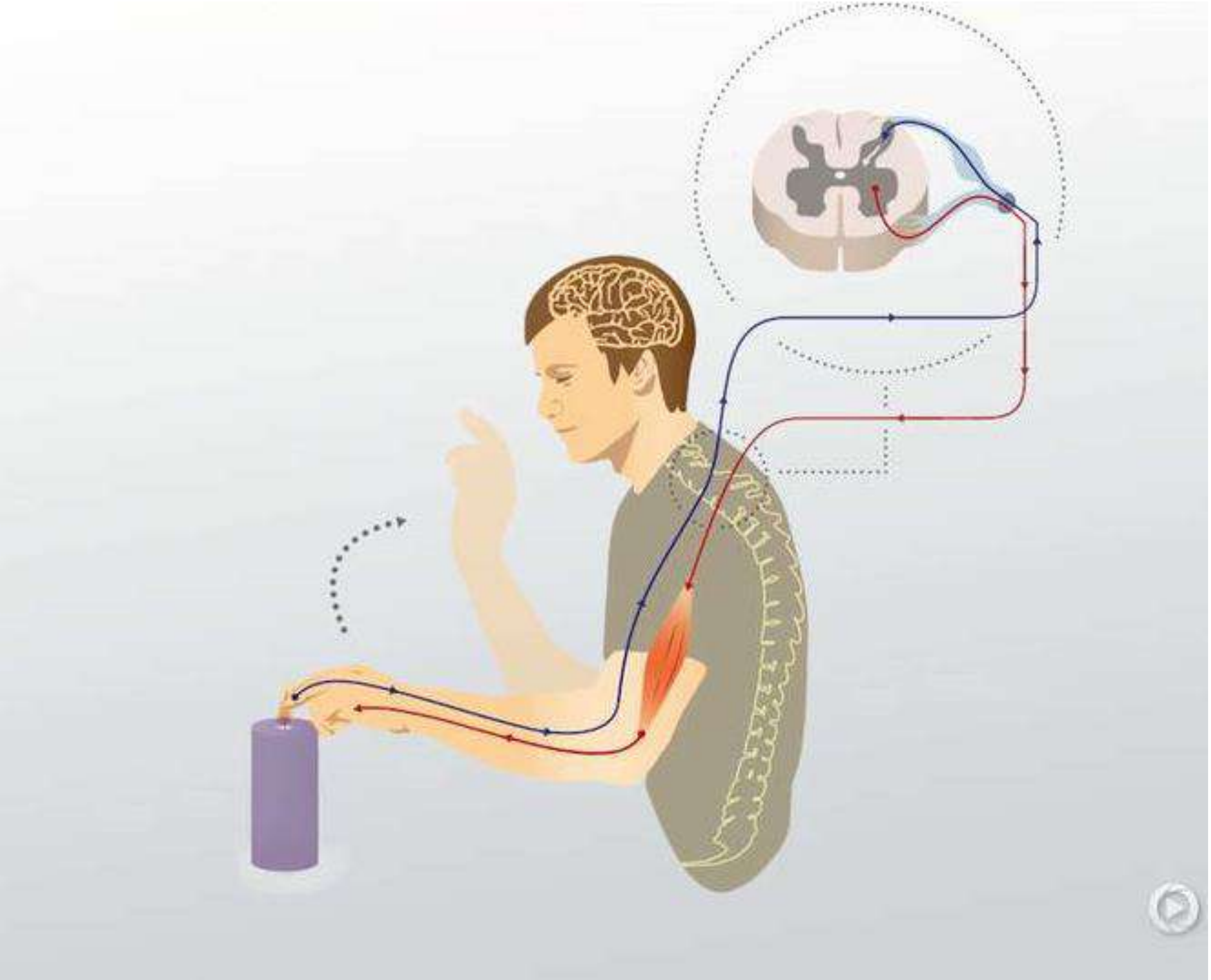
▲ TABLE 6-1

Coding of Sensory Information

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

Phantom Pain

- Activation of a sensory pathway at any point gives rise to the same sensation that would be produced by stimulation of the receptors in the body part itself.
- Example: amputated foot due to:
    - Irritation of the severed endings of the afferent pathways.
    - Remodeling of the brain region representation severed limb.



Acuity is influenced by receptive field size and lateral inhibition

1) Receptive field:

1) The size of a receptive field varies ***inversely*** with the density of receptors in the region.
2) The smaller the receptive field in a region, the greater its **acuity or discriminative ability**.
3) An estimated 17,000 tactile mechanoreceptors are present in the fingertips and palm of each hand.

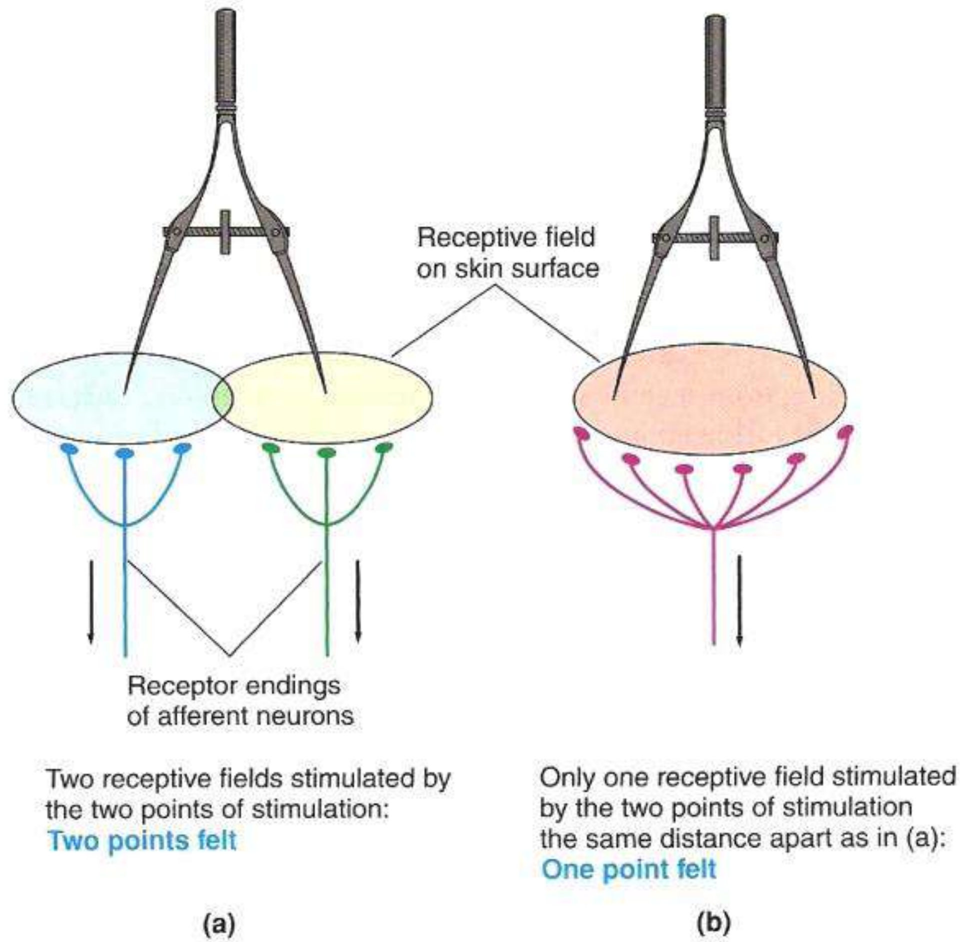


FIGURE 6-7
Comparison of discriminative ability of regions with small versus large receptive fields

Acuity is influenced by receptive field size and lateral inhibition

2) Lateral inhibition:

1) The receptive field is exited immediately under the center of the pencil point, but the surrounding receptive field are also stimulated, only to a lesser extent because they are less distorted تغير, so localization of the pencil point would be blurred.
2) To facilitate localization and sharpness contrast, lateral inhibition occurs within the CNS, via inhibitory interneurons that pass laterally between ascending fibers serving neighboring receptive fields.
3) Those with the most lateral inhibition – **touch and vision** – bring about the most accurate localization.

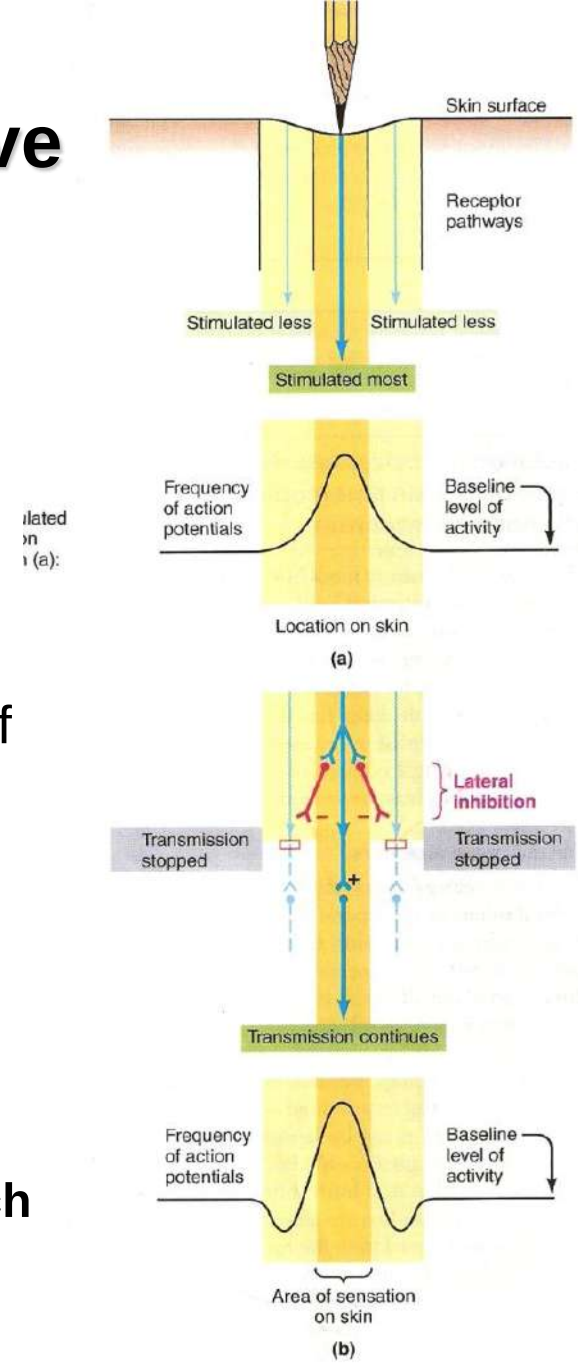


FIGURE 6-8
Lateral inhibition

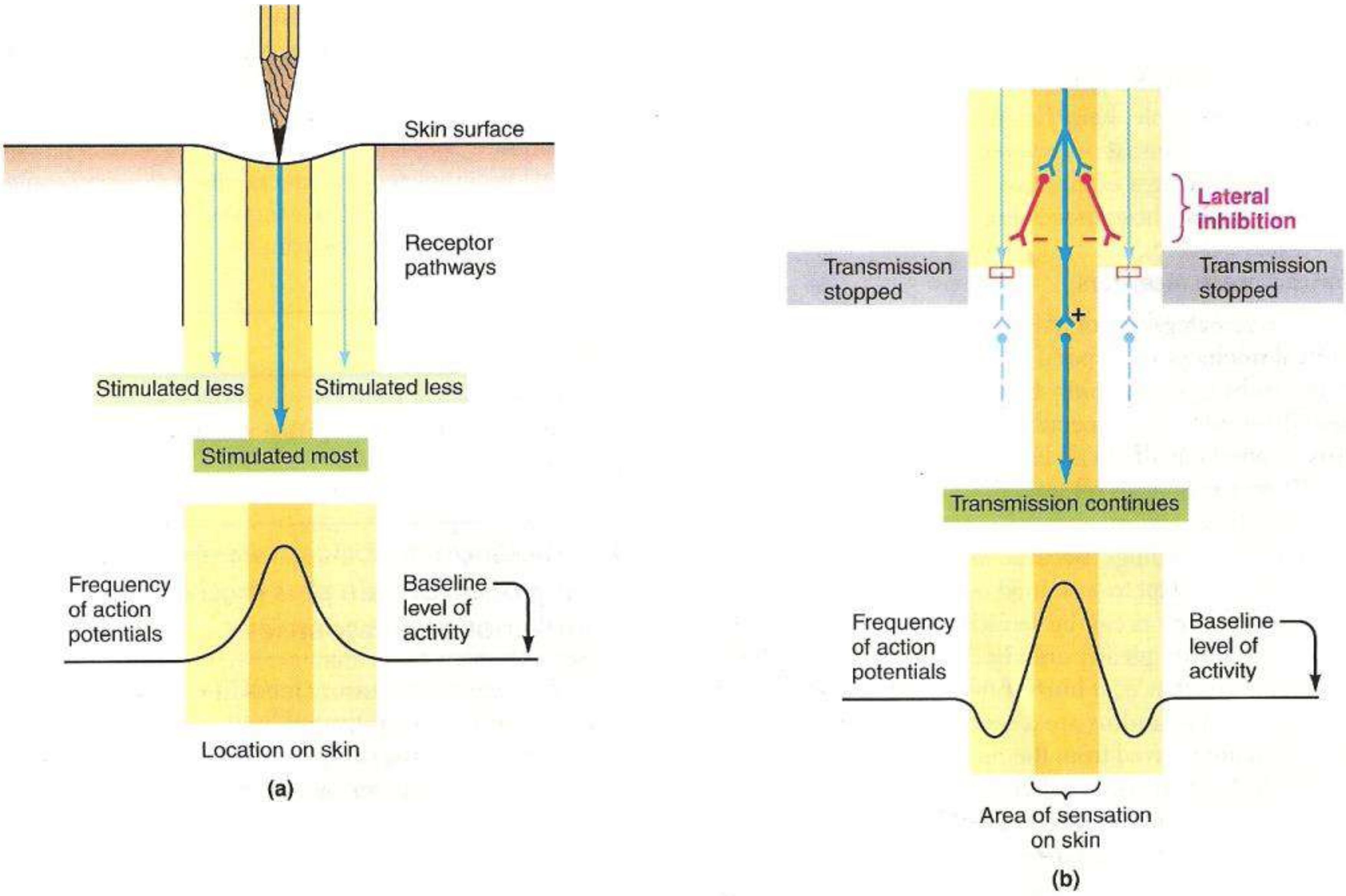


FIGURE 6-8

Lateral inhibition

Pain

- It is a protective mechanism meant to bring to conscious awareness the fact that tissue damage is occurring or is about to occur.

- **Stimulation of nociceptors elicits the perception of pain plus motivational and emotional responses:**

    - Unlike other somatosensory modalities, the sensation of pain is accompanied by motivated behavioral responses (such as withdrawal or defense) as well as emotional reactions (such as crying of fear).
    - Also the subjective perception of pain can be influenced by other past or present experiences.

Categories of pain receptors

- **Mechanical nociceptors:**

  - respond to mechanical damage such as cutting, or pinching.
- **Thermal nociceptors:**

  - respond to temperature extremes, especially heat.
- **Polymodal nociceptors:**

  -respond equally to all kinds of damaging stimuli, including irritating chemicals released from injured tissues.

- ✓ They all naked nerve endings.
- ✓ Nociceptors do not adapt to sustained or repetitive stimulation.
- ✓ All nociceptors can be sensitized by the presence of **prostaglandins,** which are a special group of fatty acid derivatives that are cleaved from the lipid bilayer of the plasma membrane and act locally on being released.
- ✓ **Aspirin-like** drugs inhibit the synthesis of **PG.**

Fast and Slow afferent pain fibers

- The slow pain pathway is activated by chemicals, especially **bradykinin,** a normally inactive substance that is activated by enzymes released into ECF from damaged tissue, also contribute to the inflammatory response to tissue injury.
- Table 6-2
- Peripheral receptors of afferent **C-**fibers are activated by **capsaicin,** in addition to binding with pain receptors, capsaicin also binds with *thermal receptors*.
- Local application of capsaicin can actually reduce clinical pain, by over stimulating and damaging the nociceptors with which it binds.

TABLE 6-2
Characteristics of Pain

Fast Pain	Slow Pain
Occurs on stimulation of mechanical and thermal nociceptors	Occurs on stimulation of polymodal nociceptors
Carried by small, myelinated A-delta fibers	Carried by small, unmyelinated C fibers
Produces sharp, prickling sensation	Produces dull, aching, burning sensation
Easily localized	Poorly localized
Occurs first	Occurs second; persists for longer time; more unpleasant

Higher-level processing of pain input

- The primary afferent pain fibers synapse with specific second order interneurons in the dorsal horn of the spinal cord.
- The two best known of these pain neurotransmitters are **Substance P** and **glutamate**:

1. **Substance P**: (Figure 6-9 a)
2. **Glutamate:**

   Glutamate acts on two different plasma-membrane receptors on the dorsal horn neurons, with two different outcomes:

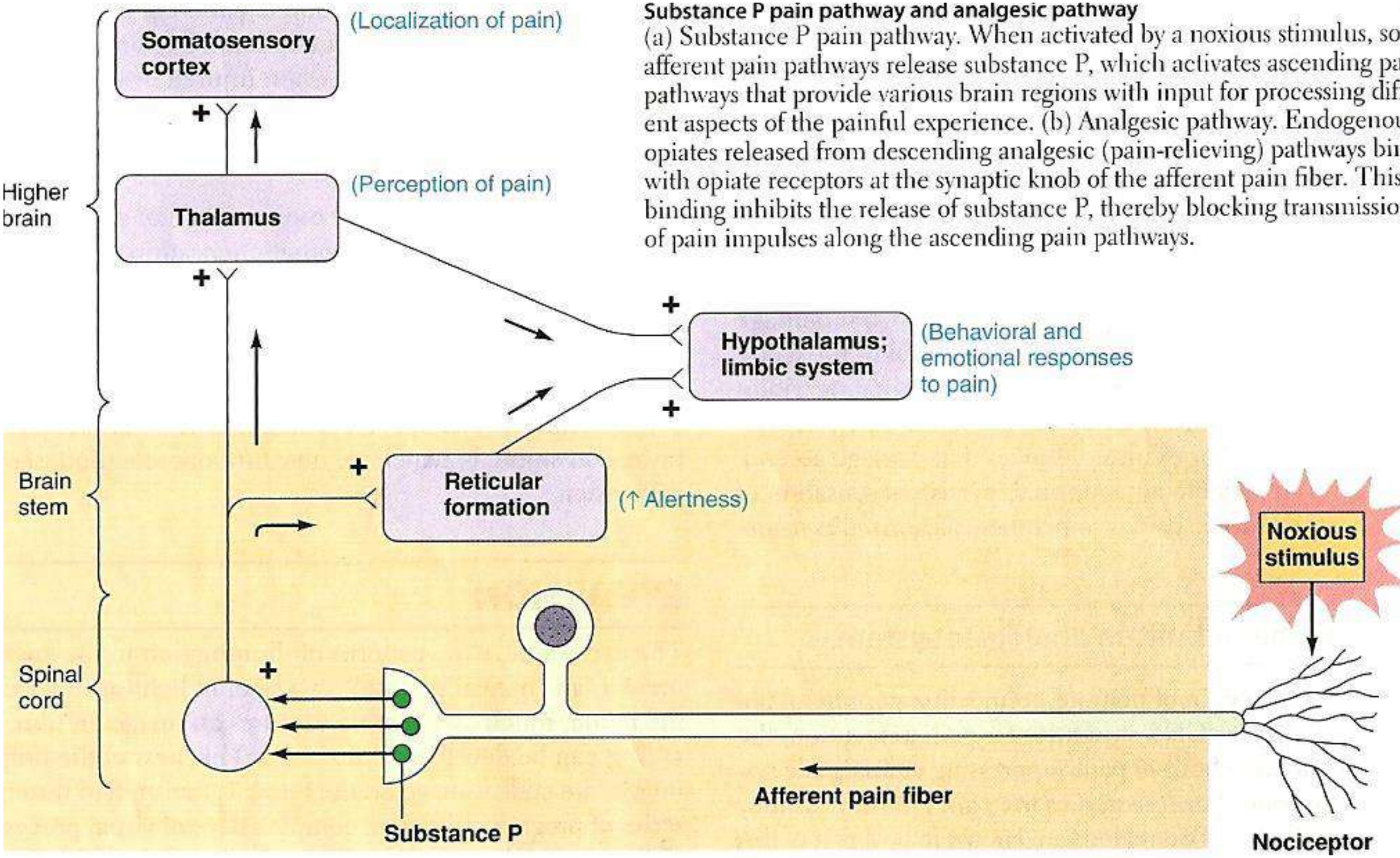
   a) Glutamate binds **AMPA receptors** lead to permeability changes then generation of action potential in dorsal horn cell then transmitted to higher centers.

   b) Glutamate binds **NMDA receptors** lead to Ca^{2+} influx initialing second-messenger systems that make the dorsal horn more excitable than usual, (hypersensitivity) e.g. supersensitivity of light touch of an injured area.

❖ **Neuropathic pain:** abnormal chronic pain states result from damage within the pain pathway in the peripheral nerves or CNS.

Substance P pain pathway and analgesic pathway

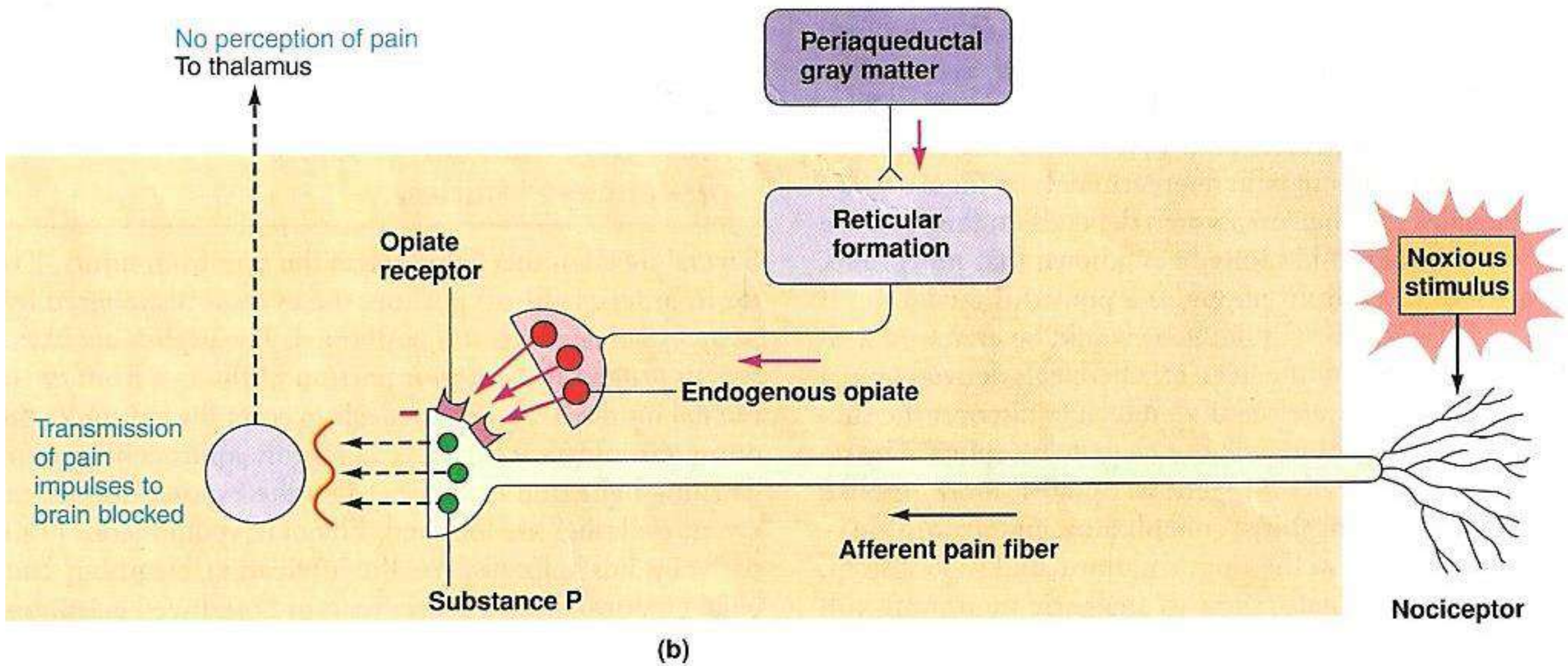
(a) Substance P pain pathway. When activated by a noxious stimulus, some afferent pain pathways release substance P, which activates ascending pain pathways that provide various brain regions with input for processing different aspects of the painful experience. (b) Analgesic pathway. Endogenous opiates released from descending analgesic (pain-relieving) pathways bind with opiate receptors at the synaptic knob of the afferent pain fiber. This binding inhibits the release of substance P, thereby blocking transmission of pain impulses along the ascending pain pathways.



(a)

The brain has a built-in analgesic system

- The CNS contains a built-in pain suppressing or analgesic system.
- The **endorphins**,**enkephalines** and **dynorphin** normally bind with endogenous opiate receptors.
- Factors known to modulate pain include exercise, stress, and acupuncture.



The End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Vision

Introduction

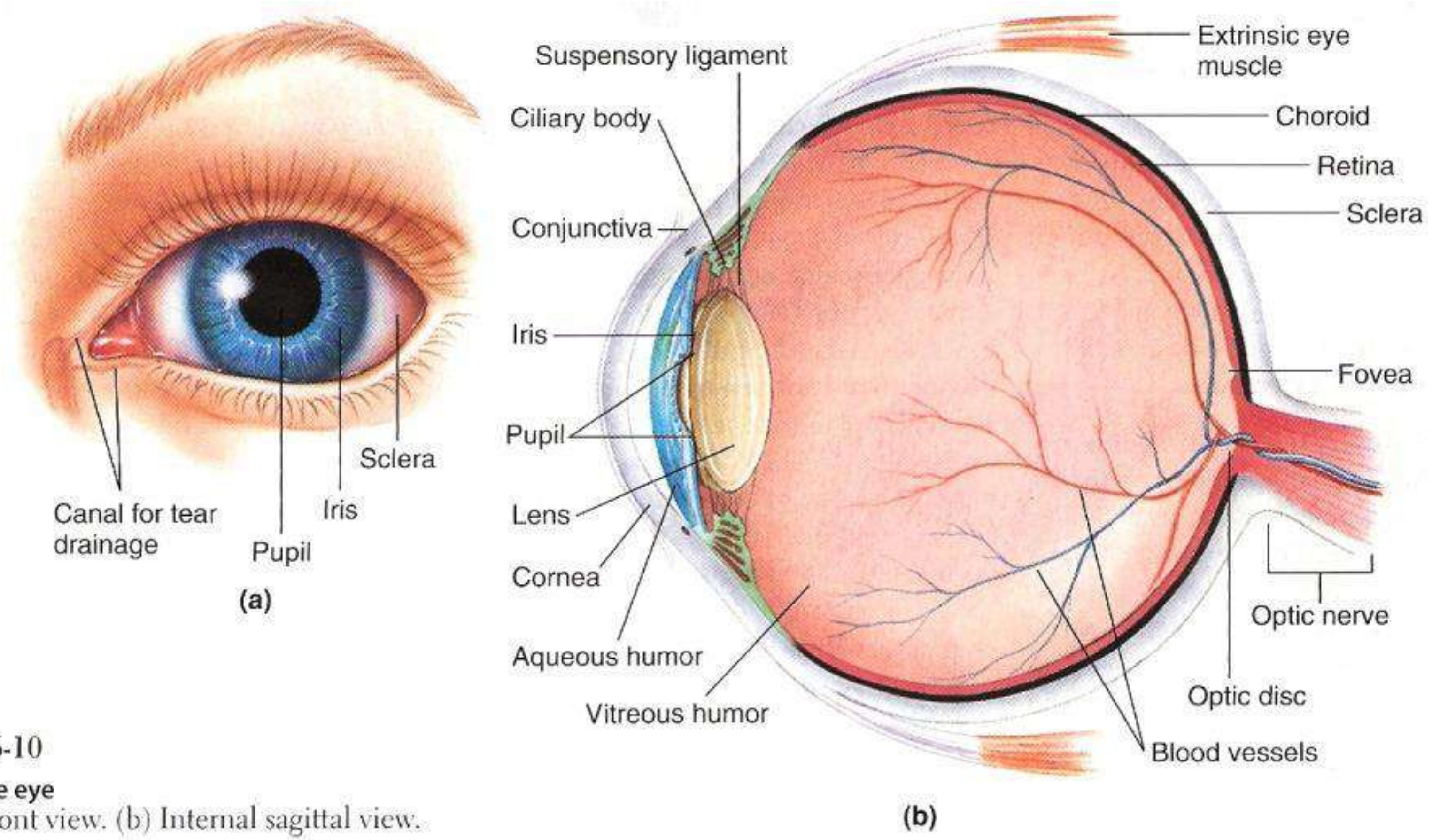

FIGURE 6-10

Structure of the eye

(a) External front view. (b) Internal sagittal view.

Protective mechanisms help prevent eye injuries

- The **eye ball** is sheltered by the bony socket in which it is positioned.
- The **eyelids** act like shutters, it is close reflexly to cover the eye under threatening circumstances and helps disperse tears.
- The lubricating, cleansing, bactericidal **tears** produced continuously by the **lacrimal gland** in the upper lateral corner under the eyelids.
- **Eyelashes** trap fine airborne debris such as dust.

FIGURE 6-10
Structure of the eye
(a) External front view.

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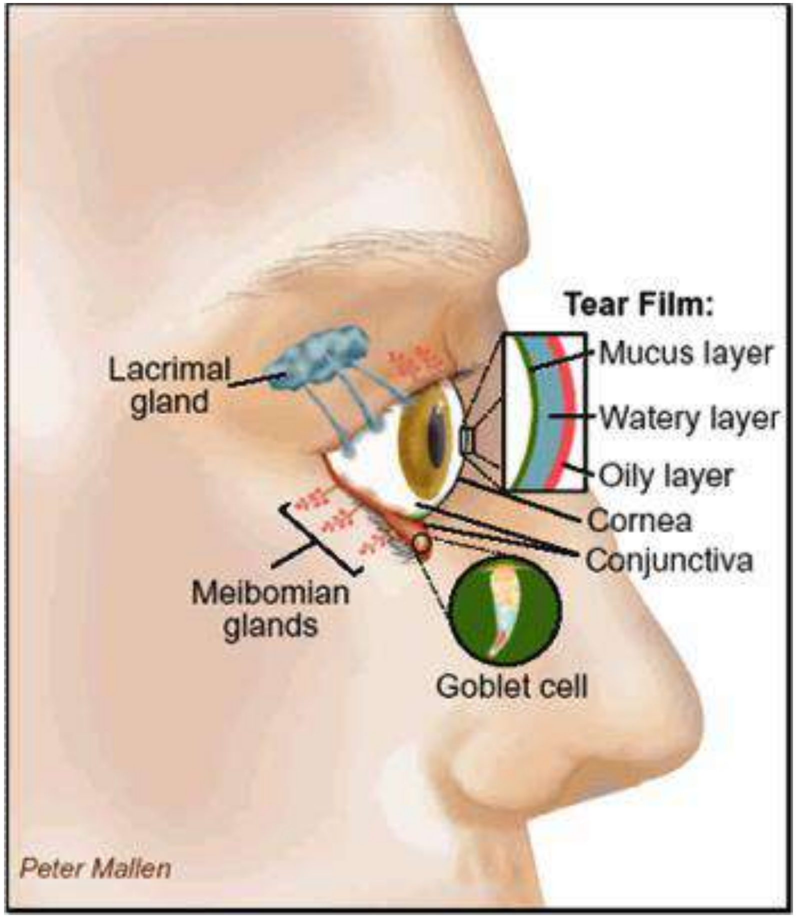


❑ The eye is a fluid-filled sphere enclosed by three specialized tissue layers

- **From outer most to innermost, these are:**

1. The sclera/ cornea.

2. The coroid/ cilliary body/ iris.

3. The retina.

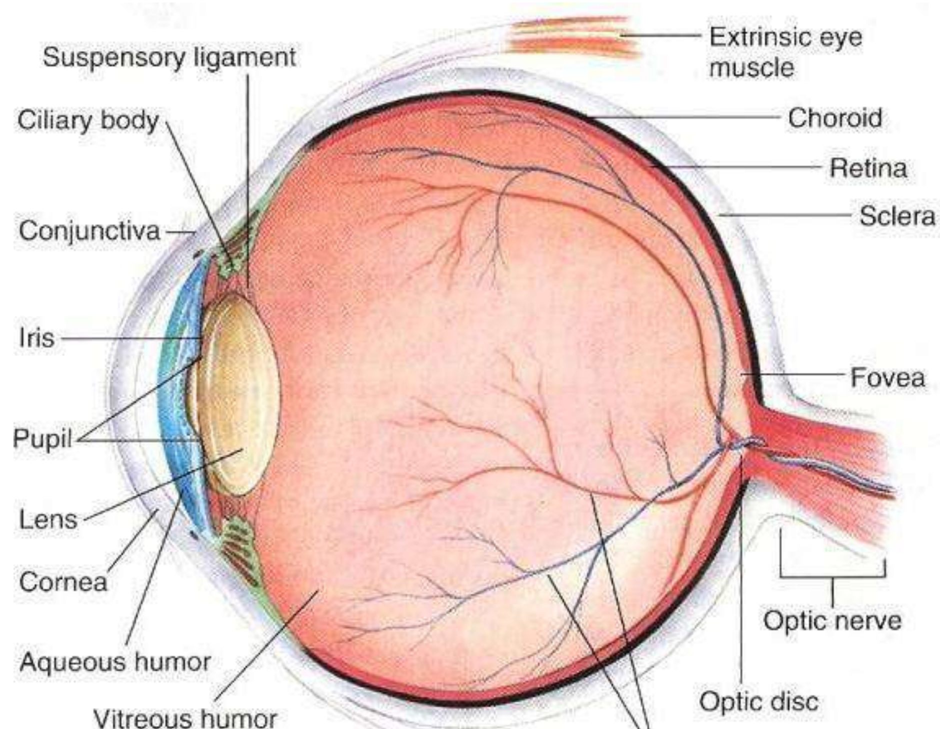
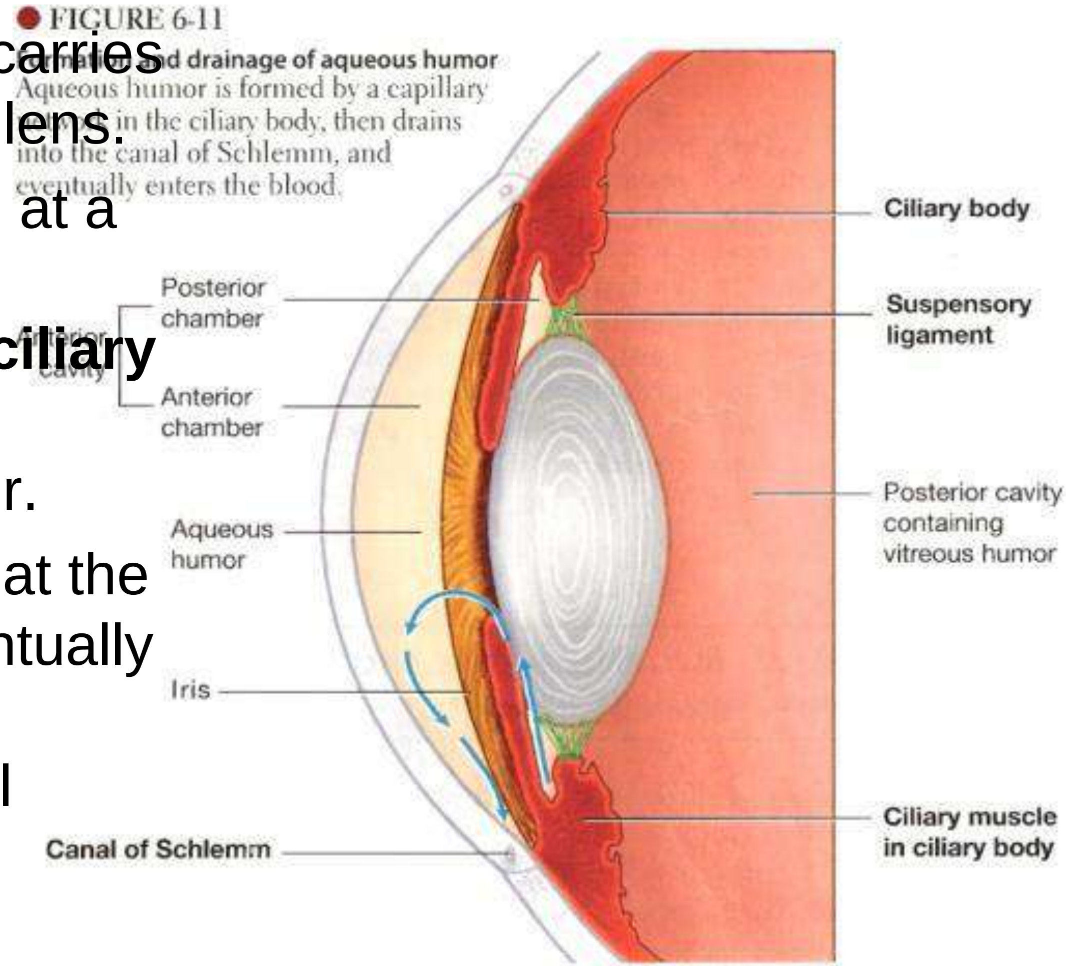


FIGURE 6-10
Structure of the eye
(b) Internal sagittal view.

Draw the eye structure

- The **vitreous humor** is important in maintaining the spherical shape of the eye ball.
- While the **aqueous humor** carries nutrients for the cornea and lens.
- Aqueous humor is produced at a rate of about 5 ml/day by a capillary network within the **ciliary body**, a specialized anterior derivative of the choroid later.
- The fluid drains into a canal at the edge of the cornea and eventually enters the blood, (**canal of schlemm**), it is blockage will accumulate the fluid in the anterior cavity, causing the pressure to rise within the eye (**Glaucome).**



The amount of light entering the eye is controlled by the iris

- The pigment in the iris is responsible for eye color.
- The varied flecks, lines, pits, and other nuances فروقات of the iris are unique for each individual, making the iris the basis of the latest identification technology and more foolproof than fingerprinting or even DNA testing.

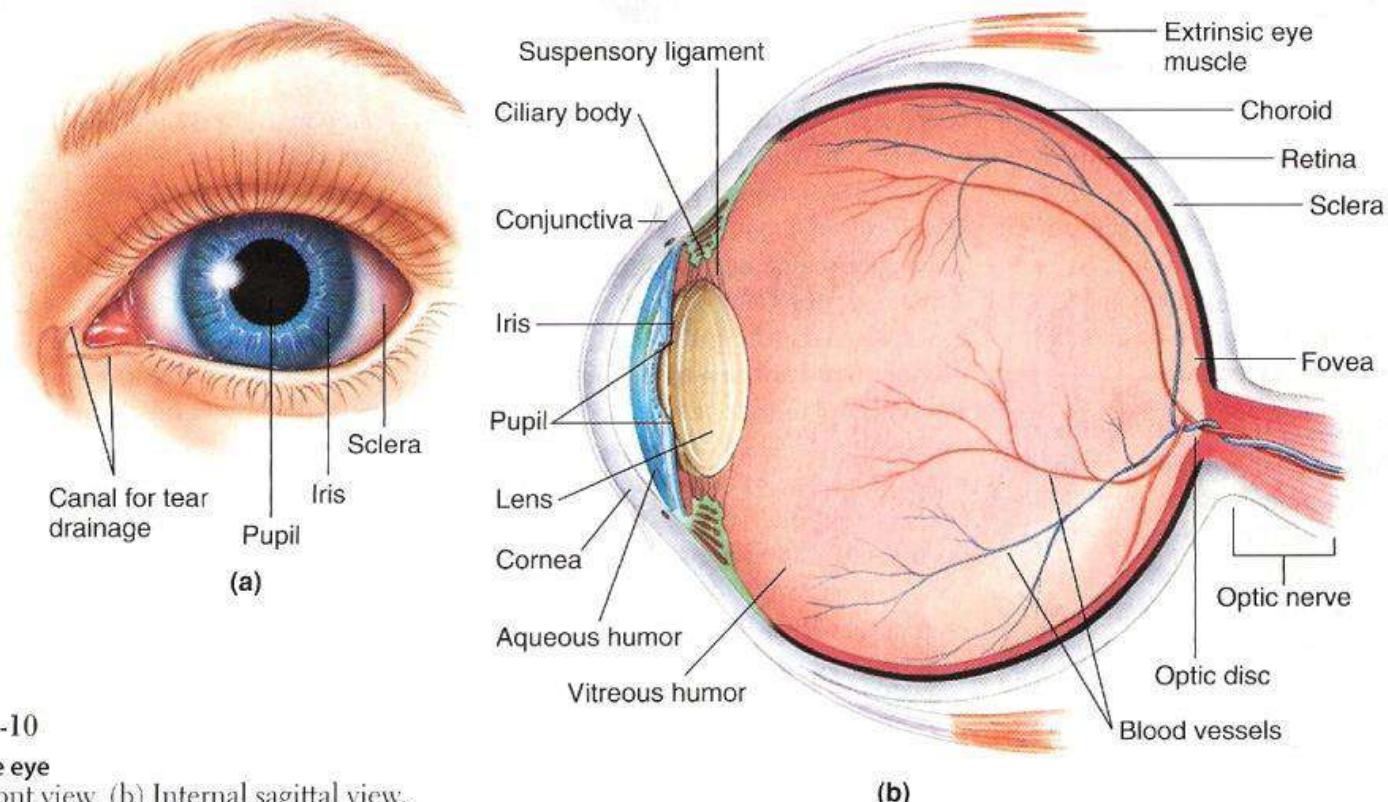
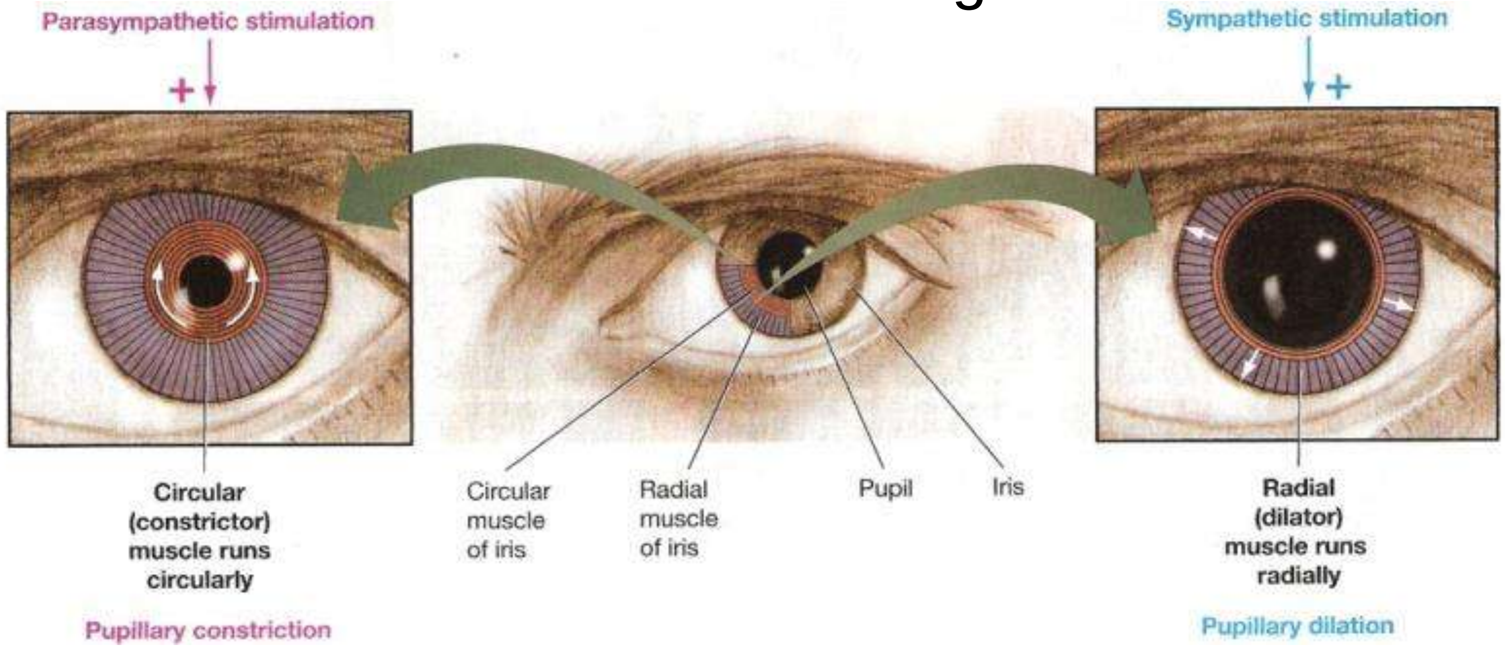


FIGURE 6-10
Structure of the eye
(a) External front view. (b) Internal sagittal view.

•The pupil size can be adjusted by variable contraction of the iris muscles to admit more or less light as needed



- **The iris contains two sets of smooth muscle networks :**

1. **The circular muscle (constrictor العضلة القابضة)**
   - Contracts and forms a smaller ring.
   - This reflex pupillary **constriction** occurs in bright light to decrease the amount of light entering the eye.
   - Parasympathetic nerve fibers innervate the circular muscle.
2. **The radial muscle (dilator العضلة الموسعة)**
   - When it shortens, the size of the pupile increases.
   - occurs in dim light to allow the entrance of more light.
   - Sympathetic fibers supply the radial muscle.

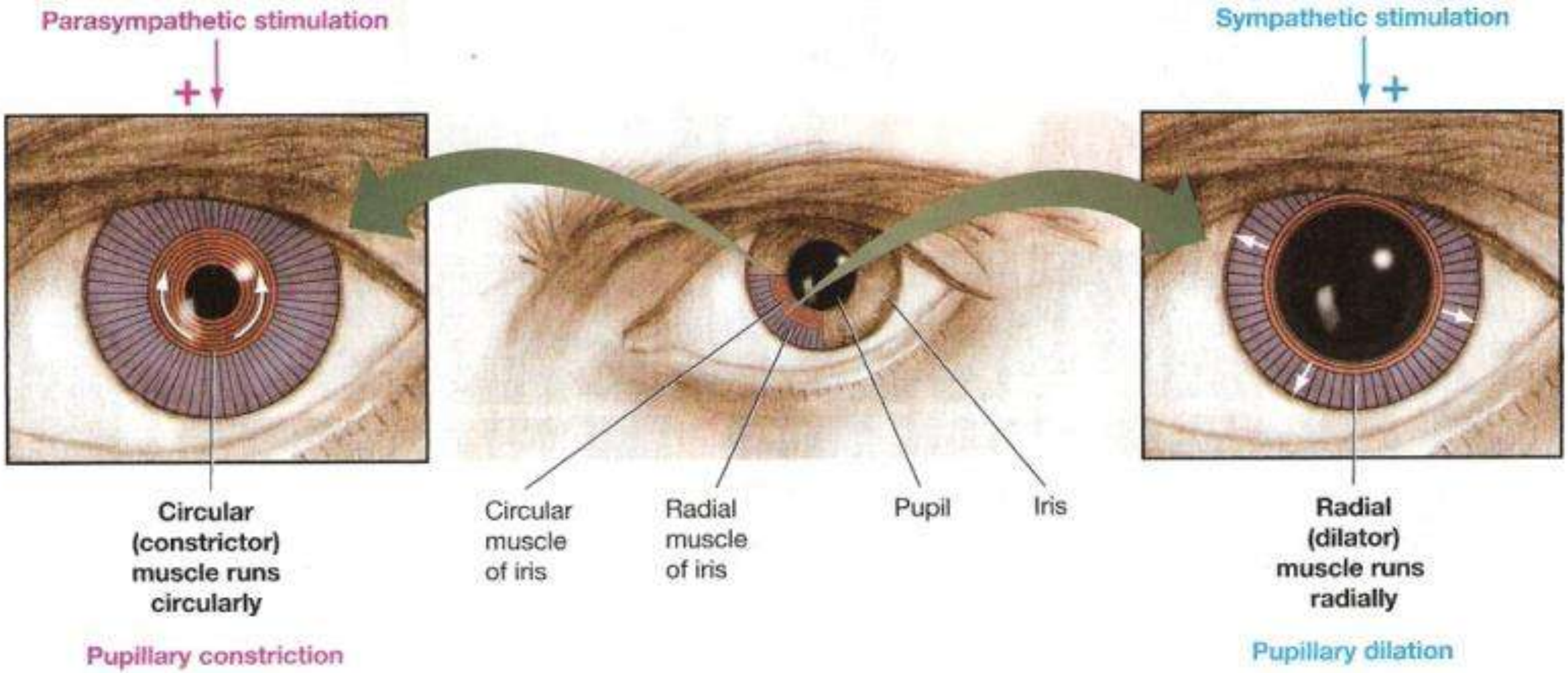


FIGURE 6-12

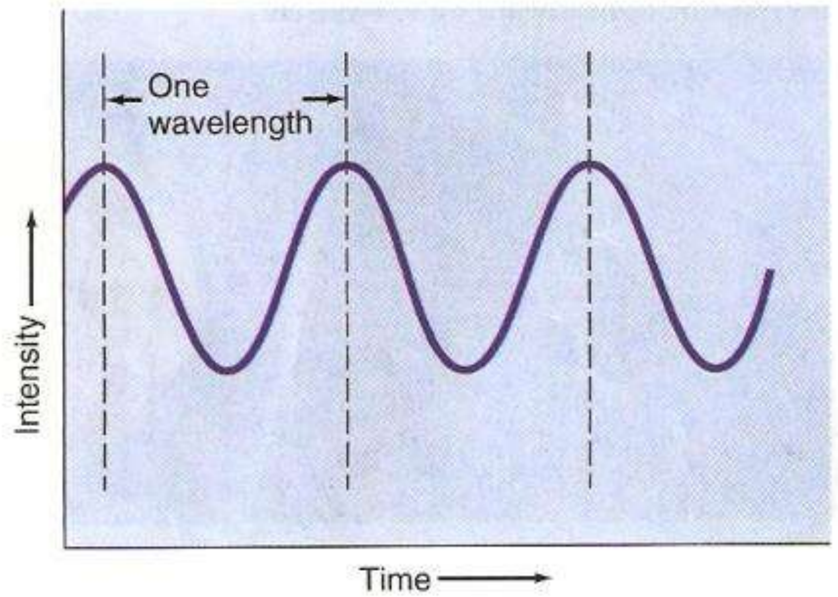
Control of pupillary size

The eye refracts the entering light to focus the image of the retina

- **light** is a form of electromagnetic radiation composed of particle-like individual packets of energy called **photons** that travel in wave like fashion.

FIGURE 6-13

Properties of an electromagnetic wave
A wavelength is the distance between two wave peaks. The term *intensity* refers to the amplitude of the wave.



- This **visible light** is only a small portion of the total electromagnetic spectrum.
- Light of different wavelengths is perceived as different color sensations.
- Short wave lengths are sensed as violet and blue; long wavelengths are interpreted as orange and red.
- Light energy also varies in **intensity**, the amplitude, or height, of the wave (Fig. 6-13)

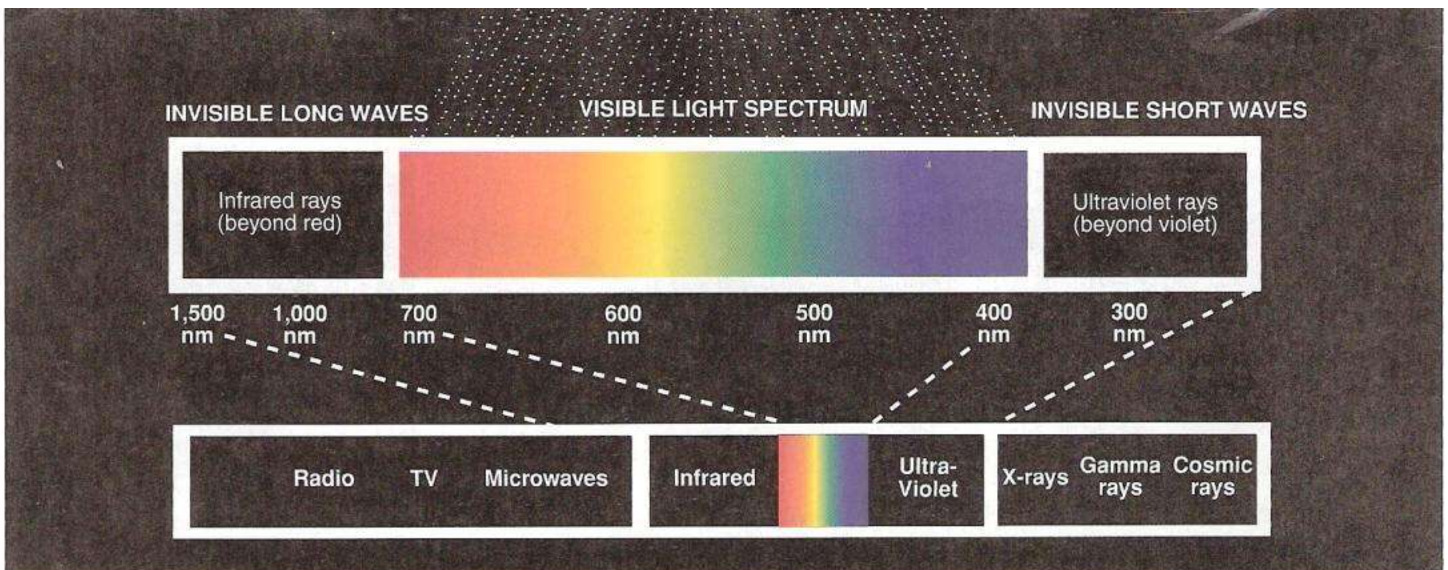


FIGURE 6-14

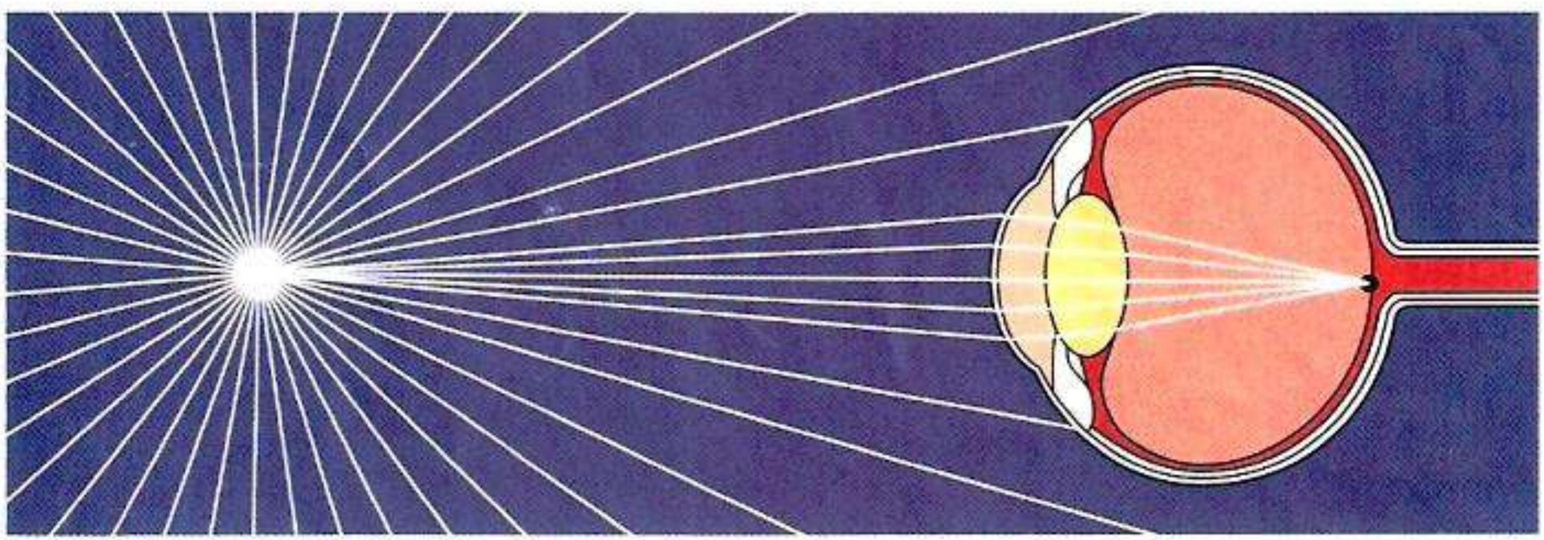
Electromagnetic spectrum

The wavelengths in the electromagnetic spectrum range from 10^4m (10 km—for example, long radio waves) to less than 10^{-14}m (quadrillionths of a meter—for example, gamma and cosmic rays). The visible spectrum includes wavelengths ranging from 400 to 700 nanometers (nm; billionths of a meter).

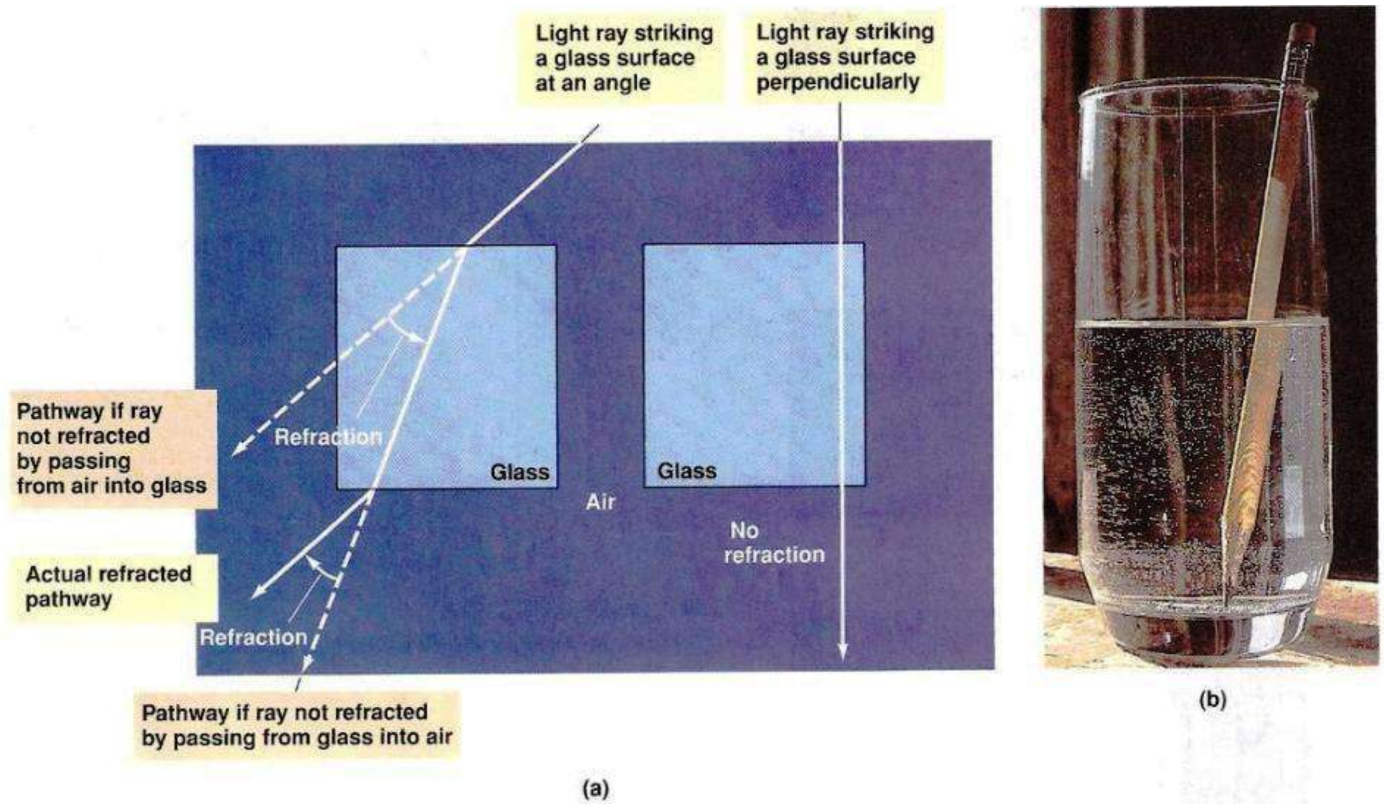
•Divergent light rays reaching the eye must be bent inward to be fused back into a point (the focal point) on the light-sensitive retina to provide an accurate image of the light source.

FIGURE 6-15

Focusing of diverging light rays
Diverging light rays must be bent inward to be focused.



Process of refraction

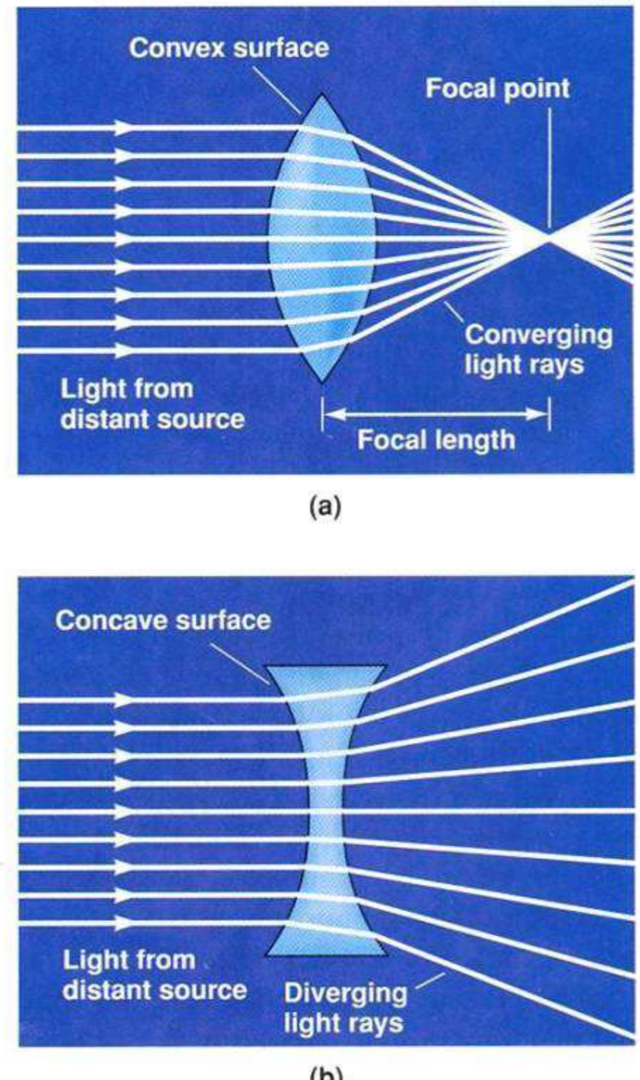


- The refraction of a light ray occurs when the ray passes from a medium of one density into a medium of a different density.
- The greater the difference in density, the greater the degree of bending, the greater the refraction.

- With a curved surface such as a lens, the greater the curvature, the greater the degree of bending and the stronger the lens.
- The direction of refraction depends on the angle of the curvature.

FIGURE 6-17

Refraction by convex and concave lenses
(a) A lens with a convex surface, which converges the rays (brings them closer together). (b) A lens with a concave surface, which diverges the rays (spreads them farther apart).

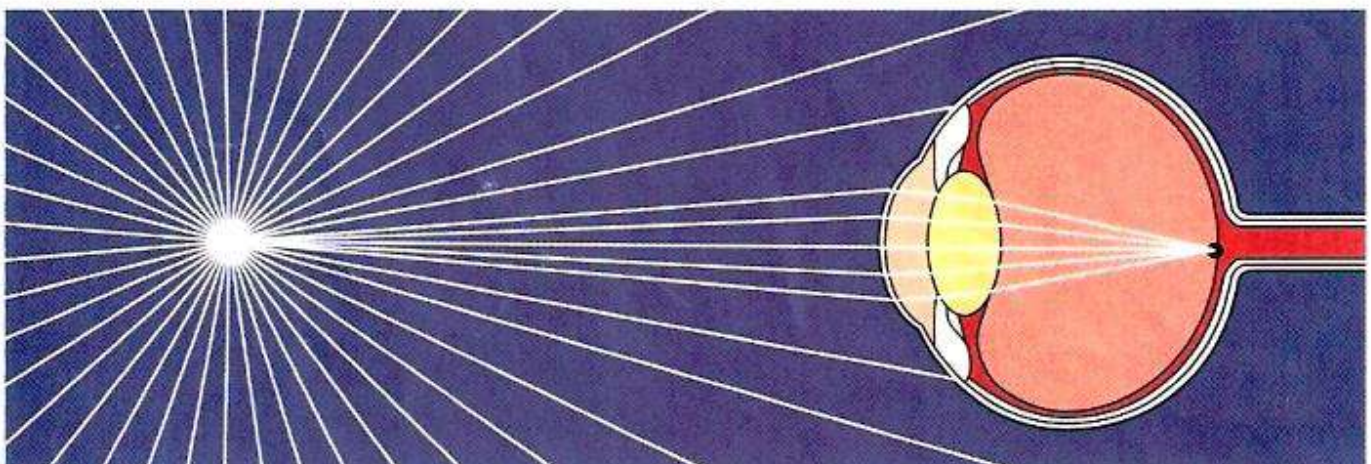


Eye refractive structures (Cornea & Lens)

- The curved corneal surface contributes most extensively to the eye's total refractive ability because the difference in density at the **air/corneal** interface is much greater than the differences in density between the lens and the fluids surrounding it.

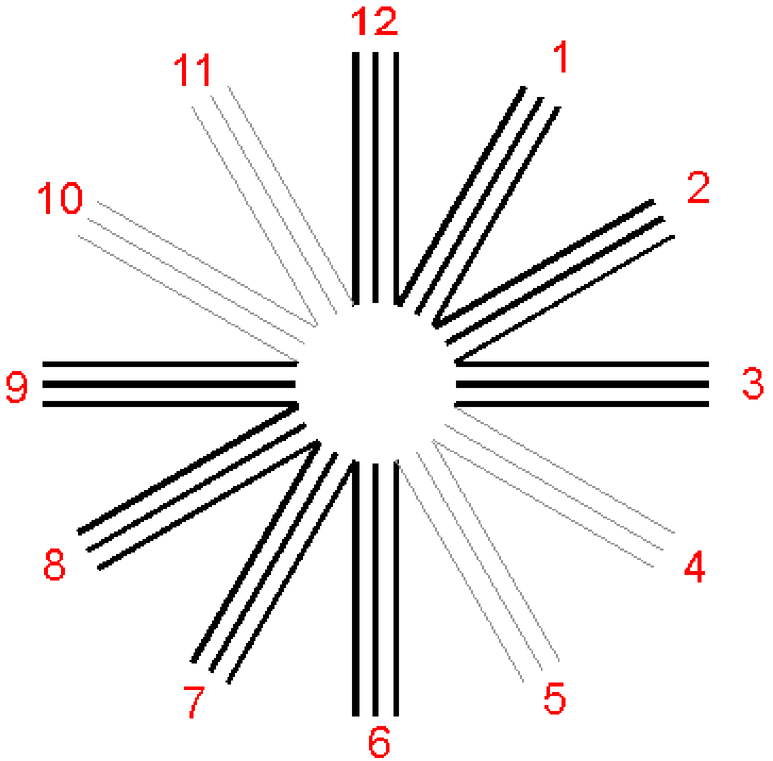
FIGURE 6-15

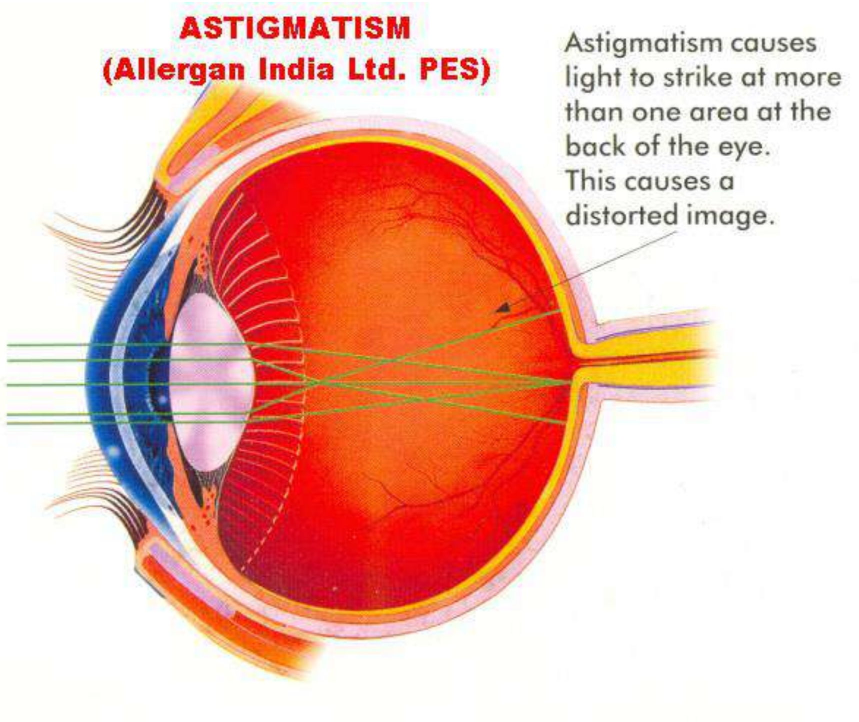
Focusing of diverging light rays
Diverging light rays must be bent inward to be focused.



Astigmatism

- It is a problem results in blurred vision where there is abnormal curvature (uneven) of the cornea **and / or** lens that prevents focusing on the retina.





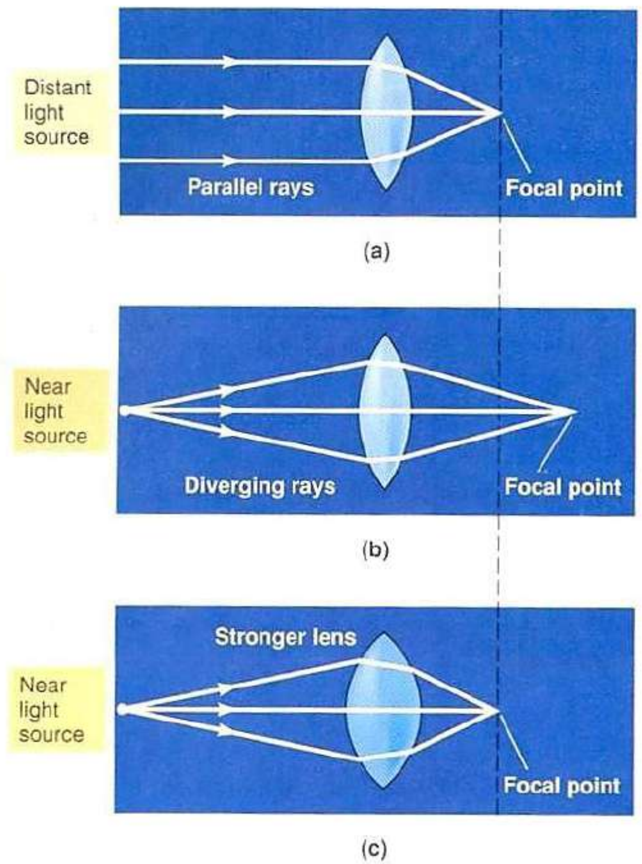


FIGURE 6-18

Focusing of distant and near sources of light

The rays from a distant (far) light source (more than 20 feet from the eye) are parallel by the time the rays reach the eye. (b) The rays from a near light source (less than 20 feet from the eye) are still diverging when they reach the eye. A longer distance is required for a lens of a given strength to bend the diverging rays from a near light source into focus compared to the parallel rays from a distant light source. (c) To focus both a distant and a near light source in the same distance (the distance between the lens and retina), a stronger lens must be used for the near source.

- **Rays from light sources more than 20 feet (6 m) away are considered to be parallel by the time they reach the eye.**
- **By contrast, light rays originating from near objects are still diverging when they reach the eye.**

- If an image is focused before it reaches the retina or is not yet focused when it reaches the retina, it will blurred.

- So, a stronger lens must be used for the near source.

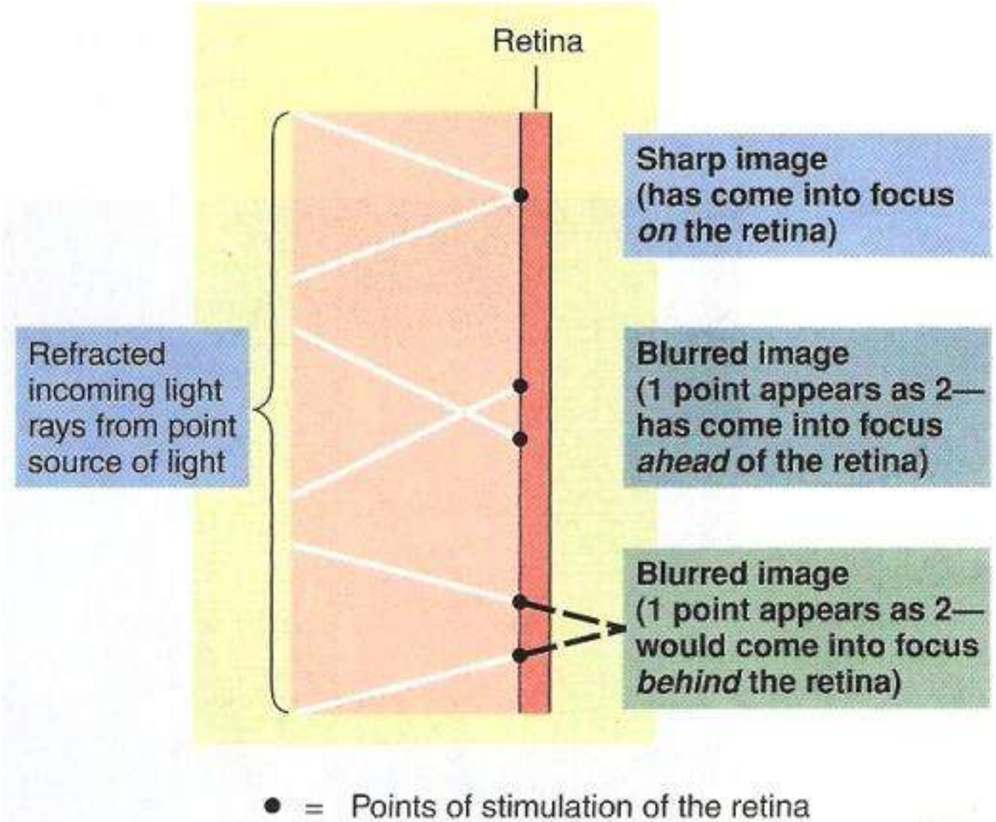


FIGURE 6-19
Comparison of images that do and do not come into focus on the retina

Accommodation increases the strength of the lens for near vision

- ***Accommodation***:

  Is the ability to adjust the strength of the lens, that depends on its shape, which in turn is regulated by the ciliary muscle.

- The ciliary body has two major components:

1. The ciliary muscle and
2. The capillary network that produces the aqueous humor.

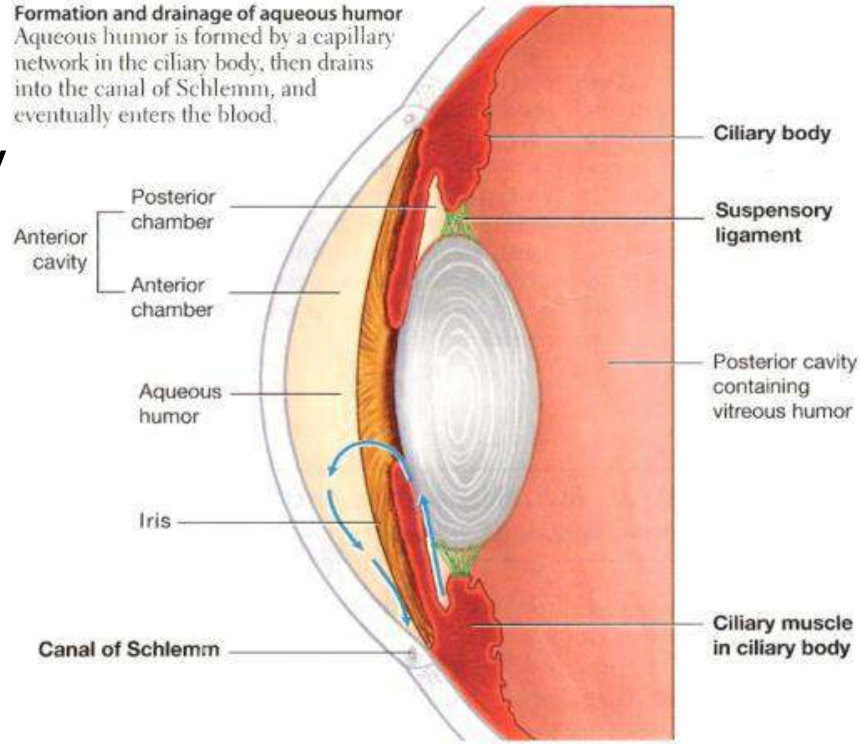


FIGURE 6-11
Formation and drainage of aqueous humor
Aqueous humor is formed by a capillary network in the ciliary body, then drains into the canal of Schlemm, and eventually enters the blood.

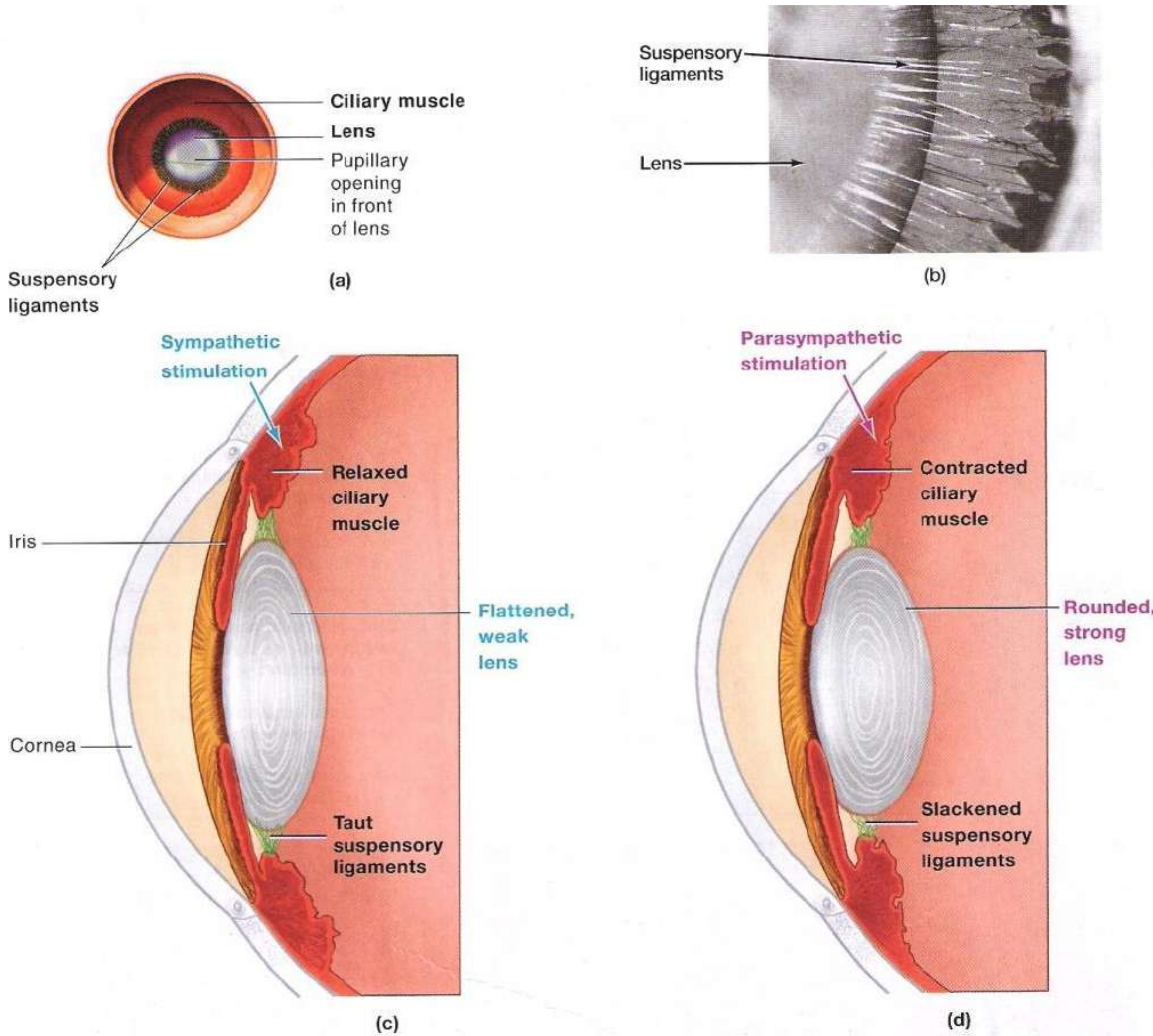
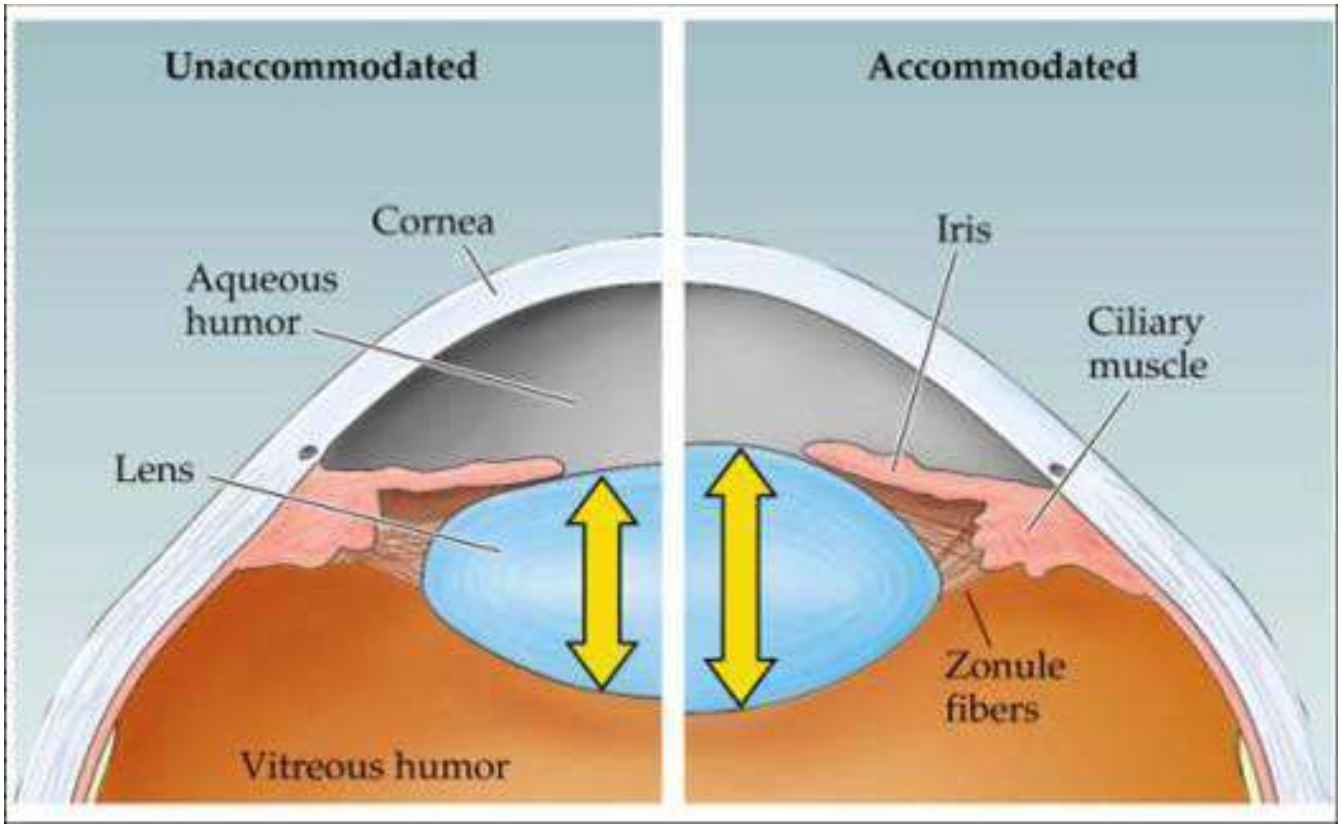


FIGURE 6-20
Mechanism of accommodation

The greater curvature of the more rounded lens increases its strength, causing greater bending of light rays



- **Cataract:** the transparent fibers of the lens become opaque so that light rays cannot pass through, and treated surgically.

- Cells in the center of the lens are in double jeopardy:

1. They are oldest; as only cells at the outer edge of the lens are replaced.
2. They are the farthest away from the aqueous humor the lens nutrient source.

- With advancing age, these nonrenewable central cells die and become stiff.
- This age-related reduction in accommodation ability called **presbyopia**, affects most people by middle age (45-50) requiring them to resort to corrective lenses for near vision (reading).

Other common vision disorders

- **Nearsightedness** (myopia)

&

- **Farsightedness** (hyperopia)

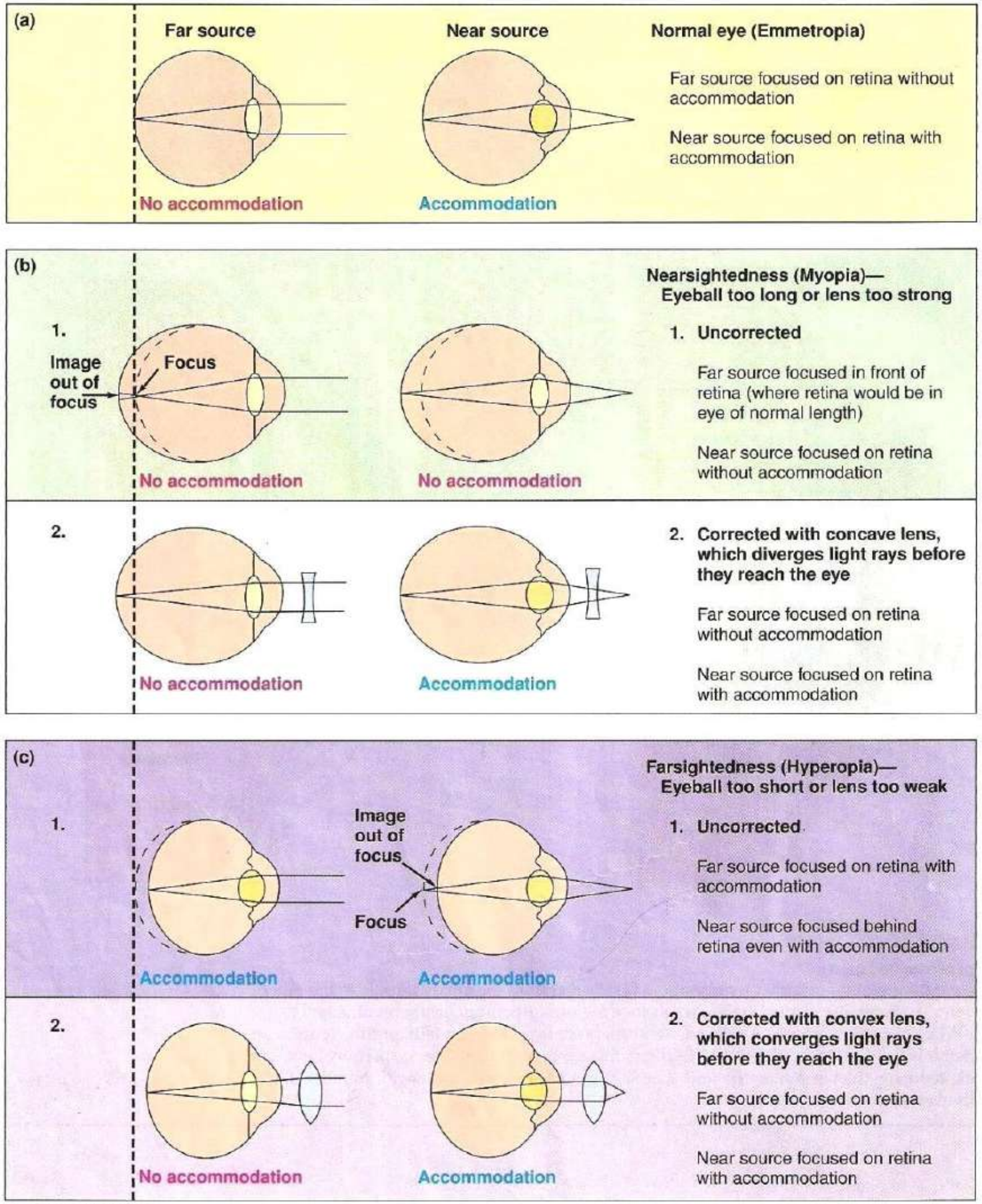
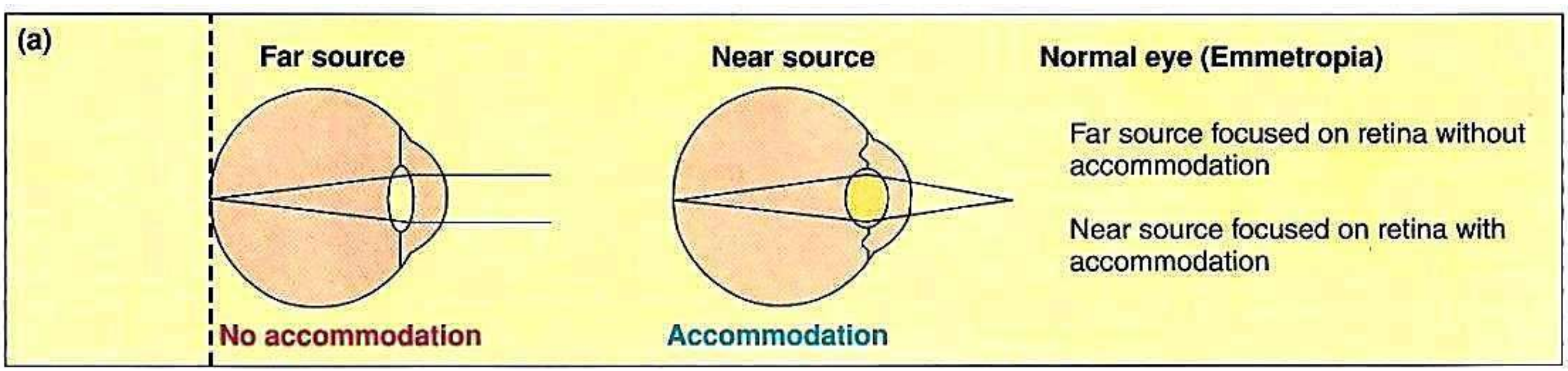


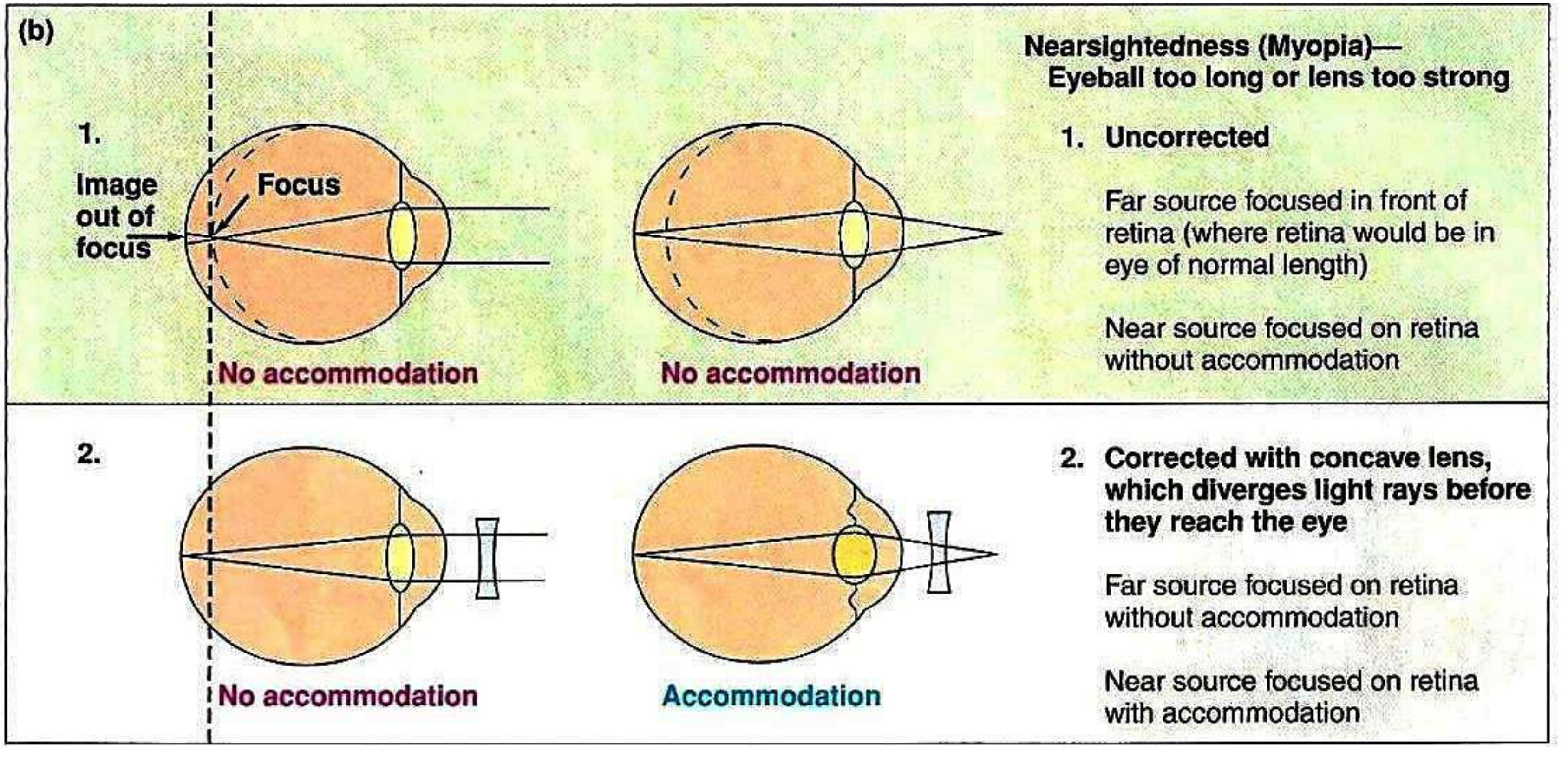
FIGURE 6-21
Emmetropia, myopia, and hyperopia

In normal eye (**emmetropia**)

- A far light source is focused on the retina without accommodation, whereas the strength of the lens is increased by accommodation to bring a near source into focus.

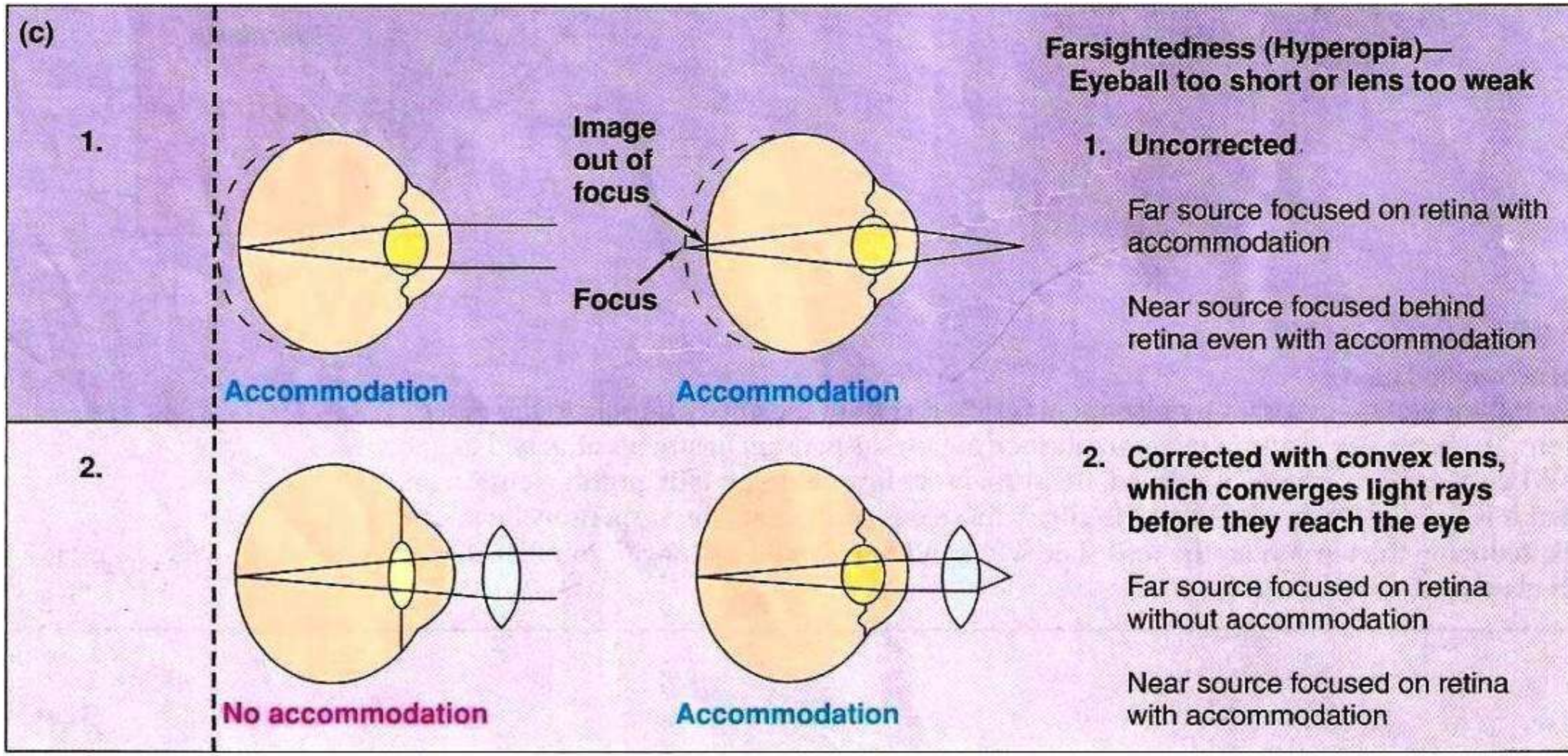


Nearsightedness (Myopia)



❖ Thus a myopic individual has better near vision than far vision, a condition that can be corrected by a concave lens.

Farsightedness (**hyperopia**)



- Thus a hyperopic individual has better far vision than near vision, a condition that can be corrected by a convex lens.

Such vision tends to get worse as the person gets older because of loss of accommodative ability with the onset of presbyopia.

Light must pass through several retinal layers before reaching the photoreceptors

- The receptor-containing portion of the retina is actually an extension of the CNS and not a separate peripheral organ, and its layer surprisingly are facing back ward.

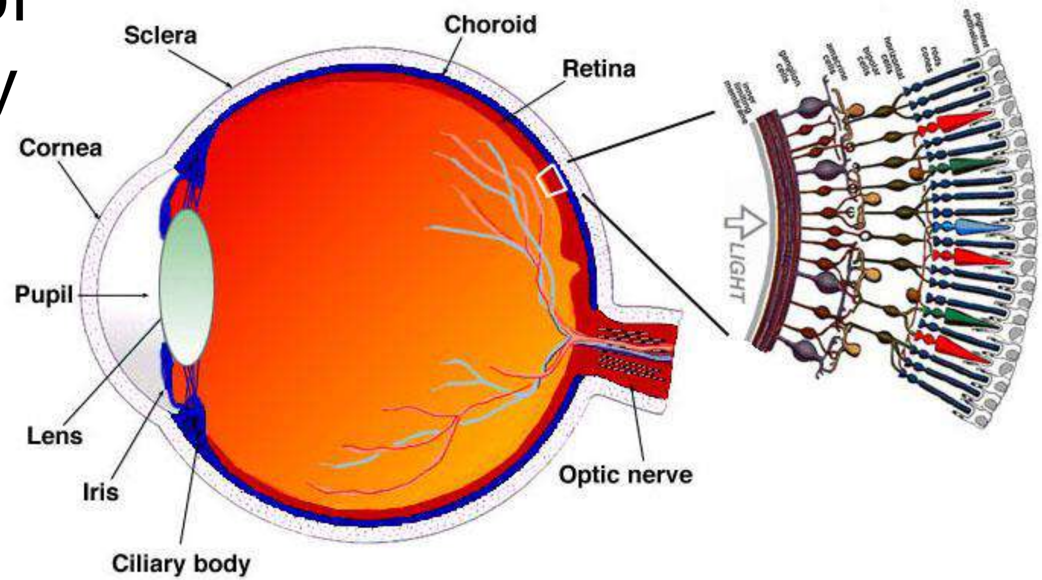
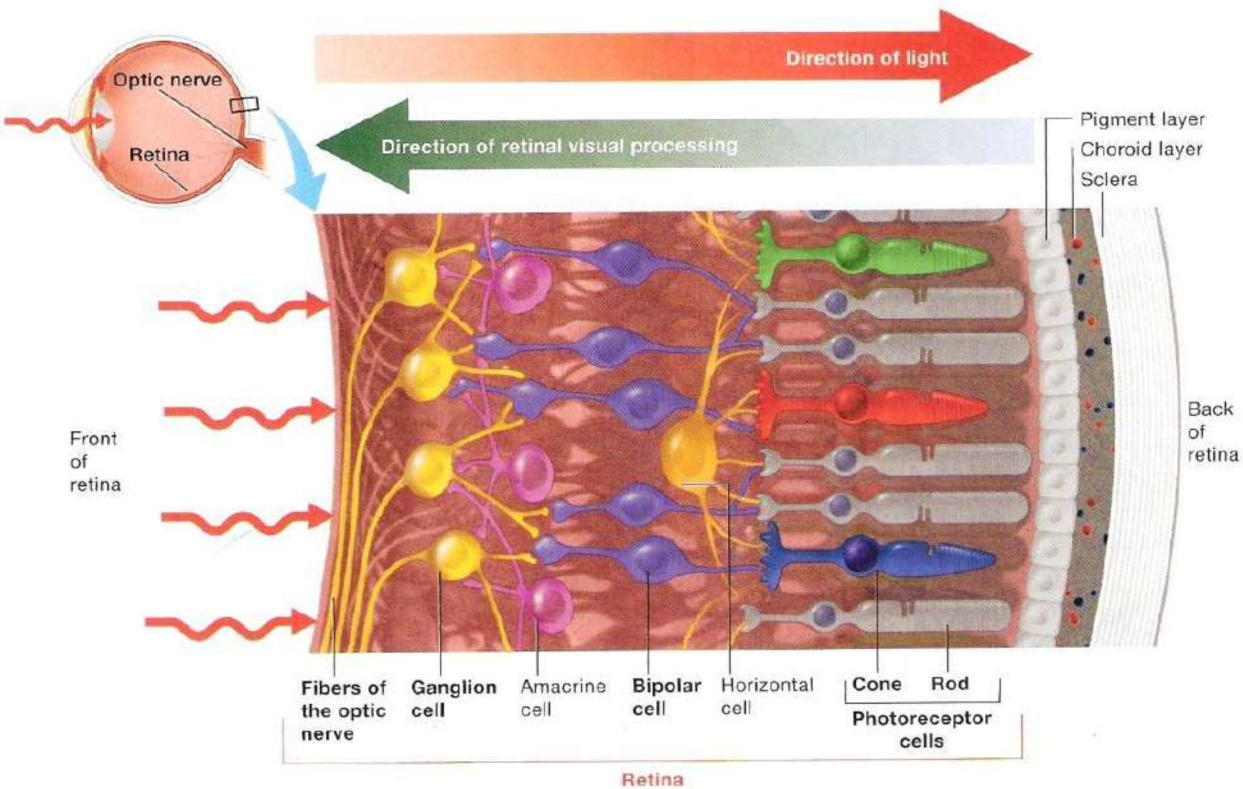
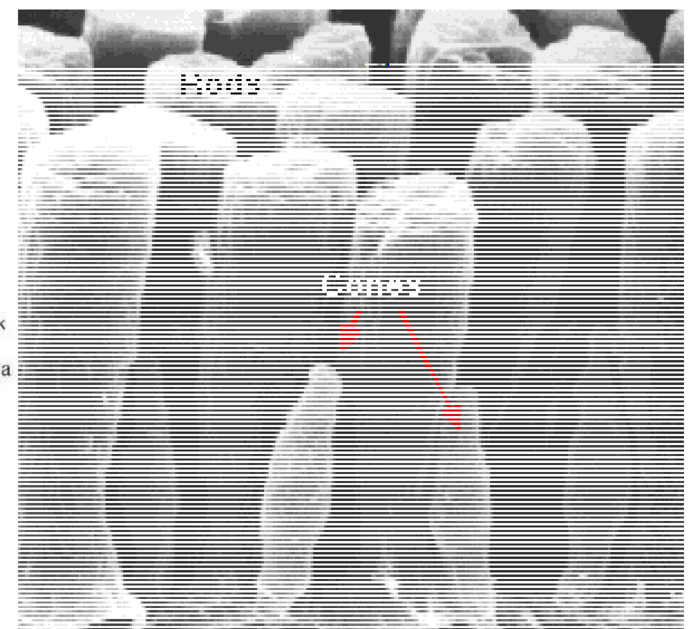


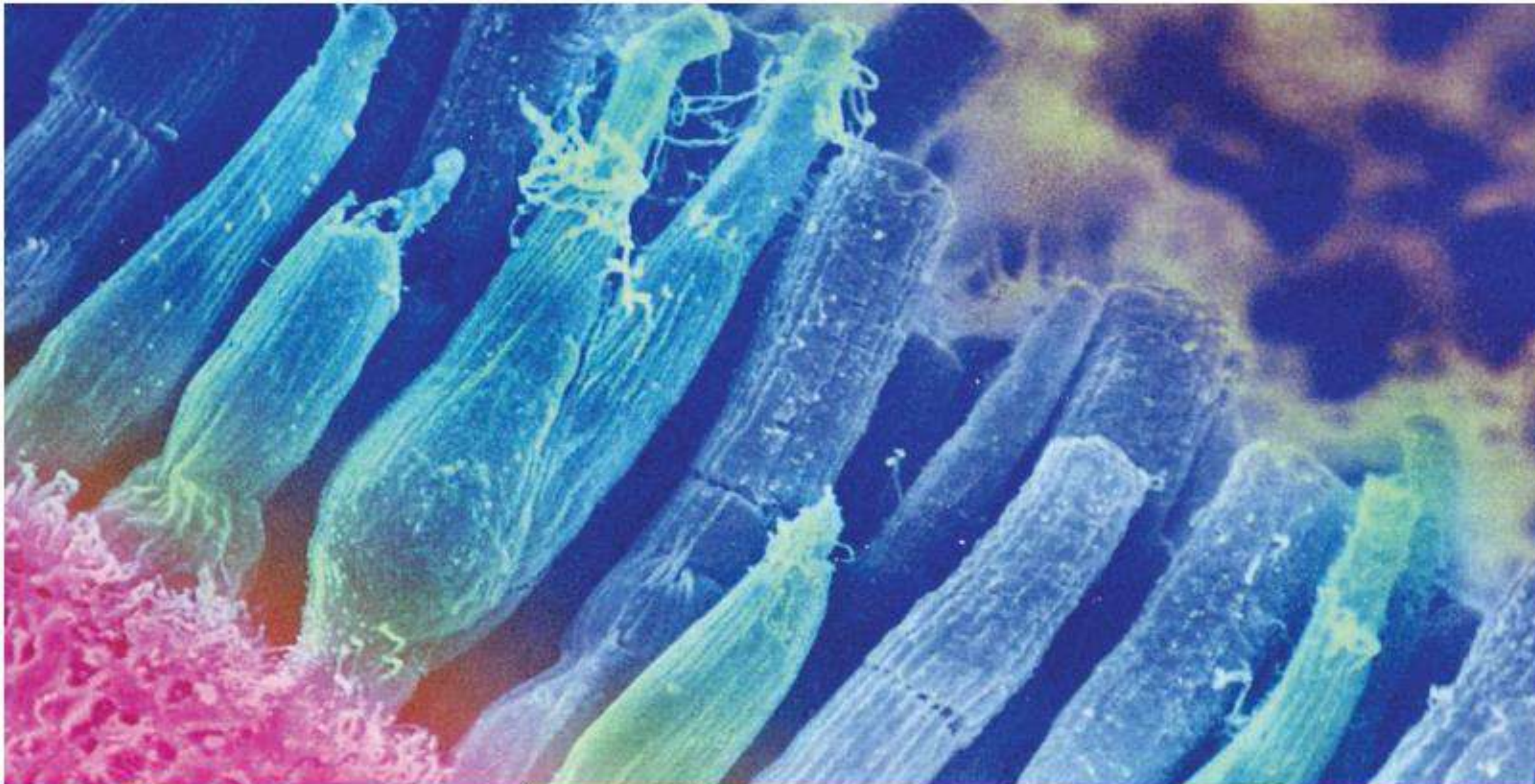
Fig. 1.1. A drawing of a section through the human eye with a schematic enlargement of the retina.

- The neural portion of the retina consists of three layers of excitable cells:

1. The enter most layer containing the **rods** and **cons**, whose light-sensitive ends face the choroids.
2. A middle layer of **bipolar cells**.
3. An inner layer of **ganglion cells**, and its axons joint together to form the **optic nerve.**







Science Source

A scanning electron micrograph of rods and cones. Rods and cones are the photoreceptors (light detectors) in the eye. Their outer segments, which are rod shaped in rods (*blue*) and cone shaped in cones (*green*), contain photopigments that absorb light in the initial step of vision.

- We are normally not aware of the blind spot, because <u>central processing somehow "fill in" the missing spot</u>.

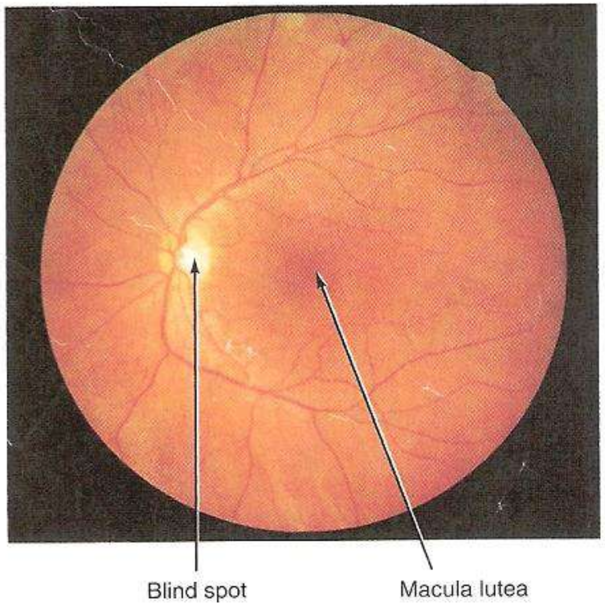
You can discover the existence of your own blind spot by a simple demonstration.

In the fovea, which is a pinhead-sized depression located in the exact center of the retina, the bipolar and ganglion cell layer are pulled aside so that light strikes photoreceptors directly.

FIGURE 6-23

View of the retina seen through an ophthalmoscope

With an ophthalmoscope, a lighted viewing instrument, it is possible to view the optic disc (blind spot) and macula lutea within the retina of the rear of the eye.



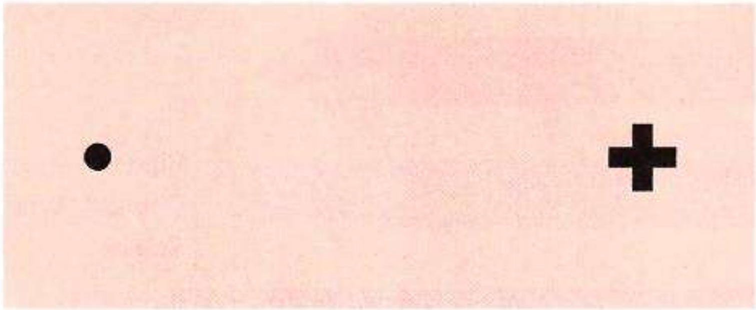


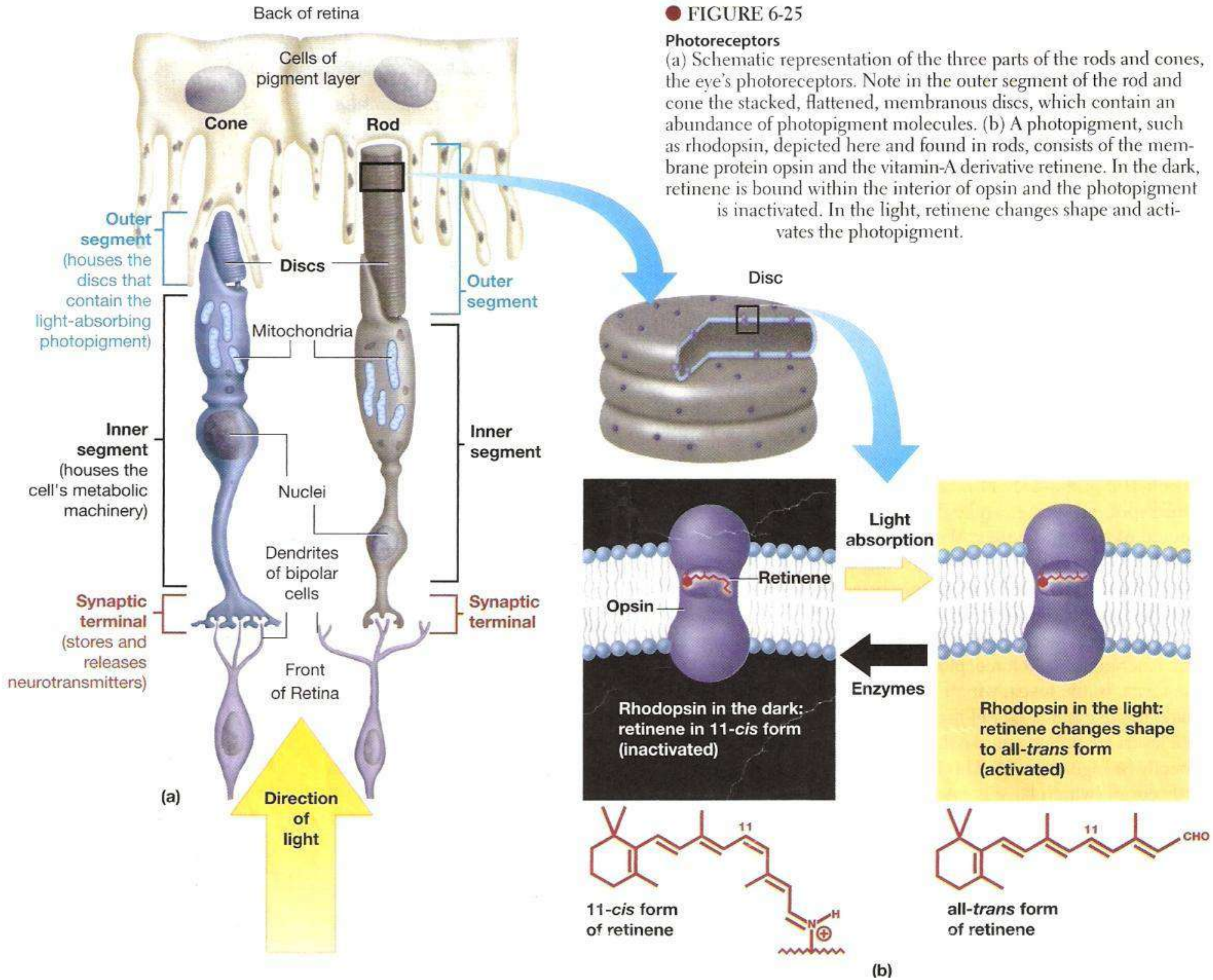
FIGURE 6-24

Demonstration of the blind spot

Discover the blind spot in your left eye by closing your right eye and holding the book about 4 inches from your face. While focusing on the cross, gradually move the book away from you until the circle vanishes from view. At this time, the image of the circle is striking the blind spot of your left eye. You can similarly discover the blind spot in your right eye by closing your left eye and focusing on the circle. The cross will disappear when its image strikes the blind spot of your right eye.

Phototransduction by retinal cells converts light stimuli into neural signal

- **Photoreceptors** (rods & cons)
  - About (100 – 150 M).
  - consists of three parts:
    1) Outer segment, detects the light stimulus
       - Composed of stacked مكدسة, flattened, membranous discs containing an abundance of light-sensitive **photopigment** molecules.
       - Over a billion photopigment molecules may be packed into the outer segment of each photoreceptor.
    2) Inner segment:
       - contains the metabolic machinery of the cell.
    3) Synaptic terminal:
       - Transmits the signal generated in the photoreceptor to the next cells in visual pathway.



● FIGURE 6-25

Photoreceptors

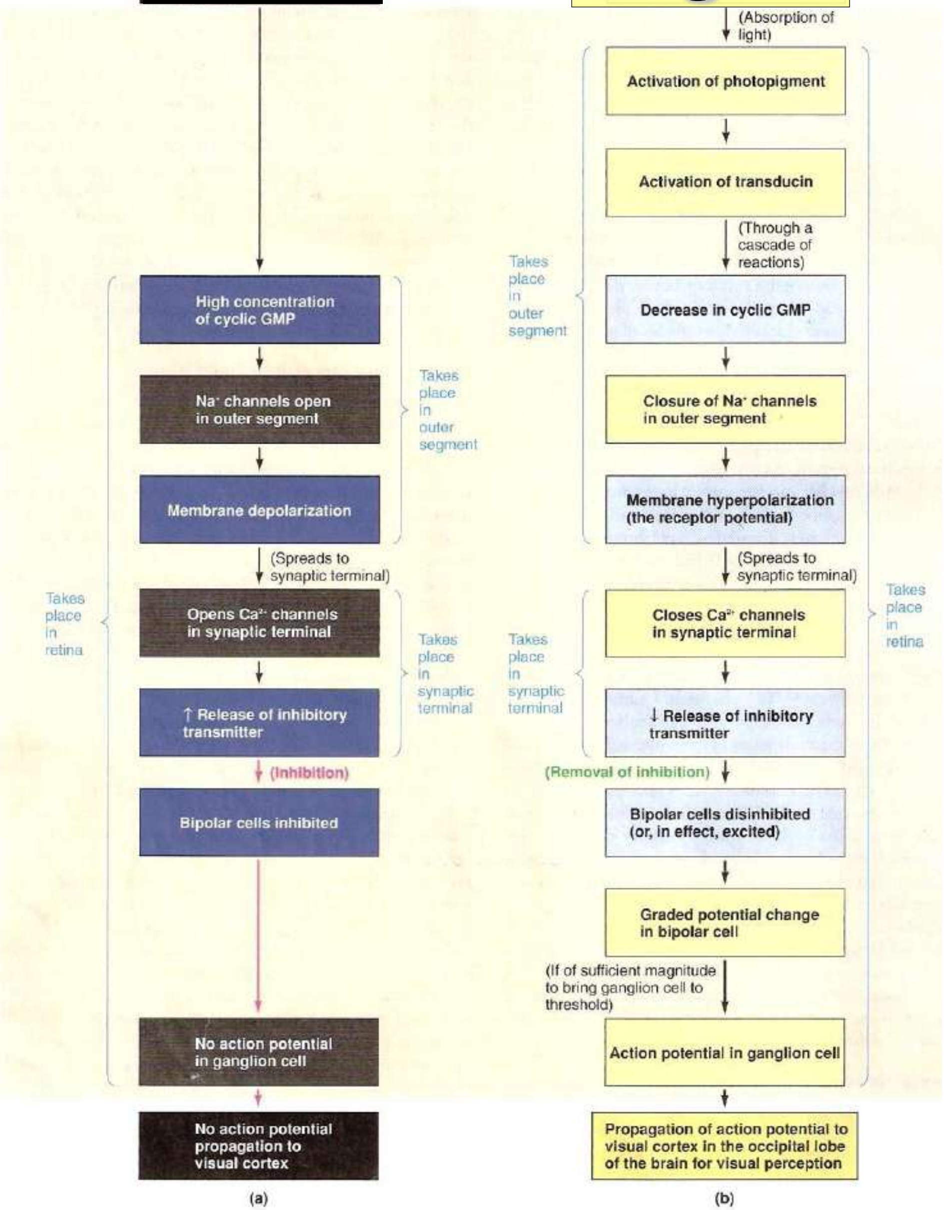
(a) Schematic representation of the three parts of the rods and cones, the eye's photoreceptors. Note in the outer segment of the rod and cone the stacked, flattened, membranous discs, which contain an abundance of photopigment molecules. (b) A photopigment, such as rhodopsin, depicted here and found in rods, consists of the membrane protein opsin and the vitamin-A derivative retinene. In the dark, retinene is bound within the interior of opsin and the photopigment is inactivated. In the light, retinene changes shape and activates the photopigment.

Photopigments

- Undergo chemical alterations when activated by light, bring about a receptor potential that ultimately leads to generation of action potentials.
- A photopigment consists of two components:
  - **Opsin:** a protein that is a integral part of the disc membrane.
  - **Retinene:**
    - a derivative of vitamin A that bound within the interior of the opsin molecule.
    - It is the light-absorbing part of the photopigment.
- Fig. 6-25 b

- There are three photopigments differentially absorb various wave lengths of light,
  - **Rhodopsin:** (**the rod photopigment**)
    - It cannot discriminate between various wave lengths in the visible spectrum; it absorbs all visible wave lengths.
  - **Red, green and blue cones:**
    - Respond selectively to various wavelengths of light, making color vision possible.
- **Phototransduction:**
  - The process of converting light stimuli electrical signals.
  - Receptors typically **depolarize** when stimulated, but photoreceptors **hyperpolarize** on light absorption.
- **Animation (Rhodopsin photoisomerisation).**

Photoreceptor activity in the Dark and Light



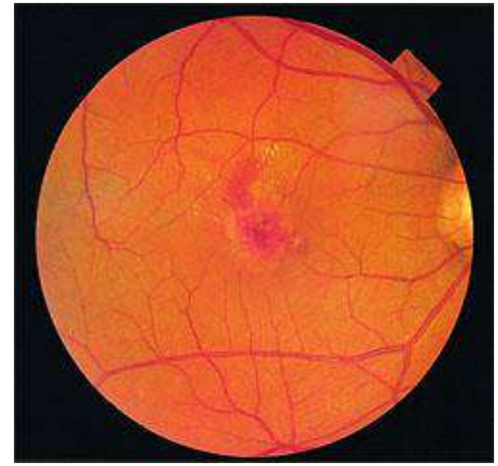
Further retinal processing of light input

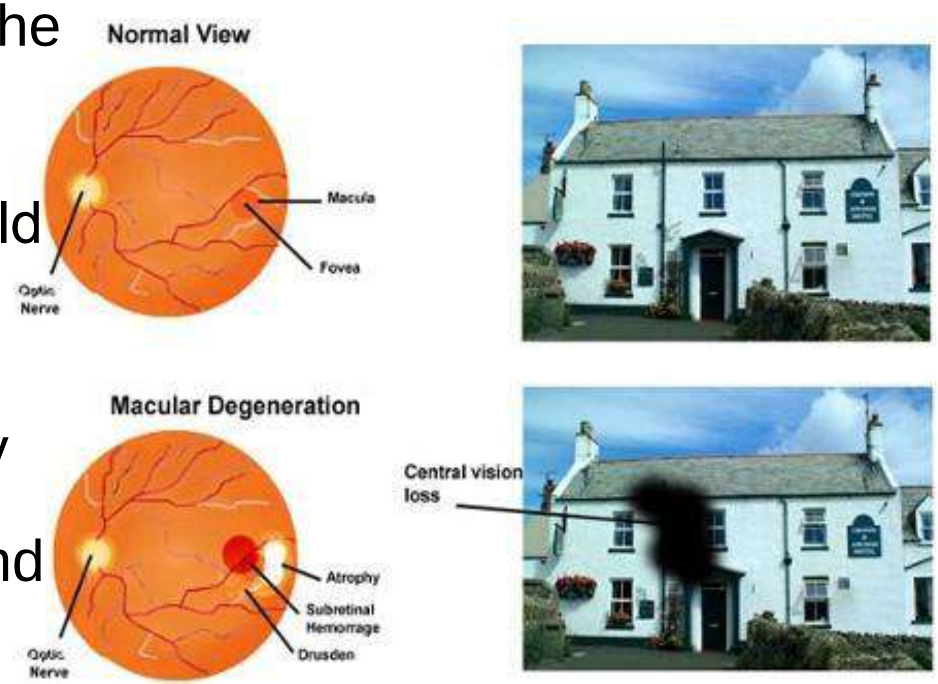
- **How does the retinal signal the brain about light stimulation through such an inhibitory response ?**
- The removal of inhibition has the same effect as direct excitation of the bipolar cells.
- The grater the illumination on the receptor cells, the greater the removal of inhibition from the bipolar cells and the greater in effect the excitation of these next cells in the visual pathway to the brain.
- Bipolar cells display graded potentials similar to the photoreceptors, while action potentials do not originate until the ganglion cells.

Researches

- currently working on an ambitious and still highly speculative micro electronic chip that would serve as a partial substitute retina, for whose ganglion cells and optic pathways remain healthy. For example: if successful the chip could benefit people with **macular degeneration**, the leading cause of blindness in the western hemisphere.

- The envisioned "**vision chip**" would bypass the photoreceptor step altogether: images received by means of a camera mounted on eyeglasses would be translated by the chip into electrical signals detectable by the ganglion cells and transmitted on for further optical processing.





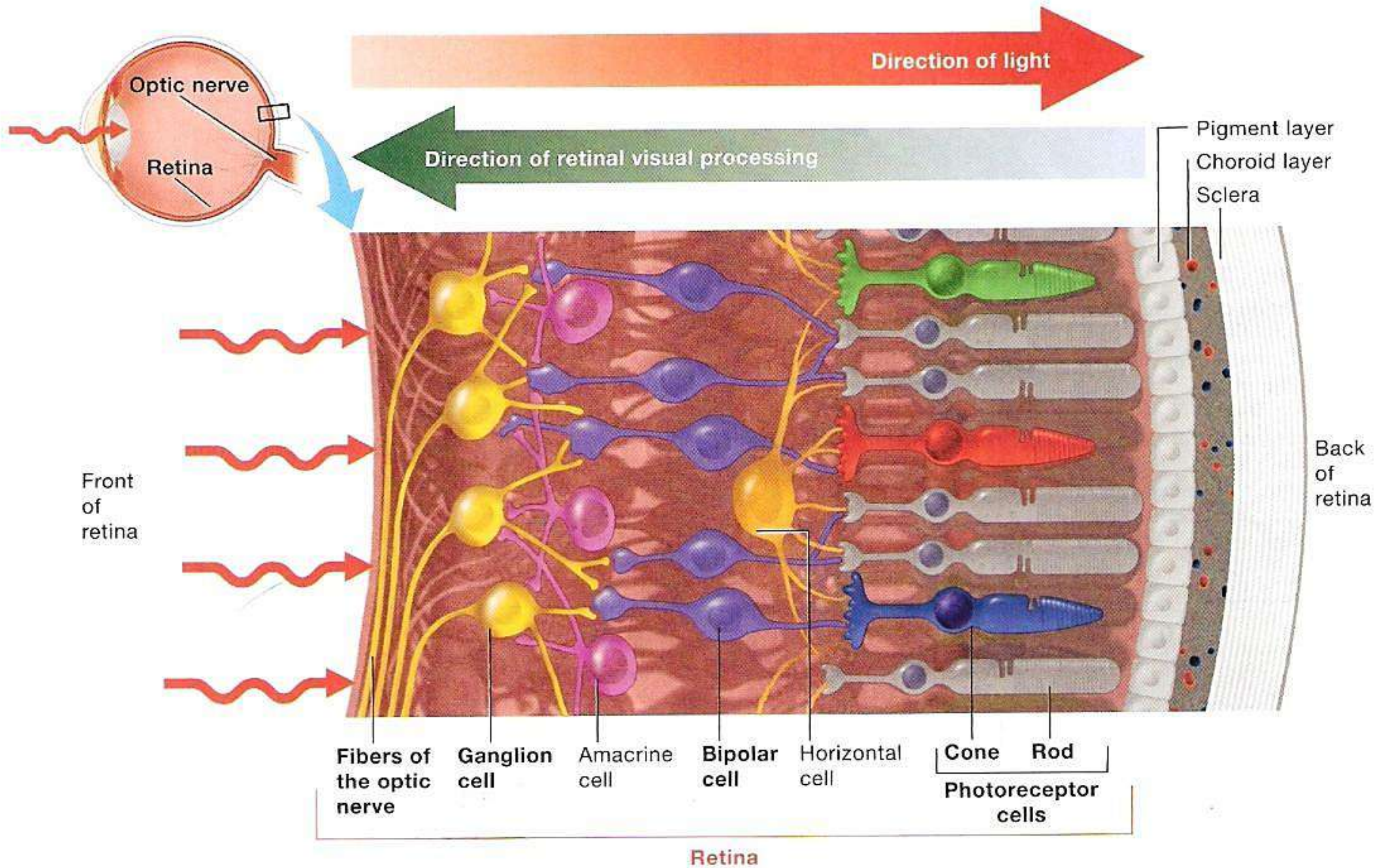
Rods provide indistinct gray vision at night, whereas, cones provide sharp color vision during the day

- Sharpness; ability to distinguish between two nearby points), thus cones provides sharp vision with high resolution for fine detail.
- Each cone generally has a private line connecting it to a particular ganglion cell.
- In contrast, there in much convergence in rod pathways, (out put from more than 100 rods may converge via bipolar cells on a single ganglion cell).

▲ TABLE 6-3

Properties of Rod Vision and Cone Vision

Rods	Cones
100 million per retina	3 million per retina
Vision in shades of gray	Color vision
High sensitivity	Low sensitivity
Low acuity	High acuity
Night vision	Day vision
Much convergence in retinal pathways	Little convergence in retinal pathways
More numerous in periphery	Concentrated in fovea



Optic nerve
Retina
Direction of light
Direction of retinal visual processing
Pigment layer
Choroid layer
Sclera
Front of retina
Back of retina
Fibers of the optic nerve
Ganglion cell
Amacrine cell
Bipolar cell
Horizontal cell
Cone
Rod
Photoreceptor cells
Retina

- Because rods can bring about action potentials in response to small amounts of light, they are much more sensitive than cones.
- However, because ones have private lines into the optic nerve, each cone transmits in formation about an extremely small receptive field on the retinal surface.
- Because many rods share a single ganglion cell, it is impossible to discern تميز which of the multiple rod inputs were activated to bring the ganglion cell to threshold.

The sensitivity of the eye can vary markedly through dark and light adaptation

1) Dark adaptation:

- Breakdown of photopigments during exposure to sunlight tremendously decreases photoreceptor sensitivity. For example; a reduction in rodopsoin content of only 0.6 % from its maximum value decreases rod sensitivity approximately 3000 times.
- In the dark, the photopigments broken down during light exposure are gradually regenerated, the sensitivity gradually increased.
- So that you can begin to see in the darkened surroundings.
- However, only the highly sensitive rejuvenated تتجدد rods are “turned on” by the dim light.

The sensitivity of the eye can vary markedly through dark and light adaptation

2) Light adaptation:

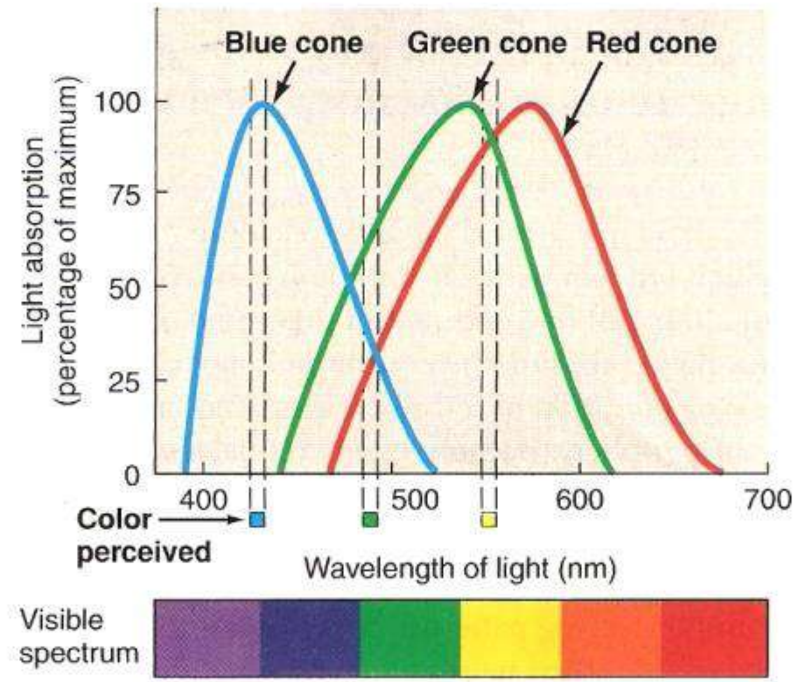
- In light adaptation your eyes are very sensitive to the dazzling light باهر at first, the entire image appears bleached with little contrast between lighter and darker parts.
- As some of the photopigments are rapidly broken down by the intense light, the sensitivity of the eyes decreases and normal contrasts can once again be detected.
- The rods are so sensitive to light that sufficient rhodopsin is broken down in bright light to essentially “burn out” the rods.
- Furthermore, a central neural adaptive mechanism switches the eye from the rod system to the cone system on exposure to bright light. Therefore, only the less sensitive cone are used for day vision.
- It is estimated that our eyes sensitivity can change as much as 1 million times as they adjust to various levels of illumination through dark and light adaptation, how ?

Night blindness

- Night blindness occurs as a result of dietary deficiency of vitamin A, as retinene (one of photopigment components) in a derivative of vitamin A.
- However, even modest reductions in rhodopsin content can decrease the sensitivity of rods so much that they cannot respond to dim light.
- Thus carrots are "*good for your eyes*" because are rich in vitamin A.

Color vision depends on the **ratios of stimulation** of the three cone types

- The pigments in various objects selectively absorb particular wave lengths of light transmitted to them from light-emitting sources, and the unabsorbed wavelengths are reflected from objects.
- Each cone type is activated by a particular wave length (**blue**, **red** and **green**).
- However, cones also respond in varying degrees to other wavelengths.



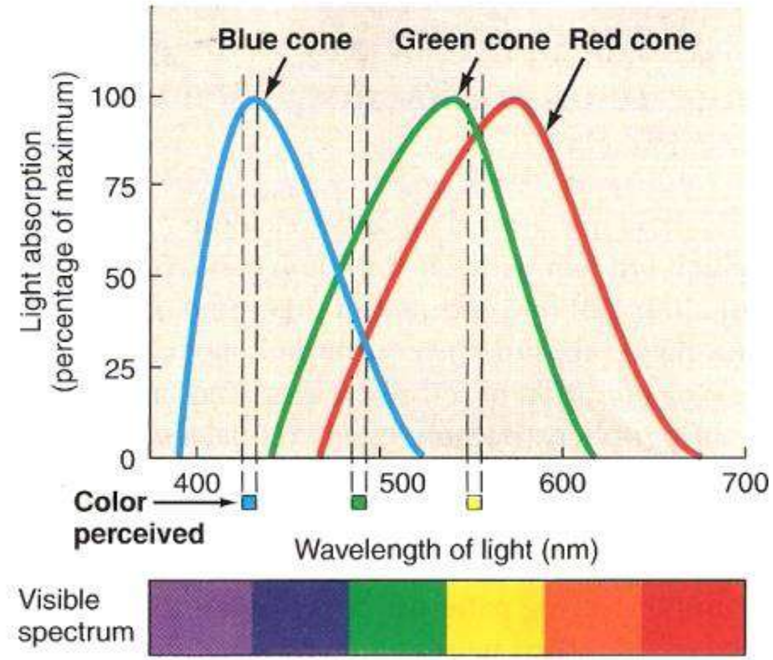
Color perceived	Percent of maximum stimulation		
	Red cones	Green cones	Blue cones
■	0	0	100
■	31	67	36
■	83	83	0

● FIGURE 6-27

Sensitivity of the three types of cones to different wavelengths The ratios of stimulation of the three cone types are shown for three sample colors.

Color vision depends on the **ratios of stimulation** of the three cone types

- **color vision**; our perception of the many colors of the world depends on the three cone types various **ratios of stimulation** in response to different wave lengths.
- The extent to which each of the cone types is excited is coded and transmitted in separate parallel pathways to the brain.
- a distinct color vision center in the primary visual cortex the perception of color, taking into consideration the object in comparison with its background.
- The concept of color is therefore in the mind of the beholder المشاهد.



Color perceived	Percent of maximum stimulation		
	Red cones	Green cones	Blue cones
(blue)	0	0	100
(green)	31	67	36
(yellow)	83	83	0

FIGURE 6-27

Sensitivity of the three types of cones to different wavelengths The ratios of stimulation of the three cone types are shown for three sample colors.

Color blindness

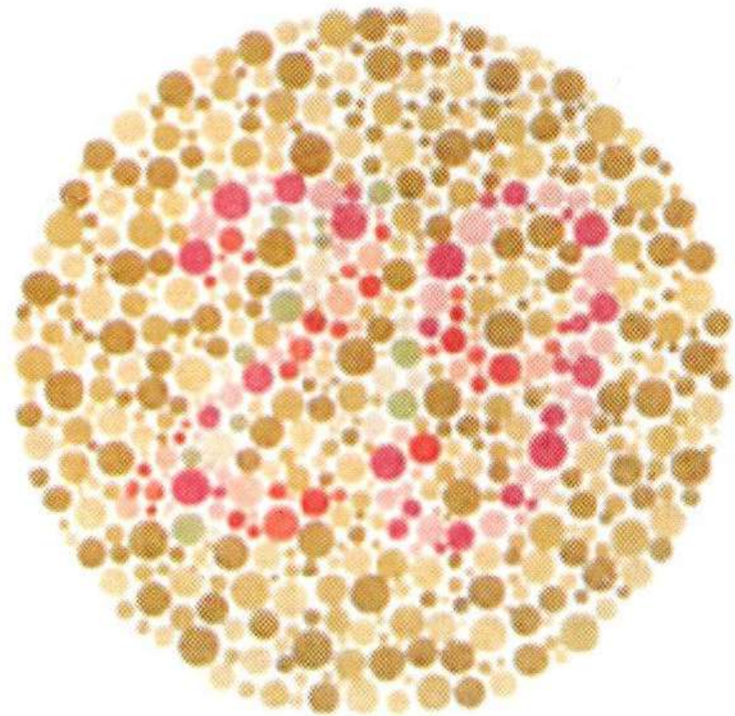
- At this condition individuals lack a particular cone type.

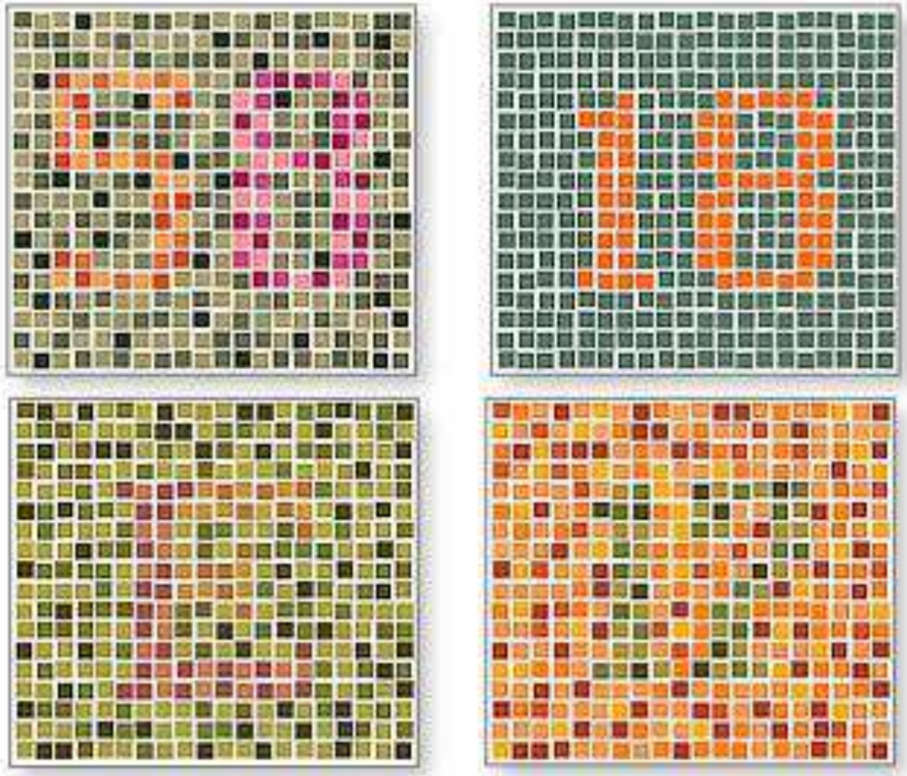
- So, their color vision is a product of the differential sensitivity of two types of cones.

FIGURE 6-28

Color blindness chart

People with red-green color blindness cannot detect the number 29 in this chart.



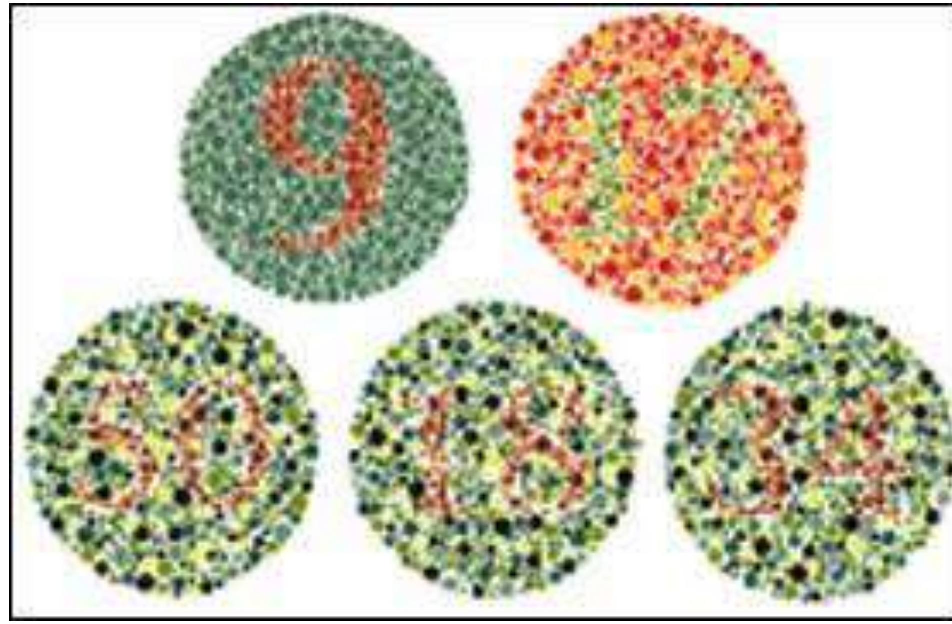


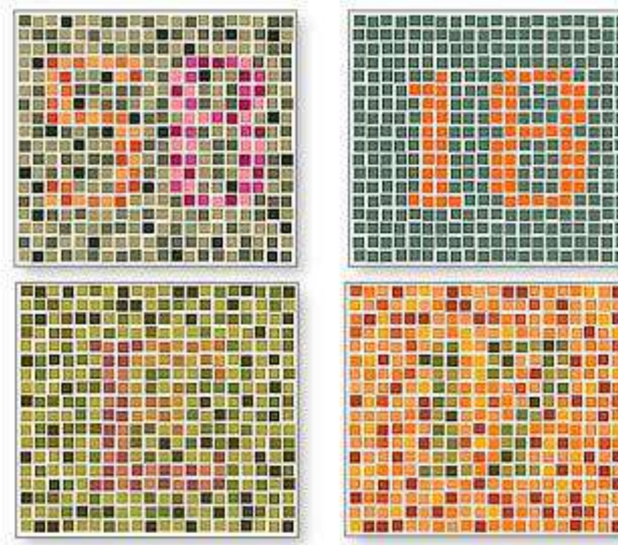
Various tests for color blindness

A.D.A.M.

Test

- **The color blindness test consists of a set of five charts. Each chart shows a number in one color on a different backgound color. People with normal color vision will have no problem seeing the numbers on the charts, but people with color blindness will see only random colored dots. Seventy-five percent of color blind people have poor green perception. Of the remaining, 24% have poor red perception, and one percent are affected by a rare tritan type.**



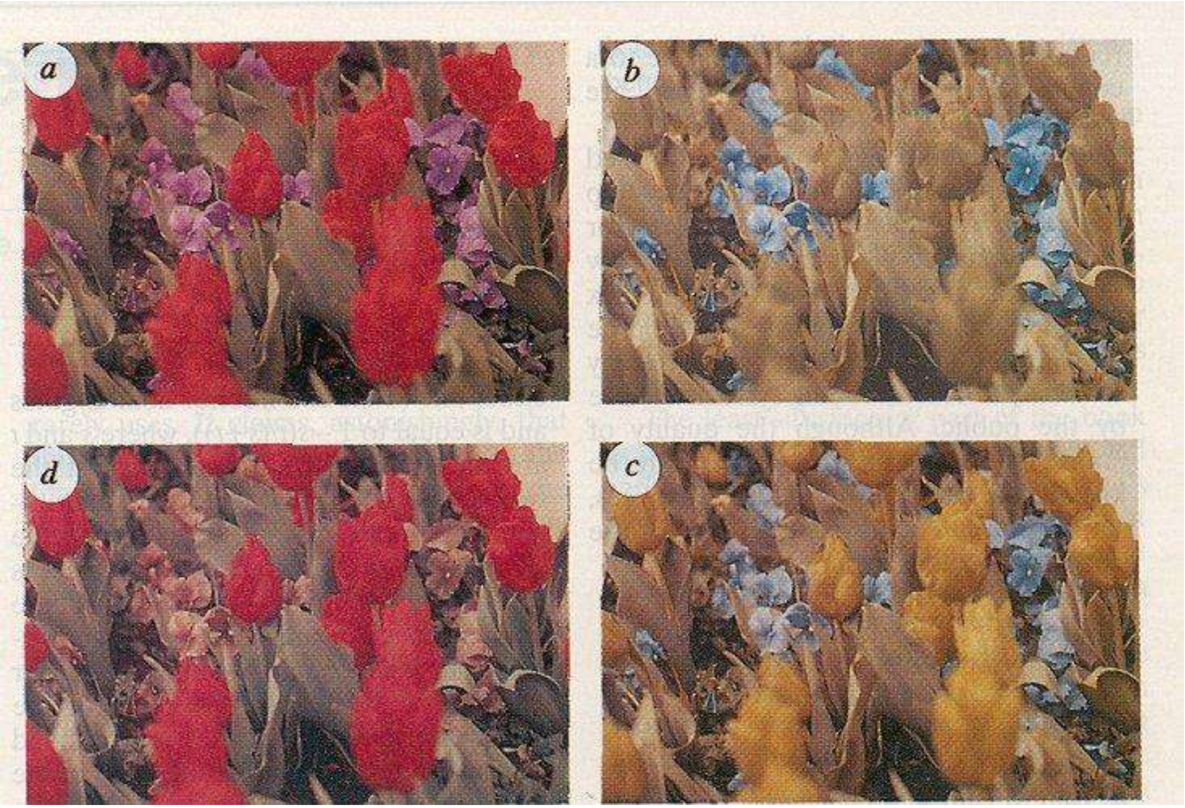


Various tests for color blindness

ADAM.

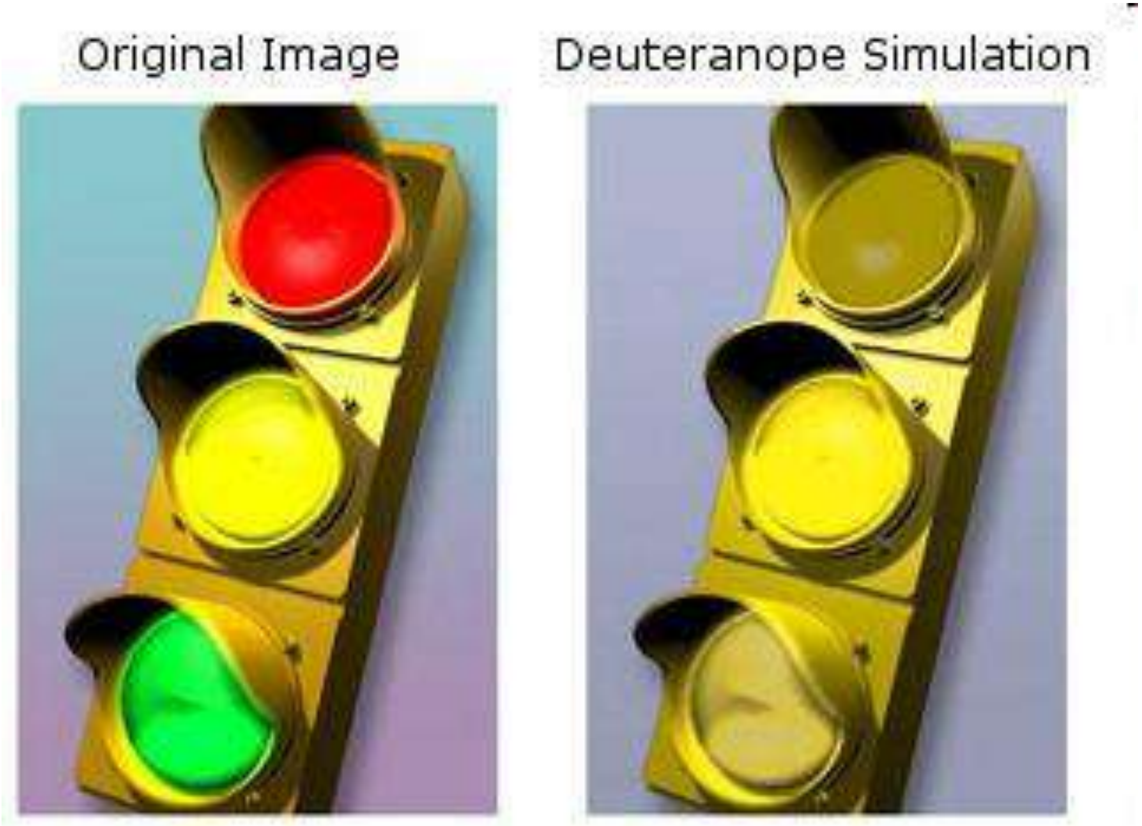
http://www.exploratorium.edu/cmp/exhibits/c/color_blindness.html

- Color-blindness individuals not only do perceive colors differently, but also unable to distinguish as many varieties of colors.



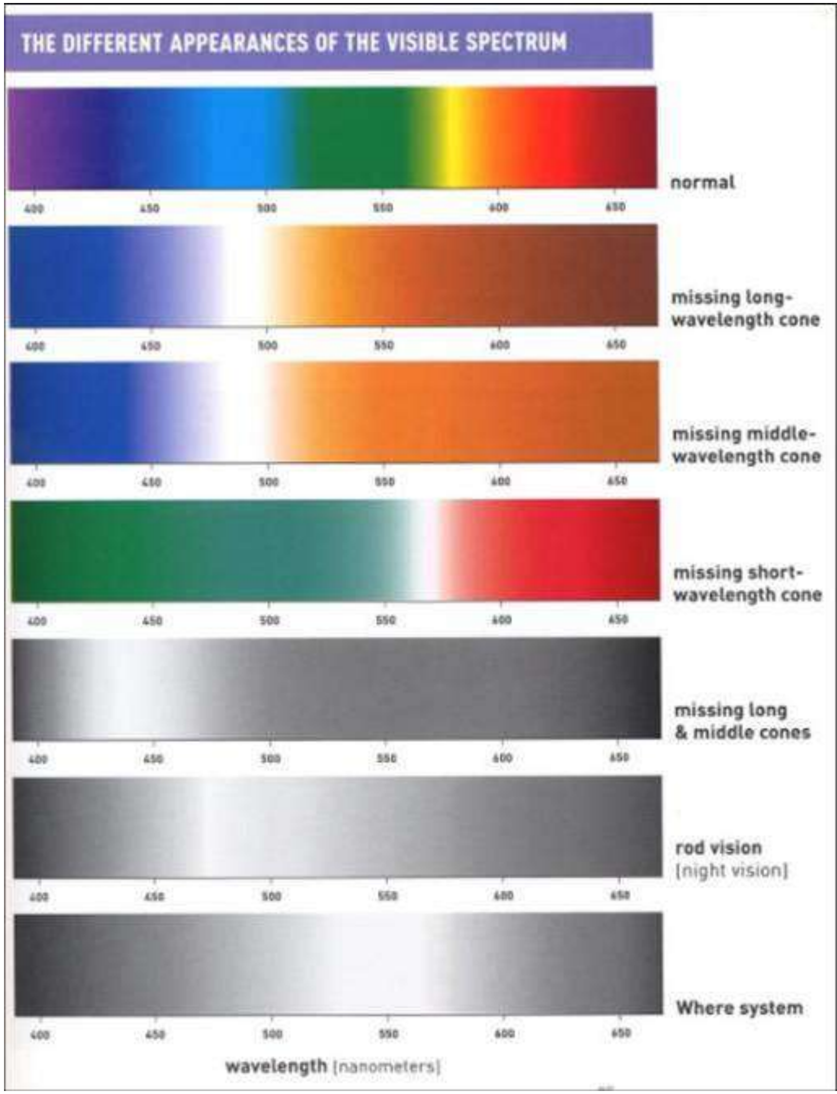
Color-Blindness

- **People who are color-blind cannot make distinctions between certain color combinations.**



Colorblind Comparison

- DNA studies have shown that men have a variable number of genes coding for cone pigments (e.g. whom have 2-4 genes for red light could distinguish more subtle differences in color in this long-wavelength range than those with single copies of red cone genes.



EAR

Hearing and Equilibrium

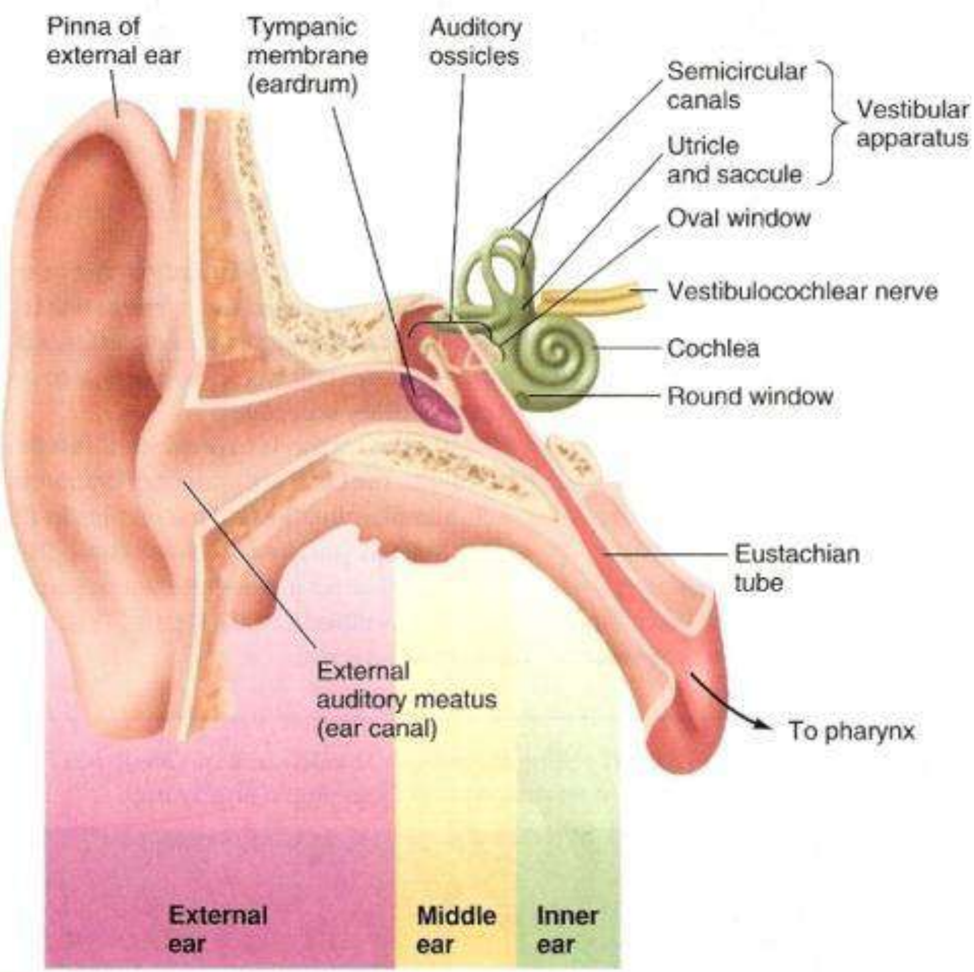


FIGURE 6-33
Anatomy of the ear

Ear: Hearing and Equilibrium

- The three parts of the ear that transmit and amplify the sound wave:

1. **External**,
2. **Middle** and
3. **Inner ear** contains ***cochlea*** (containing the receptors) and ***vestibular apparatus*** (necessary for the sense on equilibrium).

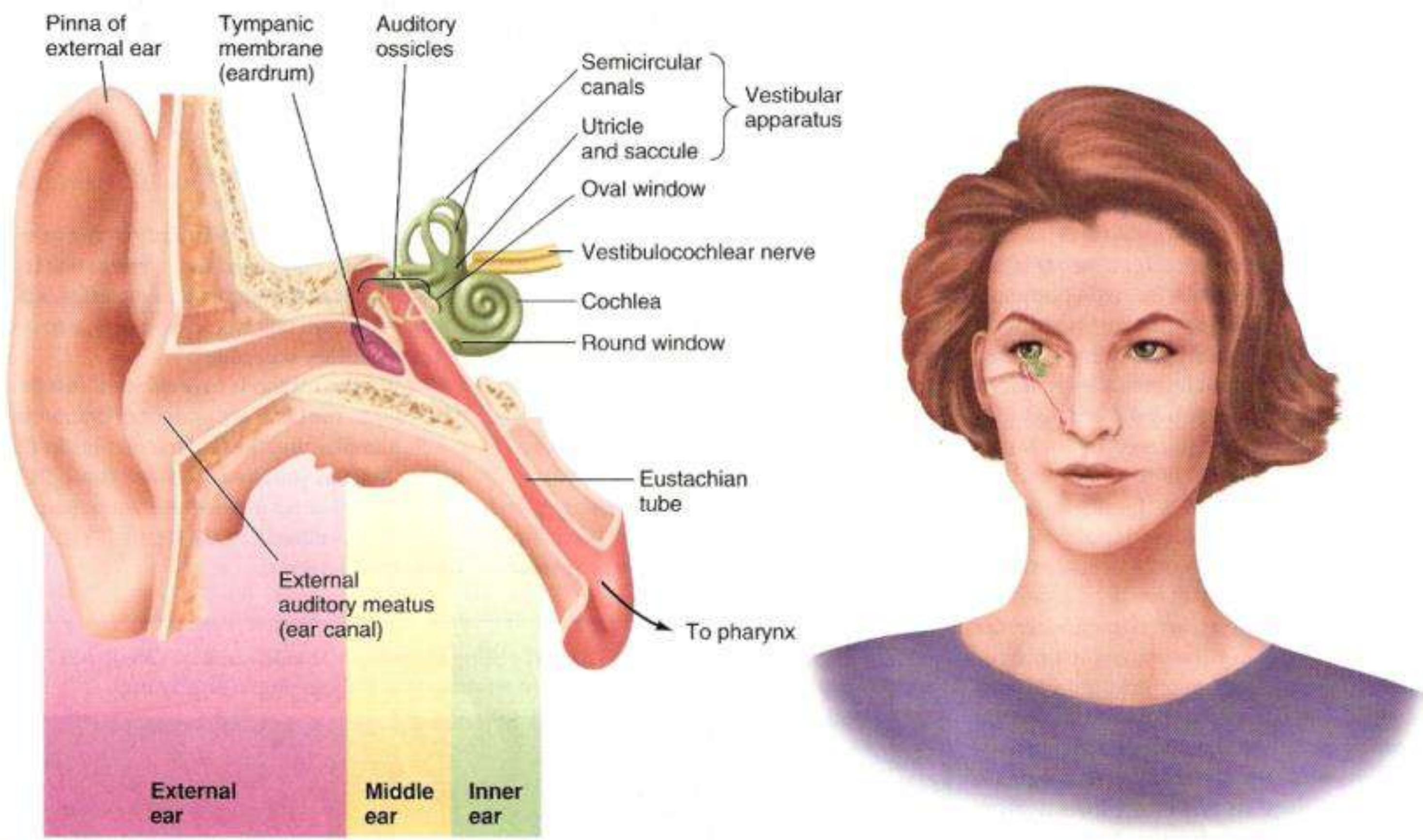
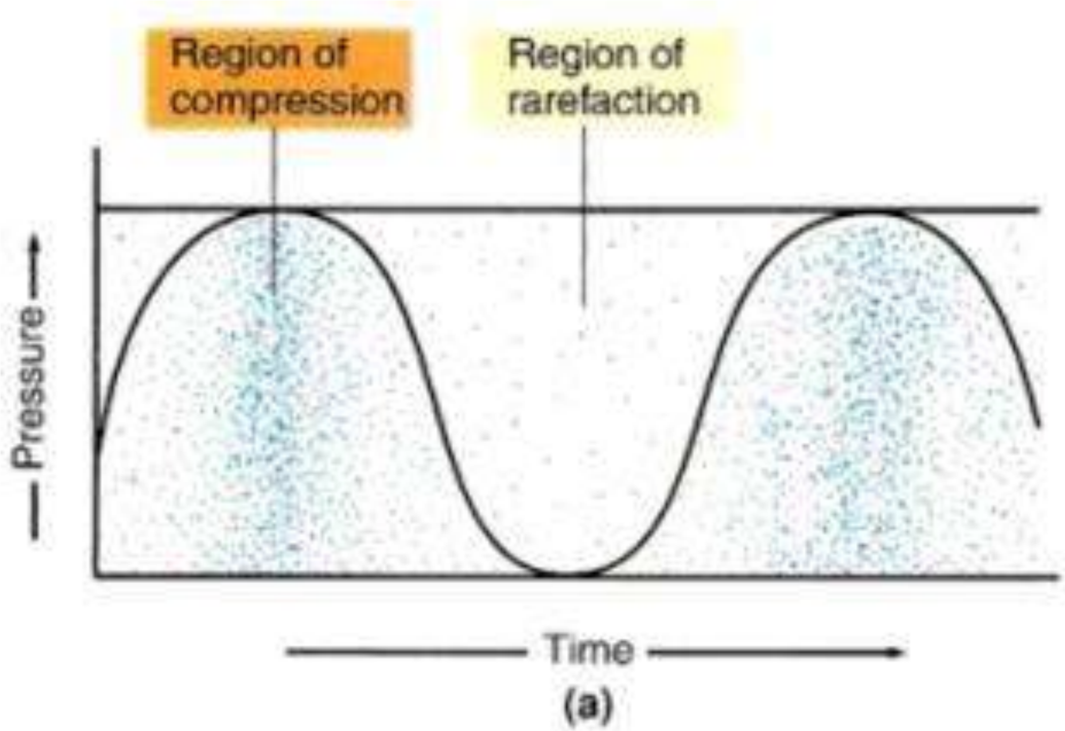


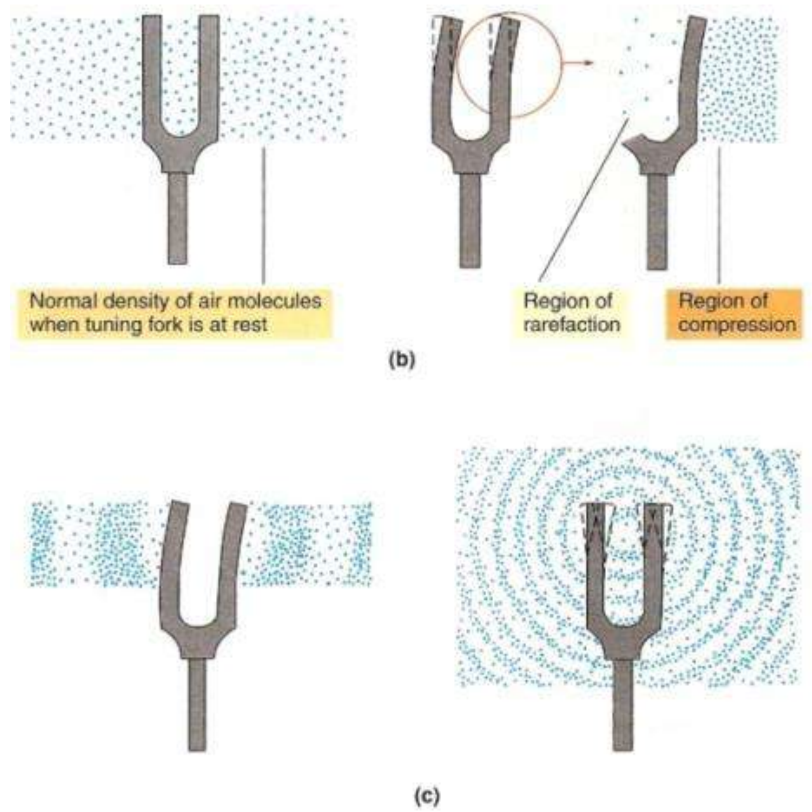
FIGURE 6-33
Anatomy of the ear

Sound waves consist of alternate regions of compression and rarefaction

- **Hearing :** is the neural perception of sound energy involving two aspects :
  - Identification of the sounds (What) and
  - Their localization (Where).
- **Sound waves:** are traveling vibrations of air that consist of regions of high pressure caused by compassion of air molecules alternation with regions of low pressure caused by **rarefaction** of the molecules.
- **Animation**.



- Any device capable of producing such a disturbance pattern in air molecules is a source of sound e.g. Tuning fork.
- As the prong شعبة moves, wave of compression and rarefaction is created, even tough individual air molecules are moved only short distances, alternation waves spread out in rippling fashion.
- Sound waves can also travel through other media like water, but they do so less efficiently, However; greater pressures are required to cause movements of fluid, because of the fluid's greater inertia (resistance to change). Animation



Sound is characterized by **Pitch**, **Intensity** & **Timbre**

1. **Pitch (tone)** of sound نغمة أو نبرة أو طبقة الصوت

- Whether it is a C or G.
- Determined by the frequency of vibration.
- The greater the frequency of vibration, the higher the pitch.
- Human ear can detect 20-20000 cycle/sec, but sensitive to frequency (1000-4000) cycle/sec.

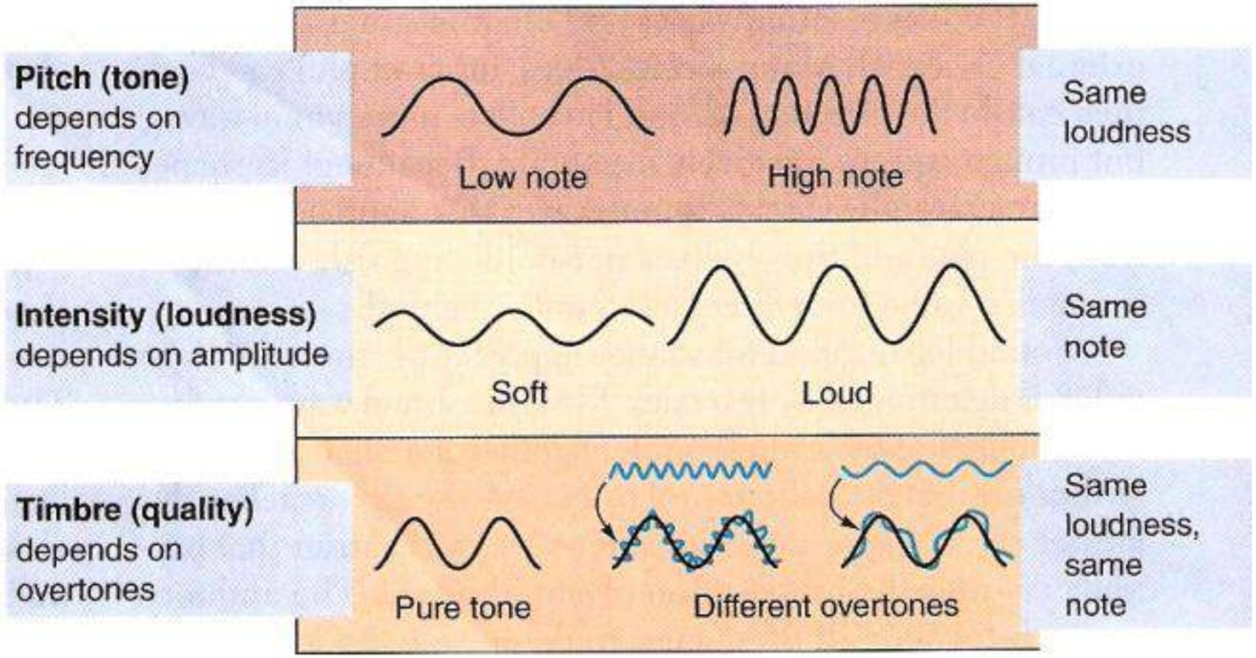


FIGURE 6-35
Properties of sound waves

Sound is characterized by Pitch, Intensity & timbre

2. **Intensity (loudness)** ارتفاع، قوة، شدة الصوت

- Depends on the amplitude of the sound wave or the pressure differences between compression and rarefaction.
- Within the hearing range, the greater the amplitude, the louder the sound.

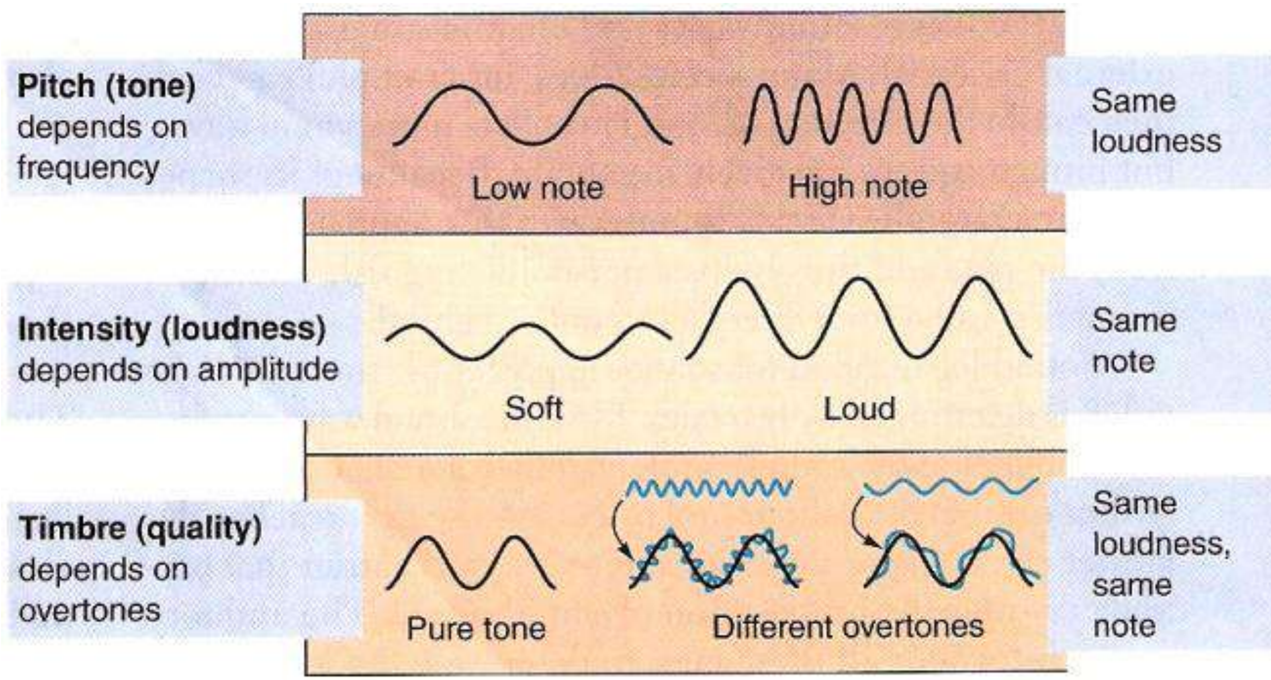


FIGURE 6-35
Properties of sound waves

- Loudness is expressed in **decibels (dB)**, which are a logarithmic measure of intensity compared with the faintest sound that can be heard **the hearing threshold.**
- Because the logarithmic relationship, every 10 decibels indicates a tenfold increase in loudness, example in table 6-5.
- Sounds greater than 100dB can permanently damage the sensitivity sensory apparatus in the cochlea.

▲ TABLE 6-5

Relative Magnitude of Common Sounds

Sound	Loudness in Decibels (dB)	Comparison to Faintest Audible Sound (Hearing Threshold)
Rustle of Leaves	10 dB	10 times louder
Ticking of Watch	20 dB	100 times louder
Hush of Library	30 dB	1 thousand times louder
Normal Conversation	60 dB	1 million times louder
Food Blender	90 dB	1 billion times louder
Loud Rock Concert	120 dB	1 trillion times louder
Takeoff of Jet Plane	150 dB	1 quadrillion times louder

Sound is characterized by Pitch, Intensity & timbre

3. Timbre (quality) الجرس، نغمة الصوت

- Depends on its **overtones**, which are additional frequencies superimposed on top of the fundamental pitch or tone.

Example: -different instruments play same note.
- characteristics differences in voices.

- Timbre enables the listener to distinguish the source of sound waves.

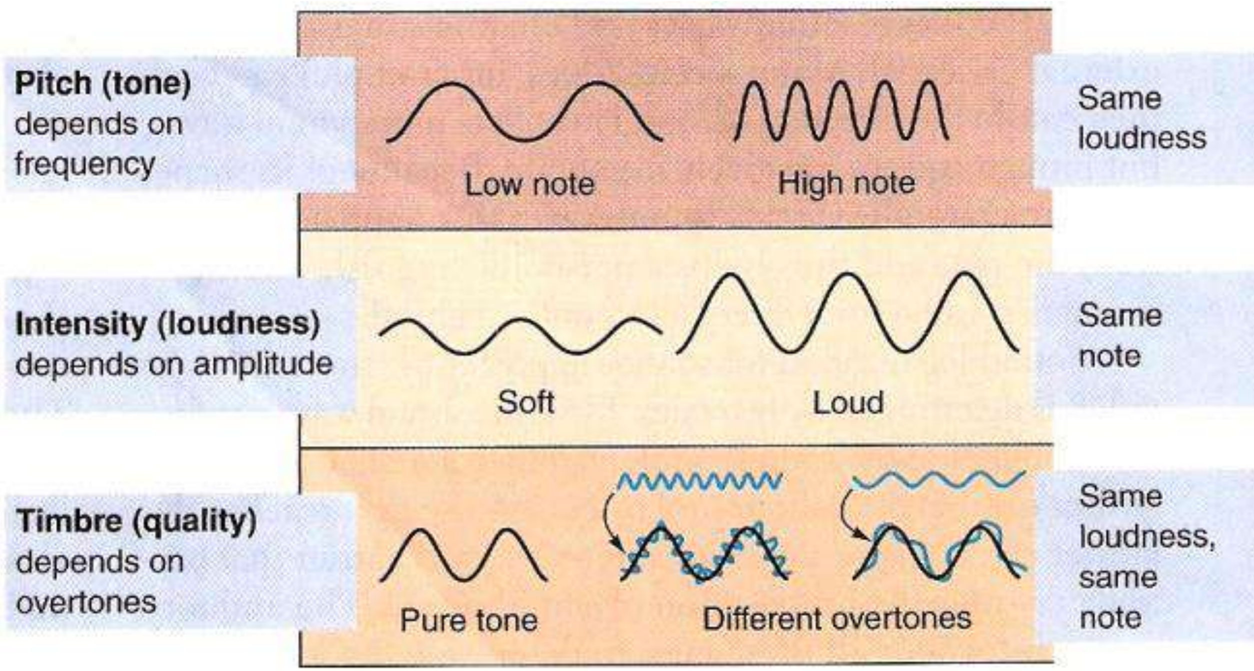


FIGURE 6-35
Properties of sound waves

The external ear play a role in sound localization

- Transmit and amplify sound wave to compensate the loss in sound energy.
- The external ear consists of **Pinna**, **External auditory meatus** and **Tympanic membrane**.
- The pinna collects sound waves and channels then to the inner ear.
- Sound localization determined by two cues:
- ***First***, the sound wave reaches the ear closer to the sound source slightly before it arrives at farther ear.
- ***Second***, the sound is less intense as it reaches the farther ear, because the head acts as a sound barrier that disrupts the propagation of sound waves.
- *Recent evidence suggests that the auditory cortex pinpoints the location of a sound by differences in the timing of neural firing patterns, not by any spatially organized map.*

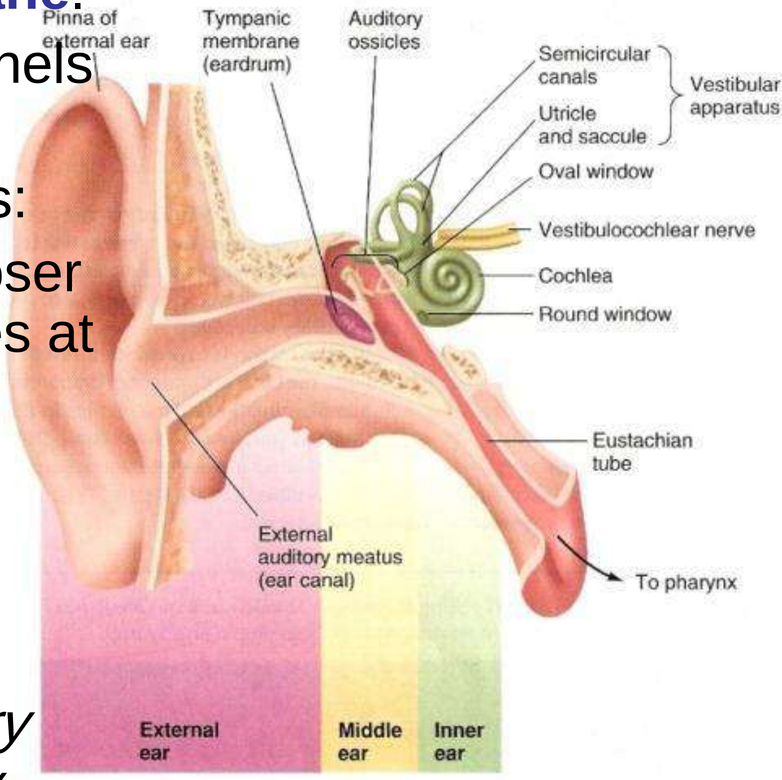


FIGURE 6-33
Anatomy of the ear

The tympanic membrane vibrates in unison انسجام with sound waves in the external ear

- The tympanic membrane vibrates when stretch by sound waves.
- air pressure on both sides of the tympanic membrane must be equalized by **Eustachian tube**, by pulled open by yawing, chewing and swallowing permits air pressure to equilibrate with atmospheric pressure.
- Examples:
  - **During air flight.**
  - **Infections (ENT).**

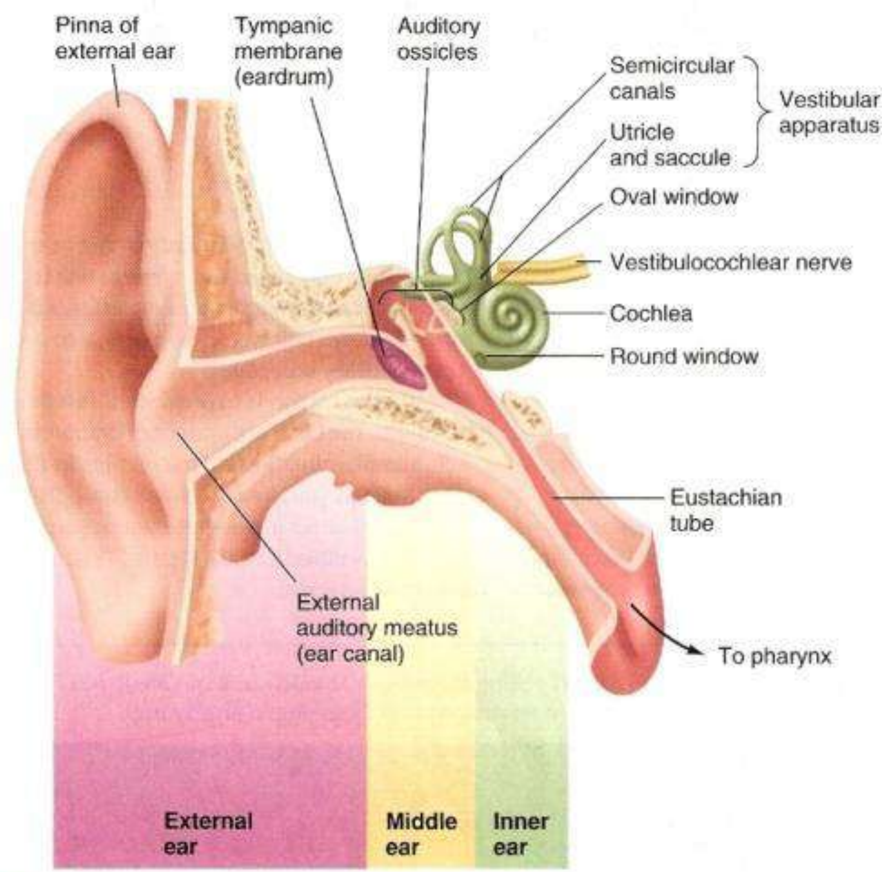
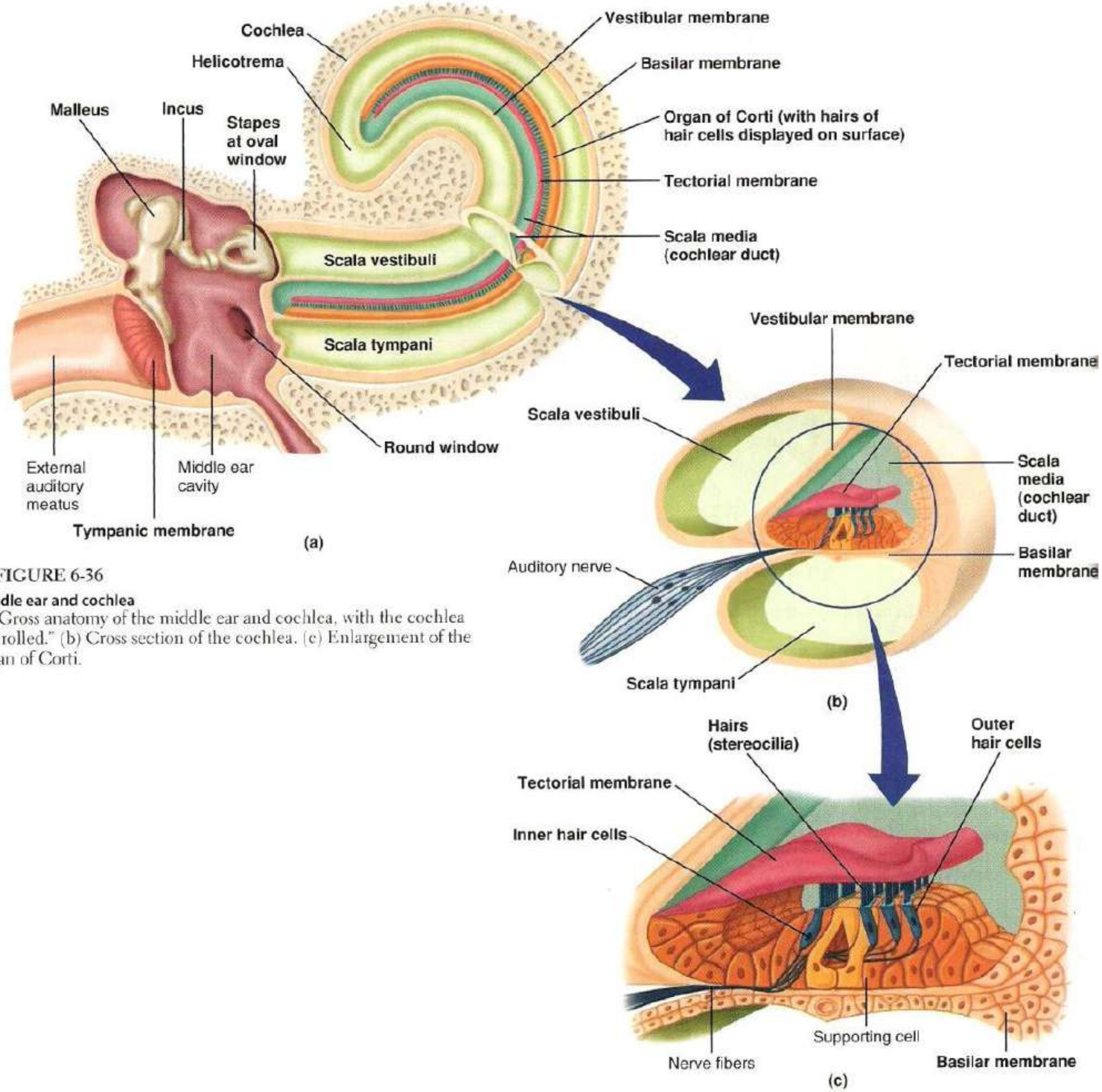


FIGURE 6-33
Anatomy of the ear



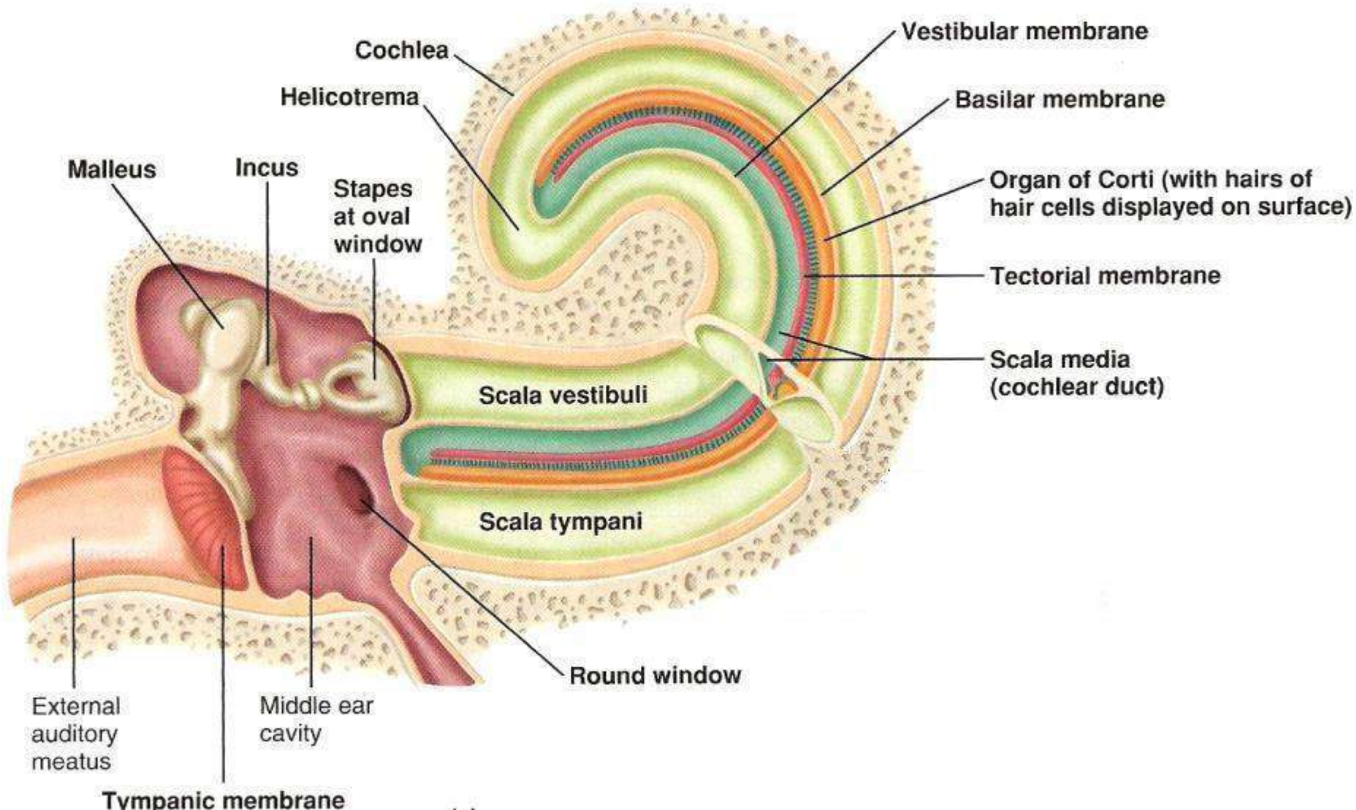
● FIGURE 6-36

Middle ear and cochlea

(a) Gross anatomy of the middle ear and cochlea, with the cochlea "unrolled." (b) Cross section of the cochlea. (c) Enlargement of the organ of Corti.

The middle ear bones convert tympanic membrane vibrations into fluid movements in the inner ear

- The transfer of sound from tympanic membrane to the oval window (at same frequency), is facilitated by a moveable chain of the three small bones or ossicles.
- The oval window with each vibration produces wave like movements in the inner ear fluid.



(a)

- Two mechanisms related to the ossiclear system amplify the pressure of the airborne sound waves to set up fluid vibrations in the cochlea

1) ***First*,** because the surface area of the tympanic membrane is much larger than that of the oval window.
2) ***Second*,** the lever رافعة action of the ossicles provides an additional advantage.

= These mechanisms increase the force exerted on the oval window by 20 times, what it would be if the sound wave struck the oval window directly.

= Several tiny muscles in the middle ear contract reflexly in response to loud sound (over 70dB), causing the tympanic membrane to tighten and limiting movement of the ossicular chain, to protect the delicate sensory apparatus from damage.

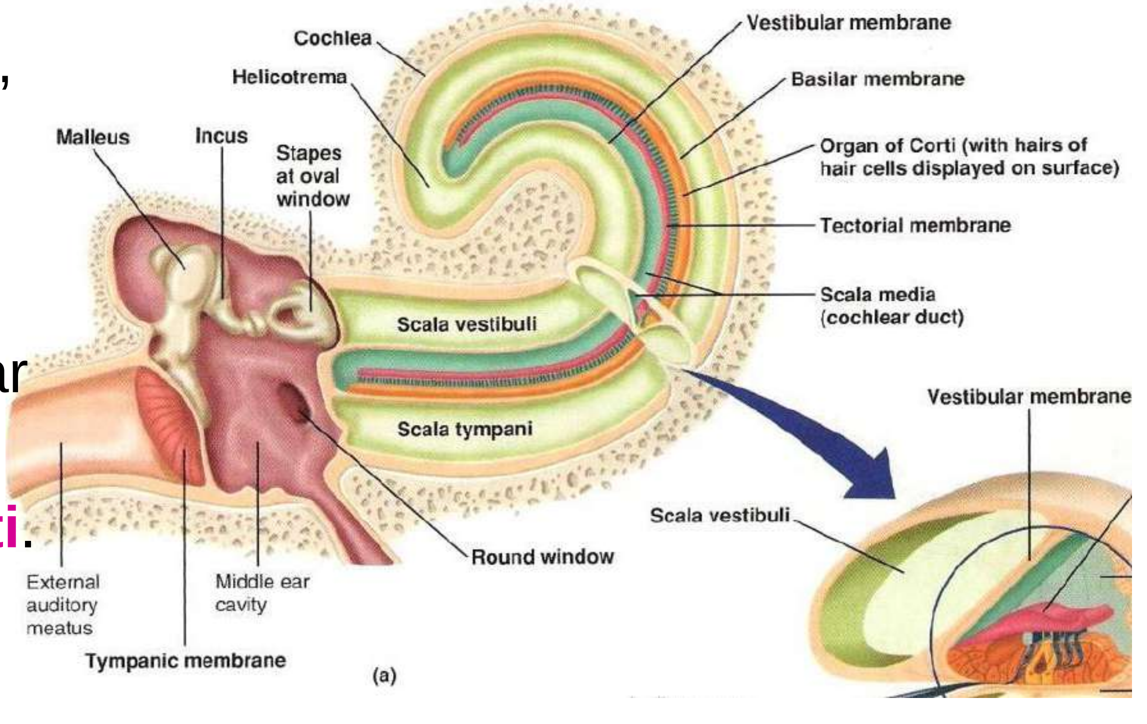
= This reflex response is relatively slow (40 msec) after exposure to loud sound, thus provides protection only from prolonged loud sounds not from sudden sounds like an explosion, e.g. World war II antiaircraft guns.

The cochlea contains the organ of corti, the sense organ for hearing

- The pea-sized, snail-shaped cochlea is coiled tubular system lying deep within the temporal bone.
- The cochlea is divided throughout most of its length into three longitudinal compartments.

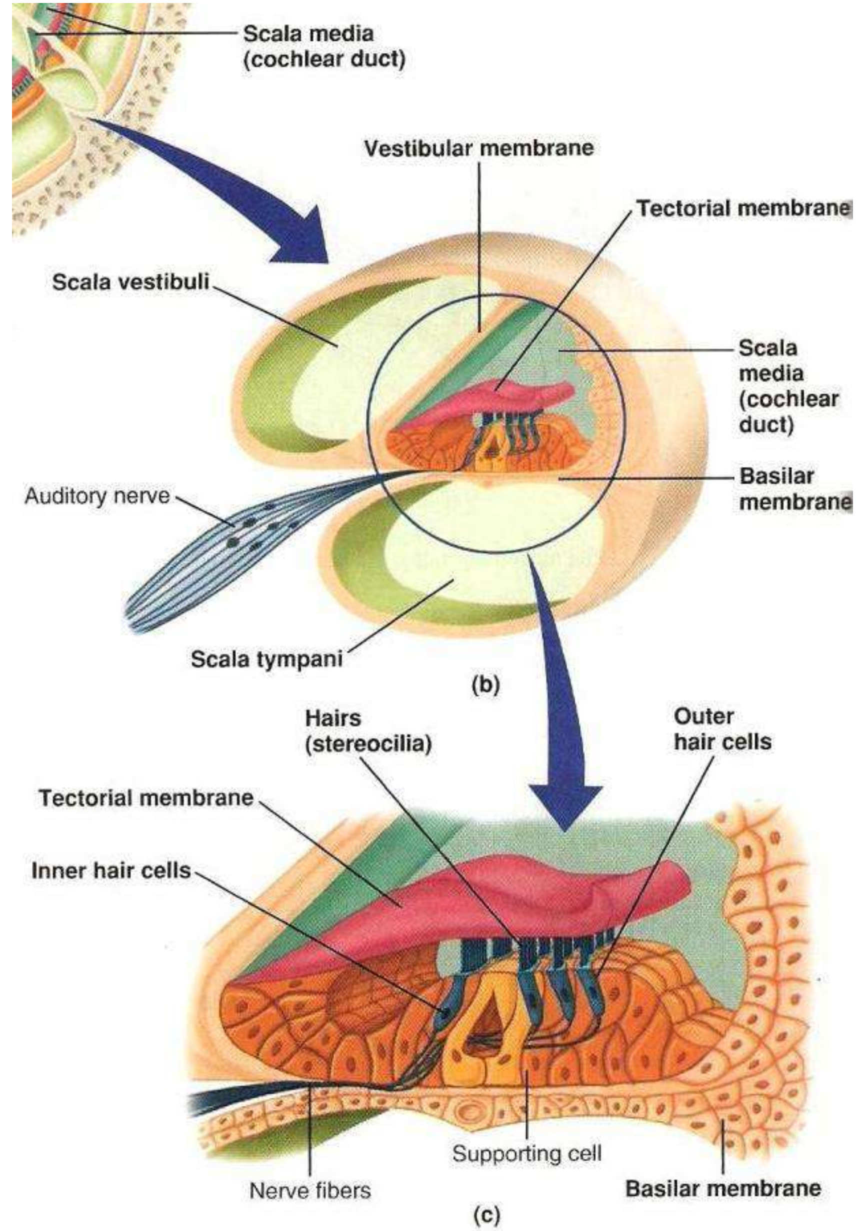
1. A blind-ended **cochlear duct**, which is also known as the **scala media**, contains ***endolymph.***
2. The upper compartment, the **scala vestibuli**, and sealed with ***oval window***.
3. The lower compartment, the **scala tympani.**

- In the scala media; the vestibular membrane is the ceiling while the basilar membrane is the floor that bears the organ of **corti**.



Hair cells in the organ of corti transduce fluid movements into neural signals

- The organ of corti contains hair cells that are receptors for sound, 16000 hair cells within each cochlea are arranged in four parallel rows along the length of the basilar membrane:
  - One row of **Inner hair cells** and
  - Three rows of **Outer hair cells**.
- Each hair cell protrude about 100 hair known as **sterocilia** (which are actin-stiffened micrivilli) that mechanically embedded in the **tectorial membrane**.
- Fig. 6-37 and **Animation**



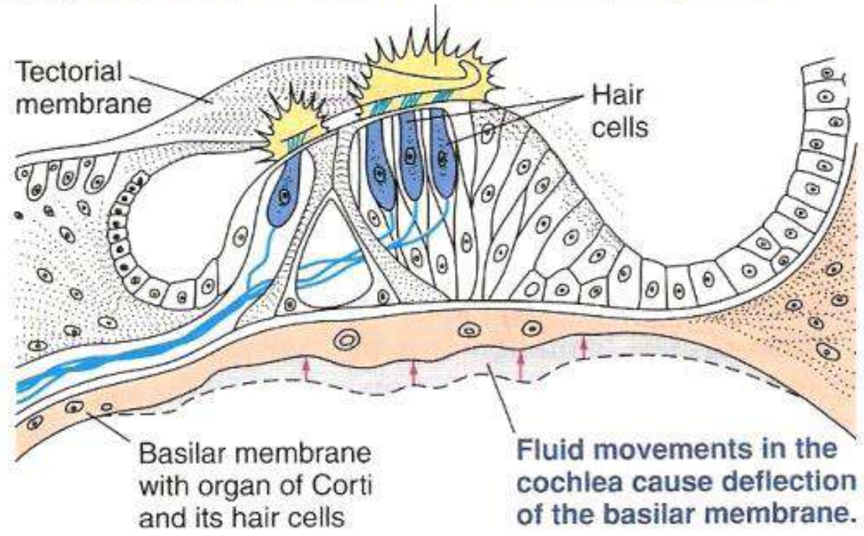
The role of Inner and Outer hair cells

- The inner hair cell are the ones that transform the mechanical forces of sound into the electrical impulses of hearing, then transmit it to the **auditory (cochlear) nerve**.
- The back-and –forth mechanical deformation of the hairs alternately opens and closes mechanically gated ion channels in the hair cell.

FIGURE 6-38

Bending of hairs on deflection of the basilar membrane

The stereocilia (hairs) from the hair cells of the basilar membrane are embedded in the overlying tectorial membrane. These hairs are bent when the basilar membrane is deflected in relation to the stationary tectorial membrane. This bending opens channels, leading to ion movements that result in a receptor potential.



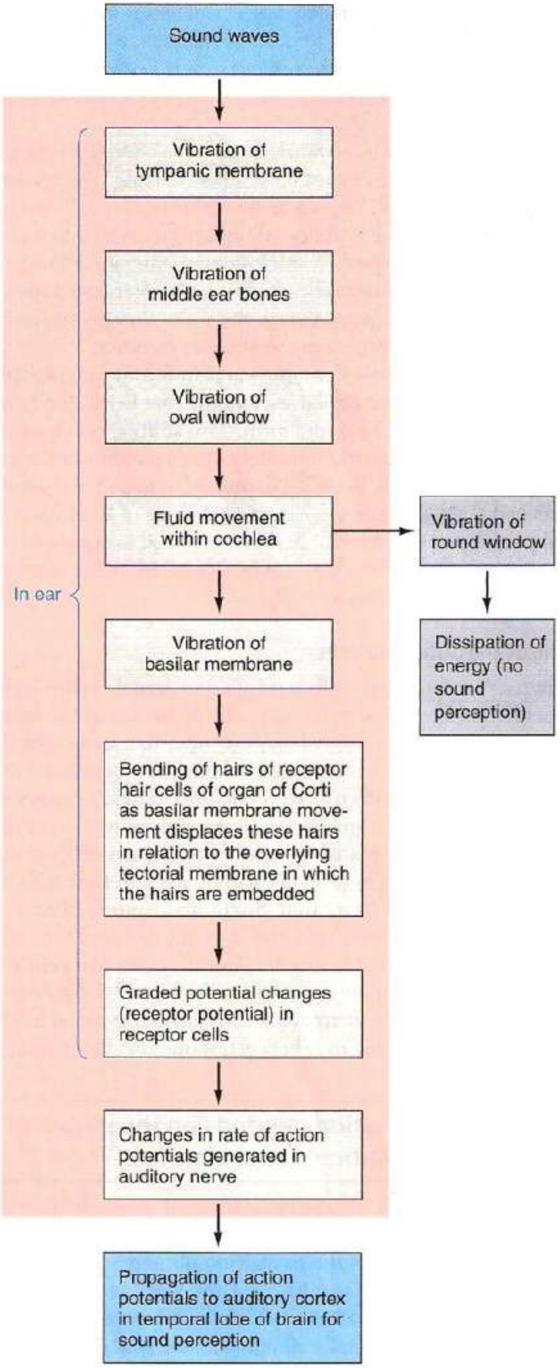


FIGURE 6-39
Sound transduction

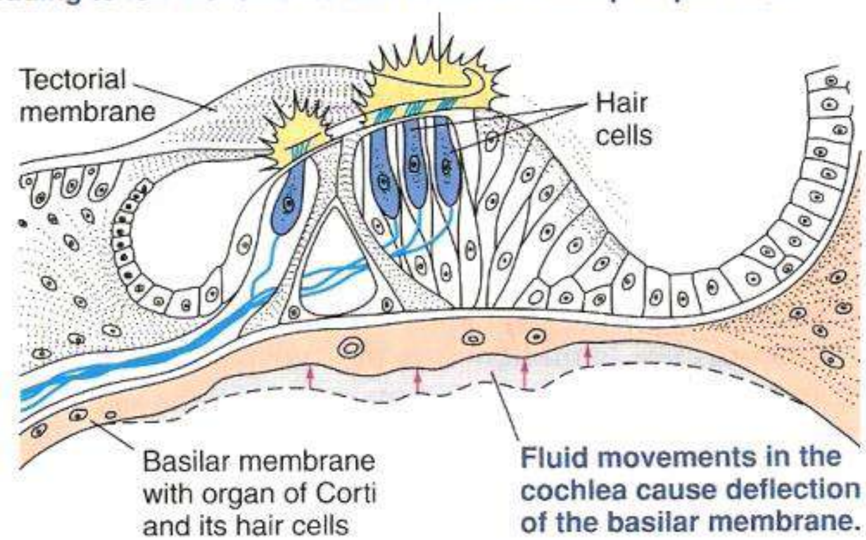
The role of Inner and Outer hair cells

- The outer hair cells actively and rapidly elongate in response to changes in membrane potential, a behavior known as **electromotility**.
- These changes in length are believed to amplify or accentuate the motion of the basilar membrane, such modification of basilar membrane movement is speculated to improve and tune the stimulation of the inner hair cells.

FIGURE 6-38

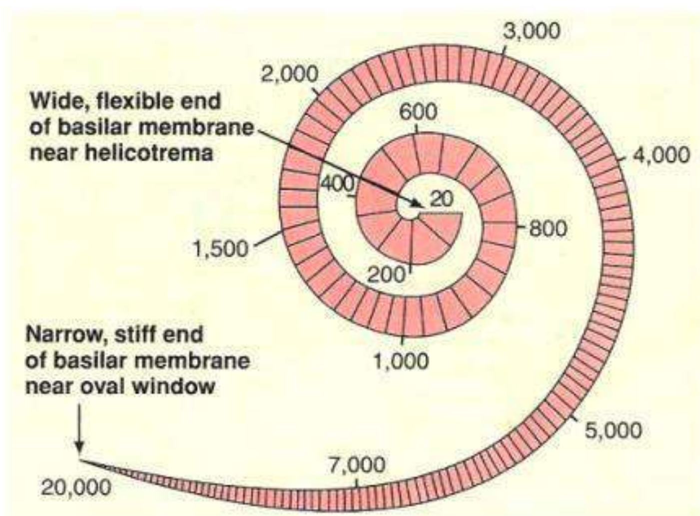
Bending of hairs on deflection of the basilar membrane

The stereocilia (hairs) from the hair cells of the basilar membrane are embedded in the overlying tectorial membrane. These hairs are bent when the basilar membrane is deflected in relation to the stationary tectorial membrane. This bending opens channels, leading to ion movements that result in a receptor potential.



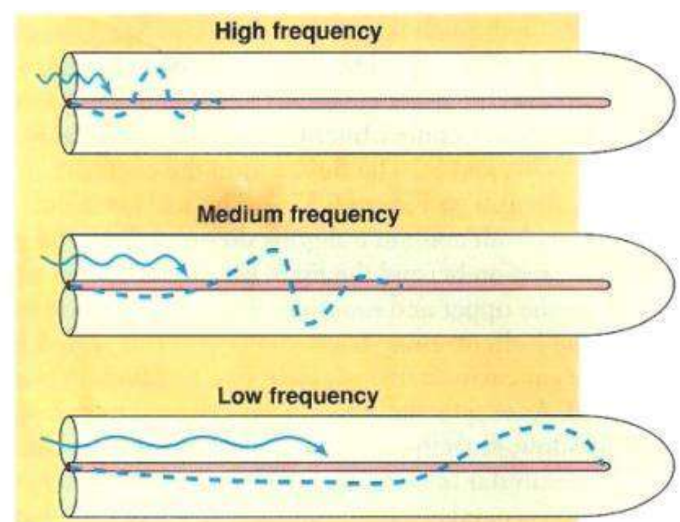
Pitch discrimination depends on the region of the basilar membrane that vibrates

- Pitch discrimination depends on the shape and properties of the basilar membrane, which is narrow and stiff at its oval window end and wide and flexible at its helicotrema end.
- The narrow end nearest to oval window vibrates best with high-frequency pitches, where as the wide and nearest the helicotrema vibrates maximally with low-frequency tones.
- Overtones of varying frequencies cause many points along the basilar membrane to vibrate simultaneously but less intensely than the fundamental tone, enabling the CNS to distinguish the timbre of the sound (**Timbre discrimination**).



(b)

The numbers indicate the frequencies in cycles per second with which different regions of the basilar membrane maximally vibrate.



(c)

Loudness discrimination depends on the amplitude of vibration

- Intensity (loudness) discrimination depends on the amplitude of vibration, louder sound source strike the eardrum, they cause it to vibrate more vigorously, then converted to greater amplitude of basilar membrane.
- The auditory system is so sensitive, as ear detect sounds so faint that the distance of basilar membrane deflection is comparable to only a fraction of the diameter of a hydrogen atom, the smallest atom.

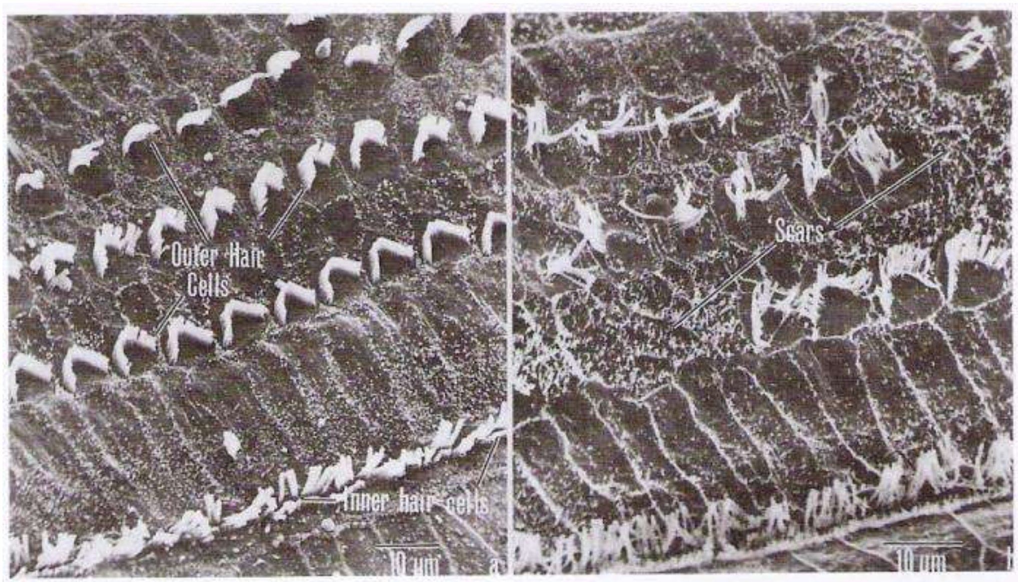
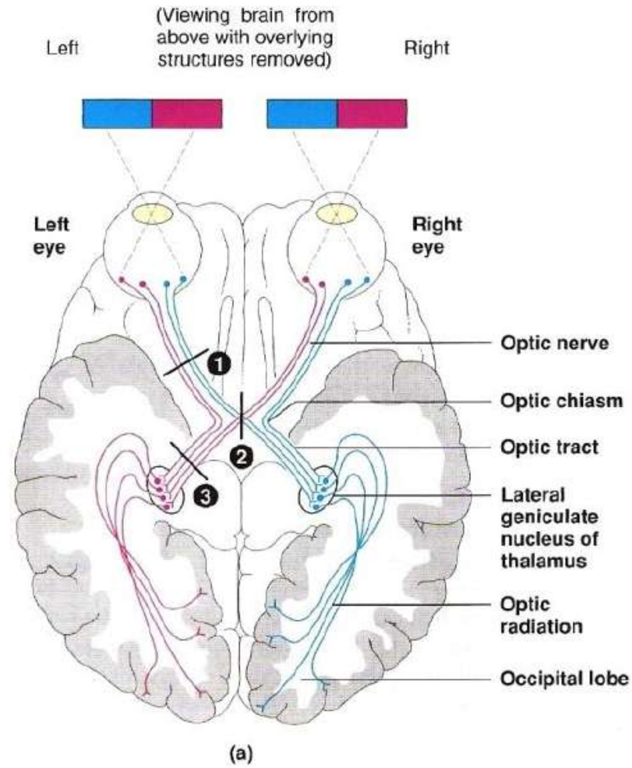


FIGURE 6-40

Loss of hair cells caused by loud noises
Injury and loss of hair cells caused by intense noise. Portions of the organ of Corti, with its three rows of outer hair cells and one row of inner hair cells, from the inner ear of (a) a normal guinea pig and (b) a guinea pig after a 24-hour exposure to noise at 120 decibels SPL, a level approached by loud rock music.

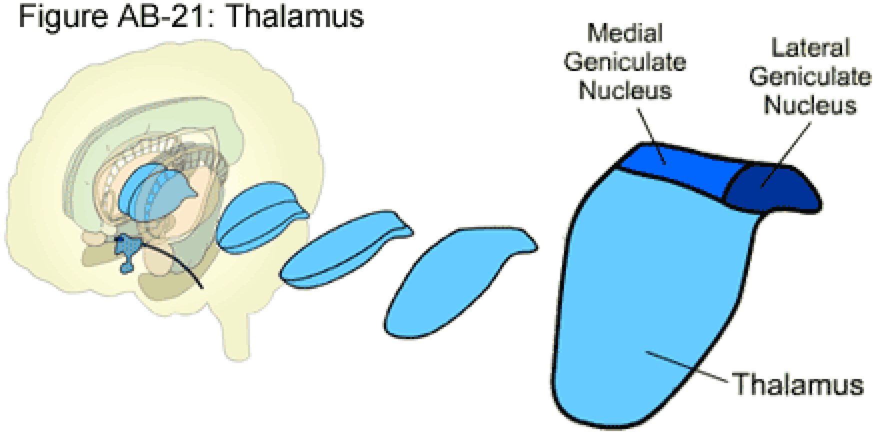
(Scanning electron micrographs by R. S. Preston and J. E. Hawkins, Kresge Hearing Research Institute, University of Michigan.)

The auditory cortex is mapped according to tone



- The primary auditory cortex in the temporal lobe is also **tonotopically organized**, each region of the basilar membrane is linked to a specific region of the primary auditory cortex.
- The efferent nervous synapse at the brain stem and **medial geniculate nucleus** in the thalamus before it reach the auditory cortex.
- Auditory signals from each ear are transmitted to both temporal lobes because the fibers partially cross over in the brain stem.
- For this reason, a disruption of the auditory pathways on one side beyond the brain stem does not affect hearing in either ear to any extent.

Figure AB-21: Thalamus



Deafness

- **Deafness**: loss of hearing, which may be *temporary* or *permanent*, *partial* or *complete.*
- **Deafness** is classified into two types:

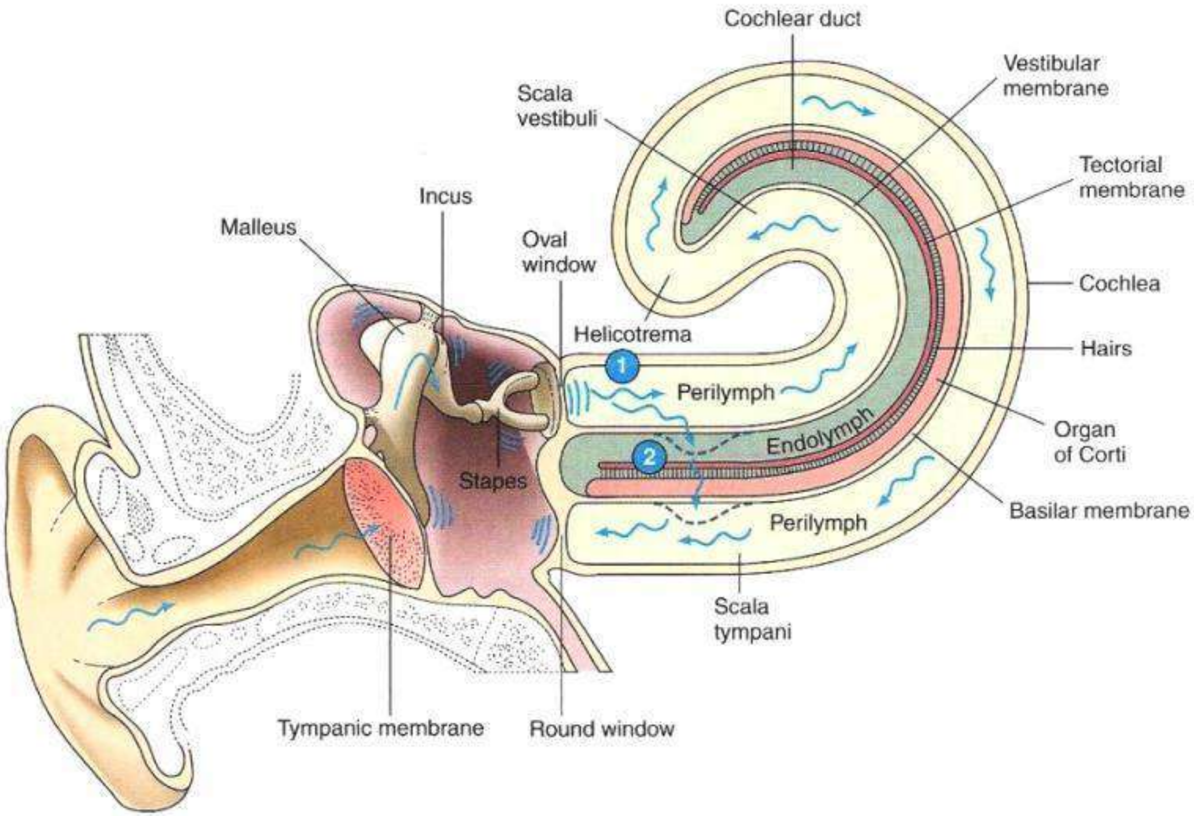
1. **Conductive deafness**: occurs when sound waves are not adequately conducted through the external and middle portions of the ear to set the fluids in the inner ear in motion.

Possible causes include physical blockage of the ear canal with earwax, rupture of the eardrum, middle ear infections with accompanying fluid accumulation.

2. **Sensorineural deafness**: the sound waves are transmitted to the inner ear, but they are not translated into nerve signals that are interpreted by the brain as sound sensations.

The defect can lie in the organ of Corti or the auditory nerves or, rarely in the ascending auditory pathways or auditory cortex.

- One of the most common cause of partial hair loss, **Neural presbysusis,** it is a degenerative age-related process that occurs as hair cell “ wear out” with use.
- 40% of adults loss their cochlear hair cells by age 65.
- Hearing aids are helpful in conductive deafness but are less beneficial for sensorineural deafness.
- In recent years, cochlear implants have become available.
- Encouraging new studies suggest that hair cells in the inner ear have the latent ability to regenerate in response to appropriate chemical signal.



Fluid movement within the perilymph set up by vibration of the oval window follows two pathways:

Pathway 1: Through the scala vestibuli, around the heliocotrema, and through the scala tympani, causing the round window to vibrate. This pathway just dissipates sound energy.

Pathway 2: A "shortcut" from the scala vestibuli through the basilar membrane to the scala tympani. This pathway triggers activation of the receptors for sound by bending the hairs of hair cells as the organ of Corti on top of the vibrating basilar membrane is displaced in relation to the overlying tectorial membrane.

(a)