NERVOUS SYSTEM

WEEK 5

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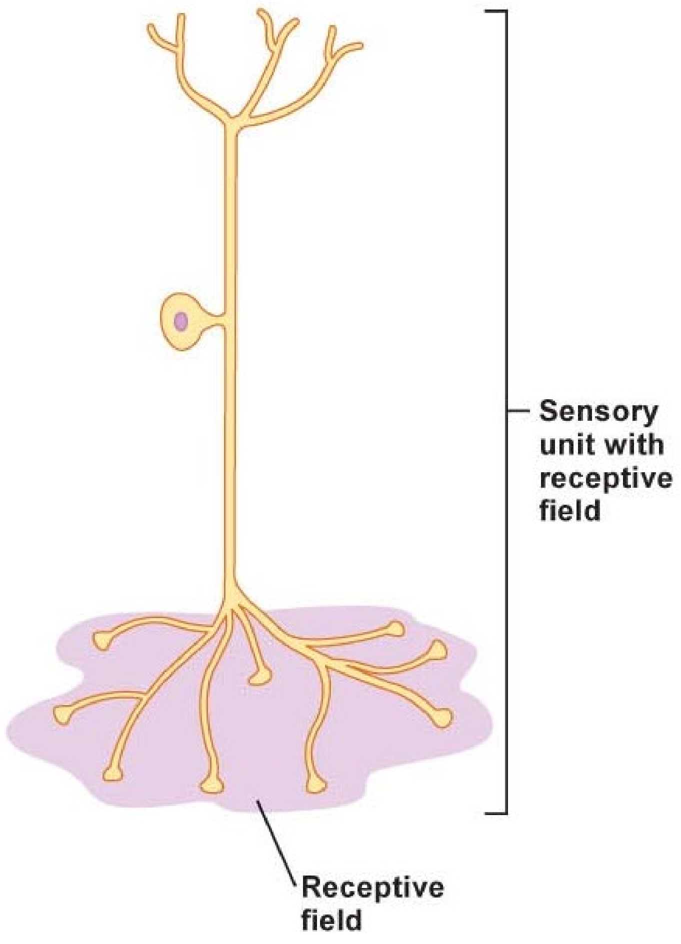
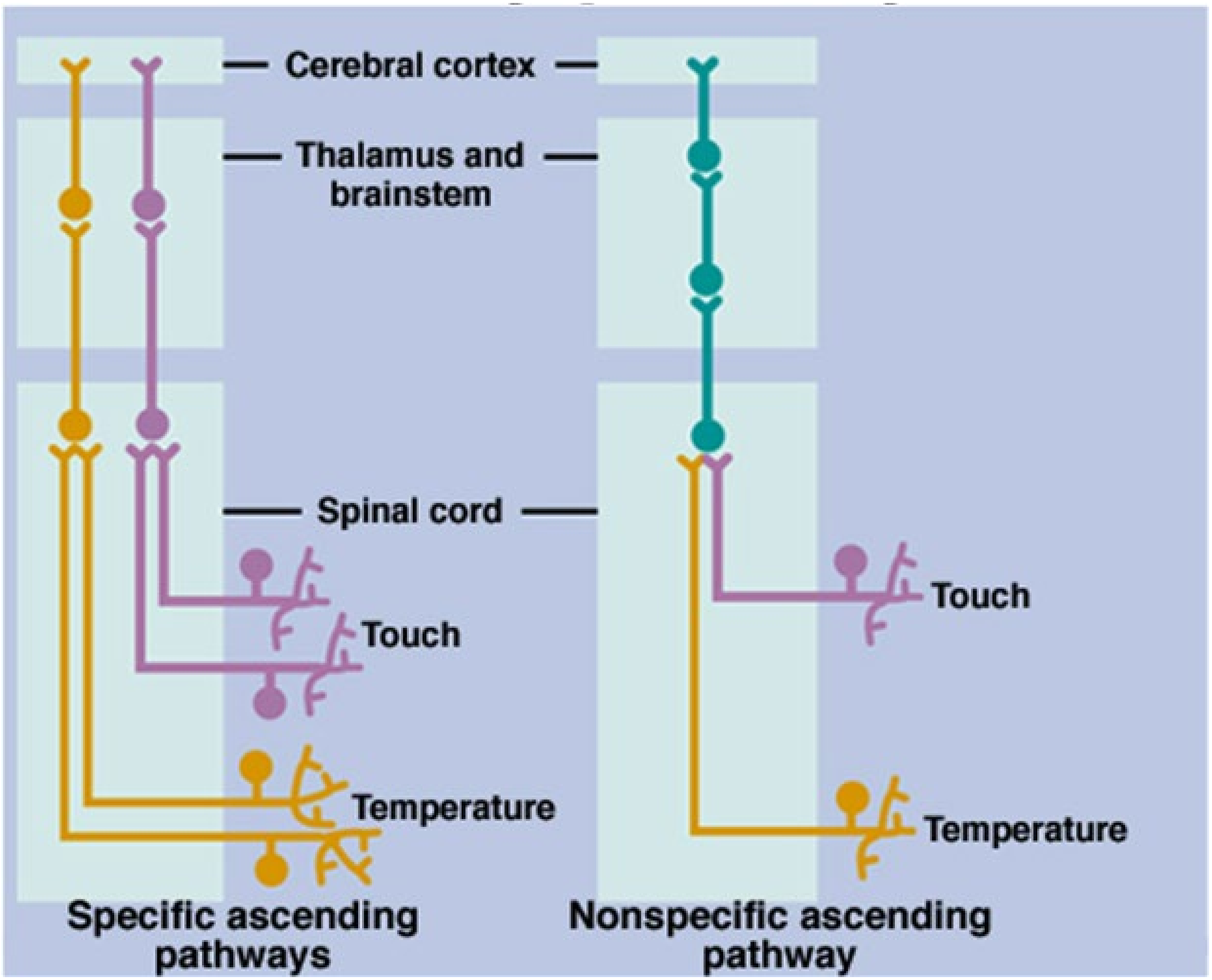
Neural Pathways in Sensory Systems

- A single afferent neuron with all its receptor endings is a **sensory unit.**
- a. Afferent neurons, which usually have more than one receptor of the same type, are the first neurons in sensory pathways.
- b. The area of the body that, when stimulated, causes activity in a sensory unit or other neuron in the ascending pathway of that unit is called the **receptive field** for that neuron.



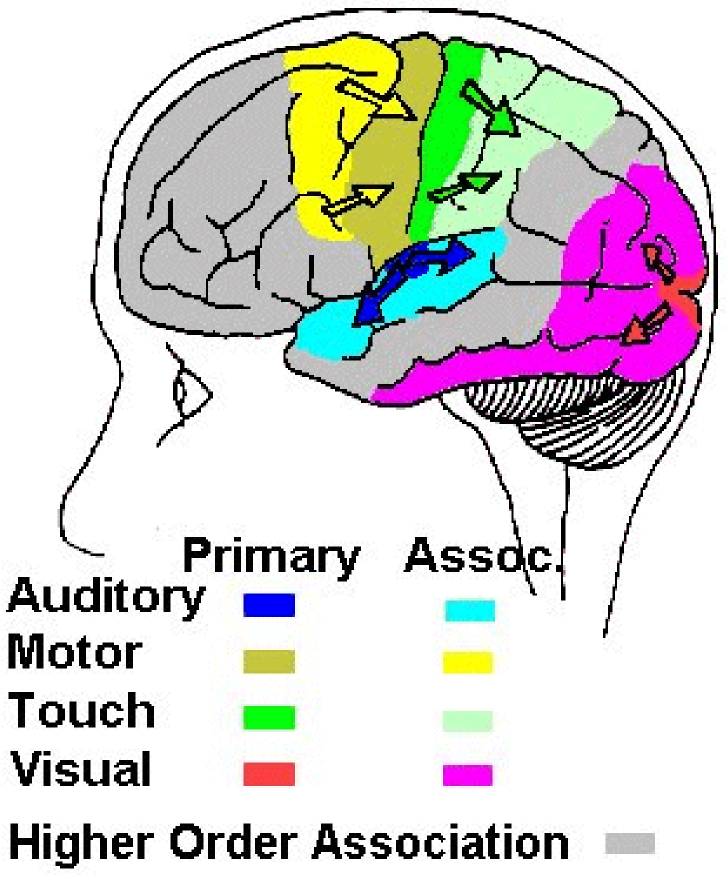
Neural Pathways in Sensory Systems

- Neurons in the specific ascending pathways convey information to specific primary receiving areas of the cerebral cortex about only a single type of stimulus.
- Nonspecific ascending pathways convey information from more than one type of sensory unit to the brainstem, reticular formation and regions of the thalamus that are not part of the specific ascending pathways.



Association Cortex and Perceptual Processing

- Information from the primary sensory cortical areas is elaborated after it is relayed to a cortical association area.
- The **primary sensory cortical** area and the region of **association cortex** closest to it process the information in fairly simple ways and serve **basic sensory-related functions**.
- Regions of **association cortex** farther from the primary sensory areas **process the sensory information in more complicated ways.**
- Processing in the association cortex includes input from areas of the brain serving other **sensory modalities, arousal, attention, memory, language, and emotions**.



Comparison of General and Special Senses

General Senses

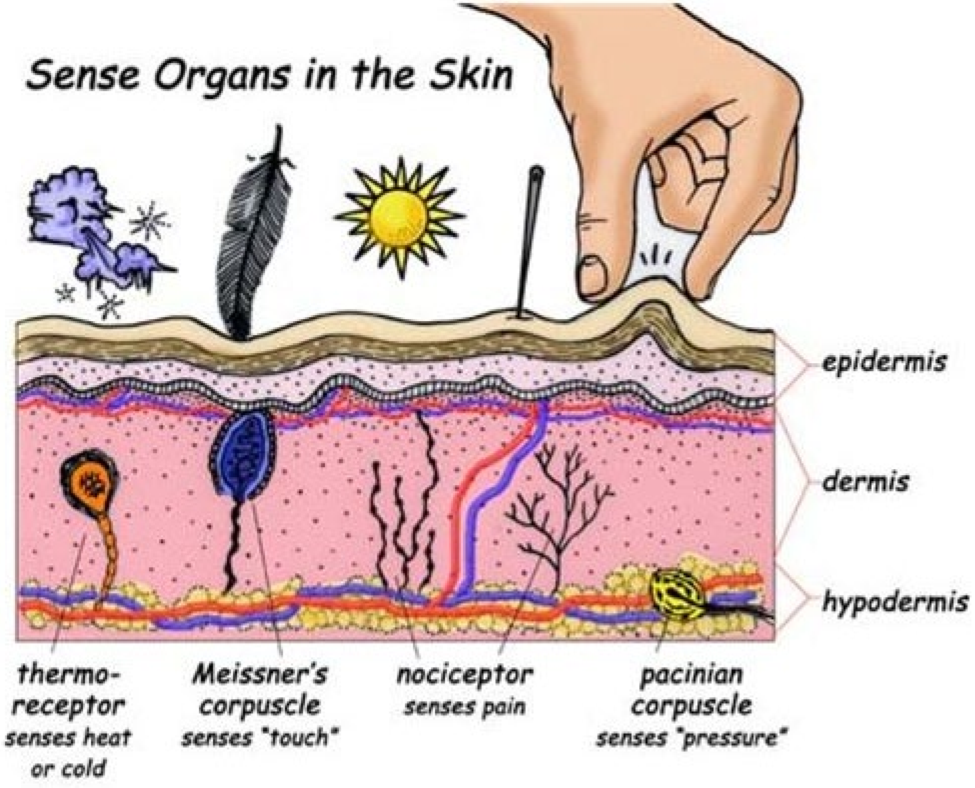
- Include somatic sensations (tactile, thermal, pain, and proprioceptive) and visceral sensations.
- Scattered throughout the body.
- Simple structures.

Special Senses

- Include smell, taste, vision, hearing and equilibrium.
- Concentrated in specific locations in the head.
- Anatomically distinct structures.
- Complex neural pathway.

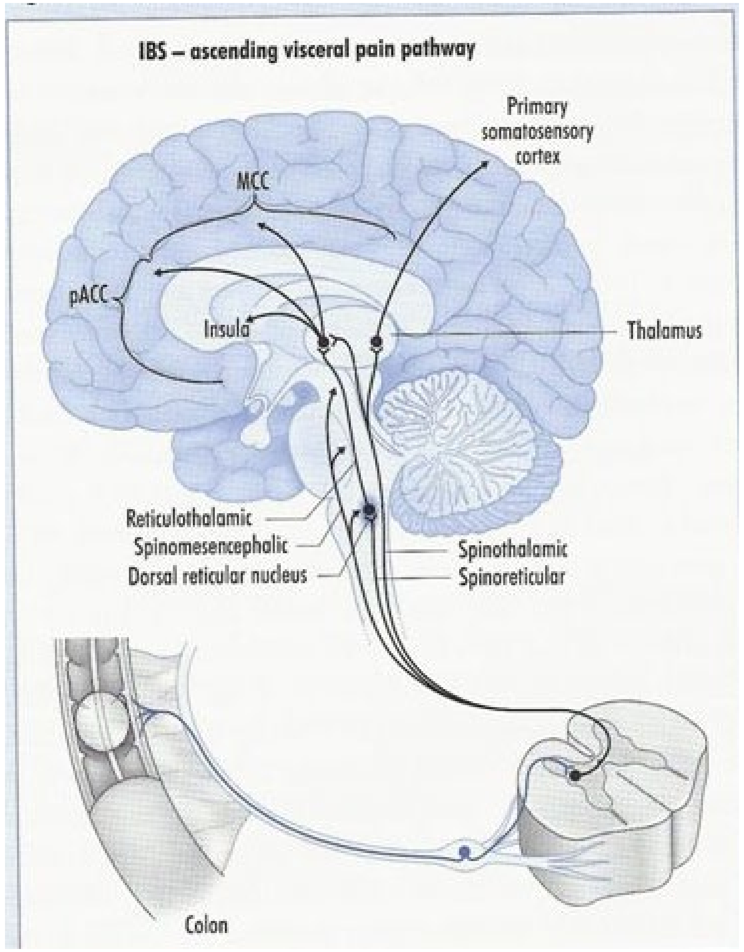
Somatic Sensation

- Sensation from the skin, muscles, bones, tendons, and joints is termed **somatic sensation**
- It is initiated by a variety of somatic receptors.
- Activation of somatic receptors gives rise to the sensations of touch, pressure, warmth, cold, pain, and awareness of the position of the body parts and their movement.



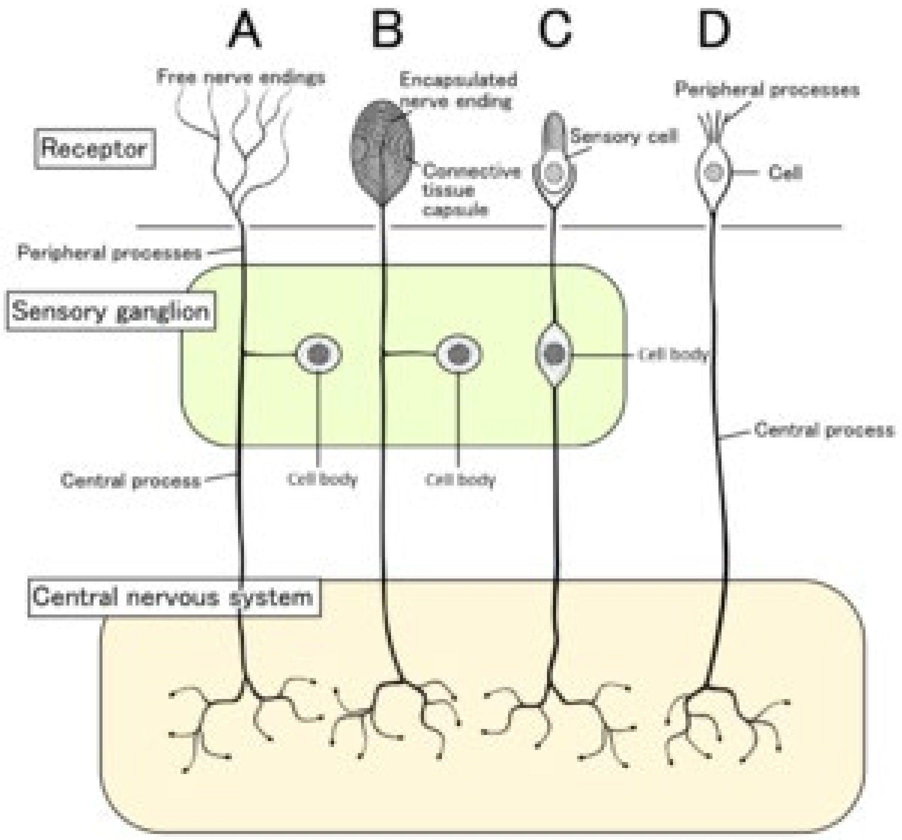
Somatic Sensation

- The receptors for **visceral sensations,** which arise in certain organs of the thoracic and abdominal cavities, are the same types as the receptors that give rise to somatic sensations.
- Some organs, such as the liver, have no sensory receptors at all.



Somatic Sensation

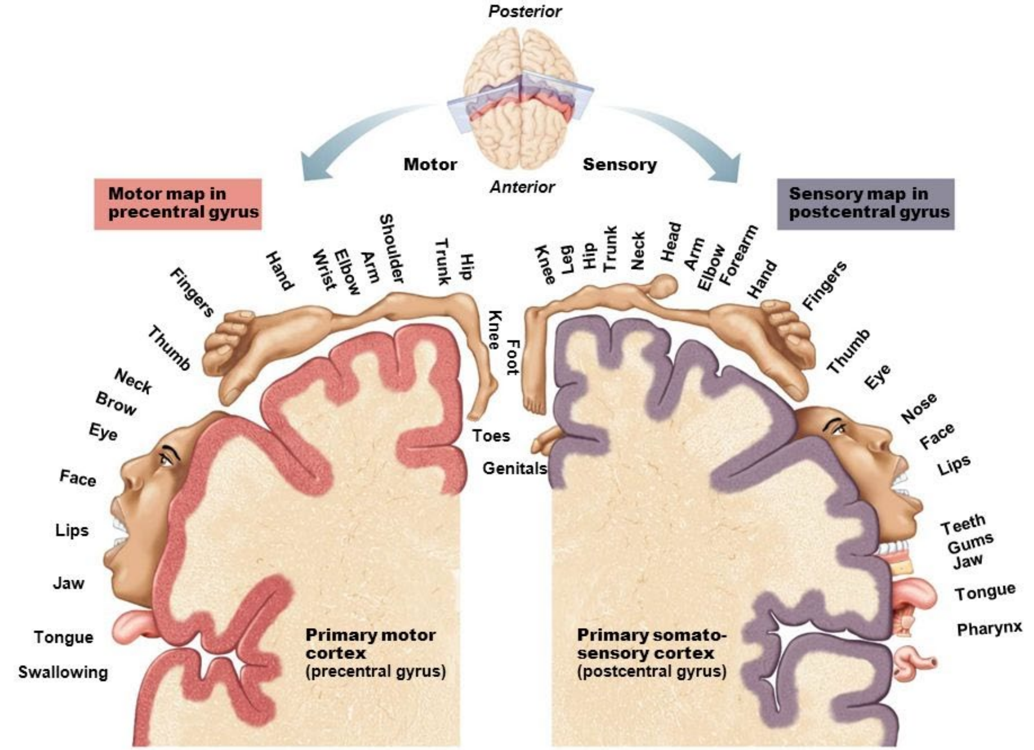
- Each sensation is associated with a specific receptor type.
- There are distinct receptors for heat, cold, touch, pressure, limb position or movement, and pain.
- After entering the CNS, the afferent nerve fibers synapse on neurons that form the specific ascending pathways
- They go primarily to the somatosensory cortex via the brainstem and thalamus.



Somatic Sensation

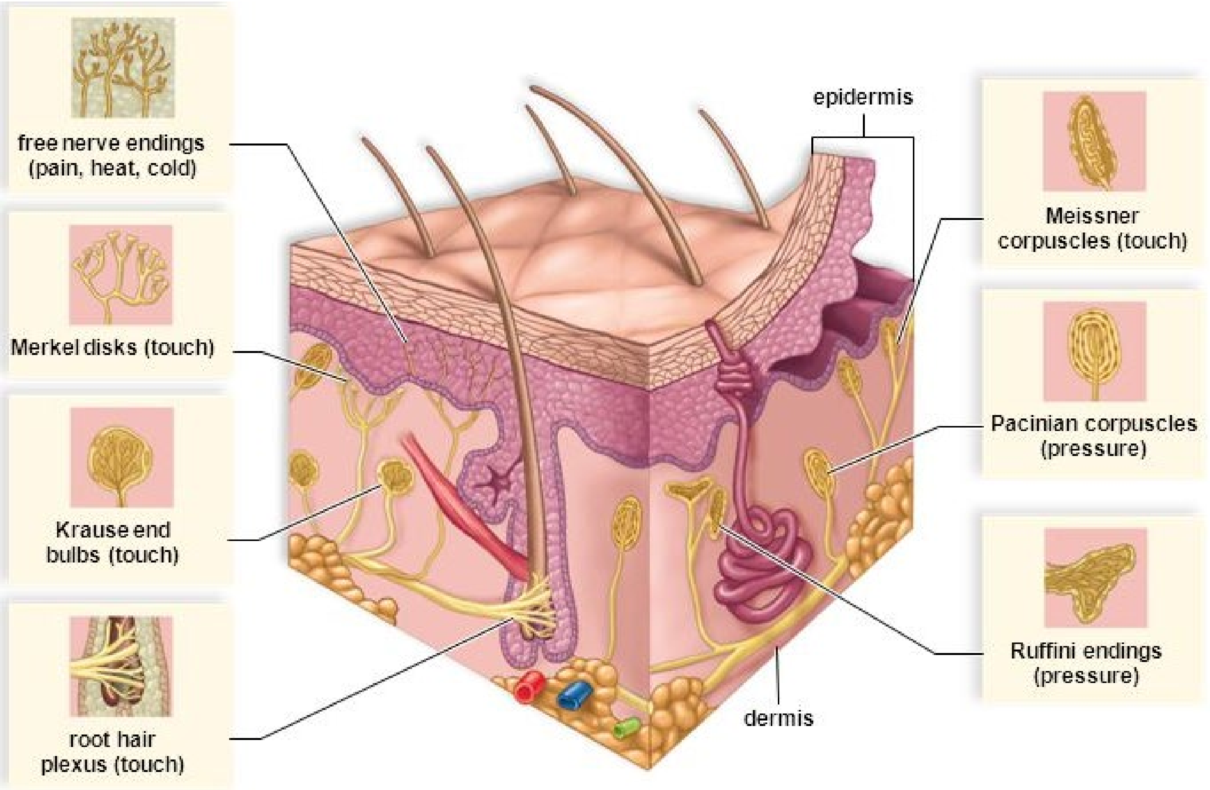
- In the somatosensory cortex, the endings of the axons of the specific somatic pathways are grouped according to the location of the receptors giving rise to the pathways.
- **The parts of the body that are most densely innervated—fingers, thumb, and lips—are represented by the largest areas of the somatosensory cortex.**
- The sizes of the areas can be modified with changing sensory experience, and there is considerable overlap of the body-part representations.

Figure 13.14 Body maps in the primary motor cortex and somatosensory cortex of the cerebrum.



Touch-Pressure

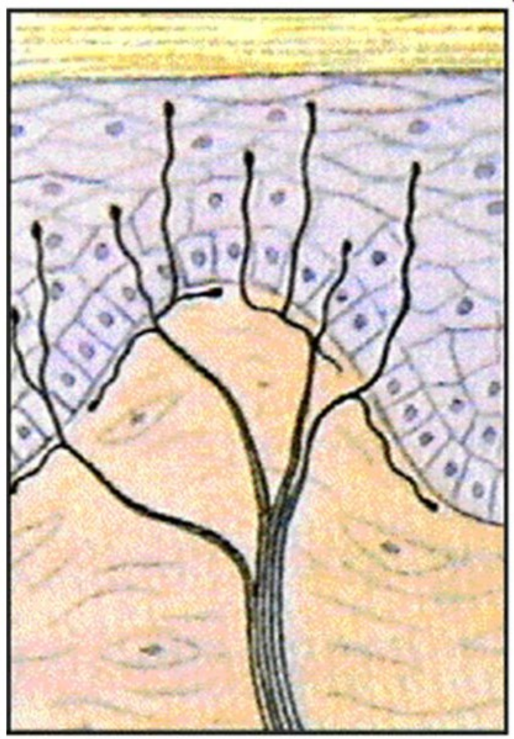
- Stimulation of the variety of **mechanoreceptors** in the skin leads to a wide range of touch pressure experiences—hair bending, deep pressure, vibrations, and superficial touch.
- The details of the mechanoreceptors vary, but generally the nerve endings are linked to collagen-fiber networks within the capsule.
- These networks transmit the mechanical tension in the capsule to ion channels in the nerve endings and activate them.



Free Nerve Endings

- Abundant in epithelia and underlying connective tissue
- Nociceptors - respond to pain
- Thermoreceptors - respond to temperature
- **Two specialized types of free nerve endings**
- **Merkel discs** – lie in the epidermis, slowly adapting receptors for light touch
- **Hair follicle receptors** – Rapidly adapting receptors that wrap around hair follicles

Free nerve endings – pain, thermal receptors

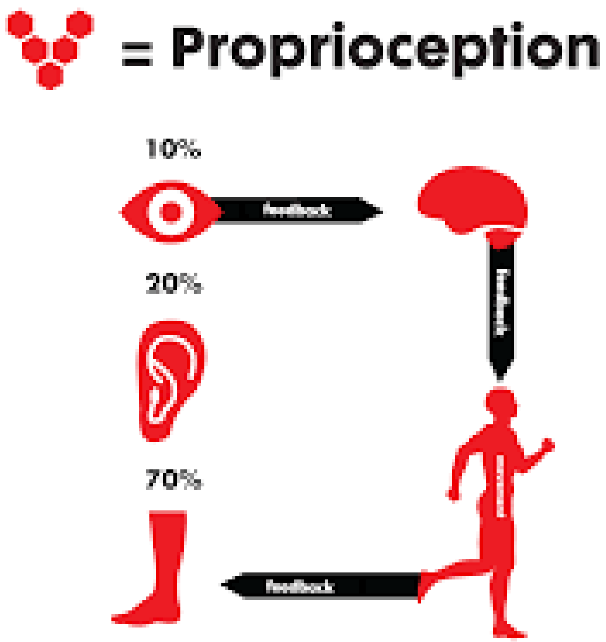


Encapsulated Nerve Endings

- **Meissner’s corpuscles**
- Spiraling nerve ending surrounded by Schwann cells
- Occur in the dermal papillae of hairless areas of the skin
- Rapidly adapting receptors **for discriminative touch**
- **Pacinian corpuscles**
- Single nerve ending surrounded by layers of flattened Schwann cells
- Occur in the hypodermis
- **Sensitive to deep pressure** – rapidly adapting receptors
- **Ruffini’s corpuscles**
- Located in the dermis and respond to pressure
- **Monitor continuous pressure on the skin** – adapt slowly

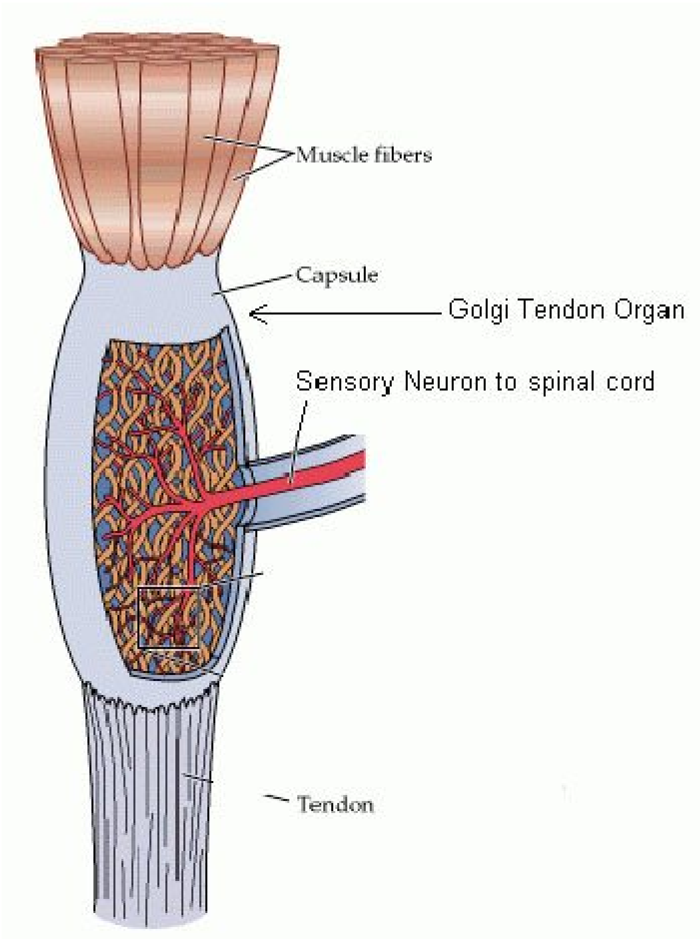
Sense of Posture and Movement

- The senses of posture and movement are complex.
- The major receptors responsible for these senses are the **muscle-spindle stretch receptors**.
- The senses of posture and movement are also supported by **vision** and the **vestibular organs**.
- **Mechanoreceptors** in the joints, tendons, ligaments, and skin also play a role.



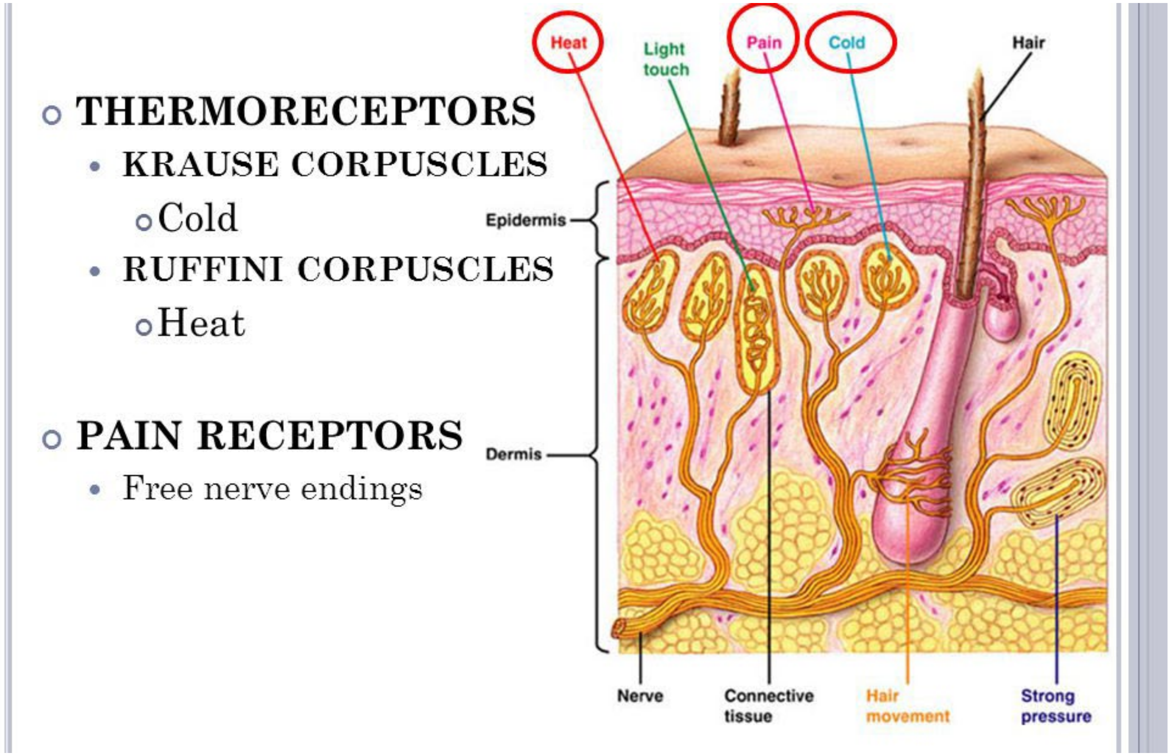
Encapsulated Nerve Endings - Proprioceptors

- Monitor stretch in locomotory organs
- **Three types of proprioceptors**
- *Muscle spindles* – monitors the changing **length of a muscle**, imbedded in the perimysium between muscle fascicules
- *Golgi tendon organs* – located near the muscle-tendon junction, monitor **tension within tendons**
- *Joint kinesthetic receptors* - sensory nerve endings within the joint capsules, **sense pressure and position**



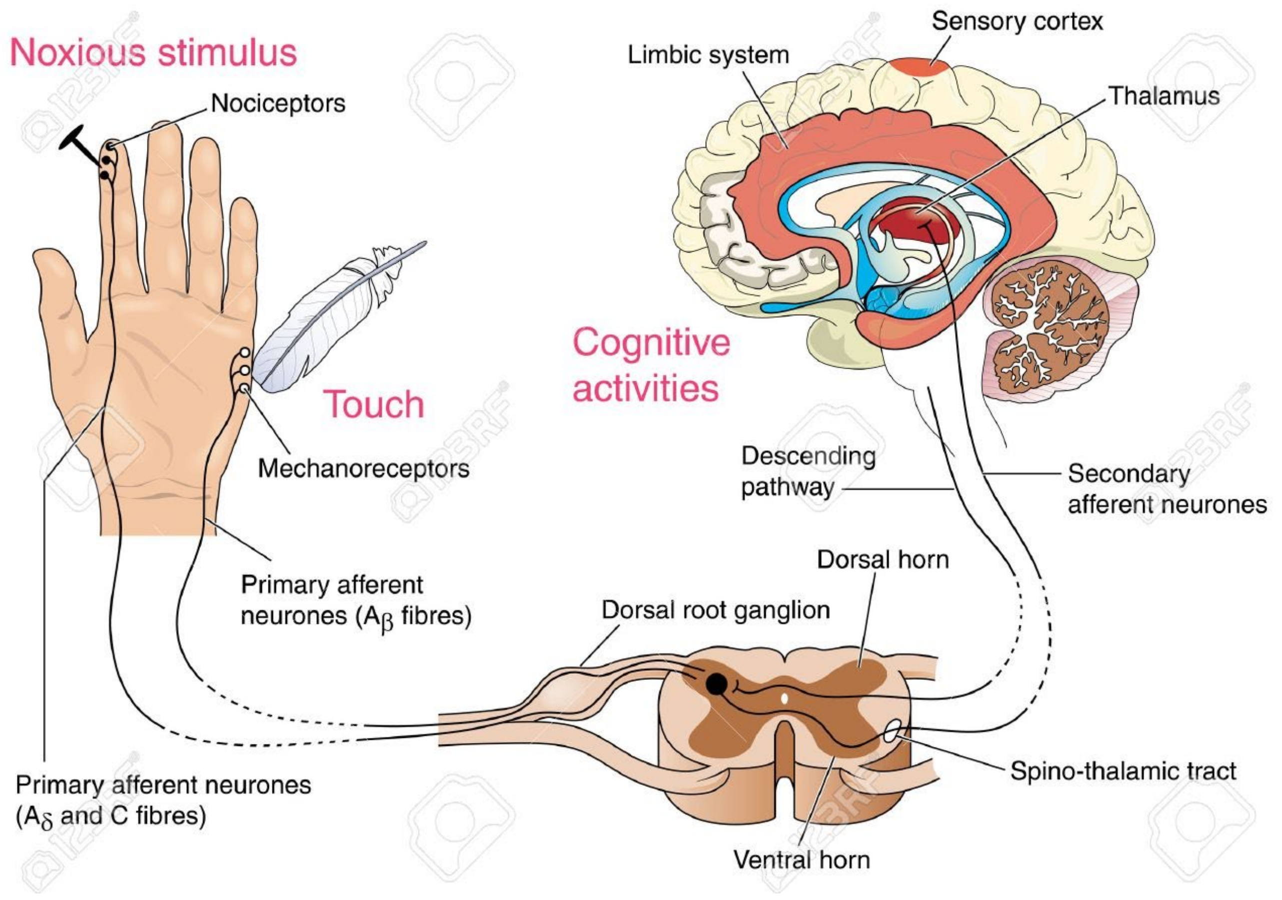
Temperature

- There are two types of thermoreceptors in the skin, each of which responds to a limited range of temperature.
- Warmth receptors respond to temperatures between 30 and 43°C with an increased discharge rate upon warming
- Receptors for cold are stimulated by small decreases in temperature.
- It is not known how heat or cold alter the endings of the thermosensitive afferent neurons to generate receptor potentials.



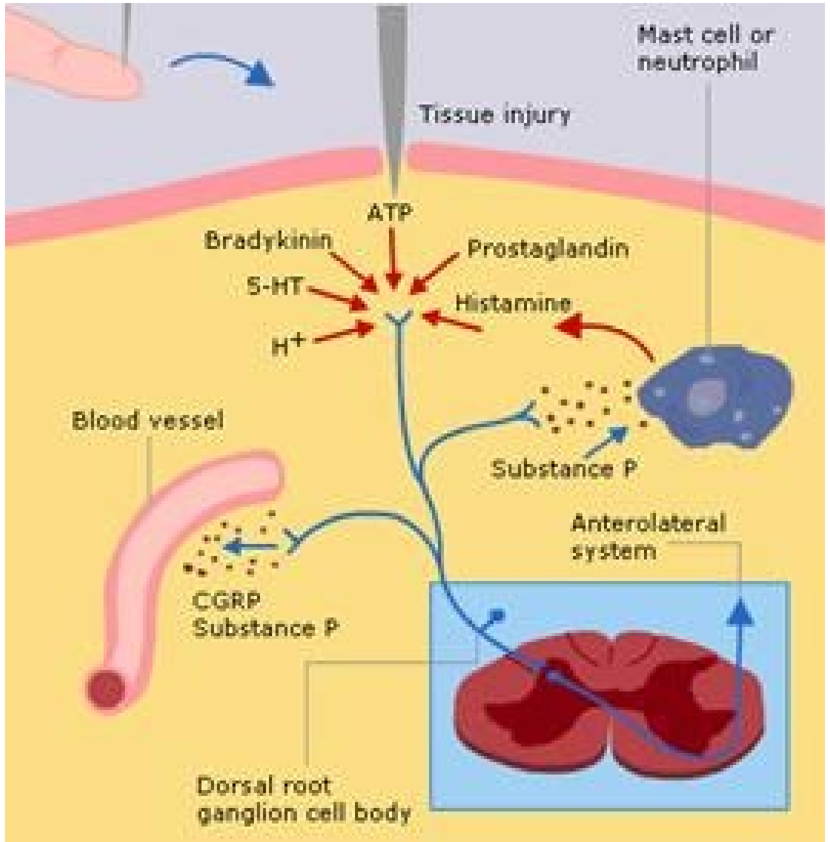
Pain

- A stimulus that causes (or is on the verge of causing) tissue damage usually elicits a sensation of pain.
- Receptors for such stimuli are known as **nociceptors**.
- They respond to intense mechanical deformation, excessive heat, and many chemicals (neuropeptide transmitters, bradykinin, histamine, cytokines, and prostaglandins) several of which are released by damaged cells.
- These substances act by combining with specific ligand-sensitive ion channels on the nociceptor plasma membrane.



Pain

- Several of these chemicals are secreted by cells of the immune system that have moved into the injured area.
- There is a great deal of interaction between substances released **from the damaged tissue, cells of the immune system**, and **nearby afferent pain neurons**.
- All three of **these—the tissue, immune cells, and afferent neurons themselves—release substances that affect the nociceptors and are, in turn, affected by these substances.**



Olfaction: Sense of Smell

- Olfactory epithelium contains 10-100 million receptors.
- Olfactory receptor- a bipolar neuron with cilia called olfactory hairs.

  - Respond to chemical stimulation of an odorant molecule.
- Supporting cells- provide support and nourishment.
- Basal cells- replace olfactory receptors.

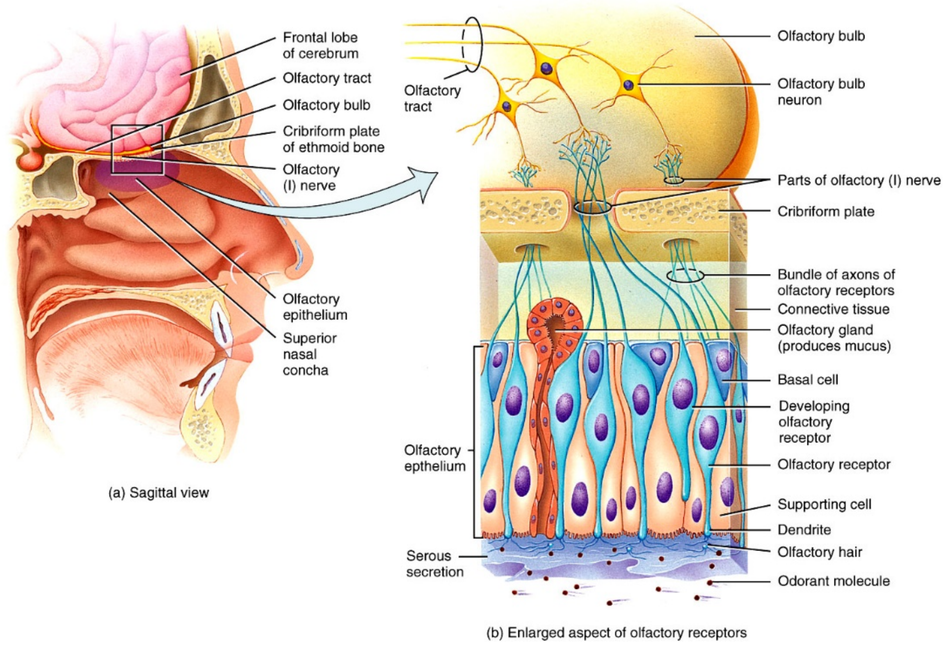
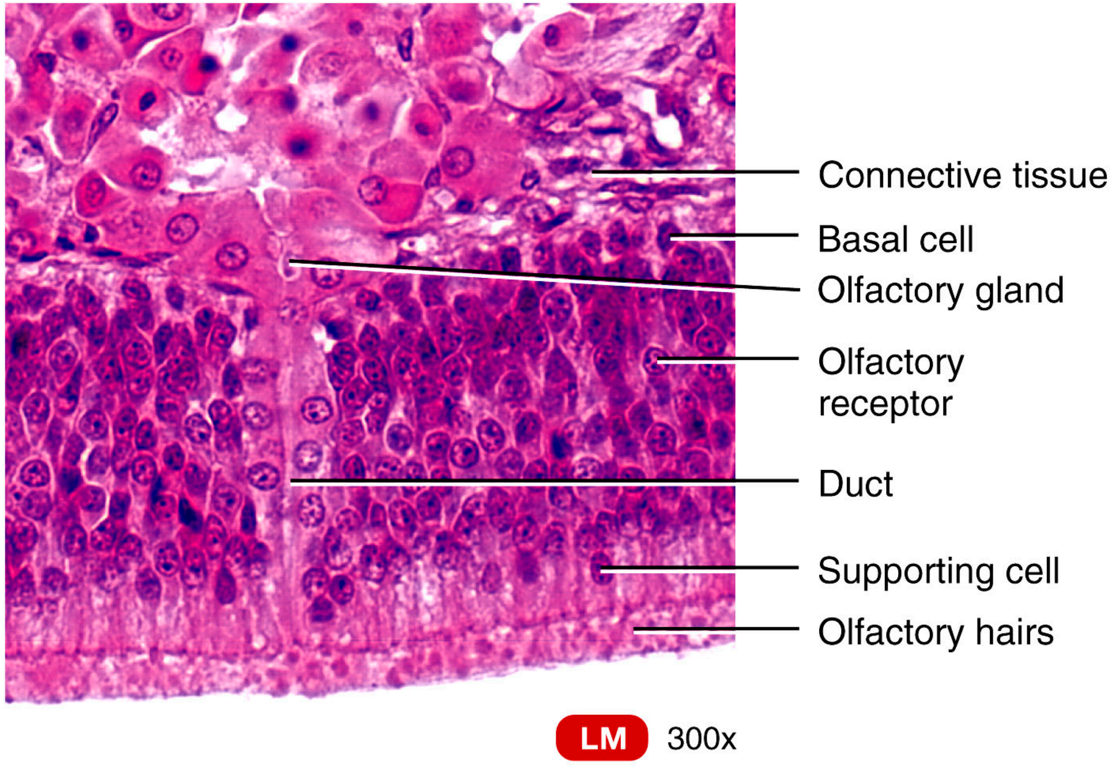
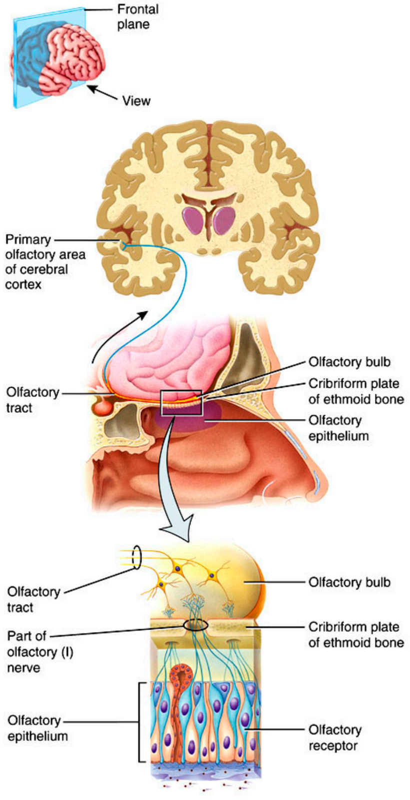


Figure 17.01ab Tortora - PAP 12/e

Olfactory Epithelium



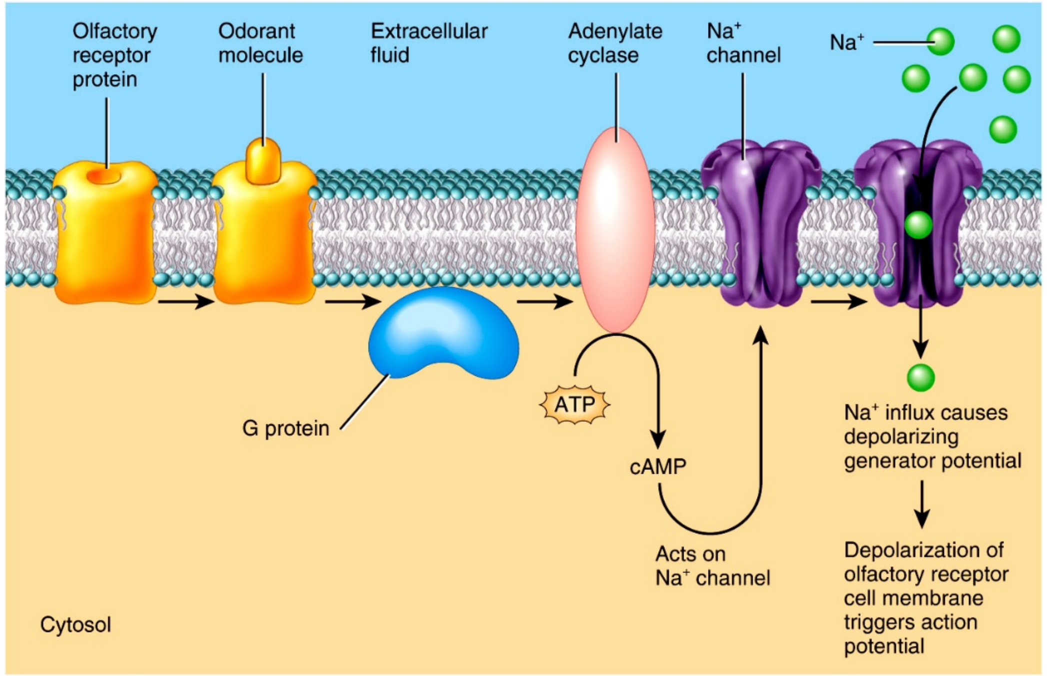
(c) Histology of olfactory epithelium



(d) Olfactory pathway

Physiology of Olfaction

- Can detect about 10,000 different odors.
- Odorant binds to the receptor of an olfactory hair→
- G-protein activation→
- activation of adenylate cyclase→
- production of cAMP→
- opening of Na+ channels→
- inflow of Na+ →
- generator potential→
- nerve impulse through olfactory nerves→
- olfactory bulbs→
- olfactory tract→
- primary olfactory area of the cerebral cortex.



Gustation: Sense of Taste

- Taste bud- made of three types of epithelial cells: supporting cells, gustatory receptor cells and basal cells.
- About 50 gustatory cells per taste bud. Each one has a gustatory hair that projects through the taste pore.
- Taste buds are found in the papillae.
- Three types of papillae: vallate (circumvallate), fungiform and foliate.

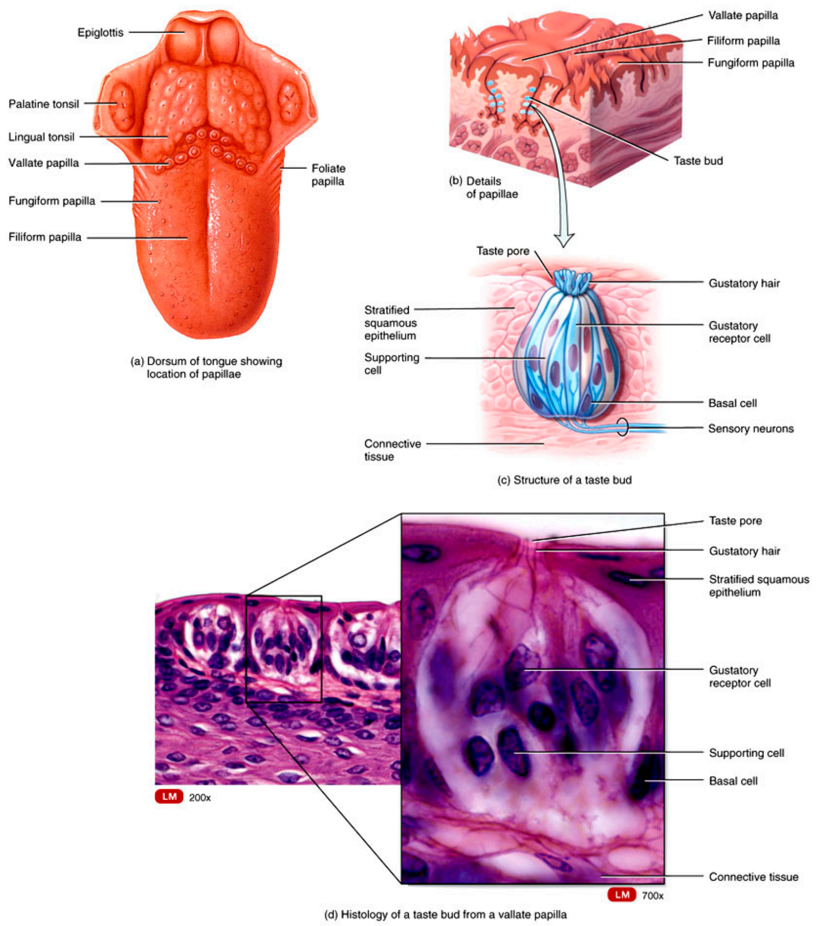
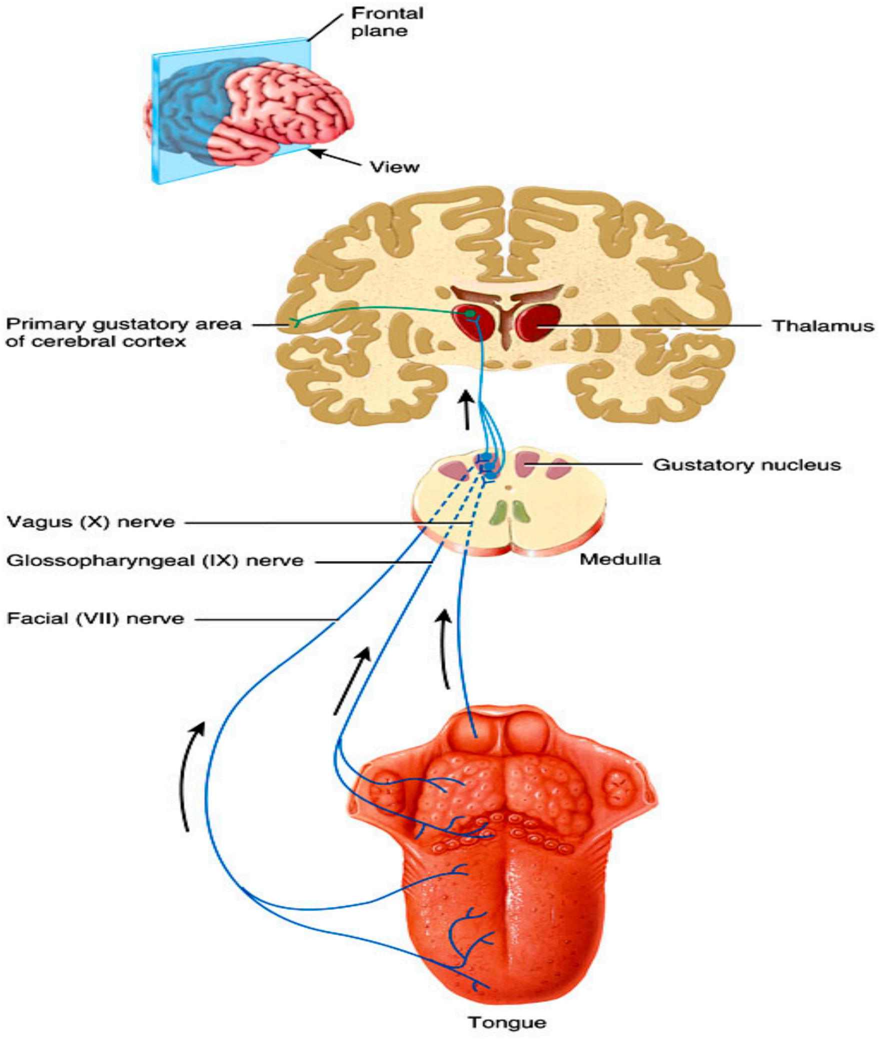


Figure 17.03abcd Tortora - PAP 12/e

Physiology of Gustation

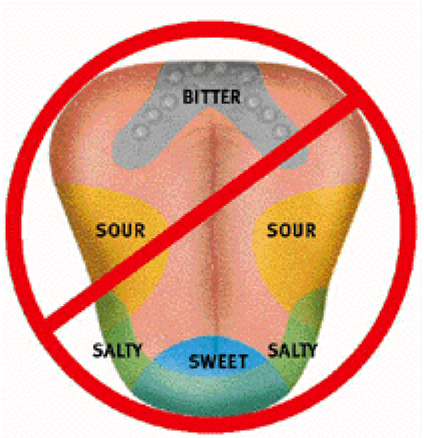
- Five types of taste: sour, sweet, bitter, salty and umami.
- Tastant dissolves in saliva → plasma membrane of gustatory hair→ receptor potential→ nerve impulse via cranial nerves VII, IX and X→ medulla→ thalamus→ primary gustatory area of the cerebral cortex.



(e) Gustatory pathway

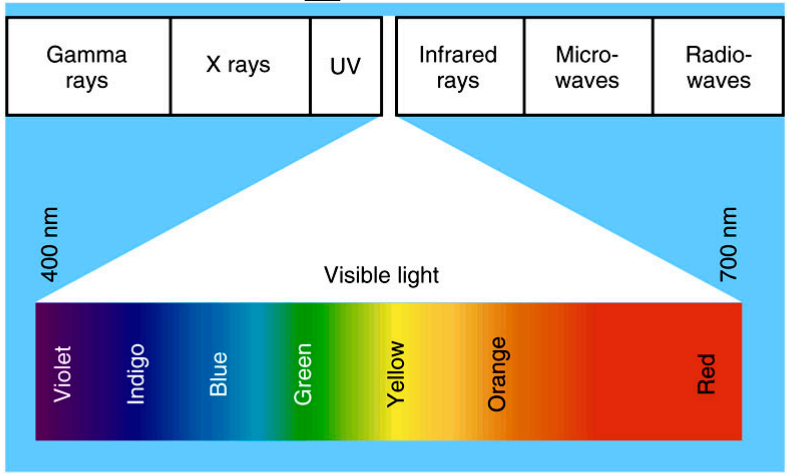
Figure 17.03e Tortora - PAP 12/e

Modern concept of a taste map

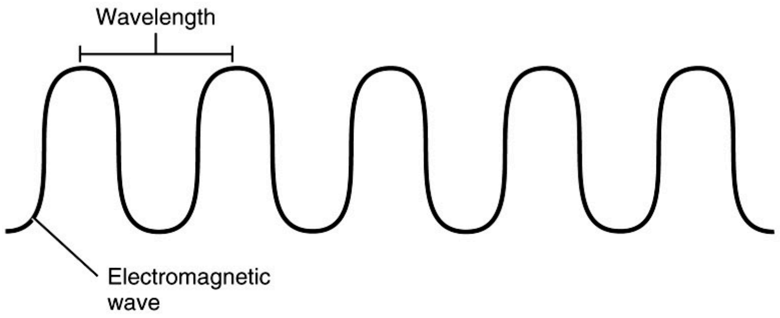


- Taste researchers have known for many years that these tongue maps are wrong. The maps arose early in the 20th century as a result of a misinterpretation of research reported in the late 1800s, and they have been almost impossible to purge from the literature. In reality, all qualities of taste can be elicited from all the regions of the tongue that contain taste buds. At present, we have no evidence that any kind of spatial segregation of sensitivities contributes to the neural representation of taste quality, although there are some slight differences in sensitivity across the tongue and palate, especially in rodents.

Vision or Sight



(a) Electromagnetic spectrum



(b) An electromagnetic wave

Figure 17.04 Tortora - PAP 12/e

- Visible light: 400-700 nm.

Accessory Structures of the Eye

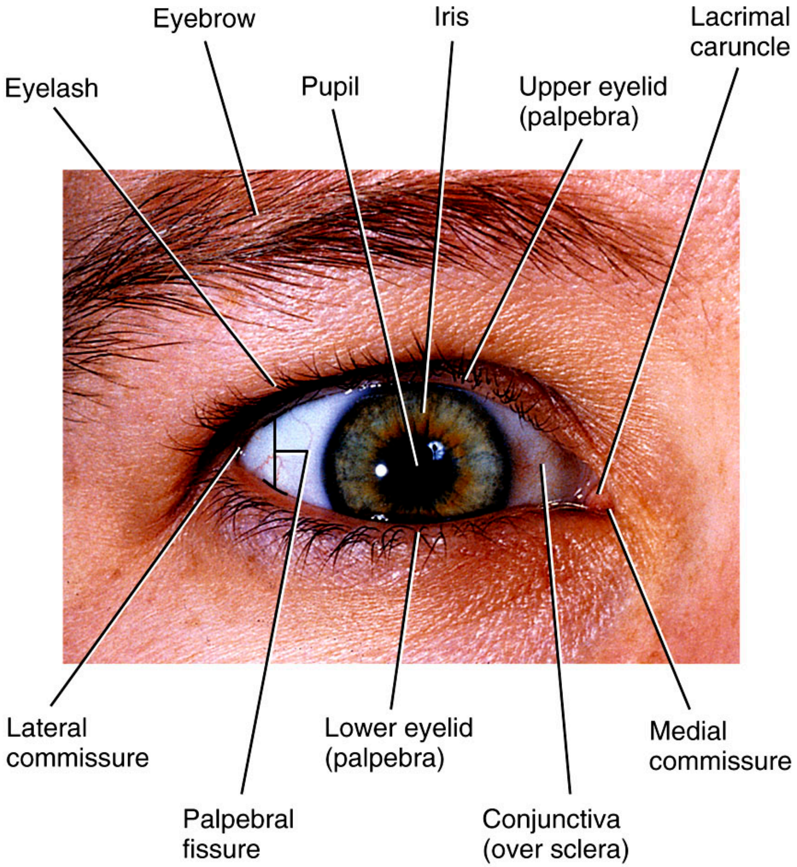
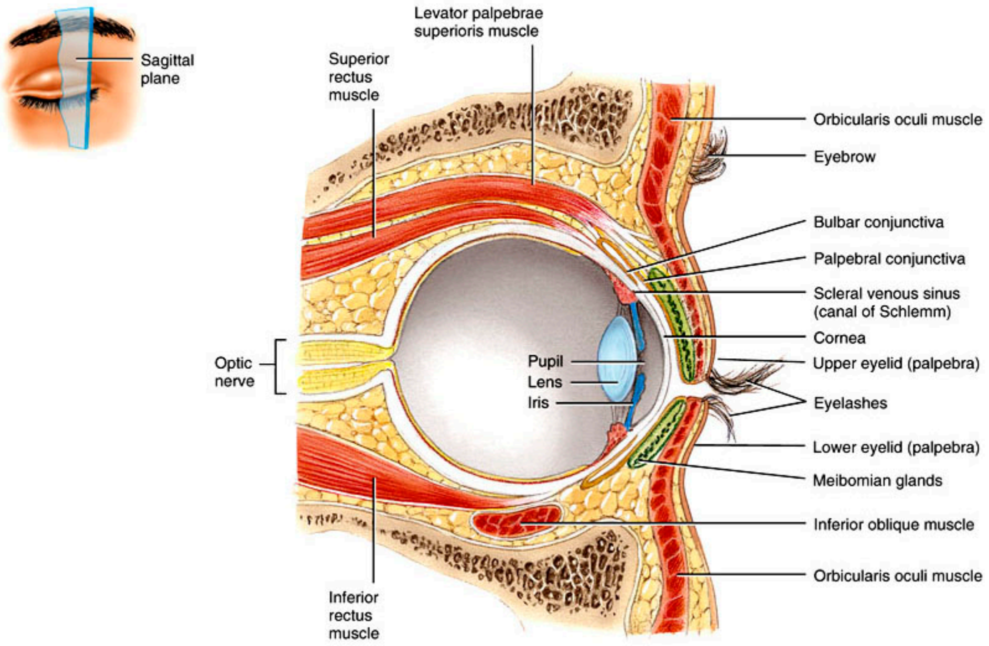


Figure 17.05 Tortora - PAP 12/e

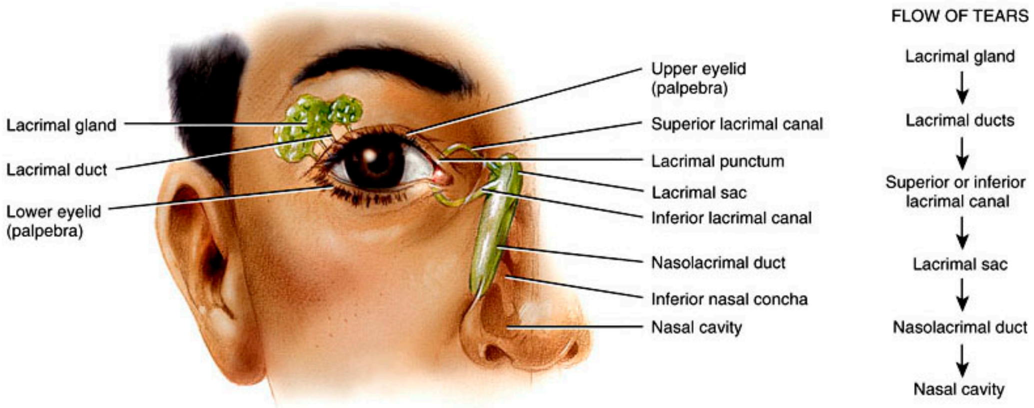
- Eyelids or palpebrae-
- Eyelashes and eyebrows-
- Extrinsic eye muscles-



(a) Sagittal section of eye and its accessory structures

Figure 17.06 Tortora - PAP 12/e

The Lacrimal Apparatus



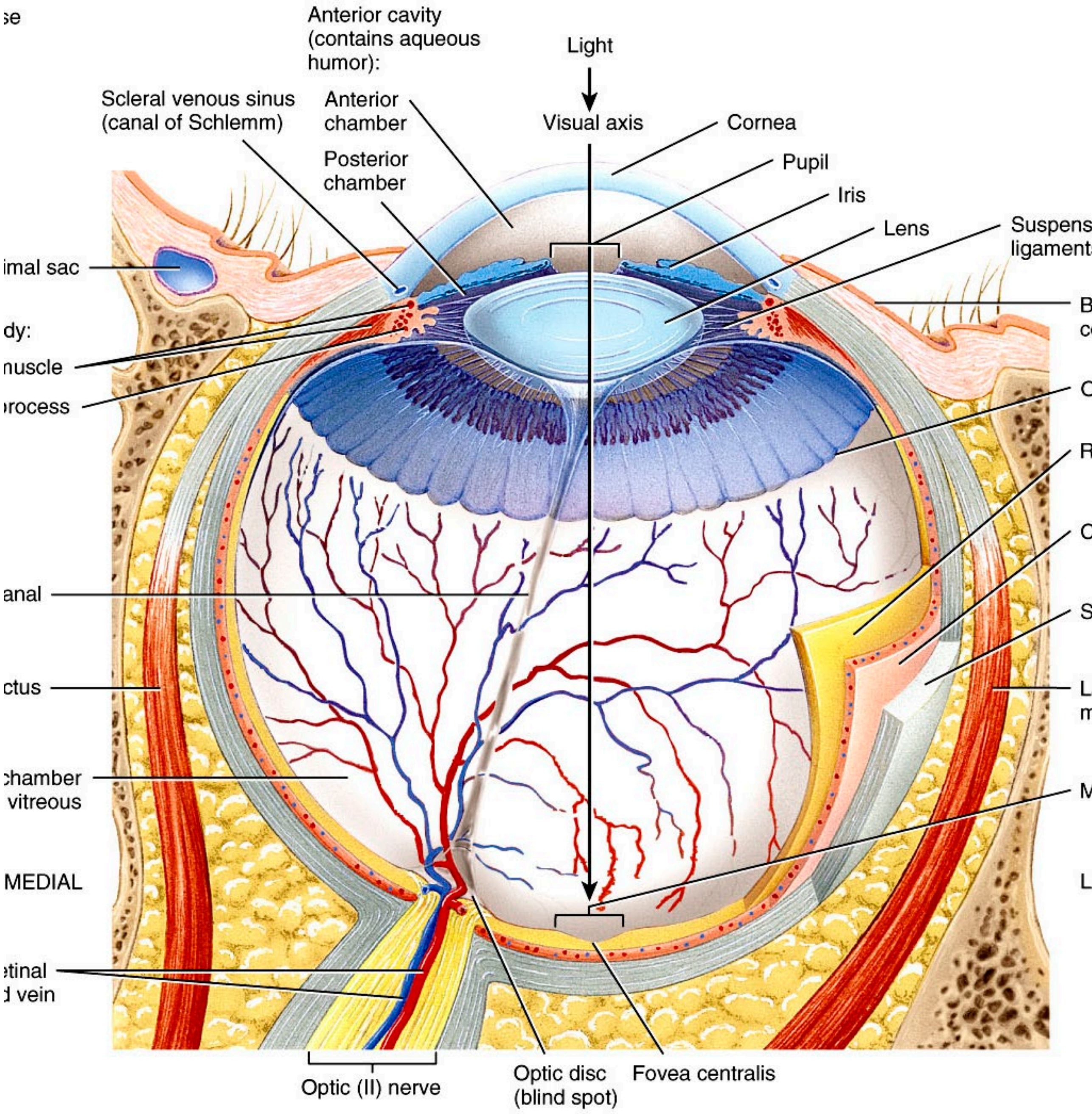
(b) Anterior view of the lacrimal apparatus

Figure 17.06 Tortora - PAP 12/e

- Tears from the lacrimal apparatus- lacrimal glands→ excretory lacrimal ducts→ lacrimal puncta→ lacrimal canals→ nasolacrimal sac→ nasolacrimal duct.

Wall of the Eyeball

- Three layers:
  - Fibrous tunic- outer layer
    - Sclera "white" of the eye
    - Cornea-transparent coat
  - Vascular tunic or uvea- middle layer
    - Choroid
    - Ciliary body consists of ciliary processes and ciliary muscle
    - Iris
  - Retina- inner layer
    - Optic disc
    - Macula lutea- fovea centralis



Superior view of transverse section of right eyeball

Responses of the Pupil to Light

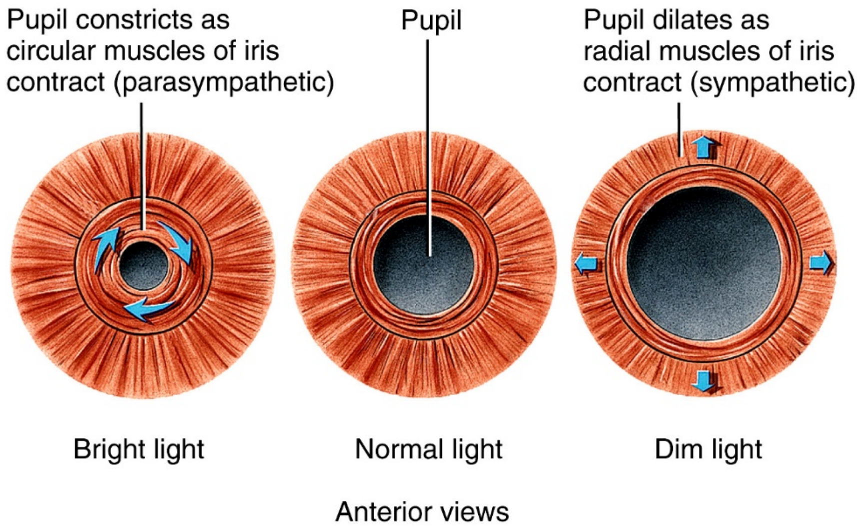
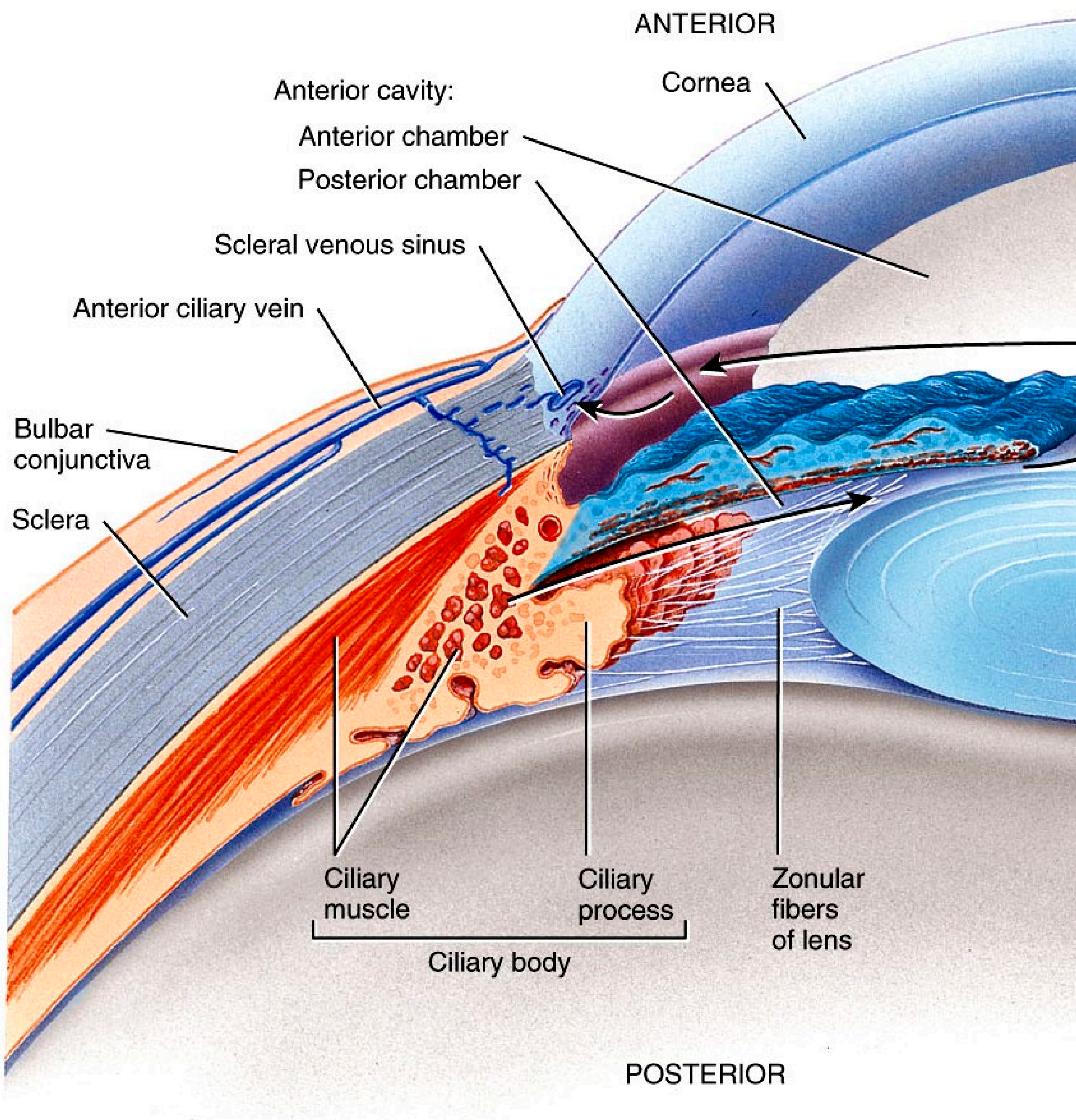


Figure 17.08 Tortora - PAP 12/e

- Pupil is an opening in the center of the iris.
- Contraction of the circular muscles of the iris causes constriction of the pupil.
- Contraction of the radial muscles causes dilation of the pupil.

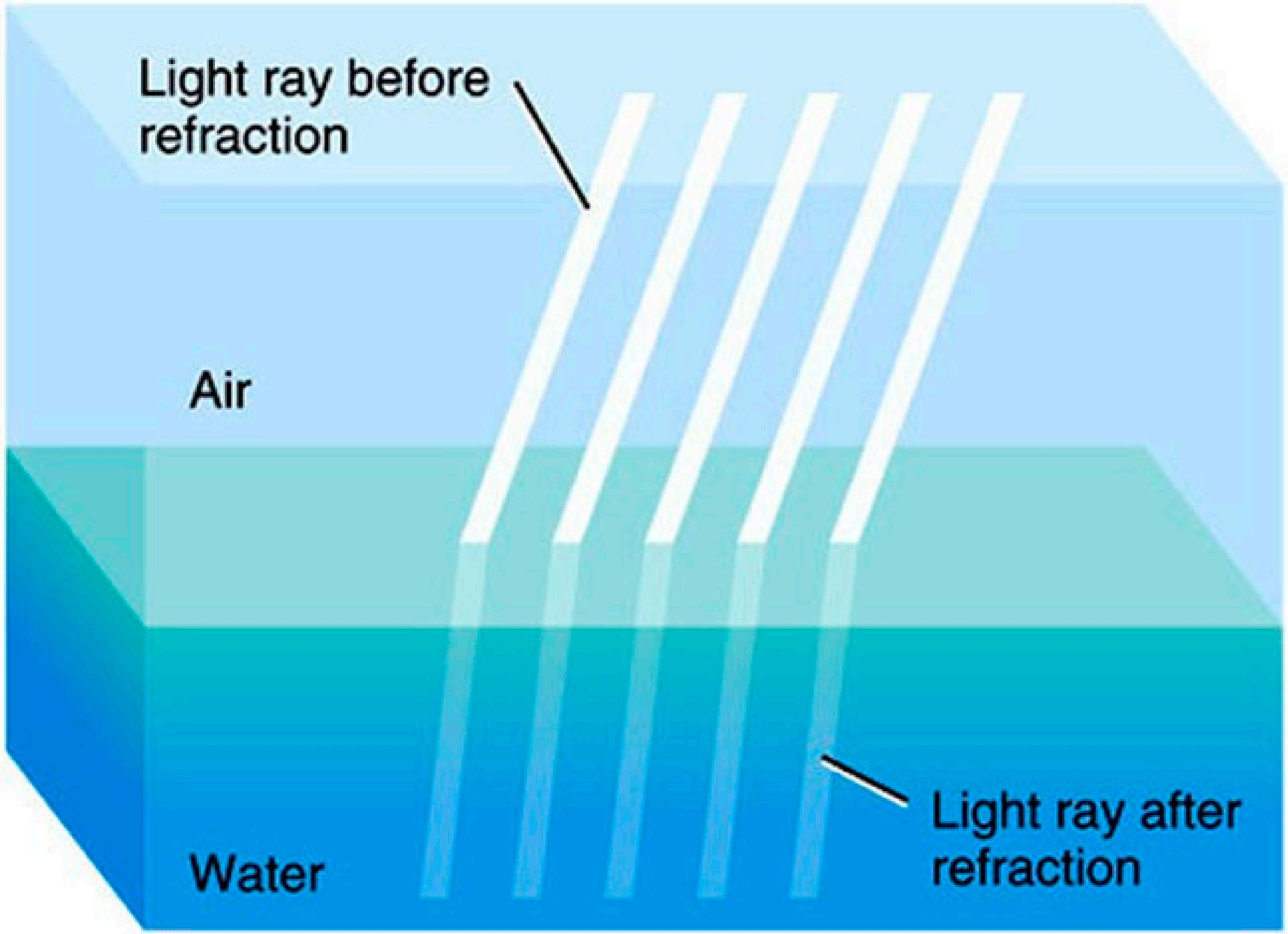
Interior of the Eyeball

- Lens-
  - lack blood vessels, consists of a capsule with proteins (crystallins) in layers; transparent.
- Lens divides the eyeball into two cavities: anterior and posterior.
- Anterior cavity- further divided into anterior and posterior chambers. Both are filled with aqueous humor.
- Posterior cavity (vitreous chamber)-filled with vitreous body.



Refraction of Light Rays

- Refraction is the bending of light rays.
- The cornea and lens refract light rays.



(a) Refraction of light rays

Figure 17.12 Tortora - PAP 12/e

Accommodation and the Near Point of Vision

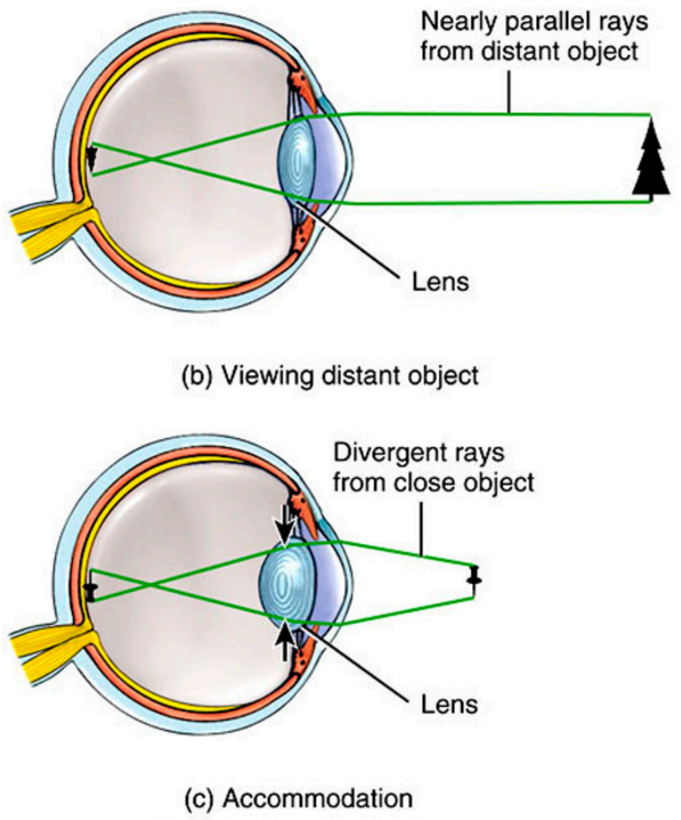


Figure 17.12 Tortora - PAP 12/e

- Increase in the curvature of the lens for near vision is called accommodation.
- Near point of vision is the minimum distance from the eye that an object can be clearly focused.

Refraction Abnormalities and their Correction

- Nearsightedness (myopia)- close objects seen clearly. Image is focused in front of the retina. Correction- use of concave lens.
- Farsightedness (hyperopia)- distant objects seen clearly. Image is focused behind the retina. Correction- use of convex lens.

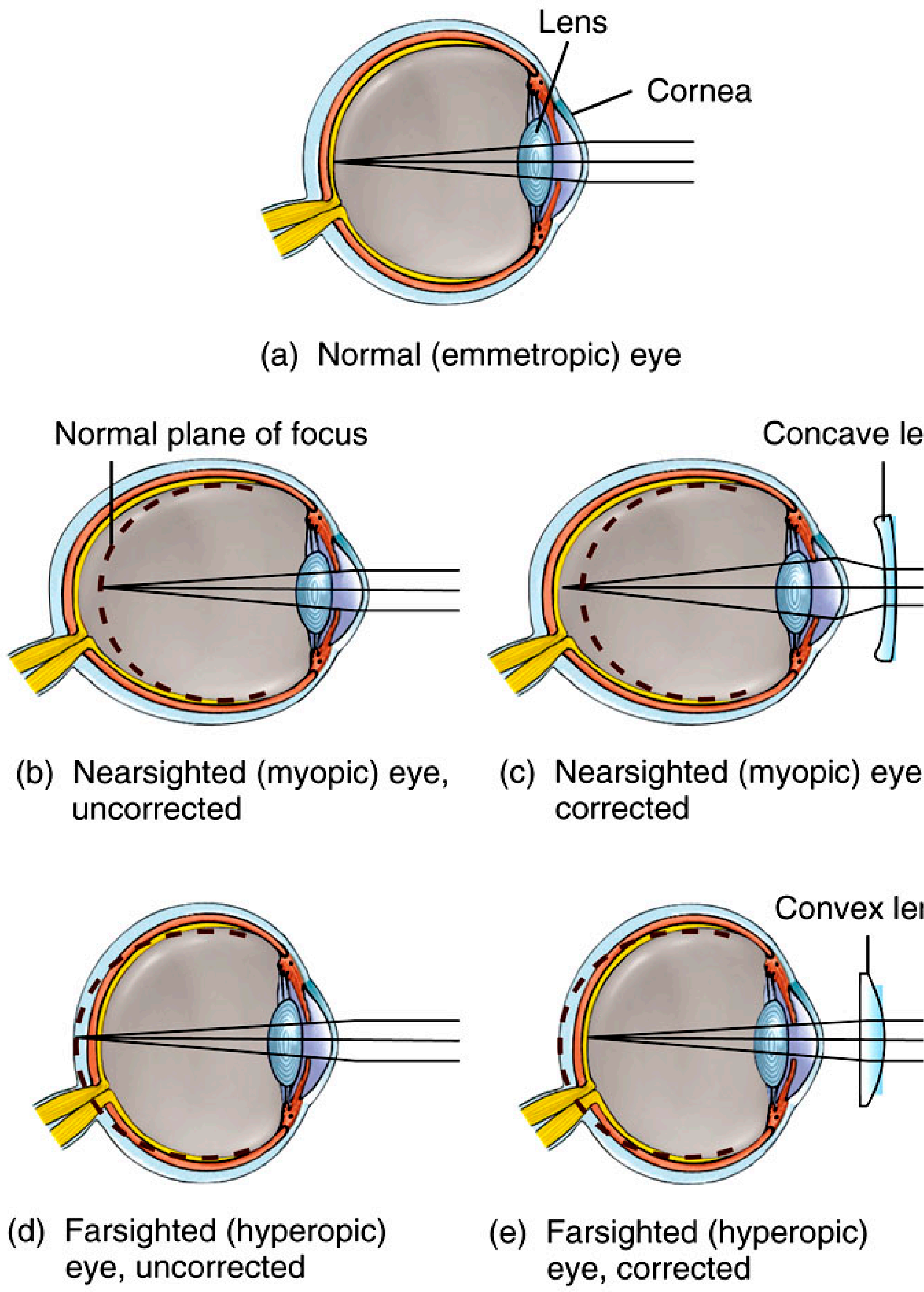
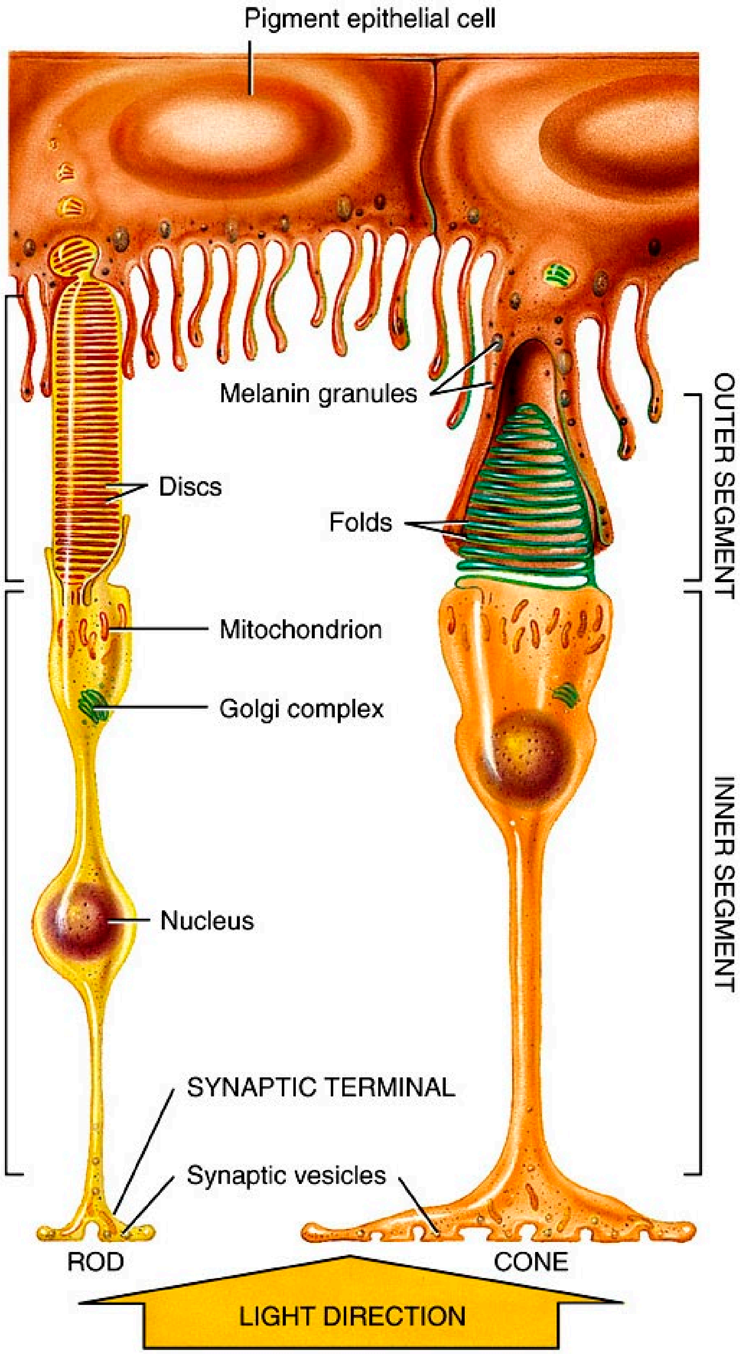


Figure 17.13 Tortora - PAP 12/e

Rods and Cones

- Named after the shapes of their outer segments.
- Rod-
- Cones- three types: red, green and blue.
- Outer segment- contains photopigments. Transduction of light energy into receptor potential occurs here.
- Inner segment- contains the nucleus, Golgi complex and mitochondria.

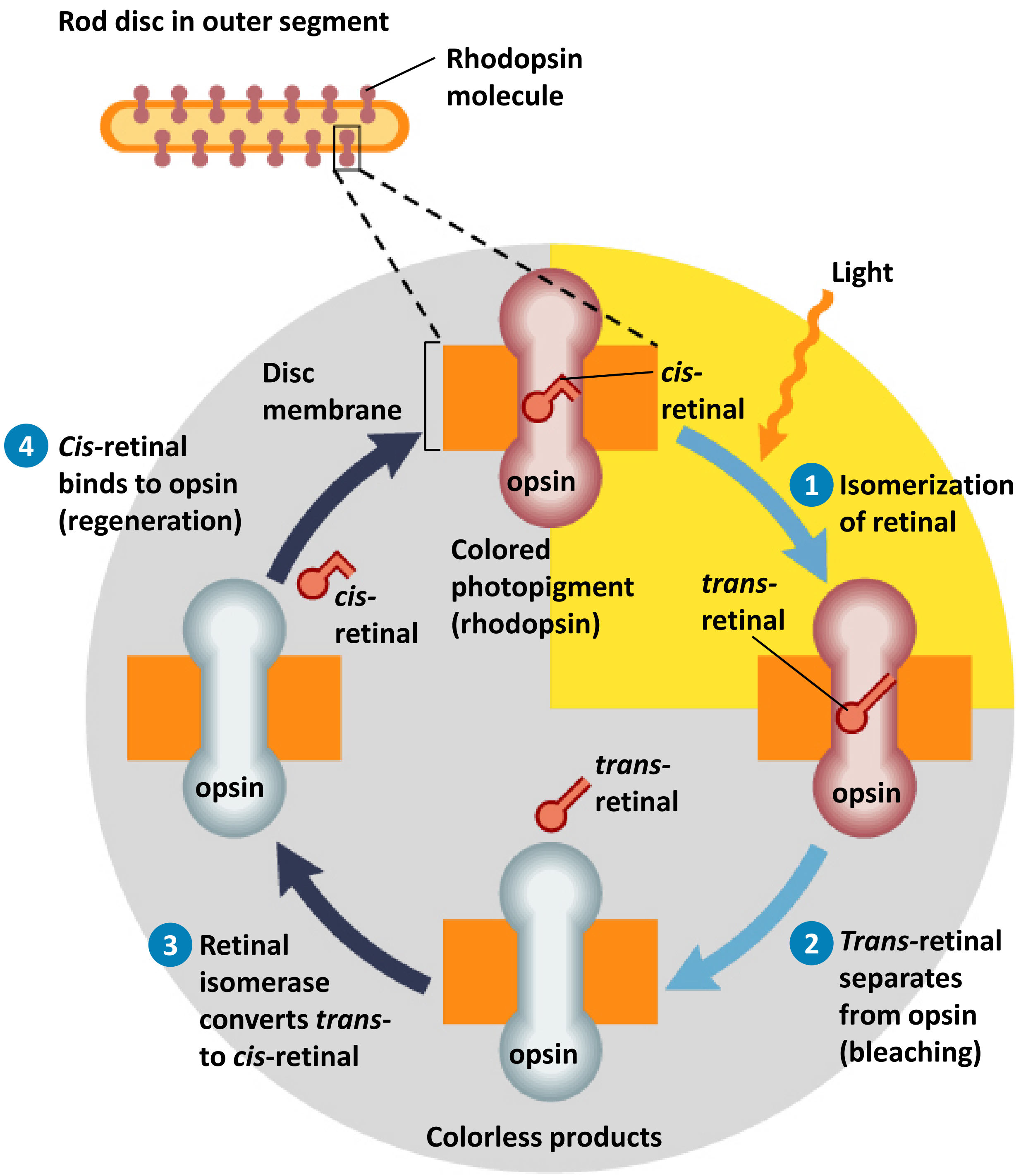


igure 17.14 Tortora - PAP 12/e

Photopigments

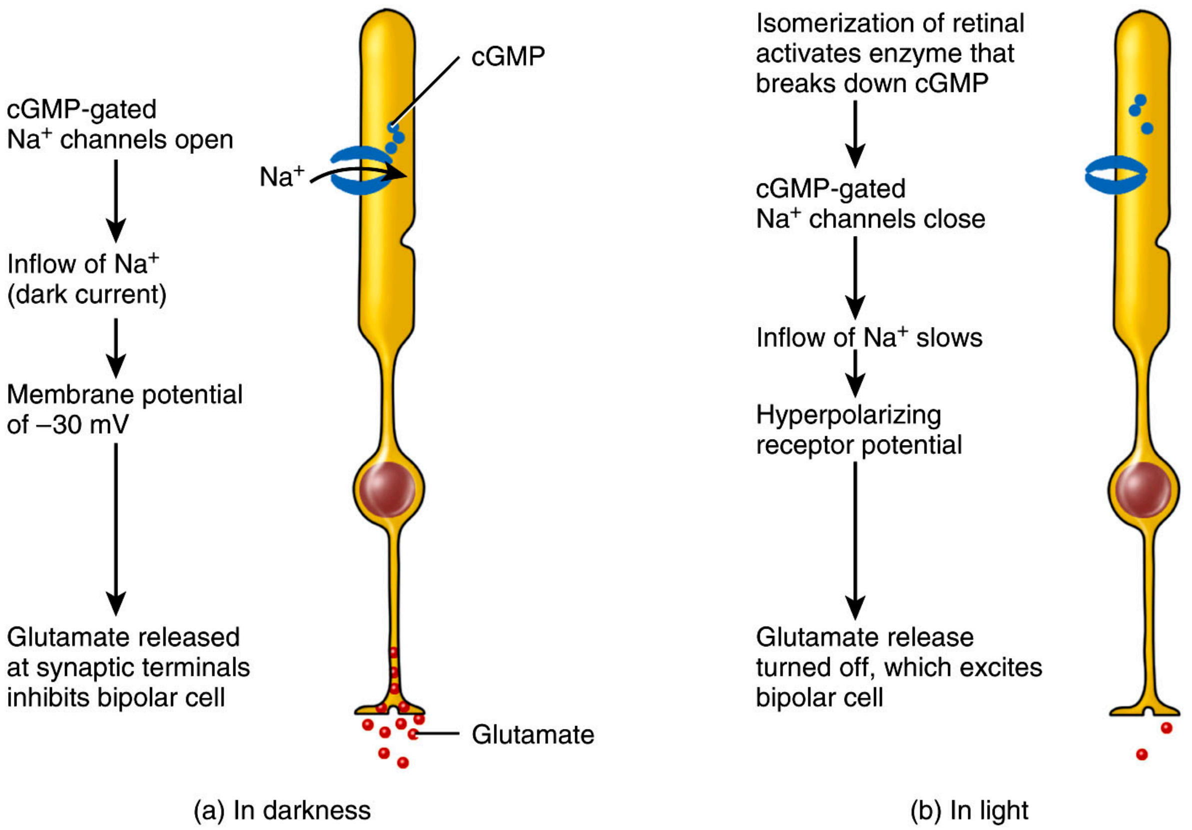
- Two parts: opsin (four types, three in the cones and one in the rod) and retinal (light absorbing part).
- Rhodopsin- photopigment in rods.
- Cone photopigments- three types.

Absorption of light by a photopigment → structural changes.



Light and Dark Adaptation

- Light adaptation: Dark → light. Faster.
- Dark adaptation: Light →dark. Slow.
- Cones regenerate rapidly whereas rhodopsin regenerates more slowly.



(a) In darkness (b) In light

Figure 17.16 Tortora - PAP 12/e

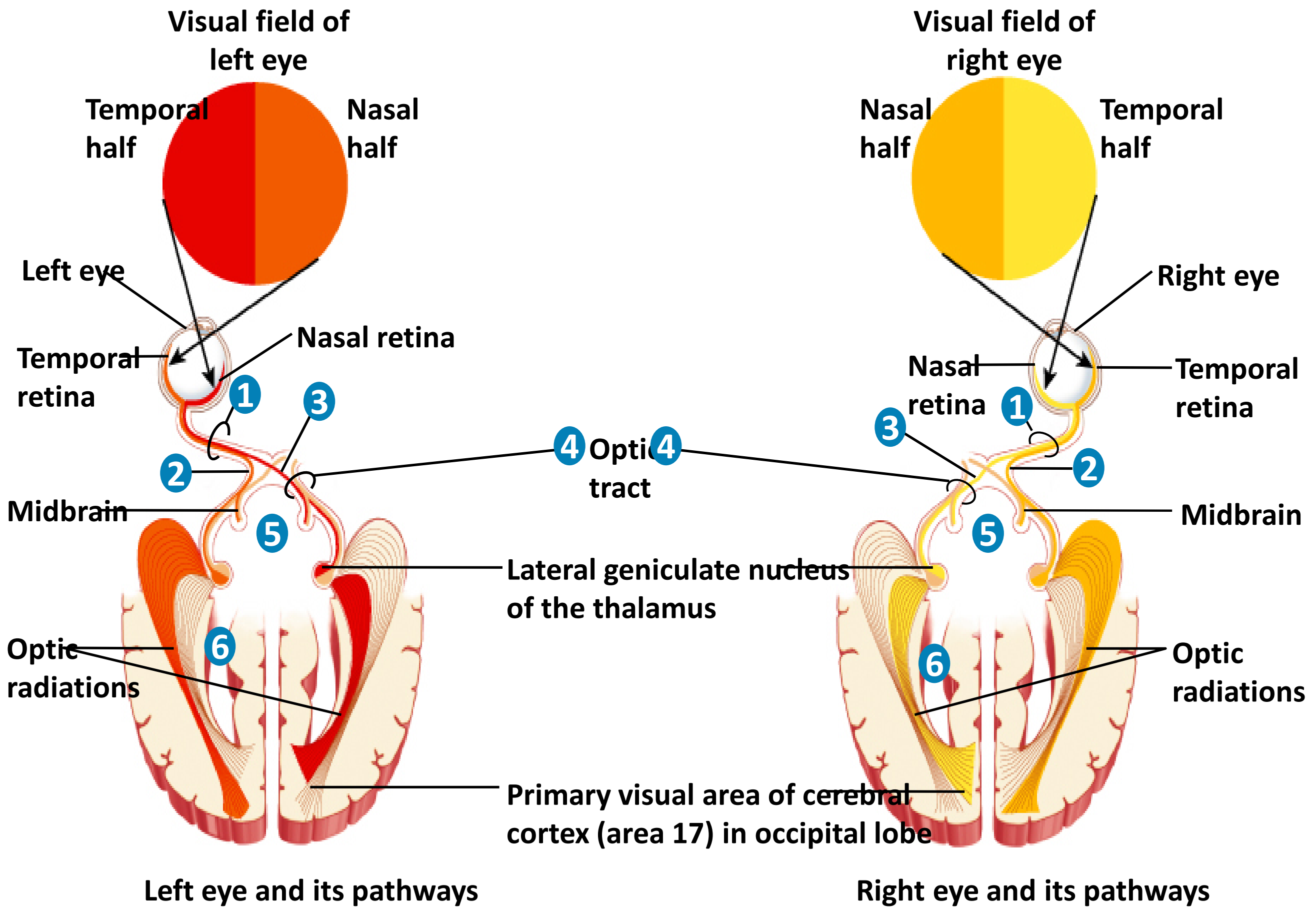
Color Blindness and Night Blindness

- Color blindness- inherited inability to distinguish between certain colors.
  - Result from the absence of one of the three types of cones.
  - Most common type: red-green color blindness.

- Night blindness or Nyctalopia- vitamin A deficiency.

Processing of Visual Input

- Receptor potential in rods and cones⟶ graded potentials in bipolar neurons and horizontal cells⟶ nerve impulses in ganglion cells⟶ optic nerve⟶ optic chiasm⟶ optic tract⟶ thalamus⟶ primary visual area of cerebral cortex in occipital lobe.



Anatomy of the Ear

- Three main regions:
    - External (outer) ear- auricle or pinna, external auditory canal, and tympanic membrane.

      Ceruminous glands-
    - Middle ear- auditory ossicles: malleus, incus and stapes.

      Auditory (eustachian) tube.
    - Internal (inner) ear- Labyrinth: bony and membranous. Bony labyrinth- perilymph and membranous labyrinth- endolymph. Oval window and round window- membranous regions.

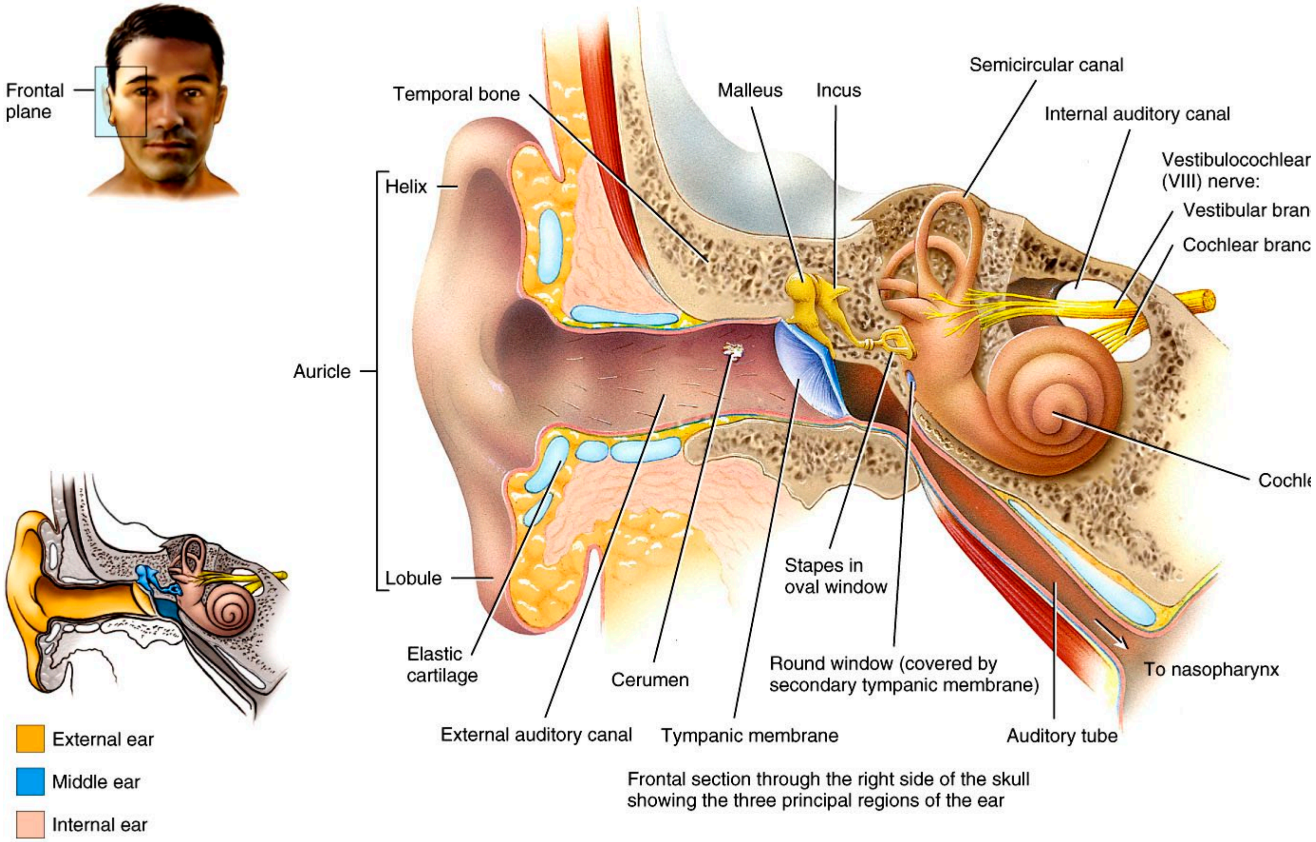
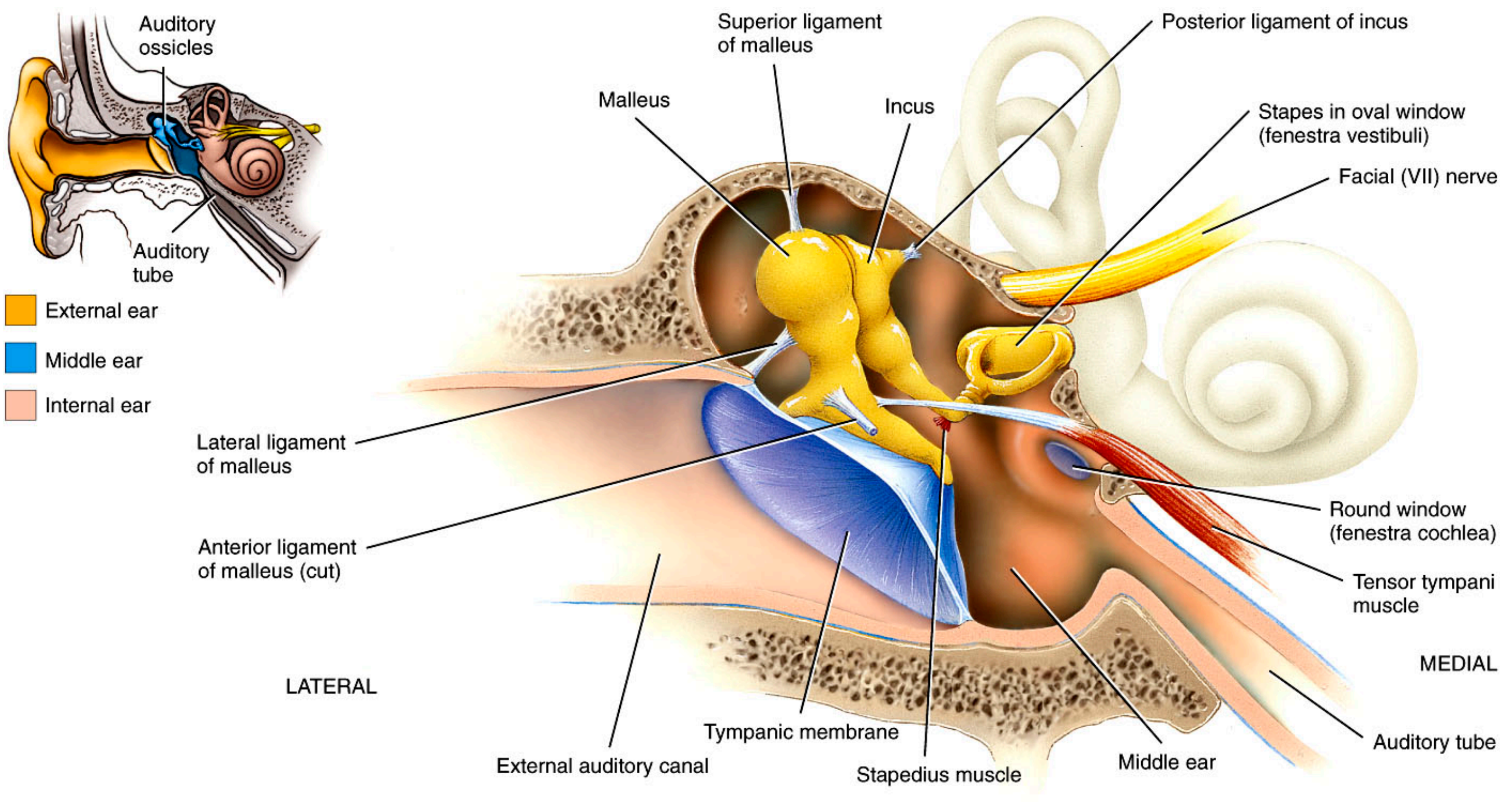


Figure 17.18 Tortora - PAP 12/e

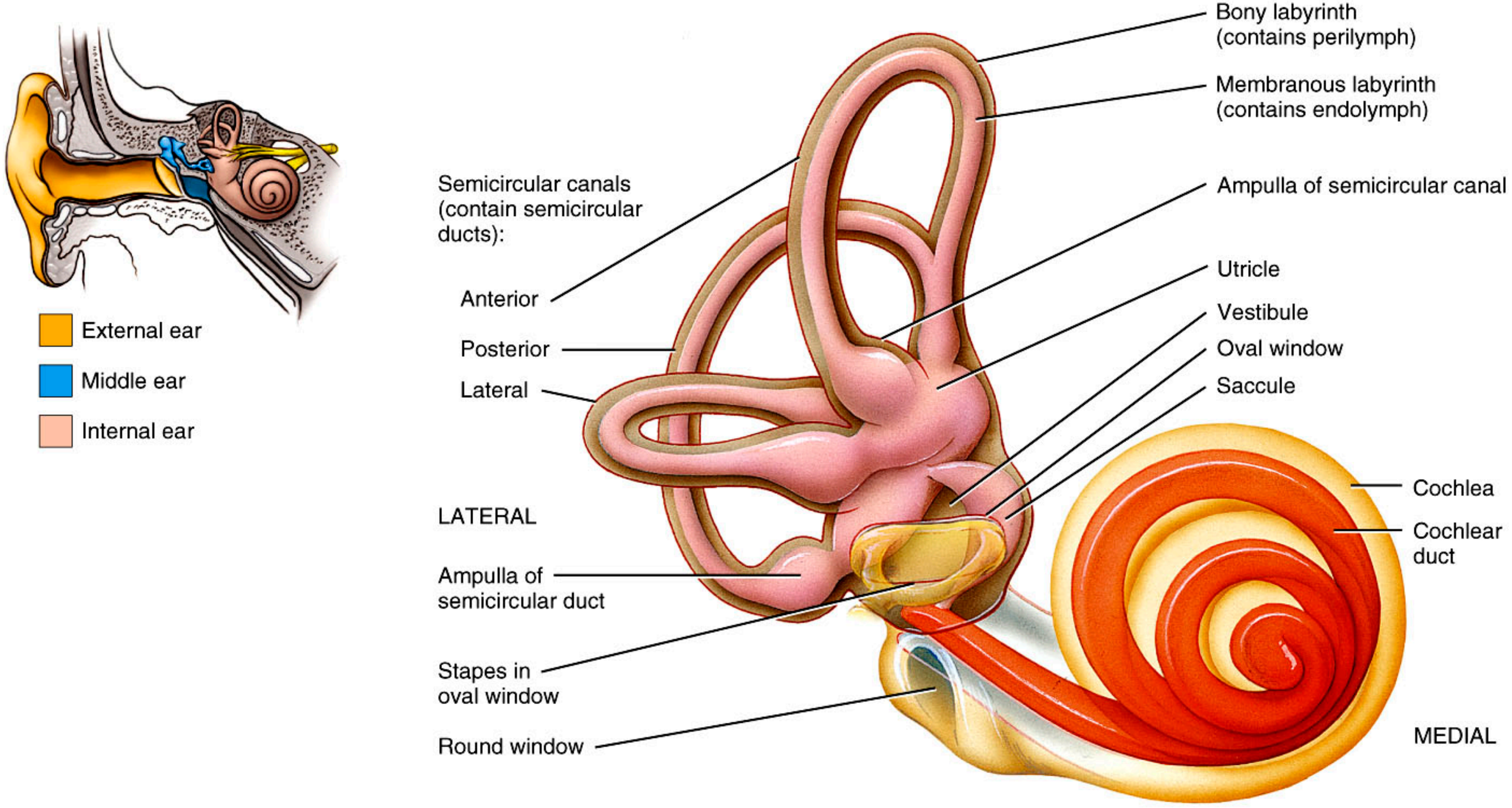
The Middle Ear and the Auditory Ossicles



(a) Frontal section showing location of auditory ossicles

Figure 17.19 Tortora - PAP 12/e

The Internal Ear



(a) Components of the right internal ear

Figure 17.20 Tortora - PAP 12/e

The Internal Ear

- Three parts: the semicircular canals, the vestibule (both contain receptors for equilibrium) and the cochlea (contains receptors for hearing).
- Semicircular canals: anterior, posterior and lateral.

  Ampulla-
- Vestibule consists of two sacs: utricle and saccule.

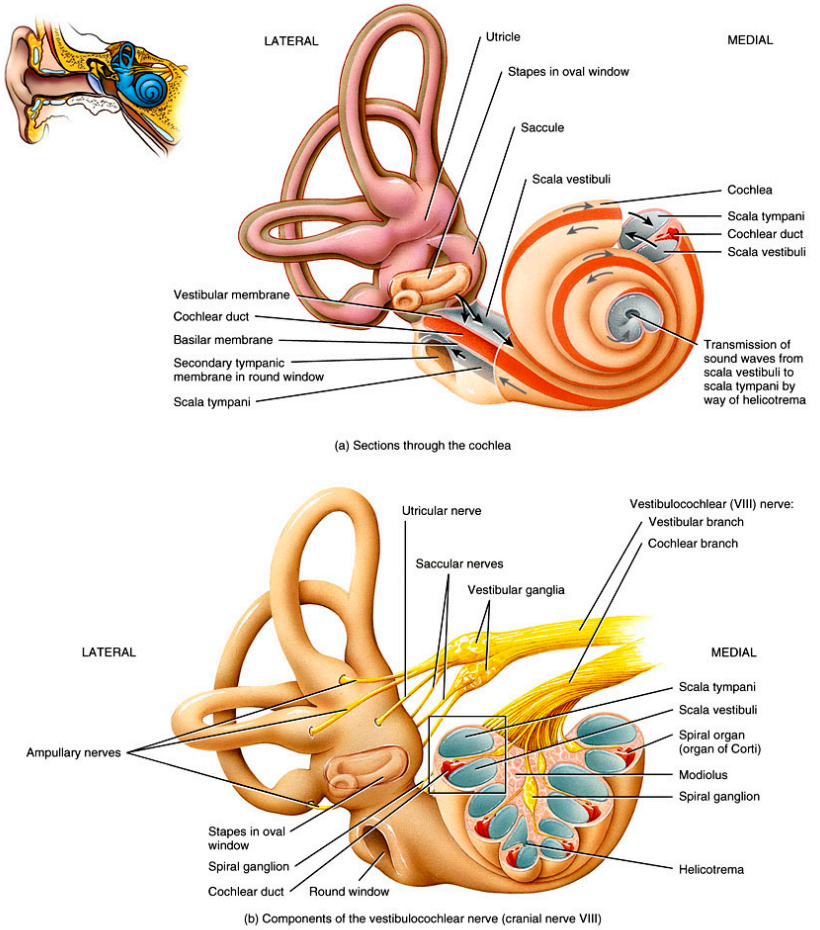
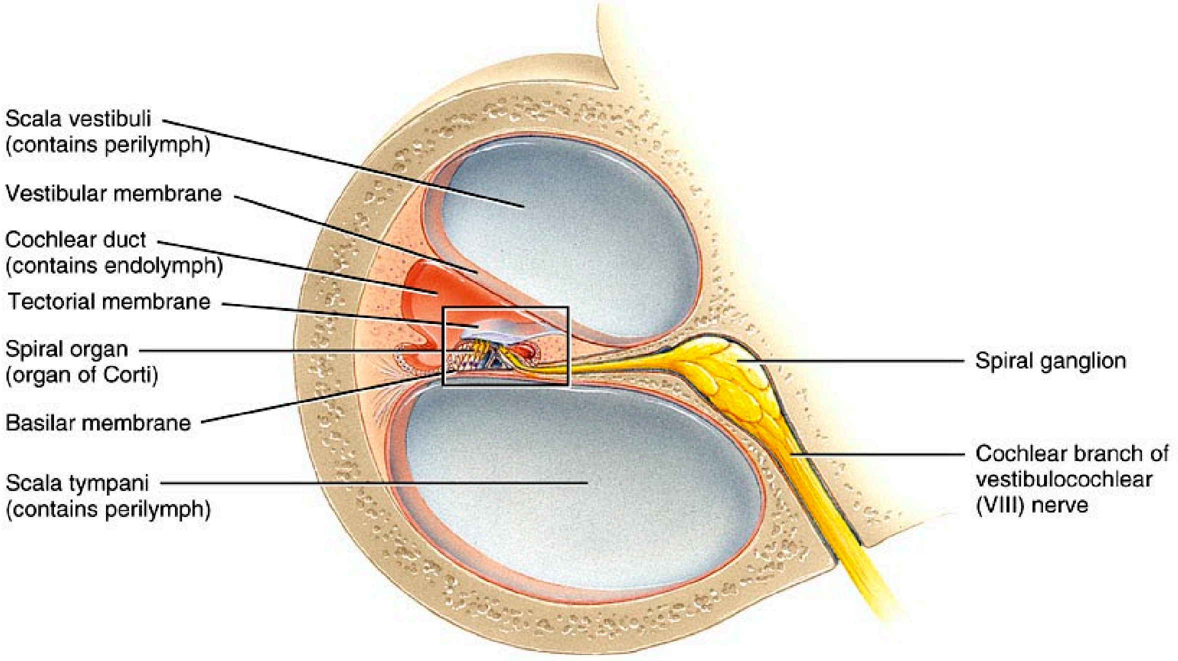


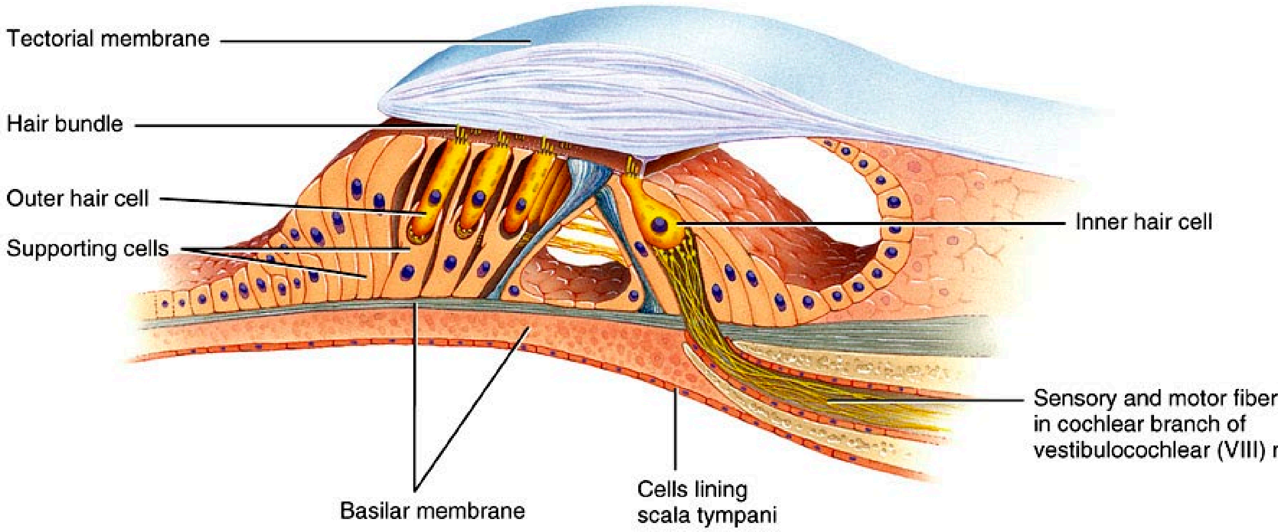
Figure 17.21ab Tortora - PAP 12/e

Cochlea

- Snail-shaped.
- Section through the cochlea shows three channels: cochlear duct, scala vestibuli and scala tympani.
- Helicotrema
- Vestibular membrane
- Basilar membrane
- Spiral organ or Organ of Corti- hair cells.



(c) Section through one turn of the cochlea



(d) Enlargement of spiral organ (organ of Corti)

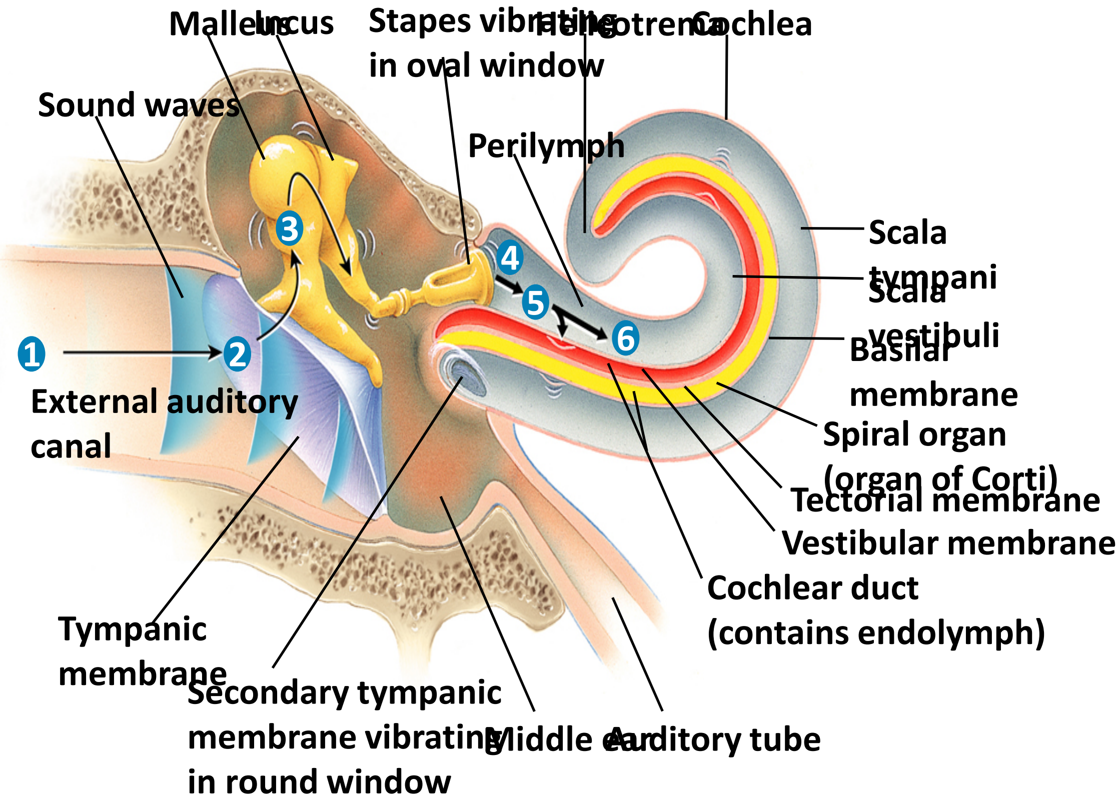
Figure 17.21cd Tortora - PAP 12/e

Physiology of Hearing

- Audible sound range: 20-20,000 Hz.
- Sound waves→ auricle→ external auditory canal→ tympanic membrane→ malleus→ incus→ stapes→ oval window→ perilymph of the scala vestibuli→ vestibular membrane→ endolymph in the cochlear duct→ basilar membrane →hair cells against tectorial membrane → bending of hair cell stereocilia→ receptor potential→ nerve impulse. Sound wave → scala tympani→ round window.

Summary of Hearing

1. Sound waves enter the external auditory meatus
2. Tympanic membrane vibrates
3. Auditory ossicles vibrate
4. Oval window vibrates
5. Fluid in inner ear vibrates
6. Basement membrane moves
7. Hairs rub against the tectorial membrane
8. Nerve impulse is sent along the auditory nerve to the brain



The Auditory Pathway

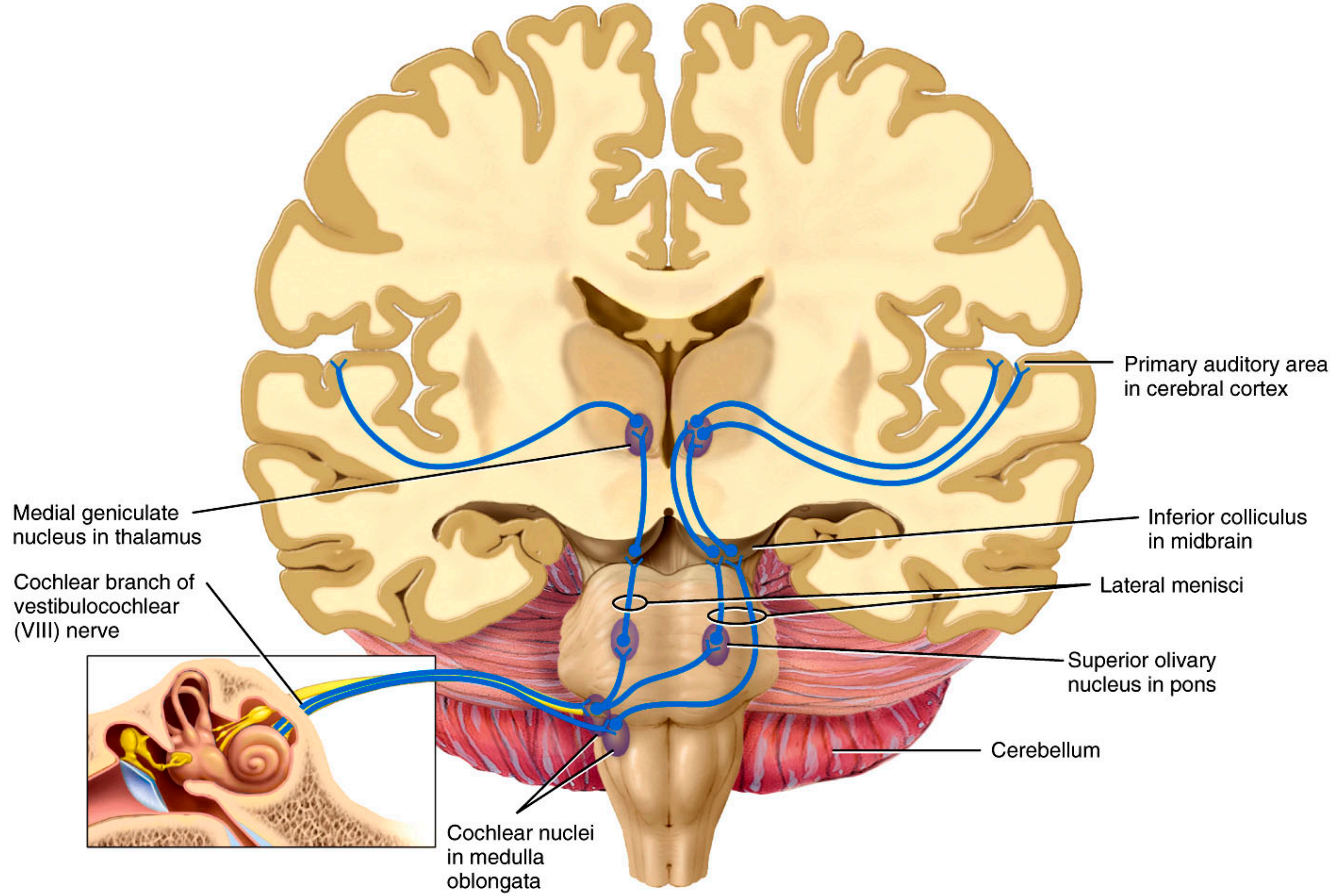


Figure 17.23 Tortora - PAP 12/e

Physiology of Equilibrium

- Two types of equilibrium:

  Static- maintenance of the body position relative to the force of gravity.

  Dynamic- maintenance of body position (mainly head) in response to rotational acceleration and deceleration.

- Receptors for equilibrium are hair cells in the utricle, saccule and semicircular canals and are collectively called **vestibular apparatus**.

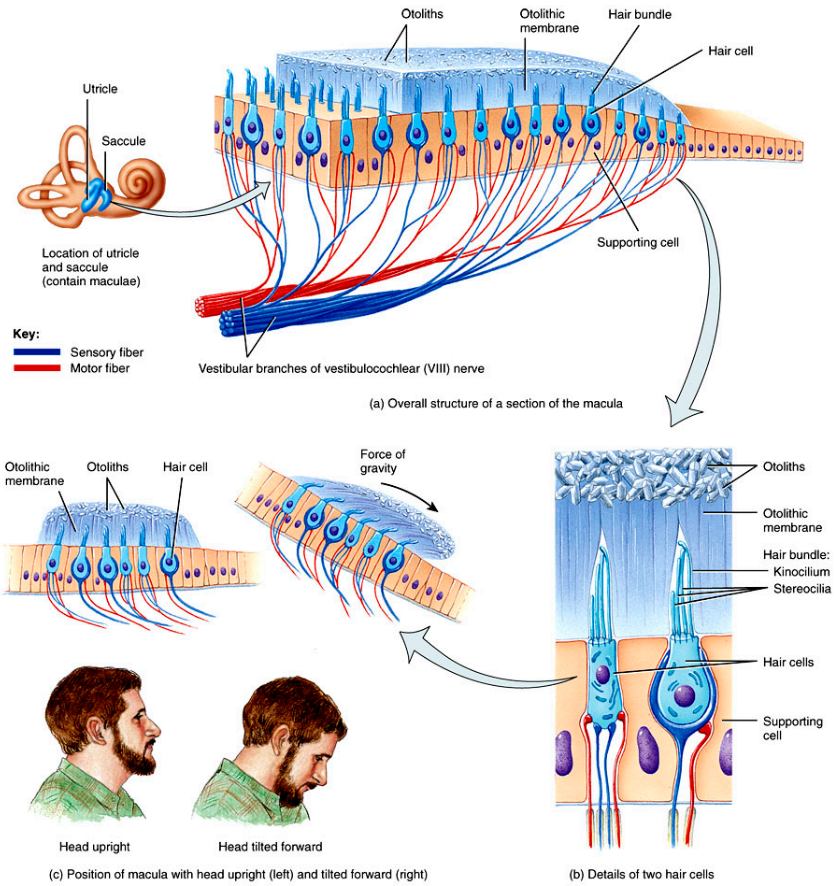
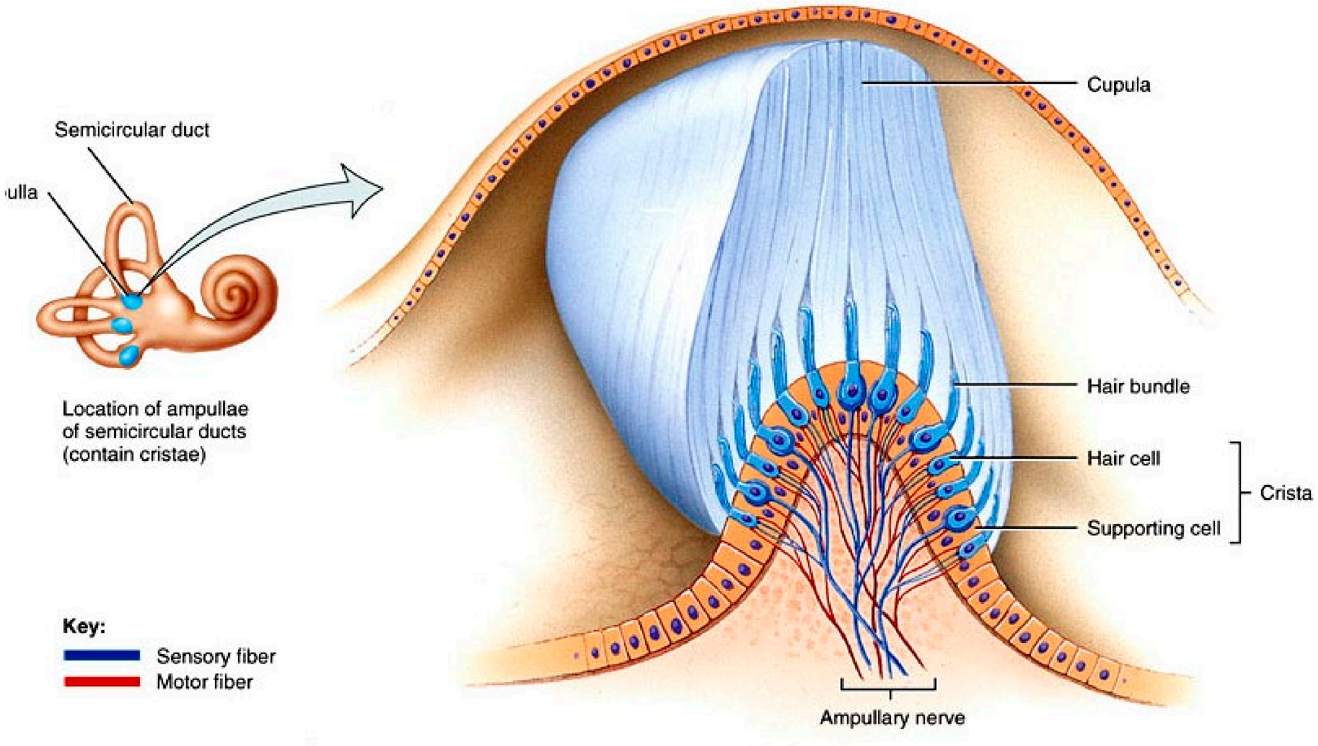


Figure 17.24 Tortora - PAP 12/e

Otolithic Organs: Saccule and Utricle

- Macula- small thickened regions within the saccule and utricle.
- Sensory structures for static equilibrium.
- Also detect linear acceleration and deceleration.
- Contain hair cells and supporting cells.
- Stereocilia and kinocilium together called hair bundle.
- Otolithic membrane rests on the hair cells and contain otoliths.

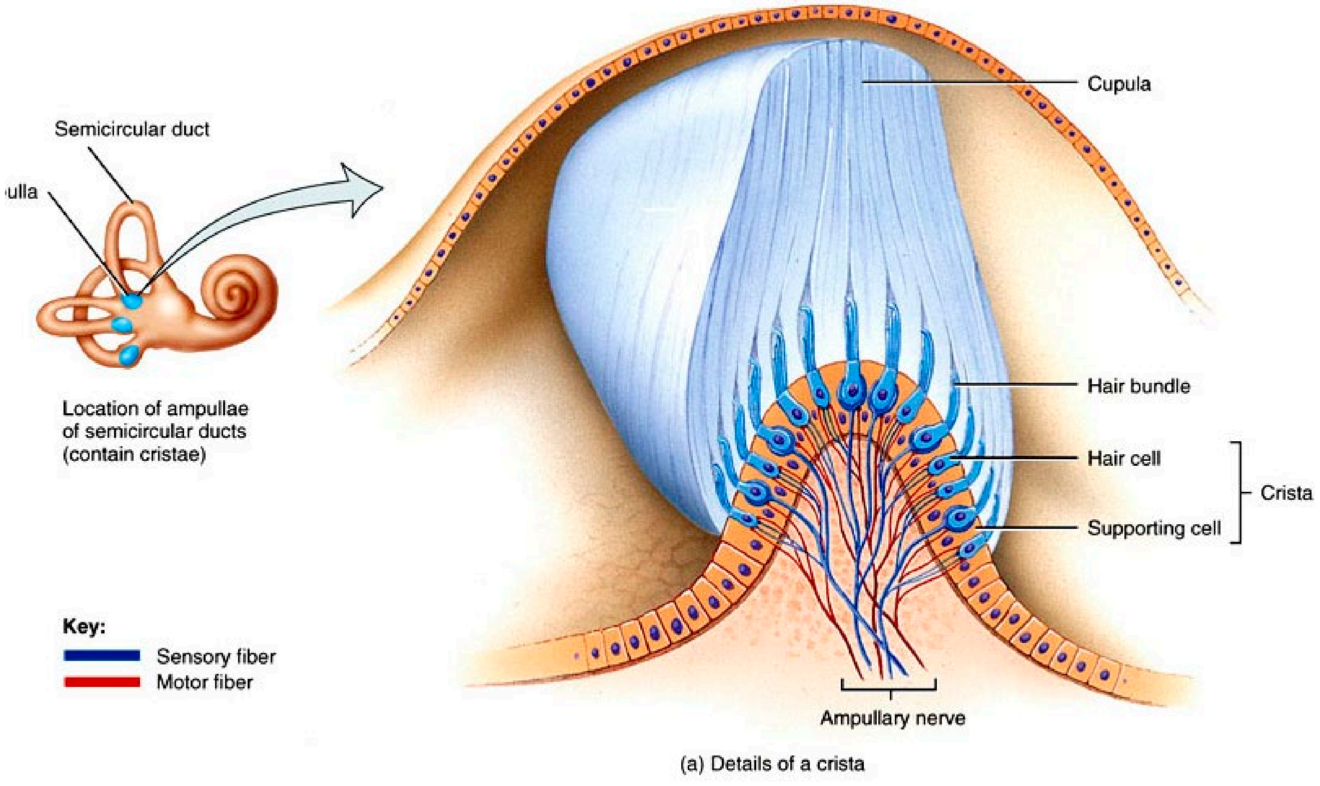


(a) Details of a crista

ure 17.25 Tortora - PAP 12/e

Physiology of Equilibrium continued

- Tilting of the head forward→ sliding of the otolithic membrane bending the hair bundles→ receptor potential→ vestibular branch of the vestibulocochlear nerve.



(a) Details of a crista

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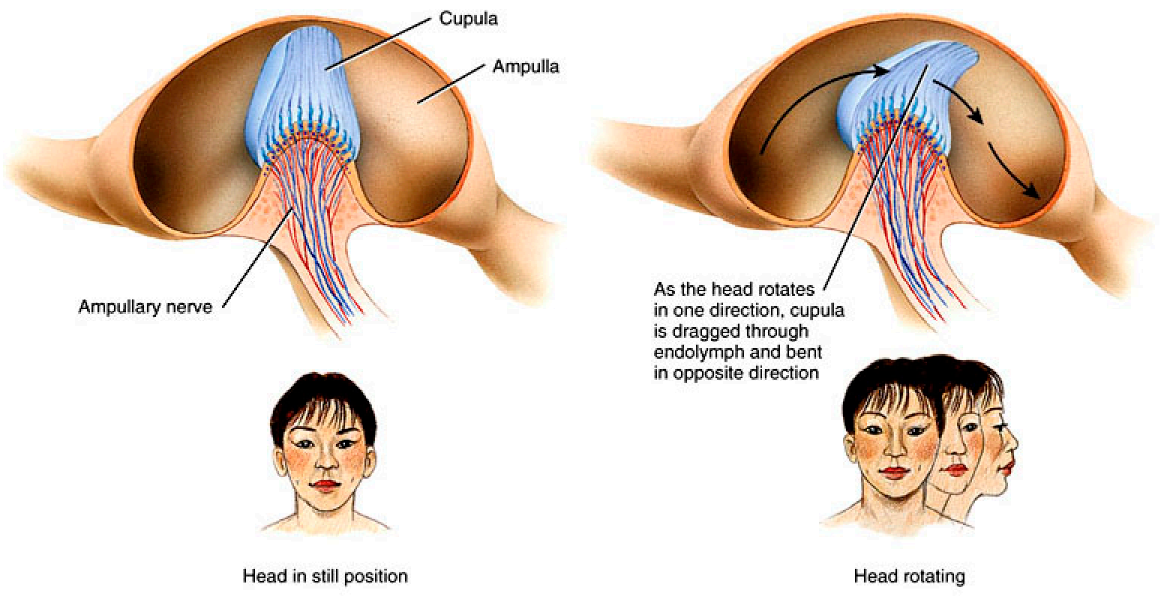
Semicircular Ducts

- Crista, a small elevation in the ampulla contain hair cells and supporting cells.
- Cupula, a mass of gelatinous material covering the crista.
- Head movement→ semicircular ducts and hair cells move with it→ hair bundles bend→ receptor potential→ nerve impulses→ vestibular branch of the vestibulocochlear nerve.



(b) Position of a cupula with the head in the still position (left) and when the head rotates (right)

Figure 17.25 Tortora - PAP 12/e

Equilibrium Pathway

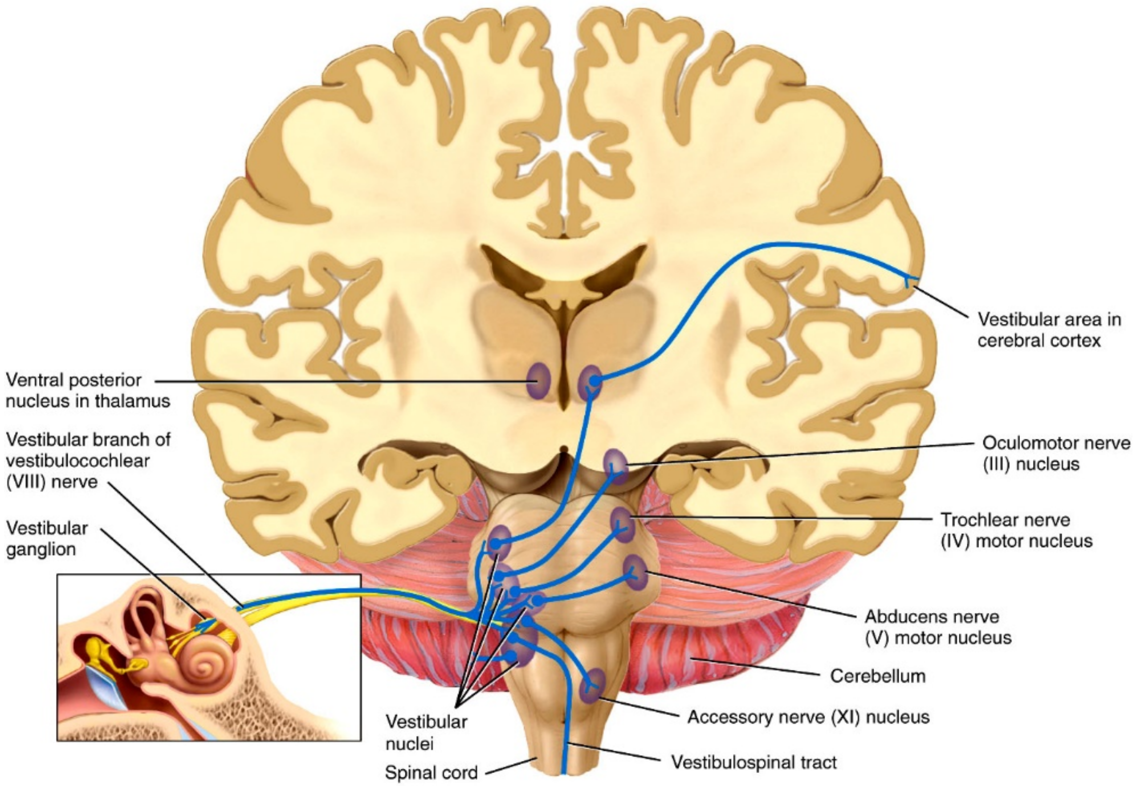


Figure 17.26 Tortora - PAP 12/e

- Hair cells of utricle, saccule and semicircular ducts→Vestibular branch of the vestibulocochlear nerve →brain stem → cerebellum and thalamus→ cerebral cortex.

ANY QUESTIONS