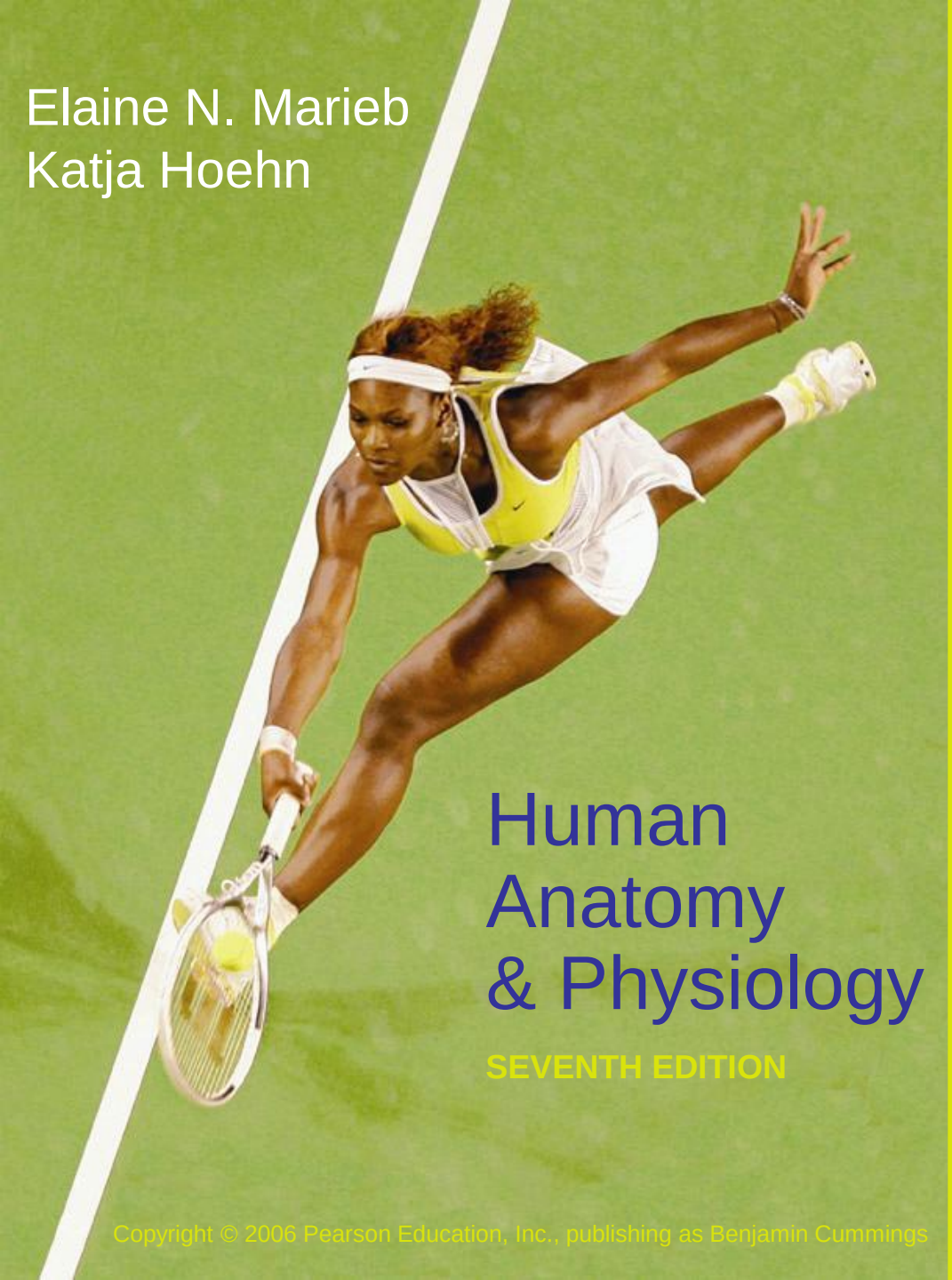
Elaine N. Marieb
Katja Hoehn



Human Anatomy & Physiology

SEVENTH EDITION

PowerPoint® Lecture Slides
prepared by Vince Austin,
Bluegrass Technical
and Community College

CHAPTER 15

The Special Senses EAR

The Ear: Hearing and Balance

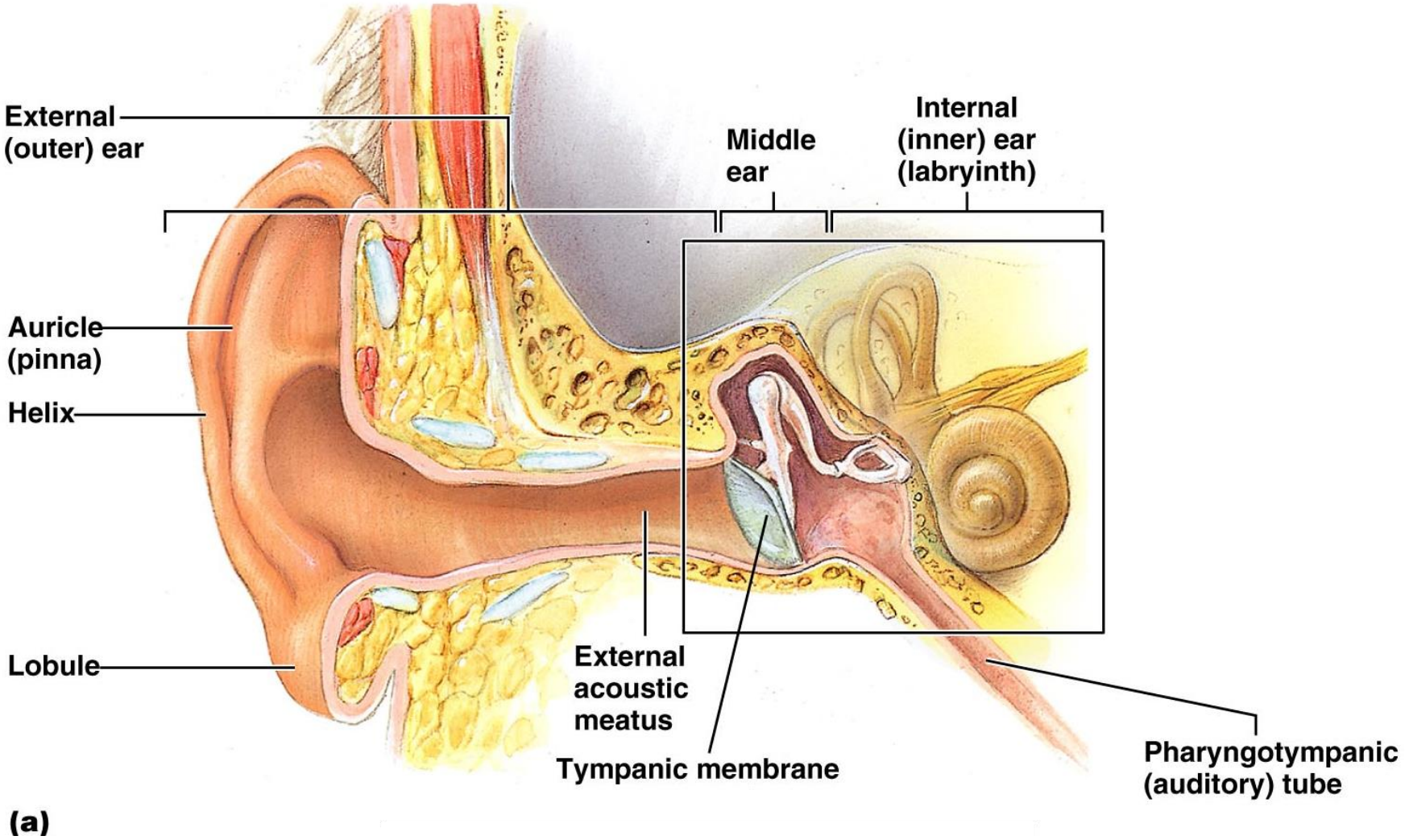


Figure 15.25a

Outer Ear

- The auricle (pinna) is composed of:
  - The helix (rim)
  - The lobule (earlobe)
- External auditory canal
  - Short, curved tube filled with ceruminous glands

Outer Ear

- Tympanic membrane (eardrum)
  - Thin connective tissue membrane that vibrates in response to sound
  - Transfers sound energy to the middle ear ossicles
  - Boundary between outer and middle ears

Middle Ear (Tympanic Cavity)

- A small, air-filled, mucosa-lined cavity
  - Flanked laterally by the eardrum
  - Flanked medially by the oval and round windows
- Epitympanic recess – superior portion of the middle ear
- Pharyngotympanic tube – connects the middle ear to the nasopharynx
  - Equalizes pressure in the middle ear cavity with the external air pressure

Middle and Internal Ear

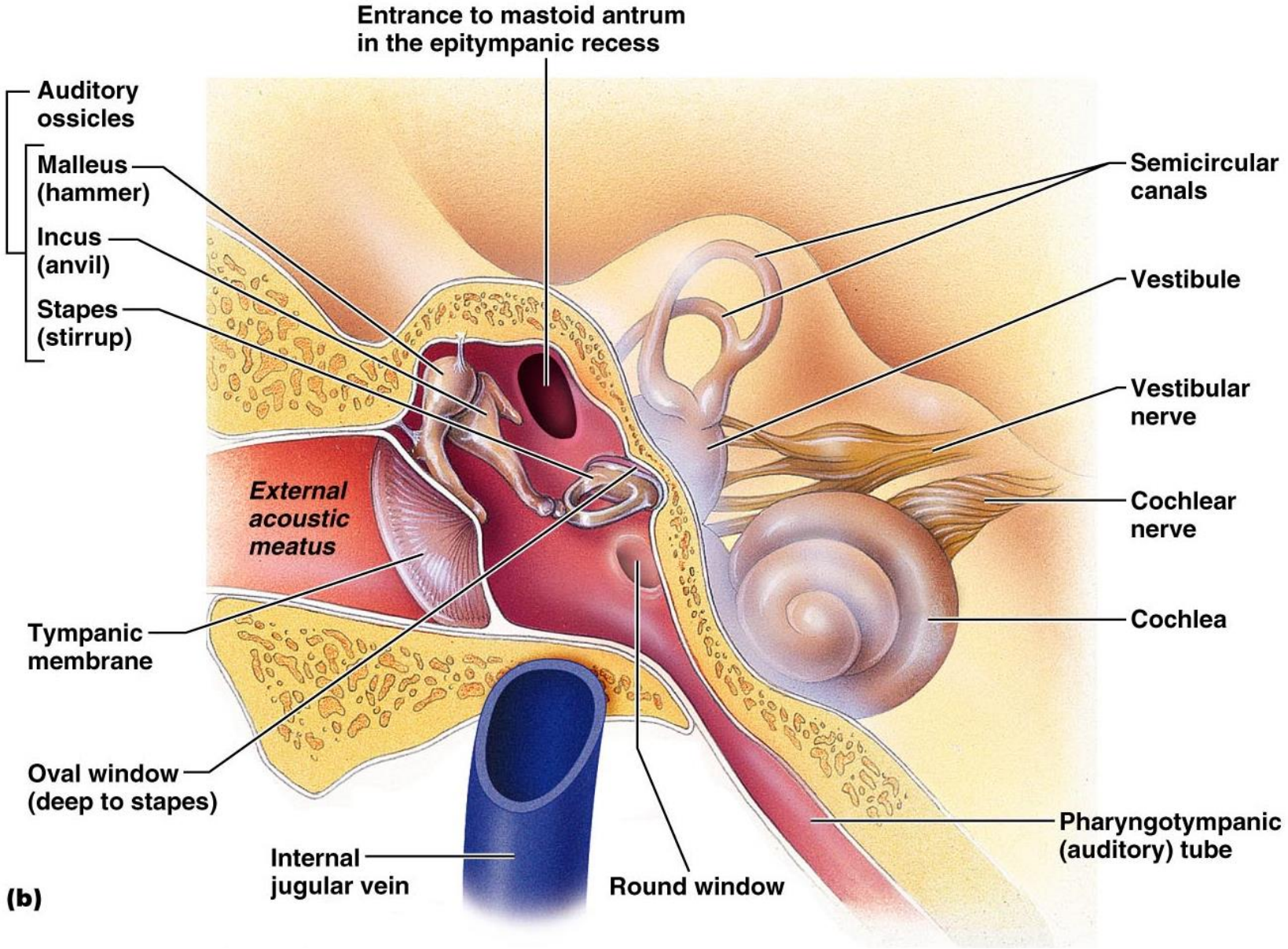


Figure 15.25b

Ear Ossicles

- The tympanic cavity contains three small bones: the malleus, incus, and stapes
  - Transmit vibratory motion of the eardrum to the oval window
  - Dampened by the tensor tympani and stapedius muscles

Ear Ossicles

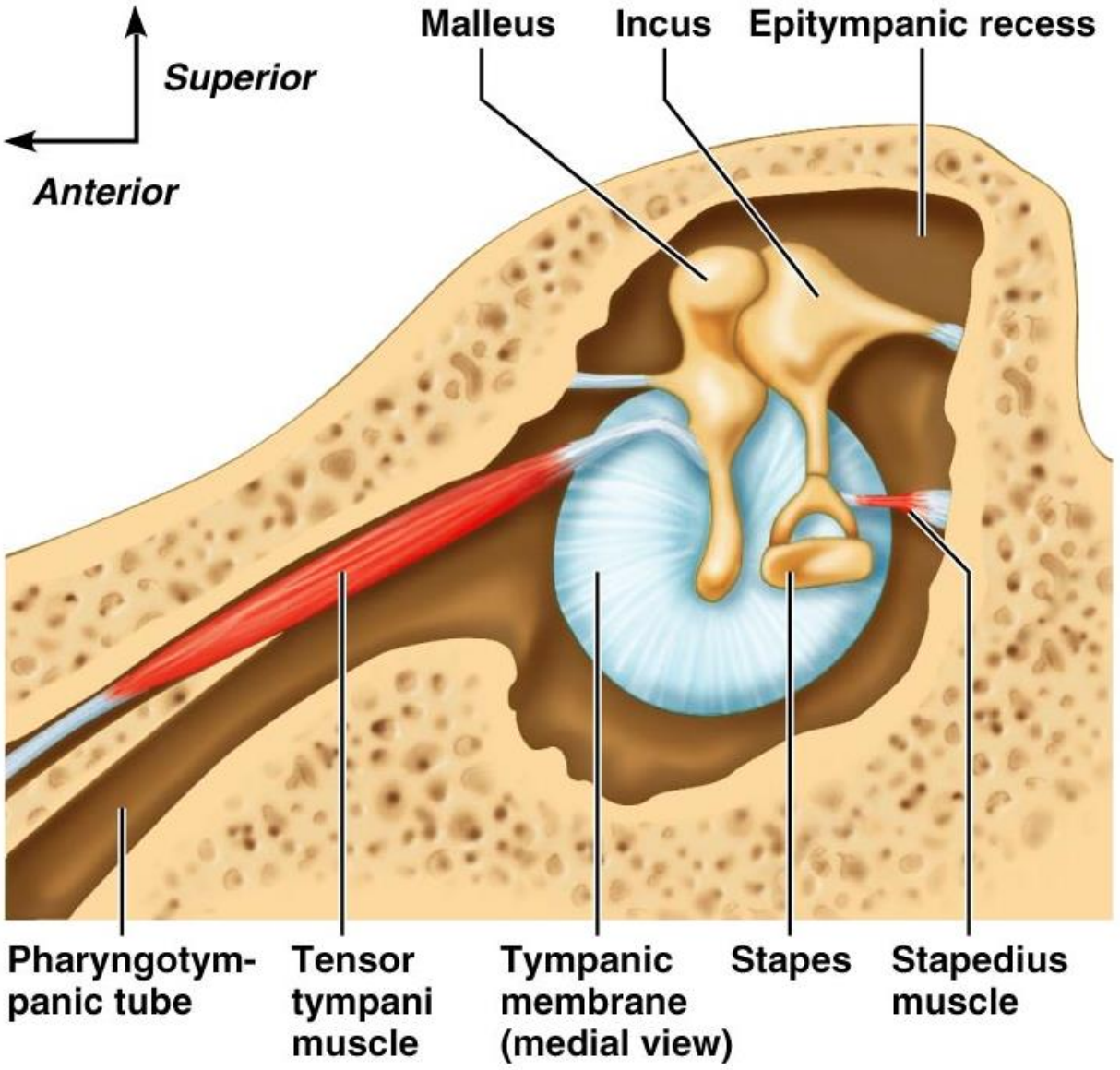


Figure 15.26

Inner Ear

- Bony labyrinth
  - Tortuous channels worming their way through the temporal bone
  - Contains the vestibule, the cochlea, and the semicircular canals
  - Filled with perilymph
- Membranous labyrinth
  - Series of membranous sacs within the bony labyrinth
  - Filled with a potassium-rich fluid

Inner Ear

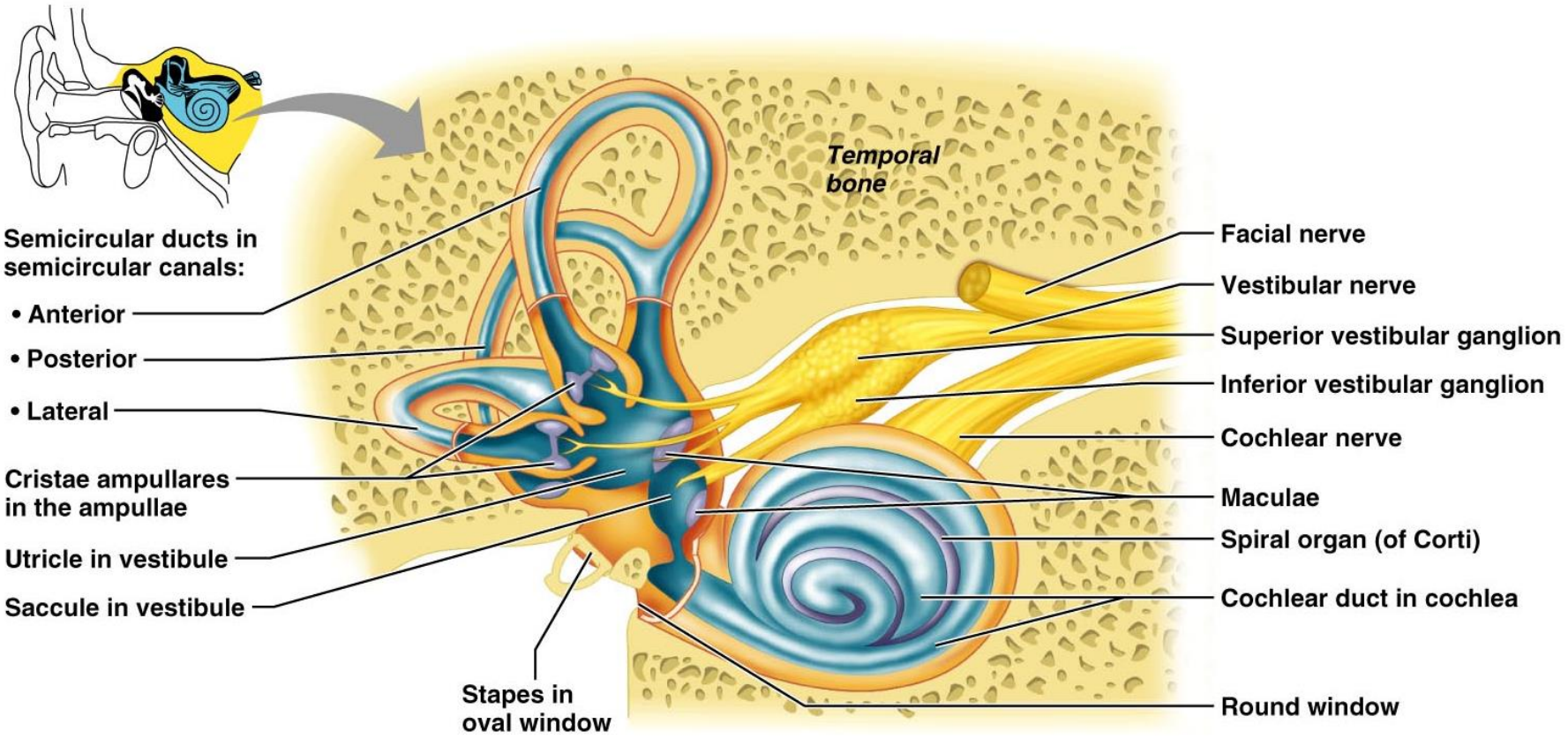


Figure 15.27

The Vestibule

- The central egg-shaped cavity of the bony labyrinth
- Suspended in its perilymph are two sacs: the saccule and utricle
- The saccule extends into the cochlea

The Vestibule

- The utricle extends into the semicircular canals
- These sacs:
  - House equilibrium receptors called maculae
  - Respond to gravity and changes in the position of the head

The Vestibule

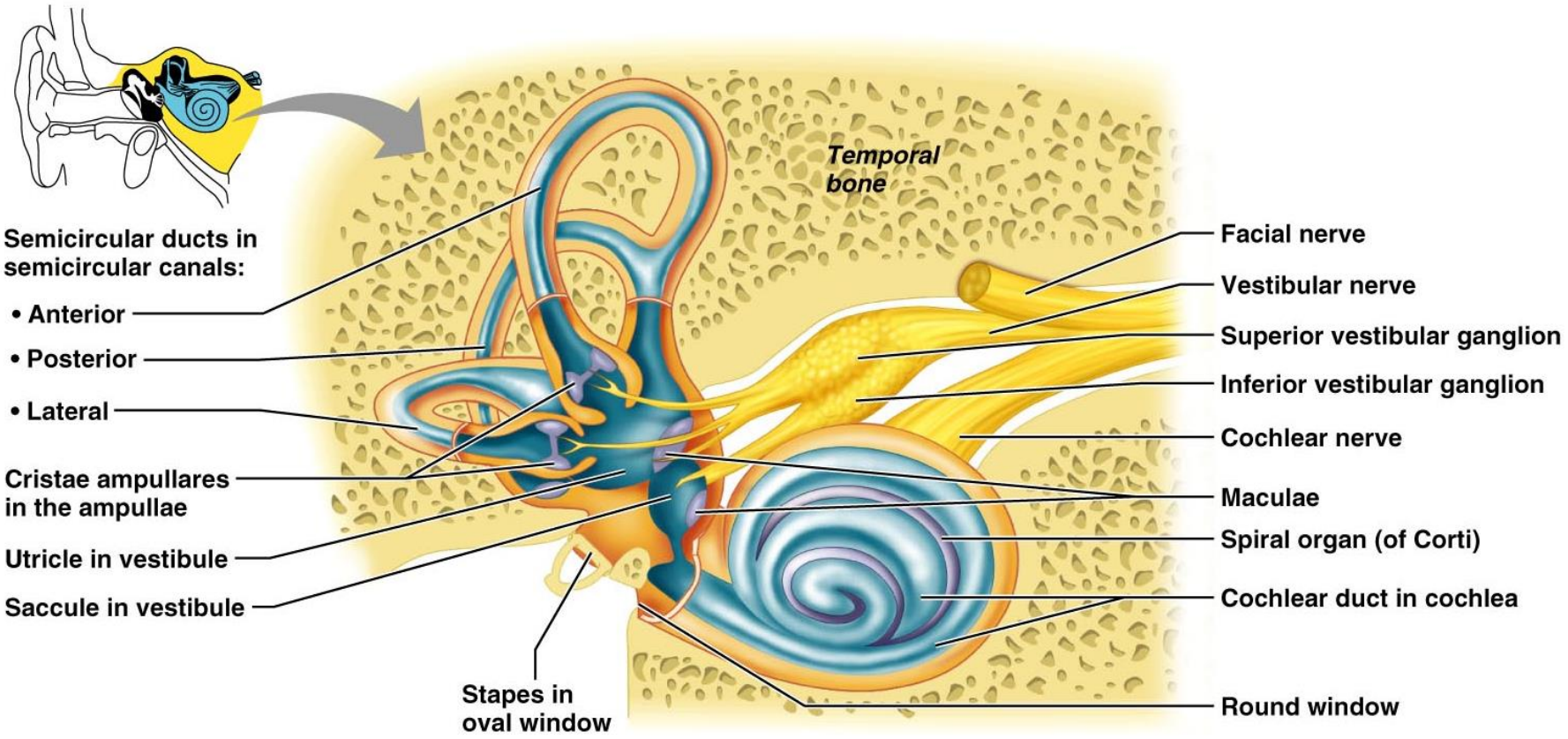


Figure 15.27

The Semicircular Canals

- Three canals that each define two-thirds of a circle and lie in the three planes of space
- Membranous semicircular ducts line each canal and communicate with the utricle
- The ampulla is the swollen end of each canal and it houses equilibrium receptors in a region called the crista ampullaris
- These receptors respond to angular movements of the head

The Semicircular Canals

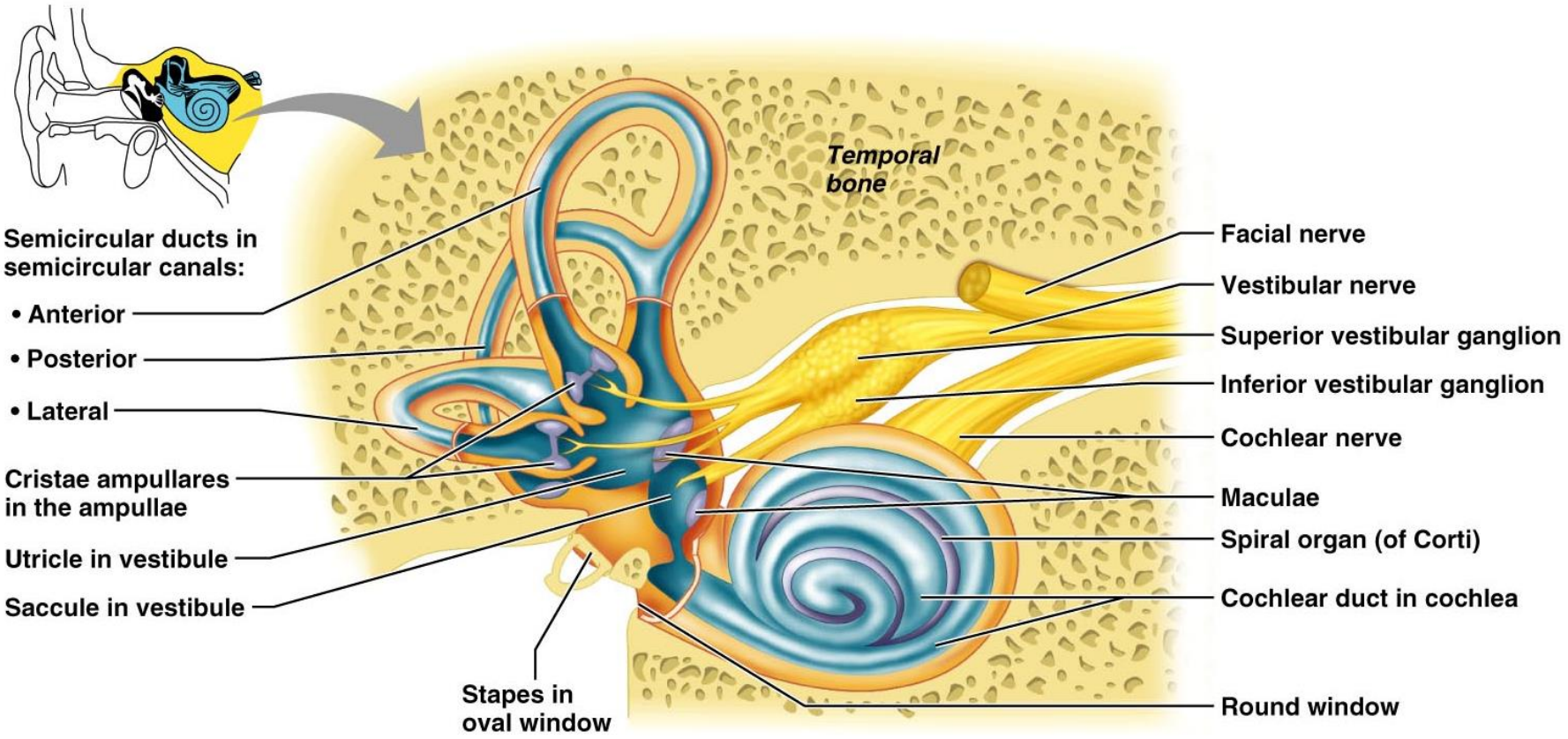


Figure 15.27

The Cochlea

- A spiral, conical, bony chamber that:
  - Extends from the anterior vestibule
  - Coils around a bony pillar called the modiolus
  - Contains the cochlear duct, which ends at the cochlear apex
  - Contains the organ of Corti (hearing receptor)

The Cochlea

- The cochlea is divided into three chambers:
  - Scala vestibuli
  - Scala media
  - Scala tympani

The Cochlea

- The scala tympani terminates at the round window
- The scalas tympani and vestibuli:
  - Are filled with perilymph
  - Are continuous with each other via the helicotrema
- The scala media is filled with endolymph

The Cochlea

- The “floor” of the cochlear duct is composed of:
  - The bony spiral lamina
  - The basilar membrane, which supports the organ of Corti
- The cochlear branch of nerve VIII runs from the organ of Corti to the brain

The Cochlea

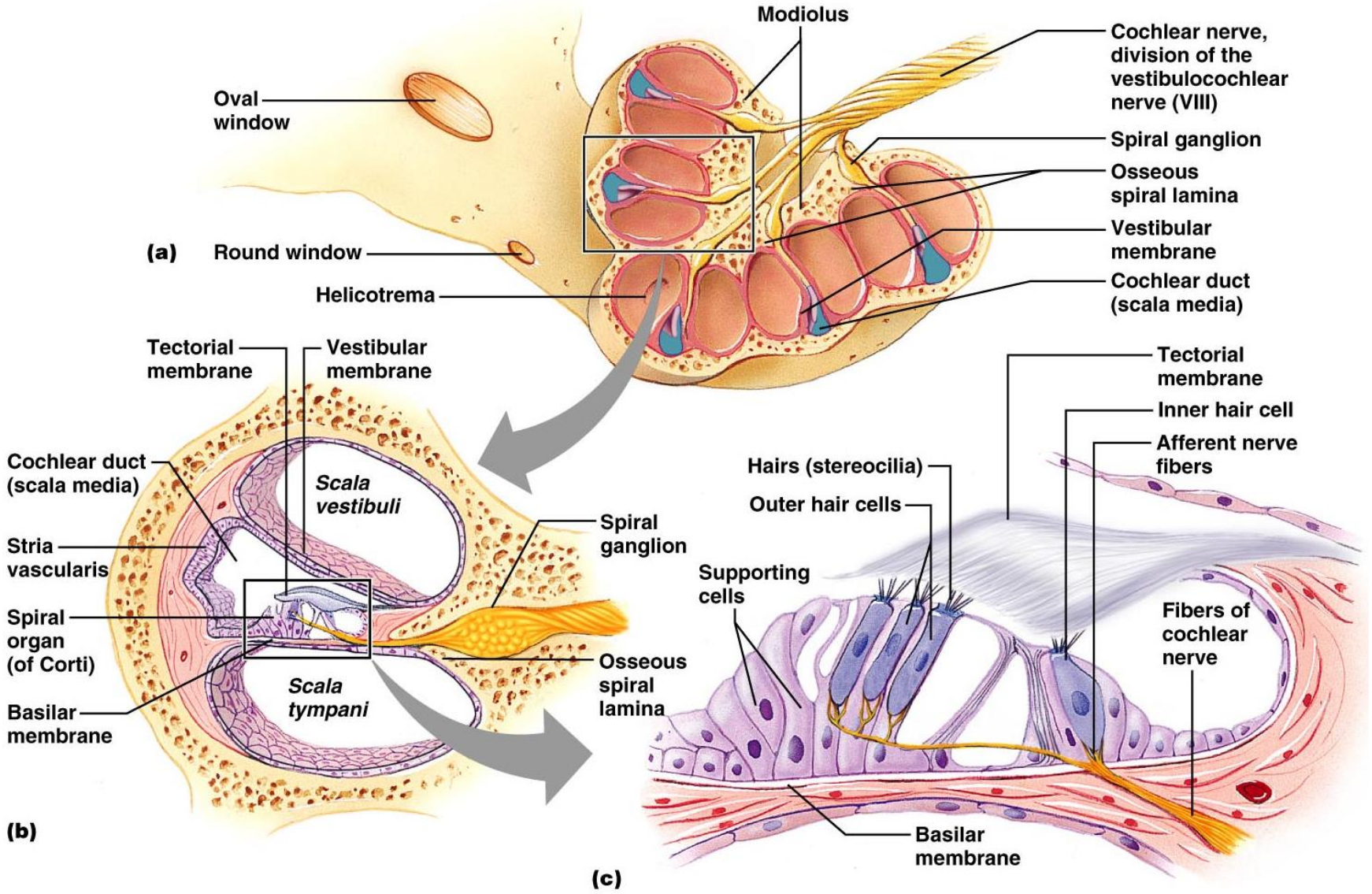


Figure 15.28

Sound and Mechanisms of Hearing

- Sound vibrations beat against the eardrum
- The eardrum pushes against the ossicles, which presses fluid in the inner ear against the oval and round windows
  - This movement sets up shearing forces that pull on hair cells
  - Moving hair cells stimulates the cochlear nerve that sends impulses to the brain

Properties of Sound

- Sound is:
  - A pressure disturbance (alternating areas of high and low pressure) originating from a vibrating object
  - Composed of areas of rarefaction and compression
  - Represented by a sine wave in wavelength, frequency, and amplitude

Properties of Sound

- Frequency – the number of waves that pass a given point in a given time
- Pitch – perception of different frequencies (we hear from 20–20,000 Hz)

Properties of Sound

- Amplitude – intensity of a sound measured in decibels (dB)
- Loudness – subjective interpretation of sound intensity

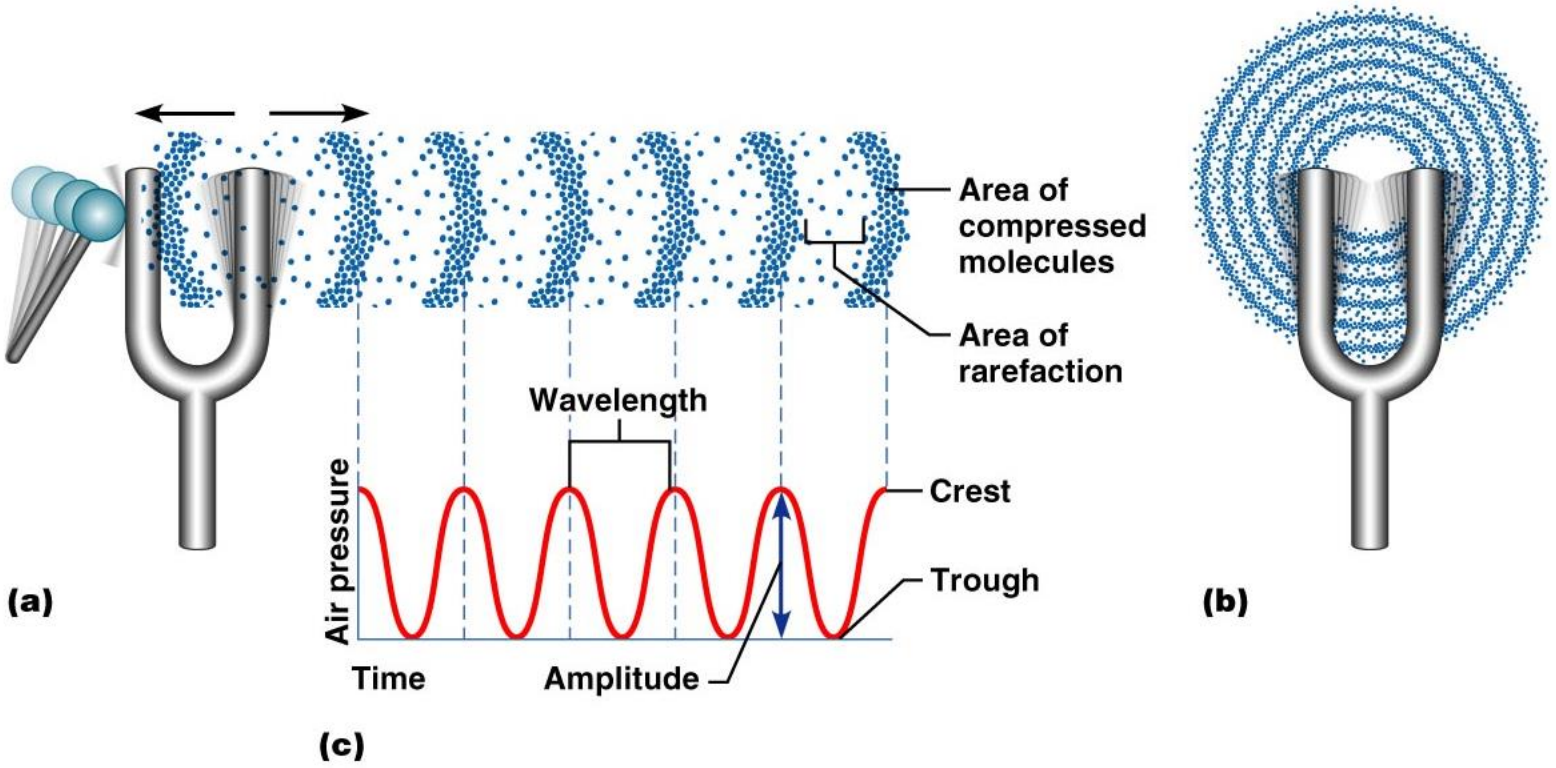


Figure 15.29

Transmission of Sound to the Inner Ear

- The route of sound to the inner ear follows this pathway:
  - Outer ear – pinna, auditory canal, eardrum
  - Middle ear – malleus, incus, and stapes to the oval window
  - Inner ear – scalas vestibuli and tympani to the cochlear duct
    - Stimulation of the organ of Corti
    - Generation of impulses in the cochlear nerve

Frequency and Amplitude

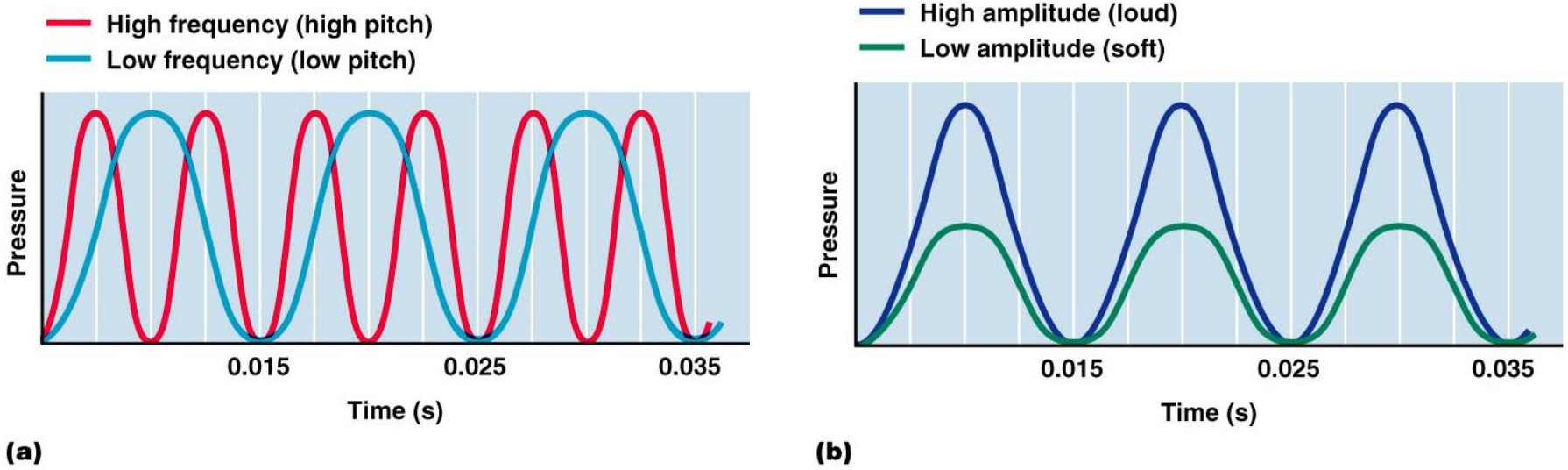


Figure 15.30

Transmission of Sound to the Inner Ear

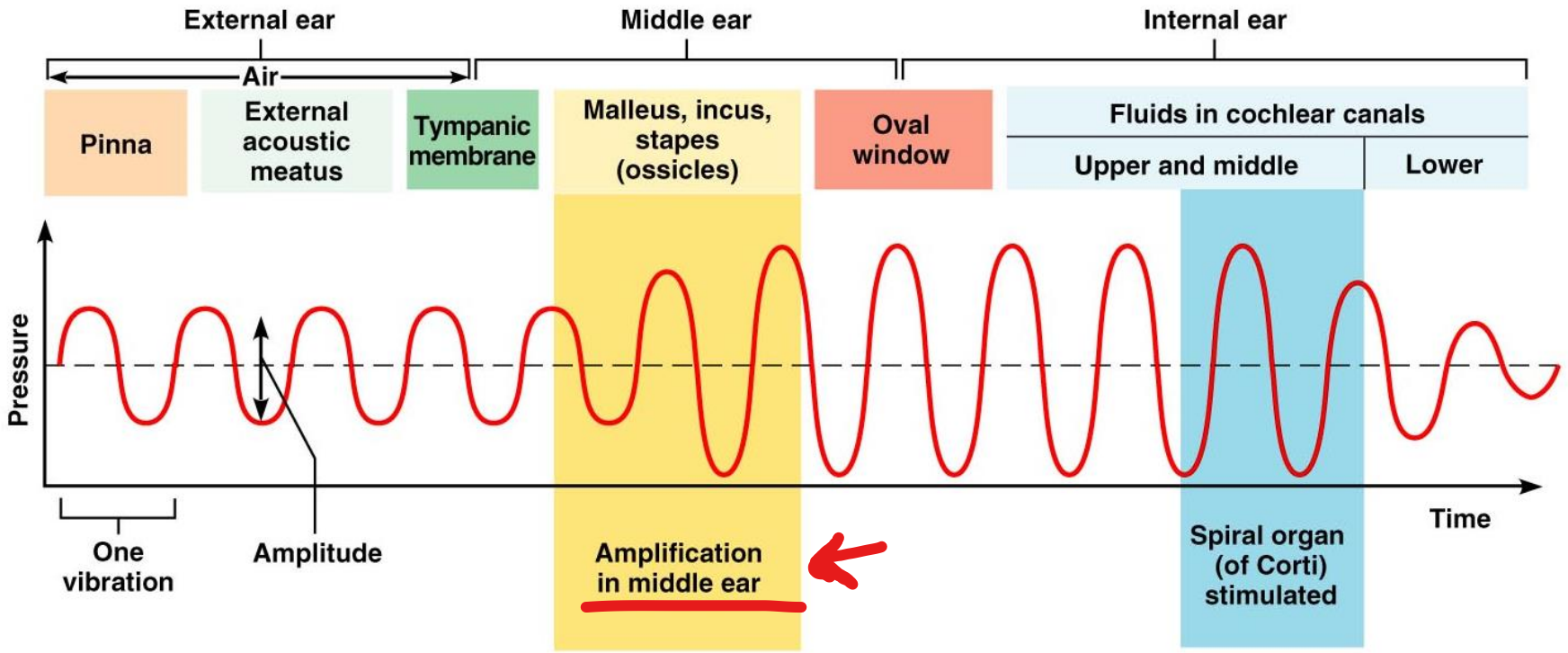


Figure 15.31

Resonance of the Basilar Membrane

- Sound waves of low frequency (inaudible):
  - Travel around the helicotrema
  - Do not excite hair cells
- Audible sound waves:
  - Penetrate through the cochlear duct
  - Vibrate the basilar membrane
  - Excite specific hair cells according to frequency of the sound

Resonance of the Basilar Membrane

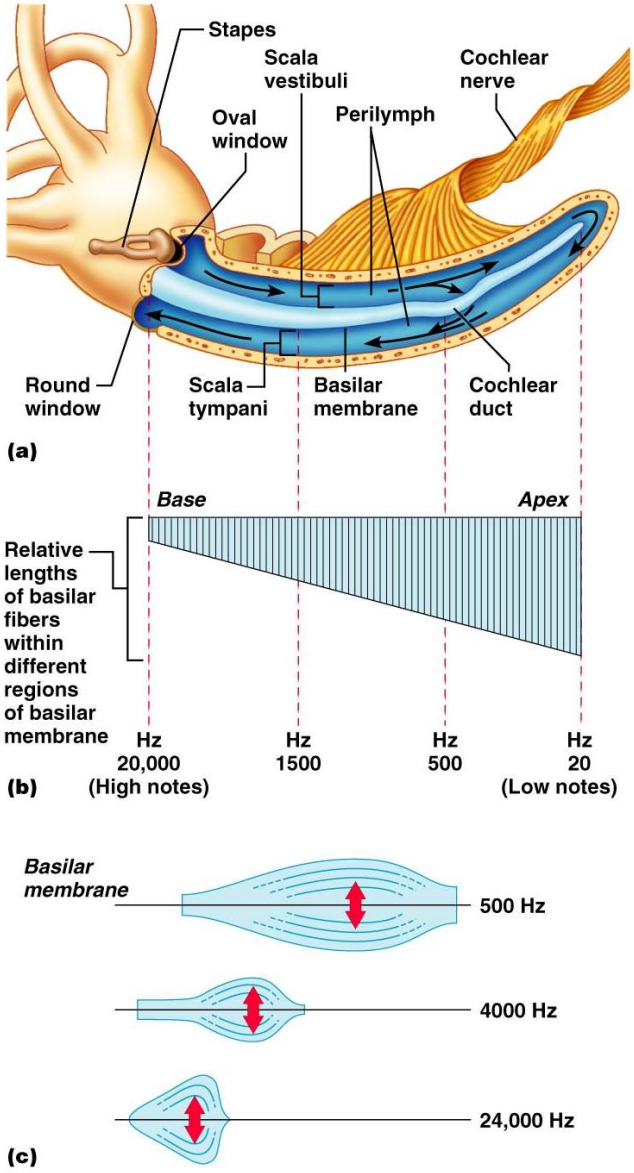


Figure 15.32

The Organ of Corti

- Is composed of supporting cells and outer and inner hair cells
- Afferent fibers of the cochlear nerve attach to the base of hair cells
- The stereocilia (hairs):
  - Protrude into the endolymph
  - Touch the tectorial membrane

Excitation of Hair Cells in the Organ of Corti

- Bending cilia:
  - Opens mechanically gated ion channels
  - Causes a graded potential and the release of a neurotransmitter (probably glutamate)
- The neurotransmitter causes cochlear fibers to transmit impulses to the brain, where sound is perceived

Excitation of Hair Cells in the Organ of Corti

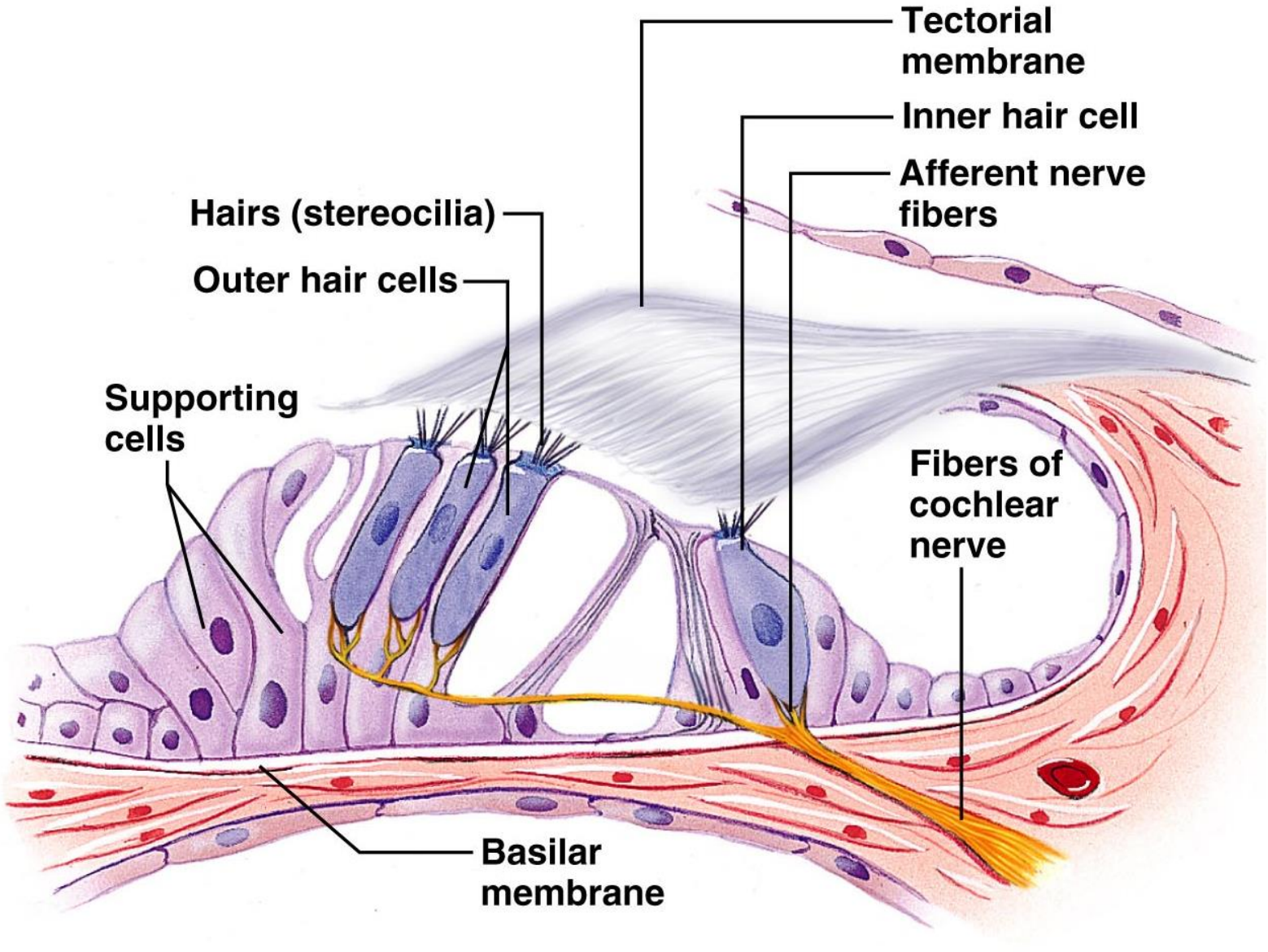


Figure 15.28c

Auditory Pathway to the Brain

- Impulses from the cochlea pass via the spiral ganglion to the cochlear nuclei
- From there, impulses are sent to the:
  - Superior olivary nucleus
  - Inferior colliculus (auditory reflex center)
- From there, impulses pass to the auditory cortex
- Auditory pathways decussate so that both cortices receive input from both ears

Simplified Auditory Pathways

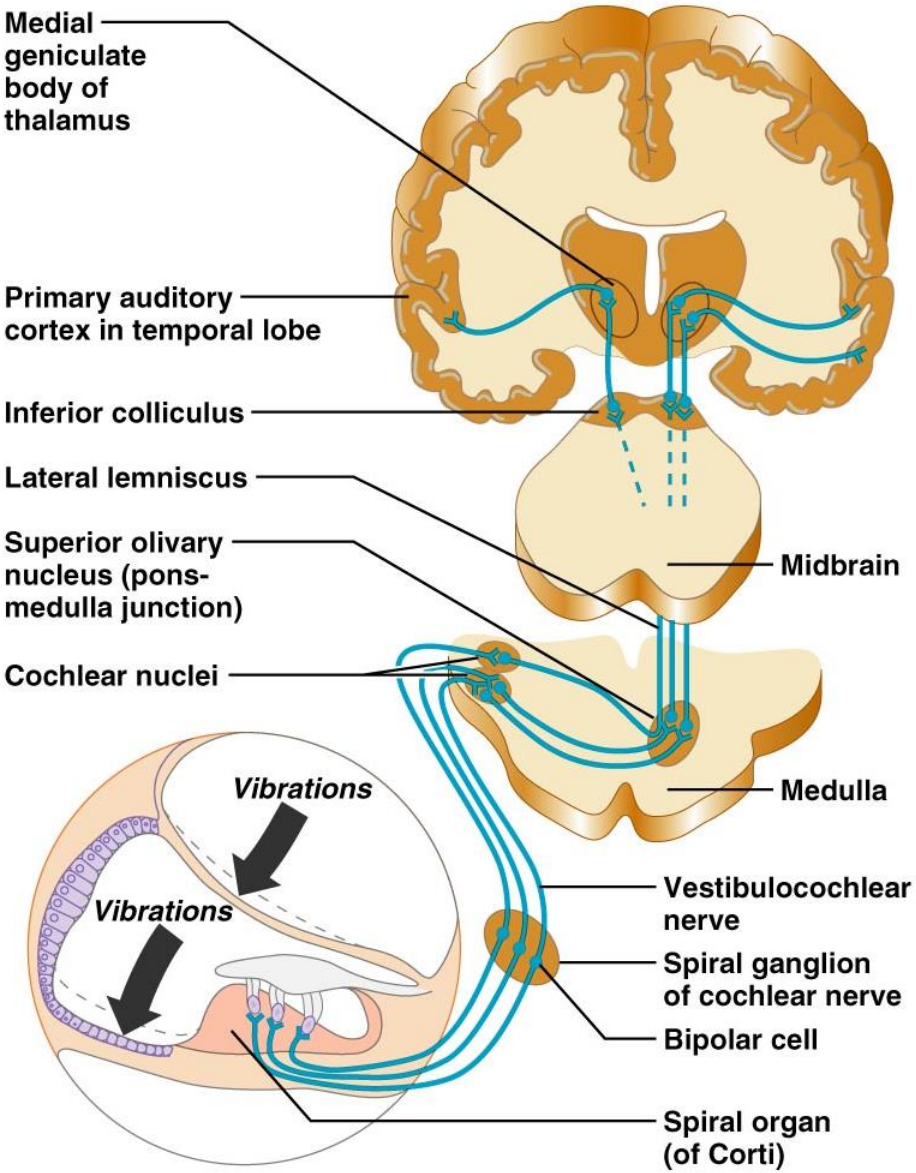


Figure 15.34

Auditory Processing

- Pitch is perceived by:
  - The primary auditory cortex
  - Cochlear nuclei
- Loudness is perceived by:
  - Varying thresholds of cochlear cells
  - The number of cells stimulated
- Localization is perceived by superior olivary nuclei that determine sound

Deafness

- Conduction deafness – something hampers sound conduction to the fluids of the inner ear (e.g., impacted earwax, perforated eardrum, osteosclerosis of the ossicles)
- Sensorineural deafness – results from damage to the neural structures at any point from the cochlear hair cells to the auditory cortical cells

Deafness

- Tinnitus – ringing or clicking sound in the ears in the absence of auditory stimuli
- Meniere's syndrome – labyrinth disorder that affects the cochlea and the semicircular canals, causing vertigo, nausea, and vomiting

Mechanisms of Equilibrium and Orientation

- Vestibular apparatus – equilibrium receptors in the semicircular canals and vestibule
  - Maintains our orientation and balance in space
  - Vestibular receptors monitor static equilibrium
  - Semicircular canal receptors monitor dynamic equilibrium

Anatomy of Maculae

- Maculae are the sensory receptors for static equilibrium
  - Contain supporting cells and hair cells
  - Each hair cell has stereocilia and kinocilium embedded in the otolithic membrane
- Otolithic membrane – jellylike mass studded with tiny $CaCO_3$ stones called otoliths
- Utricular hairs respond to horizontal movement
- Saccular hairs respond to vertical movement

Anatomy of Maculae

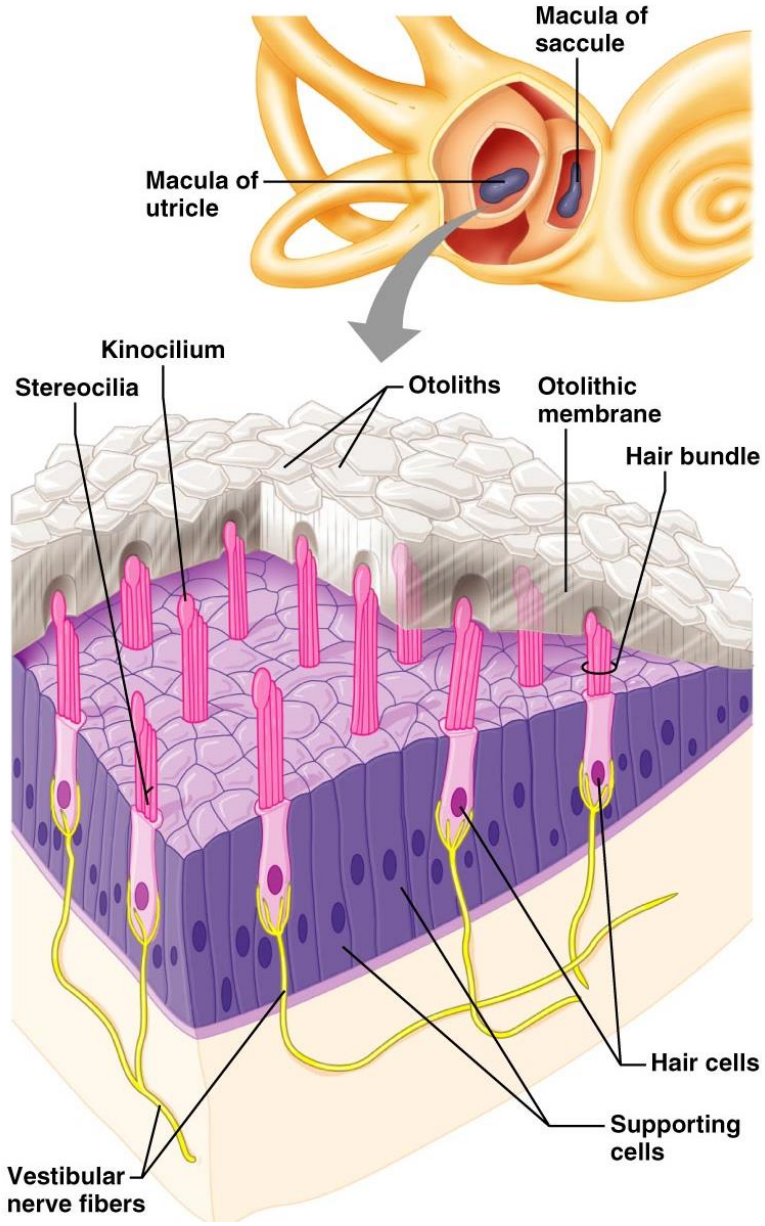


Figure 15.35

Effect of Gravity on Utricular Receptor Cells

- Otolithic movement in the direction of the kinocilia:
  - Depolarizes vestibular nerve fibers
  - Increases the number of action potentials generated
- Movement in the opposite direction:
  - Hyperpolarizes vestibular nerve fibers
  - Reduces the rate of impulse propagation
- From this information, the brain is informed of the changing position of the head

Effect of Gravity on Utricular Receptor Cells

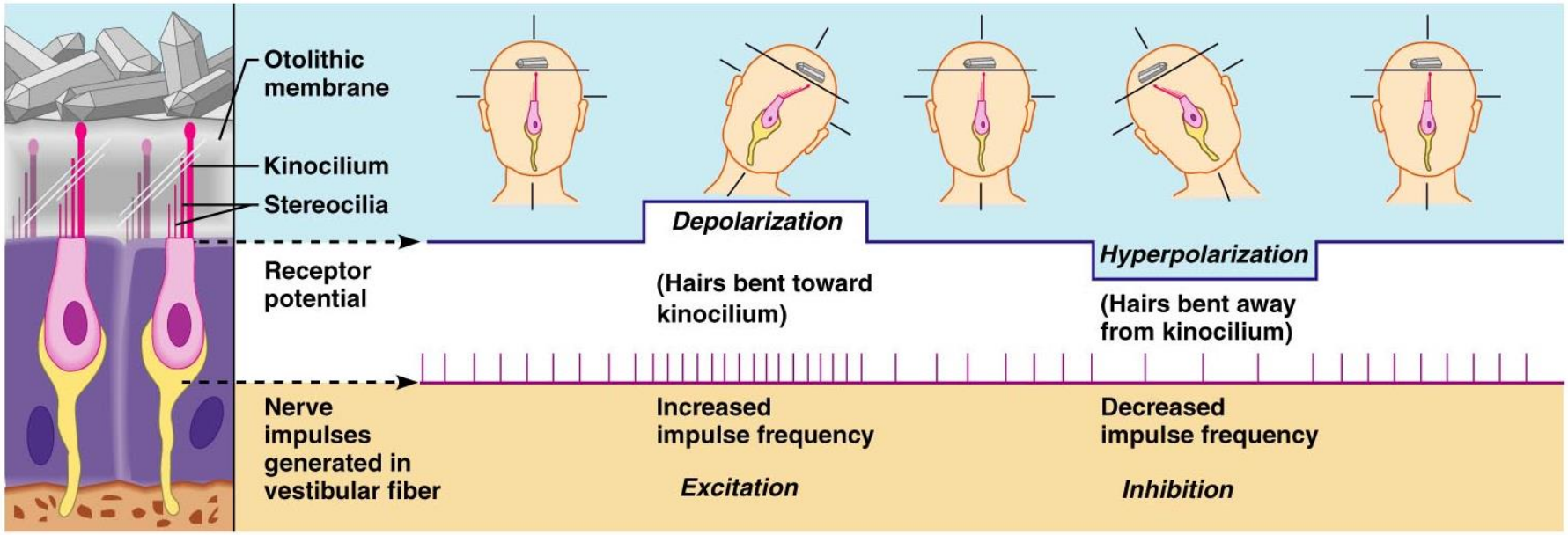
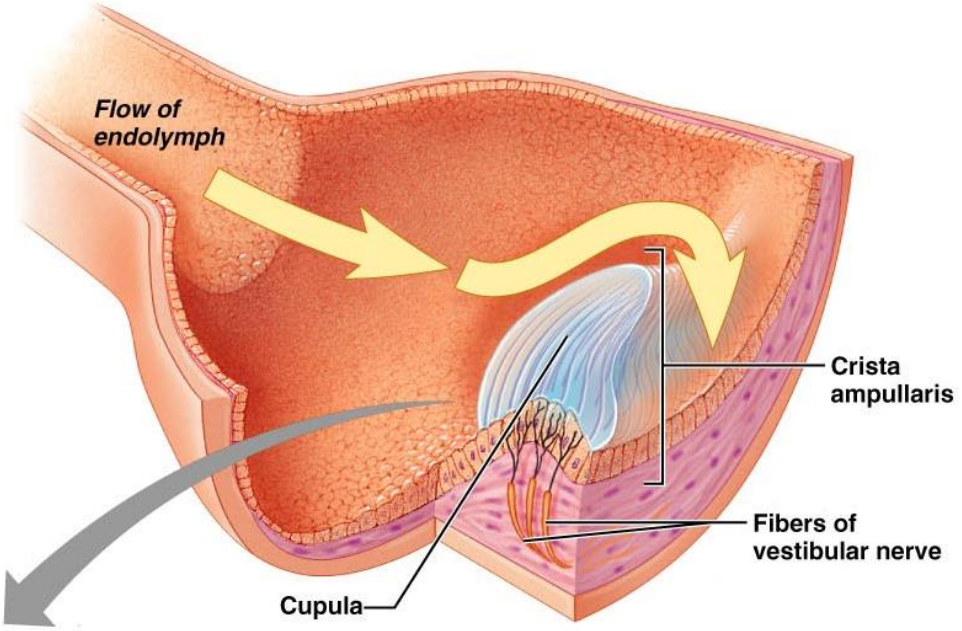


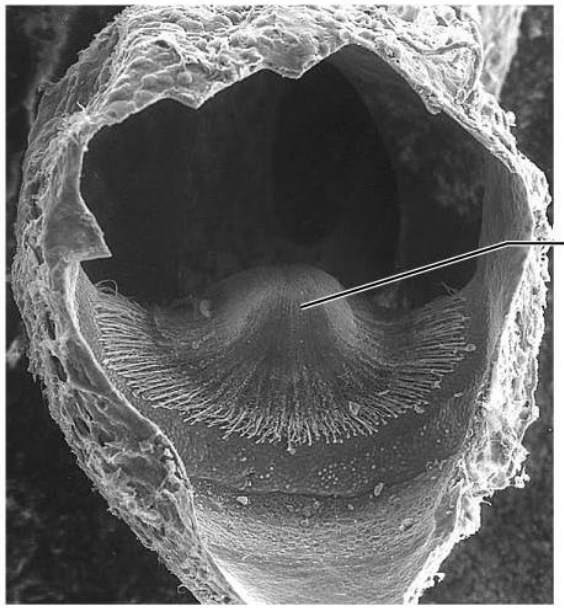
Figure 15.36

Crista Ampullaris and Dynamic Equilibrium

- The crista ampullaris (or crista):
  - Is the receptor for dynamic equilibrium
  - Is located in the ampulla of each semicircular canal
  - Responds to angular movements
- Each crista has support cells and hair cells that extend into a gel-like mass called the cupula
- Dendrites of vestibular nerve fibers encircle the base of the hair cells

Crista Ampullaris and Dynamic Equilibrium





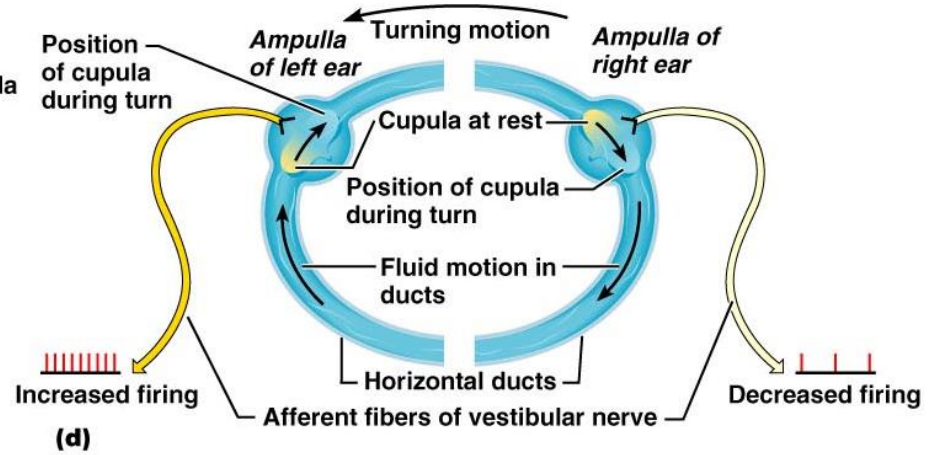


Figure 15.37b, c, d

Activating Crista Ampullaris Receptors

- Cristae respond to changes in velocity of rotatory movements of the head
- Directional bending of hair cells in the cristae causes:
  - Depolarizations, and rapid impulses reach the brain at a faster rate
  - Hyperpolarizations, and fewer impulses reach the brain
- The result is that the brain is informed of rotational movements of the head

Rotary Head Movement

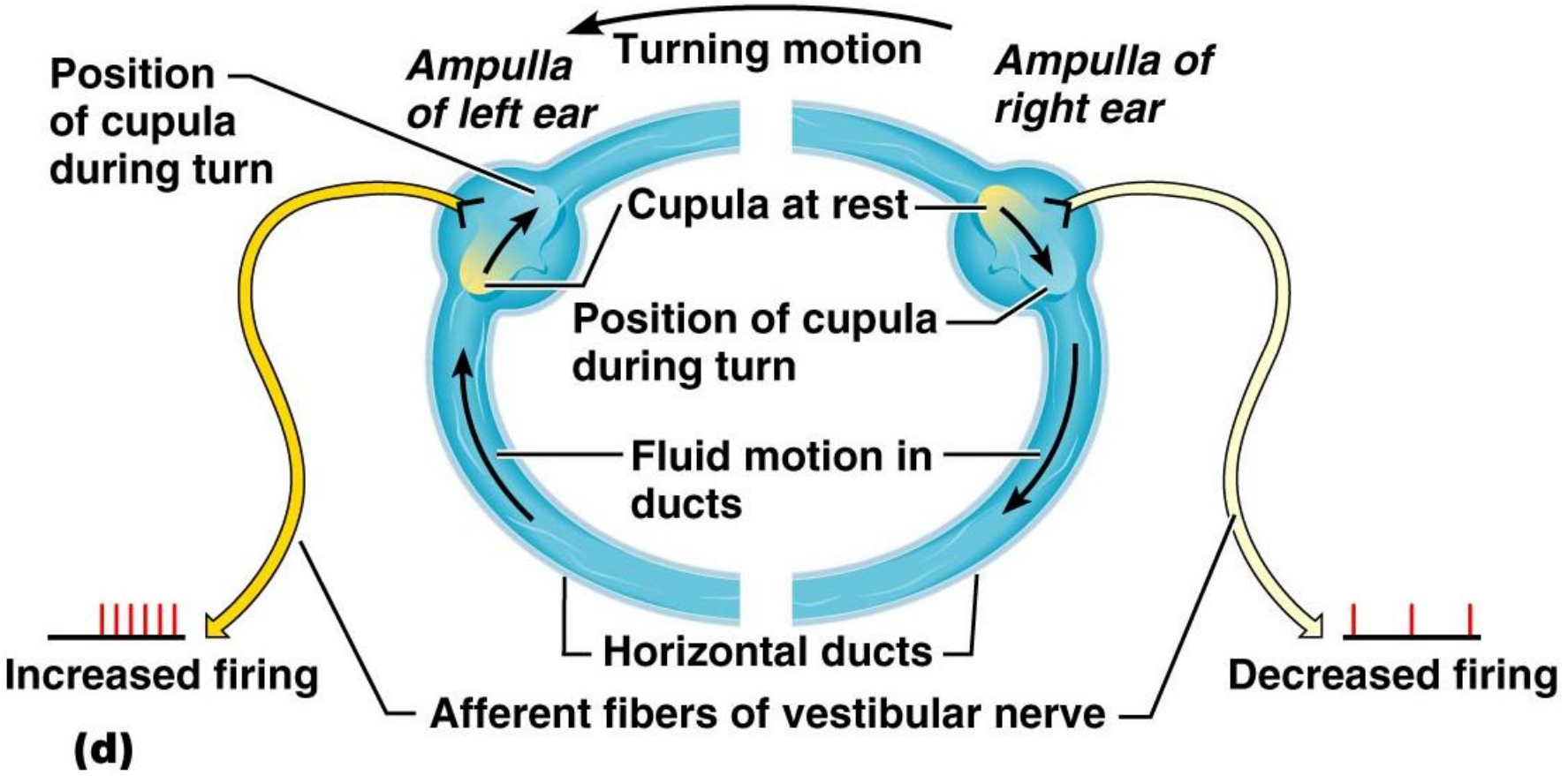


Figure 15.37d

Balance and Orientation Pathways

- There are three modes of input for balance and orientation
  - Vestibular receptors
  - Visual receptors
  - Somatic receptors
- These receptors allow our body to respond reflexively

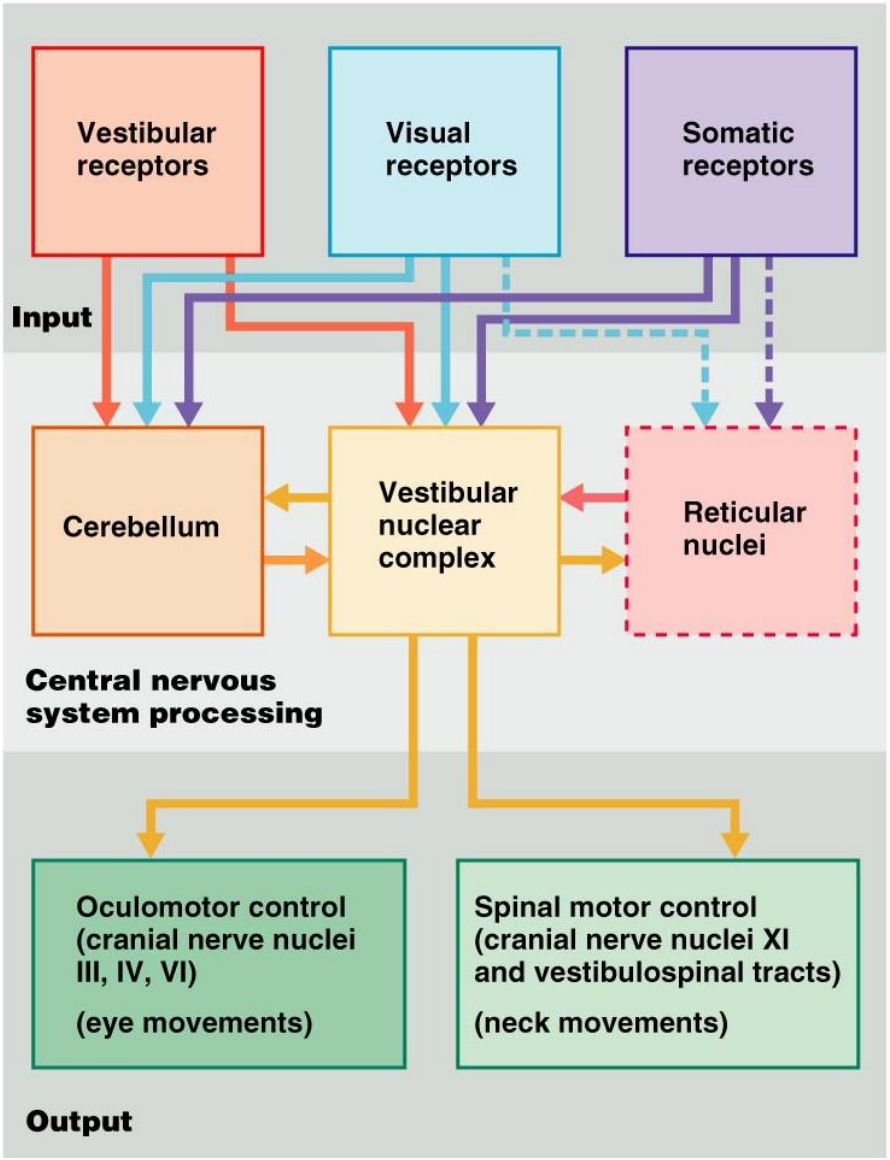


Figure 15.38