SEM IV ZOOA

CC8 UNIT 6:
NERVOUS SYSTEM AND SENSE ORGANS
(Part - 4)

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Statoacoustic Organs or Ears

✓In fishes: In fishes, the two senses of hearing and equilibrium are associated with the ears.

✓All the vertebrates possess a pair of inner ears or membranous labyrinths embedded within the otic capsules of the skull lateral to the hindbrain.

✓Each membranous labyrinth consists of 3 semicircular canals (only 1 or 2 in cyclostomes), a utriculus and a sacculus. Sacculus in fishes forms a rudimentary diverticulum, the lagena, which is a forerunner of the cochlea of higher vertebrates, concerned with audition.

✓Teleost fishes of the order Cypriniformes (catfishes, suckers, carps, etc.) utilize an air-filled swim bladder as a hydrophone.

✓Sound waves in water create waves of similar frequency in the gas filled bladder.

✓These are transmitted via a chain of small bones, the Weberian ossicles, to the sacculus. Weberian ossicles are modified transverse processes of the first 4 (occasionally 5) trunk vertebrae.

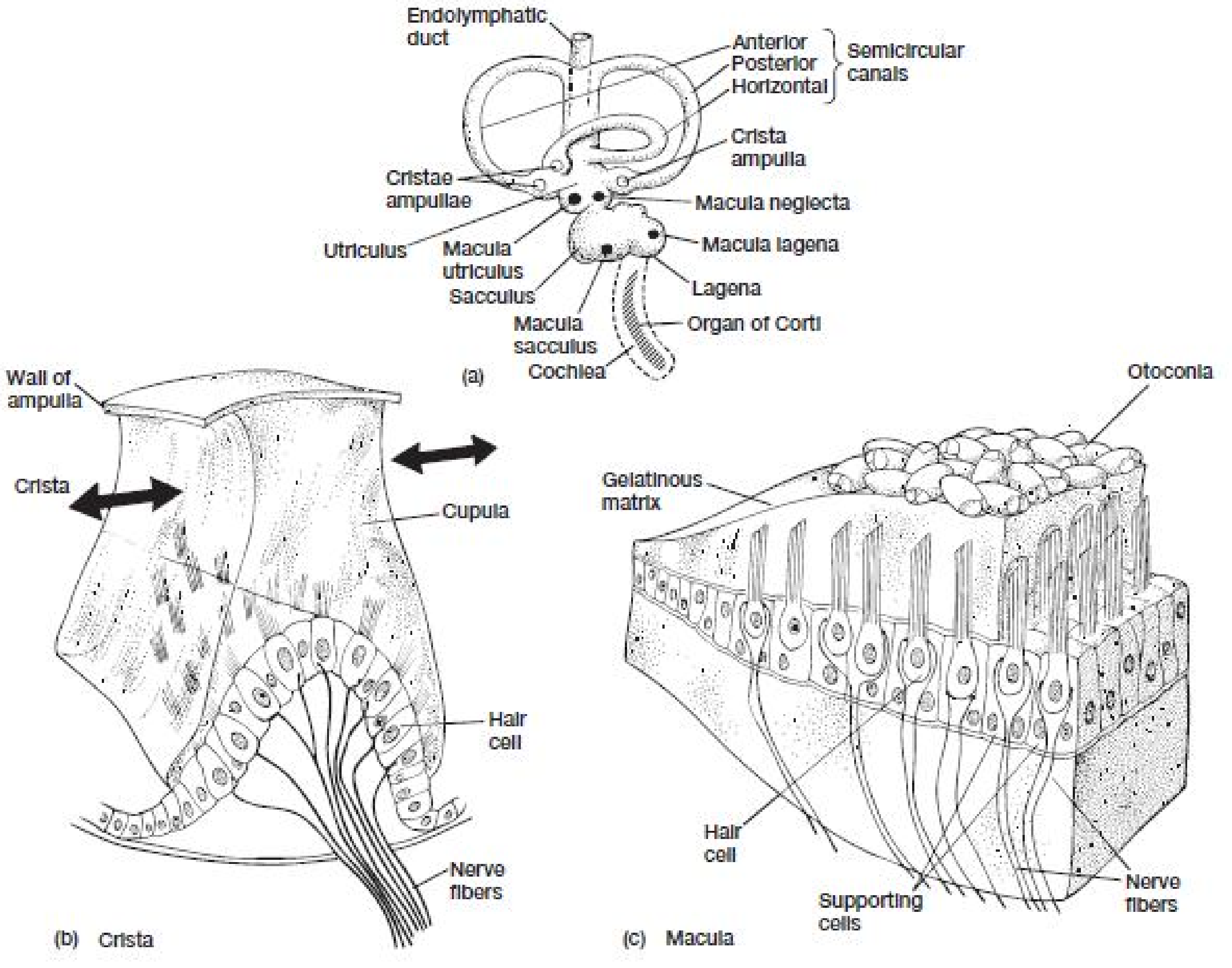


FIGURE 17.33 Vestibular apparatus. (a) Generalized vestibular apparatus showing the three semicircular canals and major compartments: utriculus, sacculus, and lagena. (b) The crista is an expanded neuromast organ. One crista resides at the base of each semicircular canal in an enlarged region, the ampulla. The gelatinous cupula extends across the ampulla and is attached to the opposite wall. Acceleration of the head (arrows) produces a shearing force of endolymphatic fluid against the cupula, which bends and deforms hair cells embedded within it. (c) The maculae form a neuromast platform containing otoconia. These maculae reside in the three compartments of the vestibular apparatus. They derive their names from these compartments. In some species a fourth macula is present, the macula neglecta.

(b,c) After Parker.

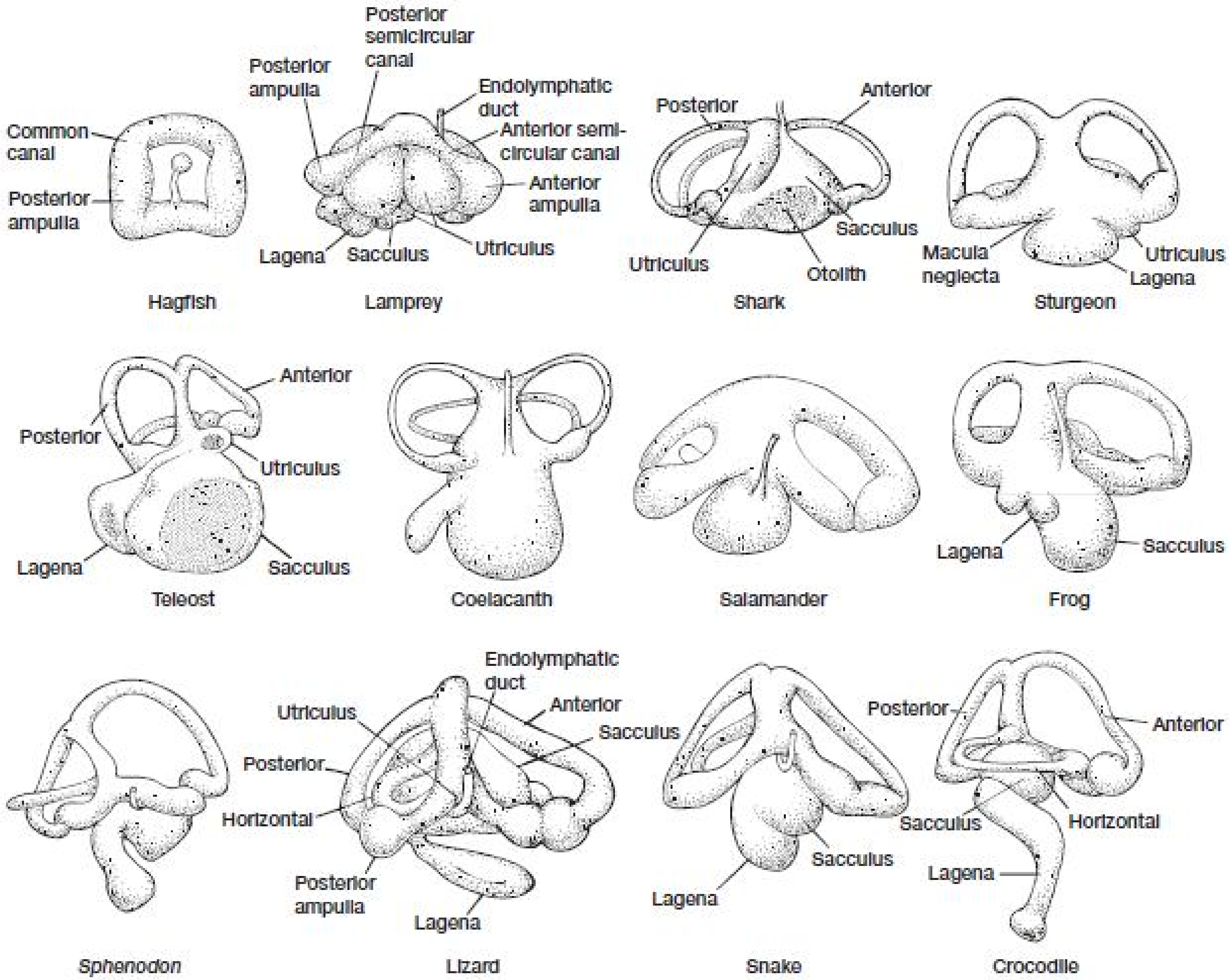
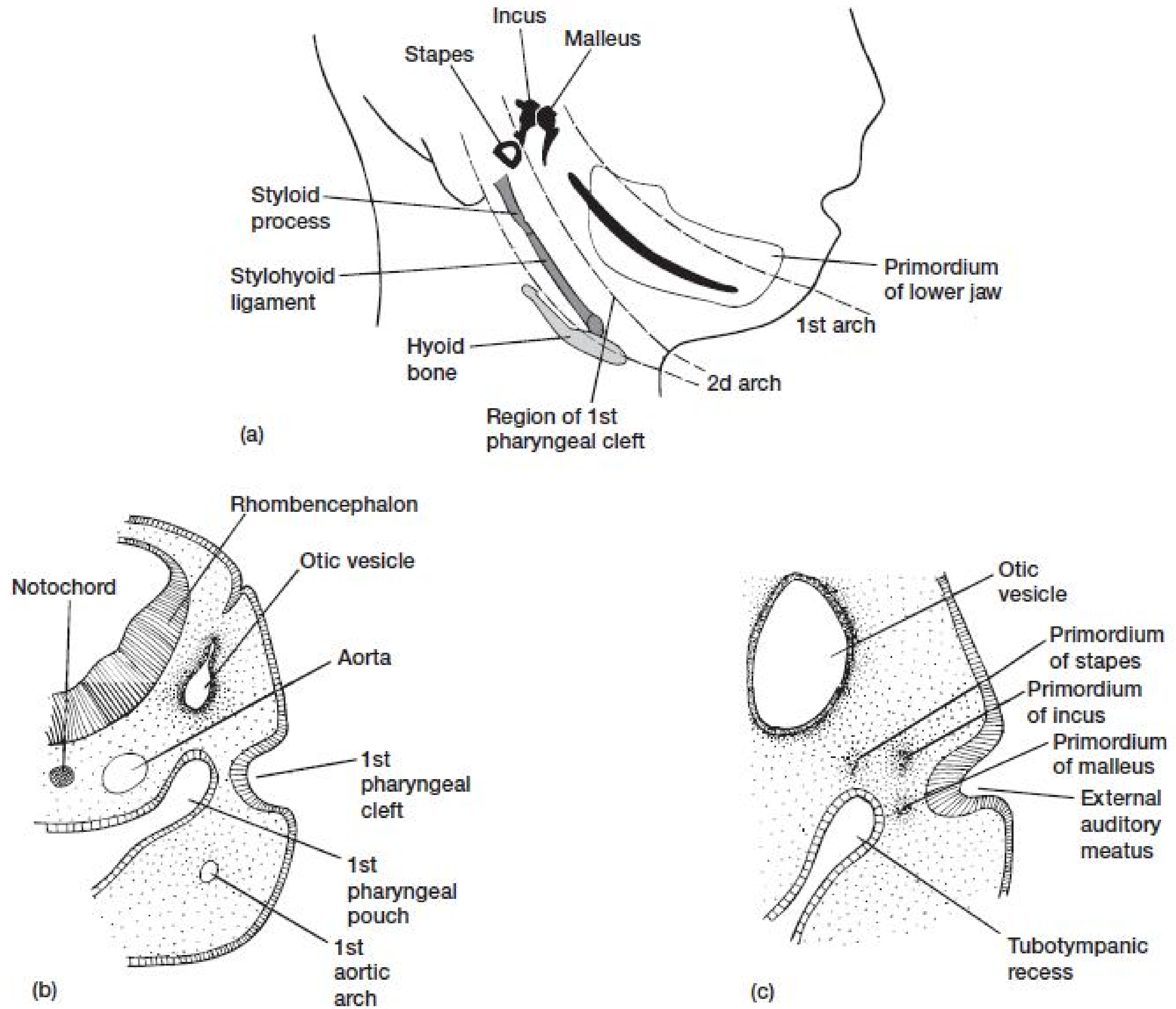


FIGURE 17.34 **Vertebrate vestibular apparatuses.**


Incus
Malleus
Stapes
Styloid process
Stylohyoid ligament
Hyoid bone
Region of 1st pharyngeal cleft
Primordium of lower jaw
1st arch
2d arch
(a)
Rhombencephalon
Otic vesicle
Notochord
Aorta
1st pharyngeal cleft
1st pharyngeal pouch
1st aortic arch
(b)
Otic vesicle
Primordium of stapes
Primordium of incus
Primordium of malleus
External auditory meatus
Tubotympanic recess
(c)

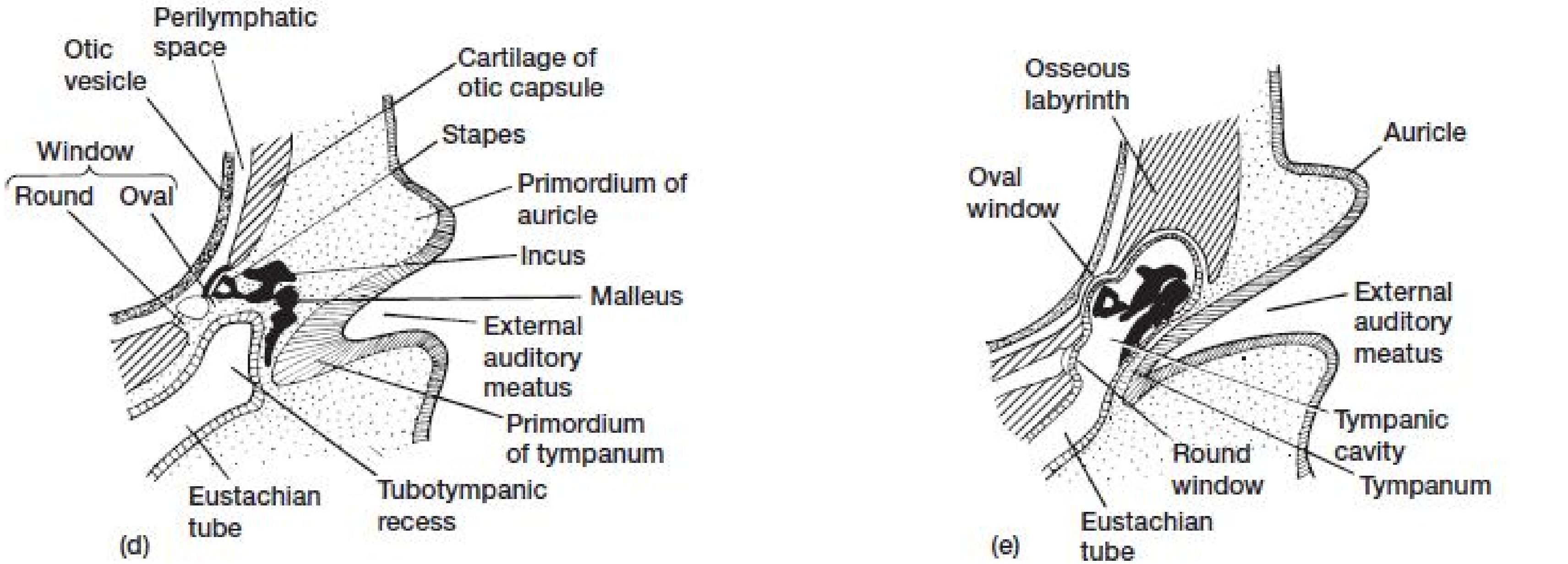


FIGURE 17.35 Embryonic formation of the middle ear. (a) Location of the middle ear ossicles relative to derivatives of the splanchnocranium. (b) The surface of the ectoderm thickens, forming an otic placode that sinks beneath the skin and gives rise to the otic vesicle. The otic vesicle moves into the vicinity of the first pharyngeal cleft and pharyngeal pouch. (c) Mesenchyme (indicated by heavy stippling) begins to condense and differentiate into the ear ossicles: the incus, the malleus, and the stapes (d,e).

Redrawn from H. Tuchmann-Duplessis et al., 1974. Illustrated Human Embryology, Vol. III, Nervous System and Endocrine Glands. © 1974 Springer-Verlag, NY. Reprinted by permission.

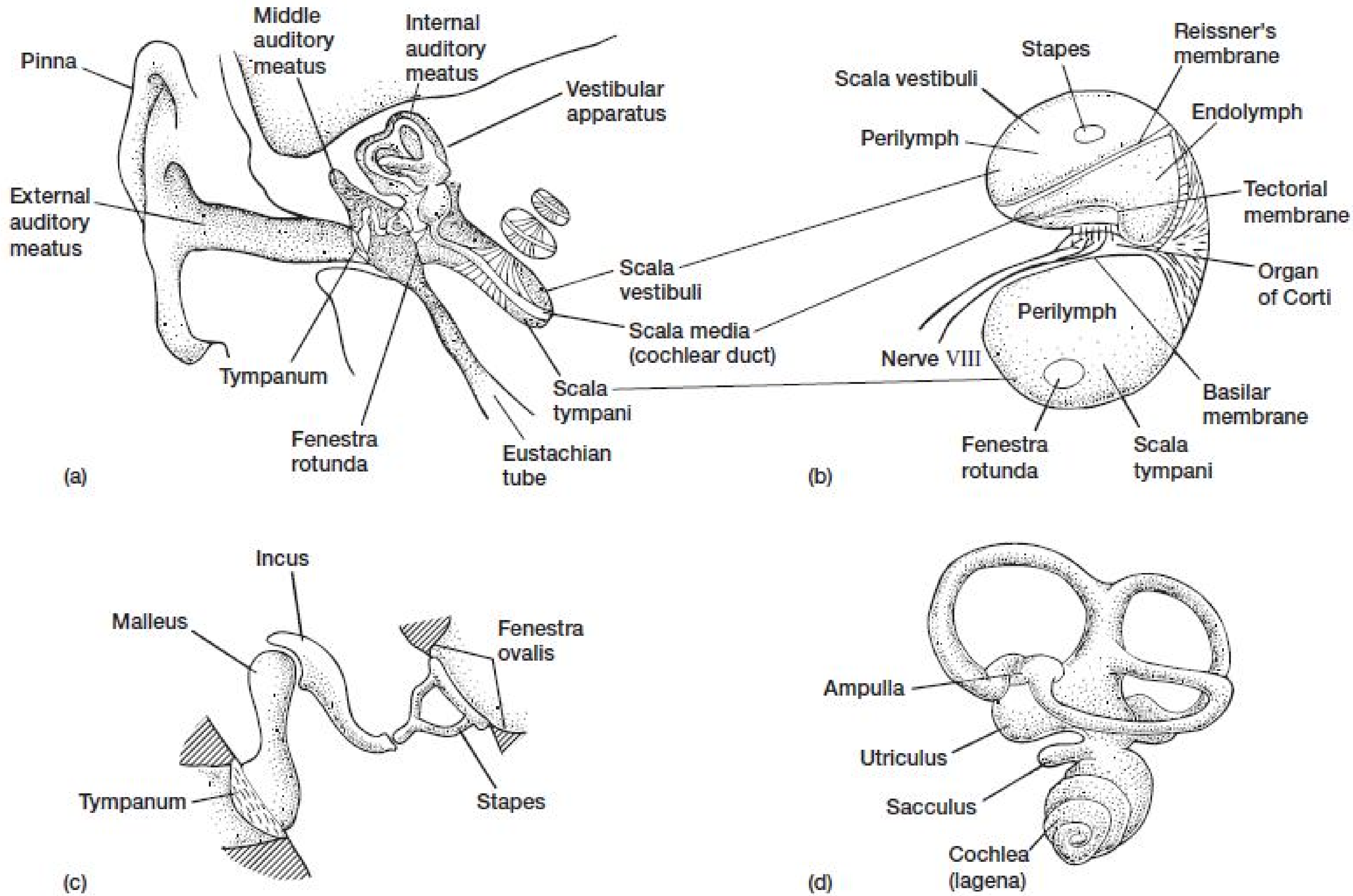


FIGURE 17.36 Anatomy of the therian ear. (a) External, middle, and inner ears. (b) Cross section of the cochlea. (c) Three middle ear ossicles of mammals. (d) Mammalian vestibular apparatus. Note that the lagena is lengthened and coiled to form the cochlea.

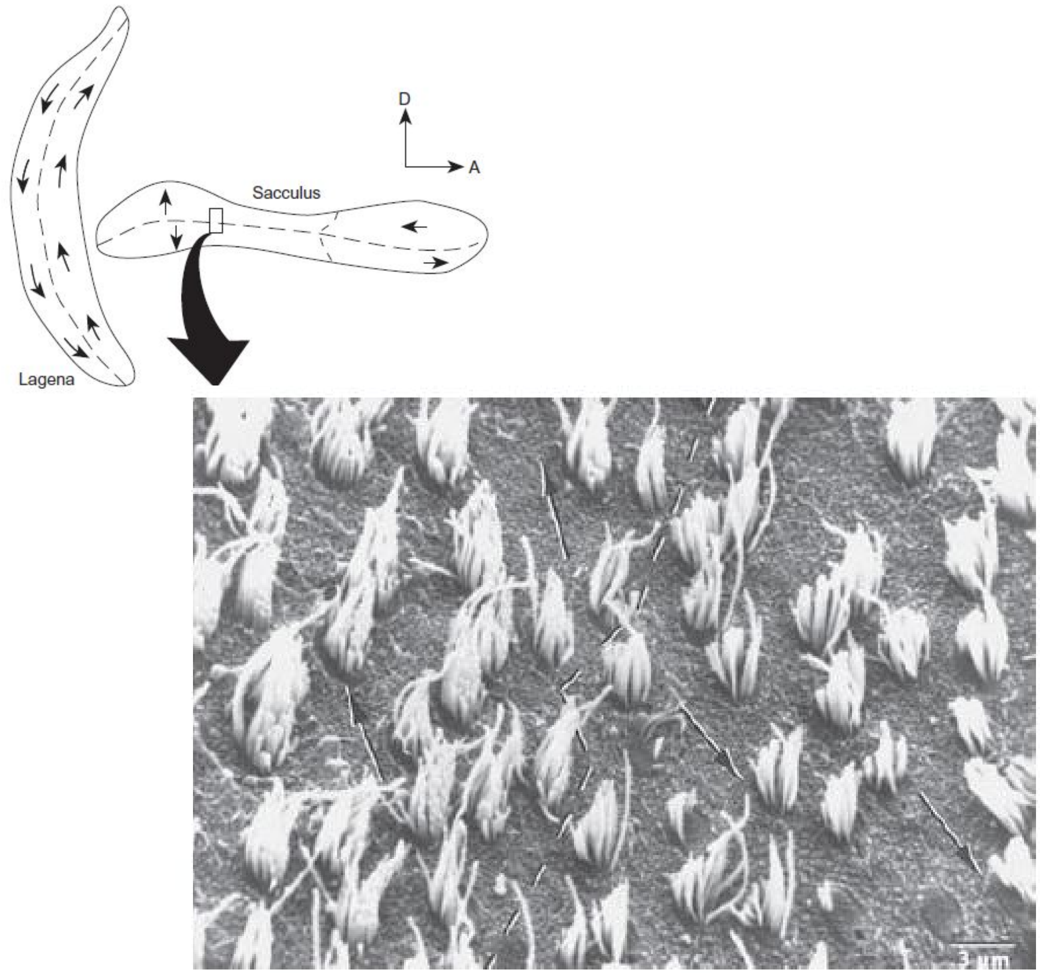
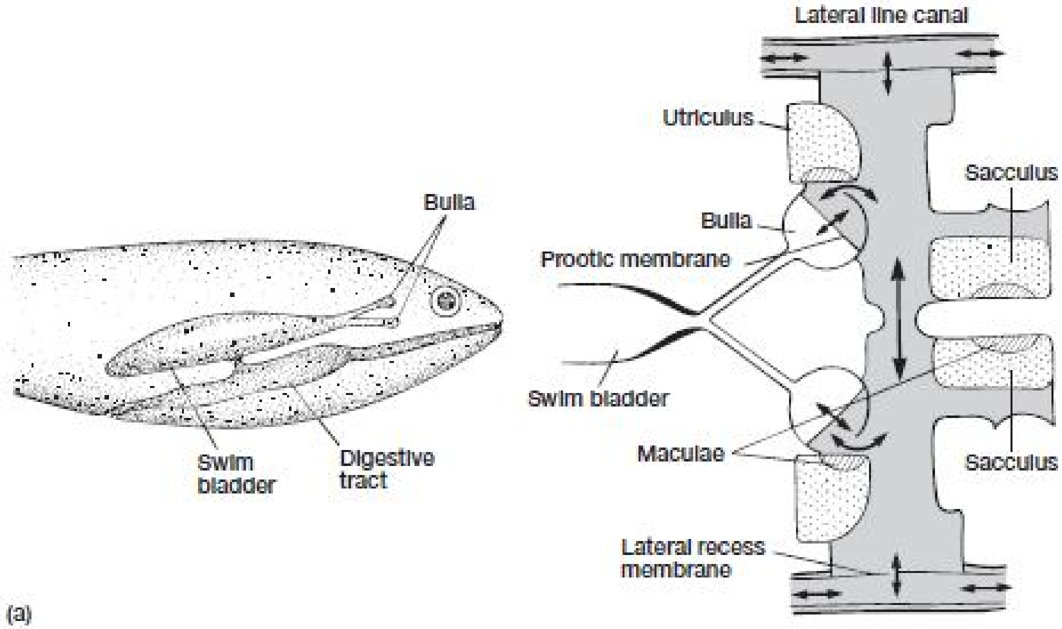
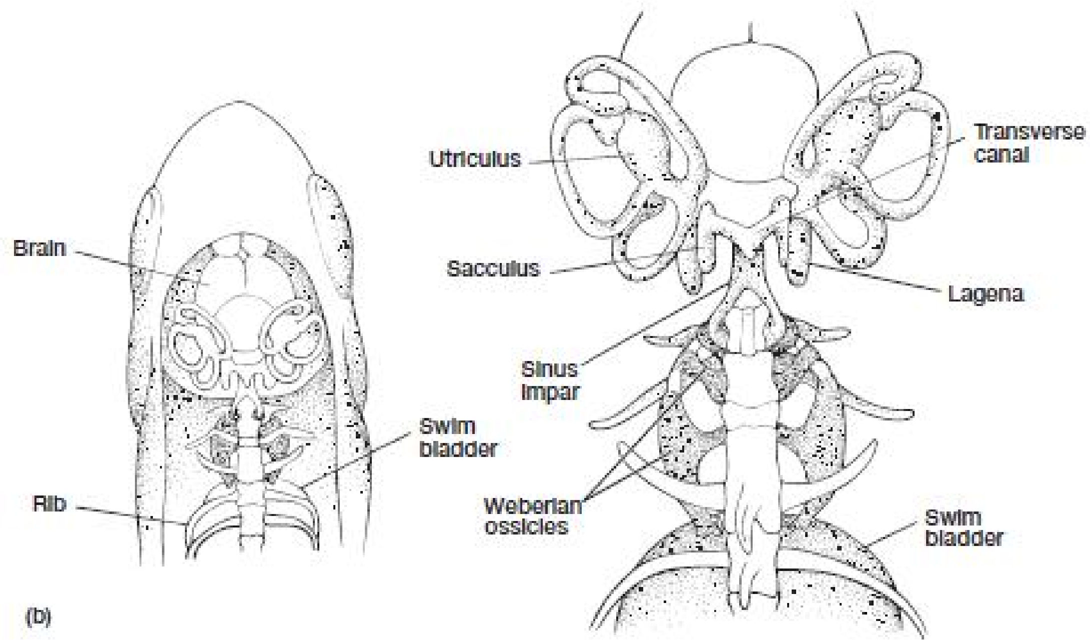


FIGURE 17.37 **Fish inner ear.** Orientations of hair cells within the sacculus and lagena are shown. Arrows indicate the side of the hair bundle on which the kinocilium lies. Dashed lines indicate the divisions between bundles with different orientations. These differences in the placement of hair bundles cause different responses to mechanical vibrations traveling in the surrounding fluid.

After Fay and Popper.



(a)



(b)

FIGURE 17.38
Route of sound transfer to the inner ears of fishes. (a) In some fishes, the swim bladder includes anterior extensions that contact the inner ear.
(b) In other fishes, the Weberian ossicles, a tiny series of bones, connect the swim bladder to the inner ear.

After Bone and Marshall; Popper and Coombs.

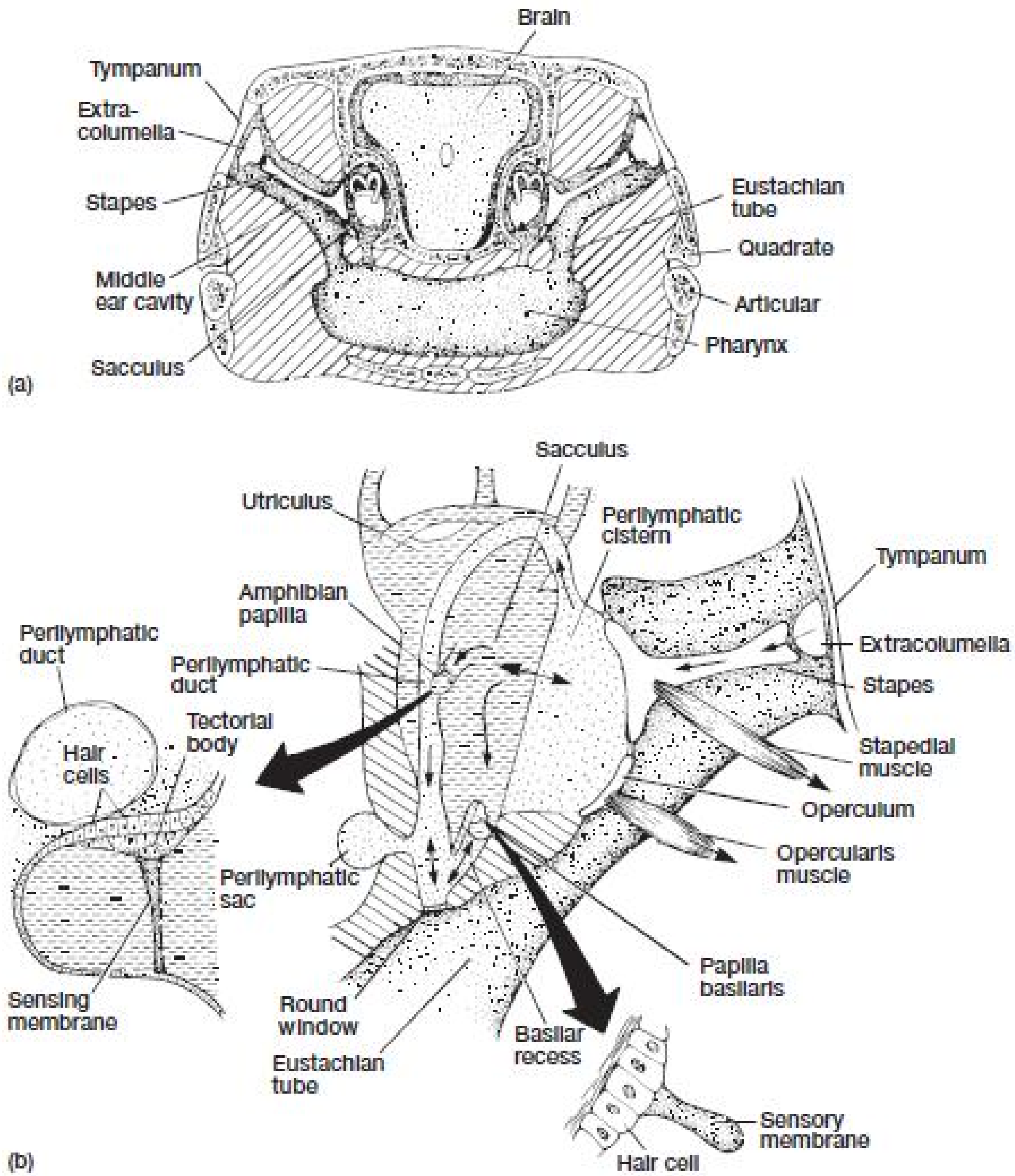
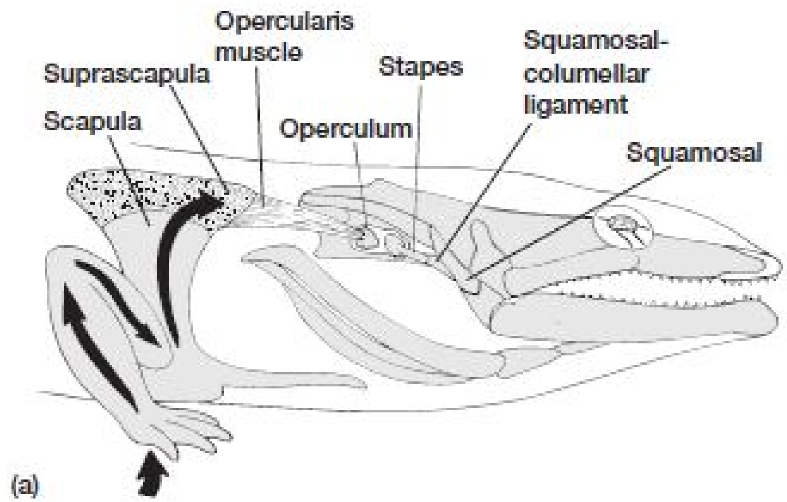


FIGURE 17.39 Hearing in frogs. (a) Cross section through the head of a frog. Because the eustachian tubes connect the two ears through the pharynx, a sound that sets one tympanum in motion also affects the ear on the opposite side by producing vibrations in the connecting air passageway. This is thought to allow frogs to localize the source of sounds. (b) Sound arrives at a frog's inner ear via two routes: One involves the tympanum-columella, and the other involves the opercularis muscle-operculum. Vibrations arriving by either pathway cause the fluid in the inner ear to vibrate. This vibration stimulates the auditory receptors. The way in which these receptors discriminate sounds is not well understood, but because they seem to be modified neuromast organs, it is thought that they respond selectively to shearing oscillations that arriving vibrations impart to the fluid of the inner ear.

(a) After Romer and Parsons; (b) after Wever.



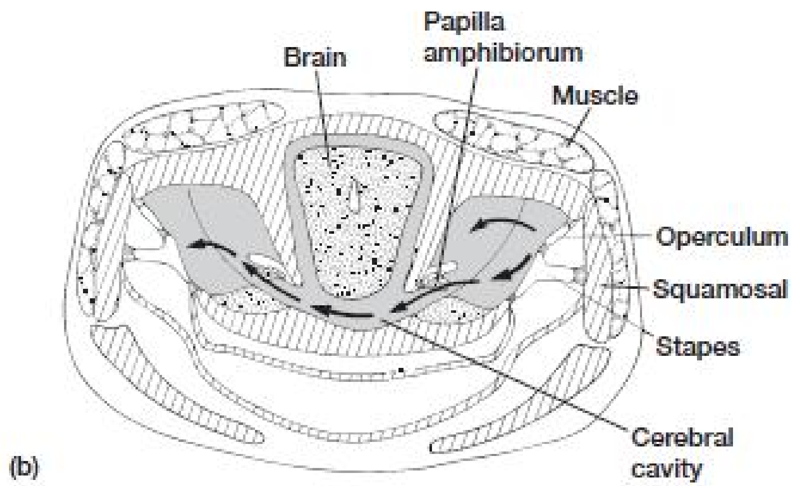


FIGURE 17.40 **Hearing in salamanders.**
(a) In many salamanders, sounds reach the inner ear via a squamosal-columella route and via the opercular muscle from the scapula. (b) The two inner ears on opposite sides of the head are connected via a fluid-filled channel that passes through the cerebral cavity. This channel may allow sonic vibrations to spread from one ear to the other (solid arrows).

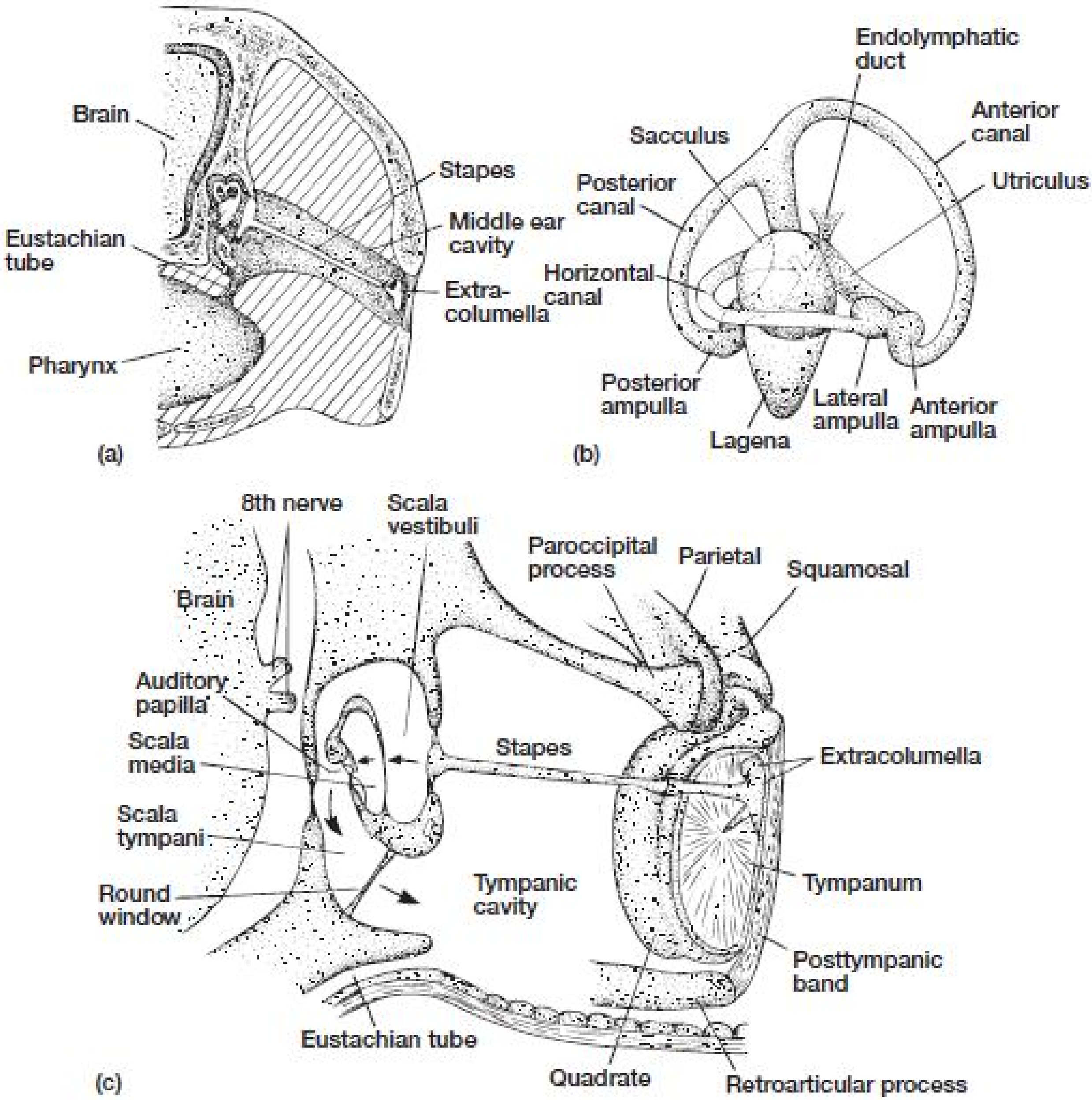
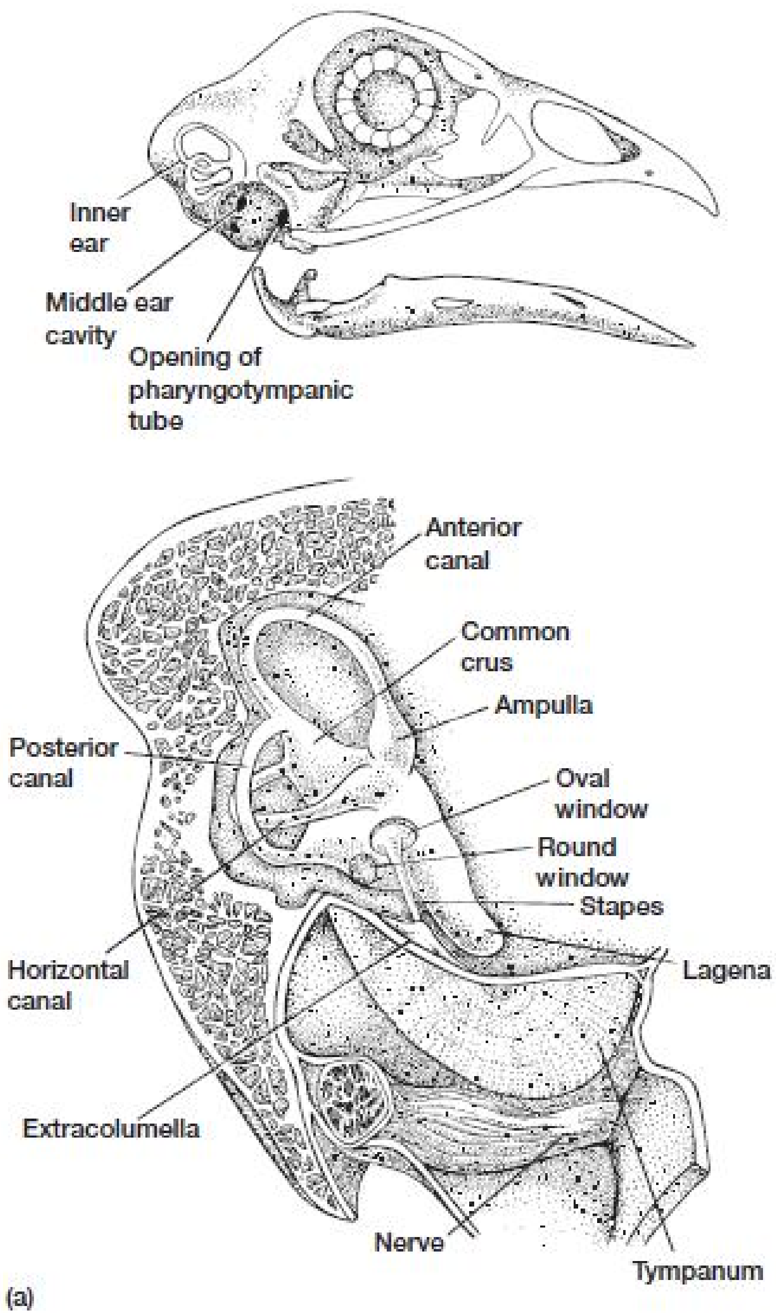


FIGURE 17.41 Hearing in reptiles. (a) Cross section through a reptilian head. (b) Vestibular apparatus of a lizard. (c) Section through the ear of an iguana showing the relationship of tympanum, extracolumella, stapes, and inner ear.

(a) After Romer and Parsons; (b,c) after Wever.



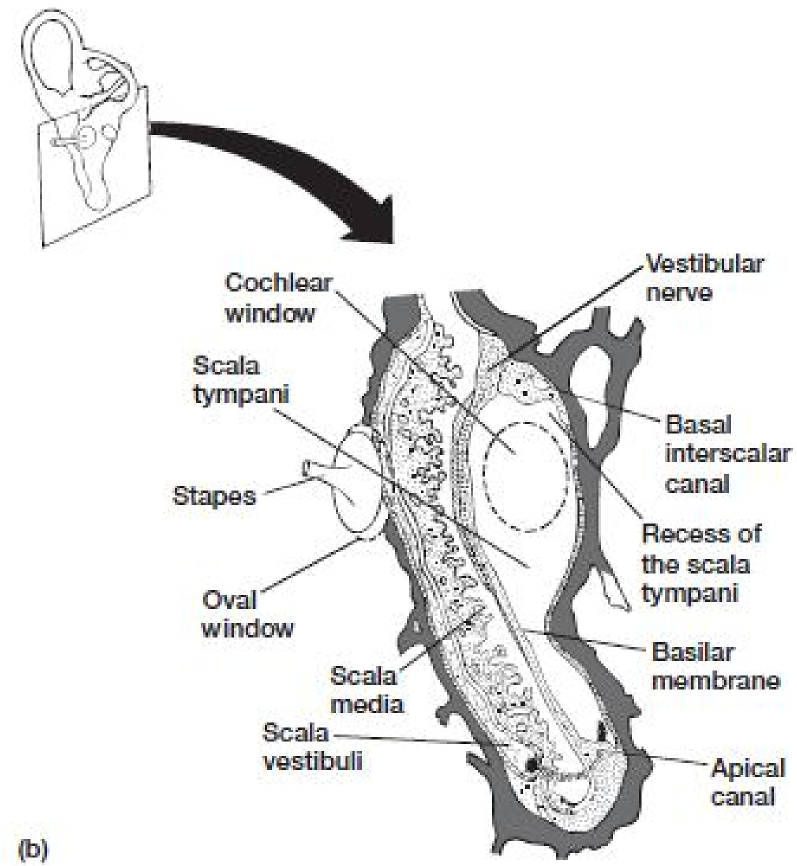
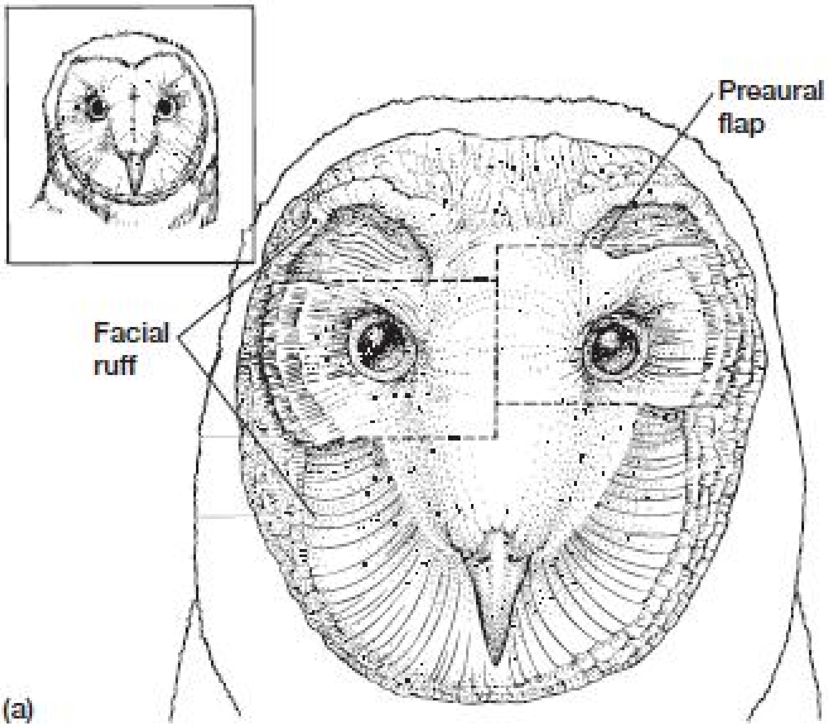
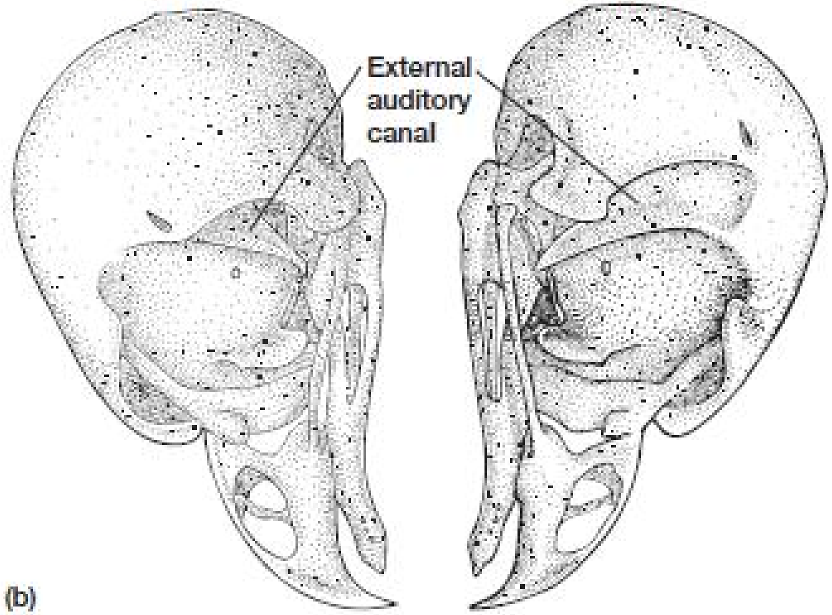


FIGURE 17.42 Hearing in birds. (a) Vestibular apparatus of a chicken. (b) Section through the lagena of a chicken.

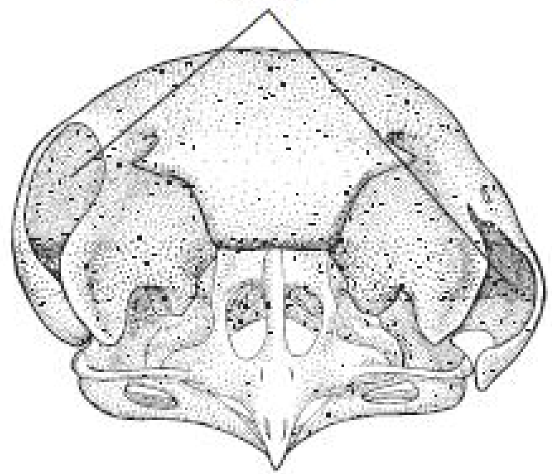
After H. Evans.



(a)



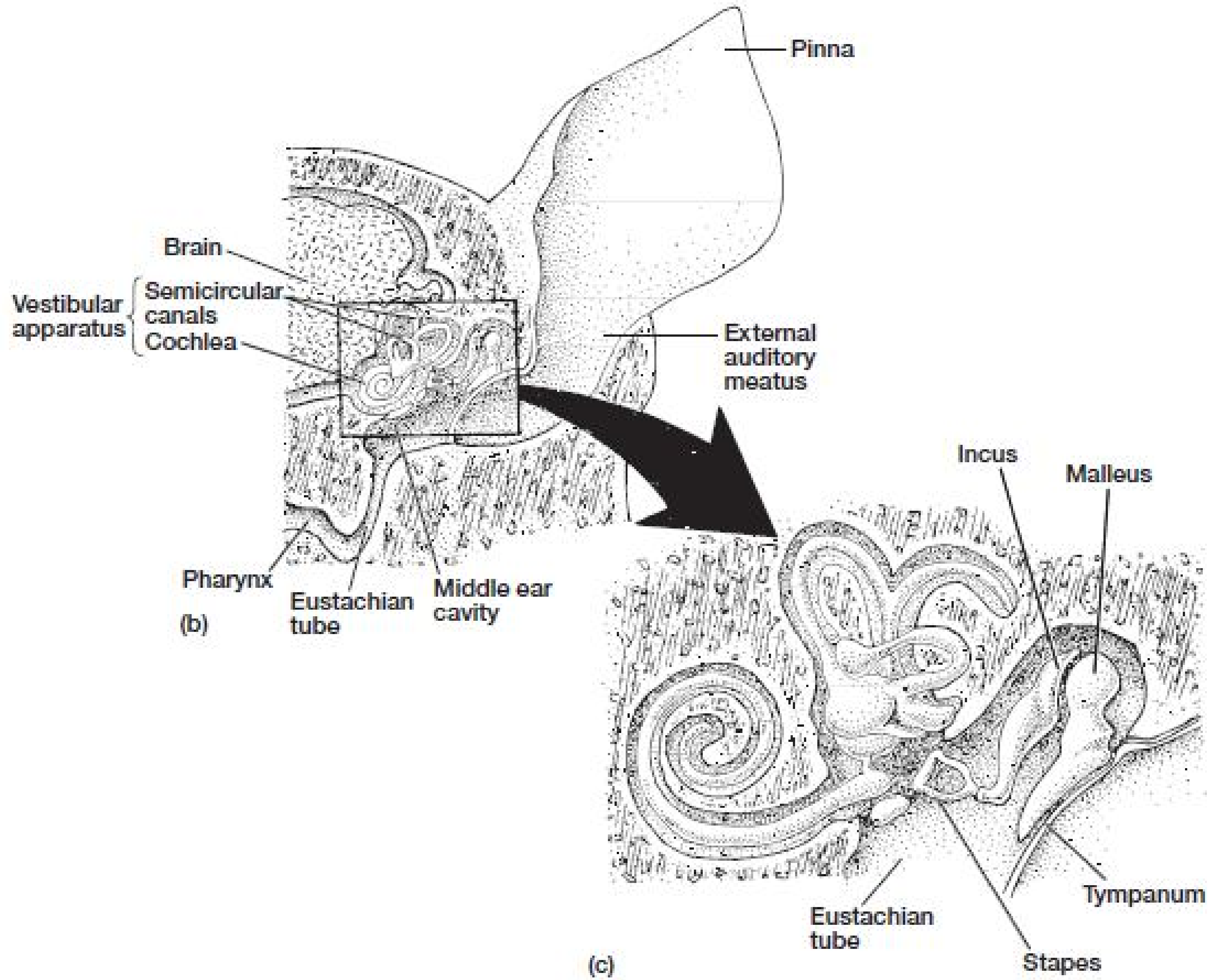
(b)



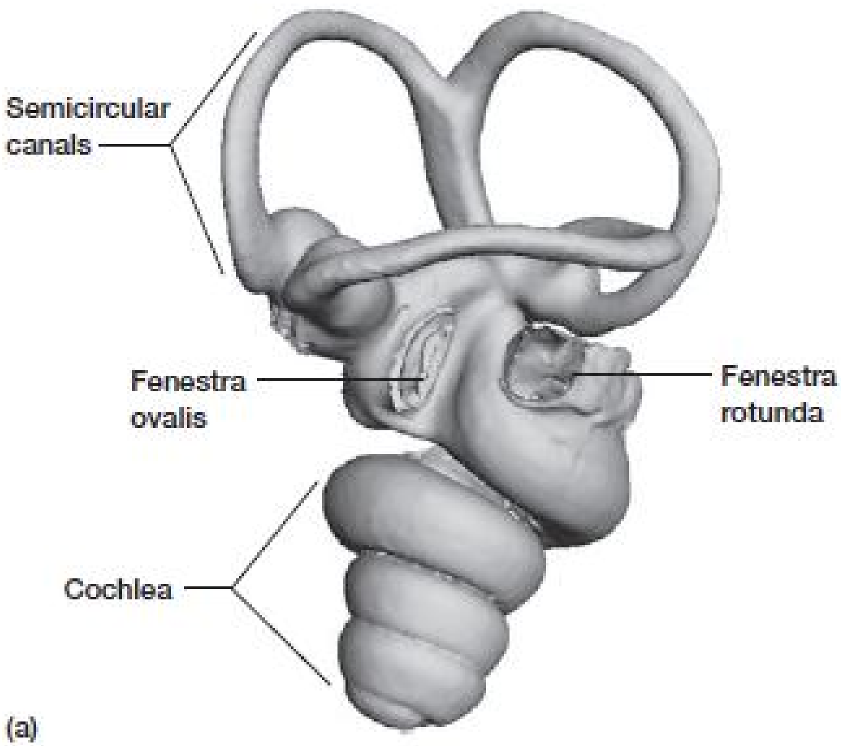
(c)

FIGURE 17.43 Auditory acuity in owls. (a) Facial disk feathers in normal position (inset) have been removed to reveal sets of auditory feathers. In this barn owl, tightly packed parabolic rims of feathers encircle the face and external orifice of the ear. This facial ruff of feathers, as it is called, collects and directs sounds to the external orifice of the ear. Note the asymmetrical positioning of the preaural flaps of feathers (dashed lines). (b) Left and right sides of the skull of a Tengmalm's owl. There are slight differences in the size of the external auditory canal. (c) Anterior view showing asymmetry of otic areas in Tengmalm's owl.

(a) After Knudson; (b,c) after Norberg. From "The Hearing of the Barn Owl" edited by E. I. Knudson, drawn by Tom Prentiss in Scientific American, December 1981.



Pinna
Brain
Vestibular apparatus
Semicircular canals
Cochlea
External auditory meatus
Pharynx
Eustachian tube
Middle ear cavity
(b)
Incus
Malleus
Tympanum
Eustachian tube
Stapes
(c)



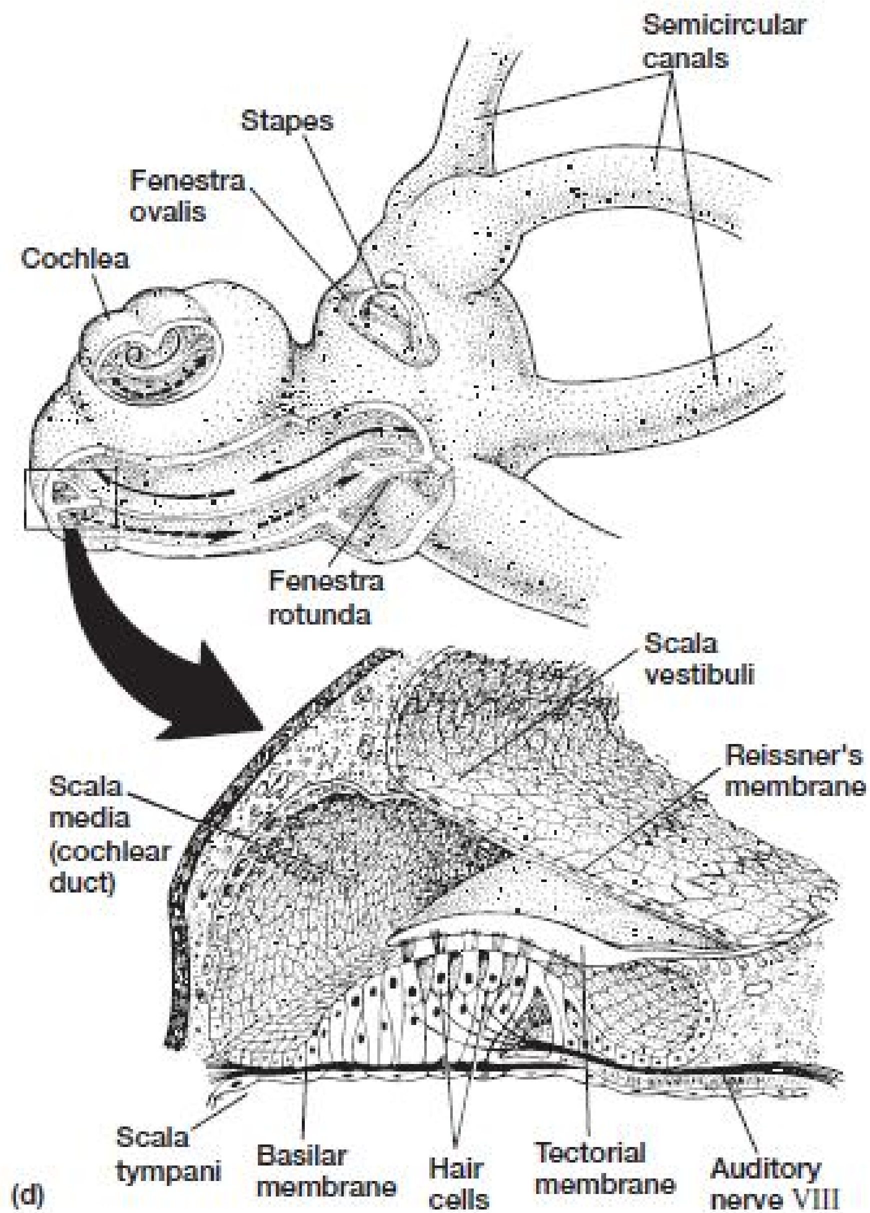


FIGURE 17.44 **Mammalian ear.** (a) Bony endocast in lateral view of left vestibular apparatus, capybara (South American rodent). (b) Cross section through a mammalian skull. (c) Internal structure of the cochlea. (d) Section through the organ of Corti showing inner and outer rows of hair cells and the tectorial membrane in which hair bundles are embedded. Sound waves travel first in the scala vestibuli (solid arrows) before passing at the apex of the cochlea into the scala tympani (dashed arrows).

(a) Image kindly supplied by Dr. Irina Ruf, Universität Bonn; (b) after H. M. Smith; (c) after Romer and Parsons; (d) after vanBeneden and vanBambeke.

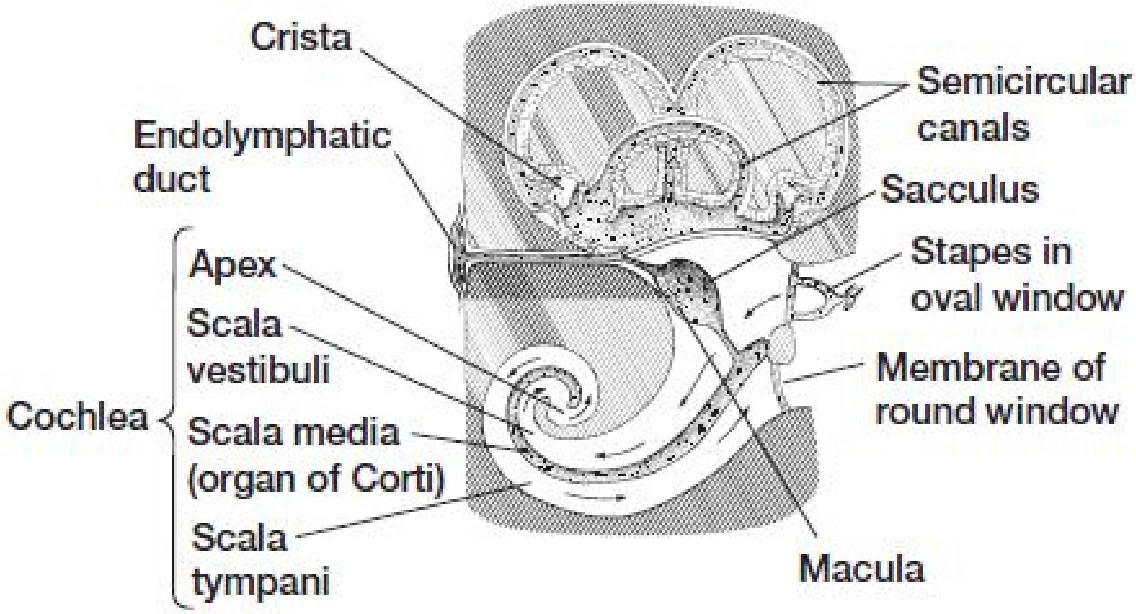


FIGURE 17.45 Distribution of sound vibrations through the cochlea. The stapes delivers vibrations at the fenestra ovalis. These vibrations spread through the perilymph within the chamber of the scala vestibuli and around the tip of the cochlea into the connecting chamber of the scala tympani. The cochlear duct, containing the organ of Corti, lies between these two chambers. Passing vibrations are thought to stimulate appropriate sections within this organ. The flexible membrane across the fenestra rotunda serves to dampen sound waves and prevent their rebound back through the cochlea.

After vanBeneden and vanBambeke.

REFERENCES:

Kardong, K. Vertebrates. Comparative Anatomy, Function and Evolution. *Sense Organs*.