CHAPTER 1
ANATOMY OF THE EAR

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1.1 EXTERNAL EAR: PINNA AND EAR CANAL

The *pinna* is the most prominent portion of the external ear (Fig. 1.1). It has an inner, concave surface and an outer, convex surface. In the standing ear, the concave surface forms a conchal cavity that is directed rostrally or laterally, while the convex surface faces medially or caudally. The distal tip of the pinna is called the *apex*, and the lateral and medial free margins of the pinna are called the *helix* (Fig. 1.2). The rostrolateral boundary of the distal portion of the ear canal is called the *tragus*. A notch caudal to the tragus, the *intertragic incisure*, separates it from the *antitragus*, which is a thin elongated piece of cartilage that extends up to the lateral margin of the helix at the *cutaneous marginal pouch*.

The margins of the pinna are divided into medial, or rostral, and lateral, or caudal (see Fig. 1.1). These variations in directional description can make the anatomy very confusing.

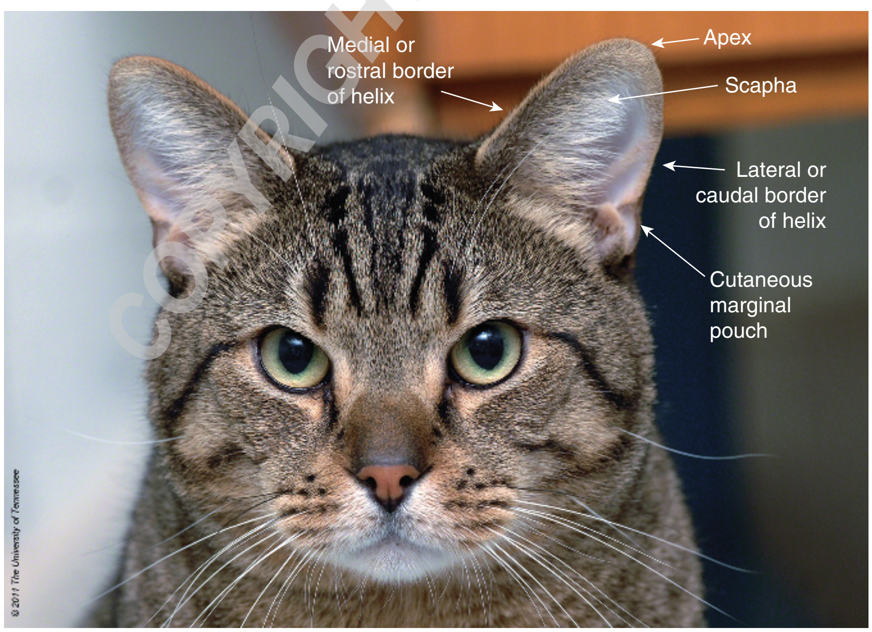

Figure 1.1 General anatomy of the pinna. The conchal cavity of the concave surface of the ear can be directed rostrally or laterally. (Photo by Phil Snow, UTCVM) © 2012 The University of Tennessee.

Atlas of Ear Diseases of the Dog and Cat, First Edition. Sue Paterson and Karen Tobias.

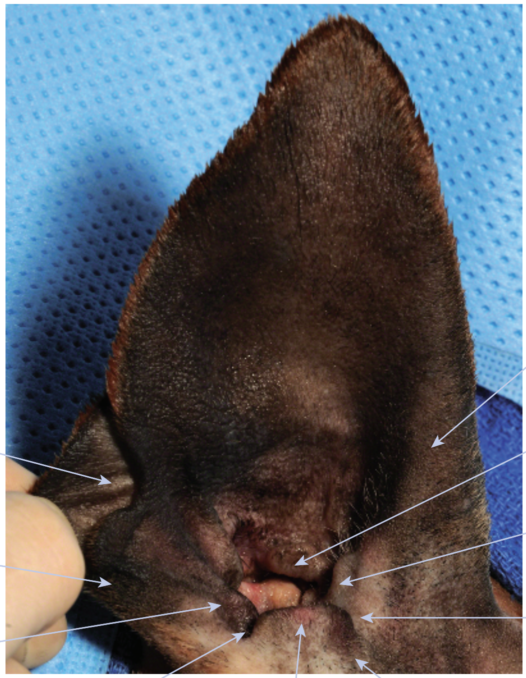

Figure 1.2 Concave surface of the right dog pinna. The antihelix and tragus form the boundaries of the ear canal opening. (Photo by Phil Snow, UTCVM) © 2012 The University of Tennessee.

The external ear is composed of three cartilages: *annular*, *auricular*, and *scutiform*. The ear canal is formed proximally (near the skull) by the annular cartilage and distally (away from the skull) by the auricular cartilage, which fans out to form the pinna (Fig. 1.3).

The auricular cartilage is divided into three sections: the *scapha*, the *concha*, and the *tubus auris*, or conchal tube (Fig. 1.4). Whereas the scapha is distally located and flattened, the concha is rolled into a trumpet shape to form the conchal cavity (Fig. 1.5). The scapha and concha are divided on the concave surface by the *antihelix*, a transverse cartilaginous fold.

The concha forms a funnel shape that thickens proximally as it becomes the *conchal tube*. The conchal tube forms the *vertical ear canal*. This canal is up to an inch (2.5 cm) deep and, as it progresses proximally towards the head, is directed ventrally, medially, and slightly rostral, spiralling inwards. It is partially surrounded along its proximal lateral border by the parotid salivary gland.

The annular cartilage is a separate, rolled, cartilaginous band that fits inside of the base of the conchal tube. It forms the *horizontal ear canal*, which runs medially toward the skull. In turn, the annular cartilage overlaps the osseous external acoustic meatus. Junctions of the auricular and annular cartilages and the annular cartilage and skull are connected by a fibrous tissue sheath. Because of these moveable joints, the auditory canal can be straightened during otoscopic examination. Epithelium lining the auricular and annular cartilage contains sebaceous and ceruminous glands and hair follicles (Fig. 1.6).

Terminology for the ear canal varies within and amongst texts. Some authors consider the osseous extension of the skull that encompasses the tympanic membrane to be the *external acoustic meatus* or *osseous external acoustic meatus*, while others consider the external acoustic meatus to be the opening of the conchal tube at the level of the tragus and antihelix. The cartilaginous tube that extends from the meatus to the concha, which is a combination of conchal tube (auricular) and annular cartilage, is sometimes called the *auditory canal*.

A variety of muscles attach the ear rostrally, ventrally, or caudally to the head (Fig. 1.7); these muscles are innervated by the facial nerve. Some of these muscles are continuous with the cervical portion of the platysma. The plate-like, L-shaped scutiform cartilage, which is medial to the auricular cartilage, lies within the muscles that attach the auricular cartilage to the head (Fig. 1.8). By acting as a fulcrum, the scutiform cartilage improves mobility of the auricular cartilage.

The major portion of the blood supply to the external ear comes from the caudal auricular artery, which arises

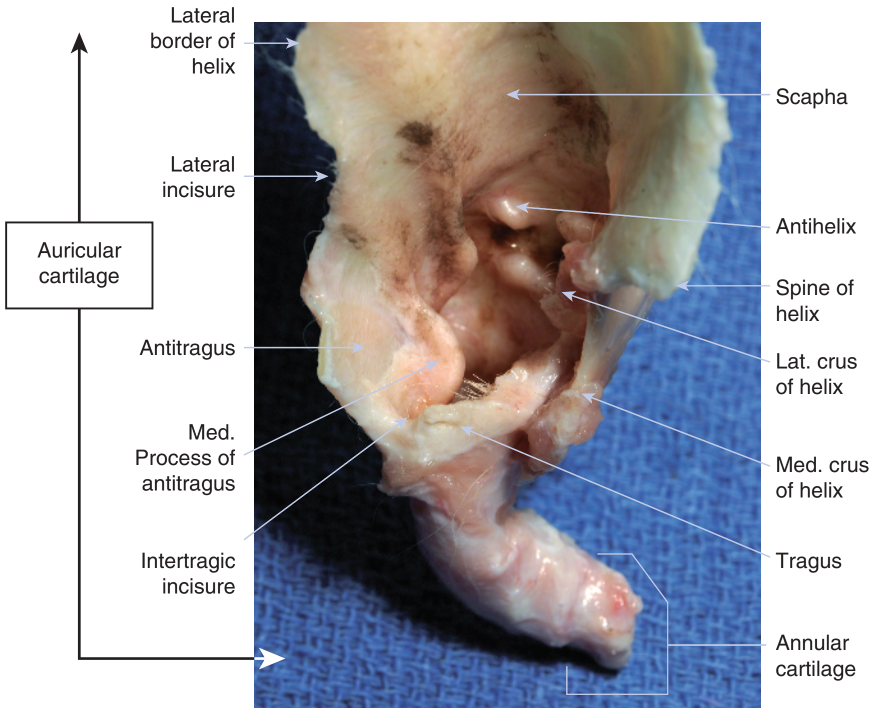

Figure 1.3 Auricular and annular cartilage of the right ear of a dog, lateral view. (Photo by Phil Snow, UTCVM) © 2012 The University of Tennessee.

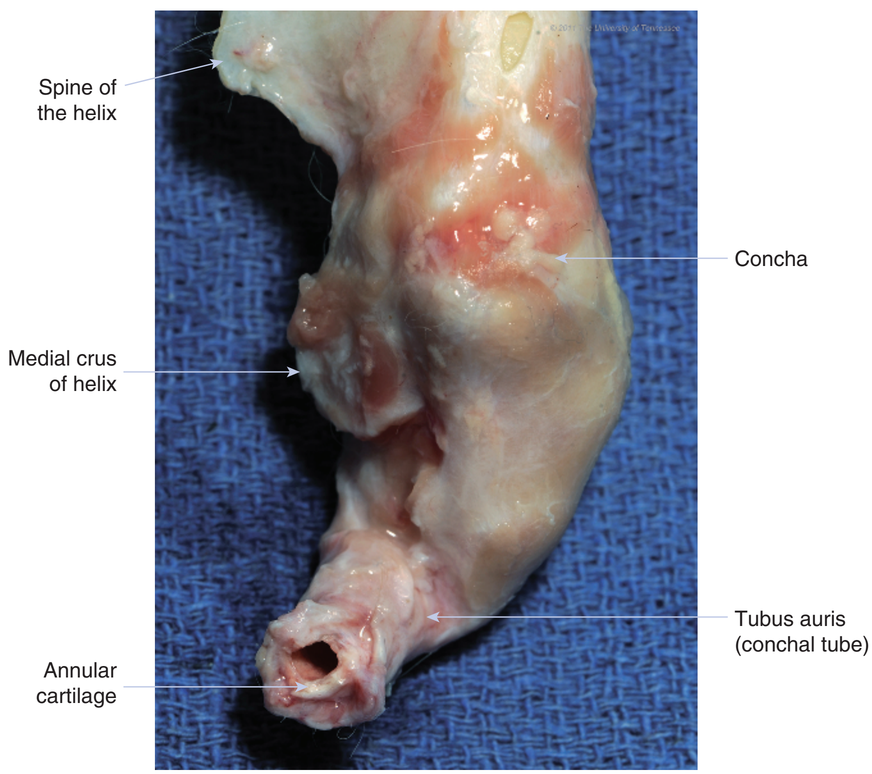

Figure 1.4 Auricular and annular cartilage of the right ear, caudal view. The annular cartilage is nestled within the auricular cartilage, which forms the pinna and vertical ear canal. Note that the proximal portion of the auricular cartilage spirals inward as it bends. (Photo by Phil Snow, UTCVM) © 2012 The University of Tennessee.

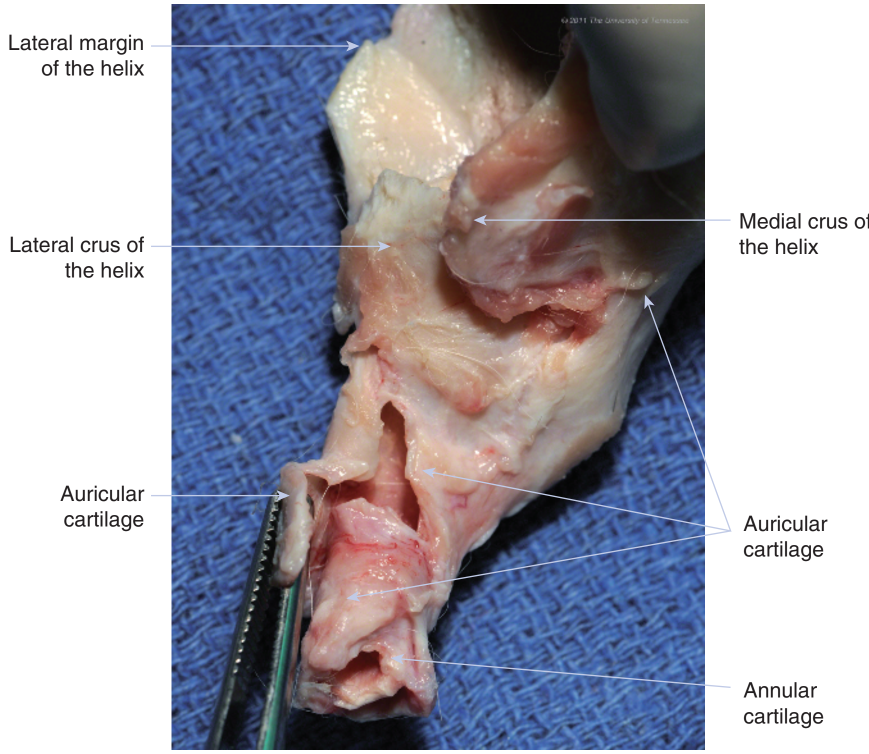

Figure 1.5 Medial view of cartilage of the right ear. A portion of the auricular cartilage that forms the conchal tube has been elevated; underneath is another extension of auricular cartilage that wraps around the annular cartilage. Note that the ear canal is not a solid funnel: the auricular and annular tubes are each formed by overlapping flaps of cartilage that allow flexibility. Animals with severe otitis externa or conchal obstruction may develop periauricular abscesses from disruption of the fibrous connective tissue sheath surrounding either the tube flaps or the auricular-annular or annular-osseous junction. (Photo by Phil Snow, UTCVM) © 2012 The University of Tennessee.

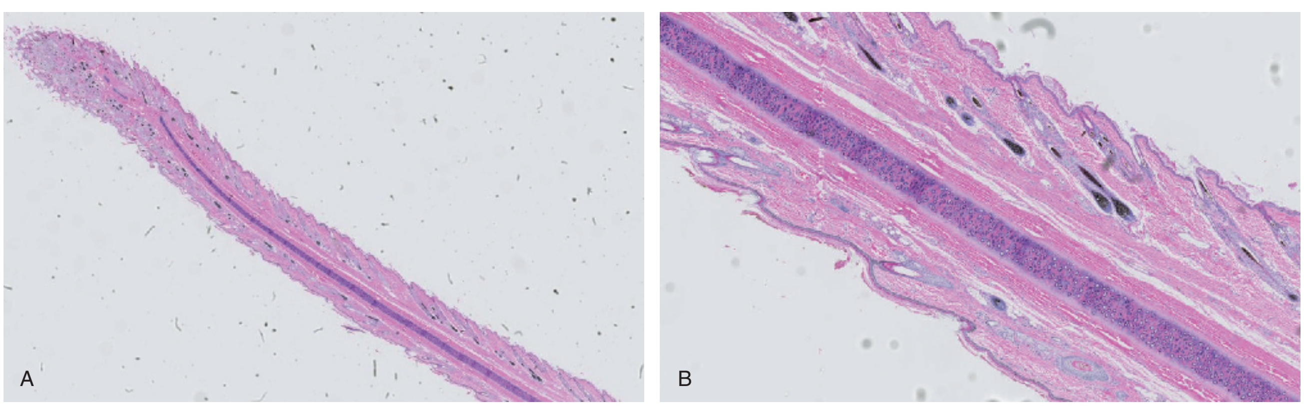

Figure 1.6 (**A**), Cross-section of the pinna of a dog. (**B**), Components including hyaline cartilage, muscle, and hair follicles are easily visible. (Courtesy, UTCVM Virtual Microscope) © 2012 The University of Tennessee.

from the external carotid artery at the base of the annular cartilage and medial to the parotid salivary gland (Fig. 1.9). The caudal auricular and superficial temporal veins, which terminate at the maxillary vein, provide drainage of the external ear (Fig. 1.10). Perforations in the auricular cartilage permit passage of blood vessels and nerves from the convex to the concave surface.

Sensory innervation to the concave surface of the pinna is provided primarily by branches of the facial nerve (Fig. 1.11) and, at the rostral extent of the pinna, by branches of

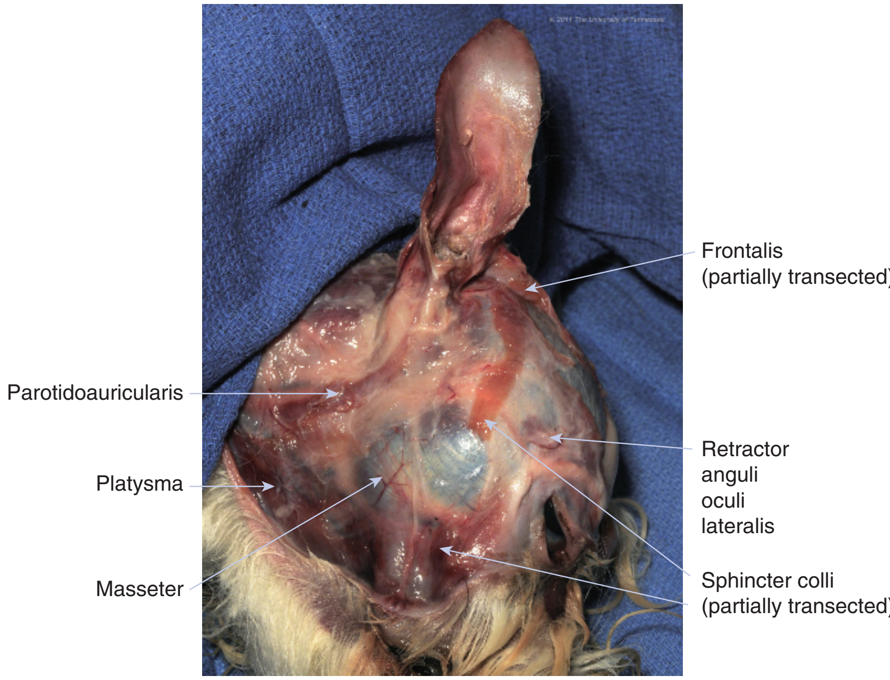

Figure 1.7 Muscles of the canine ear and face: right lateral view. (Photo by Phil Snow, UTCVM) © 2012 The University of Tennessee.

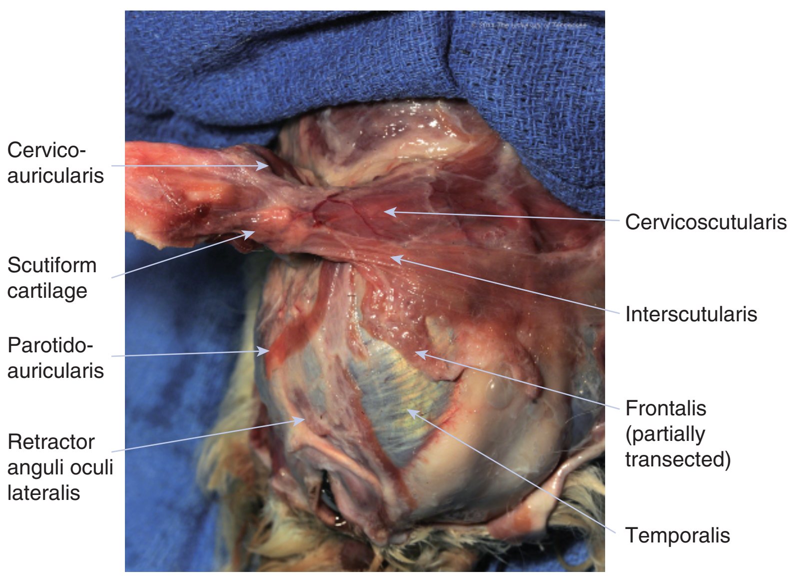

Figure 1.8 Muscles of the canine ear and head: dorsal view. The scutiform cartilage is enveloped within the dorsal group of muscles. (Photo by Phil Snow, UTCVM) © 2012 The University of Tennessee.

the trigeminal nerve. The lateral auricular branch of the facial nerve provides sensation to the majority of the vertical canal, along with a portion of the horizontal canal, while the auriculotemporal branch of the trigeminal nerve provides sensory innervation to the horizontal canal and tympanic membrane. The convex surface of the pinna receives sensory innervation via the second cervical nerve. Communications between vagal and facial nerve branches may also be present.

1.2 MIDDLE EAR OF THE DOG

The canine middle ear (Figs 1.12 and 1.13) consists primarily of an air-filled tympanic cavity that is separated from

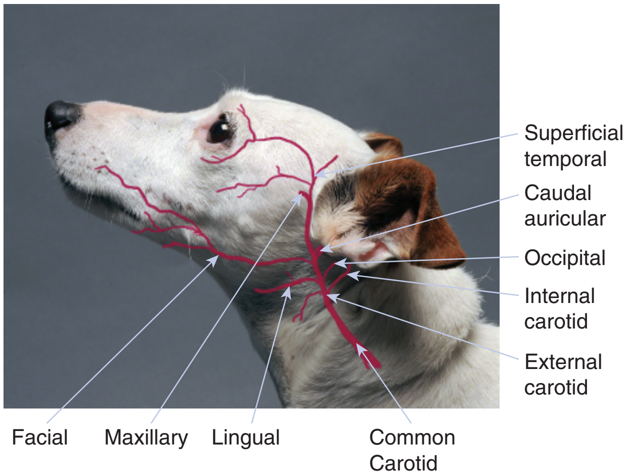

Figure 1.9 Selected branches of the common carotid artery. The external carotid artery gives off the caudal auricular artery and then travels around the ventral and rostral aspects of the horizontal canal before terminating in the maxillary and superficial temporal arterial branches. (Background photo by Phil Snow, UTCVM) © 2012 The University of Tennessee.

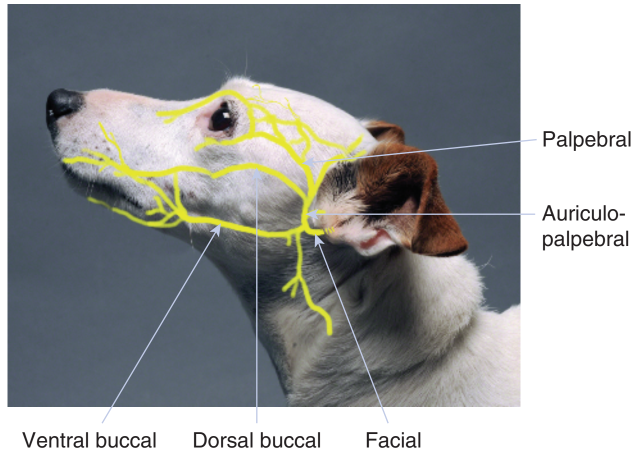

Figure 1.11 Selected branches of the facial nerve. After exiting the stylomastoid foramen, the facial nerve travels near the caudal, ventral, and rostral aspects of the horizontal ear canal. (Background photo by Phil Snow, UTCVM) © 2012 The University of Tennessee.

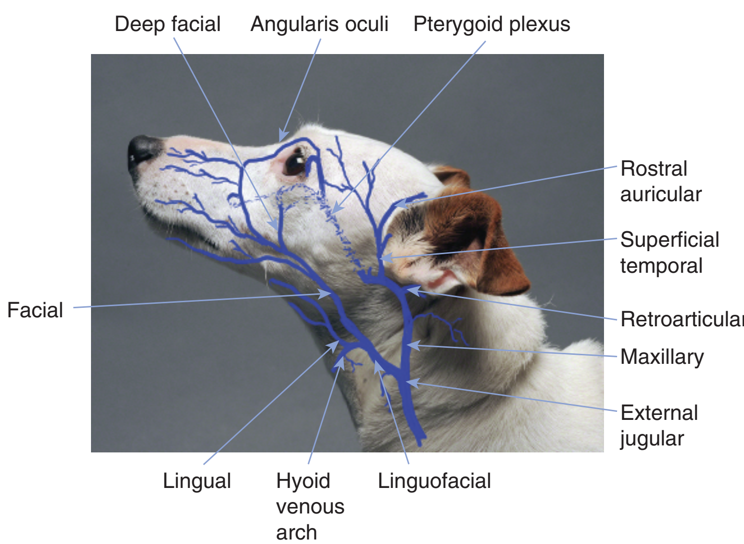

Figure 1.10 Selected tributaries of the external jugular vein. The superficial temporal vein travels ventrally around the rostral aspect of the horizontal canal and then joins the maxillary vein, which lies ventral to the canal. (Background photo by Phil Snow, UTCVM) © 2012 The University of Tennessee.

the external ear by the tympanic membrane and from the inner ear by the vestibular and cochlear windows. The middle ear is divided into three parts: (1) a large, ventral *tympanic bulla* within the temporal bone; (2) a small, dorsal *epitympanic recess*, which sits above the level of the tympanic membrane; and (3) the *tympanic cavity proper*, which connects the two and is bounded on its lateral surface by the tympanic membrane (Fig. 1.14).The tympanic cavity proper is partially separated from the ventral tympanic bulla by an incomplete septum. The tympanic cavity proper contains the cochlear (round) window along its caudal aspect. The *ossicles* of the ear – the *stapes*, *incus*,

Figure 1.12 Left lateral view of the canine skull. In this image, the mandible has been removed and the skull has been rotated slightly. Note how the bulla is less prominent than the retroarticular and jugular processes. (Photo by Phil Snow, UTCVM) © 2012 The University of Tennessee.

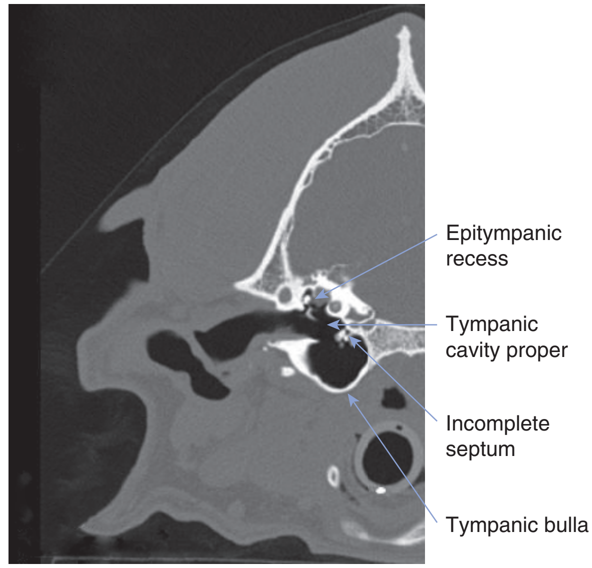

Figure 1.14 Parts of the canine middle ear. In this dog, the manubrium of the malleus is visible as an L-shaped structure, and a portion of the septum can be seen along the medial wall of the bulla. (Courtesy, UTCVM Radiology) © 2012 The University of Tennessee.

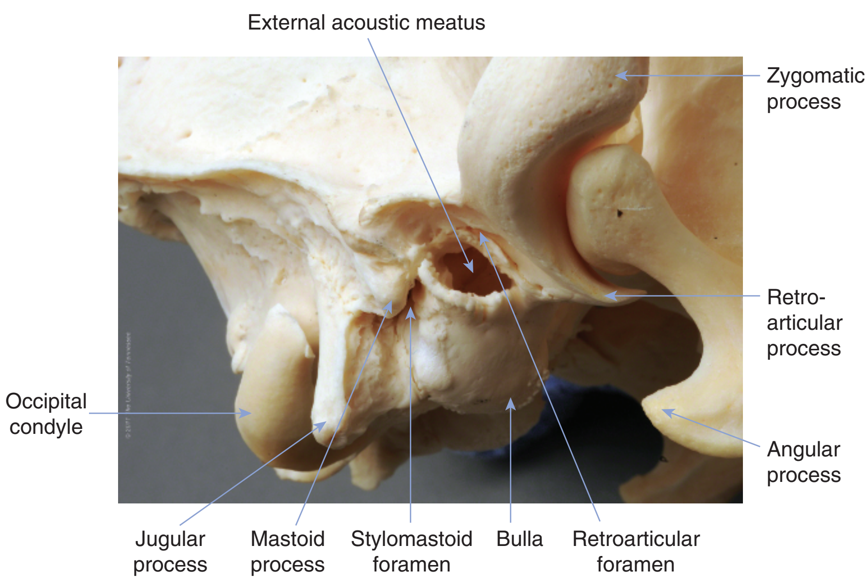

Figure 1.13 Right lateral view of the canine bulla with the mandible in place. During ventral bulla osteotomy, the position of the canine bulla is estimated by palpating the jugular and angular processes. (Photo by Phil Snow, UTCVM) © 2012 The University of Tennessee.

and portions of the *malleus* – reside within the epitympanic recess and span the distance from the inner ear to the tympanic membrane (Fig. 1.15). The tympanic cavity is lined by simple squamous or cuboidal epithelium, except at the orifice of the auditory tube.

The *tympanic membrane* is oval in shape and concave from an external viewpoint because of medial traction by the attached malleus (Fig. 1.16). In the dog it lies at a 45° angle to the long axis of the horizontal canal, with its ventral aspect farther from view than the dorsal portion.

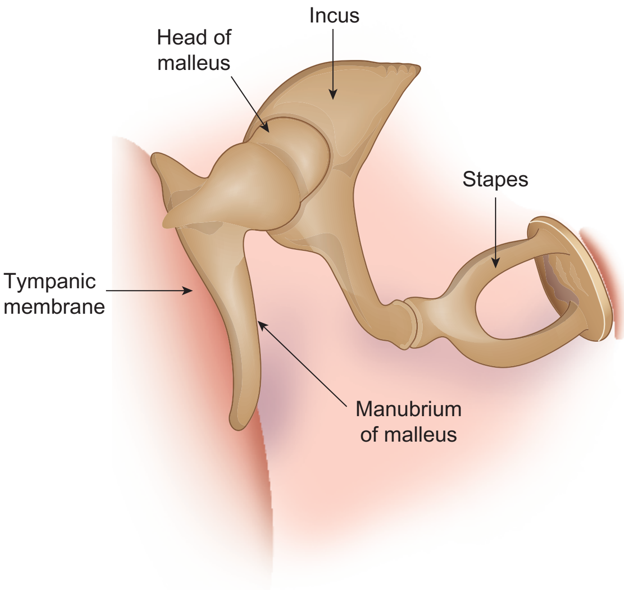

Figure 1.15 The auditory ossicles – the malleus, incus, and stapes – span the distance from the tympanic membrane to the oval window membrane.

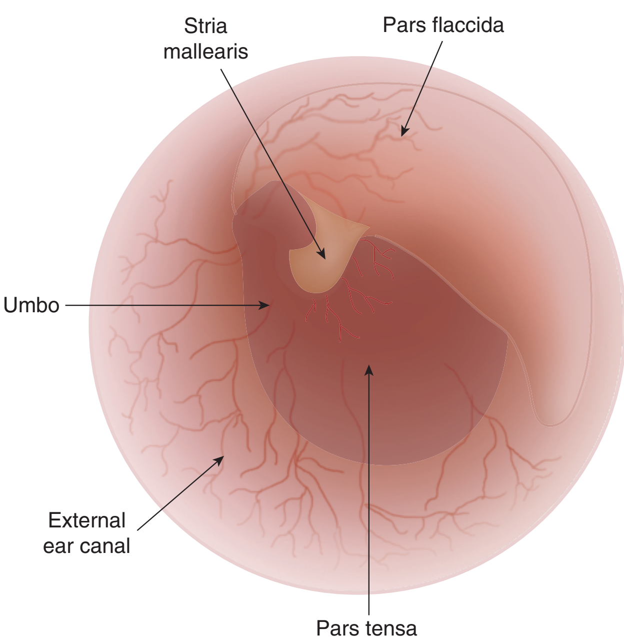

Figure 1.16 Diagram of the tympanic membrane. The tympanic membrane curves away from the external canal because of inward tension of the malleus, which attaches to it. Epithelium regenerates from the umbo outwards; this area should be avoided during myringotomy.

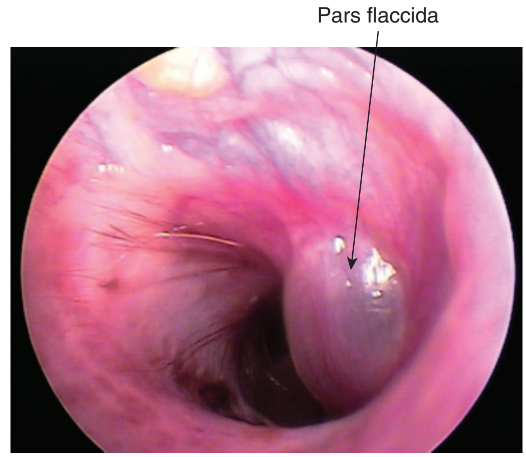

Figure 1.17 In normal dogs, the pars flaccida may be very prominent and therefore easily confused with a mass. (Courtesy, UTCVM Dermatology Service) © 2012 The University of Tennessee.

The largest portion of the tympanic membrane is called the *pars tensa*, a taut, semi-transparent, fibrous membrane. The pars tensa is firmly attached to the surrounding osseous external acoustic meatus by the *annulus fibrocartilaginous*, a fibrocartilage ring. The much smaller, dorsal portion of the tympanic membrane, known as the *pars flaccida*, is loose, opaque, and richly vascularized (Fig. 1.17).

The tympanic membrane is formed by a layer of fibrous tissue covered on its external surface with stratified squamous epithelium and on its inner surface with simple squamous or cuboidal epithelium. The *manubrium* of the malleus is embedded in the fibrous layer of the membrane (see Fig. 1.16), resulting in an inward depression called the *umbo*. The tympanic membrane regenerates radially from the umbo pars tensa and becomes thicker toward its periphery. Visibility of the malleus through the pars tensa results in a white streak known as the *stria mallearis*.

The incus and the head of the malleus almost entirely fill the small epitympanic recess (Fig. 1.18). The malleus has three attachments: the tympanic membrane, petrous temporal bone, and incus. The incus is suspended between the stapes and malleus, and the footplate of the stapes is attached to the membrane over the oval window. The malleus is controlled by the tensor tympani muscle, which originates in the tympanic bulla and is innervated by the tensor tympani nerve, a branch of the trigeminal nerve. Contraction of the tensor tympani muscle makes the tympanic membrane more rigid. The stapedius muscle also originates in the tympanic bulla. It inserts on the stapes and is innervated by the stapedial branch of the facial nerve. The stapedius muscle contracts reflexively with loud noise, decreasing movement of the stapes to protect the ear from damage.

The *promontory* is a bony eminence on the dorsomedial wall of the tympanic cavity that houses the cochlea (Fig. 1.19). The promontory lies opposite of the tympanic membrane and medial to the epitympanic recess. The *cochlear (round) window* is found in the caudolateral portion of the promontory and opens to the perilymph in the scala tympani of the cochlea. The cochlear window is covered with a thin, secondary tympanic membrane that oscillates to dampen vibrations within the cochlear perilymph. The *vestibular (oval) window* lies on the dorsolateral surface of the promontory and is covered by a thin membrane to which the foot of the stapes is attached. Facing the vestibular window is a slit-like opening into the facial canal, through which the facial nerve travels.

The *auditory* or *eustachian tube* connects the tympanic cavity to the nasopharynx (Fig. 1.20). It is oval in shape, 5–15 mm long, and 1–3 mm in diameter. The auditory tube begins as a short osseous tube – a canal through the temporal bone – that exits the skull rostromedial to the bulla as the *musculotubal canal* (see Fig. 1.19). Within the tympanic cavity, its proximal ostium can be seen on the rostral surface of the tympanic cavity proper. The distal end of the tube is supported by a narrow cartilaginous trough and opens on the lateral wall of the nasopharynx, dorsolateral to the soft palate at its midpoint.

The auditory tube functions to equalize pressure across the tympanic membrane. Its distal end can be actively

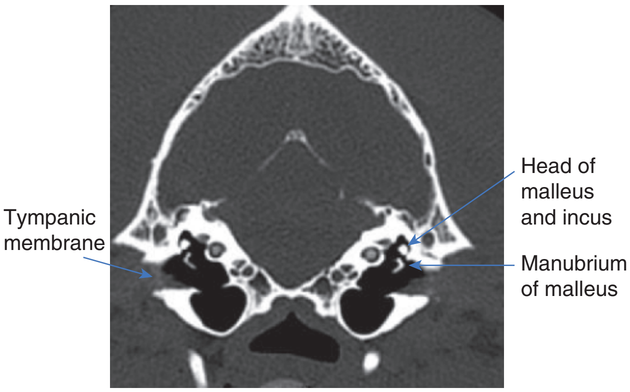

Figure 1.18 Transverse CT image of a dog skull showing the position of the malleus and tympanic membrane. (Courtesy, UTCVM Radiology) © 2012 The University of Tennessee.

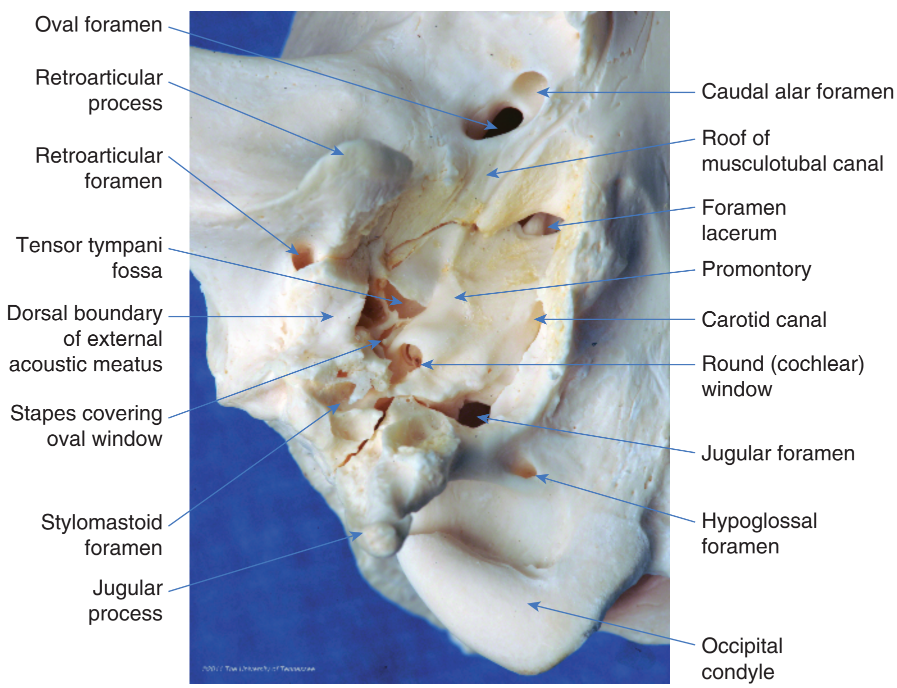

Figure 1.19 Ventral view of the right caudal canine skull with the tympanic bulla removed. The vestibular, or oval, window is on the dorsolateral surface of the promontory and just rostral to the cochlear (round) window. (Photo by Phil Snow, UTCVM) © 2012 The University of Tennessee.

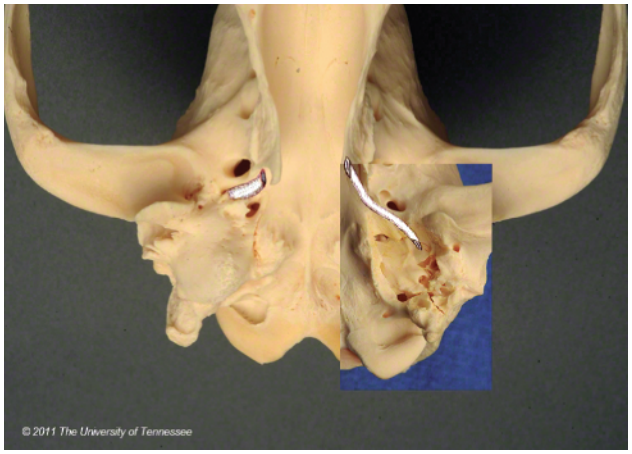

Figure 1.20 Ventral view of the caudal half of the canine skull (mandible removed). The auditory tube originates from the dorsolateral wall of the bulla (inset), just rostral to the tensor tympani muscle attachment, as the musculotubal canal. The distal end opens rostrally on the dorsolateral wall of the nasopharynx, just medial to the ipsilateral pterygoid process, or hamulus. (Photos by Phil Snow, UTCVM) © 2012 The University of Tennessee.

opened through tension by the tensor veli palatini muscle but otherwise remains closed because of surface tension caused by contact between air and mucus. Like the respiratory tract, the auditory tube is lined by ciliated pseudostratified columnar epithelium containing goblet cells.

The tympanic cavity is closely associated with several nerves and vessels that can become damaged with middle ear disease or surgical trauma (Fig. 1.21). The sympathetic postganglionic nerves to the eye and orbit are collectively called the *internal carotid nerves*. In the dog they travel along with the internal carotid artery through the carotid canal, which is separated from the tympanic cavity by a thin bony plate.

The *facial nerve* travels through the sigmoid-shaped *facial canal* of the petrous temporal bone. The facial canal is an incomplete tunnel that opens into the tympanic cavity lateral to the vestibular window. The facial nerve leaves the petrous part of the temporal bone through the *stylomastoid foramen*.

The *chorda tympani*, a branch of the facial nerve, travels medial to the base of the malleus in the epitympanic recess. It is sometimes called the *tympanic nerve*. The chorda

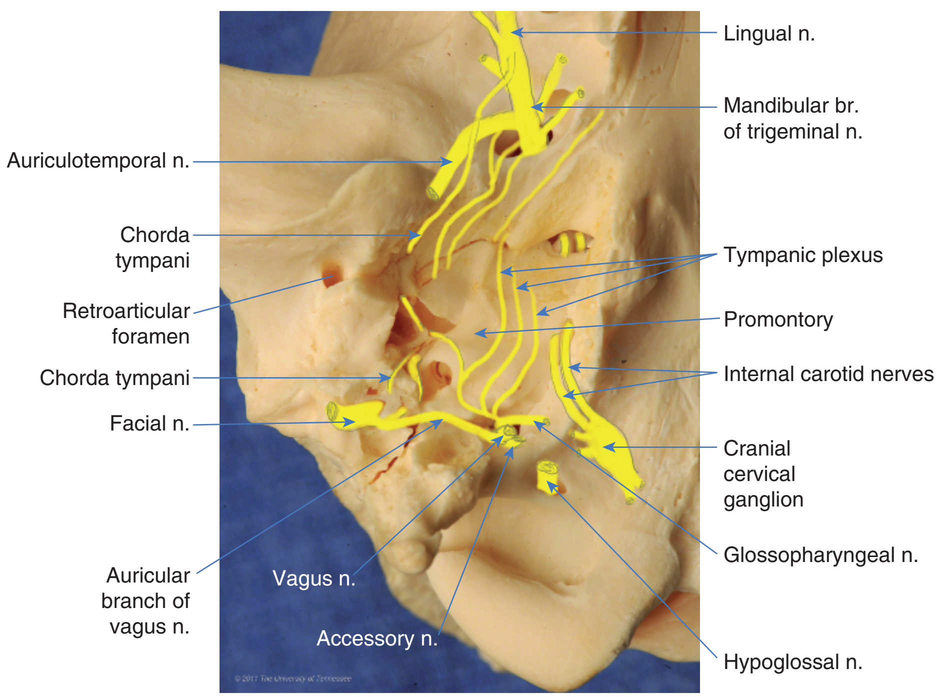

Figure 1.21 Ventral view of the canine skull (right bulla removed) with diagram of regional nerves. The facial nerve travels through the facial canal, an S-shaped trough in the epitympanic recess, and exits at the stylomastoicd foramen just caudal to the external acoustic meatus. The retroarticular vein, which is the termination of the temporal sinus, exits from the retroarticular foramen, while the internal carotid artery travels under a thin shelf of bone with the internal carotid nerves. The jugular process serves as the caudal attachment site of the digastricus muscle. (Photos by Phil Snow, UTCVM) © 2012 The University of Tennessee.

tympani provides innervation to the mandibular and sublingual salivary glands and fungiform papillae on the rostral two thirds of the tongue. Ipsilateral papilla may atrophy if the nerve on the affected side is damaged from otitis media.

The *tympanic plexus* lies on the promontory and is formed primarily by fibres from the tympanic branch of the glossopharyngeal nerve (cranial nerve IX). The tympanic branch of the glossopharyngeal nerve supplies innervation to the lining of the tympanic bulla, providing pressure and pain sensation, and to the parotid and zygomatic salivary glands.

The *auriculotemporal nerve*, a branch of the mandibular nerve, passes medial and caudal to the retroarticular process of the temporal bone and emerges between the base of the auricular cartilage caudally and masseter muscle cranial. One of its branches – the *external acoustic meatus nerve* – is sensory to the external acoustic meatus near the tympanic membrane. Another branch – the *rostral auricular nerve* – supplies the skin over the lateral aspect of the tragus and a rostroventral portion of the pinna's concave surface.

The *internal carotid artery* (Fig. 1.22) enters the *jugular foramen* and travels with the sympathetic fibres of the internal carotid nerve via the *tympano-occipital* or *petro-occipital fissure* into the middle ear, where it travels through the *carotid canal* (Fig. 1.23). It exits the canal at the rostromedial edge of the tympanic bulla at the *foramen lacerum*. The nearby petro-occipital canal transmits the ventral petrosal venous sinus. Axons of the glossopharyngeal (IX), vagus (X), and accessory (XI) nerves also pass through the jugular foramen and travel in the tympano-occipital fissure.

Beyond its bifurcation with the internal carotid artery, the *external carotid artery* travels rostrally, forming an S shape (see Fig. 1.22) that traverses from medial to lateral over the base of the bulla and then rostrally under the external acoustic meatus. It gives off several branches, including the caudal auricular and superficial temporal arteries. The caudal auricular artery circles the caudal half of the ear at the base of the annular cartilage. The superficial temporal artery is found at the rostral extent of the base of the auricular cartilage.

1.3 MIDDLE EAR OF THE CAT

As in the dog, the ossicles in the cat rest high up within the epitympanic recess (Fig. 1.24). Cats have a much less

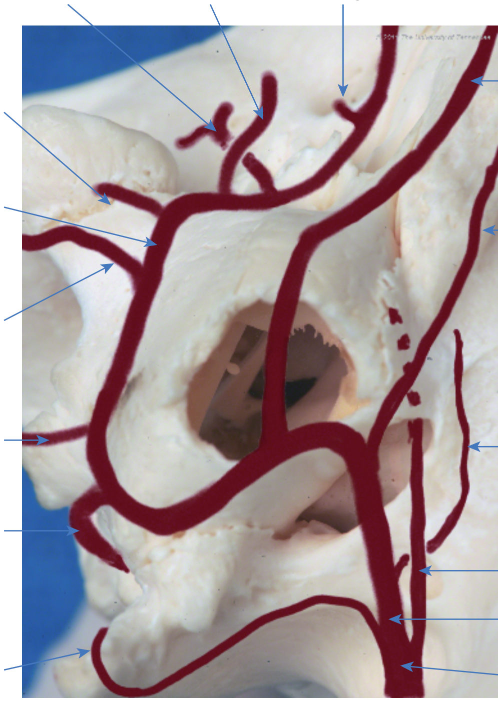

Figure 1.22 Relationship of selected arteries with the right bulla of a dog. In this view, a ventral bulla osteotomy has been performed and the manubrium is visible. The internal carotid artery passes through the tympano- (or petro-) occipital fissure, travels within the carotid canal, and passes out and then back into the foramen lacerum before travelling on to the brain. (Background photo by Phil Snow, UTCVM) © 2012 The University of Tennessee.

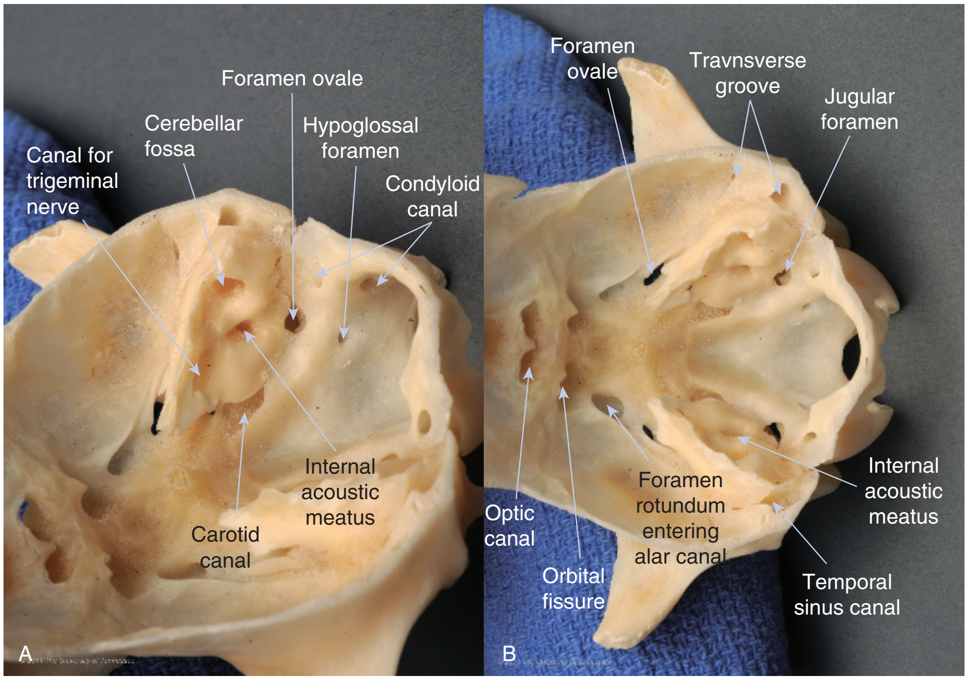

Figure 1.23 Dorsolateral (**A**) and dorsal (**B**) views of the open canine skull. (Photos by Phil Snow, UTCVM) © 2012 The University of Tennessee.

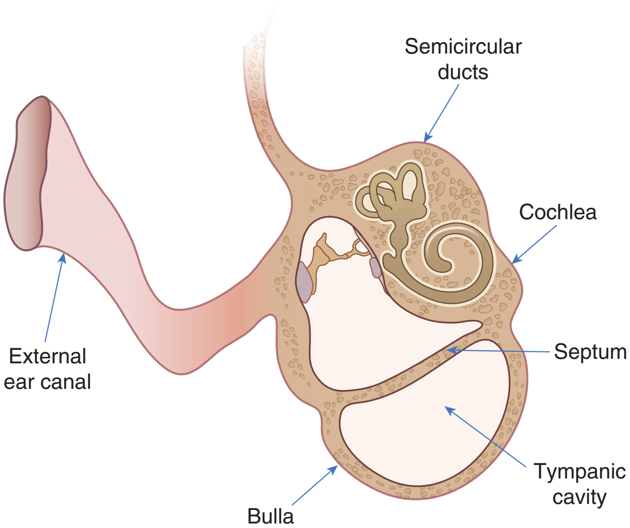

Figure 1.24 As in the dog, the ossicles of the cat lie within the epitympanic recess and extend from the tympanum to the oval window. A bony septum separates the bulla into two cavities.

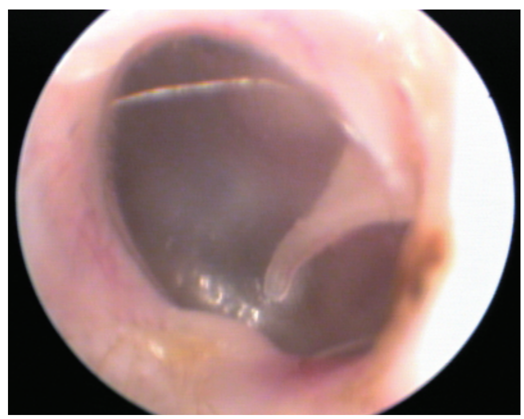

Figure 1.25 The manubrium in this cat is easily visible through the tympanic membrane. (Courtesy, UTCVM Dermatology) © 2012 The University of Tennessee.

prominent pars flaccida, so the manubrium is more easily visible through the tympanic membrane (Fig. 1.25). The bulla is more prominent in cats that in dogs, making it easier to locate by palpation during ventral bulla osteotomy (Fig. 1.26). In cats, the tympanic cavity is divided into two compartments by a thin bony septum (Fig. 1.27) that runs from a midrostral to a midlateral position (Fig. 1.28). The dorsolateral compartment is the smaller of the two (Fig. 1.29). Its lateral wall is comprised primarily by the tympanic membrane, which is oriented perpendicular to the long axis of the horizontal canal. Much of the dorsolateral compartment is occupied by the auditory ossicles immediately medial to the tympanum. The opening of the auditory tube is within the rostromedial aspect of the dorsolateral

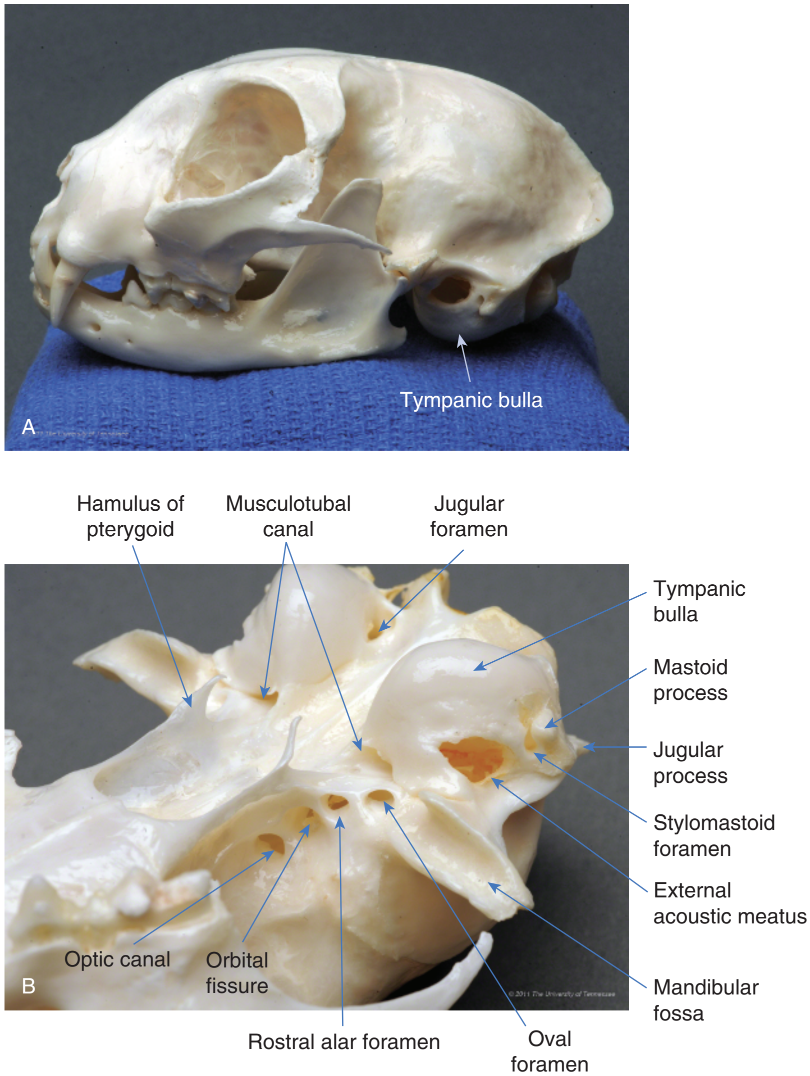

Figure 1.26 Anatomy of the cat skull. (**A**) Left lateral view. (**B**) Right ventrolateral view. The bulla extends ventral to the retroarticular and jugular processes, making it easily palpable. (Photos by Phil Snow, UTCVM) © 2012 The University of Tennessee.

compartment. The ventromedial compartment, which also extends caudal to the dorsolateral compartment, is primarily an air-filled bulla.

The septum dividing the bulla is incomplete dorsally: a narrow fissure on the caudomedial aspect of the dorsolateral compartment permits communication with the ventromedial compartment (Fig. 1.30). The caudal end of the fissure enlarges into a triangular foramen, which is occupied along its medial wall by the cochlear (round) window, which faces laterally. The promontory on the dorsal wall of the bulla is medial to the cochlear window and extends to both sides of the septum.

The chorda tympani, which originates from the facial nerve caudal to the tympanic membrane, travels rostrally, medial to the auditory ossicles (Fig. 1.31). The origin of the auditory tube is found on the dorsomedial portion of the rostral wall of this compartment.

The postganglionic sympathetic nerves enter the tympano-occipital fissure caudal to the bulla, travelling adjacent to the internal carotid artery. The tympanic branch of the glossopharyngeal nerve joins them within the tympano-occipital fissure so that collectively they form the caroticotympanic nerves. The nerves enter the ventromedial compartment of the tympanic cavity at the caudal end of the promontory, then branch and fan out to form the tympanic plexus. The plexus lies on the exposed surface of the promontory and is thus vulnerable to trauma. Damage to these fibres results in Horner's syndrome, with signs of

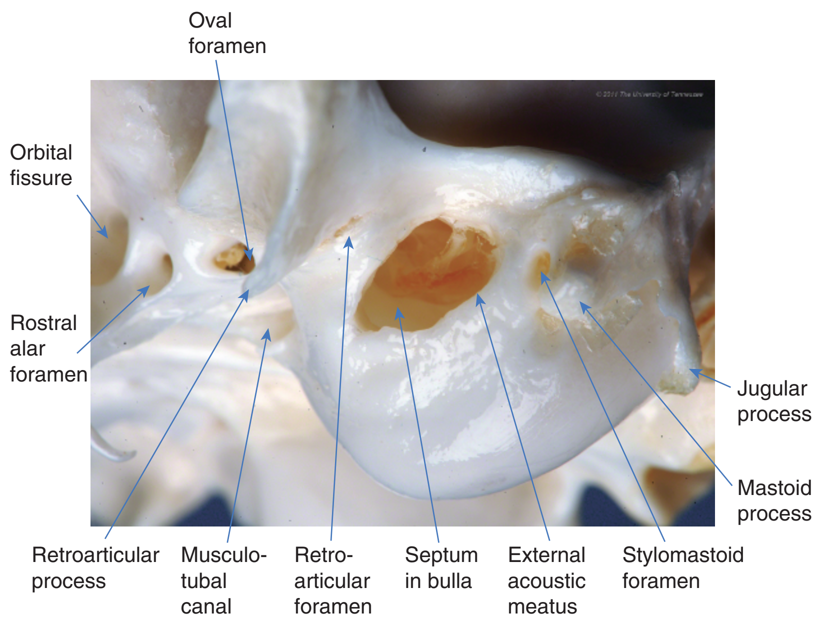

Figure 1.27 On the close-up view of the left feline bulla, the septum is visible through the osseous external acoustic meatus. (Photo by Phil Snow, UTCVM) © 2012 The University of Tennessee.

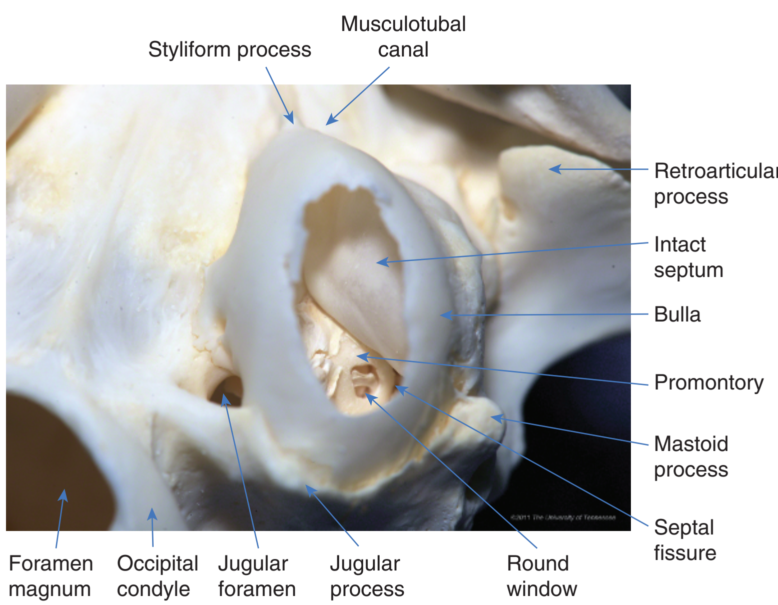

Figure 1.28 Ventral view of a cat skull: the floor of the left bulla has been removed (similar to ventral bulla osteotomy) to show the intact septum. (Photo by Phil Snow, UTCVM) © 2012 The University of Tennessee.

meiosis, enophthalmos, and third eyelid prolapse. Along the rostral edge of the promontory the plexus fibres enter through the communicating fissure into the dorsomedial compartment, where they are somewhat protected by a ridge of bone ventral to the promontory. The sympathetic fibres of the tympanic plexus exit the middle ear through the petrous temporal bone medial to the os of the auditory (eustachian) tube (Fig. 1.32) and join the ophthalmic branch of the trigeminal nerve (V), which carries them to the eye. The auditory (eustachian) tube terminates in the dorsolateral nasopharynx just medial to the hamulus of the pterygoid bone (Fig. 1.33).

1.4 INNER EAR

The inner ear contains the sensory organs for hearing and balance (Figs 1.34 and 1.35). It resides within the petrous part of the temporal bone (Fig. 1.36) and consists of a membranous labyrinth enclosed within a bony labyrinth.

The *bony labyrinth* includes the *semicircular canals*, *cochlea*, and a central chamber known as the *vestibule* that connects the two (Fig. 1.37). The bony vestibule is divided into the *utricle* and *saccule*. The *membranous labyrinth* resides within the bony labyrinth, and its components have names similar to those of their surrounding osseous structures. They include the *semicircular ducts*, *cochlear duct*, *utriculus*, and *sacculus*. The membranous utriculus and sacculus give rise to the semicircular ducts and cochlear duct, respectively.

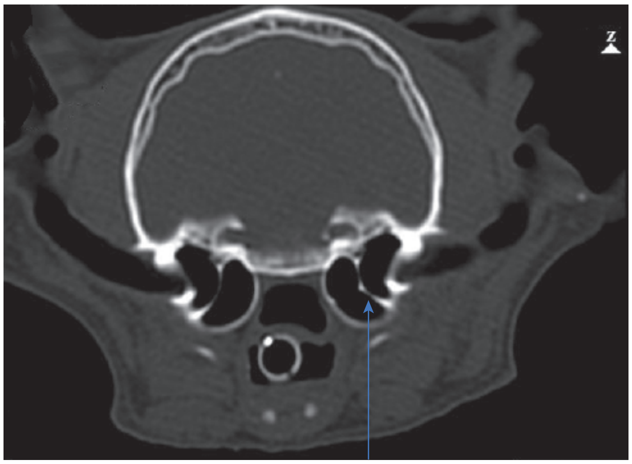

Figure 1.29 Normal cat CT scan. Note the septum (arrow) that divides the dorsolateral and ventromedial chambers. (Courtesy, UTCVM Radiology) © 2012 The University of Tennessee.

Fluid within the membranous labyrinth is called *endolymph*, and fluid that surrounds it is called *perilymph*. The system can be likened to an egg, in that the membranous labyrinth – the egg yolk – is suspended in a layer of perilymph within the bony labyrinth – the eggshell. The utriculus and sacculus are connected via the intervening *utriculosaccular duct*, which permits endolymph flow between the cochlear and semicircular ducts and therefore between the organs for hearing and balance.

The *cochlear aqueduct* connects the perilymphatic space of the scala tympani with the subarachnoid space (Fig. 1.38). Via the *perilymphatic duct* within the cochlear aqueduct, perilymph is continuous with cerebrospinal fluid, allowing middle ear infections to spread to the meninges. The endolymphatic duct travels through the *vestibular aqueduct*. Although the endolymphatic duct is not directly connected to the subarachnoid space, it ends in an *endolymphatic sac* that lies along the meninges in the epidural space.

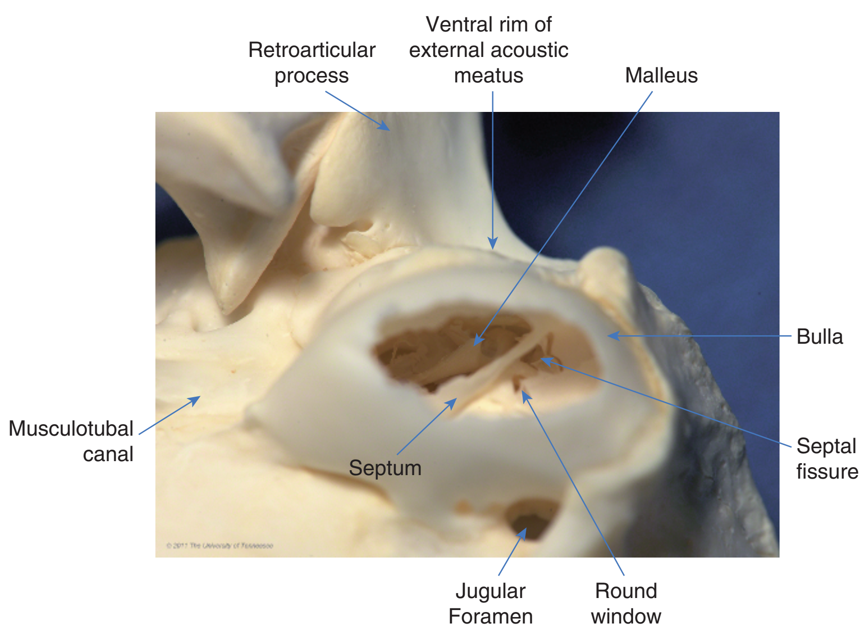

Figure 1.30 Ventral view of a cat skull showing interior of the left bulla after partial removal of the septum. A fissure in the caudodorsal aspect of the septum allows connection of the two compartments. The round window is located along the dorsal aspect of the fissure. (Photo by Phil Snow, UTCVM) © 2012 The University of Tennessee.

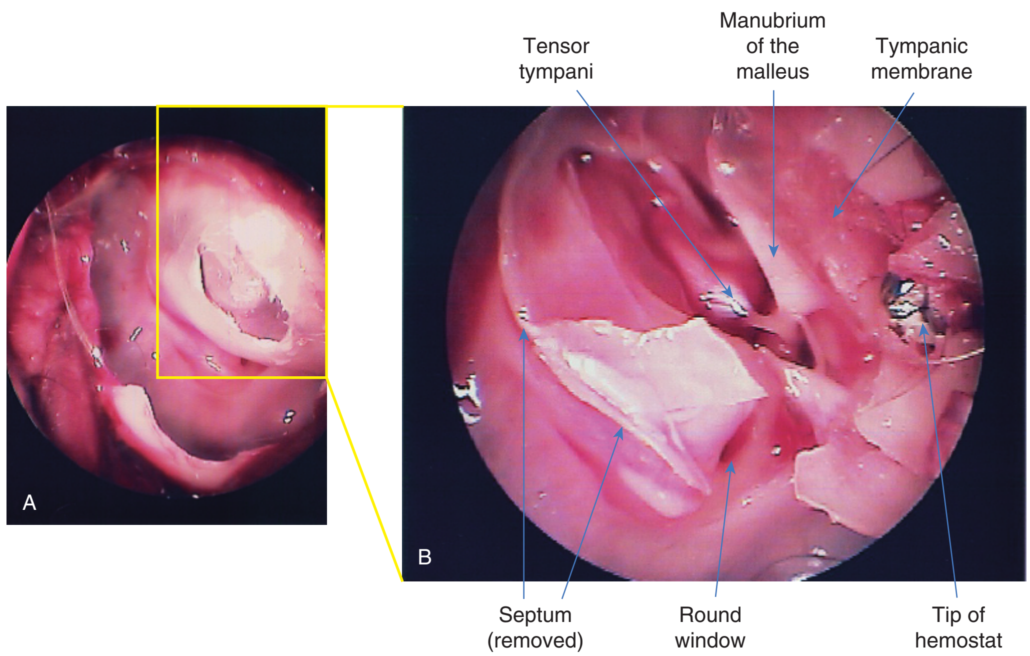

Figure 1.31 Ventral view of the left feline bulla (cadaver specimen) through a video otoscope. (**A**) The septum has been partially removed, but the inner lining is still intact. (**B**) Most of the septum and lining has been removed and the video otoscope advanced into the dorsolateral compartment. For orientation, a haemostat was inserted down the external ear canal and through the ventral portion of the tympanic membrane. The manubrium of the malleus is embedded within the dorsal half of the tympanic membrane.

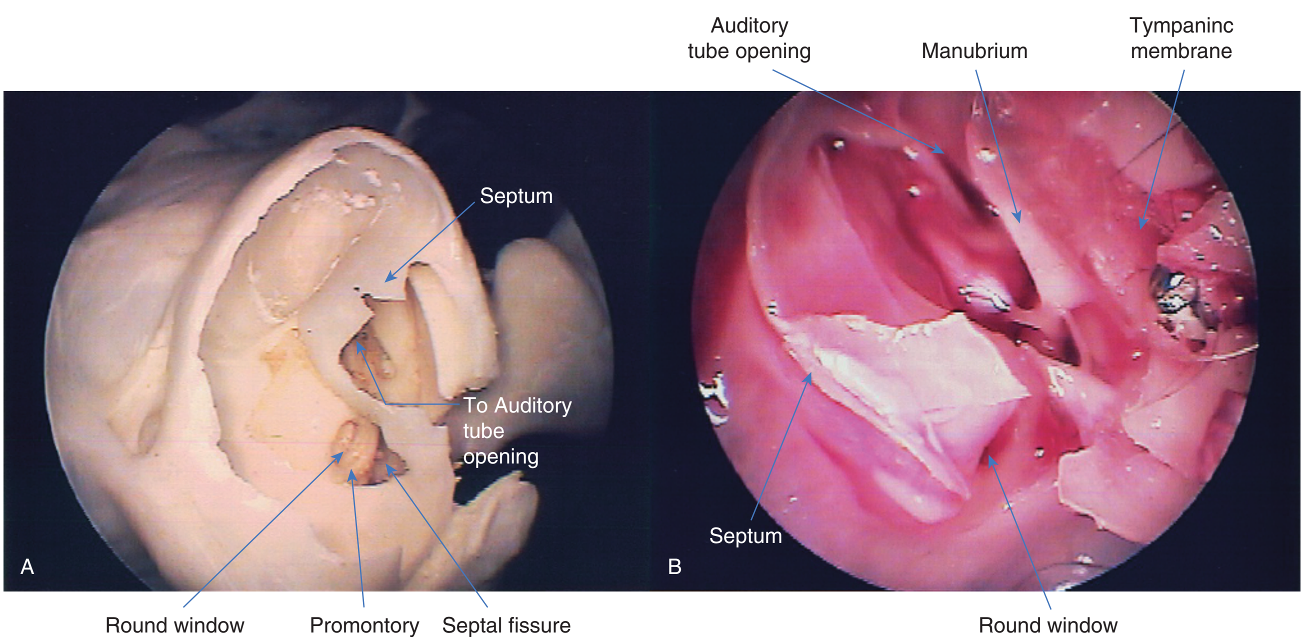

Figure 1.32 Opening of the auditory tube within the left feline bulla. The tympanic bulla has been removed and septum has been opened. The opening of the musculotubal canal is visible in the dorsolateral compartment of the cat skull (**A**) and appears as a slit-like opening in this otoscopic view (**B**) of a ventral bulla osteotomy in a cat cadaver.

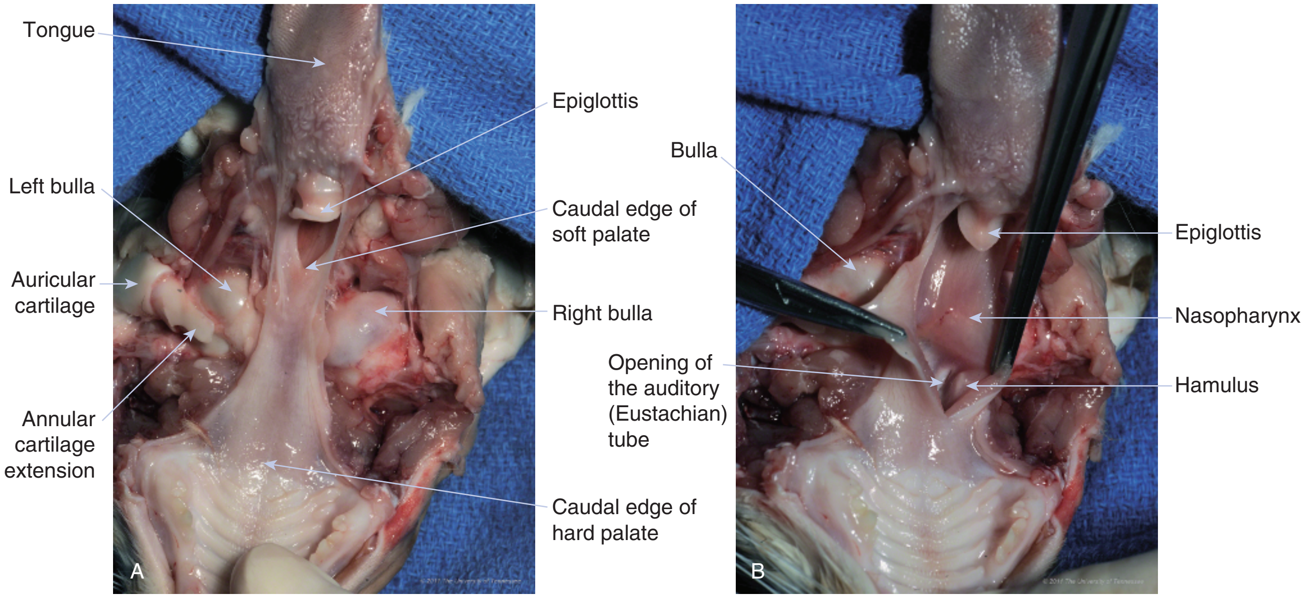

Figure 1.33 Ventral view of the cat head after removal of the mandible. (**A**) The bullae are closely associated with the nasopharynx. In the cat, the annular cartilage has a tongue-like extension that normally attaches to the ventral surface of the bulla. In this cadaver, the extension has been removed from the right side and shifted cranially on the left. (**B**) The opening of the right eustachian tube is visible once the soft palate is incised and retracted. (Photos by Phil Snow, UTCVM) © 2012 The University of Tennessee.

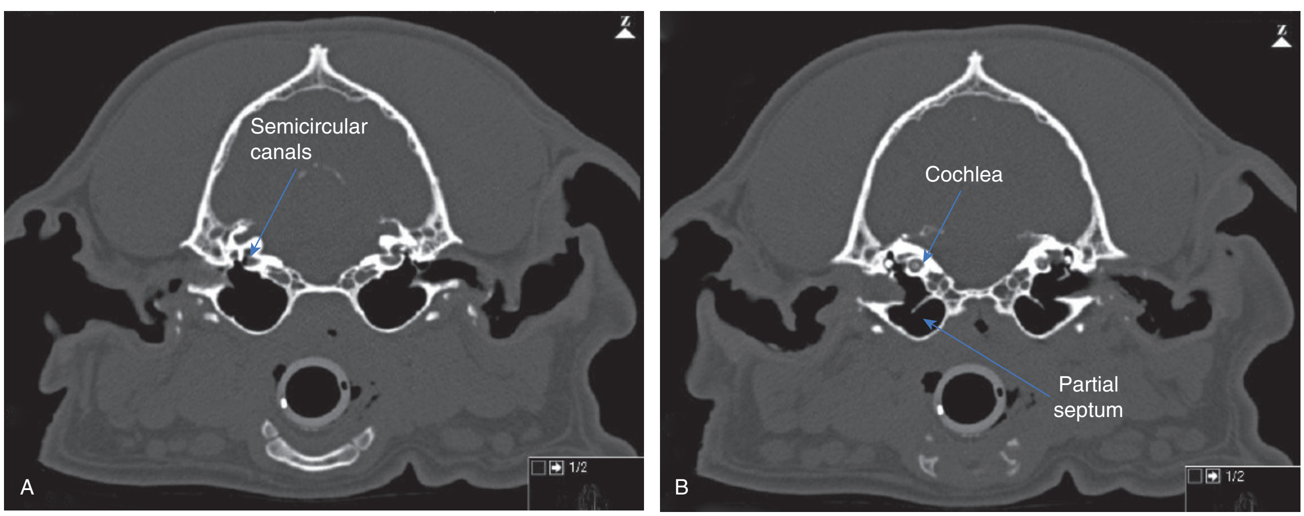

Figure 1.34 CT scan of the middle and inner ear of a dog. (**A**) The semicircular canals are visible above the right bulla, while the vestibule and caudal edge of the cochlea are visible above the left bulla. (**B**) In a more rostral image, the cochlea can be seen above the tympanic cavity proper of the right bulla, with the foot of the stapes covering the oval window. The round window is visible entering the cochlea of the left bulla. The malleus and septa are evident in both bulla. (Courtesy, UTCVM Radiology) © 2012 The University of Tennessee.

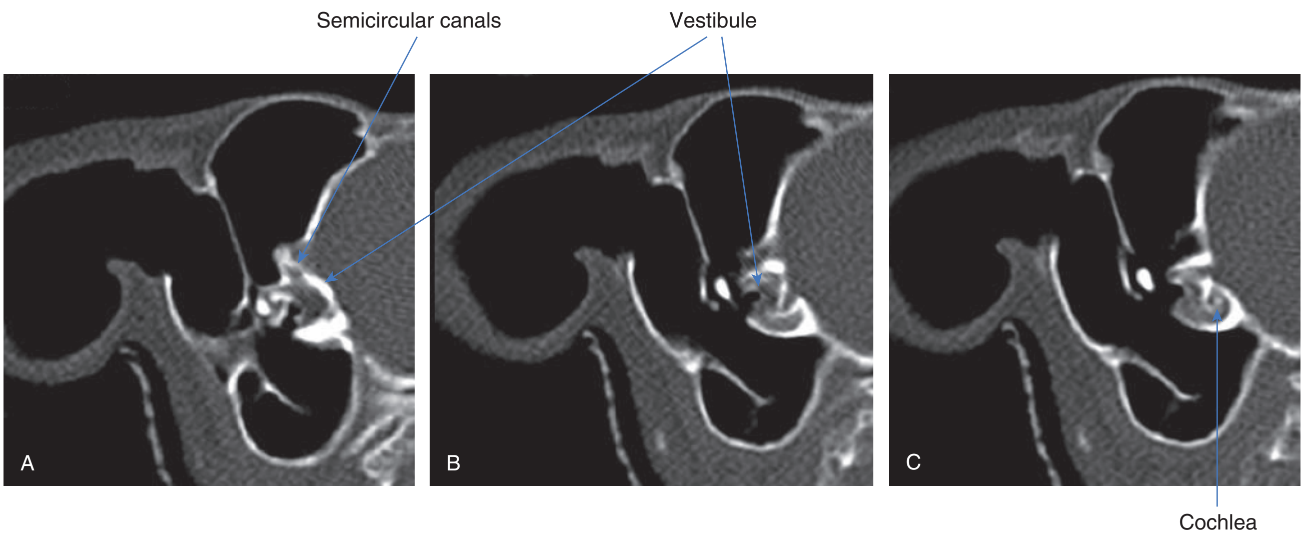

Figure 1.35 CT series of the right inner ear of a chinchilla, moving from caudal to rostral. The semicircular canals (**A**), vestibule (**B**), and cochlea (**C**) are easily detectable on CT in this species. (Courtesy, UTCVM Radiology) © 2012 The University of Tennessee.

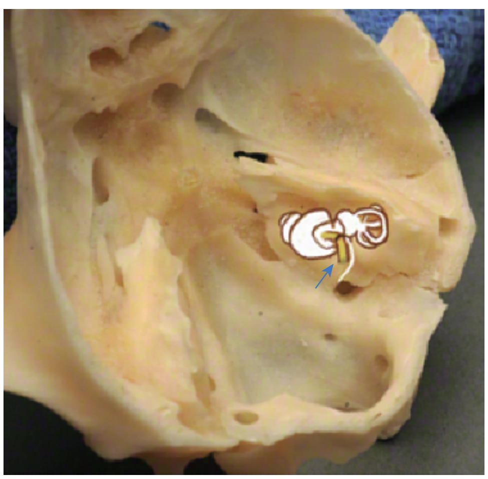

Figure 1.36 The inner ear (diagram) resides in the petrous part of the temporal bone, which is visible from the inside of the skull. The vestibulocochlear nerve (blue arrow) exits the petrous temporal bone via the internal acoustic meatus. (Background photo by Phil Snow, UTCVM) © 2012 The University of Tennessee.

1.4.1 Balance

Dogs and cats have three semicircular ducts that are oriented at right angles to one another. Each semicircular duct terminates in an *ampulla* that contains a ridge or crest called the *crista ampullaris* (Fig. 1.39). This crest is oriented transversely to the course of endolymph flow within the associated semicircular duct. Sensory cells on the crista ampullaris are covered by *cilia*, or hair cells, that are embedded in a gelatinous matrix, or *cupula ampullaris*. This matrix reacts to rotational acceleration as endolymph flows in or out of the associated duct. The resulting movements of the cilia stimulate action potentials that are carried by the vestibular nerve to the brain. Within the utriculus and sacculus are sensory fields called *macula* that are oriented in horizontal and vertical planes, respectively. Macular sensory cells are also covered with cilia that react to linear acceleration and deceleration in different directions and are responsible for the sensation of static head position.

1.4.2 Hearing

The cochlea is the primary organ involved in translation of sound waves to nerve impulses (Fig. 1.40). The cochlea spirals from dorsal to ventral around a hollow core – the *modiolus* – that contains the cochlear nerve. A shelf (*spiral lamina*) projecting from the modiolus serves as the inner attachment site to the cochlear duct, which extends all the way to the bony outer wall. The spiral lamina and cochlear duct divide the cochlea into two perilymph-filled chambers: the *scala vestibuli* and the *scala tympani* (Fig. 1.41). The foramen connecting the scala tympani and scala vestibuli at the apex or *cupulla cochleae* of the spiral is called the *helicotrema*. The cochlear (round) window is found at the end of the scala tympani, while the vestibular (oval) window is found at the vestibule near the beginning of the scala vestibuli.

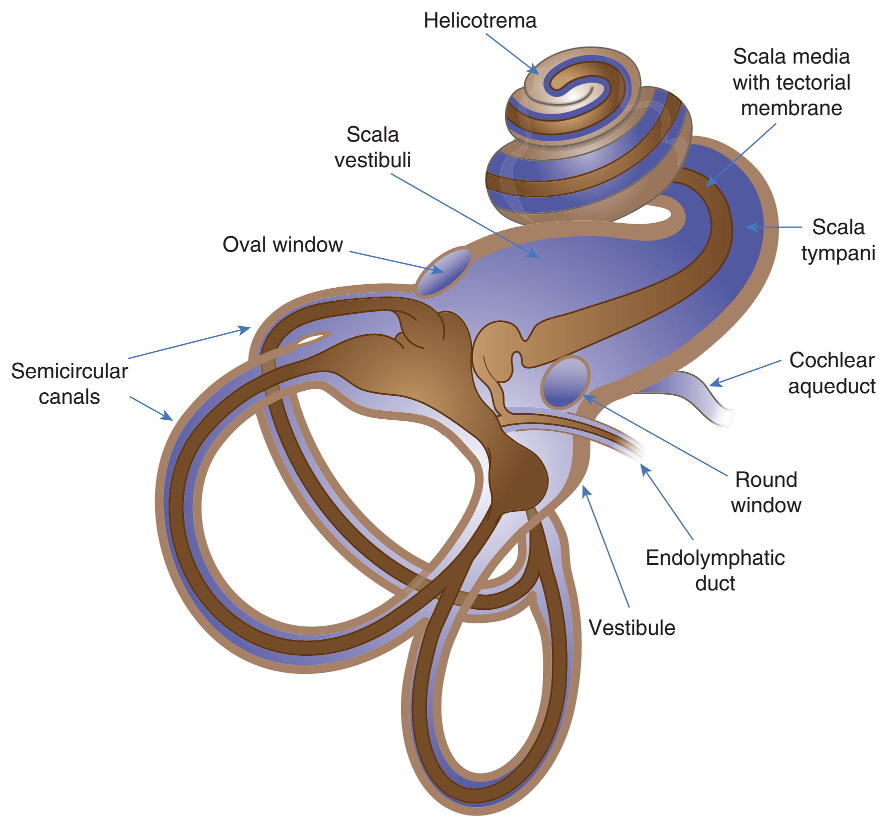

Figure 1.37 The membranous labyrinth, which contains the endolymph (brown), is surrounded by perilymph (blue), which is contained within the bony labyrinth and is continuous with cerebral spinal fluid via the cochlear aqueduct. Vibrations in perilymph propagate up the scala vestibuli to the helicotrema and back down the scala tympani. A, ampulla; S, sacculus; U, utriculus.

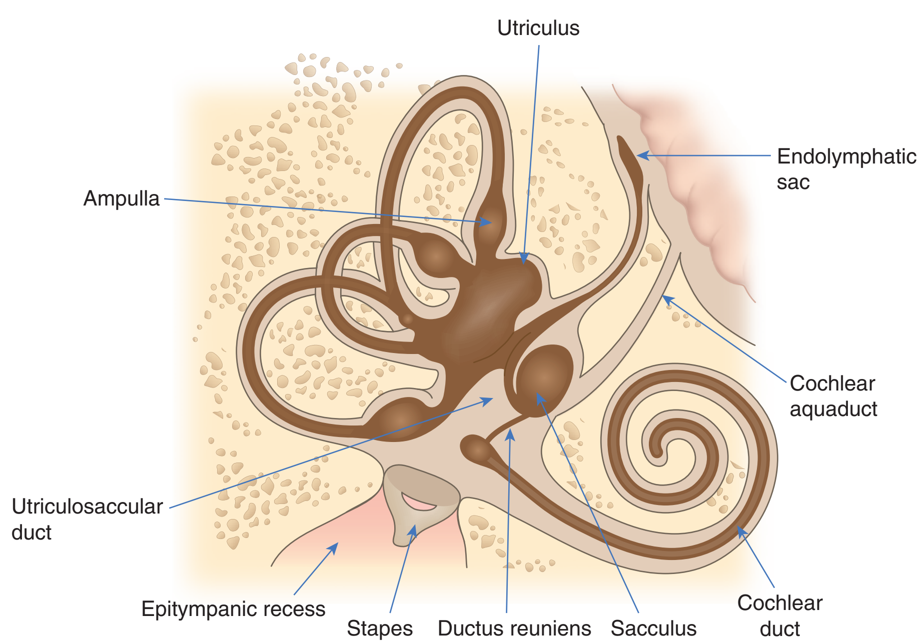

Figure 1.38 Endolymph (brown) flows into the endolymphatic sac, which lies along the meninges.

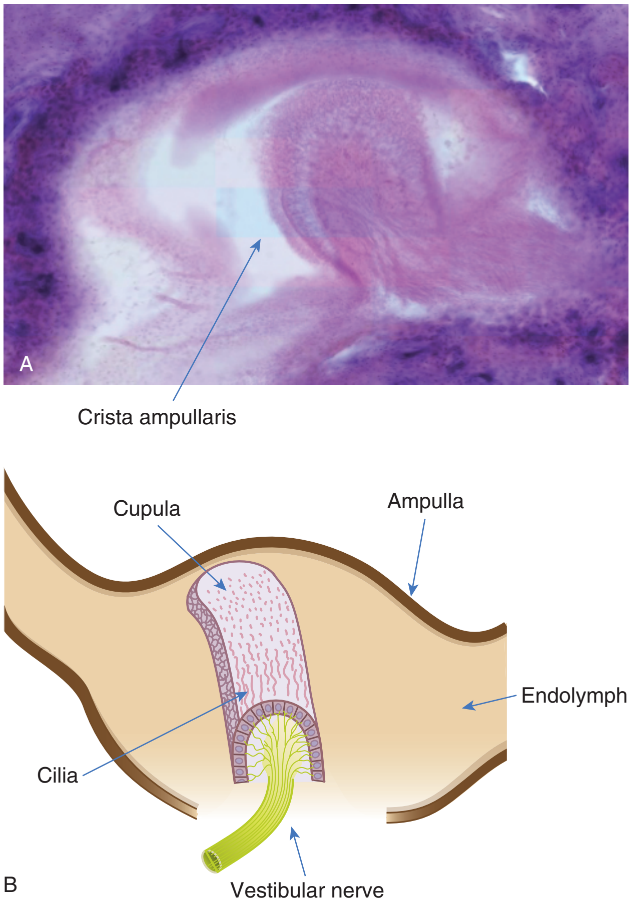

Figure 1.39 The crista ampullaris (**A**) consists of sensory cells covered by cilia that are embedded in a cupula of loose gelatinous tissue (**B**). Bending of the cupula ampullaris secondary to endolymph flow stimulates formation of action potentials that are carried by the vestibular nerve to the brain. (Specimen photo courtesy, UTCVM Virtual Microscope) © 2012 The University of Tennessee.

The endolymph-filled chamber within the cochlear duct is called the *scala media* (Fig. 1.42). The floor of the scala media is formed by the *basilar membrane*, and the ceiling is formed by *Reissner's membrane*. The wall along the outside curve of the cochlear duct is formed by the *spiral ligament*, a thickened segment of periosteum. A portion of the spiral ligament, the *stria vascularis*, contains numerous capillary loops and produces endolymph for the scala media.

The *organ of Corti* (Fig. 1.43) is a layer of specialized, thickened epithelium that spirals along the basilar membrane of the scala media. Sensory hair cells (*stereocilia*) of

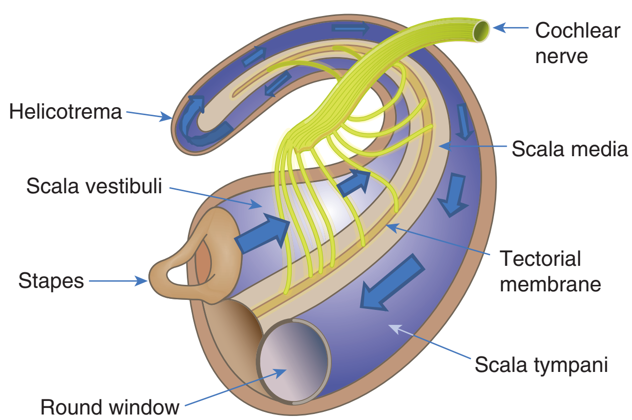

Figure 1.41 Schematic of cochlea, unrolled. Fluid waves travel up the scala vestibuli and down the scala tympani, reaching the round window, which provides a dampening effect. The waves vibrate the endolymph in the scala media. In turn, the tectorial membrane vibrates along hair cells, stimulating nerve impulses that are transmitted by the cochlear nerve to the brain.

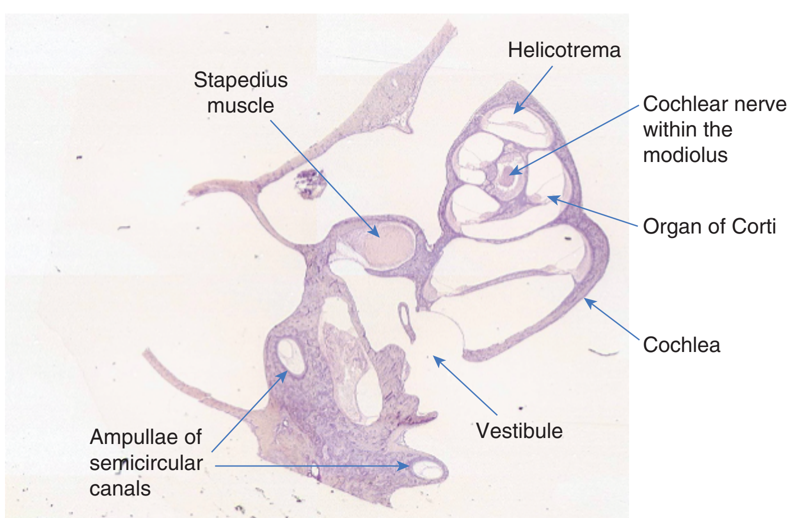

Figure 1.40 Cross-section of the inner ear of a rat showing the relationship of the cochlea, vestibule, and semicircular canals. (Courtesy, UTCVM Virtual Microscope) © 2012 The University of Tennessee.

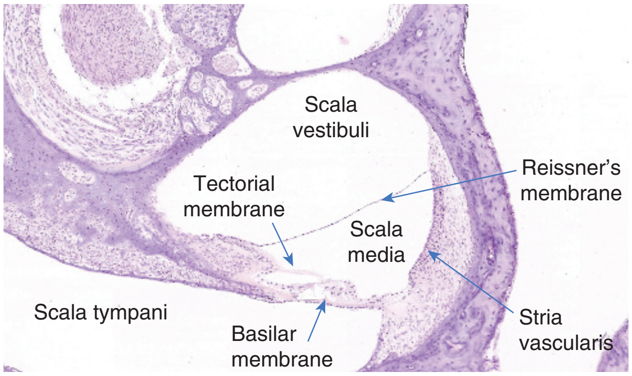

Figure 1.42 The organ of Corti, which is the sensory organ for hearing, lies along the basilar membrane. (Courtesy, UTCVM Virtual Microscope) © 2012 The University of Tennessee.

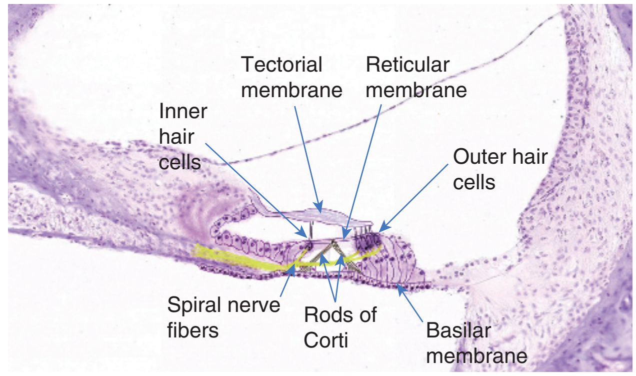

Figure 1.43 The organ of Corti consists of the tectorial membrane, hair cells, and support cells. Oscillations of the basilar membrane result in shearing forces between the stereocilia and tectorial membrane. Subsequent depolarization of the hair cells sends nerve impulses via cochlear nerve fibres to the brain.

the organ of Corti are innervated by cochlear nerve endings. The *tectorial membrane*, a leaf-like structure, lies over the stereocilia. The reticular membrane along the apex of the stereocilia is supported by the *rods of Corti.*

Sound waves collected by the pinna and external ear cause vibration of the tympanic membrane. These vibrations are transmitted via the ossicles through the vestibular (oval) window and into the scala vestibuli. Sound waves propagating through the scala vestibuli are transmitted by the intervening Reissner's membrane to the endolymph of the scala media. In turn, the tectorial membrane vibrates, touching the stereocilia. As the stereocilia bend they depolarize, initiating nerve impulses that are carried by the cochlear nerve to the brain.