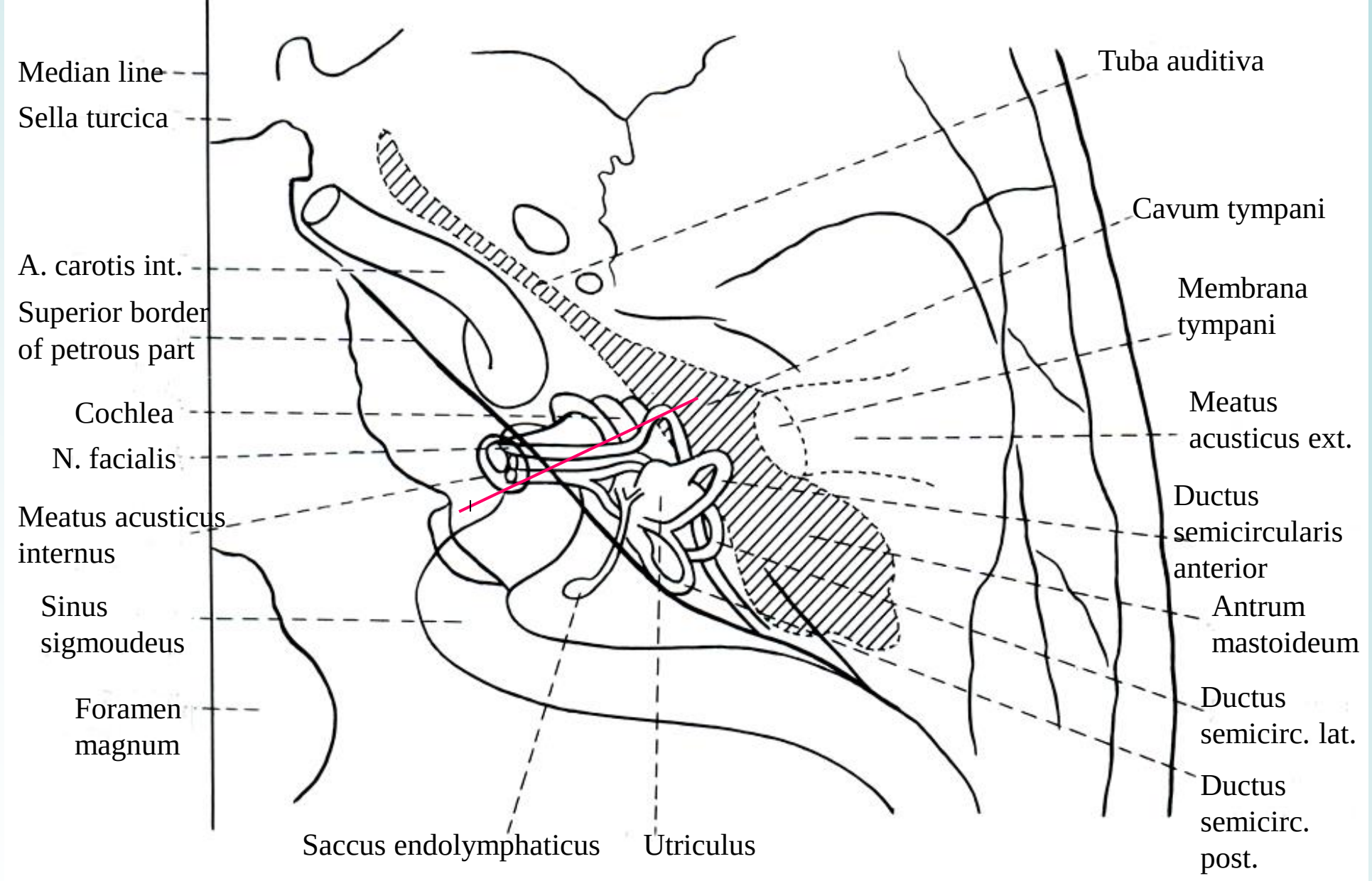
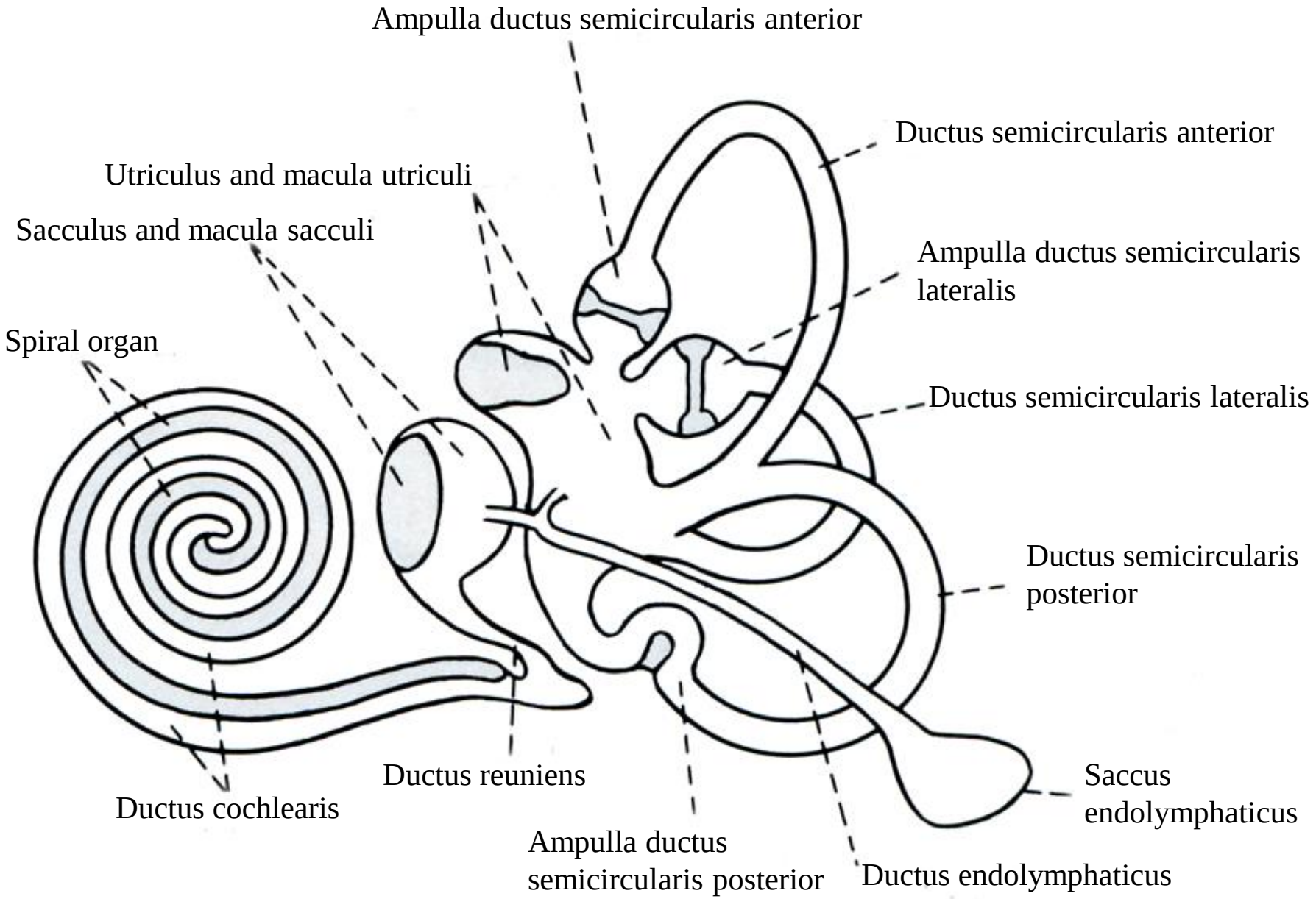
20-00
The Ear
(Vestibulo-acoustic Organs)

20 The Ear (Vestibulo-acoustic Organs) Menu

20-00. The Ear(Vestibulo-acoustic Organs)
20-01. Location of vestibulo-acoustic organs in the temporal bone (Scheme)
20-02. Scheme showing the structure of membranous labyrinth.
20-001. Cochlea, and External and Middle Ear
20-03. Cochlea, vertical section, 1. Monkey, Held' s hematoxylin stain, x 4.
20-04. Cochlea, vertical section, 2. Monkey, Held' s hematoxylin stain, x 10.
20-05. Cochlear canal, vertical section, 3. Monkey. Held's hematoxylin stain, x 25.
20-06. Cochlear duct and organ of Corti 1. Monkey, Held's hematoxylin stain, x 64.
20-07. Cochlear duct and organ of Corti 2. Monkey, H-E stain, x 50.
20-08. Cochlear duct and organ of Corti 3. Monkey, H-E stain, x 64.
20-09. Organ of Corti. Monkey, H-E stain, x 100.
20-10. Scheme showing the structure of organ of Corti
20-11. Reticular membrane (Scheme)
20-12. Spiral ganglion. Monkey, Held's hematoxylin stain, x 160.
20-13. Stria vascularis. Monkey, H-E stain, x 100.
20-14. Tympanic membrane 1. Monkey, H-E stain, x 64.
20-15. Tympanic membrane 2. Monkey, H-E stain, x 160.
20-16. External acoustic meatus. Monkey, H-E stain, x 2.5.
20-002. Vestibular Organs
20-17. Vestivulum 1. Sacculus and ampulla posterior. Monkey, H-E stain, x 5.0.
20-18. Vestibulum 2. Stapes and utriculus 1. Monkey, H-E stain, x 5.0.
20-19. Vestibulum 3. Stapes and utriculus 2. Monkey, H-E stain, x 5.0.
20-20. Vestibulum 4. Macula utriculi and crista ampullaris posterior. Monkey, H-E stain, x 5.0.
20-21. Vestibulum 5. Crista ampullaris anterior and crista amp. lateralis. Monkey, H-E stain, x 5.0.
20-22. Crista ampullaris 1. Monkey, H-E stain, x 13.2.
20-23. Crista ampullaris 2. Monkey, H-E stain, x 50.
20-24. Macula utriculi 1. Monkey, H-E stain, x 33.
20-25. Macula utriculi 2. Monkey, H-E stain, x 100.
20-003. Horizontal Sections of Human Temporal Bone
20-26. Horizontal section of human temporal bone 1. H-E stain, x 1.0.
20-27. Horizontal section of human temporal bone 2. H-E stain, x 1.0.
20-28. Horizontal section of human temporal bone 3. H-E stain, x 1.0.
20-29. Horizontal section of human temporal bone 4. H-E stain, x 1.8.

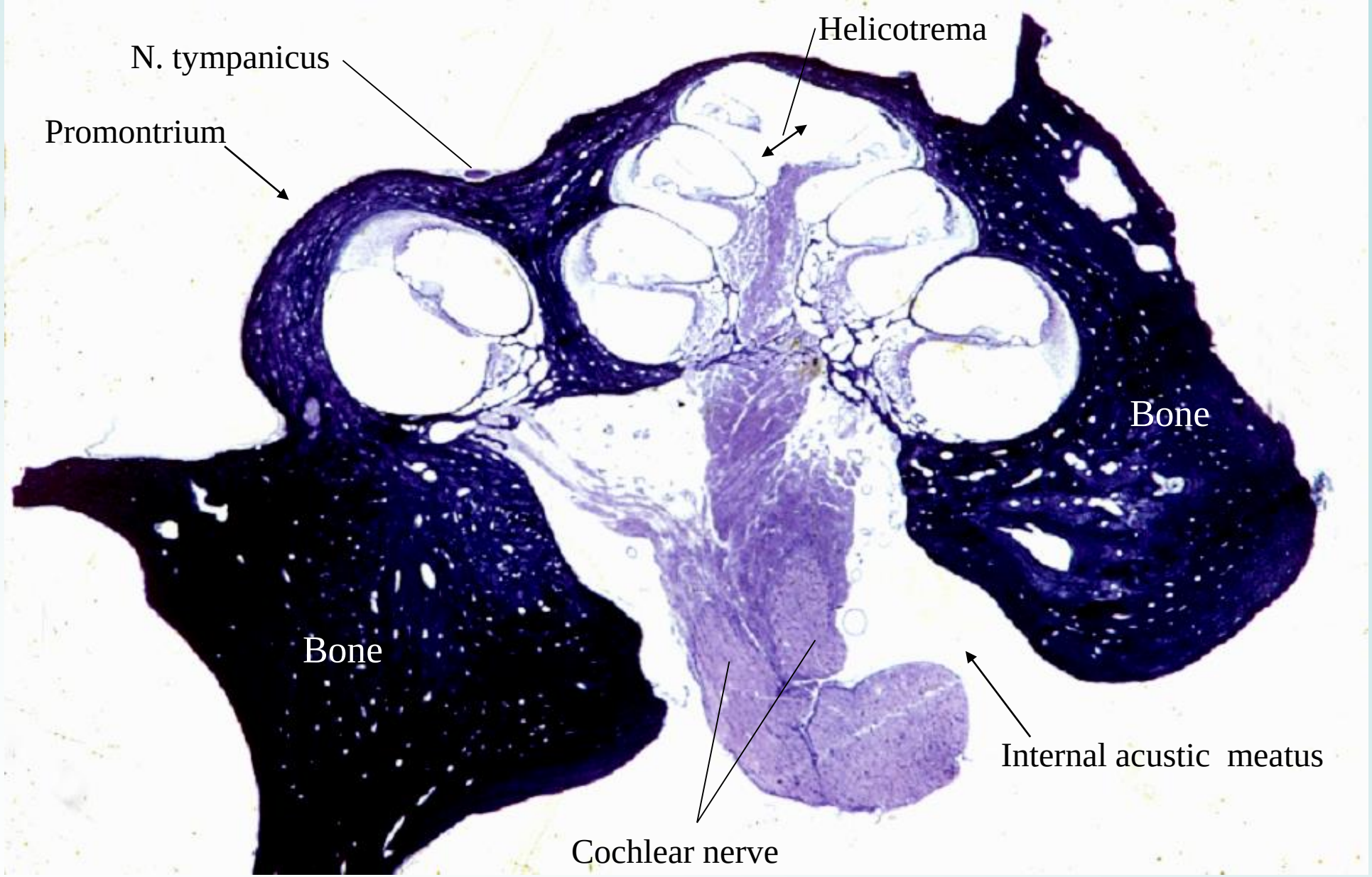


20-01 Location of vestibulo-acoustic organs in the temporal bone（Scheme）

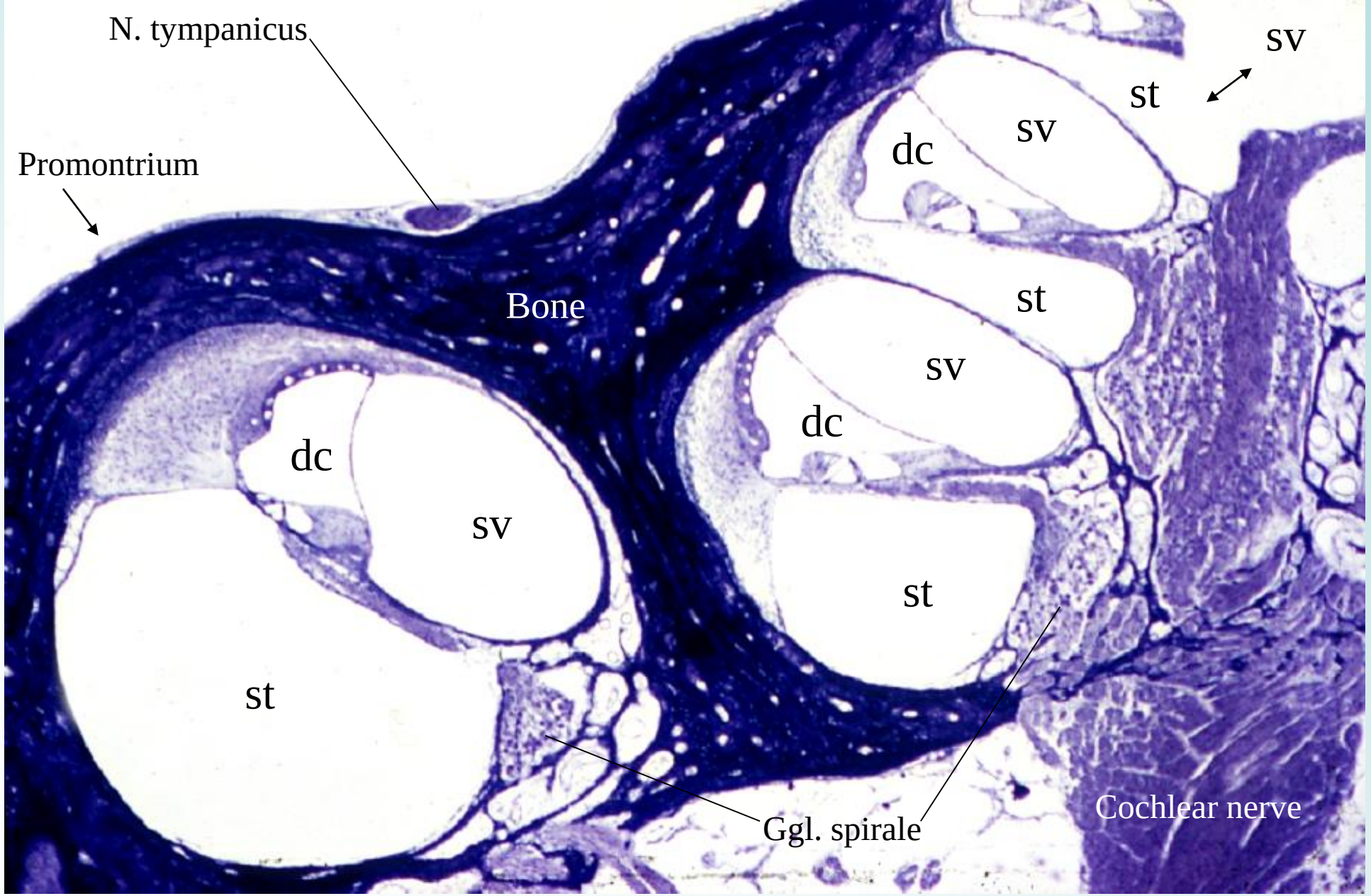


20-02 Scheme showing the structure of membranous labyrinth.

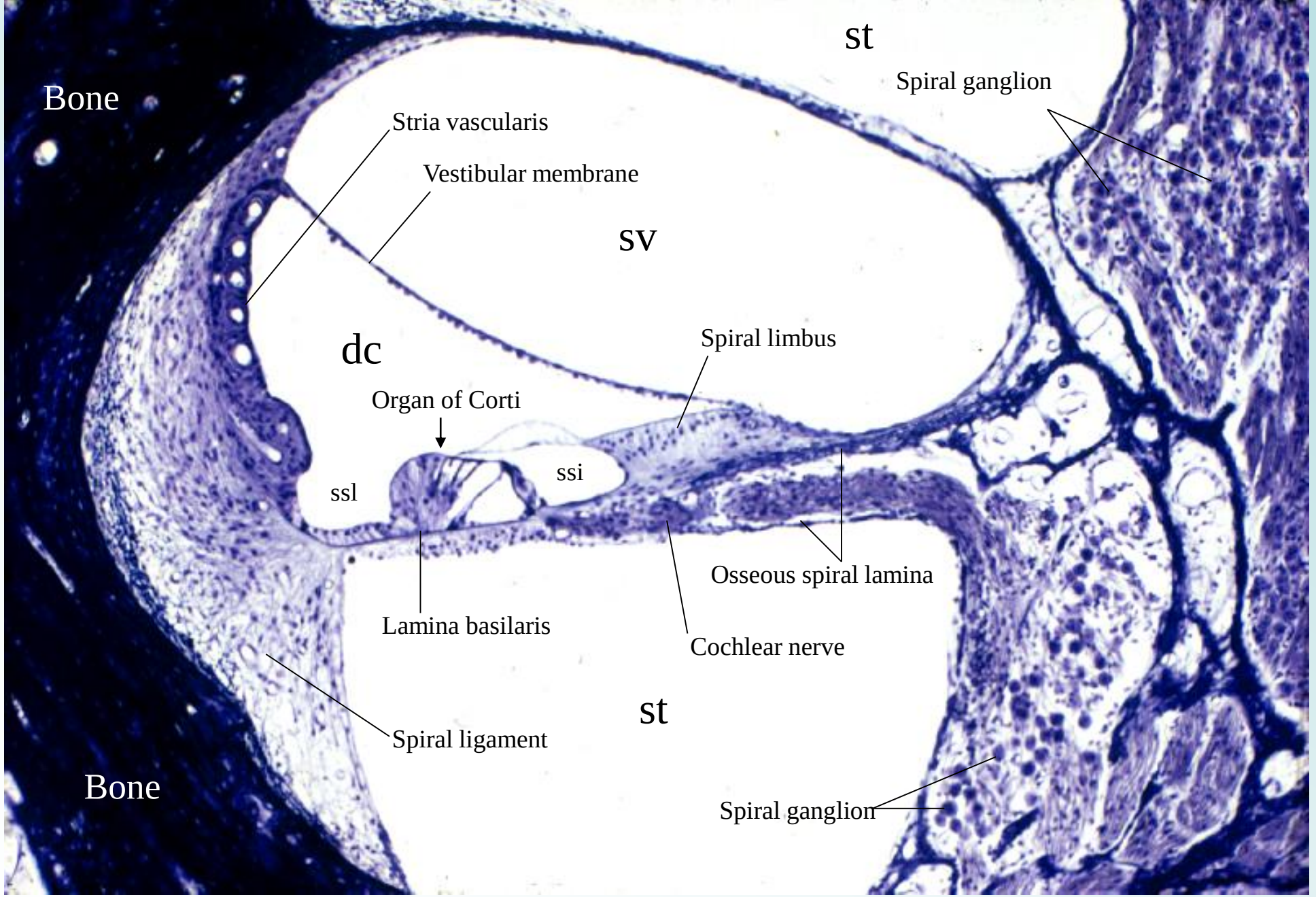
20-001 Cochlea,and External and Middle Ear



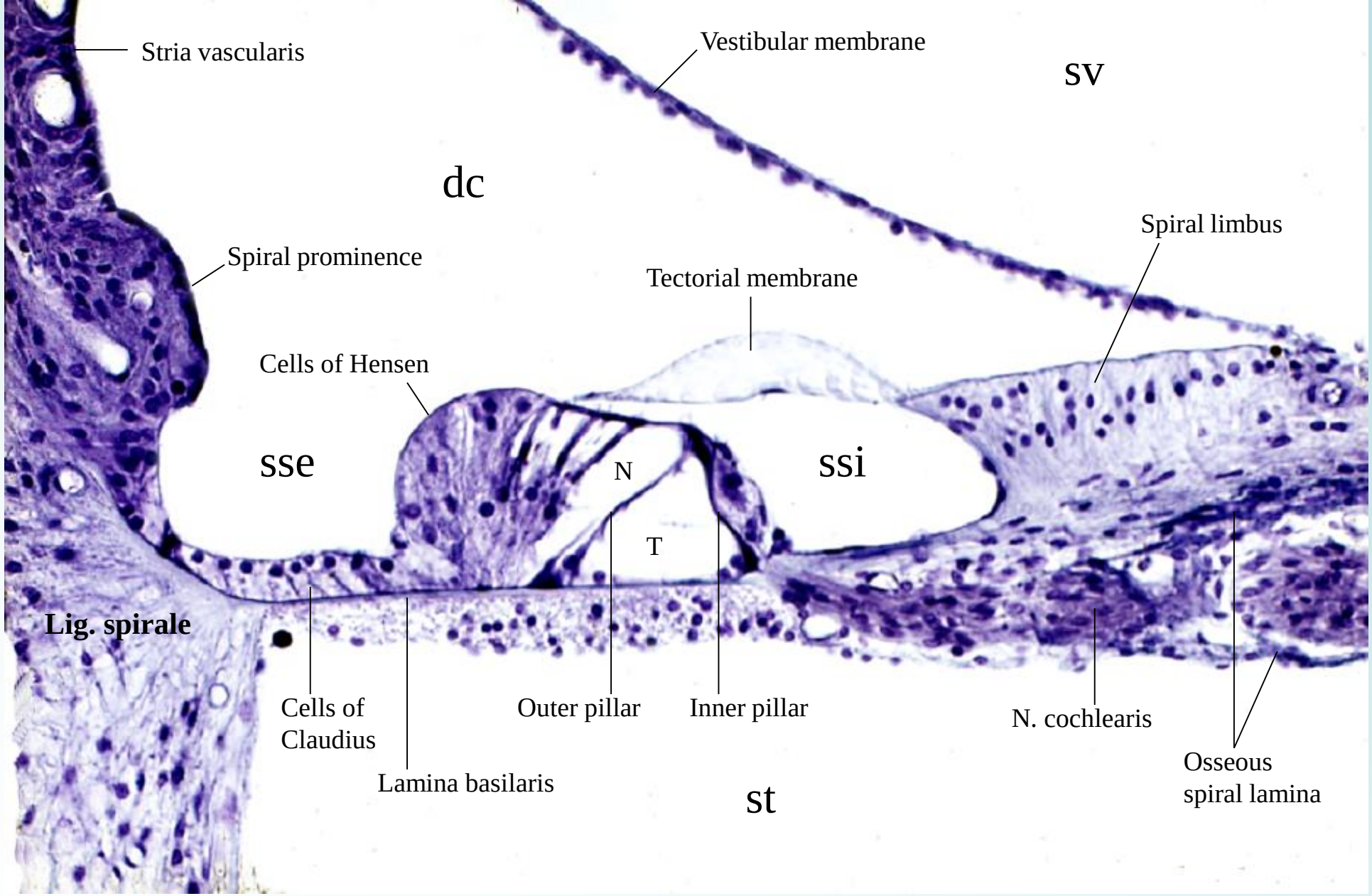
20-03 Cochlea, vertical section, 1. Monkey, Held's hematoxylin stain, x 4.



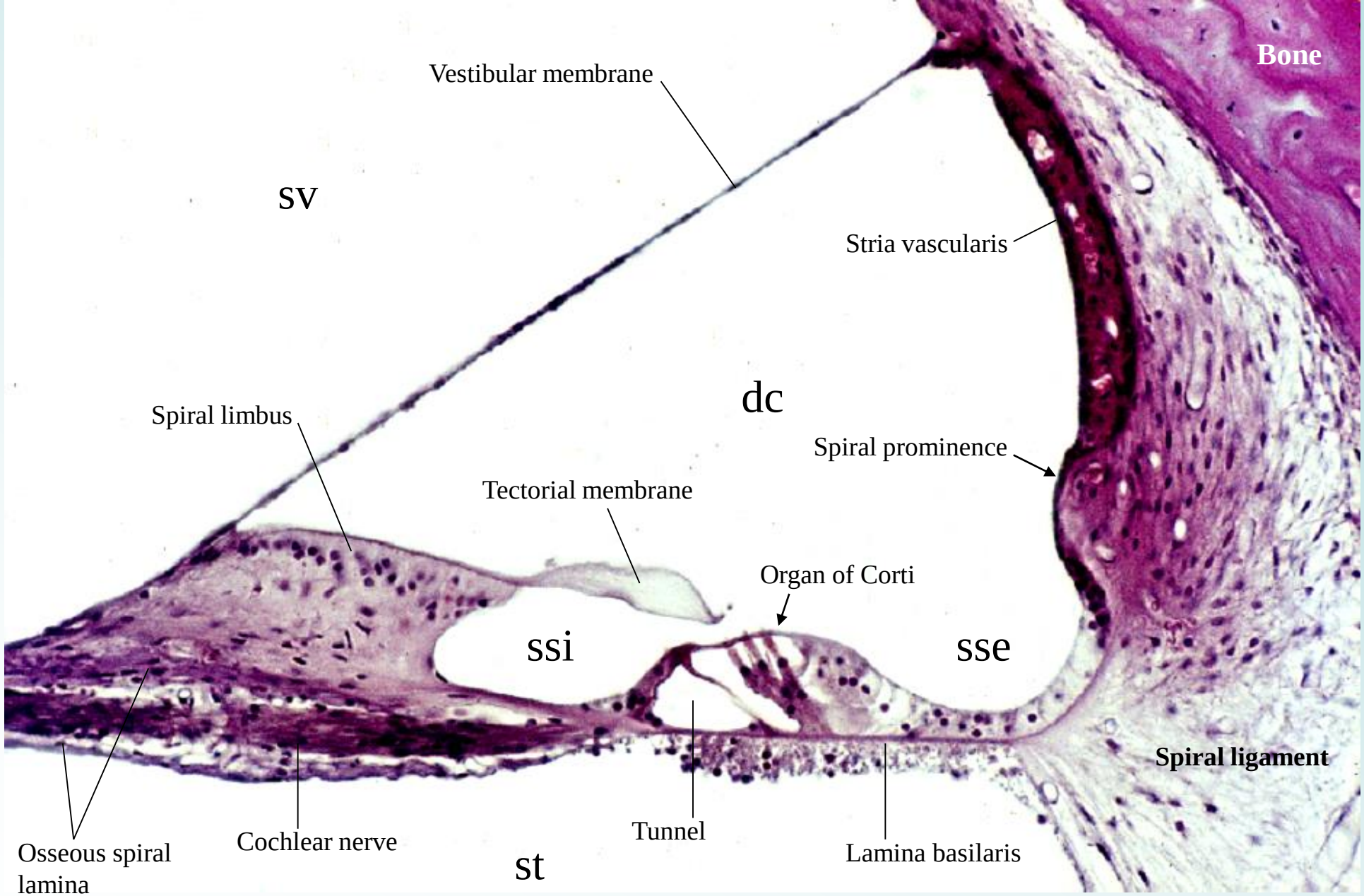
20-04 Cochlea, vertical section, 2. Monkey, Held's hematoxylin stain, x 10.



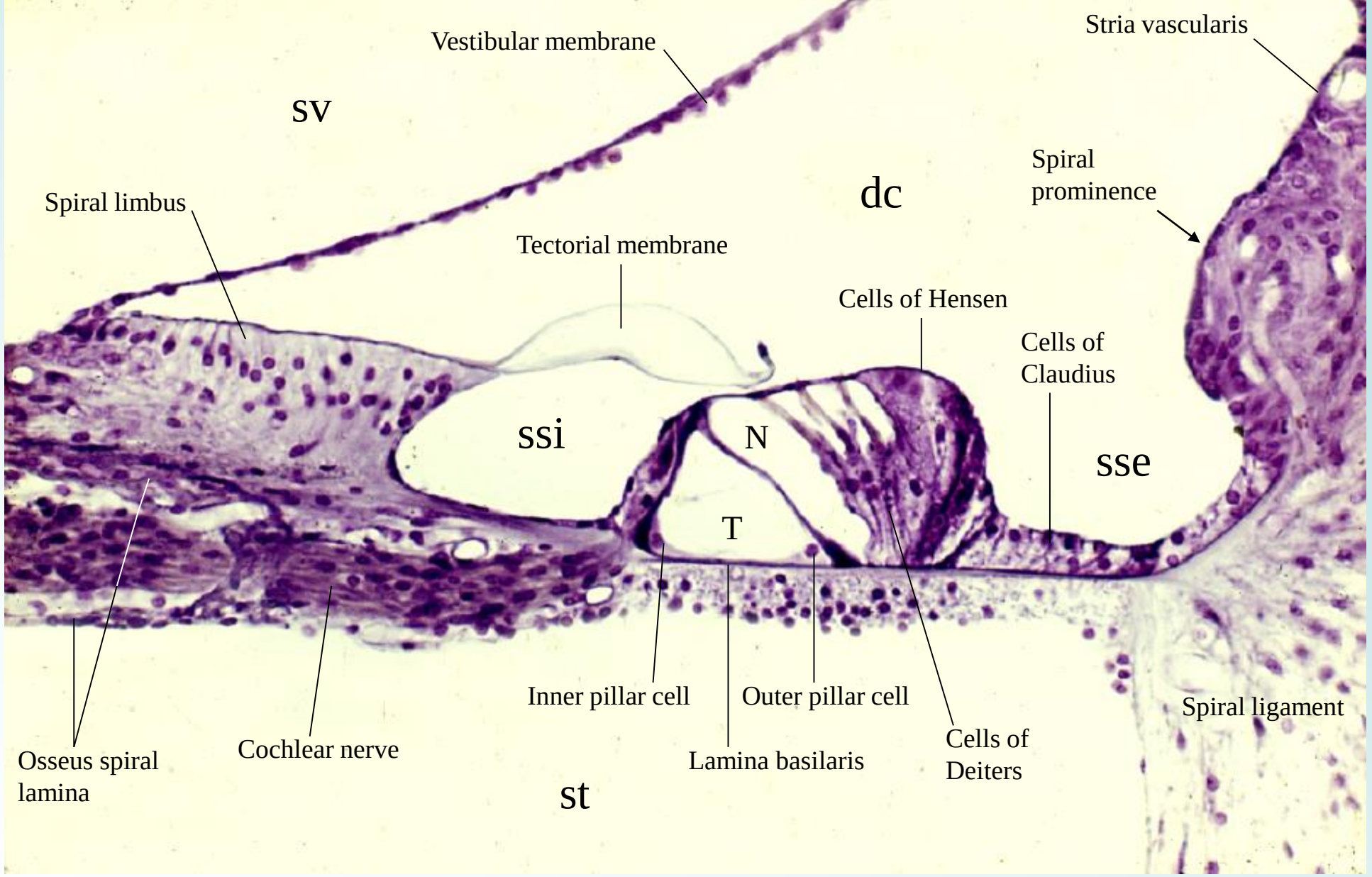
20-05 Cochlear canal, vertical section, 3. Monkey. Held's hematoxylin stain, x 25.



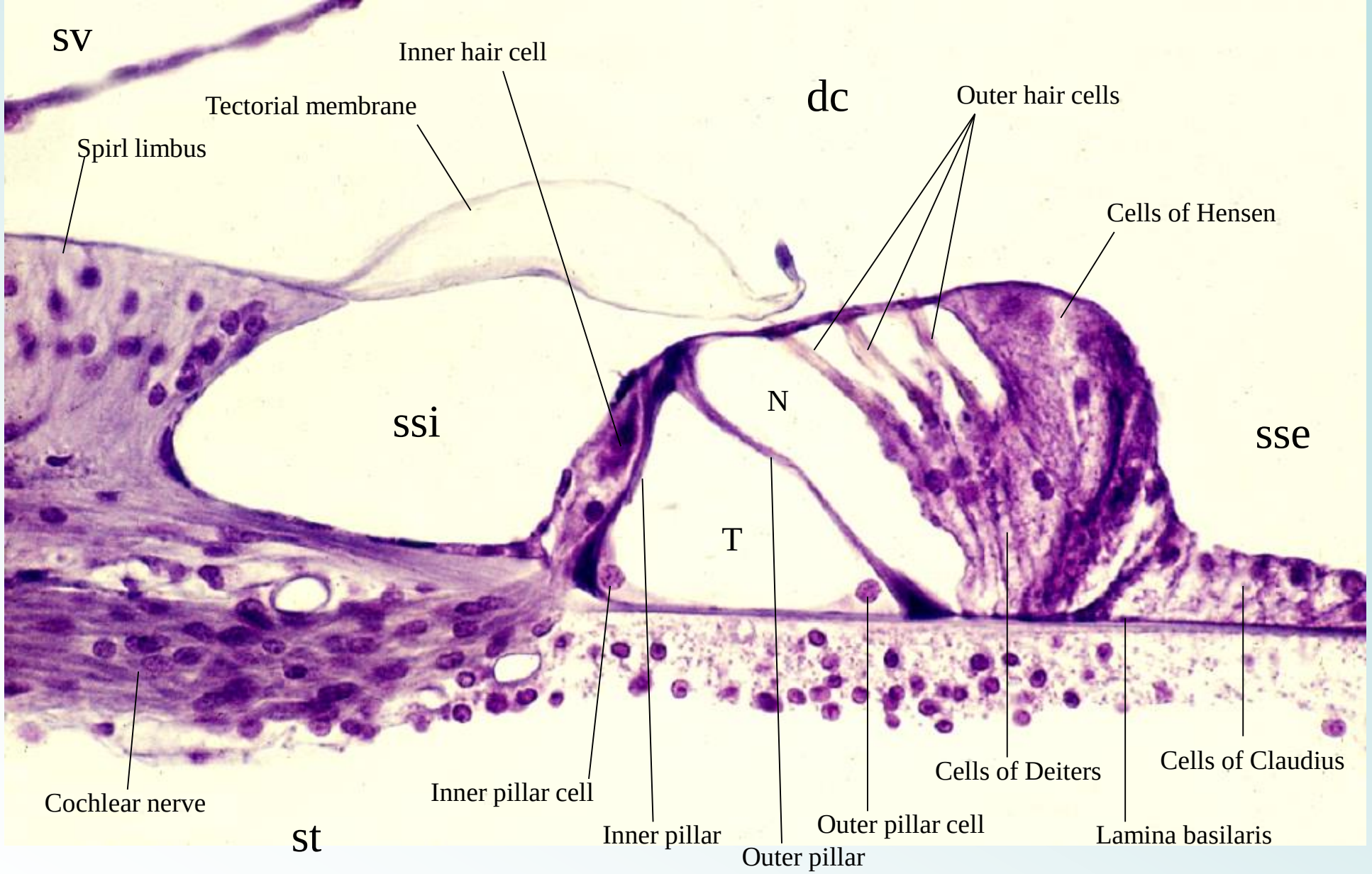
20-06 Cochlear duct and organ of Corti 1. Monkey, Held's hematoxylin stain, x 64.



20-07 Cochlear duct and organ of Corti 2. Monkey, H-E stain, x 50.

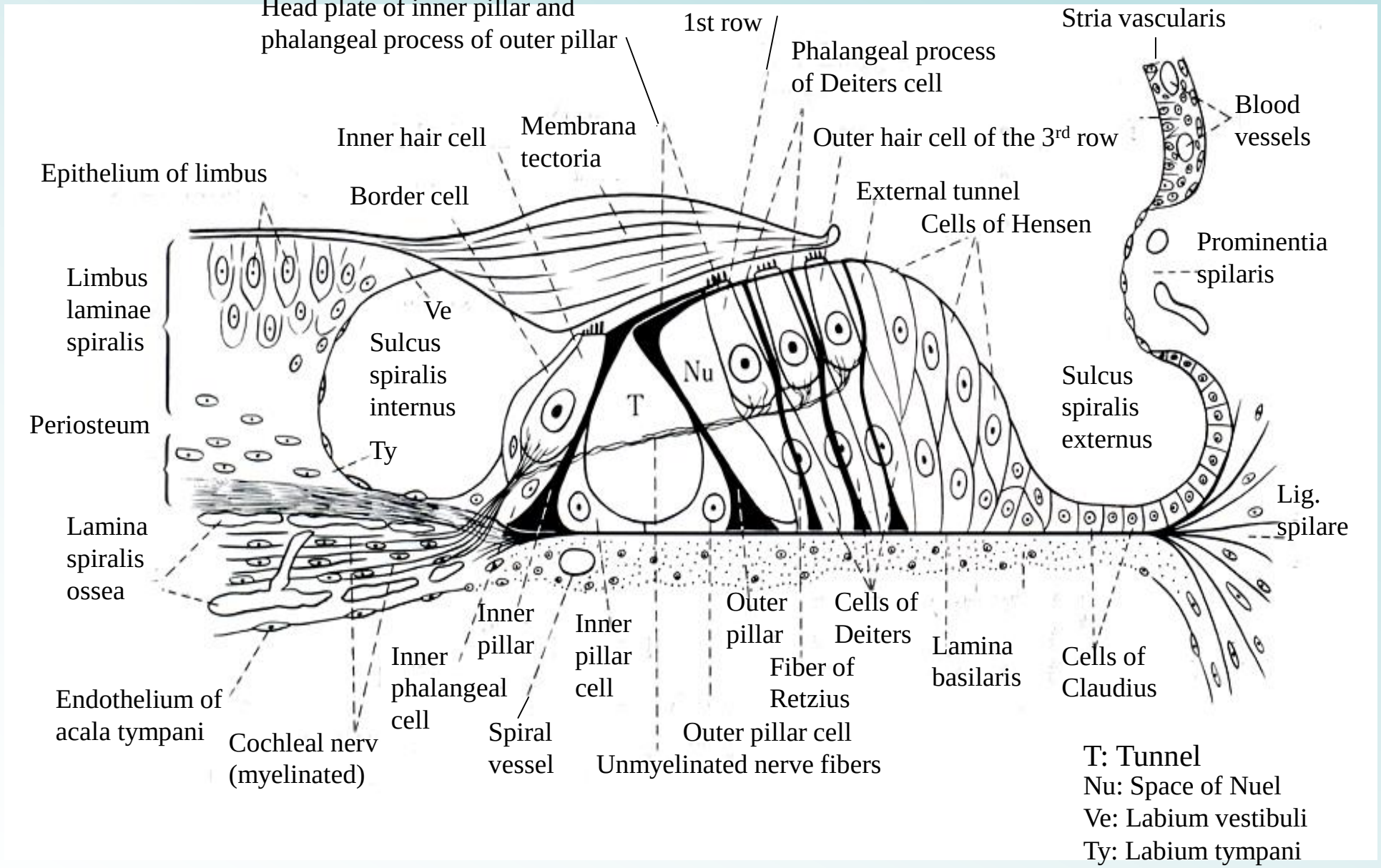


20-08 Cochlear duct and organ of Corti 3. Monkey, H-E stain, x 64.

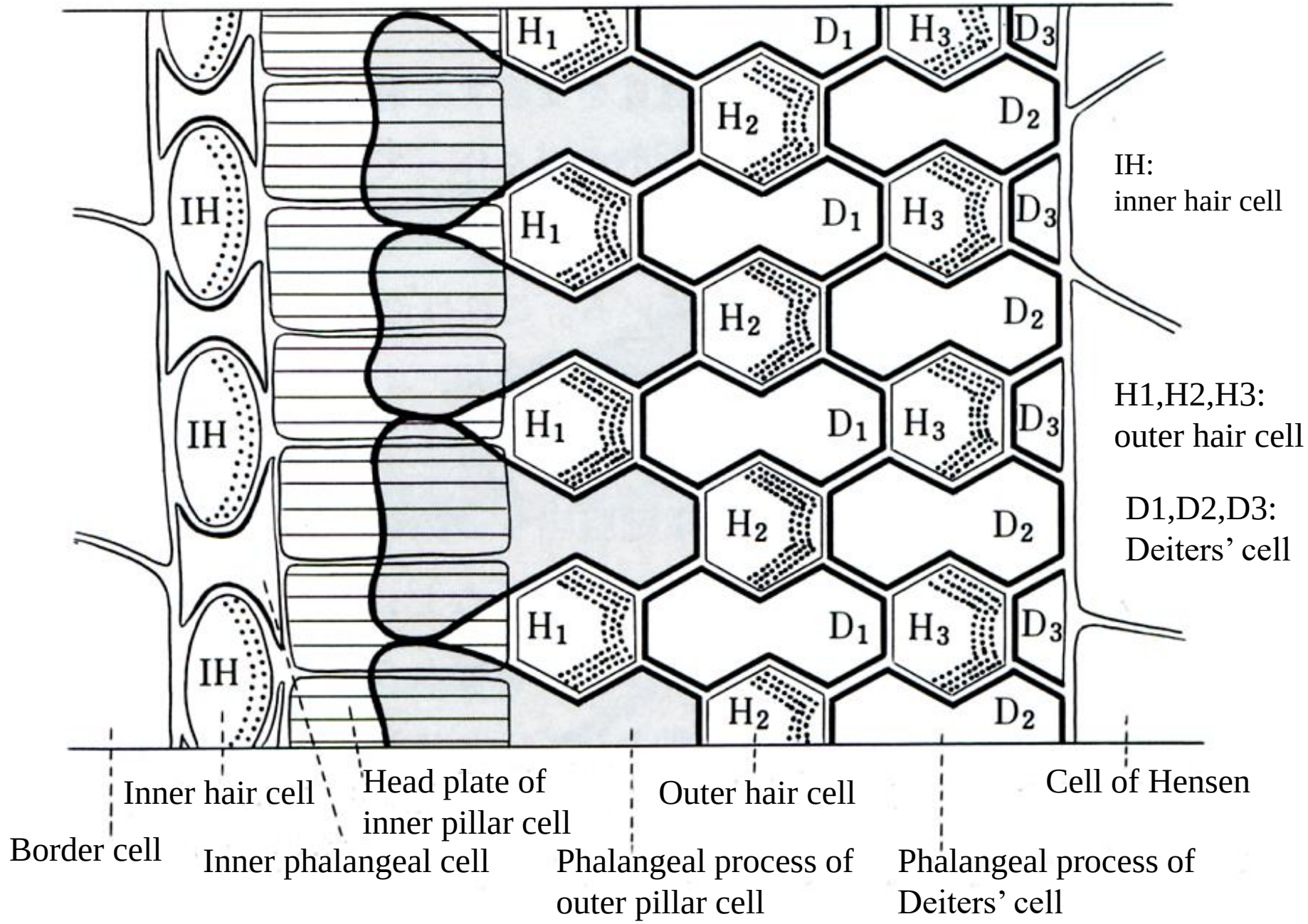


T: Tunnel
N: Space of Nuel

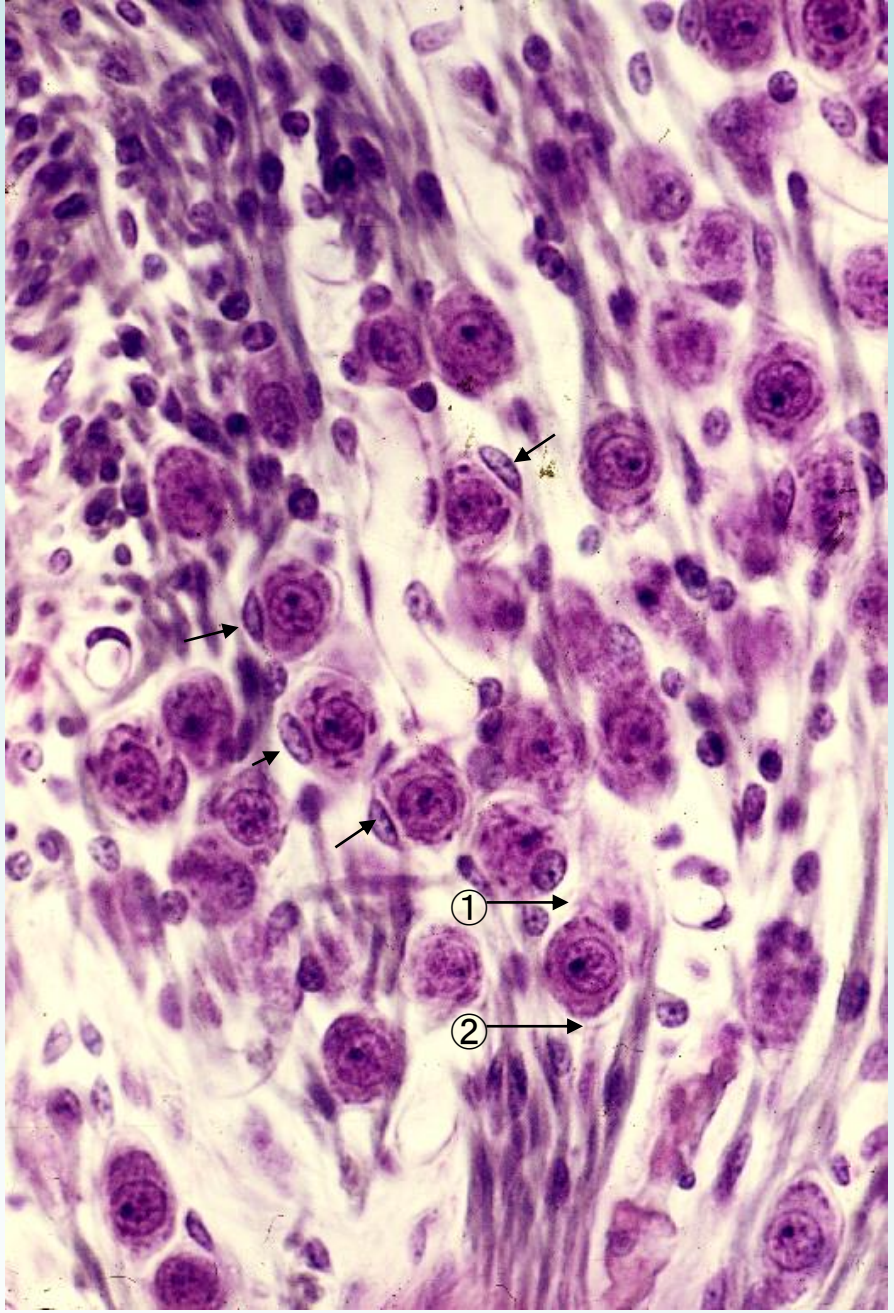
20-09 Organ of Corti. Monkey, H-E stain, x 100.



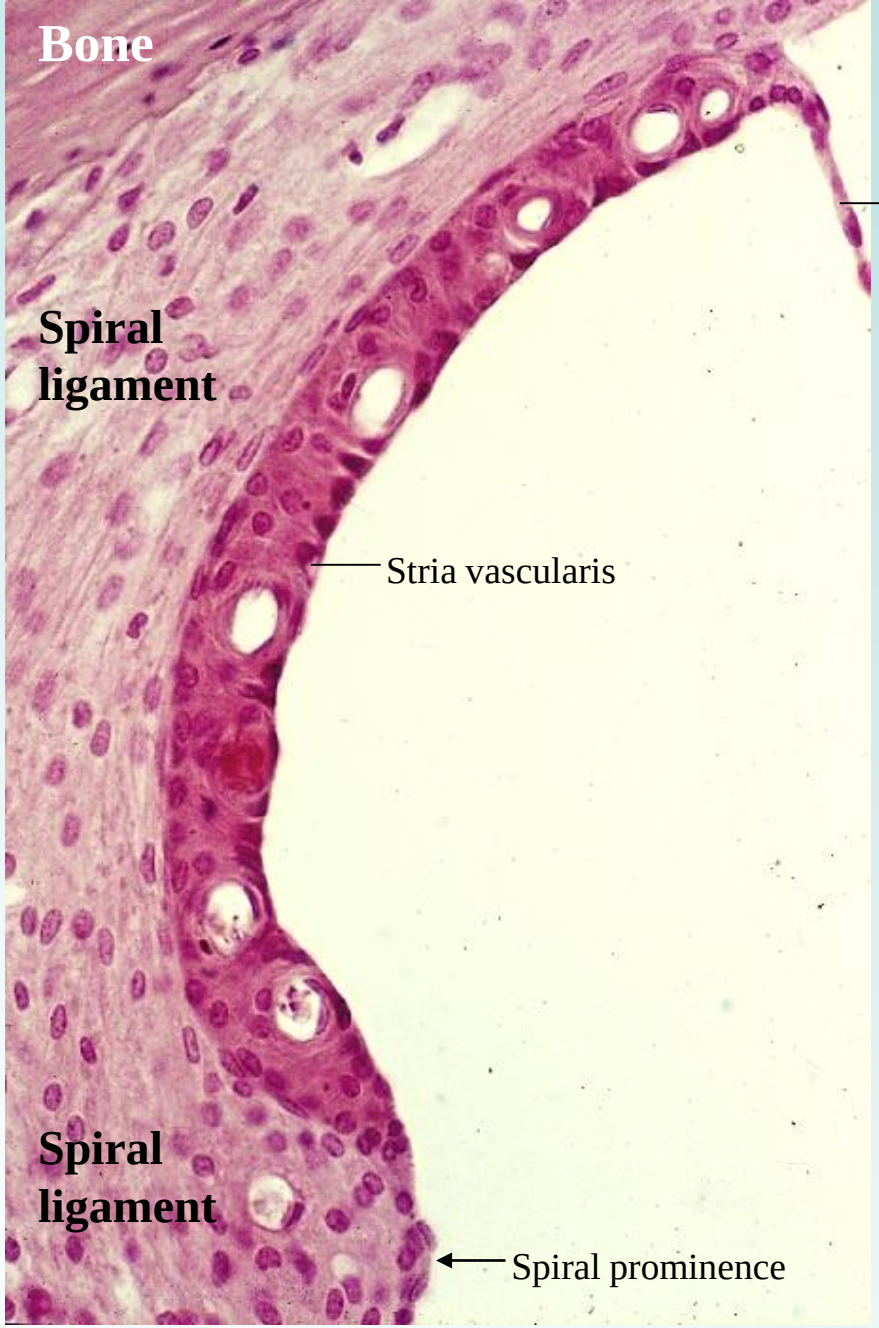
20-10 Scheme showing the structure of organ of Corti



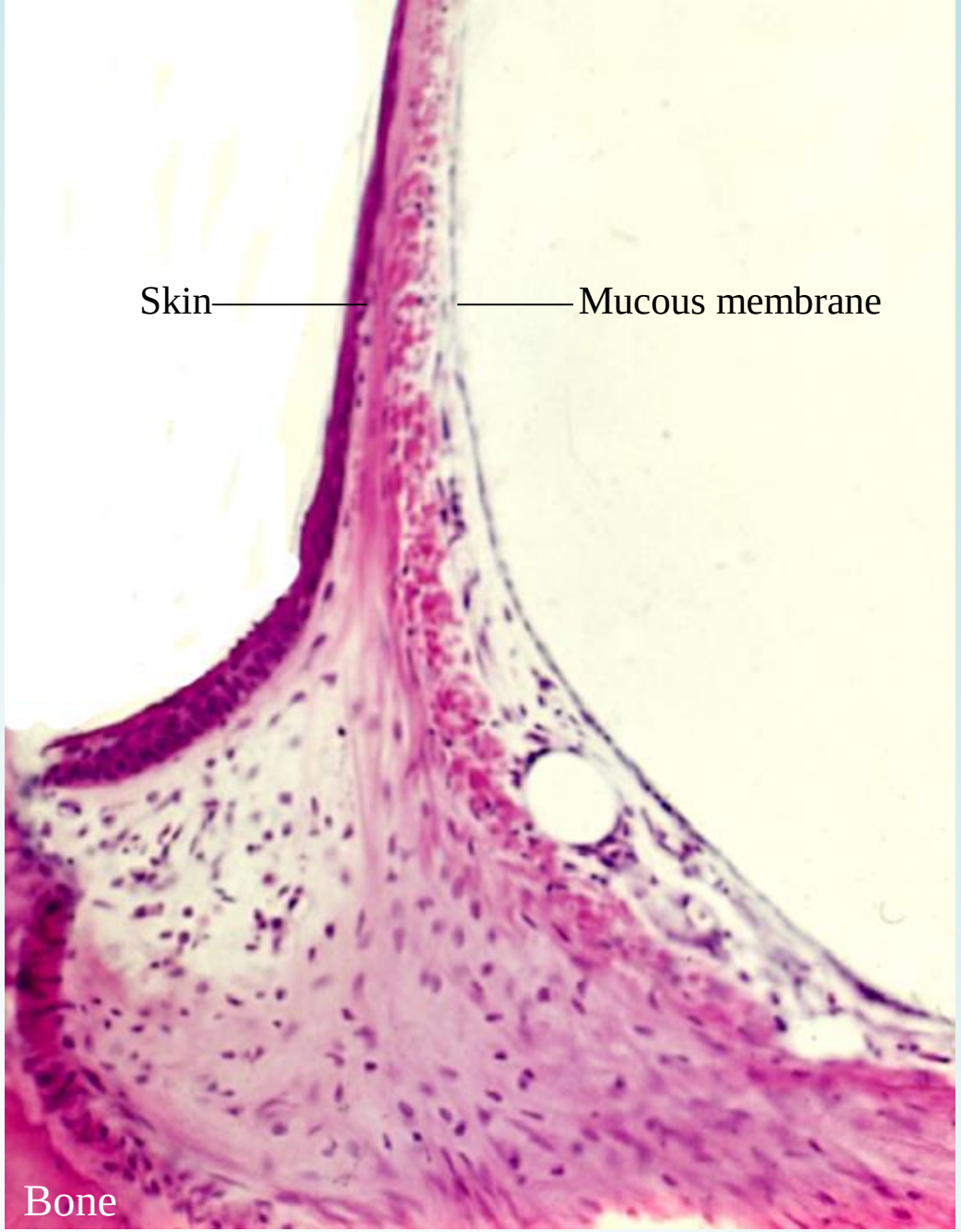
20-11 Reticular membrane（Scheme）



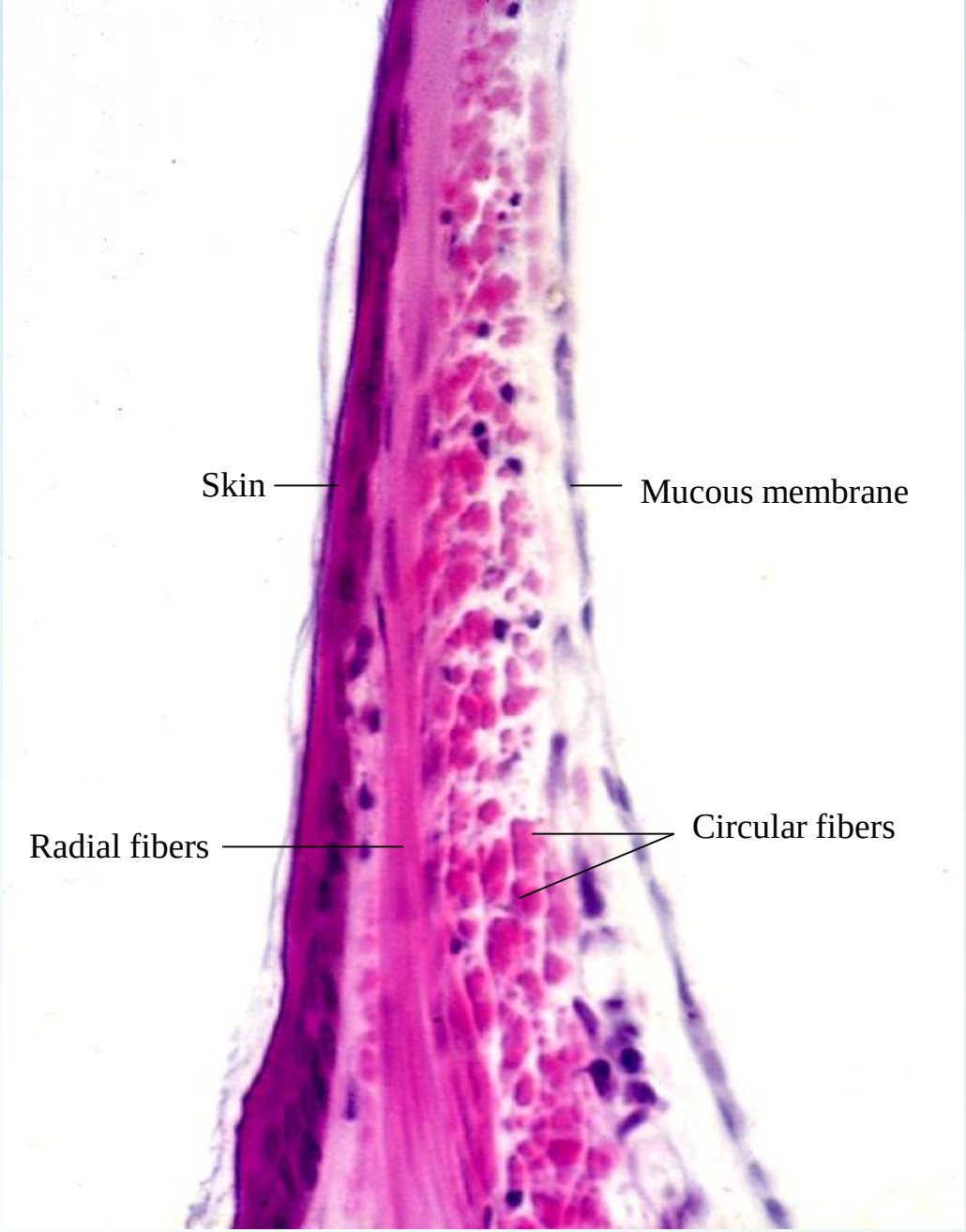
20-12 Spiral ganglion. Monkey, Held's hematoxylin stain, x 160.



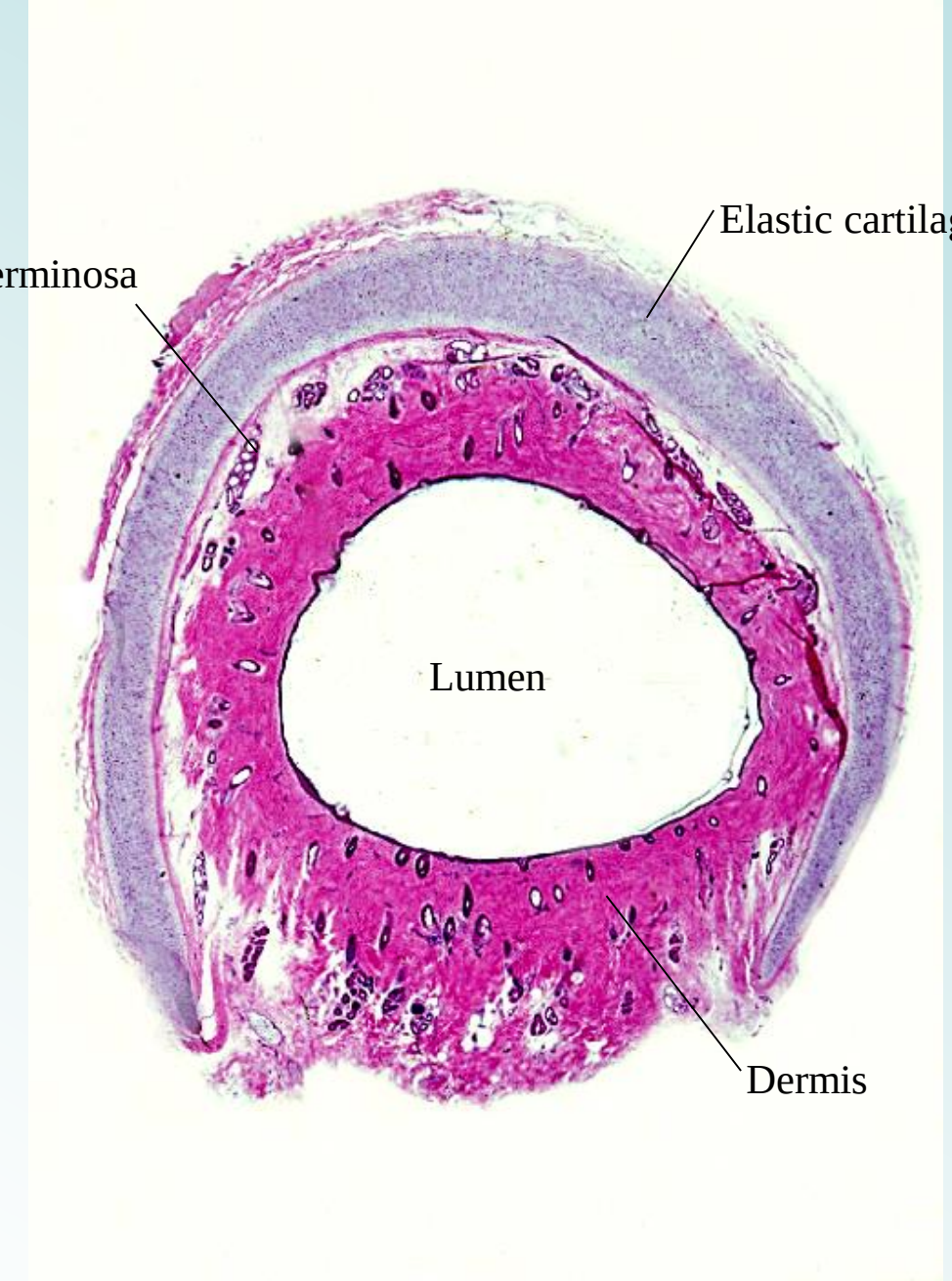
20-13 Stria vascularis. Monkey, H-E stain, x 100.



20-14 Tympanic membrane 1. Monkey, H-E stain, x 64.

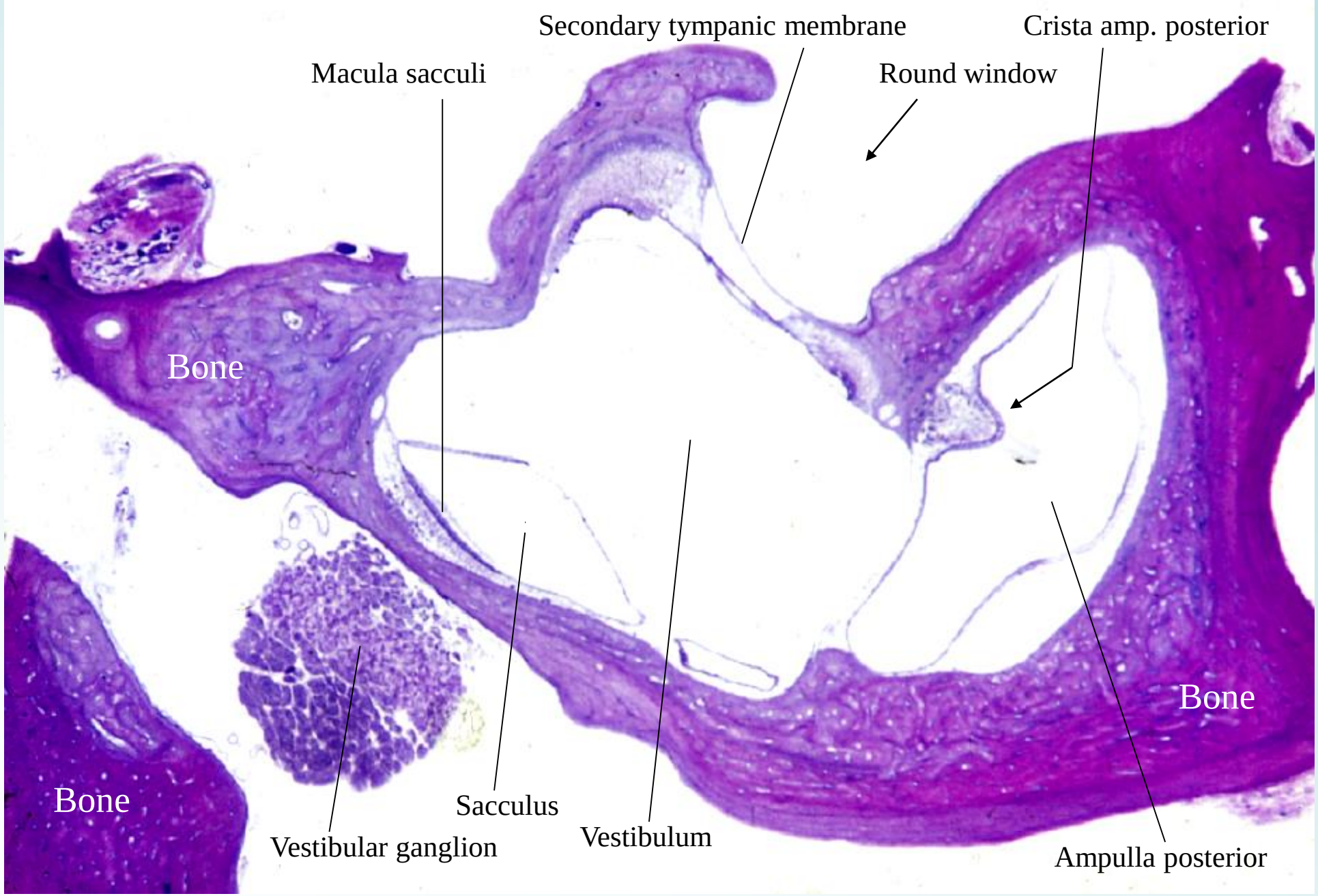


20-15 Tympanic membrane 2. Monkey, H-E stain, x 160.

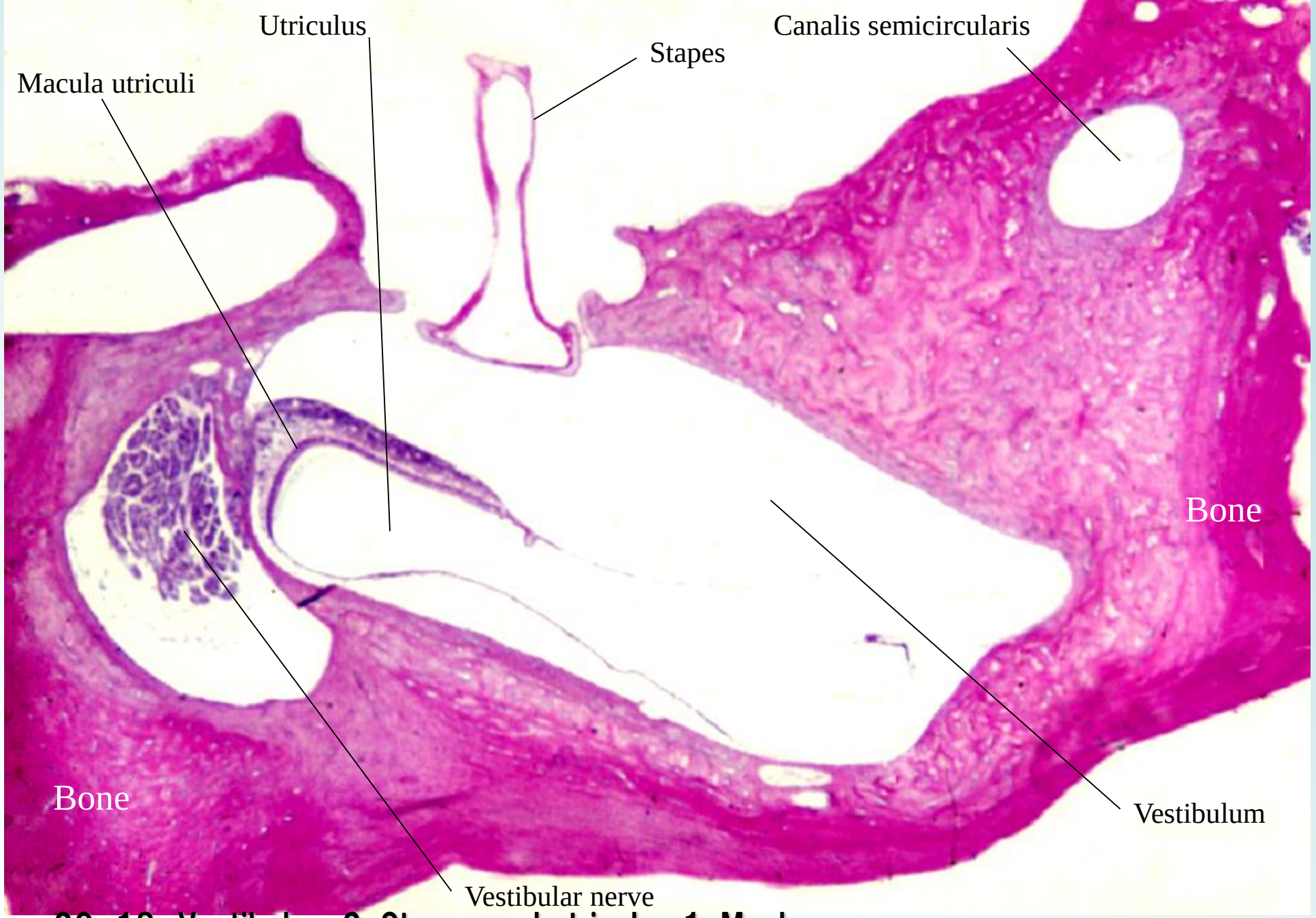


20-16 External acoustic meatus. Monkey, H-E stain, x 2.5.

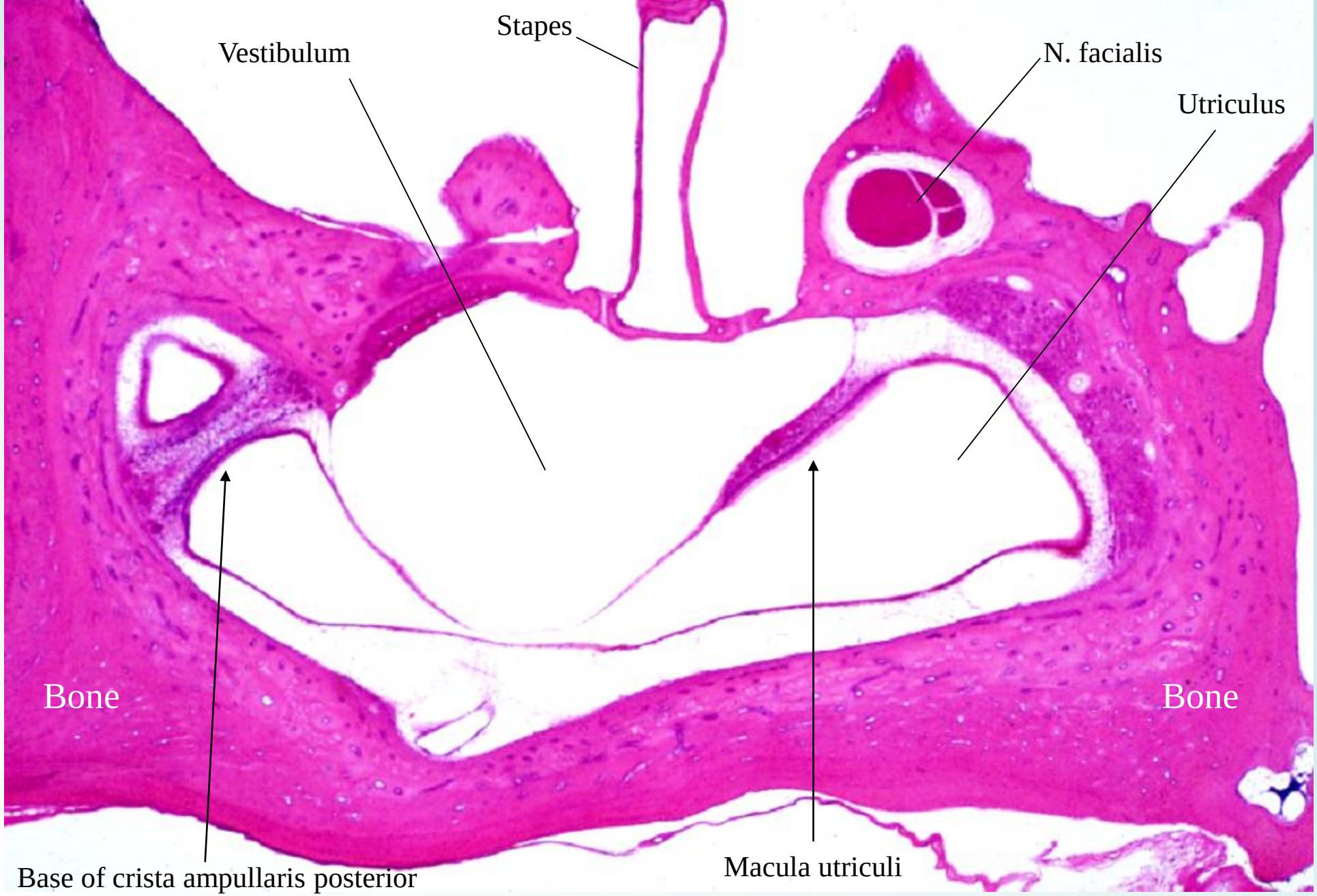
20-002 Vestibular Organs



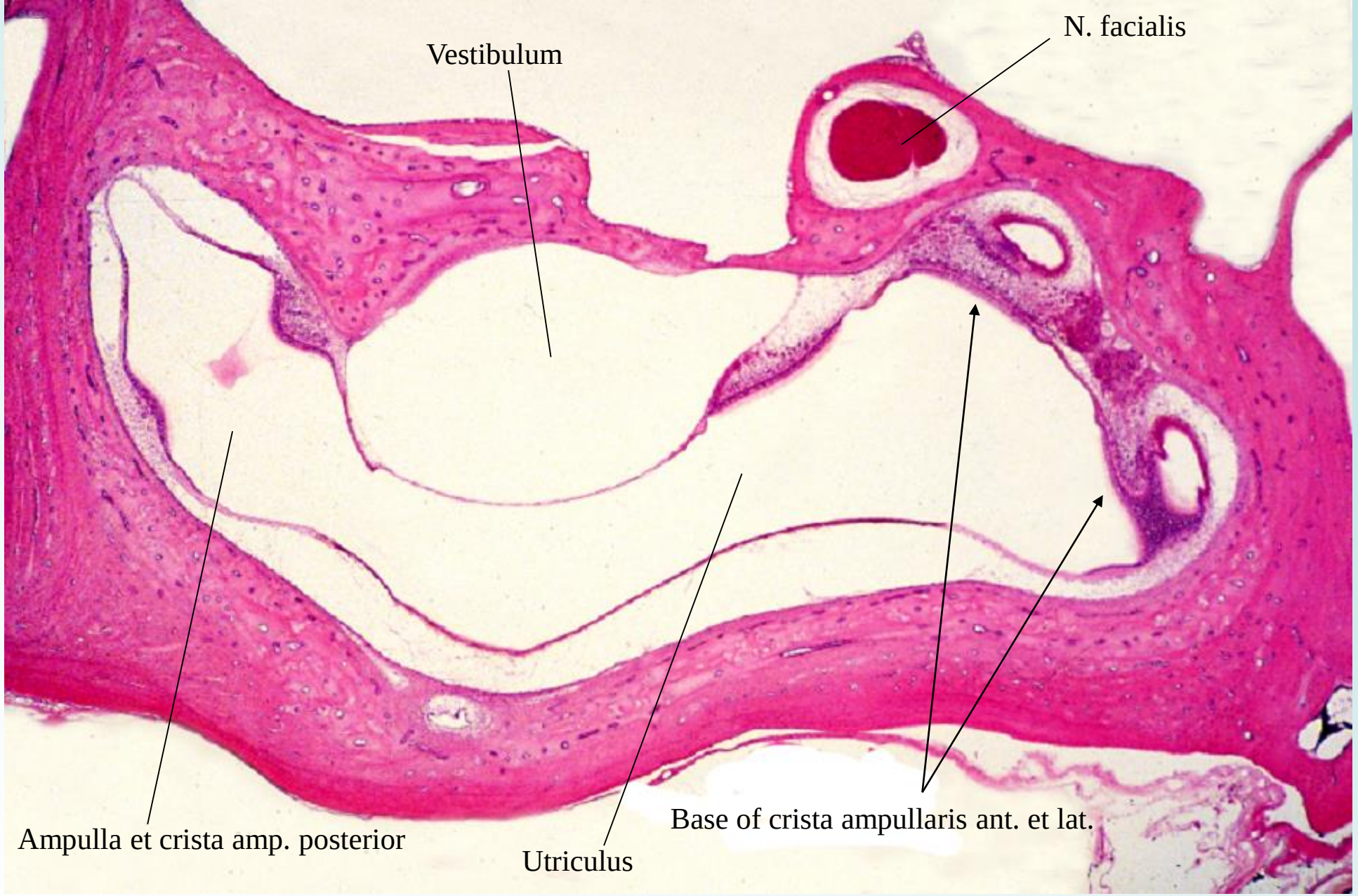
20-17 Vestivulum 1. Sacculus and ampulla posterior. Monkey, H-E stain, x 5.0.



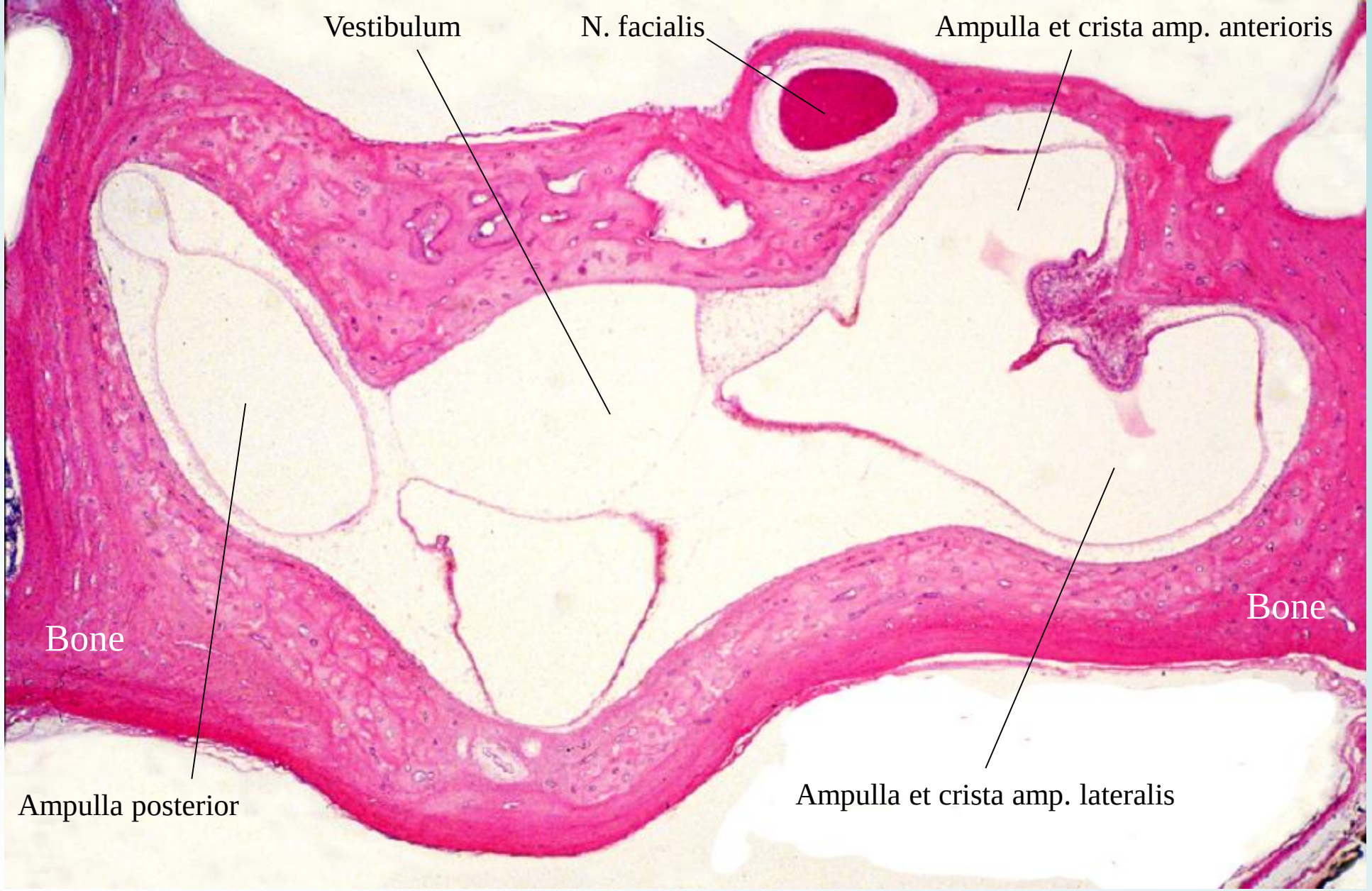
20-18 Vestibulum 2. Stapes and utriculus 1. Monkey, H-E stain, x 5.0.



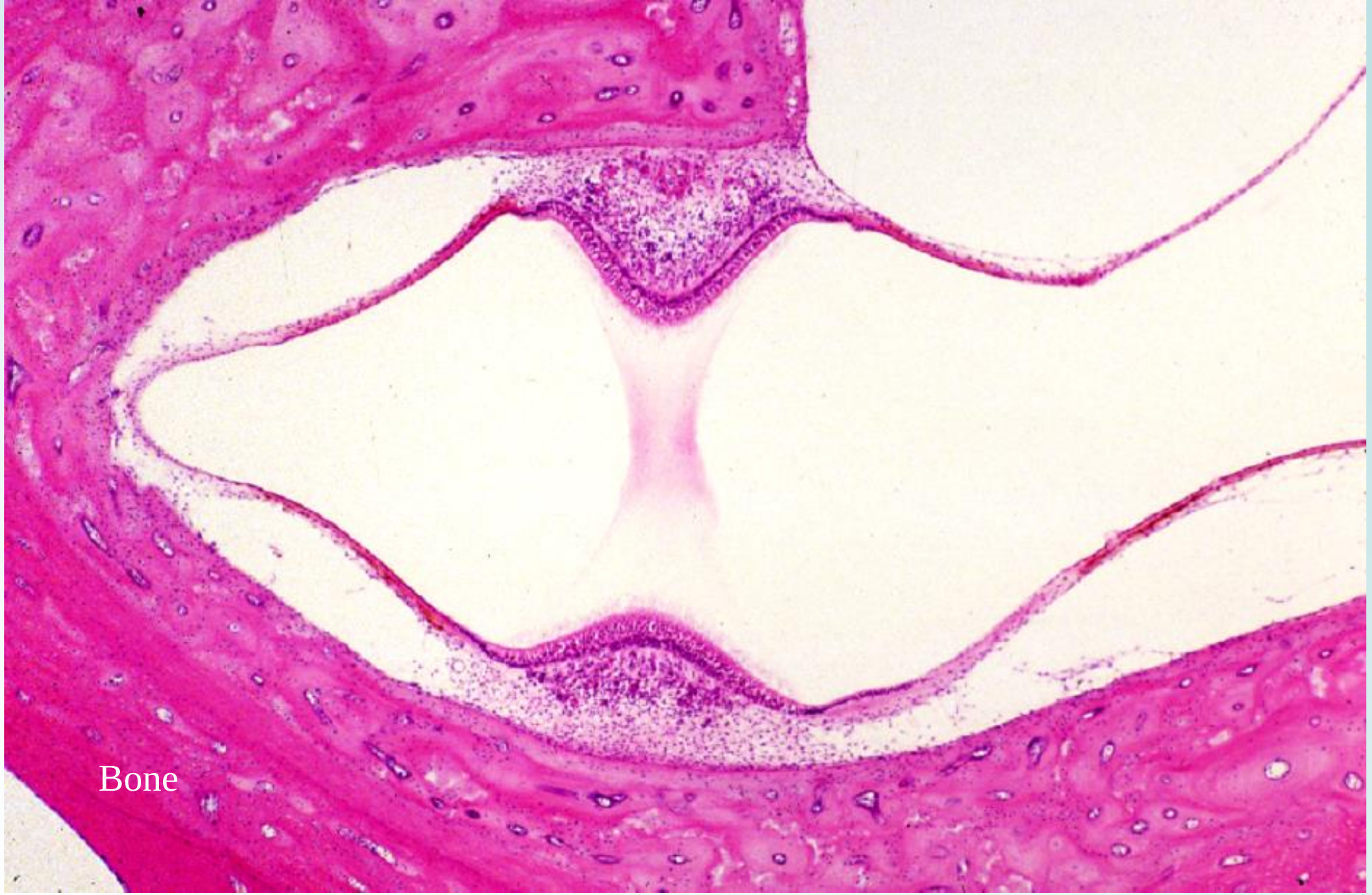
20-19 Vestibulum 3. Stapes and utriculus 2. Monkey, H-E stain, x 5.0.



20-20 Vestibulum 4. Macula utriculi and crista ampullaris posterior. Monkey, H-E stain, x 5.0.

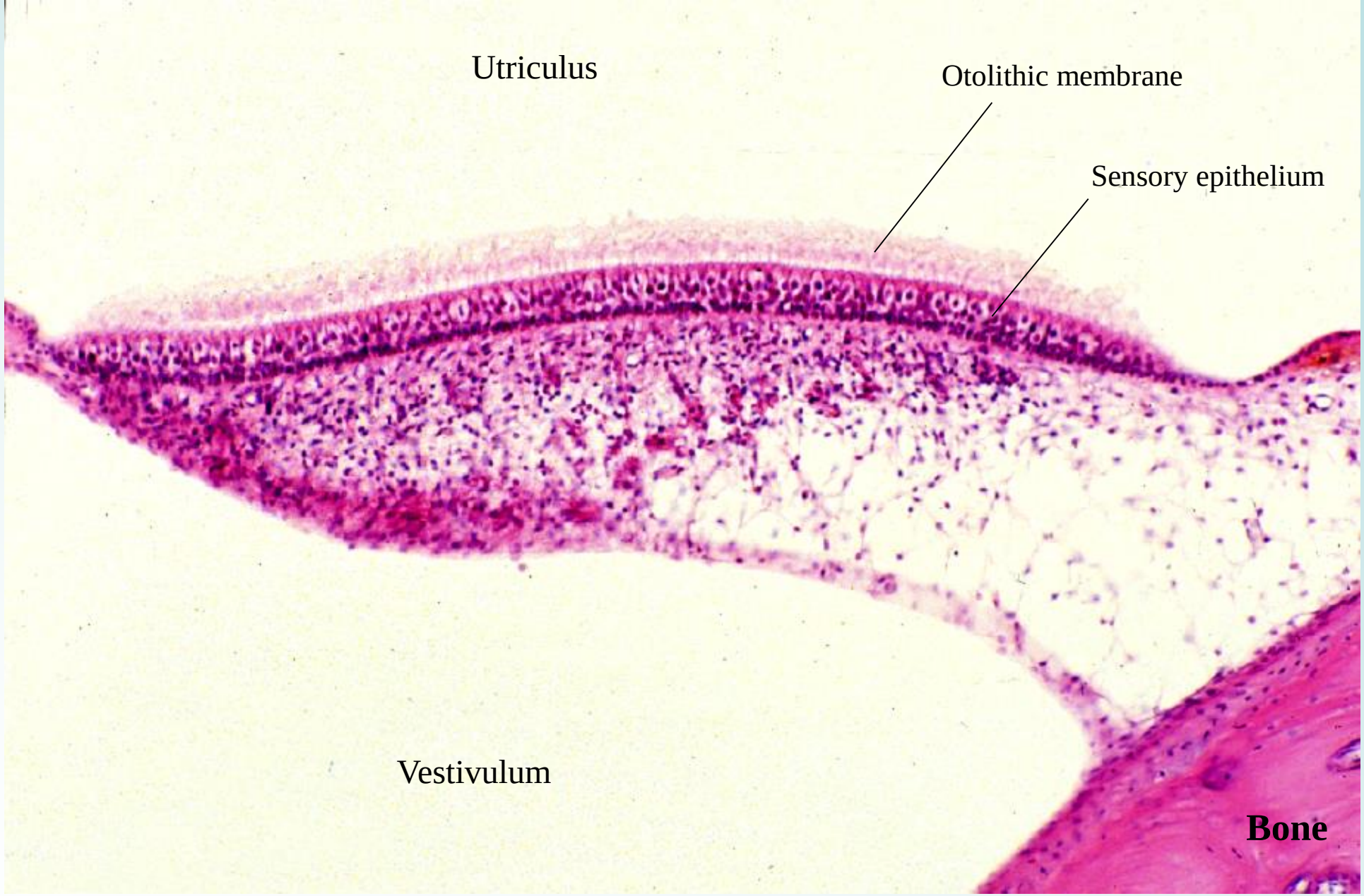


20-21 Vestibulum 5. Crista ampullaris anterior and crista amp. lateralis. Monkey, H-E stain, x 5.0.

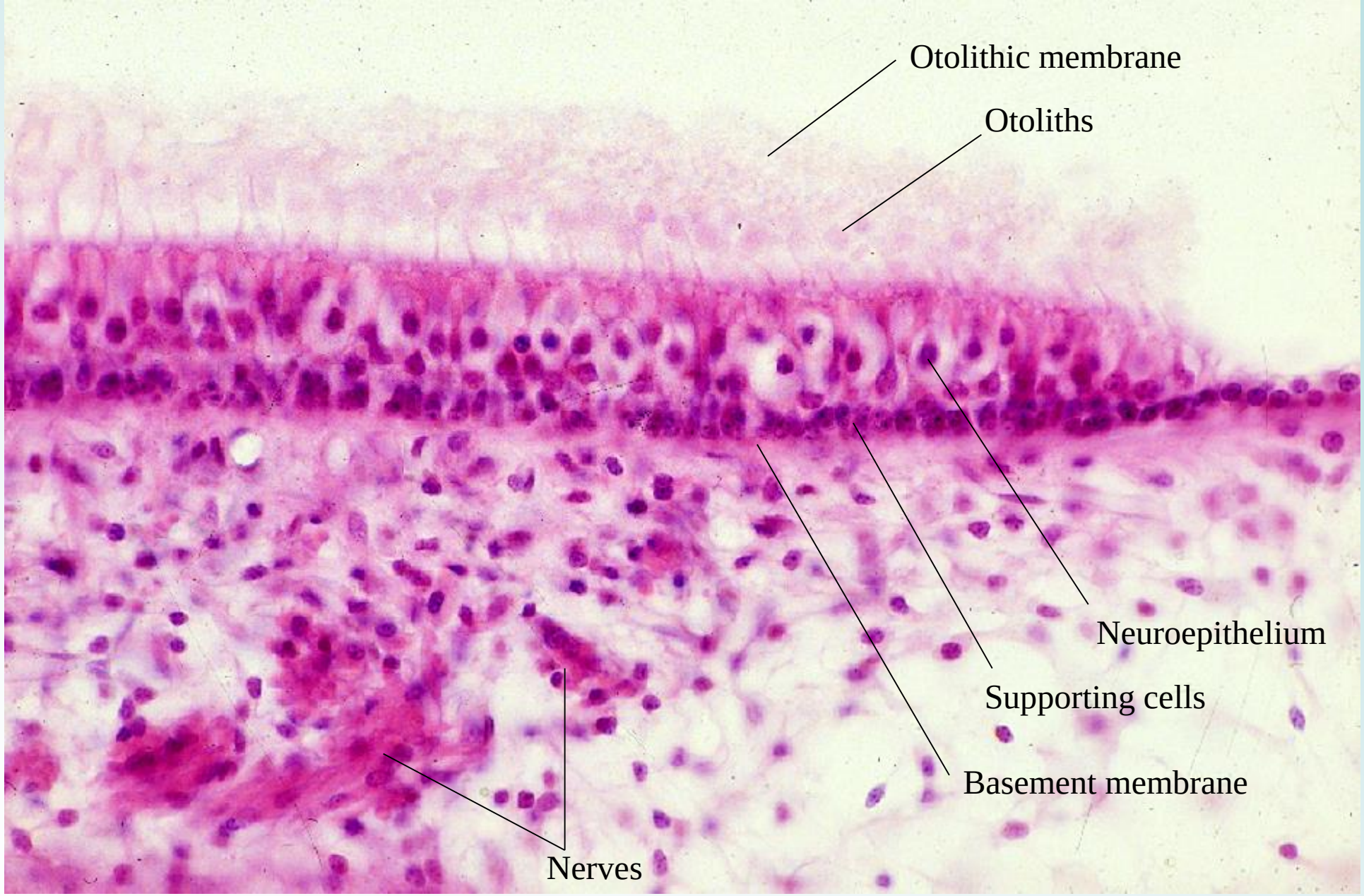


20-22 Crista ampullaris 1. Monkey, H-E stain, x 13.2.

20-23 Crista ampullaris 2. Monkey, H-E stain, x 50.



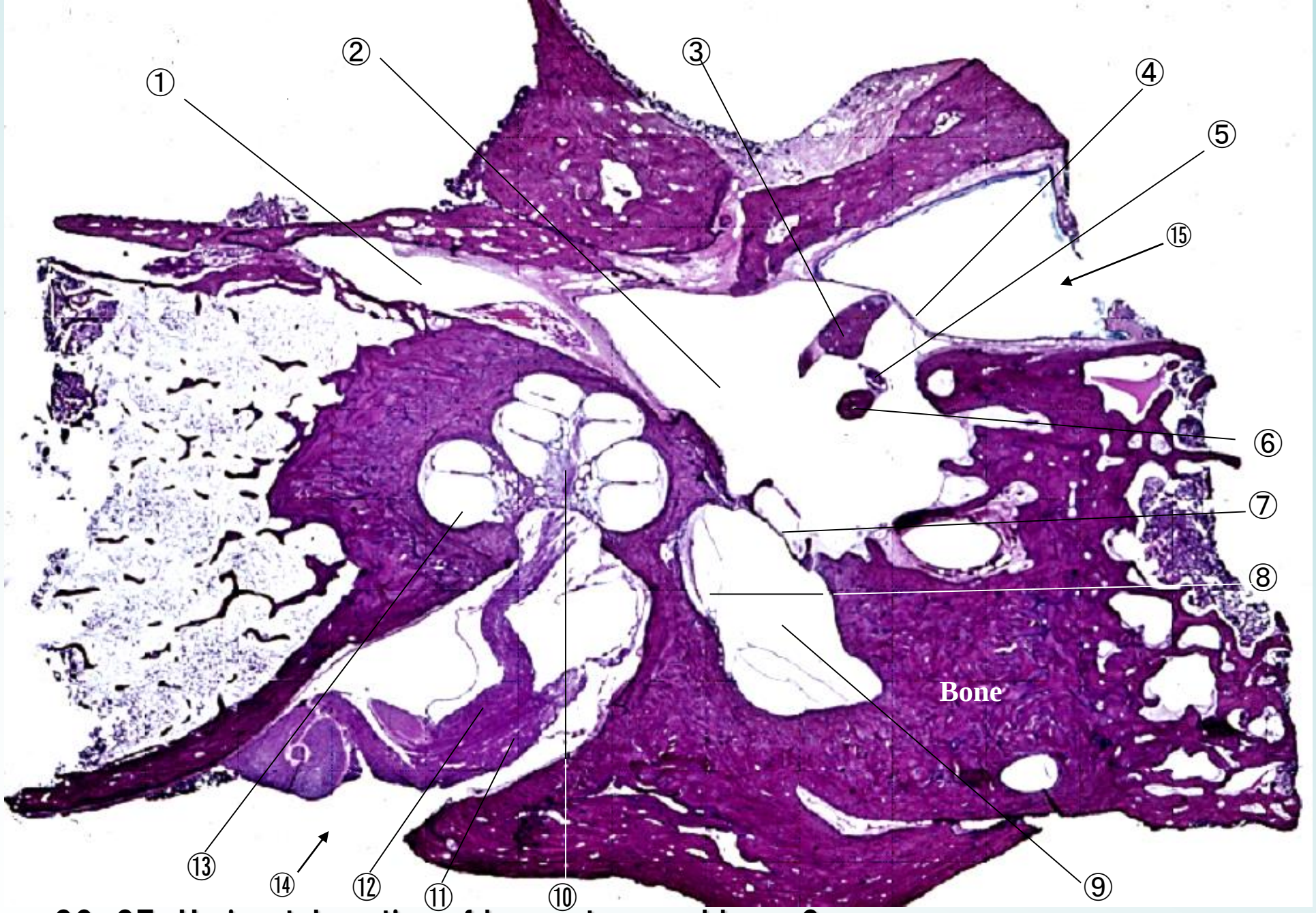
20-24 Macula utriculi 1. Monkey, H-E stain, x 33.



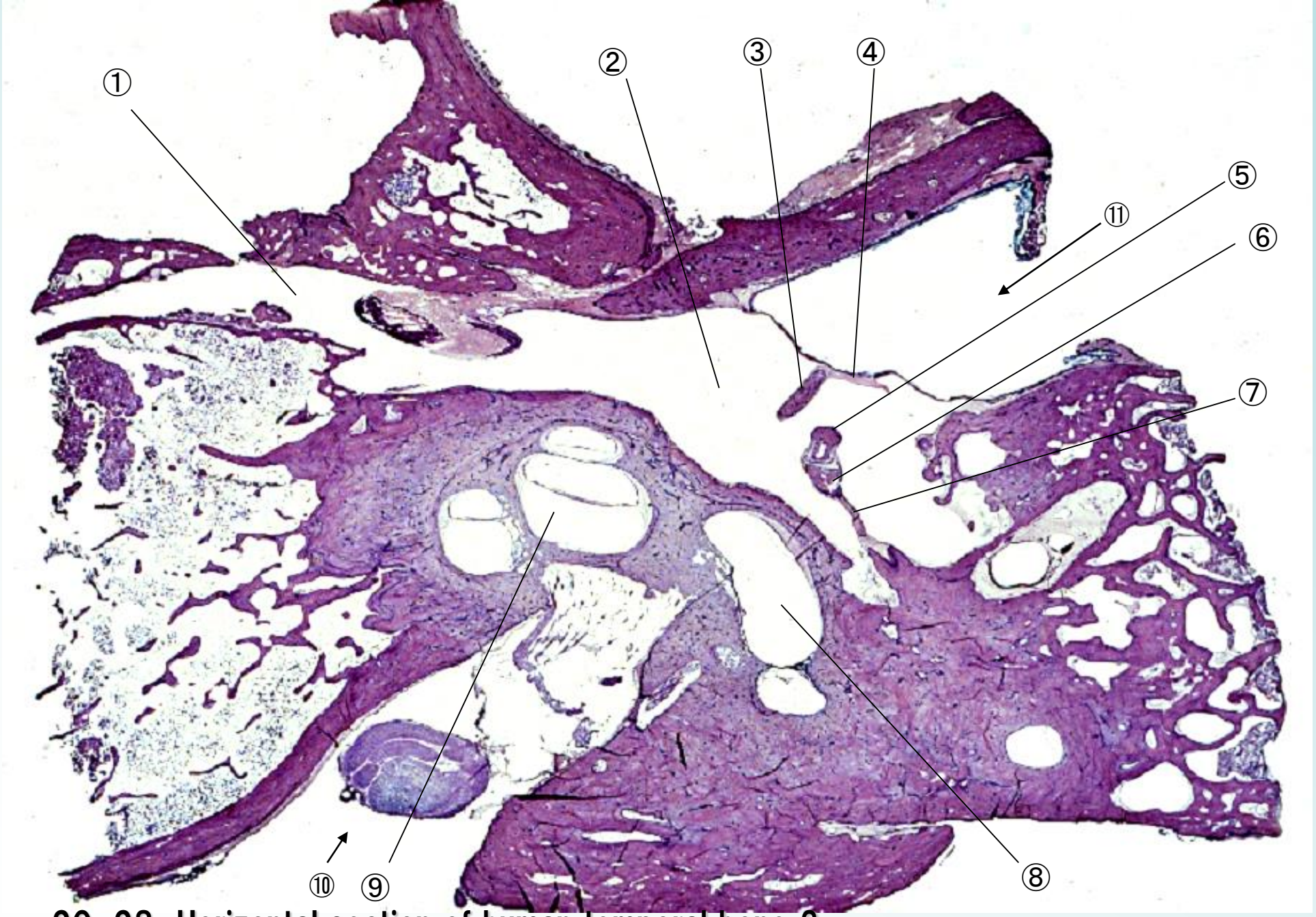
20-25 Macula utriculi 2. Monkey, H-E stain, x 100.

20-003
Horizontal Sections of Human Temporal Bone

20-26 Horizontal section of human temporal bone 1.
H-E stain, x 1.0.



20-27 Horizontal section of human temporal bone 2.
H-E stain, x 1.0.



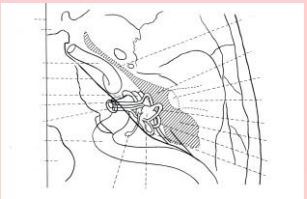
20-28 Horizontal section of human temporal bone 3.
H-E stain, x 1.0.

20-29 Horizontal section of human temporal bone 4.
H-E stain, x 1.8.

20- e Ear (Vestibulo-acoustic Organs)

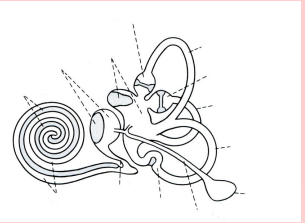
- The ear (vestibulo-acoustic organs) consists of vestibular organs and acoustic organs; the former concern the sense of equilibrium and motion of the body and reflex control of the skeletal muscles, and the latter, the perceiving the vibration of the air, the sound, which developed phylogenetically later than the former.
- These organs originate embryologically from a common anlage, namely from the otic vesicle. In the early half of the fourth gestational week, in the area adjacent to the dorsal end of the second branchial groove the surface ectoderm invaginates into the mesenchyme and forms a spherical vesicle, the otic vesicle. This vesicle, enclosed by the ectodermal epithelium, undergoes afterwards complicated morphological changes and finally establishes a complex of vesicles and connecting ducts, called the labyrinth, consisting of ductus cochlearis, sacculus, utriculus, three semicircular ducts, and ductus and saccus endolymphaticus (see 20-02). Among these, the cochlear duct concerns the hearing of the sound, and all others, the sense of equilibrium. These are called, as a whole, the membranous labyrinth, because they are all composed of the ectodermal epithelium and supporting connective tissue. Around them develops a bony capsule of about the same form but of somewhat larger size, called osseous labyrinth, Except for the definite places, where the membranous adheres to the osseous, there is an interspace between the membranous and osseous labyrinths, that is filled by fluid, called perilymph. The membranous labyrinth is a closed system, also filled by fluid, called endolymph. There is no communication between the endolymph and perilymph.
- The membranous ductus cochlearis corresponds in form with the osseous canalis cochlearis, but the sacculus, utriculus, and three ampullae of ductus semicirculares are accommodated in one cavity in the petrous part of the temporal bone, called the vestibulum, because of that they are called the vestibular organs.

20- cation of vestibulo-acoustic organs in the temporal bone (Sc



- The vestibulo-acoustic organs are embedded in the petrous part of the temporal bone; the cochlear duct at the antero-medial position, indicated by the internal acoustic meatus, and the sacculus, utriculus and three semicircular ducts at the postero-lateral position. The longitudinal axis of the vestibulo-acoustic organs is parallel to the upper margin of the petrous part of the temporal bone.
- The external ear consists of the auricle, external acoustic meatus, and tympanic membrane. They collect the sound wave and conduct it to the middle ear.
- The middle ear is composed of the tympanic membrane, three otic (auditory) ossicles, the eustachian tube and tympanic cavity. The tympanic membrane and three otic ossicles transmit the sound wave to the internal ear as the mechanical vibrations , that are converted to the movement of the fluid, perilymph, of the internal ear.
- The red line indicates the axis of the cochlear duct, which is horizontal, and perpendicular to the longitudinal axis of the superior border of the petrous part.

20- heme showing the structure of membranous labyrinth.

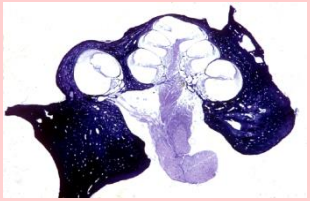


- This is a schematic drawing of the right side membranous labyrinth, seen from inside. The locations of the sensory epithelium are indicated by light blue color.

20- ochlea, and External and Middle Ear

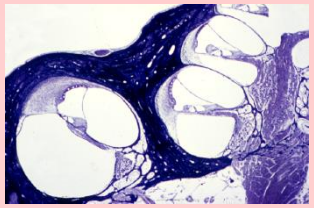
- The cochlea consists of the membranous ductus cochlearis and the osseous canalis cochlearis. The ductus cochlearis is a spiral duct with blind end at each extremity. The number of spiral turns are two and three fourths in human and three and half in monkey. The basal turn is the largest and it becomes smaller as going to the top.
- The ductus cochlearis and the surrounding osseous canalis cochlearis are structurally and functionally not dividable and should be described as a whole. Their structures are composed symmetrically around a conical pillar of spongy bone, called the modiolus.
- For the convenience of description, words of directions are set here as follows: direction nearing modiolus is medial-ward (inner), leaving it, lateral-ward (outer); direction to the base of the spiral is downward, and to the top, upward.

20-[redacted]chlea, vertical section, 1. Monkey, Held's hematoxylin stain, 4.



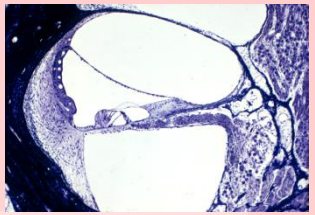
- This is a general view of a monkey cochlea, exactly vertically sectioned through the plane containing the modiolus. This section was stained with Held's hematoxylin, which stains bone dark blue and others light bluish-violet.
- The upper left contour of this figure is the inner wall of the tympanic cavity, where the promontrium and tympanic nerve are seen. The lower contour is the inner surface of the petrous part of the temporal bone and the internal acoustic meatus containing the cochlear nerve is evident.
- As in monkey the cochlear turns are three and half, sections of cochlear canal (ducts) appear six and at the top the hericotrema is clearly recognized (indicated with a bilateral arrow).

20-[redacted]chlea, vertical section, 2. Monkey, Held's hematoxylin stain, 10.



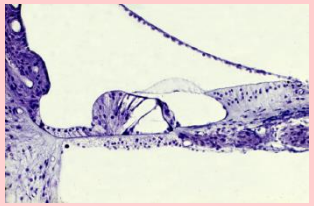
- Higher magnification of the upper left quadrant of the figure 20-03, and the first, the second, and the third turns of the cochlear canal are seen. Along the right edge of the figure stands the modiolus containing the cochlear nerve and at its top the helicotrema is seen, indicated with a bilateral arrow. Each turn of the cochlear canal is divided by a horizontal plate into two, upper and lower, cavities; the lower is called scala tympani (st). The upper is further divided by a thin oblique membrane into larger medial cavity, scala vestibuli (sv), and smaller lateral cavity, ductus cochlearis (dc). At the helico- trema, scala tympani is continuous with scala vestibuli. The interior of the modiolus is filled by cochlear nerve fibers, stained blueish violet. The bone is stained dark blue and conspicuous to the soft tissue, stained blueish violet.

20- chlear canal, vertical section, 3. Monkey. Held's hematoxylin stain .



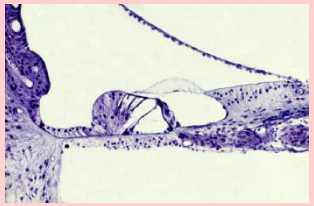
- A thin spiral osseous plate projects from the modiolus into the cochleal canal, called osseous spiral lamina, and from its lateral edge a sheet of connective tissue extends across the canal to its opposite wall to join the spiral ligament, which is a special thickening of the periosteum. On the lateral half of the osseous spiral lamina, the cells of the periosteum proliferate and form a spiral limbus. Between its upper medial edge and the upper portion of the opposite wall a thin membrane is spread; this is the vestibular membrane. The lumen of the cochlear canal is, thus, partitioned into three spiral chambers: the scala vestibule (sv), above, scala tympani(st), bolow, and scala media, that is ductus cochlearis (dc).
- On the lateral half of the osseous spiral lamina and on its lateral continuation, lamina basilaris, locates the organ of Corti, the organ of hearing.
- In the modiolus, at the lower medial portion to the osseous spiral lamina there is a group of bipolar nerve cells; this is called the spiral ganglion of the cochlear nerve. The distal axons starting from this ganglion run upper-laterally, then through the space between the upper and lower osseous laminae laterally and attain the organ of Corti. The proximal axons enter into the interior of the modiolus and form all together the cochlear nerve.

20- chlear duct and organ of Corti 1. Monkey, Held's hematoxylin stain . (1/4)



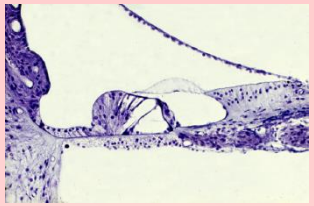
- The ductus cochlearis is triangular in cross section with its apex at the limbus. Its roof is the vestibular membrane and its floor is formed by the spiral lamina and basilar membrane. Its lateral wall consists of stria vascularis and prominentia spiralis, both underlaid by the connective tissue of spiral ligament. The cochlear duct is filled by fluid, named endolymph, and its inner surface is covered throughout by the ectodermal epithelial cells, that show, however, marvelous local specialisations.
- The cells covering the inner surface of the vestibular membrane are simple squamous in shape, containing a nucleus protruding into the lumen. They continue at lower medial corner of the cochlear duct to the cells covering the spiral limbus, that are simple columnar in shape and their bases are firmly embedded in the connective tissue of the thickened periosteum of the osseous spiral lamina. These cells secrete from the apical surface tectorial membrane, which extends laterally and covers the organ of Corti. The tapering upper and lower edges of the spiral limbus project laterally as vestibular and tympanic lips; the latter is continuous with the basilar membrane. The space surrounded by these two lips is named the internal spiral sulcus (ssi), whose surface is covered by flat simple squamous epithelial cells.
- At the upper lateral corner of the cochlear duct the epithelial cells of the vestibular membrane are continuous with the cells of the stria vascularis, that constitutes the lateral wall of the cochlear duct. The stria vascularis consists of a stratified columnar epithelium containing an intraepithelial plexus of capillaries. Its lower end protrudes into the lumen of the cochlear duct as spiral prominence, covered by a simple squamous epithelium. At the lower end of the spiral prominence begins the simple cuboidal epithelial cells, which cover the lowermost portion of the lateral wall of the cochlear duct and then medially the upper surface of the most lateral portion of the basilar membrane. These cells are called the cells of Claudius. The space below the spiral prominence and lined by the cells of Claudius is called the external spiral sulcus (sse).

20-[redacted]chlear duct and organ of Corti 1. Monkey, Held's hematoxylin stain[redacted]. (2/4)



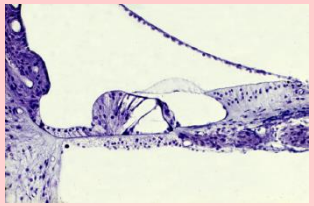
- The organ of Corti locates on the medial half of the basilar lamina and is composed of the highly specialized cells. It consists of the sensory cells (hair cells) and the supporting cells (about the details see 20-12 to 20-16).
- The supporting cells have certain characteristics in common. They are tall slender cells extending from the basilar membrane to the free surface of the organ of Corti and they contain conspicuous bundles of microtubules and filaments. Although the bodies of some of these cells are separated by wide intercellular spaces, their apical portions are in contact with each other, and with the hair cells, to form a highly ordered continuous free surface of the organ of Corti, referred to the reticular membrane (20-16). The several types of supporting cells include inner and outer pillar cells, inner and outer phalangeal cells, border cells, and the cells of Hensen.
- The inner pillar cells have a broad base resting on the basilar lamina and a slender conical body extending upward. The segment of cell body containing the nucleus is situated basally, at the inner angle of a wide triangular intercellular space, called the inner tunnel (T). This space is continuous throughout the length of the cochlea and is bounded below by thin lateral extensions of the base of the pillar cells that rest on the basilar lamina. It is bounded above by the converging cylindrical bodies of the inner and outer pillar cells. The most distinctive feature of the inner pillar cells, viewed with the light microscope, is a large, dark-staining bundle of filaments that courses from the base, upward through the slender cell body to end at the apex, where the cell widens into a thin horizontal plate that contacts neighboring pillar cells and the inner hair cells.

20- chlear duct and organ of Corti 1. Monkey, Held's hematoxylin stain . (3/4)



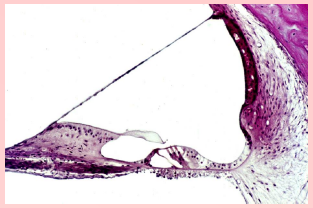
- The outer pillar cells are longer and more oblique in their orientation, leaning toward the inner pillars. They have a broad thin base adjoining that of the inner pillar cells. The cell body is similar, but its expanded upper end has a somewhat different shape. It abuts the under side of the flat head of the inner pillar cells. From lower down on the cell body, it also sends out a phalangeal process with a flat head that forms junctions, in the reticular lamina, with the hair cells and the expanded head of the phalangeal processes of the outer phalangeal cells, located between the rows of hair cells. The inner pillar cells number about 5600 and the outer pillars 3800. On average, the heads of three inner pillars abut the heads of two outer pillars. The area of contact between them is quite large, ensuring that they form a sound support for the hair cells.
- The outer phalangeal cells (cells of Deiters) are the supporting cells for the three or four rows of outer hair cells. Their base is columnar with a cup-shaped upper end occupied by the inferior one third of a hair cell. Thus, they surround the base of the hair cell and also the bundles of afferent and efferent nerves traveling to the hair cells. The apex of these cells does not reach the free surface of the organ of Corti, but a slender phalangeal process projecting from the side of the cell does reach the reticular lamina. This process is internally reinforced by a bundle of microtubules and filaments and its expanded distal end forms a flat plate joined, at its edges, to the hair cell it is supporting, and to the hair cell in the next row. The upper two-thirds of the hair cells is not immediately surrounded by other cells but is exposed within a fluid-filled space of Nuel (N), which communicates with the inner tunnel through clefts between the pillar cells.

20-[redacted]chlear duct and organ of Corti 1. Monkey, Held's hematoxylin stain[redacted]. (4/4)



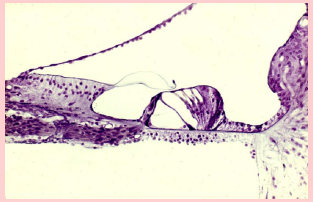
- The inner phalangeal cells are arranged in a row on the inner side of the inner pillar cells. In contrast to the outer phalangeal cells, there are no large intercellular spaces between these supporting cells and the inner hair cells; indeed, they completely surround them. The inner phalangeal cells are contiguous with a row of slender cells, termed border cells, which mark the inner boundary of the organ of Corti.
- The outer border of the organ of Corti is delimited by the tall cells of Hensen adjacent to the last row of outer phalangeal cells. These are arranged in several rows decreasing rapidly in height to become continuous laterally with the cells of Claudius.
- There are two types of hair cells in the cochlea. The inner hair cells are arranged in a single row along the entire length of the organ of Corti. The outer hair cells form three rows and are lodged between the outer pillar cells and outer phalangeal cells. In human, a fourth row may be found near the apex of the cochlea.
- The cochlear nerve fibers starting from the spiral ganglion run laterally, as the myelinated nerve fibers, through the space between two laminae of osseous spiral lamina and at its lateral end they loose the myelin sheath and penetrate, as naked nerve fibers, the basilar lamina at the base of the inner phalangeal cells, and here divide into two groups: the one attains the base of the inner hair cells and forms the synapses with them; the other travels through the intercellular spaces between the inner pillar cells, tunnel, intercellular spaces of the outer pillar cells, space of Nuel, and attains the base of the outer hair cells, and forms the synapses with them.

20- chlear duct and organ of Corti 2. Monkey, H-E stain, x 50.



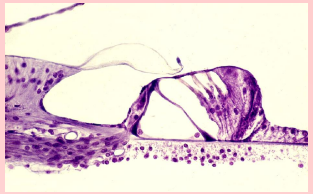
- These three pictures are made from the specimen, in which preservation of the fine structures was very well so that the details of the organ of Corti are clearly seen. The above descriptions in 20-06 about the organ of Corti are all recognized in these pictures. The stria vascularis, shown in 20-13, was also microphotographed from this specimen.
- 20-07 shows the general view of the cochlear duct. The inner surface of the cochlear duct (dc) is covered throughout by the ectodermal epithelial cells, that show the marvelous local specialization. The inner surfaces of scala tympani (st) and scala vestibuli (sv) are lined by very flat mesenchymal squamous cells.

20- chlear duct and organ of Corti 3. Monkey, H-E stain, x 64.



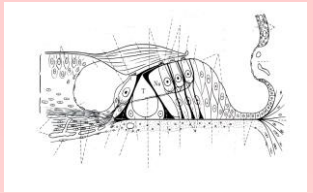
- These three pictures are made from the specimen, in which preservation of the fine structures was very well so that the details of the organ of Corti are clearly seen. The above descriptions in 20-06 about the organ of Corti are all recognized in these pictures. The stria vascularis, shown in 20-13, was also microphotographed from this specimen.
- In 20-08 the arrangement of various types of cells constituting the lower surface of the cochlear duct is evidently seen. The innermost portion, the spiral limbus, is lined by simple and / or pseudostratified columnar epithelium, then the surface of the inner spiral sulcus, by the flat squamous epithelium, next, border cell, inner phalangeal cell and inner hair cell, inner and outer pillar cells, then outer phalangeal cells and outer hair cells, followed by the cells of Hensen and cells of Claudius. The lower surface of the basilar membrane is covered by mesenchymal cells, which continue laterally with the spiral ligament. A thin naked nerve fiber traveling the tunnel is clearly seen.

20- gan of Corti. Monkey, H-E stain, x 100.



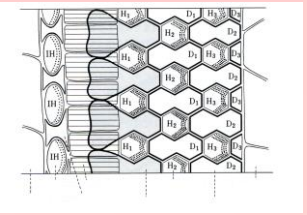
- These three pictures are made from the specimen, in which preservation of the fine structures was very well so that the details of the organ of Corti are clearly seen. The above descriptions in 20-06 about the organ of Corti are all recognized in these pictures. The stria vascularis, shown in 20-13, was also microphotographed from this specimen.
- 20-09 shows the detail of the organ of Corti. The inner pillar and inner pillar cell, and the outer pillar and outer pillar cell are evident. The myelinated cochlear nerve fibers loose the myelin sheath at the base of the inner pillar and the naked nerve fibers penetrate the basilar lamina and attain the base of the inner hair cell. The inner hair cell leaning on the inner pillar and the three rows of the outer hair cells supported by the outer phalangeal cells, cells of Deiters, are evident. The cells of Hensen and cells of Claudius are also conspicuous. The lining cells of the spiral limbus and the tectorial membrane are well recognized. The naked nerve fiber traveling the tunnel is faintly suggested.

20- heme showing the structure of organ of Corti



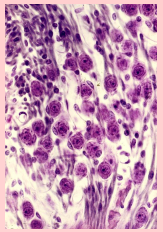
- This is to show the structural details of the organ of Corti. Compare with 20-05 ~ 20-09.

20- icular membrane（Scheme）



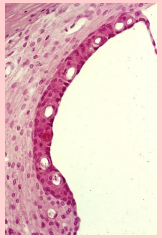
- This scheme shows the surface view of the reticular membrane. As is seen here the position of the apical surface of the inner and outer hair cells is quite firmly kept by the border cells, inner phalangeal cells, head plate of the inner pillar cells, phalangeal process of outer pillar cells, phalangeal process of cells of Deiters of the first, second and third row, and cells of Hensen.
- The arrangement of the hairs of the inner hair cells and that of the outer hair cells differs from each other and both are characteristic, respectively.

20- ral ganglion. Monkey, Held's hematoxylin stain, x 160.



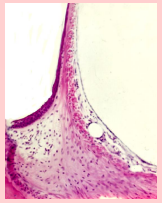
- The spiral ganglion consists of bipolar nerve cells and locates in the medial wall of the cochlear duct, lower medial to the starting place of the osseous spiral lamina In this figure, a nerve cell is seen with the distal (①) and the proximal (②) axons. In this ganglion the Schwann cells enclose not only the nerve fibers but also the cell body of the nerve cells; they are indicated by short arrows. The myelin sheath is blackened by the pretreatment with the osmic acid.

20- ia vascularis. Monkey, H-E stain, x 100.



- The stria vascularis composes the most of the lateral wall of the cochlear duct and consists of a thick stratified columnar epithelium, which contains an intraepithelial plexus of blood capillaries. In this epithelium three layers of cells are distinguished. The superficial layer consists of cylindrical cells arranged perpendicular to the free surface of the stria vascularis. They are believed to produce the endolymph. The cells of basal and intermediate layers are polyhedral in shape and contain a round or oval nucleus. The intraepithelial capillaries are closely enveloped by protoplasmic processes of the epithelial cells. The basal cells are underlain by the connective tissue of the spiral ligament. The epithelial cells of the stria vascularis are continuous with the cells that cover the lower surface of the vestibular membrane, superiorly, and inferiorly, with a thin layer of the squamous epithelial cells over the spiral prominence, which is a highly vascular thickening of the connective tissue of the spiral ligament. .

20- npanic membrane 1. Monkey, H-E stain, x 64.

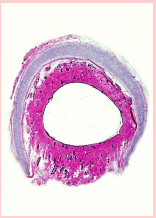


- The tympanic membrane is a roughly round strong membrane of about 10 mm in diameter and about 0.1 mm in thickness, which bounds the tympanic cavity from the external acoustic meatus, It is covered by the skin, exteriorly, and by the mucous membrane of the tympanic cavity, interiorly. Its substance consists of two layers of collagenous fibers and fibroblasts. In the outer layer the collagenous fibers are oriented radially, whereas those of the inner layer have a circular disposition. The skin is very thin and consists of a stratified squamous epithelium supported by very little connective tissue. The moucous membrane of the tympanic cavity is also very thin and consists of a squamous epithelium and a thin lamina propria containing sparse collagen fibers and capillaries.
- In 20-14, it is clearly seen that at the periphery of the tympanic membrane the radiating collagen fibers disperse and adhere to the bone.

20-15 Tympanic membrane 2. Monkey, H-E stain, x 160.

- The tympanic membrane is a roughly round strong membrane of about 10 mm in diameter and about 0.1 mm in thickness, which bounds the tympanic cavity from the external acoustic meatus, It is covered by the skin, exteriorly, and by the mucous membrane of the tympanic cavity, interiorly. Its substance consists of two layers of collagenous fibers and fibroblasts. In the outer layer the collagenous fibers are oriented radially, whereas those of the inner layer have a circular disposition. The skin is very thin and consists of a stratified squamous epithelium supported by very little connective tissue. The moucous membrane of the tympanic cavity is also very thin and consists of a squamous epithelium and a thin lamina propria containing sparse collagen fibers and capillaries.
- In 20-14, it is clearly seen that at the periphery of the tympanic membrane the radiating collagen fibers disperse and adhere to the bone.

20-16 External acoustic meatus. Monkey, H-E stain, x 2.5.



- This is a general view of transverse section of the external acoustic meatus. Its wall is composed of concentrically arranged layers; around the lumen encircles the skin consisting of a thin epidermis and very thick dense dermis, and very loose subcutaneous connective tissue, containing the cerminosa glands. The outermost layer is the thick elastic cartilage.

20- estibular Organs (1/3)

- The vestibular organs consist of sacculus, utriculus and three semicircular ducts opening into the utriculus. During sudden changes in orientation, sensory receptors in the semicircular ducts and the sacculus as well as utriculus respond to acceleration of the head to generate nerve impulses to the brain that initiate reflexes which tend to restore normal body position.
- **The semicircular ducts** (20-17, 20-20 ~ 20-23).
- Three semicircular ducts are named according to their position, namely ductus semicircularis anrerior (D.s.ant.), ductus semicircularis posterior (D.s.post.), and ductus semicircularis lateralis (D.s.lat.). D.s.ant. turns vertically upward and perpen-dicular to the long axis of the petrous part (of the temporal bone). D.s.post. turns vertically postero-lateral-ward and parallel to the long axis of the petrous part. D.s.lat. turns horizontally lateral-ward and parallel to the long axis of the petrous part. Each duct opens into the utriculus with two openings; one with a small dilatation (ampulla) and another without ampulla (simple limb).
- In the floor of each ampulla, there is a transverse ridge, called the crista ampullaris. The orientation of the ridge ensures that it is affected by any movement of the ridge with respect to the endolymph within the semicircular duct. The sensory epithelium over the top of the crista consists of two cell types, namely hair cells and supporting cells. The hair cells do not extend down to the basal lamina but occupy rounded recesses between the apices of the surrounding supporting cells. On their free surface, they have a single kinocilium and a cluster of specialized stereocilia ("hairs") that extend upward into the base of gelatinous structure, called the cupula, which projects into the lumen of the ampulla.

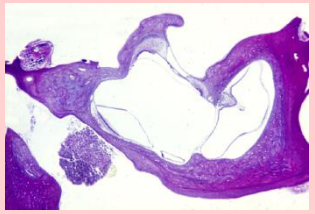
20- estibular Organs (2/3)

- Two types of hair cells are recognized. Type I hair cells are plump, flask-shaped cells with a round base and narrower neck region. The nucleus locates basally and surrounded by mitochondria. The Golgi complex locates in the supranuclear region. The 50 to 100 stereocilia on the free surface vary in length in a stepwise fashion, so that the bundle, as a whole, has a beveled appearance, with the tallest hairs (10 μ m) near the kinocilium and the shortest (1 μ m) on the opposite side.
- The type II hair cells are more columnar in form and their kinocilium, stereocilia, and cytoplasmic organelles are similar to those of the type I cells. The distinction between the two types of hair cells depends more on the configuration of their innervation than on the cytological differences.
- In the case of the type-I hair cells, nerves penetrate between the supporting cells and form a chalice-like ending completely investing their rounded base. At one or more sites in the peripheral cytoplasm of the rounded base of the hair cell, there is a dense band oriented perpendicular to the plasmalemma and surrounded by a halo of small vesicles, These structures resemble the so-called synaptic ribbons.
- The nerves to the type-II hair cells do not form a calyx but end in a number of relatively small terminal boutons. Synaptic ribbons are also found in the peripheral cytoplasm of the type-II hair cells opposite the thickened plasmalemma of certain of terminal boutons.
- **The sacculus and the utriculus** (20-17 ~ 20-20, 20-24 and 20-25).

20- estibular Organs (3/3)

- The vestibulum is a roughly rectangular cavity in the petrous part of the temporal bone, locating medio-anterior to the tympanic cavity, in which the sacculus, the utriculus and three ampullae of the semicircular canals are accommodated.
- The sacculus is a flattened cone, setting the round base on the medio-anterior wall of the vestibulum and projecting the top into the vestivular cavity. The utriculus is an oblong vesicle protruding horizontally from the medio-anterior wall into the vestibular cavity, upper and posterior to the sacculus. The lining cells of the sacculus and the utriculus are simple squmous epithelial cells, except for the specialized sensory regions that are called macula sacculi and macula utriculi, respectively. In the sacculus the macula covers most of the basal wall, whereas in the utriculus it covers the wall from the medio-anterior portion to the latero-anterior portion, that protrudes into the vestibular cavity.
- Both the macula sacculi and the macula utriculi consist of two kinds of tall columnar epithelial cells, namely, hair cells and supporting cells. They are essentially identical to that of the crista ampullaris, except for that the stereocilia are even in length. The kinocilium and stereocilia of the hair cells project into the underside of the covering membrane, otolithic membrane, that is a moderately thick layer of the gelatinous material. The otilithic membrane contains a multitude of minute crystalline bodies (3 to 5 μ m in largeness). These are called the otoliths or otoconia and are partially embedded in the upper surface of this membrane. These consist of protein and calcium carbonate. They are thought to provide additional inertia that resists displacement of the membrane by external force. Thus, when a linear acceleration is applied to the head, the otolithic membrane tends to remain stationary while the hair cells beneath it slide slightly, bending the hairs backward. Bending of the hairs triggers changes in the frequency of the nerve impulses reaching the brain.

20-5.0. stivulum 1. Sacculus and ampulla posterior. Monkey, H-E stain,



- This is a roughly vertical section of a monkey vestibulum. In this section, the round window (fenestra cochleae) closed by the secondary tympanic membrane, the sacculus with the macula, and ampulla and crista posterior are encountered. Outside of the vestibulum, inferior to the macula sacculi, the vestibular nerve and its ganglion are recognized.

20- stibulum 2. Stapes and utriculus 1. Monkey, H-E stain, x 5.0.

- This is a parallel section to the 20-17. The whole figure of the stapes, whose base is fitted in the oval window (fenestra vestibuli), and macula utriculi are shown.

20- stibulum 3. Stapes and utriculus 2. Monkey, H-E stain, x 5.0.

- 20-19 ~ 20-25 are photomicrographs of another series of specimens, sectioned in the different plane than 20-17 and 20-18.
- In 20-19, the stapes with the base fitting in the oval window, the utriculus with macula utriculi, and the base of the crista ampullaris posterior are seen. Facial nerve in the canalis facialis is also shown.

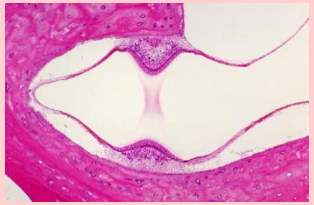
20- stibulum 4. Macula utriculi and crista ampullaris posterior. Monke
H-E x 5.0.

- In this figure macula utriculi, ampulla and cista ampularis posterior and the basal portions of the anterior and lateral cristae ampullares are seen. The facial nerve in the canalis facialis is also seen.

20- stibulum 5. Crista ampullaris anterior and crista amp. lateralis.
Monl E stain, x 5.0.

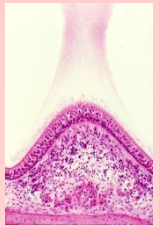
- In this figure, crista ampullaris anterior and crista ampullaris lateralis are shown. The ampulla posterior is now empty. The facial nerve is still recognized.

20- sta ampullaris 1. Monkey, H-E stain, x 13.2.



- This is the higher magnification of 20-20. As the cupula towers so highly that in some sections the cupula appears to tie together the both side of the wall of the crista. The left side of the ampulla goes into the crus simplex of the semicircular duct and the right side it continues with the utriculus. Between the bone and membranous ampulla is filled by very loose connective tissue. The substance of the crista consists of proliferated connective tissue and nerve fibers.

20- sta ampullaris 2. Monkey, H-E stain, x 50.

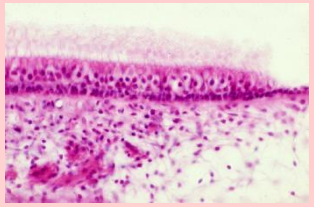


- The higher magnification of 20-22. The surface of the crista ampullaris is covered by two kinds of epithelial cells, namely, neuroepithelium (sensory cells) and supporting cells. The nuclei of the supporting cells align densely above the basement membrane and their apical cytoplasm supports the basal portion of the neuroepithelial cells (hair cells). The nuclei of the hair cells locate at about the middle height of the epithelium. A number of the cinocilia are tied up in a bundle and form the cupula. Beneath the basement membrane among the proliferated connective tissue a number of sections of the vestivular nerve fibers are seen.

20- cula utriculi 1. Monkey, H-E stain, x 33.

- The utriculus is an oblong vesicle protruding horizontally from the medio-anterior wall into the vestibular cavity. The macula utriculi, consisting of the tall sensory epithelium, extends from the medio-antderior portion to the latero-anterior portion of the utricular wall, that protrudes into the vestibular cavity. The macula utriculi is covered by a relatively thick gelatinous membrane , called otolithic membrane, which contains a multitude of minute (3 to 5 μ m) crystalline bodies, called otoliths or otoconia.
- In this figure, the macula utriculi covers the utricular wall protruding into the vestibulum. Beneath the macula underlies the loose connective tissue, in which numerous sections of vestibular nerve fibers are seen.

20- cula utriculi 2. Monkey, H-E stain, x 100.

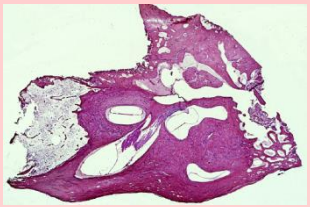


- Higher magnification of 20-24.
- The supporting cells are tall slender cells standing on the conspicuous basement membrane and extending to the free surface of the macula. Their nuclei are densely aligned above the basement membrane. Among the hair cells two types are dis- tinguished; the one are plump, flask-shaped cells with a round base and narrower neck region, the other are more slender and columnar in form. The basal portion of both types of hair cells does not extend down to the basement membrane but occupies rounded recesses between the apices of the surrounding supporting cells. The hair cells have one long kinocilium and numerous stereocilia of even length that project into the under side of the covering gelatinous membrane, called otolithic membrane, that contains a multitude of minute crystalline bodies (otoliths or otoconia). They are partially embedded in its upper surface.
- Beneath the basement membrane among the very loose connective tissue numerous sections of vestibular nerve fibers are seen.

20- orizontal Sections of Human Temporal Bone

- This specimen was donated by a patient died of cancer of the middle ear. The temporal bone of the sound side was carefully treated and prepared for the specimen and sectioned horizontally.

20-26 Horizontal section of human temporal bone 1. H-E stain, x 1.0.

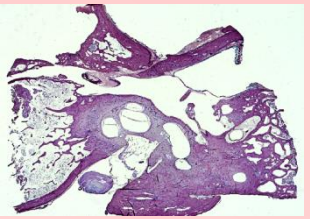


- This is the uppermost section passing through the upper pert of the tympanic cavity.
  ①:Tendon of M. tensor tympani.
  ②:Malleus.
  ③:Incus.
  ④:Tympanic cavity.
  ⑤:Ampulla and crista ampullaris.
  ⑥:Antrum mastoideum.
  ⑦:Ductus semicircularis.
  ⑧:Vestibular nerve.
  ⑨:Cochlear nerve.
  ⑩:Cochlear canal, the first turn.
  ⑪:Internal acoustic meatus.

20-27 Horizontal section of human temporal bone 2. H-E stain, x 1.0.

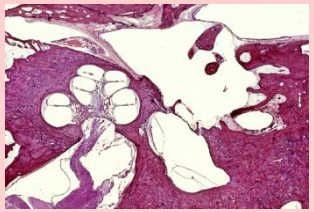
- The section is passing through the modiolus.
  ①: The space where the M. tensor tympani locates in.
  ②: Tympanic cavity.
  ③: Manubrium mallei with tendon of M. tensor tympani.
  ④: Tympanic membrane.
  ⑤: Chorda tympani.
  ⑥: Crus longum of incus.
  ⑦: Basis of stapes
  ⑧: Sacculus and macula sacculi.
  ⑨: Vestibulum.
  ⑩: Modiolus.
  ⑪: Vestibular nerve.
  ⑫: Cochlear nerve.
  ⑬: Cochlear canal, the first turn.
  ⑭: Internal acoustic meatus.
  ⑮: External acoustic meatus.

20-28 Horizontal section of human temporal bone 3. H-E stain, x 1.0.



- Section of lower portion of cochlea passing through the tendon of M. stapedius.
  ①:Eustachian tube.
  ②:Tympanic cavity.
  ③:Manubrium mallei.
  ④:Tympanic membrane.
  ⑤:Crus longum of incus.
  ⑥:Head of stapes
  ⑦:Tendon of M. stapedius.
  ⑧:Vestibulum.
  ⑨:Cochlear canal.
  ⑩:Internal acoustic meatus.
  ⑪:External acoustic meatus.

20-29 Horizontal section of human temporal bone 4. H-E stain, x 1.8.



- Higher magnification of the central portion of 20-18; section passing through the modiolus.
  ①: The space where M. tensor tympani locates is.
  ②: Tympanic cavity.
  ③: External acoustic meatus.
  ④: Tympanic membrane.
  ⑤: Manubrium mallei with tendon of M. tensor tympani.
  ⑥: Chorda tympani.
  ⑦: Crus longum of incus.
  ⑧: Basis of stapes.
  ⑨: Vestibulum.
  ⑩: Sacculus and macula sacculi.
  ⑪: Modiolus.
  ⑫: Cochlear canal, the first turn.
  ⑬: Cochlear nerve.
  ⑭: Vestibular nerve.
  ⑮: Internal acoustic meatus.
  ⑯: Canal through which facial nerve passes through.