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André Leblanc

ATLAS OF HEARING AND BALANCE ORGANS

A Practical Guide for Otolaryngologists

Forewords by J. P. Francke, Y. Guerrier, and C. Frèche

Springer

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Foreword

Twenty years ago André Leblanc first walked into the department to present his manuscript on the determination of the axes of the various foramens, canals, and sulci of the base of the skull, their tomographical investigation and their environment, to my master, Professor Claude Libersa. The project was thoroughly remodeled and enhanced by coupling classical anatomy with the exploding new imaging techniques.

Only a curious, minute, inventive, and tireless worker like André Leblanc could make this ambitions project a success. Thanks to his determination, he mobilized some of the best radiologists, clinicians, editors, and even anatomists, and urged each one of them on toward excellency. I admit that at times, we felt annoyed but we have forgiven him for the sake of his rigourous demonstration and admirable results.

André Leblanc's volume entitled "The Cranial Nerves", which was first published in French in 1989, and later in English, quickly became the definitive reference book for all those who deal with the cranial nerves, whether on a regular basis or occasionally. Thus a new updated edition was published both in French and English in 1995.

While others would have savoured their success, André Leblanc never stopped working, running from one congress to the next, and charming everybody from Chicago to Singapore to Taiwan... Not a month goes by without one of André Leblanc's new posters, more educational than ever, being added to the others to the walls of radiology practices or MRI centers.

The book we present today, entitled "Atlas of Hearing and Balance Organs A Practical Guide For Otolaryngologists", is a model of its kind in terms of rigour, knowledge, and aesthetics. The new perspectives that it offers will help each and everyone get a better grasp of the ear's organization and identify the 70 elements that are said to compose it.

We extend our deepest thanks to André Leblanc, for he is a wonderful teacher, and an heir, as Pierre Lasjaunias once said, to the French clinical and anatomical tradition. His many publications open a remarkable window onto the fields of anatomy and imaging. As Yves Guerrier stated without hesitation, here is a scientist whose reputation has reached far beyond our borders.

Professor Jean Paul Francke
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Foreword

It is an honour and a pleasure to write a foreword to Mr. André Leblanc's outstanding publication.

I have known him for many years. His exceptional talent has already been recognized, and will probably be appreciated worldwide in the forthcoming months.

It is a great honor for the French Society of Otolaryngology, of which I am president, to have contributed to such a success.

Professor Charles Frèche
Secretary General,
French Society of Otolaryngology
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American Hospital of Paris, Paris

Foreword

André Leblanc is an extremely talented illustrator of anatomy. He ranks among the most famous graphists of morphological textbooks published in the last few years.

He has now chosen to depict the auditory and vestibular pathways: nothing can be more abstract, as are the perilymphatic spaces that he represented with talent and precision. For those of us who already know, and even more so for those who are learning, these structures are very elaborate, and have been called, rightly so, the labyrinth.

Those who should know the constitution of the ear often didn't take time to look into it because, they said, it was too complex and too tedious. They will no longer be able to say that: the beauty and the precision of André Leblanc's drawings make the study of anatomy pleasant.

I would have liked to work with him, much as an author likes to write for a gifted musician.

Professor Yves Guerrier
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Preface and Acknowledgements

This volume on the internal ear adds substantial information to the eighth chapter of the second edition of my atlas entitled "The Cranial Nerves" (1995). Many preliminary explorations on dry bone and dissections were necessary to develop it. In contrast, imaging in a multitude of planes seems effortless, thanks to the angles that I have defined and tried on many morphologically very different patients over the years. These reference angles enable the investigator to determine the precise axis of an orifice or to view the course of a nerve. They can be used regardless of the morphology or the state of the patient, and take possible asymmetries into account.

This new publication entitled "Atlas of Hearing and Balance Organs" is a simple yet original approach to anatomical investigation and imaging. When used as a guide (the auditory tract is depicted by means of serial macroscopic sections and dissections, but also imaging), most of the vulnerable parts of the nerve and the vestibulocochlear pathway can be quickly visualized.

The benefits of this book lie not only in the combination of anatomy with modern imaging techniques (CT and MRI), but also and predominantly in the numerous diagrams of bony fenestrations of the cochlea, the vestibule and the semicircular canals. These views reveal the membranous labyrinth, the internal organs of balance and audition, and highlight their innervation, as well as the utricular and saccular nerves, the nerve of the spiral organ of Corti....

The vestibulocochlear nerve is depicted from its true (nuclei) and apparent (bulbopontine sulcus) origins, on through its course in the canal, and to the innermost part of the ear. The endolymphatic system is described by means of computed tomographies and shows the aqueduct of the vestibule and the endolymphatic duct. The study of perilymphatic space also relies on computed tomography to evidence the aqueduct of the cochlea and the perilymphatic duct.

Vasculature of the auditory tract is traced from the vertebral artery to the arteries of the internal ear.

Constant progress in new imaging techniques has broadened the possibilities of oblique planes and three-dimensional reconstruction. This new "method" can thus be easily adapted to new technologies, although the reading of the views may prove more delicate.

It is a fact that clinicians and radiologists need extremely detailed anatomical references. This work will be a precious guide for them in the areas of anatomy and imaging techniques.

Let us list a few of the most relevant aspects of the book:

- a guide for otolaryngologists, neurologists, anatomists, and radiologists;
- valuable teaching material for this difficult-to-explore area;
- assistance the investigation of temporal neuralgia and otalgia, early diagnosis of neurinoma, otosclerosis, cholesteatoma, and tumoral formations, though limited in size, from the onset of clinical signs;
- easier exploration, regardless of the state and morphology of the patient;
- a means to obtain CT and MRI views in minimum time thanks to the precisely defined reference angles;
- a channel to renew interest in this part of the body also due to the progress in tomography and in magnetic resonance imaging. The quality of spatial resolution now makes it possible to visualize the meanders in the canal, the intracranial course of the nerves, and the cavities of the inner ear.

This book is the fruit of 40 years of work and research, during which I was assisted by the Institute of Anatomy of the Faculty of Medicine in Lille, and in particular by Professor J. P. Francke, whom I wish to thank for the anatomical sections and dissections that he has faithfully carried out since 1980 every time a chapter required this type of illustration.

I wish to dedicate this book to Professor Claude Libersa. By his presence and expertise, he gave me the means to pursue my study of an arduous discipline when others didn't attribute much credit to this work.

Thanks to his generous support and his determination, the many posters illustrating the course and vasculature of the cranial nerves, as well as the first two editions of the atlas dedicated to the cranial nerves, were able to be completed and published, and thus satisfy the needs of medicine and modern science.

Today the third edition of the atlas, which is under way, and this volume more specifically geared toward otolaryngologists, came to be because of him, and I wish to express my gratefulness to him.

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Important Notice

Before reaching the muscles they supply, the cranial nerves pass through a number of foramina, canals, and sulci. Each one of these orifices has a very specific axis, and it is along this axis that it should be viewed.

Traumatism on the skull can cause a number of pathologies ranging from anaesthesia to paralysis. They are the result of either haematomas due to a fracture, or tumoral lesions which compress the canal containing the nerve.

Each structure through which the cranial nerves pass has its vulnerable points. Therefore great care should be taken to explore each channel along its own axis, for fear of deforming the image and thus, making the wrong diagnosis.

A few years back imaging relied exclusively upon conventional X-ray machines, which mainly provided views of the bones. When exploring a cranial nerve related pathology, radiological examination was limited to viewing the bony orifice of interest, exactly along its axis, based on two reference lines. These reference lines were constant, regardless of the morphology and the state of the patient, and took possible asymmetries into account.

Thus, conventional X-ray investigations required a very detailed knowledge of anatomy. Unfortunately, modern imaging techniques have contributed to the decline of anatomy as a discipline.

It is true that computed tomography and magnetic resonance imaging have become the main tools in intracranial exploration, for they provide the likes of an anatomical section. Nevertheless, CT and MRI views are rarely taken along the axis of the ostia and canals. Although the images are three-dimensional, and because most channels are extremely sinuous, the operator can fail to notice a small fracture, a haematoma, or a minute lesion compressing a nerve if proper orientation of the views is not respected.

Reliable views can be obtained by following the conventional technique based on centreing and anatomical references. This is also possible with CT and MRI, thanks to the broad possibilities of orientation and three-dimensional reconstruction.

Thus the conventional method can easily be adapted to modern imaging. Interpretation is rendered more delicate, it is true. But clinicians and radiologists must refer to detailed anatomical information.

That is why the author continues to present the descriptions and diagrams, which he has adapted to modern imaging techniques, of conventional reference angles in both the present volume and the third edition of his atlas entitled "The Cranial Nerves" © 2000.

André Leblanc

Contents

Anatomy	Imaging
Origin – Distribution – Collaterals	Areas explored
To study these structures	*Explore the areas*
Real and apparent origins, intracisternal course.	Pontine cistern, study of the bulbopontine sulcus and the inferior portion of the pons for the anterior part of the fourth ventricle.
Intracanalar course.	Investigation of the external acoustic meatus.
Spiral organ of Corti, cochlear ganglion. Vestibular ganglion, utricle, saccule, ampullary crests.	Study of the cochlea, vestibule, and semicircular canals.
Endolymphatic system. Perilymphatic space.	Exploration of the semicircular canals, vestibule and cochlea to visualize the aqueduct of the vestibule and the endolymphatic duct for the endolymphatic system, and the aqueduct of the cochlea for the perilymphatic space.
Ossicles, middle ear.	Views of the incudomallear and incudostapedial articulations (hearing ossicles) and of the epitympanic recess.
Auditory tube, cavities of the middle ear.	Exploration of the auditory tube, the pharyngeal recess, the epitympanic recess and the mastoid antrum.

Fig. 1

The vestibulocochlear nerve is a sensory nerve. It consists of two parts: the cochlear nerve and the vestibular nerve. The nerve enters the pons at the lateral extremity of the medullopontine sulcus, lateral to the facial nerve and a little above and in front of the glossopharyngeal nerve.

Topographical description

Real origins of the vestibular and cochlear nerves (nuclei)
- Inferior pons
- Floor of the fourth ventricle

Apparent origin of the vestibulocochlear nerve
- Bulbopontine sulcus
- Pontine cistern

Vestibular nerve, vestibular ganglion
Utricle, saccule, ampullary crests
- Internal acoustic meatus
- Vestibule
- Semicircular canals

Cochlear nerve, cochlear ganglion
Spiral organ of Corti
- Internal acoustic meatus
- Cochlea

Endolymphatic system
- Vestibule
- Semicircular canals
- Cochlea
- Cochlear duct
- Membranous labyrinth
- Aqueduct of vestibule
- Endolymphatic duct

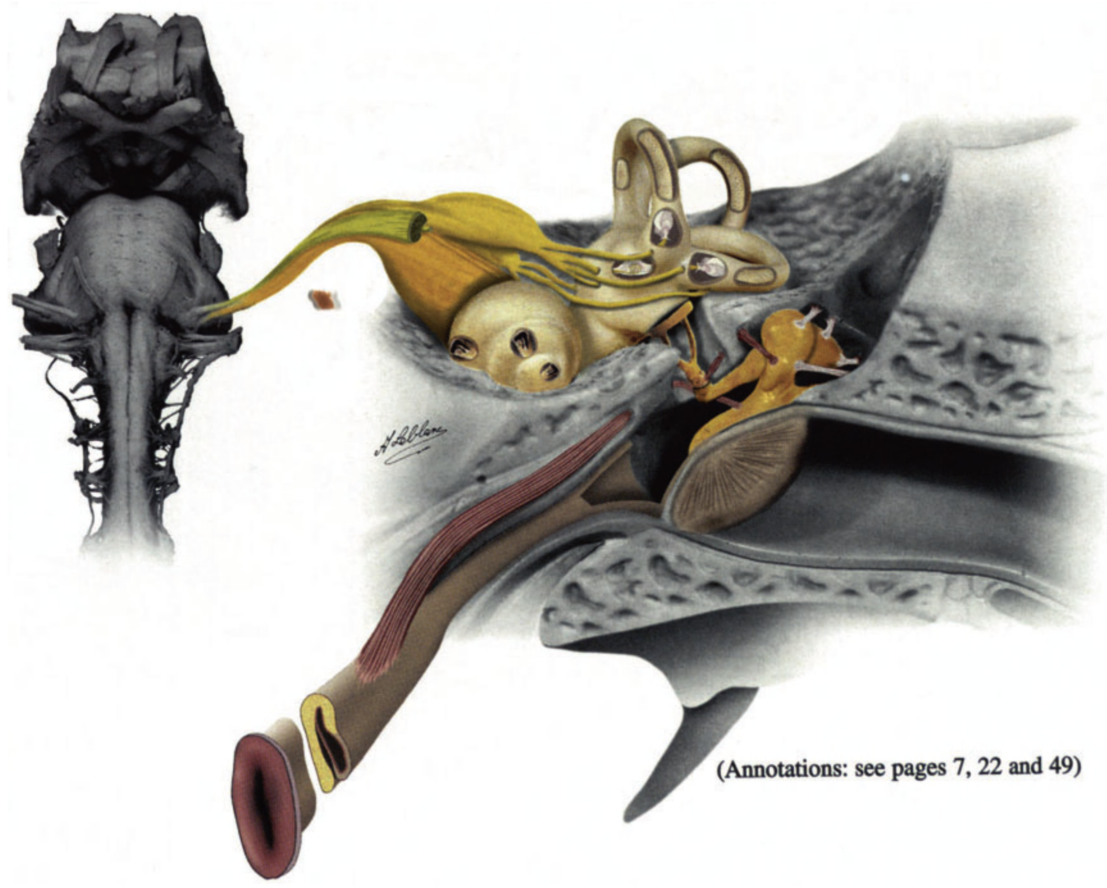
Perilymphatic space
- Vestibule
- Semicircular canals
- Cochlea
- Scalae vestibuli and tympani
- External orifice of perilymphatic duct
  (petrosal fossula of IX)
  and perilymphatic duct

Internal ear

Middle ear
- Tympanic cavity
- Ossicular chain
- Epitympanic recesses
- Mastoid antrum
- Epitympanic space

Nasotubal orifices of the middle ear
- Auditory tube
- Pharyngeal or Rosenmüller's recess
- Nasal cavity
- Epitympanic recess
- Mastoid antrum

External ear
- External acoustic meatus



(Annotations: see pages 7, 22 and 49)

Fig. 2 Diagram of internal, middle, external ear and organs of hearing and balance

TRUE ORIGIN OF THE VESTIBULOCOCHLEAR NERVE
VESTIBULAR AND COCHLEAR NUCLEI

Anatomy, diagrams, and MRI views

Cochlear and vestibular nuclei

The **cochlear nuclei** collect information from the inner and outer hair cells contained in Corti's spiral organ via the cochlear root of the vestibulocochlear nerve. Dendrites pass through the spiral lamina and reach the spiral canal of the modiolus (Rosenthal's canal) (Fig. 12. e; 15. b, h).

The cochlear nuclear complex is located on the dorsolateral side of the brain stem, next to the bulbopontine junction. It consists in a ventral nucleus and a dorsal nucleus. The anterior nucleus rests on the anterior and exterior face of the inferior cerebellar peduncle, while the posterior nucleus is continuous with the lateral recess of the fourth ventricle (Fig. 3. a– f).
This is where an electrode should be placed for central stimulation.
The secondary sensory neurons in the cochlear path extend to the medial geniculate body after 80% of them have decussated. They form a polysynaptic chain called the lateral lemniscus.
The terminal neurons arise from the geniculate body and end in the transverse temporal gyrus (area 41).

The **vestibular nuclei** collect the impulses from the base of the ciliated cells in the vestibular epithelium that coats the labyrinth, e.g., the semicircular canals, utricle, and saccule (Fig. 14. b– g; 15. e, f).
Dendrites belonging to the vestibular nerve form two roots: the superior vestibular root, resulting from the merging of the utricular nerve and fibers from the ampullary crests on the anterior and lateral semicircular canals; and the inferior vestibular root, which is constituted by the fibres from the saccular macula and the posterior semicanal. Both roots reach the vestibular ganglion located in the most posterior part of the external acoustic meatus (Fig. 4; 11. b, c; 14. c; 15. f).
Classically, the vestibular nuclei, located at the bulbopontine junction, are divided into four groups: the superior vestibular nucleus (Bekhterev's nucleus), the medial, lateral, and inferior vestibular nuclei. They connect with the archeocerebellum, the thalamus, and the cerebral cortex via the central vestibular pathway, and with the spinal cord via the vestibulospinal tract (Fig. 3. a–f).

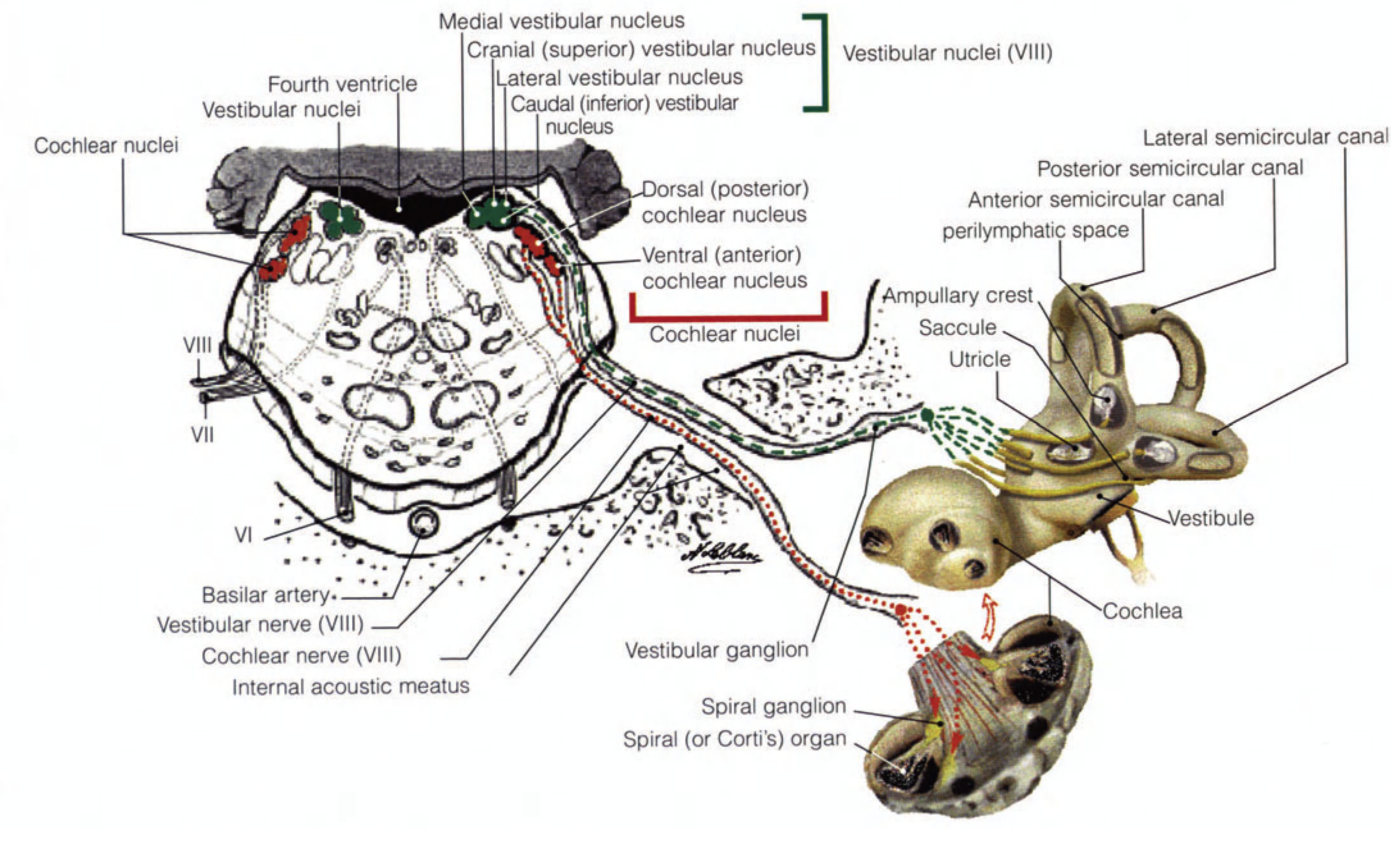
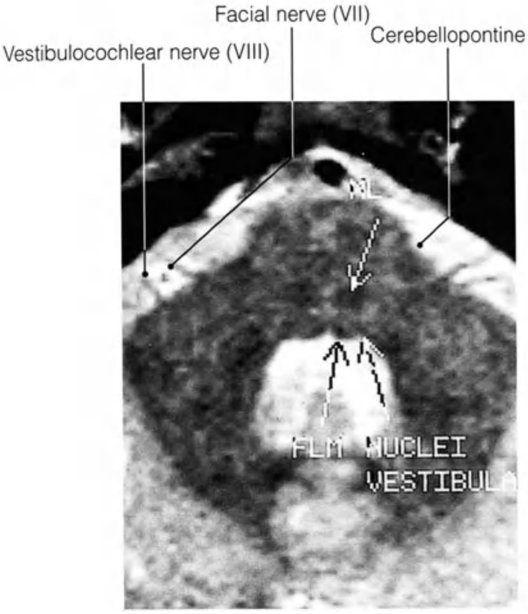


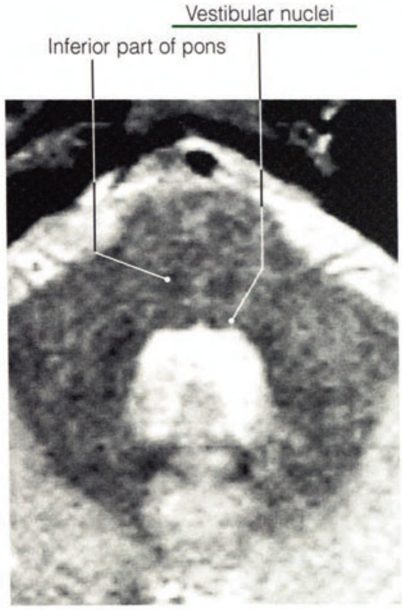
Fig. 3 a–f. Diagram of vestibulocochlear nuclei (**a**), red dotted lines: cochlear nuclei; green dotted lines: vestibular nuclei; axial MRI view at the level of the pons for the nuclei (**b–e**); posterior anatomical view of the brain stem at the level of the floor of the fourth ventricle showing the position of the vestibulocochlear nuclei (**f**) (MRI: Dr. J. W. Casselman, A.Z. St Jan, Brugge)



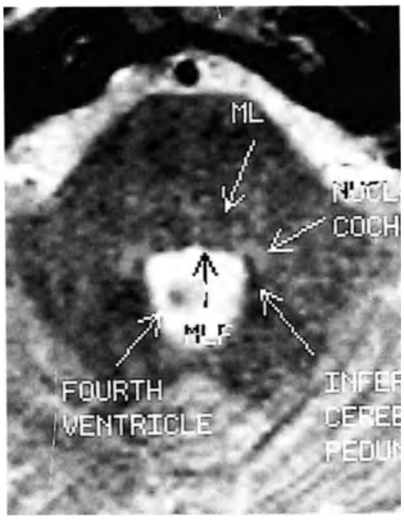
Facial nerve (VII)
Vestibulocochlear nerve (VIII)
Cerebellopontine angle
ML
FLM
NUCLEI
VESTIBUL

b

c



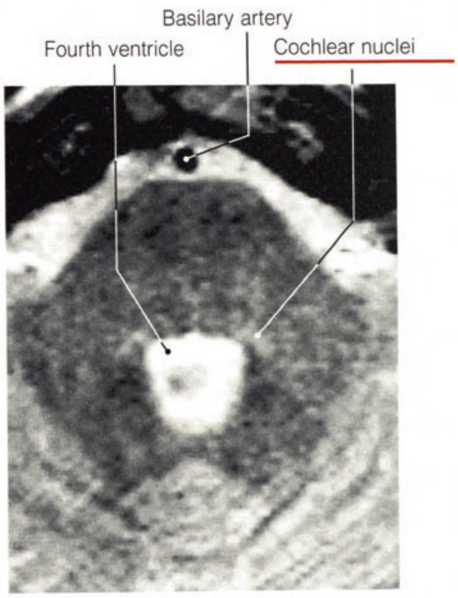
Vestibular nuclei
Inferior part of pons



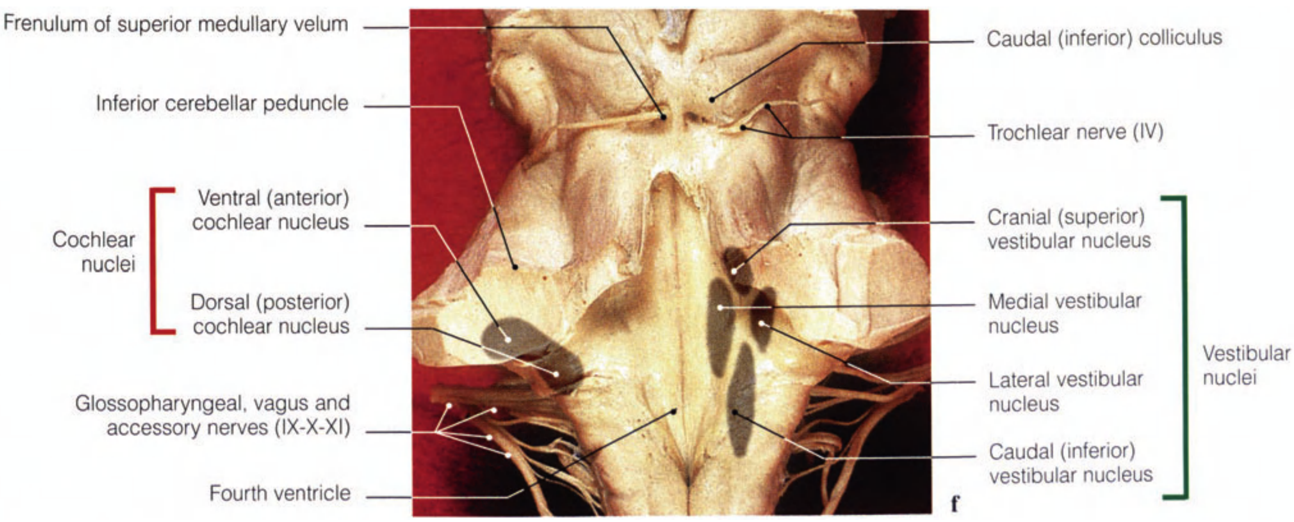
ML
NUCL
COCH
MLF
FOURTH
VENTRICLE
INFER
CEREB
PEDUN

d

e



Basilary artery
Fourth ventricle
Cochlear nuclei



Frenulum of superior medullary velum
Inferior cerebellar peduncle
Cochlear nuclei
Ventral (anterior) cochlear nucleus
Dorsal (posterior) cochlear nucleus
Glossopharyngeal, vagus and accessory nerves (IX-X-XI)
Fourth ventricle
Caudal (inferior) colliculus
Trochlear nerve (IV)
Cranial (superior) vestibular nucleus
Medial vestibular nucleus
Lateral vestibular nucleus
Caudal (inferior) vestibular nucleus
Vestibular nuclei

f

APPARENT ORIGIN OF THE VESTIBULOCOCHLEAR NERVE

BULBOPONTINE SULCUS

Anatomy, diagrams, and MRI views

(Pages 6–9)

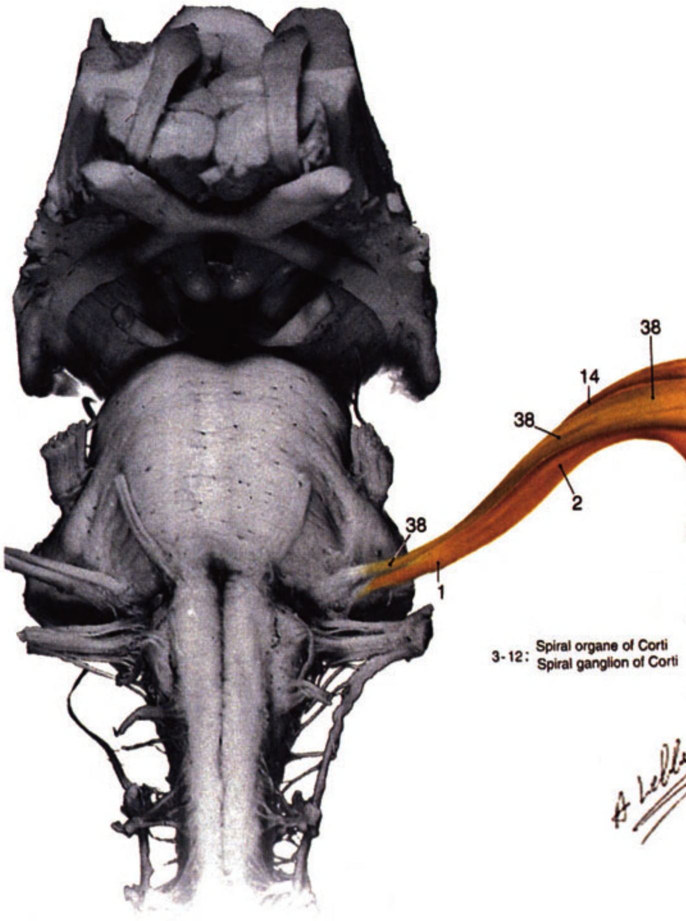


Fig. 4

1 Vestibulocochlear nerve (VIII)

COCHLEAR NERVE (VIII)

2 Cochlear nerve (VIII)
3 Spiral ganglion of Corti (VIII)
4 Scala tympani
5 Outer hair cells
6 Cochlear duct
7 Scala vestibuli
8 Inner sulcus cells
9 Hensen's cells
10 Stereocilia
11 Tectorial membrane
12 Vestibular membrane
13 Cochlea

VESTIBULAR NERVE (VIII)

14 Vestibular nerve (VIII)
15 Superior vestibular ganglion of Scarpa
16 Anterior ampullary nerve (VIII)
17 Anterior ampullary nerve entering ampullary crest
18 Neuroepithelium
19 Hair cells
20 Sensory hair of cupula
21 Osseous labyrinth
22 Membranous labyrinth
22b Perilymphatic space
23 Anterior semicircular canal
23b Common bony canal
24 Lateral ampullary nerve
25 Ampullary sulcus
26 Ampullary crest
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29 Posterior ampullary nerve
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32 Stereocilia
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38 Facial nerve (VII)
39 Intermediate nerve [Wrisberg] (VIIb)

MIDDLE AND EXTERNAL EAR

40 External acoustic meatus
41 Tympanic membrane
42 Handle of malleus
43 Anterior process of malleus
44 Lateral process of malleus
45 Neck of malleus
46 Head of malleus
47 Lateral ligament of malleus
48 Superior ligament of malleus
49 Malleus muscle
50 Short crus of incus
51 Body of incus
52 Superior ligament of incus
53 Posterior ligament of incus
54 Long crus of incus
55 Lenticular process of incus
56 Stapedius muscle
57 Head of stapes
58 Posterior crus of stapes
59 Oval window and base of stapes
60 Superior epitympanic recess
61 Mastoid antrum
62 Auditory tube
63 Tensor muscle of tympanum

Anatomy

The **vestibulocochlear nerve** is a sensory nerve and consists of two parts: the cochlear nerve (for audition) and the vestibular nerve (for balance).

The **cochlear nerve** joins the vestibular nerve, traverses the internal acoustic meatus, becomes intracisternal and then enters the neuraxis via the lateral part of the medullopontine sulcus. It terminates in the cochlear nuclei at the lower part of the pons: the anterior nucleus and the dorsal nucleus.

The **vestibular nerve** gathers the auditory impressions in the internal ear and then transmits these centrally.

POSSIBLE CAUSES: Inferior protuberantial syndrome (Foville's syndrome), acousticofacial neurinoma (VII - VIIb - VIII) at the level of the cerebellopontine angle, lesions of the pons and the medulla oblongata.

EXAMINATION: Study by magnetic resonance imaging (MRI) or computed tomography (CT) of the cerebellopontine angle of the medullopontine sulcus, so as to visualize the apparent origin of the vestibulocochlear nerve (VIII) in sagittal and axial views and the Worms-Bretton semiaxial view.

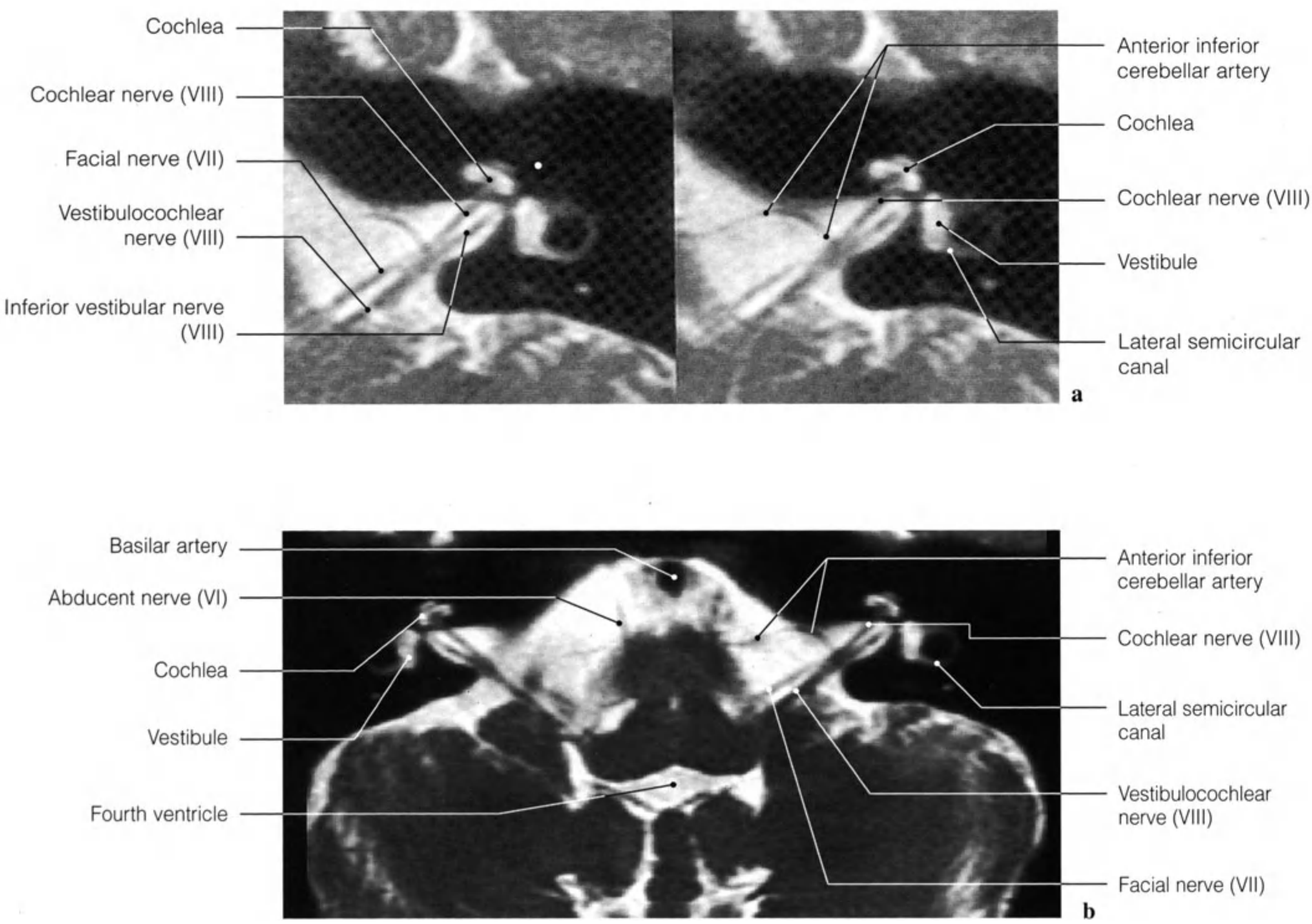
The sections in the Worms-Bretton view are made starting from the level of the sella turcica up to below the external acoustic meatus. The technique of examination is identical to that used for the apparent origin of the facial nerve (VII).

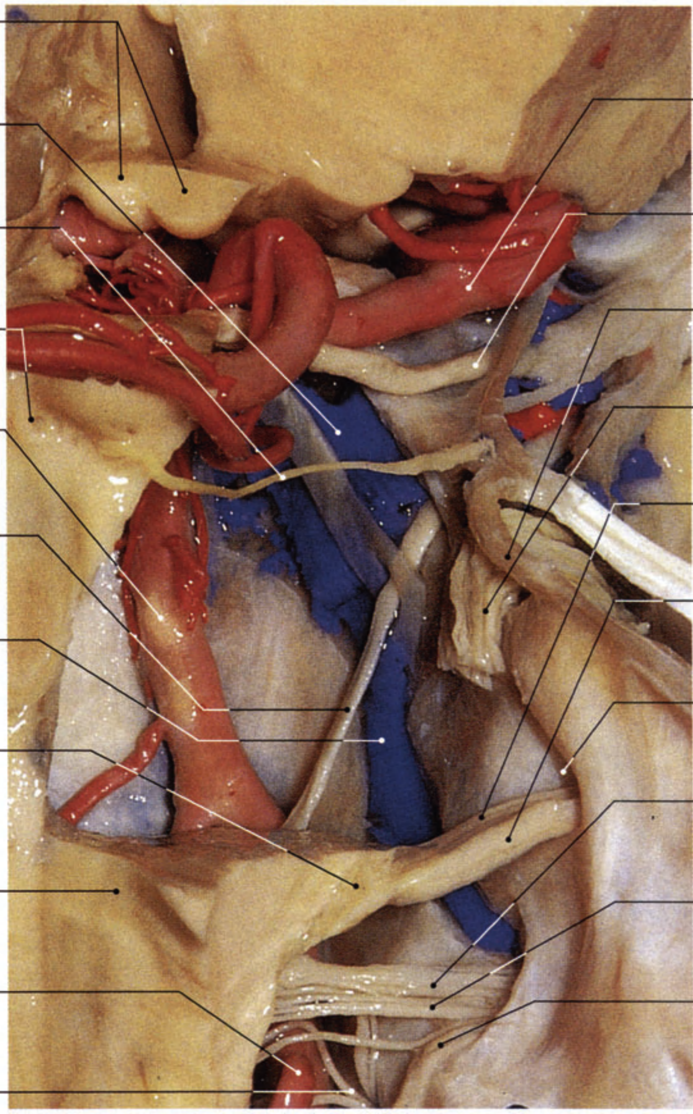
Note: In order to eliminate any possibility of an intracanalicular lesion (ballooning of the internal acoustic meatus), it is necessary to make a comparative study of the internal acoustic meatuses should be carried out using the intraorbital survey view before embarking on this study.

Cerebellopontine angle

Magnetic resonance imaging (MRI)

AXIAL VIEWS





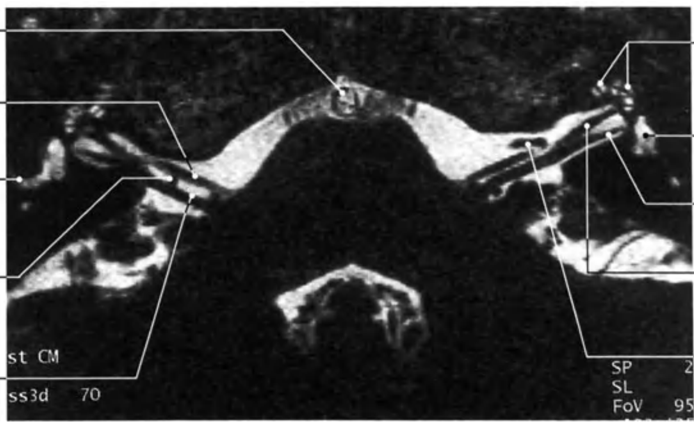
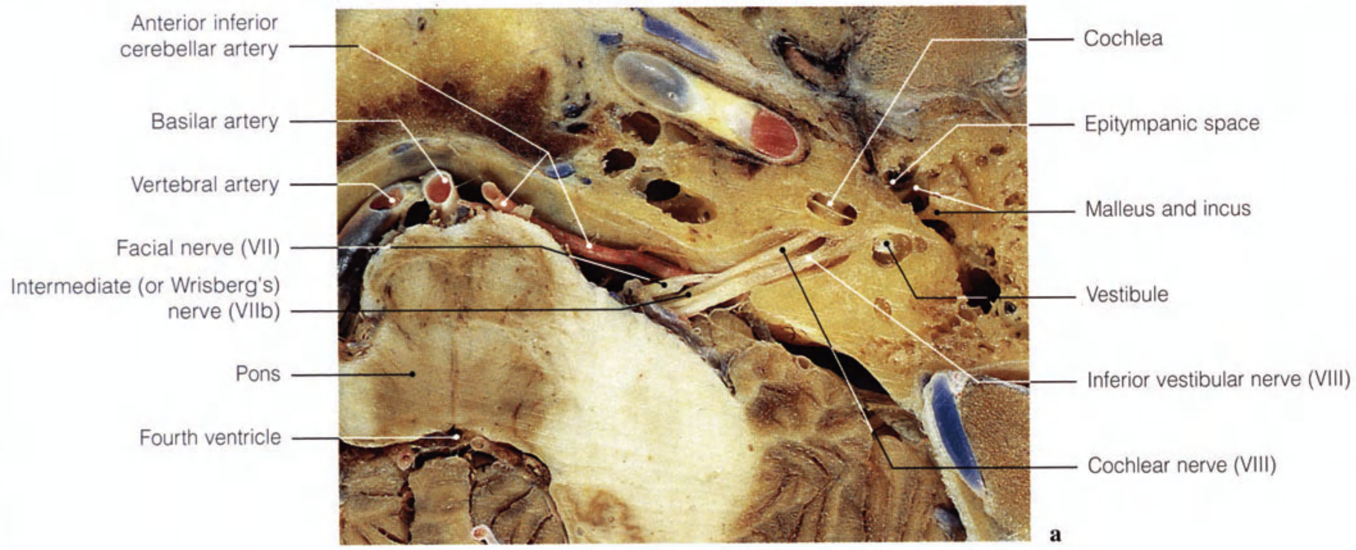
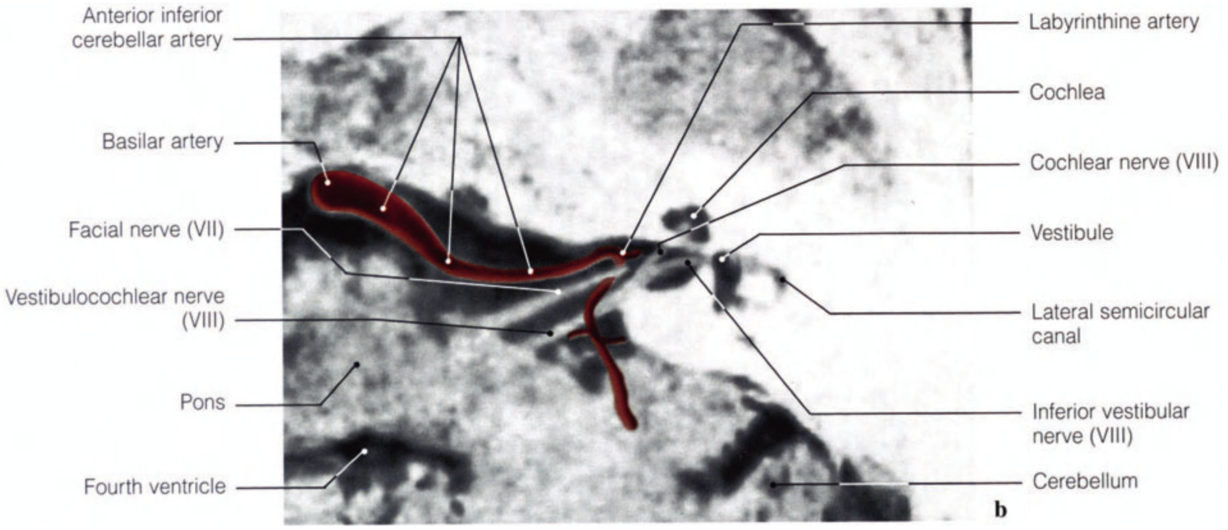


Fig. 5 a–d MRI views (**a, b, d**) and posterior anatomical view (**c**) of the brain stem showing the apparent origin of the vestibular and cochlear nerves (anatomical view: Prof. C. Sen, Prof. C. S. Chen, Prof. K. D. Post, *Microsurgical Anatomy of the Skull Base*, Thieme, 1997)

VESTIBULAR AND COCHLEAR NERVES
CEREBELLOPONTINE ANGLE – EXTERNAL ACOUSTIC MEATUS



a



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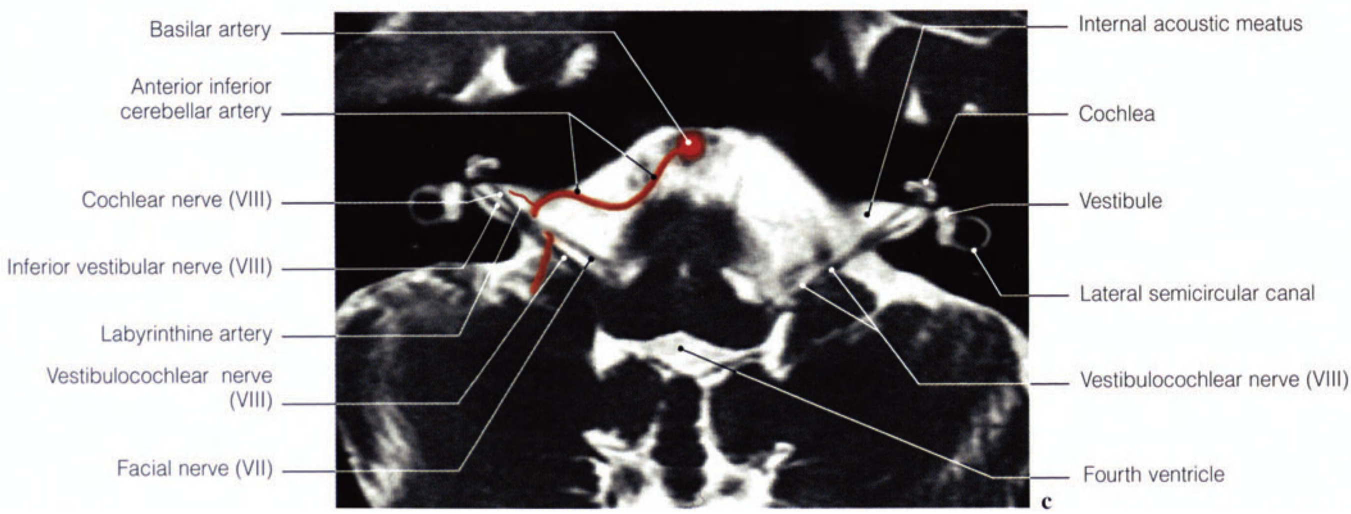

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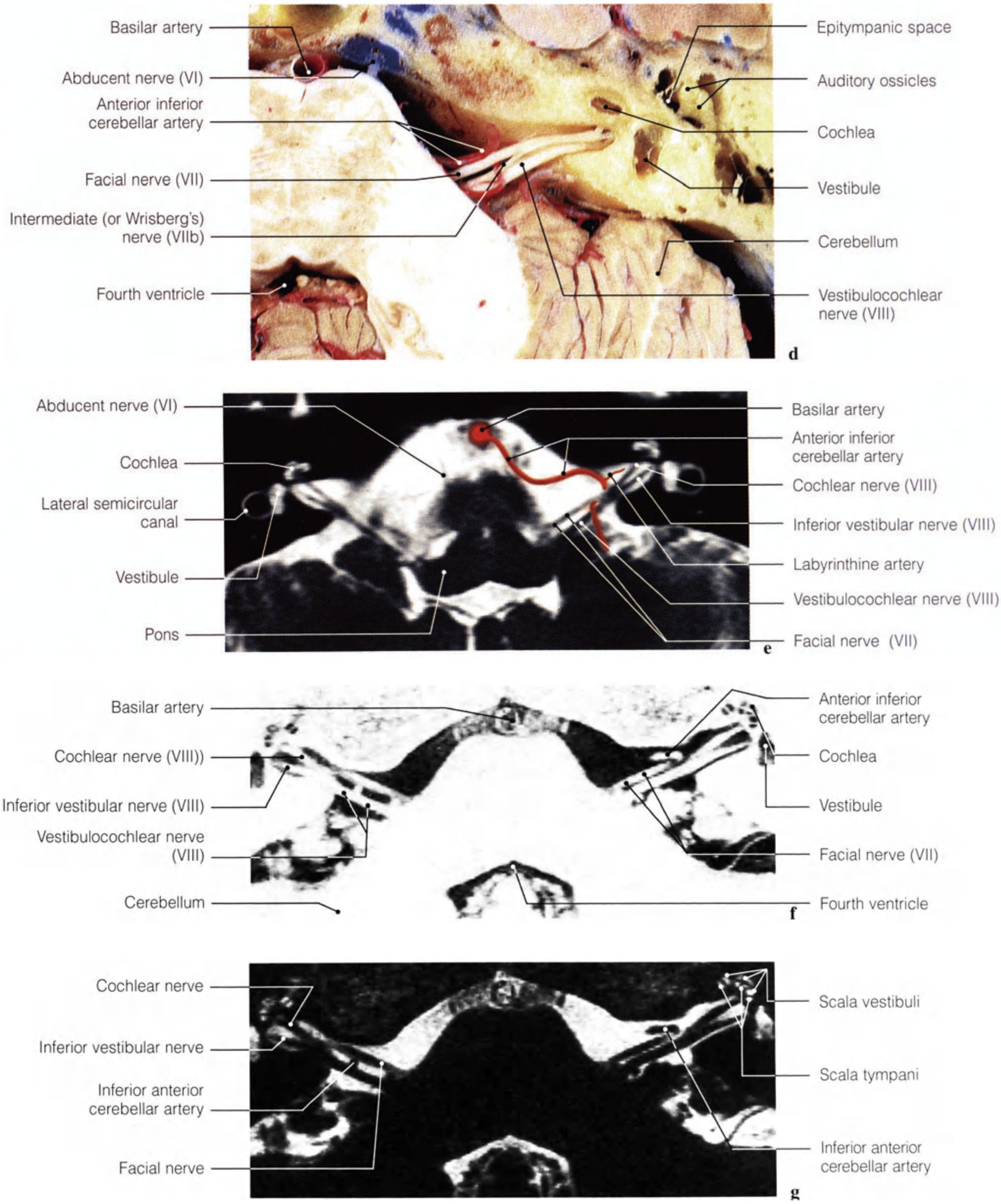


Fig. 6 a–g. Axial anatomical sections **(a, d)** and MRI views **(b, c, e–g)** of the cerebellopontine angle showing the vestibular and cochlear nerves (anatomical sections: Prof. J. P. Francke, Faculty of Medicine, Lille; MRI: **b, c, e,** Prof. Y.S. Cordoliani, Dr. J. L.Sarrazin, Hôpital du Val-de-Grâce, Paris; **f, g,** Dr. J. W. Casselman, A.Z. St Jan, Brugge)

INTERNAL EAR AND VESTIBULOCOCHLEAR PATHWAYS ORGANS OF HEARING AND BALANCE

SPIRAL ORGAN OF CORTI, AMPULLARY CRESTS, MEMBRANOUS LABYRINTH, MODIOLUS, UTRICLE, SACCULE, VESTIBULE, SEMICIRCULAR CANALS

Anatomy, diagrams, CT and MRI views

(Pages 12-28)

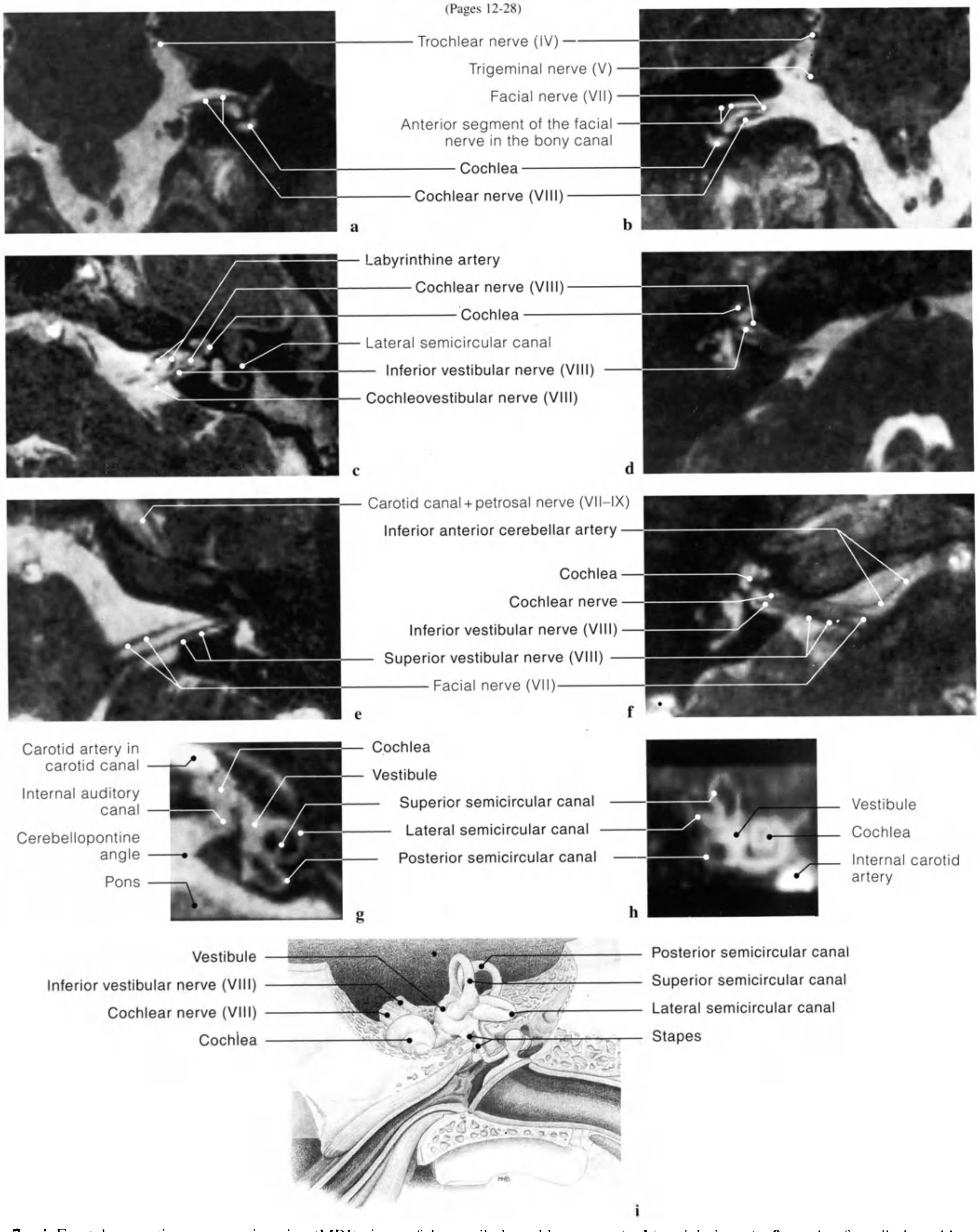


Fig. 7 a–i. Frontal magnetic resonance imaging (MRI) views of the vestibulocochlear nerve **(a, b)**; axial views **(c–f)**; study of vestibulocochlear pathways **(g–i)** of antro-attical passages and of the ossicles and vestibulocochlear pathways. (MRI: Dr. J. W. Casselman, A.Z. St Jan, Brugge)

The internal ear includes the *bony labyrinth* and the *membranous labyrinth.*
The vestibular and acoustic nerve pathways arise from the membranous labyrinth.

The bony labyrinth consists of three parts :
– a media chamber, the vestibule,
– the semicircular canals in a posterior position,
– the cochlea, located anteriorly.

The internal acoustic meatus also forms part of the bony labyrinth (Fig. 8. b).

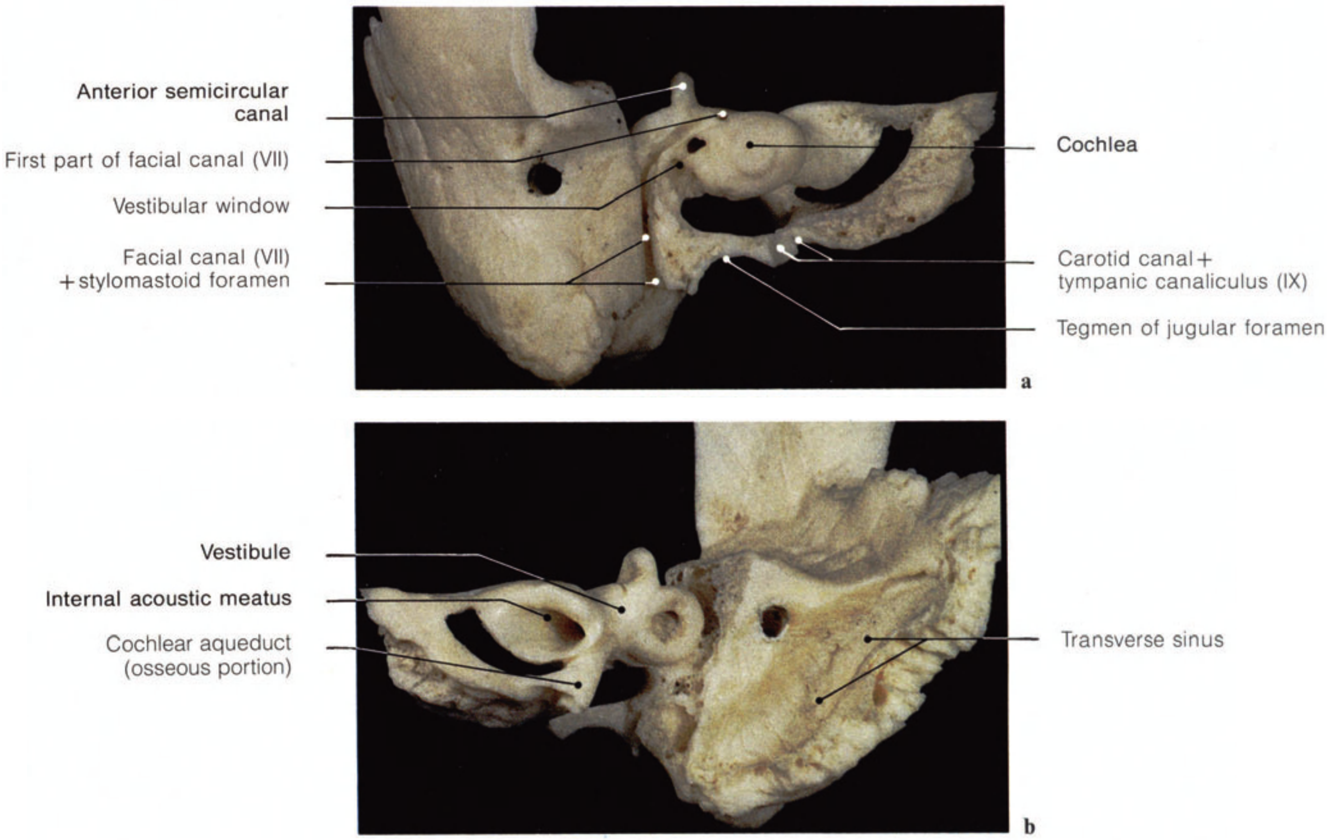


Fig. 8 a, b. Anterior **(a)** and posterior **(b)** views of bony labyrinth

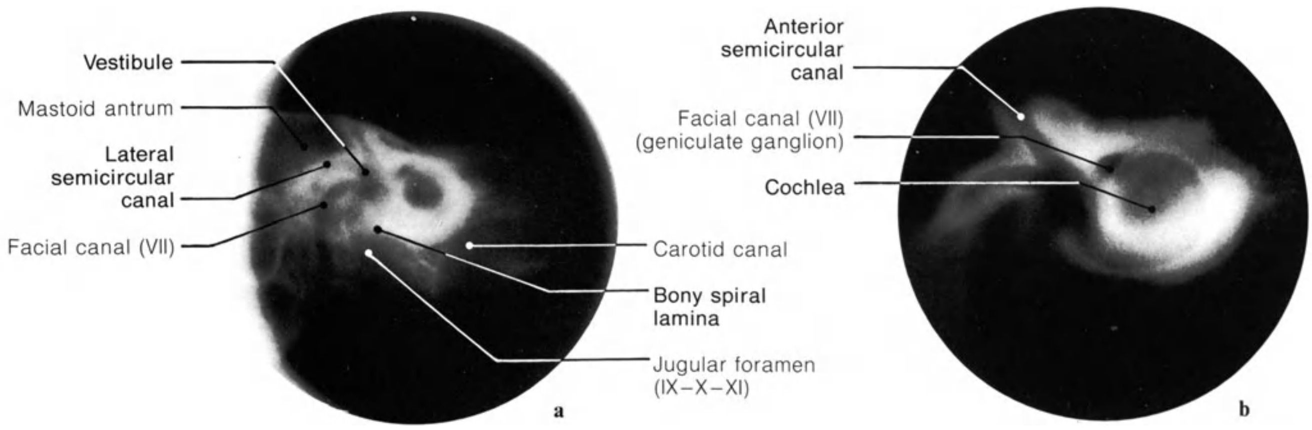


Fig. 9 a, b. Tomograms of semicircular canals, vestibule and facial canal (anatomic specimen)

Anatomy

COURSE – RELATIONS

The *cochlear ganglion* occupies the extent of the spiral cochlear canal.

The ramifications of origin of the vestibulocochlear nerve join the cochlear ganglion via the canaliculi of the secondary spiral lamina.

The axons of the cells of the cochlear ganglion constitute the fibres of the cochlear nerve. This nerve reaches the pons in the lateral part of the medullopontine sulcus. It ends in the ventral and dorsal cochlear nuclei.

The *ganglion of Scarpa* is situated in the fundus of the internal acoustic meatus (Fig. 10, 11). The axonal prolongations of its cells conduct sensations arising in the saccule, utricle and the ampullae of the semicircular canals.

These axons form the fibers of the vestibular nerve, which enters the pons at the same site as the cochlear nerve and medial to it. It terminates in the nuclei of the vestibular region of the floor of the fourth ventricle.

POSSIBLE CAUSES

- Acoustic neurinoma,
- extensive cholesteatoma of the antro-adito-attical region expanding inwards and capable of damaging either the vestibule or the cochlear region,
- otosclerosis of the base of stapes, stage 5, penetrating the vestibule and the first turn of the cochlear spiral,
- fracture of the bony labyrinth, especially of the internal acoustic meatus,
- spreading fracture with disjunction of the lambdoid suture.

EXAMINATION

- Radiologic and computed tomographic (CT) studies of the internal acoustic meatuses in symmetric, intraorbital, frontal survey view,
- radiographic or CT study of the internal acoustic meatus in the long axis of the petrous bone in unilateral Chaussé IV view,
- study of the internal acoustic meatus in Pöschl-Meyer view,
- radiography in Stenvers view,
- study in 40° opposed transorbital view of François and Barrois,
- tomographic study in prestudied inclined sagittal view of Cornélis.

These views display the internal acoustic meatus, its transverse (or falciform) crest, the cochlea, vestibule, semicircular canals, chain of ossicles and the antro-adito-attical region (Fig. 27–36).

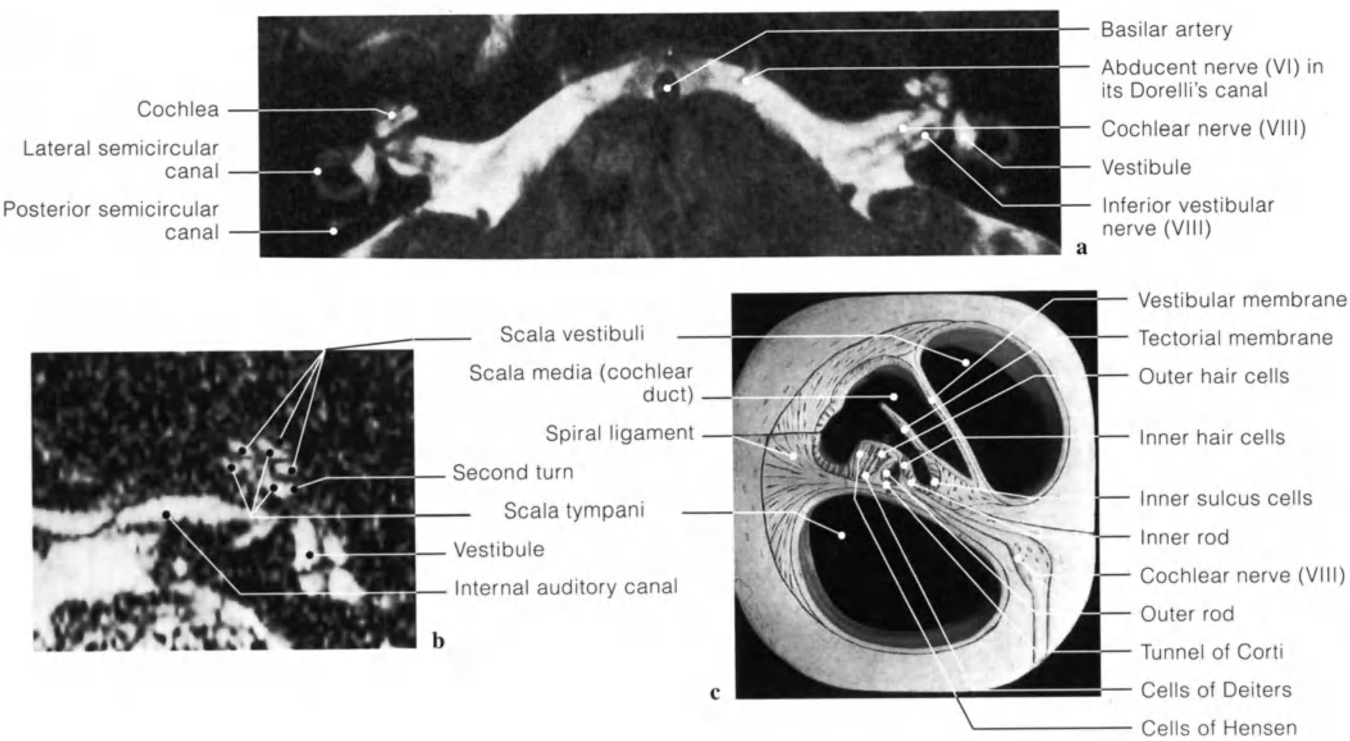
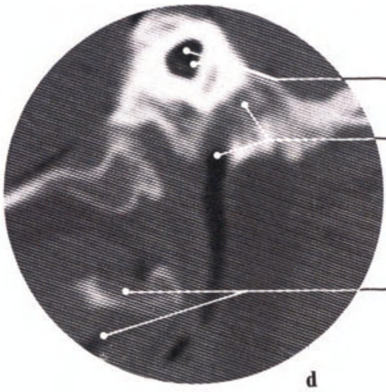
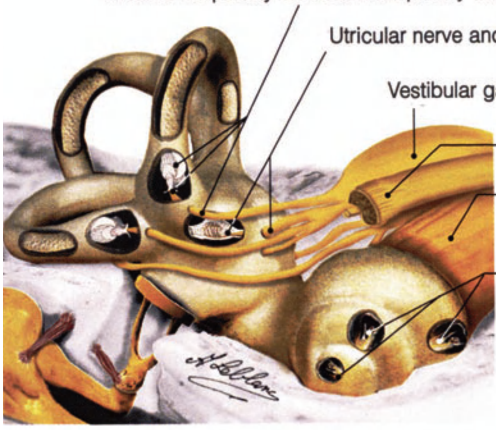


Fig. 10 a–j. Magnetic resonance (MRI) view and section through the cochlea showing the detail of spiral organ of Corti (**a–c**); diagrams, tomography, MRI, computed tomography (CT) and anatomic sections showing the vestibulocochlear nerve and the cavities of the internal ear (**d–j**). (MRI: Dr. J. W. Casselman, A.Z. St Jan, Brugge)

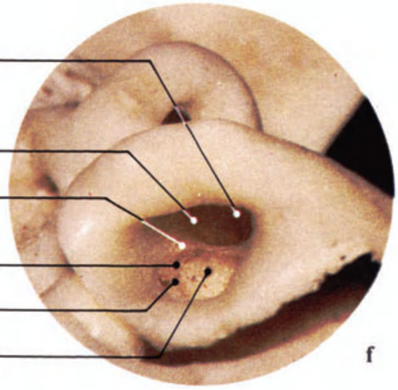


d

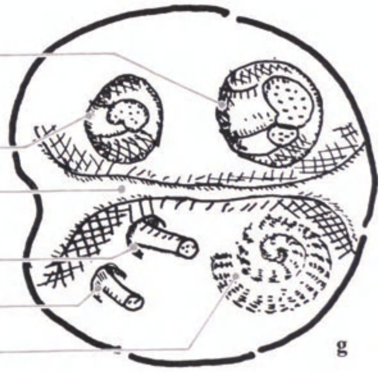


See page 22

e

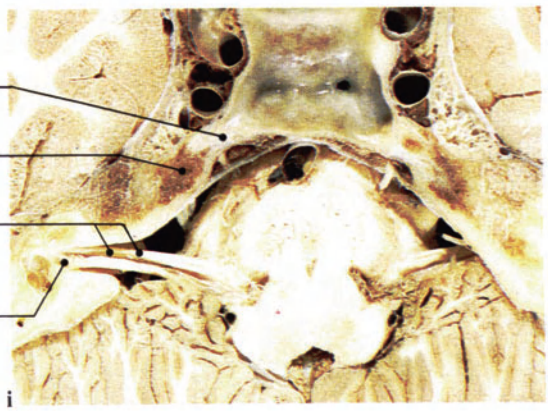


f

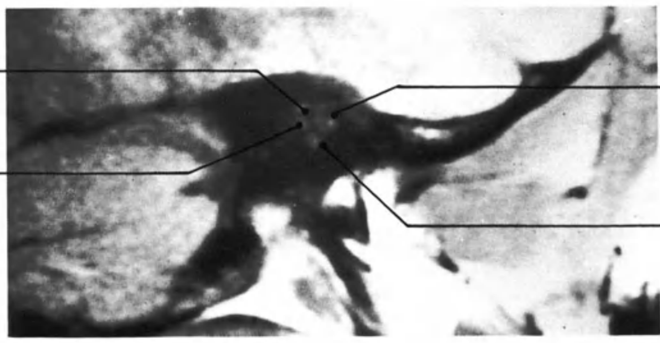


g

h



i



j

The **membranous labyrinth** is a system of interrelated cavities with membranous walls. The posterior labyrinth is involved in balance. It comprises the saccule, the utricle, the semicircular canals, and the endolymphatic duct. The anterior labyrinth consists in the cochlear duct, and is responsible for audition.

These cavities communicate by means of canals filled endolymph. The semicircular canals and the cochlear duct follow the bony cavities (Fig. 18. a–d).

A second compartment the perilymphatic space filled with fluid is located between the osseous labyrinth and the membranous labyrinth: (Fig. 19. a–d).

The **organ of Corti:**

- It is a sensorineural organ containing the auditory receptors. It rests on the basilar membrane between two sulci: the external spiral sulcus and the internal spiral sulcus.
- sensory epithelium in the spiral organ of Corti is composed of three rows of outer hair cells with stereocilia (Fig. 12. e).

These cells may be contractile.

There is only one row of inner hair cells.

The **tectorial membrane of cochlear duct** is composed of a gelatinous layer and a superficial fibrous layer. It can be divided into three segments: the internal segment, the medial segment, and the external segment (Fig. 12; 13).

The **utricle** is a long, oval vesicle solidly attached with utricular nervous fibers and conjunctive tissue.

- The macula represents the sensory area of the utricle. It is located on the anterior part of the floor, facing the semioval fossula, in a horizontal plane.
- The utricular branch of the endolymphatic duct opens immediately behind the macula (Fig. 16. b, c, e).
- The apertures of the semicircular canals in the utricle are divided into two groups:

• the ampullary orifice of the posterior canal opens with the non-ampullary orifice of the lateral canal;

• the ampullary orifices of both the anterior and lateral canals open in the ceiling of the anterior extremity (Fig. 16. e).

The **saccule** is a rounded vesicle resting on the floor of the vestibule. From its inferior posterior pole stems the canalis reuniens, which connects the saccule to the cochlear duct. The posterior inferior end of the saccule bears the saccular branch of the endolymphatic duct (Fig. 16. c, e).

The macula of saccule is located on the medial face, in the vertical plane.

See caption on page 22

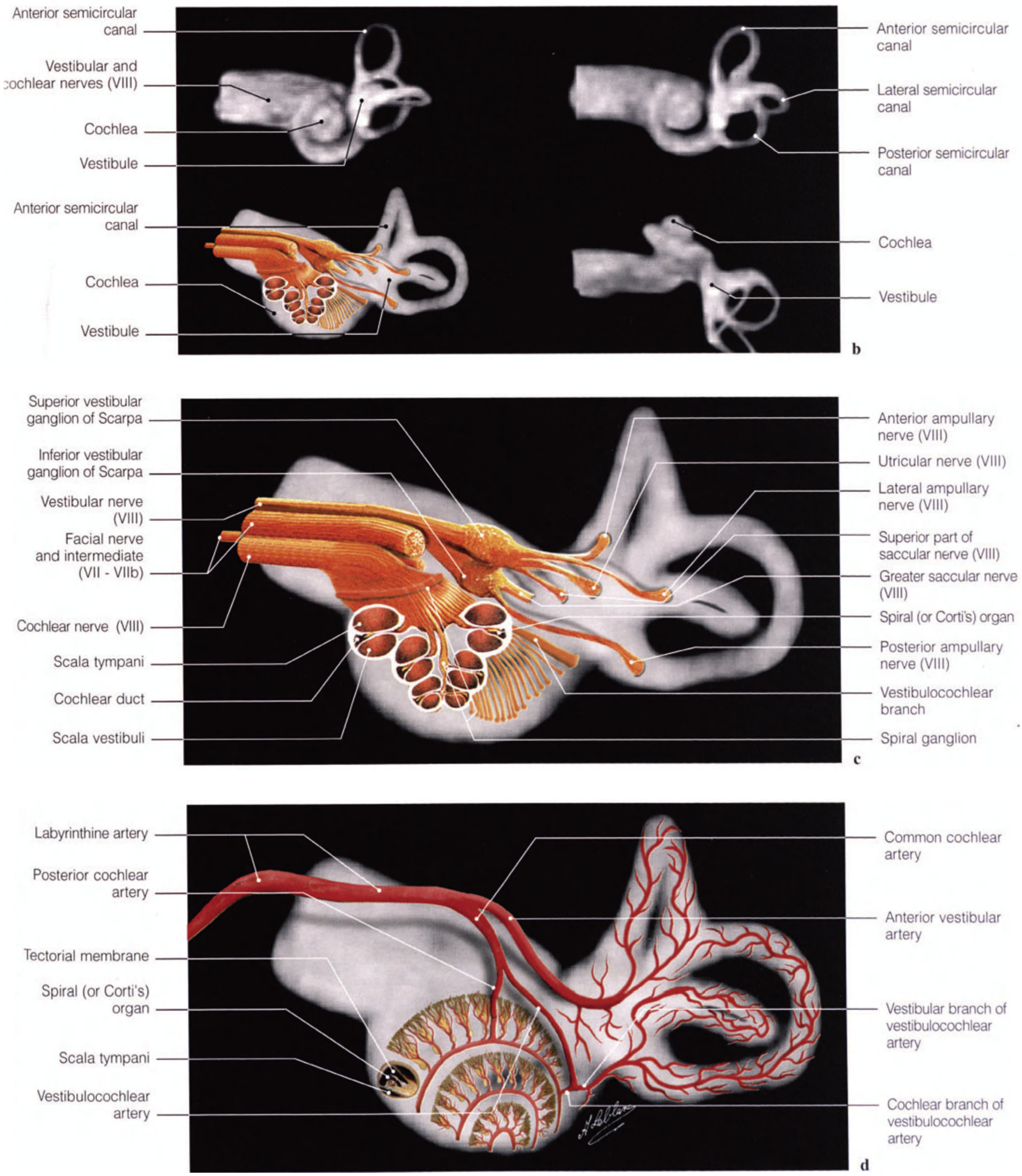


Fig. 11 a–d. Diagram of fenestrations to evidence the organs of hearing and balance **(a)**; diagram of nerves and arteries superimposed on CT views of the cochlea and the semicircular canals **(b–d)**. (CT: Prof. Y. S. Cordoliani, Dr. J. L. Sarrazin, Hôpital du Val-de-Grâce, Paris)

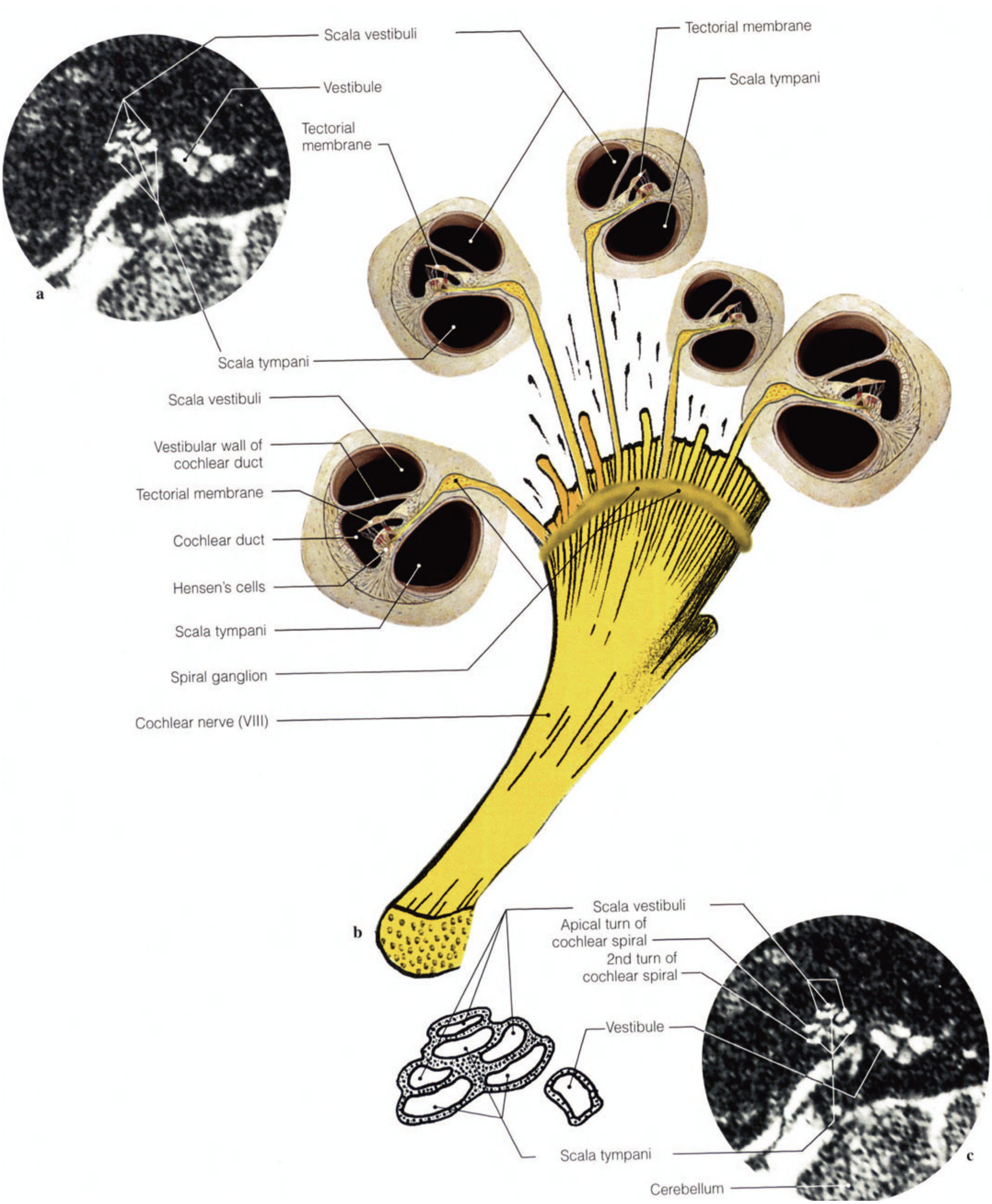
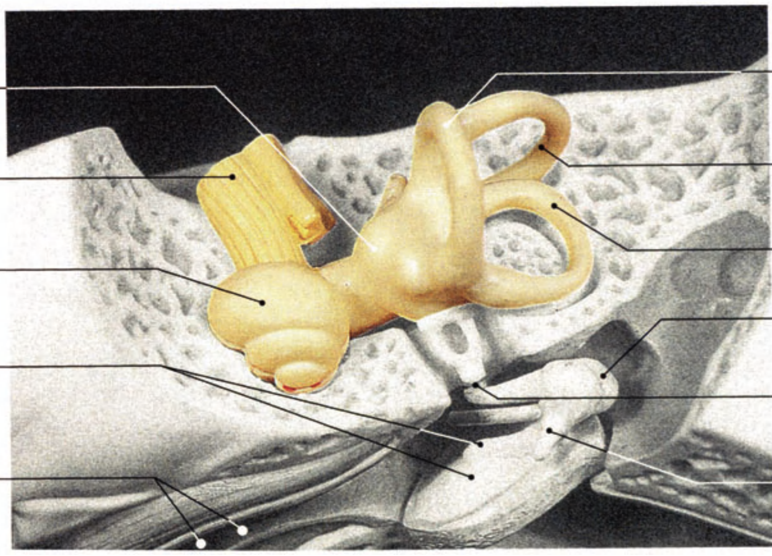
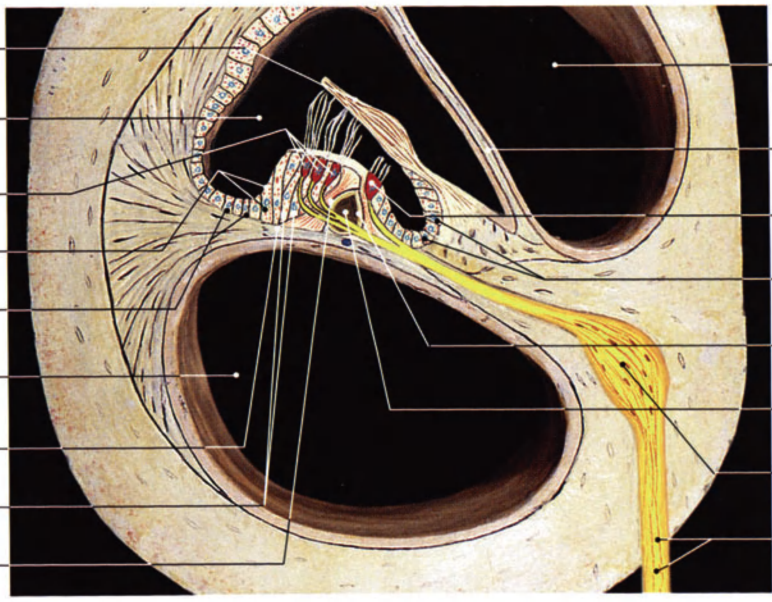
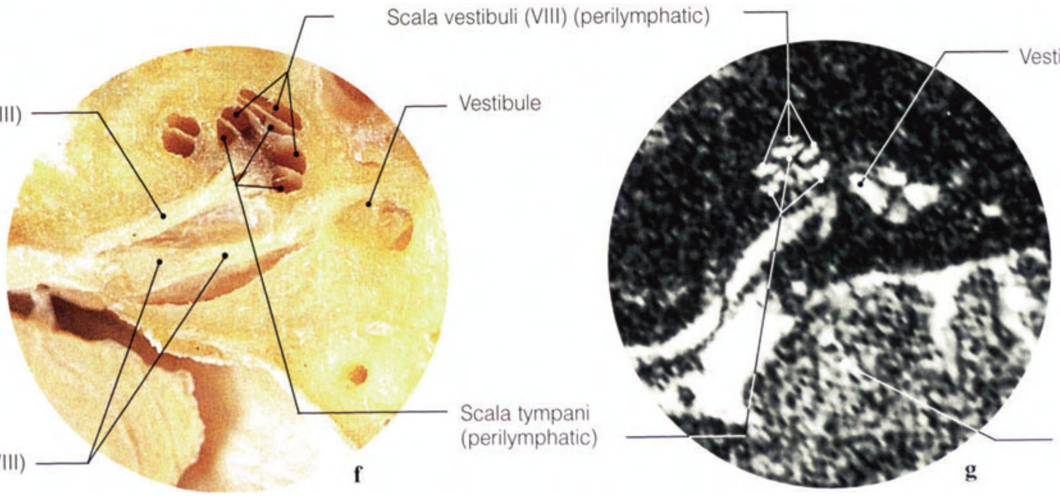
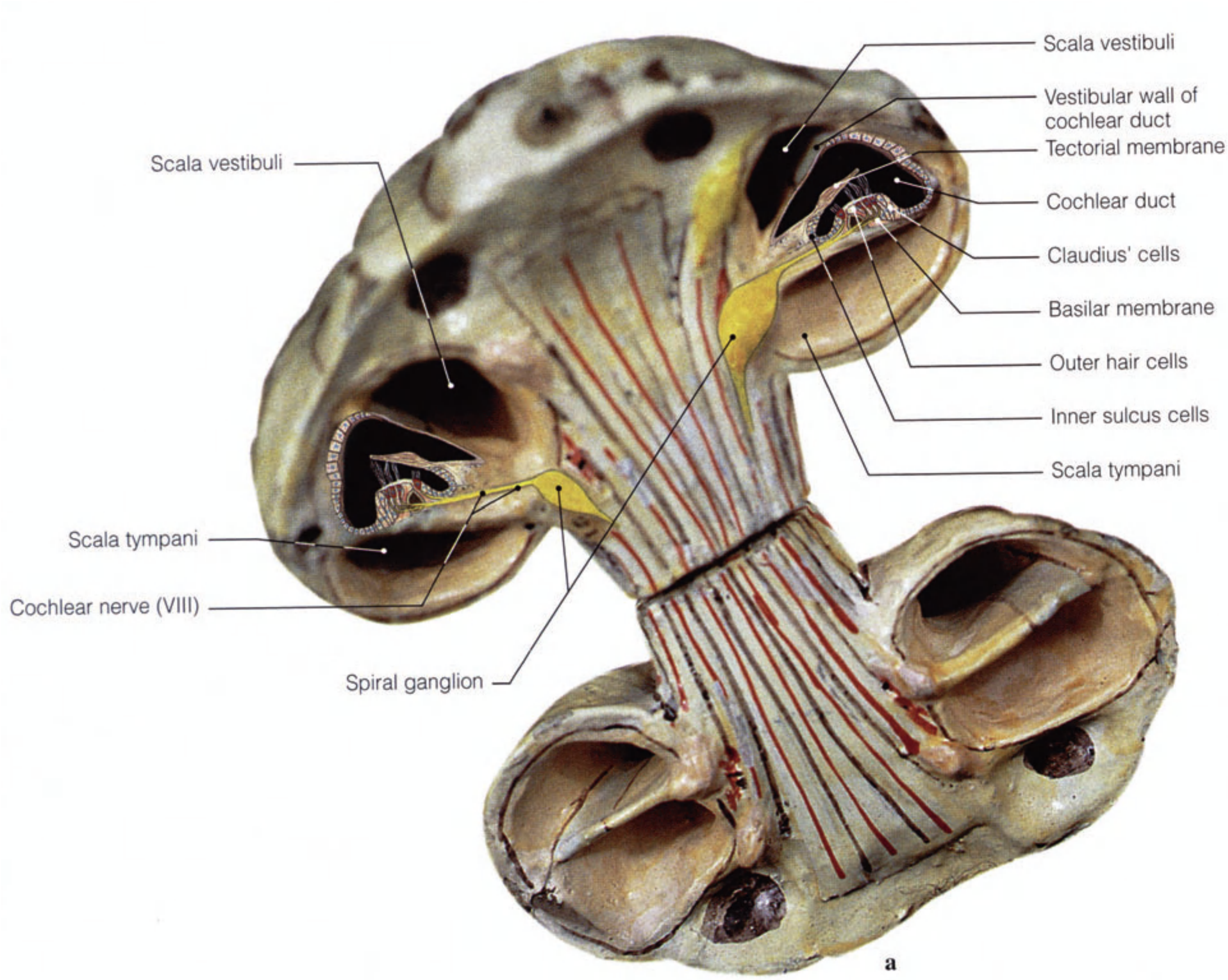


Fig. 12 a–g. Diagrams of the spiral ganglion of the cochlea and the organ of Corti superimposed on anatomical preparations and correlated to MRI views


Vestibule
Cochlear nerve (VIII)
Cochlea
Handle of malleus and tympanic membrane
Auditory tube
Anterior semicircular canal
Posterior semicircular canal
Lateral semicircular canal
Body of incus
Lenticular process of incus
Anterior process of malleus
d


Tectorial membrane
Cochlear duct (endolymphatic)
Outer hair cells
Hensen's cells
Claudius' cells
Scala tympani (perilymphatic)
Basilar membrane
Deiters' cells
Outer rod
Scala vestibuli (perilymphatic)
Vestibular wall of cochlear duct
Inner hair cells
Inner sulcus cells
Inner rod
Corti's tunnel
Spiral ganglion
Cochlear nerve (VIII)
e


Scala vestibuli (VIII) (perilymphatic)
Cochlear nerve (VIII)
Vestibule
Vestibular nerve (VIII)
Scala tympani (perilymphatic)
Vestibule
Cerebellum
f g



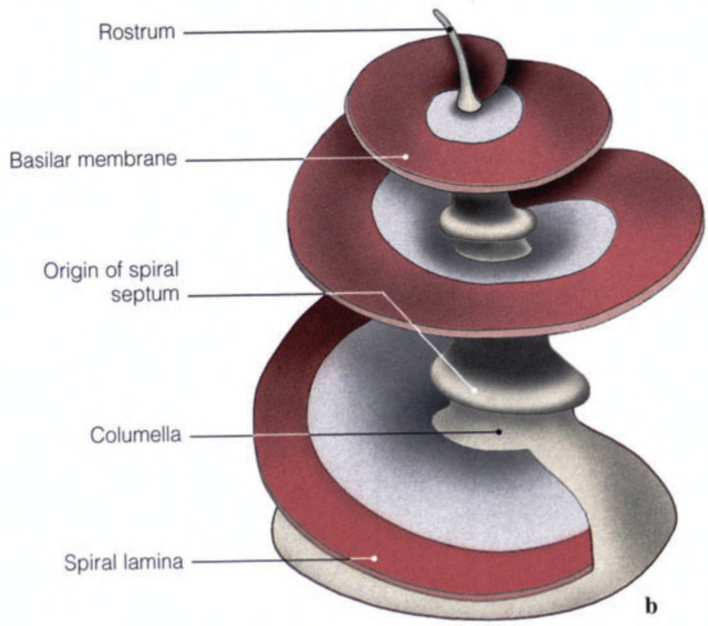
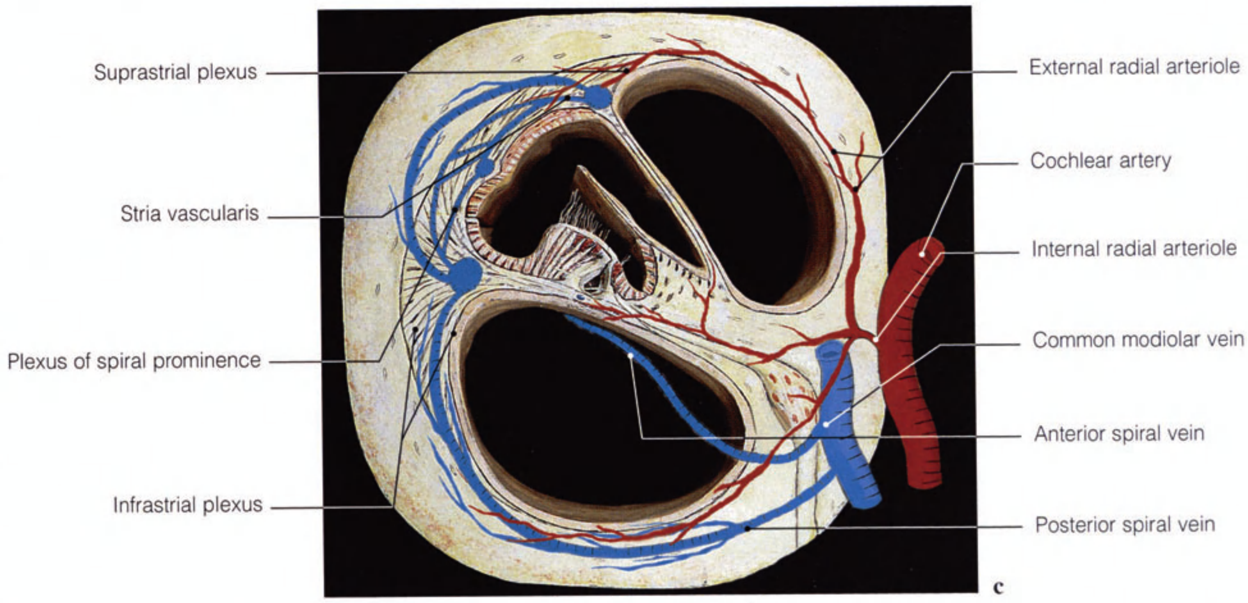
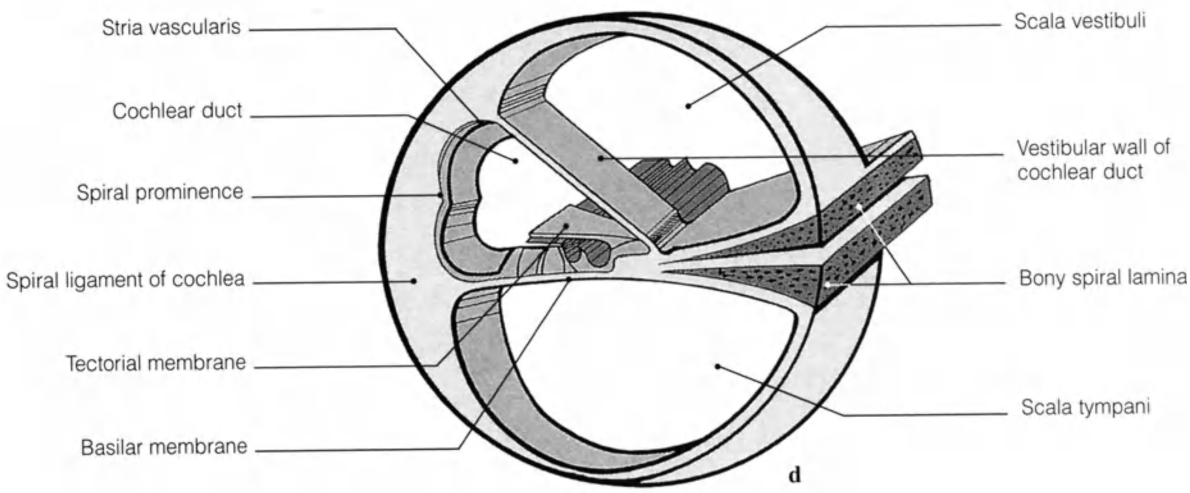


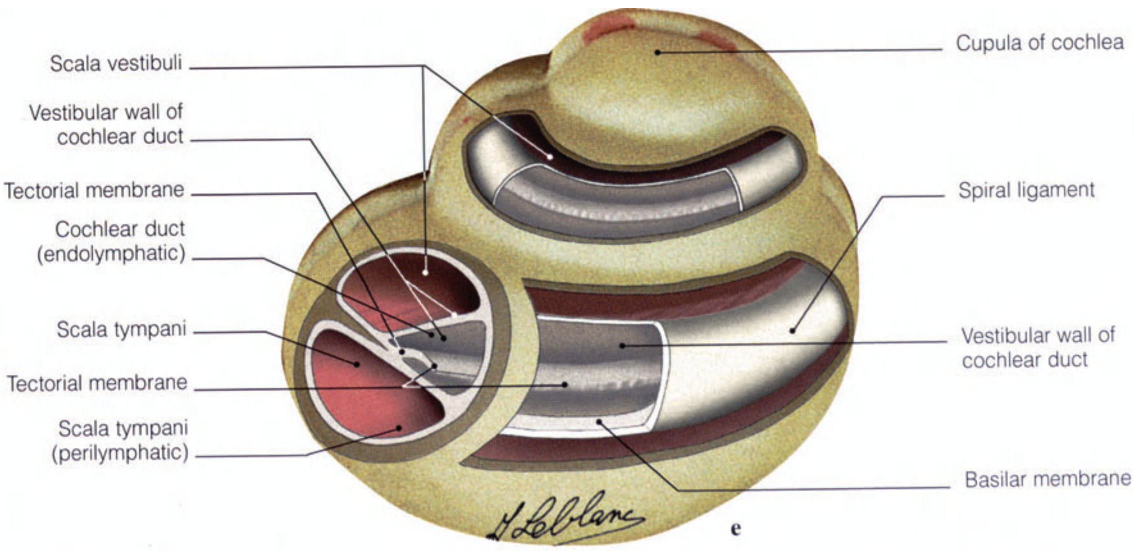
Fig. 13 a–e. Diagrams of the components of the organ of Corti **(a, c, d)** and of the bony spiral lamina of the cochlea: endo- and extra-cochlear views **(b, e)**


Suprastrial plexus
Stria vascularis
Plexus of spiral prominence
Infrastrial plexus
External radial arteriole
Cochlear artery
Internal radial arteriole
Common modiolar vein
Anterior spiral vein
Posterior spiral vein

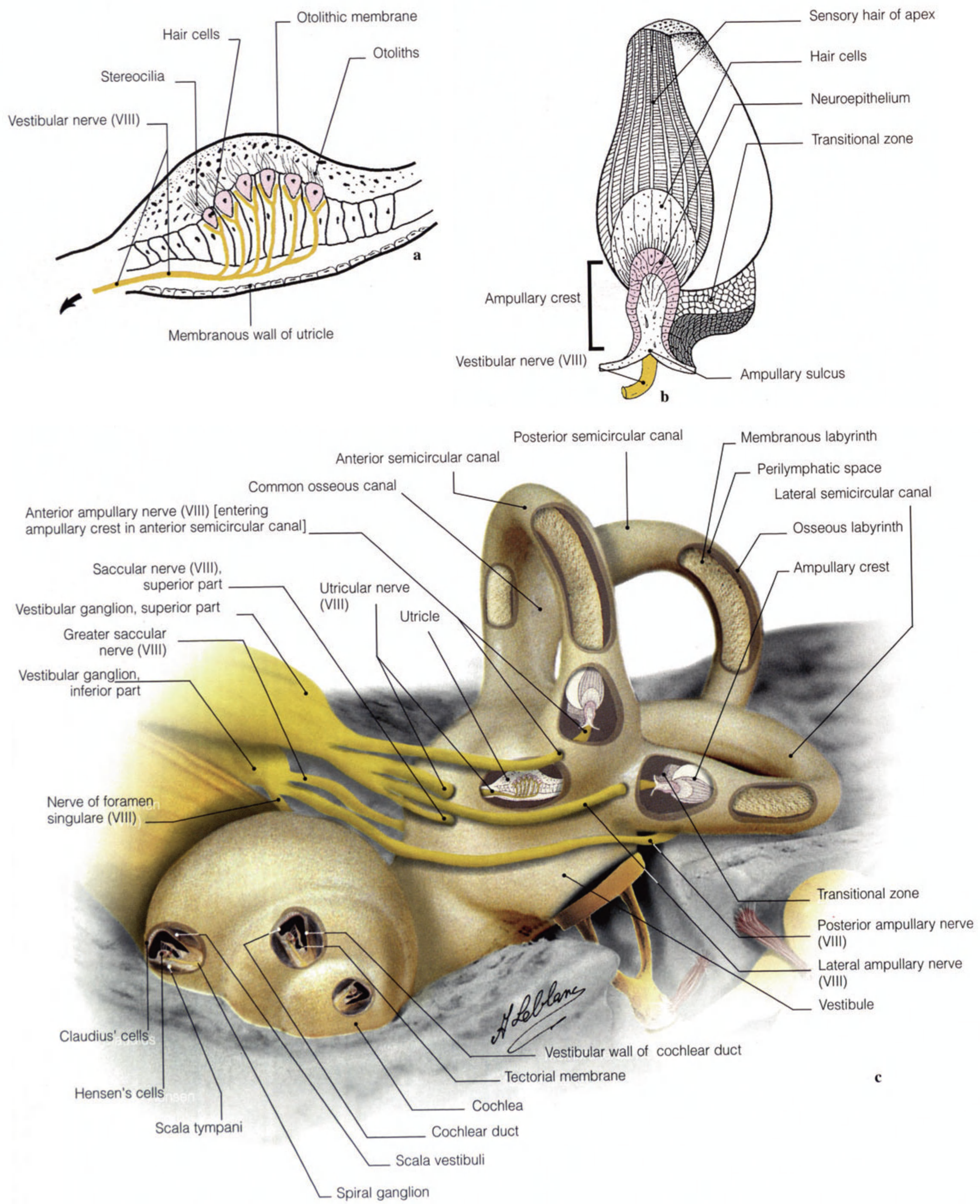
c


Stria vascularis
Cochlear duct
Spiral prominence
Spiral ligament of cochlea
Tectorial membrane
Basilar membrane
Scala vestibuli
Vestibular wall of
cochlear duct
Bony spiral lamina
Scala tympani

d


Scala vestibuli
Vestibular wall of
cochlear duct
Tectorial membrane
Cochlear duct
(endolymphatic)
Scala tympani
Tectorial membrane
Scala tympani
(perilymphatic)
Cupula of cochlea
Spiral ligament
Vestibular wall of
cochlear duct
Basilar membrane

e


Otolithic membrane
Hair cells
Otoliths
Stereocilia
Vestibular nerve (VIII)
a
Membranous wall of utricle
Sensory hair of apex
Hair cells
Neuroepithelium
Transitional zone
Ampullary crest
Vestibular nerve (VIII)
Ampullary sulcus
b
Posterior semicircular canal
Membranous labyrinth
Anterior semicircular canal
Perilymphatic space
Common osseous canal
Lateral semicircular canal
Anterior ampullary nerve (VIII) [entering
ampullary crest in anterior semicircular canal]
Osseous labyrinth
Ampullary crest
Saccular nerve (VIII),
superior part
Utricular nerve
(VIII)
Vestibular ganglion, superior part
Utricle
Greater saccular
nerve (VIII)
Vestibular ganglion,
inferior part
Nerve of foramen
singulare (VIII)
Transitional zone
Posterior ampullary nerve
(VIII)
Lateral ampullary nerve
(VIII)
Vestibule
Claudius' cells
Vestibular wall of cochlear duct
Tectorial membrane
c
Hensen's cells
Cochlea
Scala tympani
Cochlear duct
Scala vestibuli
Spiral ganglion

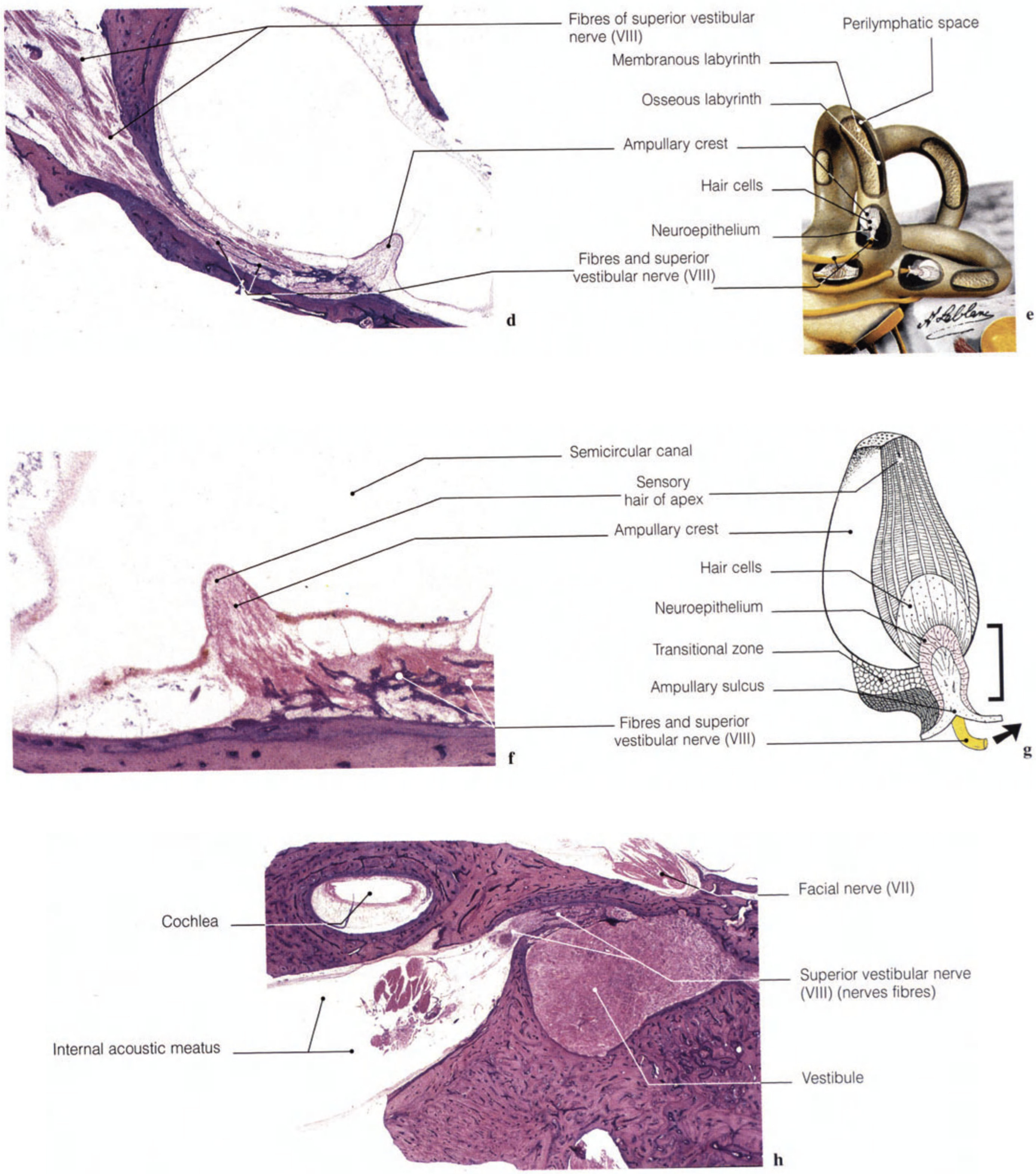
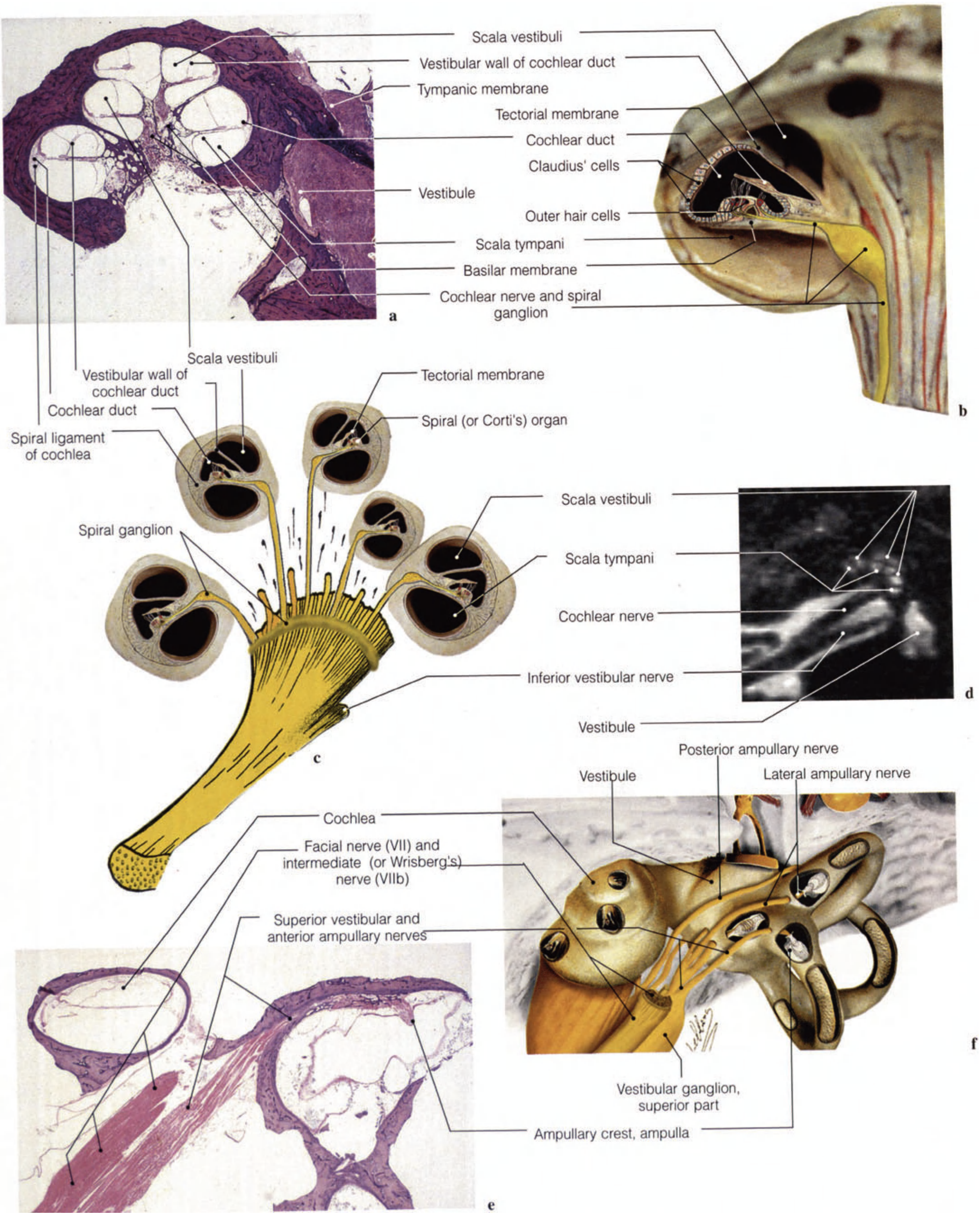
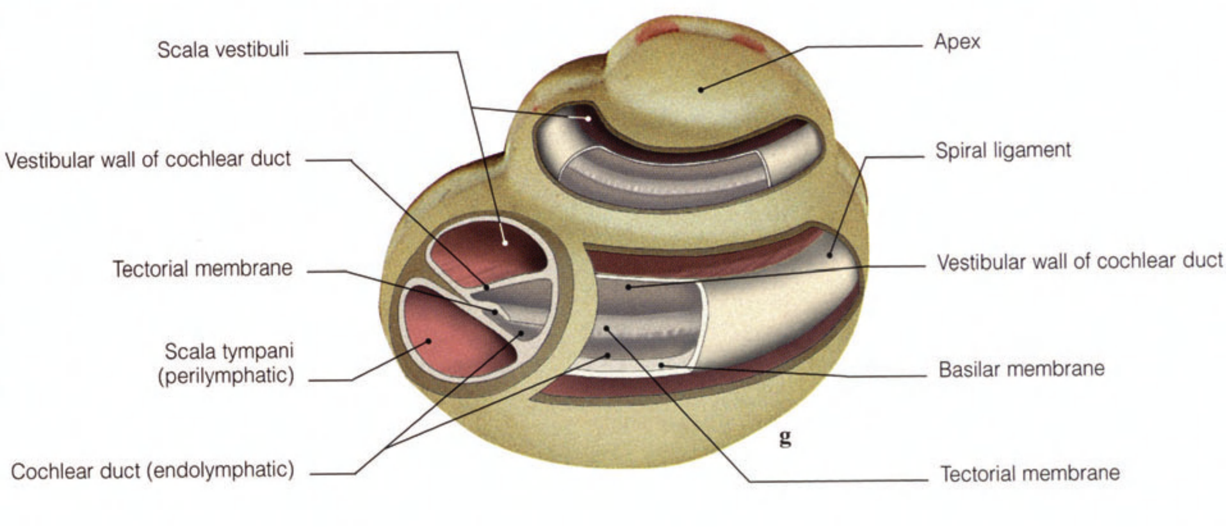


Fig. 14 a–h. Diagrams and imaging (cochlear implant) of the utricle, the ampullary crests and the vestibular nerve


Scala vestibuli
Vestibular wall of cochlear duct
Tympanic membrane
Tectorial membrane
Cochlear duct
Claudius' cells
Vestibule
Outer hair cells
Scala tympani
Basilar membrane
Cochlear nerve and spiral ganglion
a
b
Scala vestibuli
Vestibular wall of cochlear duct
Tectorial membrane
Cochlear duct
Spiral (or Corti's) organ
Spiral ligament of cochlea
Spiral ganglion
Scala vestibuli
Scala tympani
Cochlear nerve
Inferior vestibular nerve
d
Vestibule
c
Posterior ampullary nerve
Vestibule
Lateral ampullary nerve
Cochlea
Facial nerve (VII) and intermediate (or Wrisberg's) nerve (VIIb)
Superior vestibular and anterior ampullary nerves
f
Vestibular ganglion, superior part
Ampullary crest, ampulla
e

The modiolus



For extracochlear course of bony spiral lamina see **Fig. 13. b**

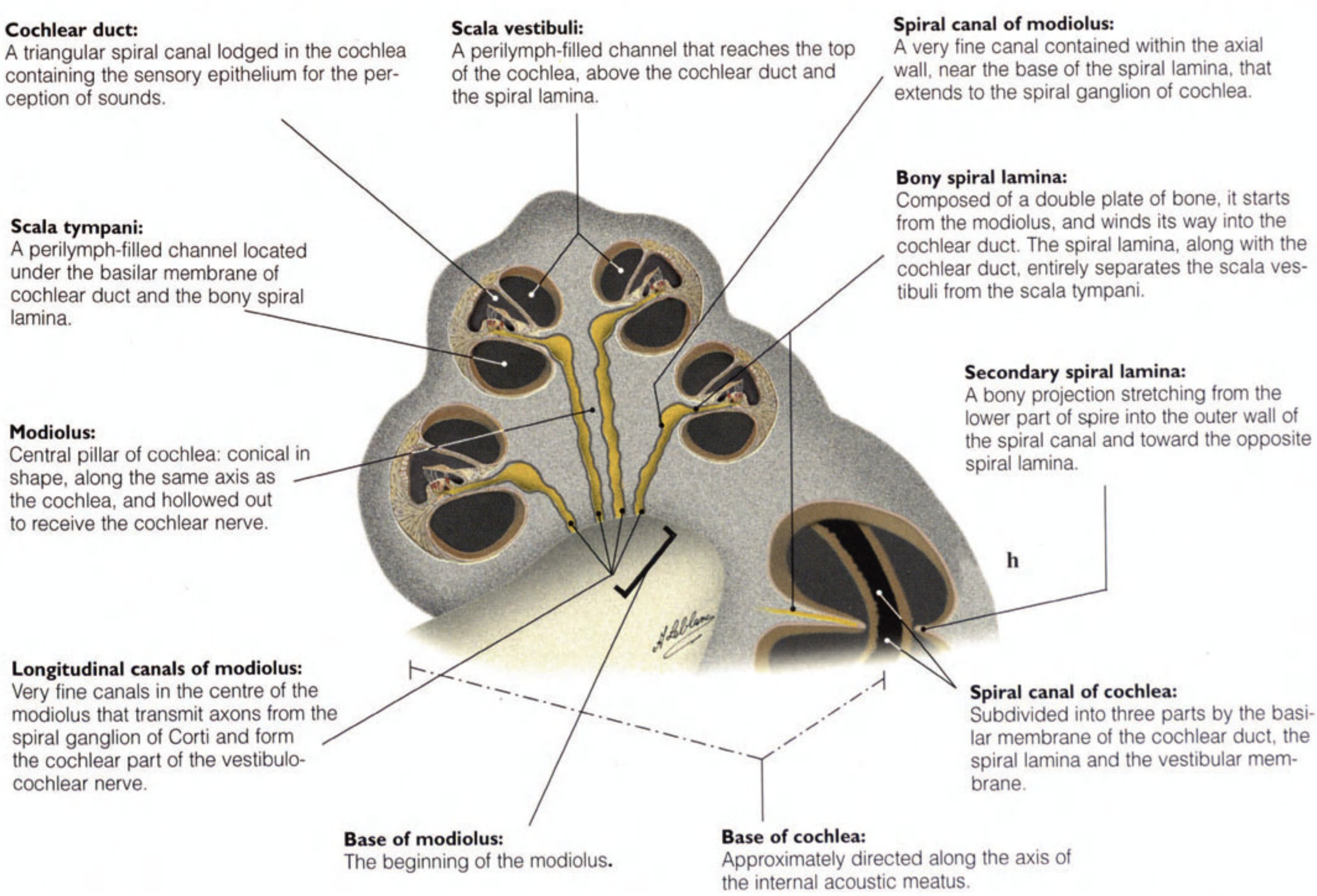
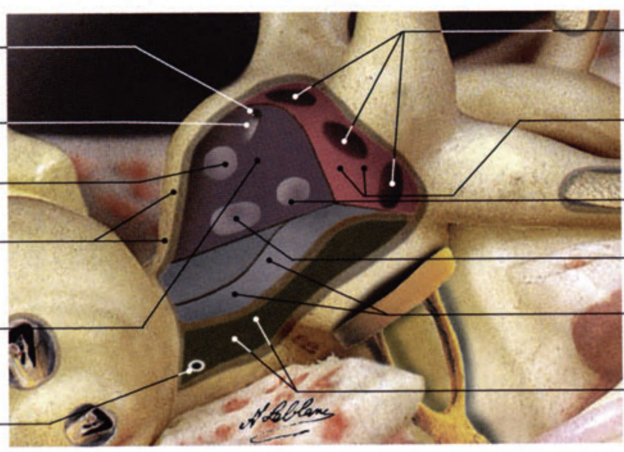


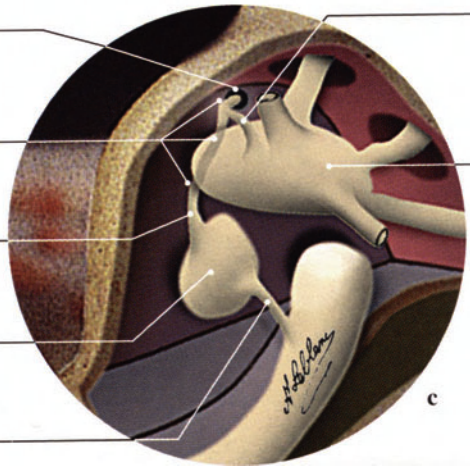
Fig. 15. a-h. Diagram showing the relationship between modiulus and cochlear nerve; bony spiral lamina and the connections between the cochlear canal and the scalae tympani and vestibuli **(a-d ; g,h)**; MRI views correlated to a diagram for the ampullar crests, with their corresponding utricular nerve **(e, f)**

a

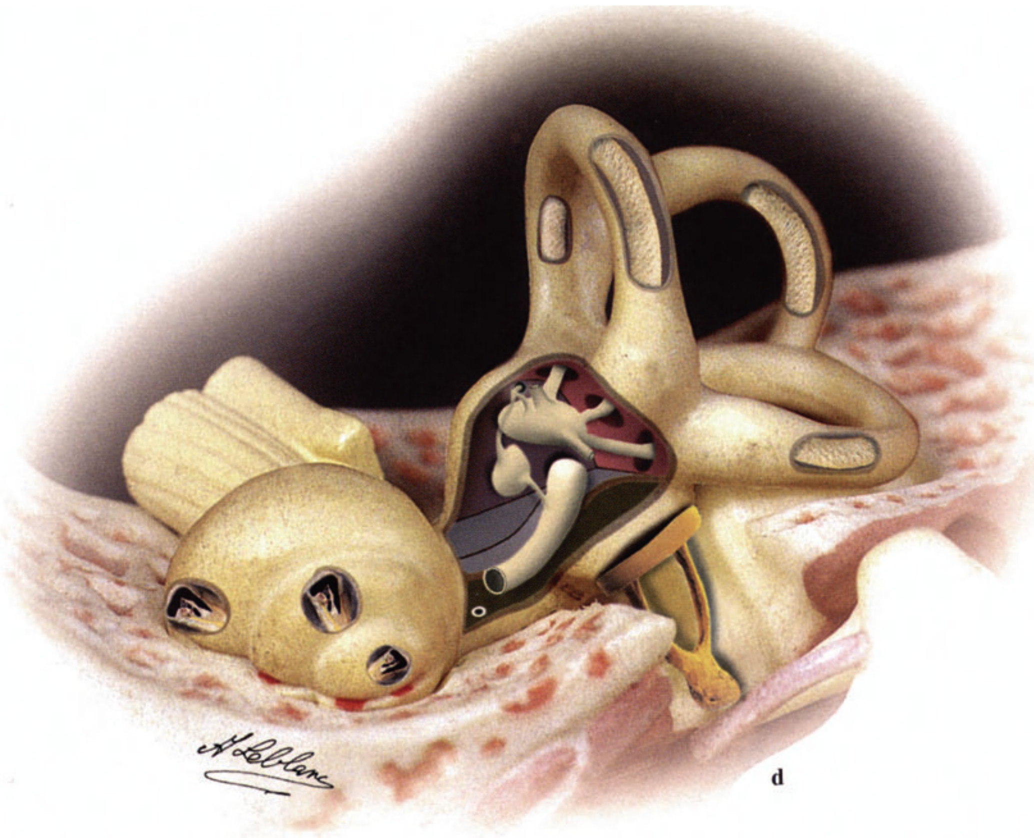


b

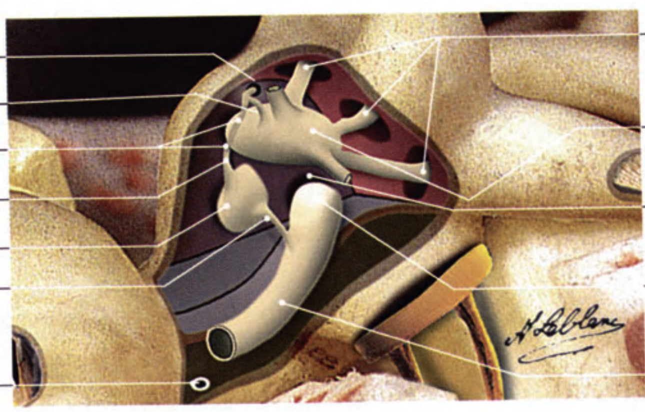
Fig. 16 a–e. Fenestration of the vestibule to show the openings, of the semicircular canals, the cochlear and vestibular aqueducts in the perforated bony walls **(a, b)**; the same fenestrated vestibule showing the position of the utricle, the saccule and the endolymphatic duct **(c–e)**


Orifice of vestibular aqueduct
[for endolymphatic system]
Endolymphatic canal
Saccular duct
Saccule
Hensen's duct
Utricular duct
Utricle

c



d


Orifice of vestibular aqueduct
[for endolymphatic system]
Utricular duct
Endolymphatic duct
Saccular duct
Saccule
Hensen's duct (ductus reuniens)
Orifice of cochlear aqueduct
[for perilymphatic space]
Entry of semicircular canals
Utricle
Cochlear fossula
Vestibular cecum
Cochlear duct
(endolymphatic)

e

Semicircular canals

They are composed of three membranous ducts that open into the utricle via five orifices (Fig. 16. a–e).

Each duct is contained in a semicircular canal, but only occupies a little over a fourth of its diameter, and is affixed to the bony canal by its outer wall.

The ducts each possess their own membrane. A basal membrane rests upon it and carries the epithelial cells (Fig. 16. a–e).

The dilated ends of the semicircular ducts form ampullae, all three of which are very near the utricle.

- Each ampulla features a sulcus. This fold, located on the medial part of the ampulla, corresponds to a localized thickening of the membrane called the ampullary crest. Nervous fibres enter the ampullae through this sulcus.
- The ampullary crests are covered with a neuroepithelium of cells with one kinocilia and smaller stereocilia (Fig. 14. b, c; 15. e, f).

The stereocilia and kinocilia are both located on the same side in an ampulla.

In the lateral semicircular duct, the kinocilia are located on the wall near the utricle, while the opposite is true of the posterior and anterior ampullae.

The cupula is a mass that rests on the neuroepithelium affixed to the walls of the ampulla. It seals the duct containing the endolabyrinthic fluids. Acceleration causes both the cupula and the cilia to undergo angular movements. The sterocilia and kinocilia, immersed in the fluids, analyse their deformation.

ENDOLYMPHATIC SYSTEM
PERILYMPHATIC SPACE

THE ENDOLYMPHATIC SYSTEM

(Pages 29, 30)

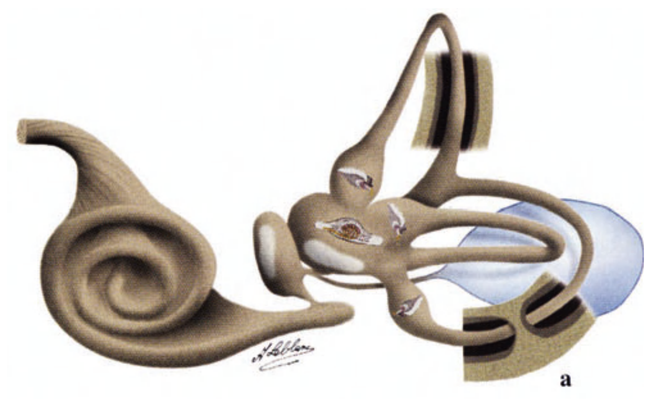
Endolymphatic sac and duct

The **endolymphatic duct** is formed by the reunion of two canaliculi that come from the saccule and the utricle.

The utricular segment merges with the utricle through a very small fissure.

The endolymphatic duct first presents an enlarged intravestibular portion called the sinus. Its diameter decreases when it reaches the isthmus and penetrates the aqueduct of the vestibule, and finally becomes larger again. The duct is covered with connective tissue along most of its length. The type of epithelium varies with the portion of the duct.

The **endolymphatic sac** continues and ends the endolymphatic duct. It constitutes a true intracranial extension of the membranous labyrinth of approximately 10 mm width, overlapping the ungual fossa to line the dura mater (Fig. 18 a–d)



a

THE PERILYMPHATIC SPACES

(Pages 29-31)

Cochlear aqueduct and perilymphatic duct

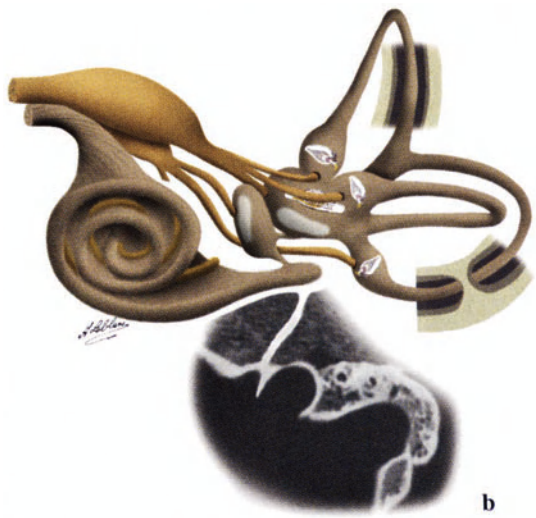
The cochlear aqueduct communicates with the perilymphatic space (Fig. 19 a–e).

Its ostium is located on the medial cochlear wall, very close to the round window and the inferior side of the spiral lamina.

It is directed toward the back, downward and to the inside. It slips under the ampulla of the posterior semicircular canal, at the level of the inferior edge of the acoustic meatus.

It ends at the lower part of the pyramid, and opens in the floor of the petrosal fossa [cavitas of Andersch's ganglion (IX)] behind the jugular foramen and before the carotid canal, next to the tympanic canaliculus (Fig. 19. b, d).

The perilymphatic duct connects the perilymphatic space with the subarachnoid space located between the arachnoid and the pia mater.

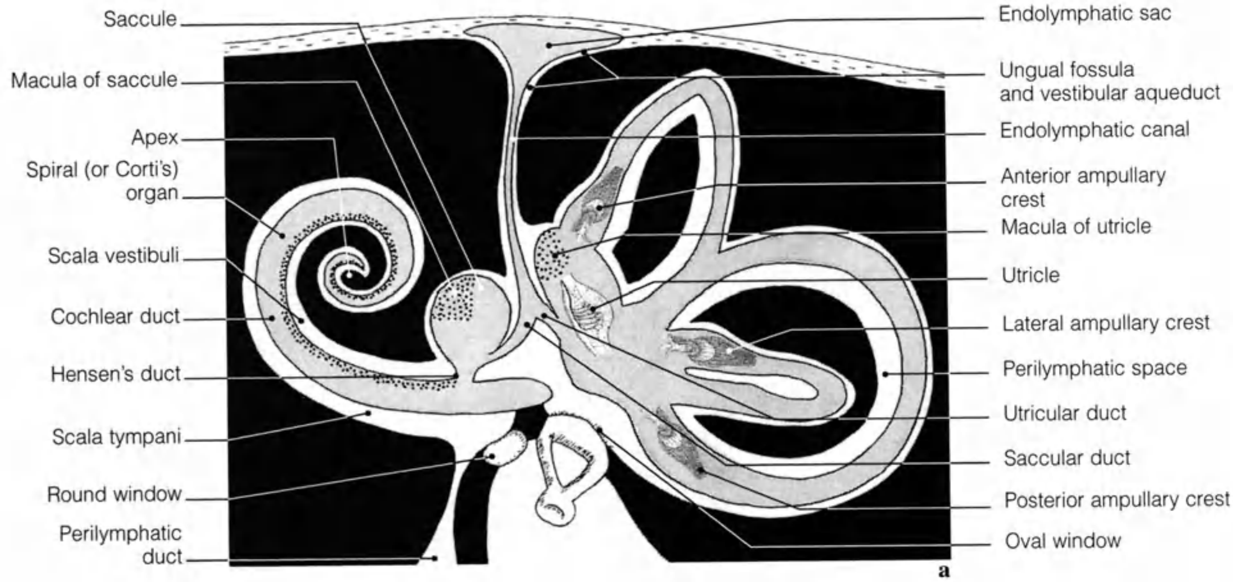


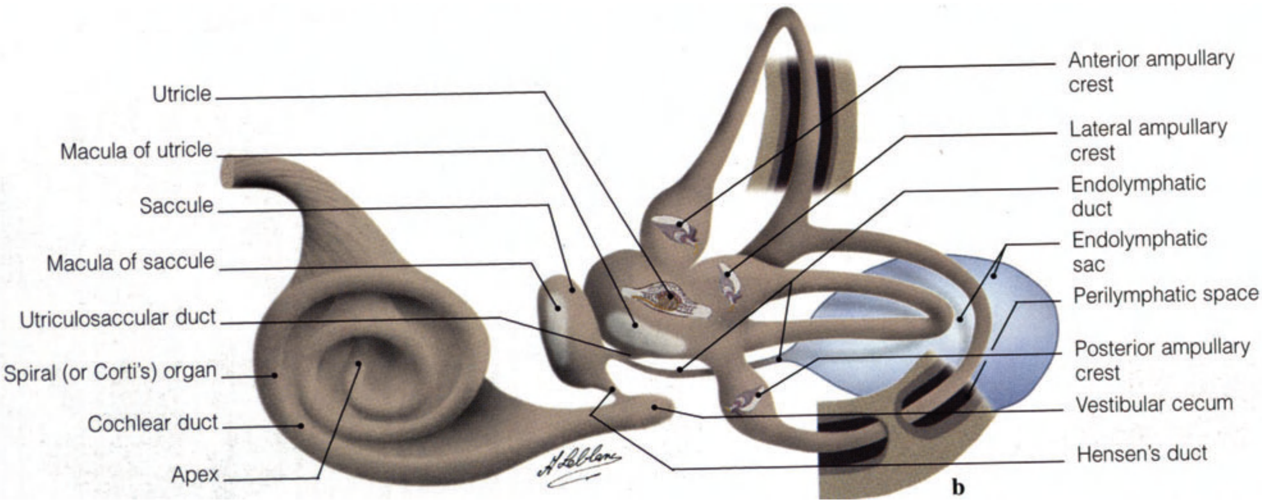
b

Fig. 17 a, b. Diagrams of the endolymphatic system **(a)** and the perilymphatic spaces **(b).**

ENDOLYMPHATIC SYSTEM
ENDOLYMPHATIC SAC, ENDOLYMPHATIC DUCT
VESTIBULAR AQUEDUCT

Anatomical diagrams and CT views





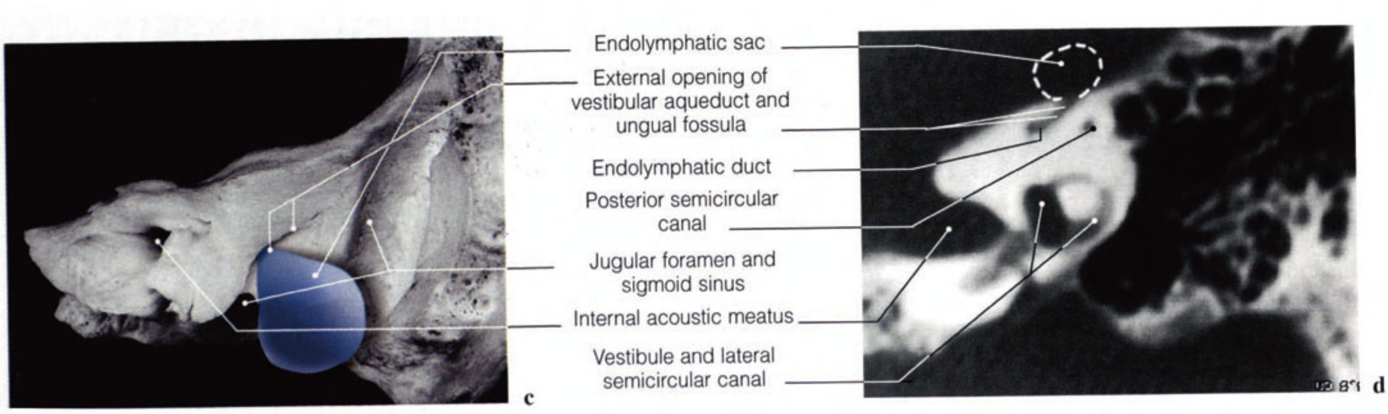


Fig. 18 a–d. Anatomical diagrams showing the endolymphatic system (**a, b**); computerized axial tomography of the vestibular aqueduct and the endolymphatic duct (**d**); photograph of the posterior area of the petrosal part of the temporal bone (**c**) showing the external opening of the vestibular aqueduct (ungual fossa) with a diagram of the endolymphatic sac (CT: Dr. J .W. Casselman, A.Z. St Jan, Brugge)

PERILYMPHATIC SPACE

PERILYMPHATIC DUCT, COCHLEAR AQUEDUCT

Anatomical diagrams and CT views

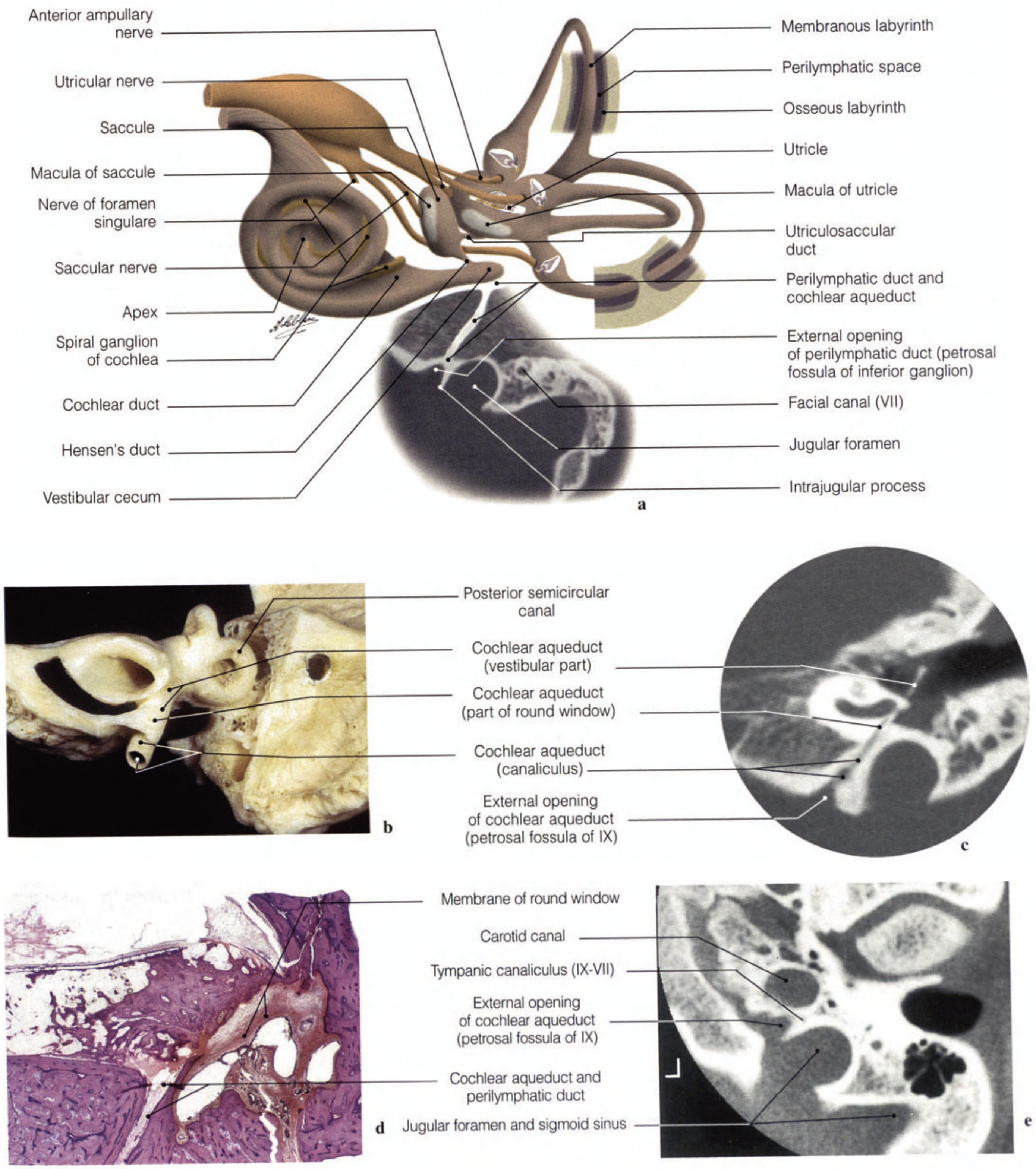


Fig. 19 a–e. Diagram showing the perilymphatic spaces (**a**); posterior anatomical view of the vestibulocochlear area (**b**); imaging of the cochlear aqueduct (**d**); CT views of the cochlear aqueduct and the external ostium of its canaliculus (**c, e**) (CT: Dr. J. W. Casselman, A.Z. St Jan, Brugge)

LABYRINTHINE VASCULATURE
ANTERIOR INFERIOR CEREBELLAR ARTERY, LABYRINTHINE ARTERY, VESTIBULAR AND COCHLEAR ARTERIES

Anatomy, diagrams, CT and MRI views

(Pages 32-40)

Vasculature of the internal ear

The vasculature of the bony inner ear is independent from that of the membranous inner ear.

Vasculature of the bony labyrinth is supplied by:

- the stylomastoid artery, a branch of the posterior auricular artery;
- the tympanic artery, inferior, a branch of the ascending pharyngeal artery;
- the subarcuate artery, that originates either directly from the anterior inferior cerebellar artery, or more particularly from the internal auditory artery.

The subarcuate artery passes through the petrosomastoid canal.

The membranous labyrinth has its own vasculature:

The labyrinthine artery or internal auditory artery: supplied by the inferior anterior cerebellar artery (i.e., the middle cerebellar artery) or directly by the basilar artery, the labyrinthine artery arrives at the back of the acoustic meatus and divides into three branches (Fig. 22; 23. b):

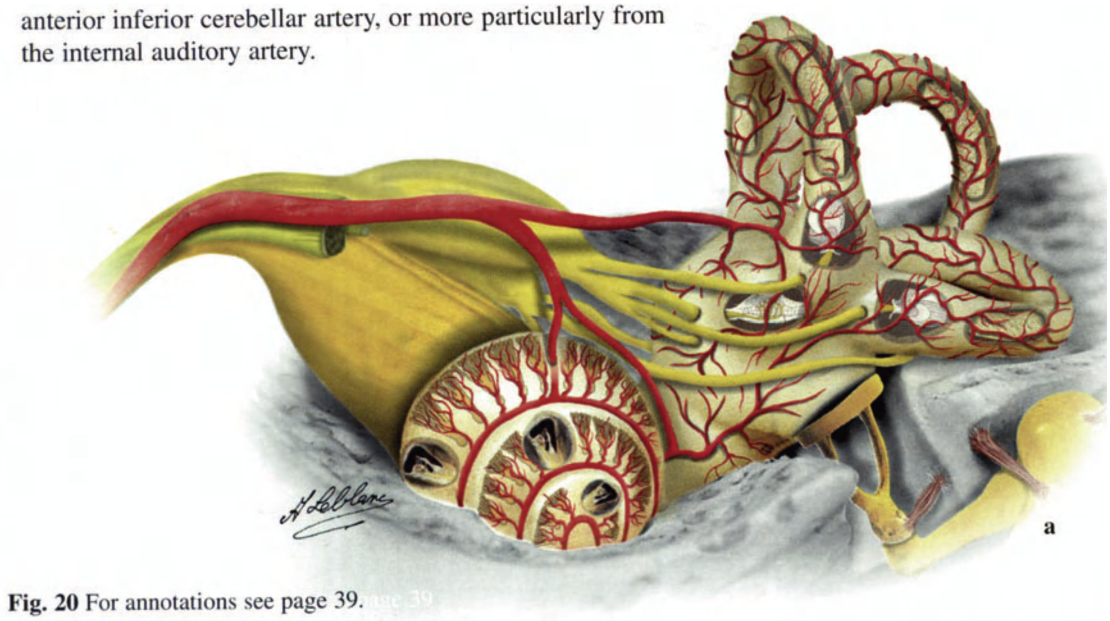


Fig. 20 For annotations see page 39.

* the cochlear artery,
* the anterior vestibular artery,
* the cochleovestibular artery.

The cochlear artery enters the modiolus, where it forms a spiral and supplies two types of radial arteries:

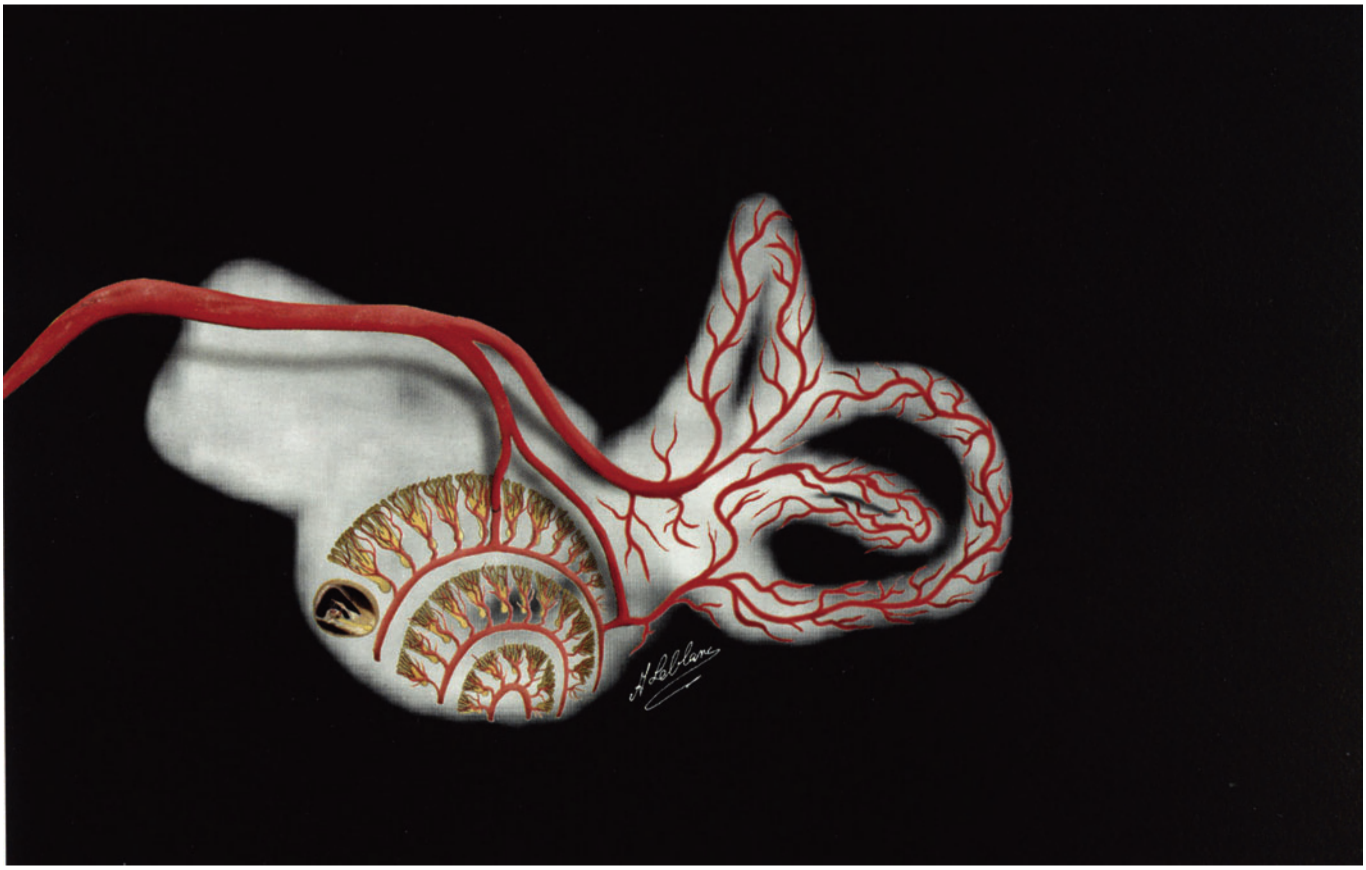
- the external radial arteriolae that run under the bony scala vestibuli and supply four main capillary networks:
  - the helicotrema
  - the suprastrial capillaries, which are thought to secrete most of the perilymph,
  - the stria vascularis of the cochlear duct,
  - the infrastrial network, which is anastomosed to the venous capillaries.
- the internal radial arteriolae supply the spiral ganglion of the cochlea and the bony spiral lamina.

The anterior vestibular artery supplies branches for the posterior sides of the utricle and saccule, and extends to the lateral and anterior semicircular canals (Fig. 22; 24. d–f).

The vestibulocochlear artery divides into two branches:

The cochlear branch irrigates the inferior fourth of the cochlear duct, and then merges with the ramus cochlearis.

The posterior vestibular branch vascularizes the macula, the saccule, the walls and the ampulla of the posterior semicircular canal, and the inferior poles of the saccule and utricle.



b

Annotations: see page 17

Fig. 21 a, b. Diagrams of labyrinthine vasculature **(a)**, superimposed on a computed tomography (CT) view of the semicircular canals and the cochlea

Veins

There are two main venous networks:
* the plexus for the cochlear aqueduct,
* the plexus for the vestibular aqueduct.

* The plexus for the cochlear aqueduct includes:

– Veinules from the sensory areas of the vestibule:
• the posterior vestibular vein [ampulla of the posterior semicircular canal, saccule];
• the anterior vestibular vein [utricle].

– The common modiolar vein, which results from the merging of the anterior and posterior spiral veins.

• the posterior spiral vein collects blood from the spiral ganglion of cochlea and then merges with the infrastrial capillary network;
• the anterior spiral vein collects blood from the limbus spiralis, and then anastomoses with the internal radial arteriolae at that same level;
• within the modiolus, the anterior and posterior spiral veins communicate in several points.

– The vein of round window.

This plexus follows the course of the cochlear aqueduct in a separate canal, and drains into the vein of the cochlear aqueduct.

* The plexus for the vestibular aqueduct is an anastomosis of veins coming from the non-sensory areas of the vestibular labyrinth, particularly from the semicircular canals. It drains into the vein of the vestibular aqueduct, which runs in a canal parallel to the aqueduct, and finally receives veins from the endolymphatic sac.

* Both of these plexuses drain into the inferior petrosal sinus, and finally into the jugular bulb.

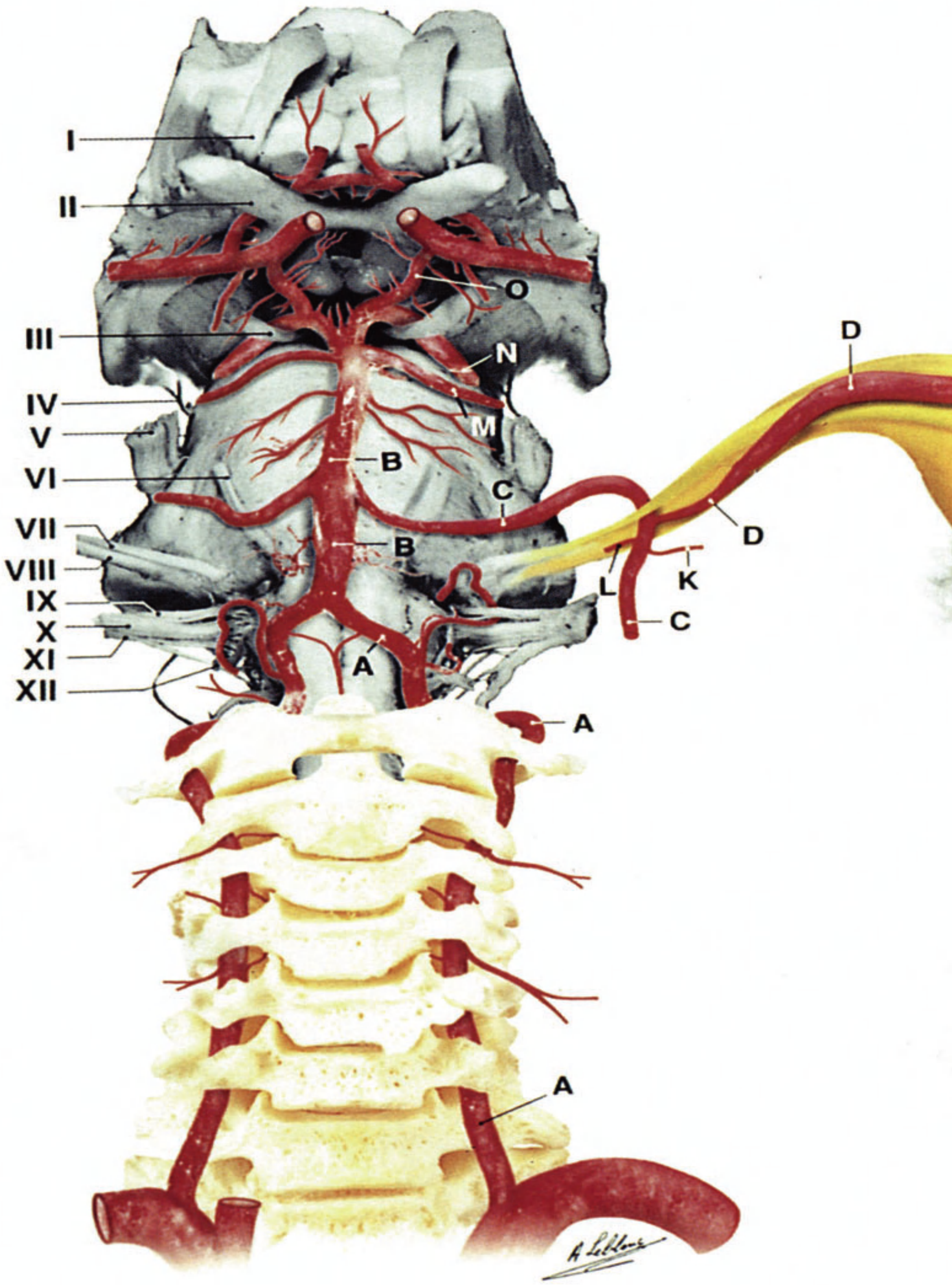
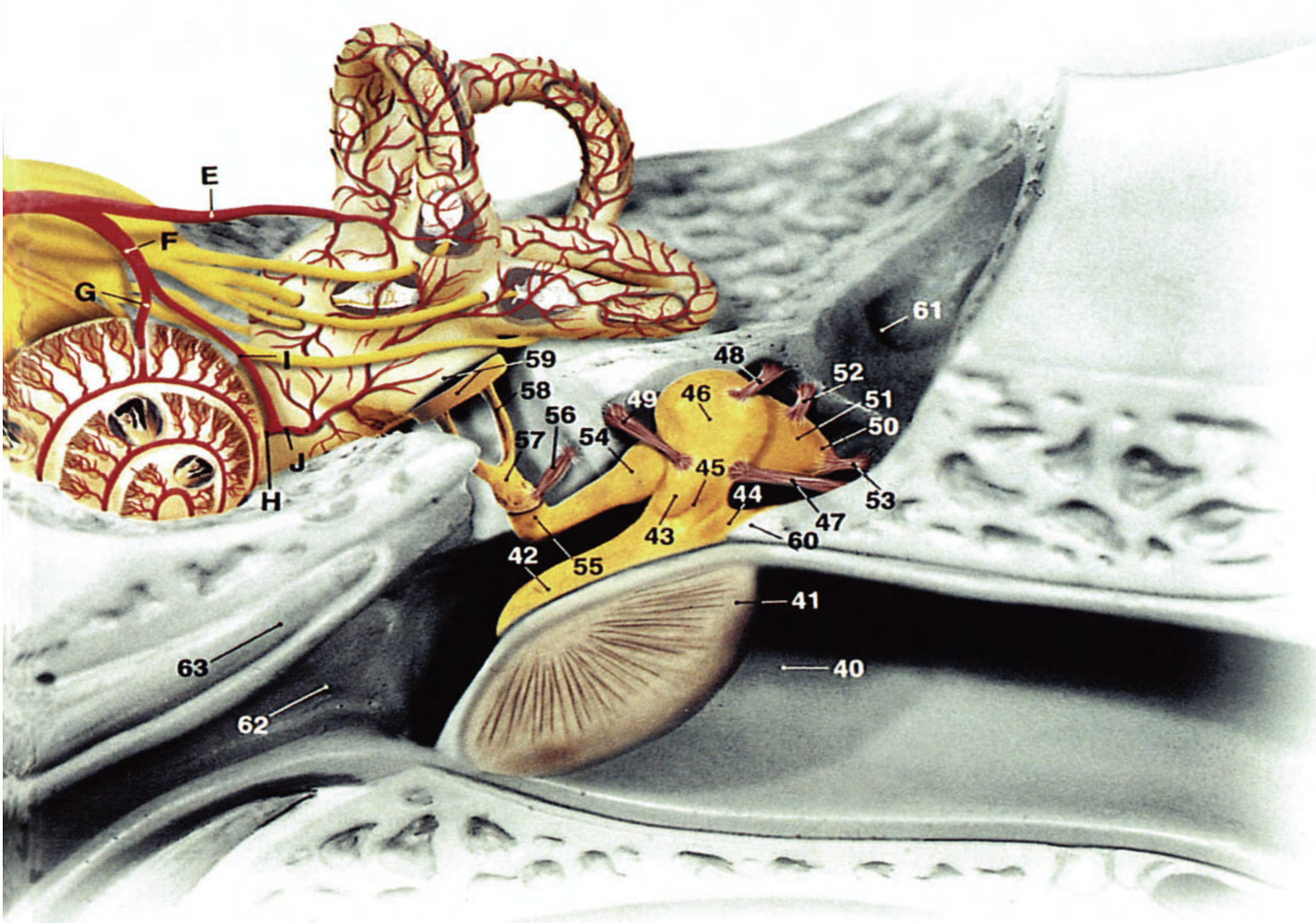


Fig. 22

VASCULARIZATION

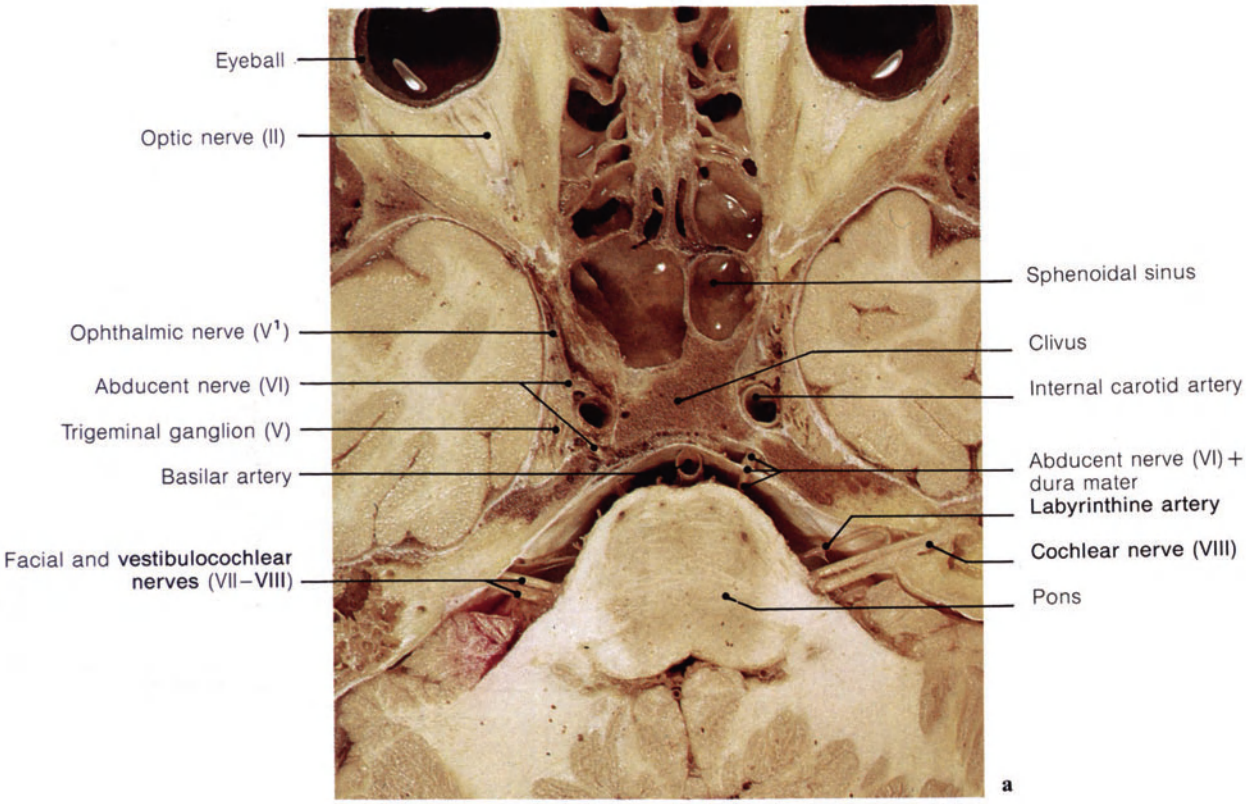
Labyrinthine artery

A	Vertebral artery
B	Basilar artery
C	Inferior anterior cerebellar artery
D	Labyrinthine artery
E	Anterior vestibular artery
F	Common cochlear artery
G	Posterior cochlear artery
H	Cochlear branch of vestibulocochlear artery
I	Vestibulocochlear artery
J	Vestibular branch of vestibulocochlear artery
K	Subarcuate artery *[anastomoses in middle ear with branches of the external carotid artery]*
L	Recurrent artery
M	Superior cerebellar artery
N	Posterior cerebral artery
O	Posterior communicating artery



MIDDLE AND EXTERNAL EAR

40	External acoustic meatus
41	Tympanic membrane
42	Handle of malleus
43	Anterior process of malleus
44	Lateral process of malleus
45	Neck of malleus
46	Head of malleus
47	Lateral ligament of malleus
48	Superior ligament of malleus
49	Malleus muscle
50	Short crus of incus
51	Body of incus
52	Superior ligament of incus
53	Posterior ligament of incus
54	Long crus of incus
55	Lenticular process of incus
56	Stapedius muscle
57	Head of stapes
58	Posterior crus of stapes
59	Oval window and base of stapes
60	Epitympanic recess
61	Mastoid antrum
62	Auditory tube
63	Tensor tympani muscle



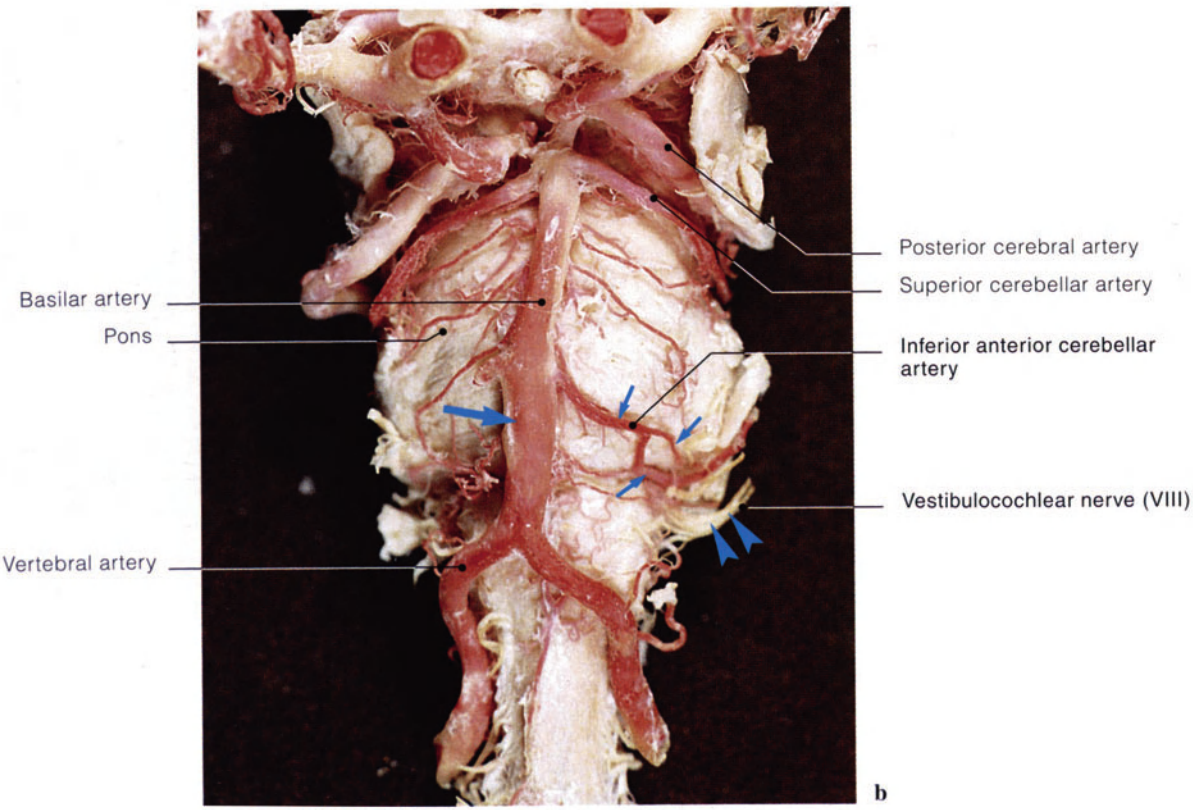
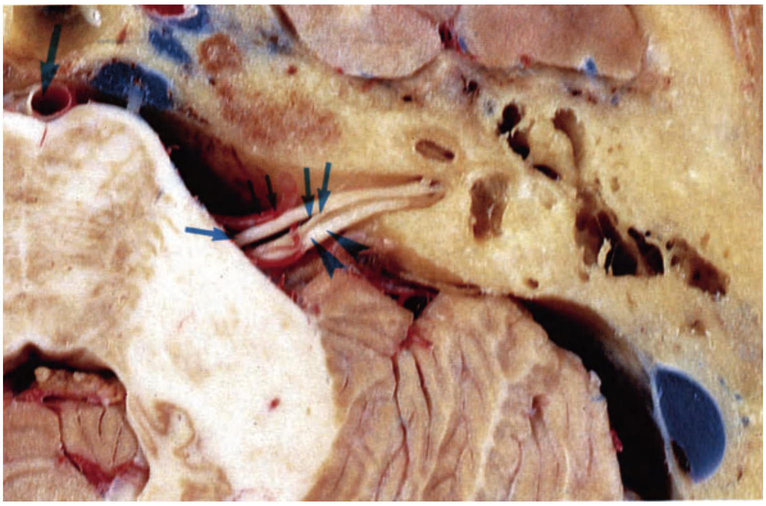
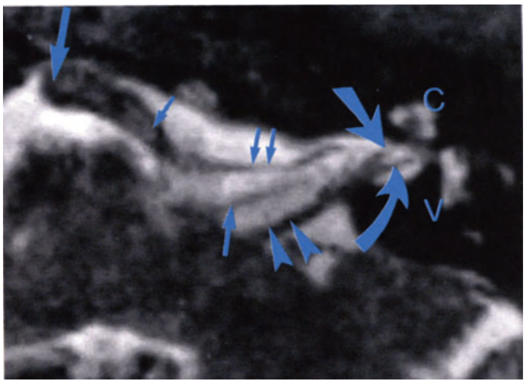
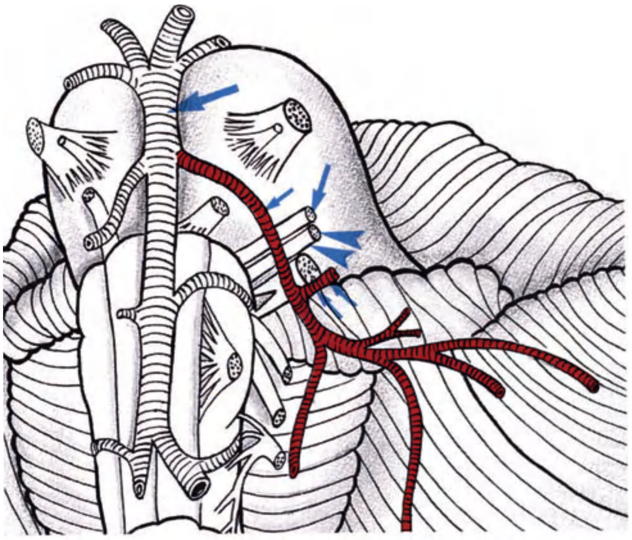
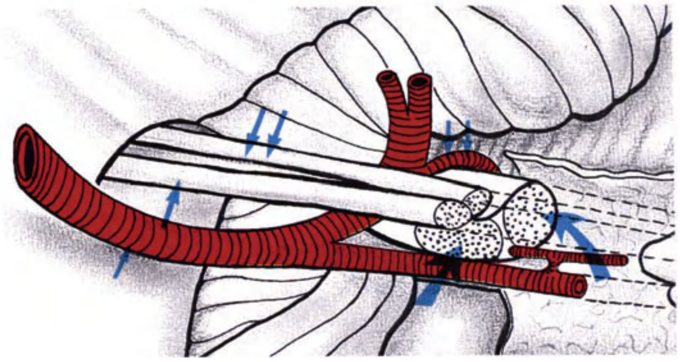


Fig. 23 a–i. Axial section of the brain stem in the internal acoustic meatus at the level of the vestibulocochlear nerve and of the labyrinthine artery **(a)**; dissection of the brain stem showing the anterior inferior cerebellar artery **(b)**; axial anatomical section **(c)**, MRI views **(d, g, h, i)** and diagrams **(e, f)** depicting the vascular relationships between vestibular, cochlear, facial and intermediate (VIII-VII-VIIb) nerves. (Dissection and anatomical sections: Prof. J. P. Francke, Faculty of Medicine, Lille; diagrams **e, f**: Prof. Y. Guerrier, *Anatomie Chirurgicale de l'os temporal de l'oreille et de la base du crâne,* Tome 1, La Simarre, 1988)

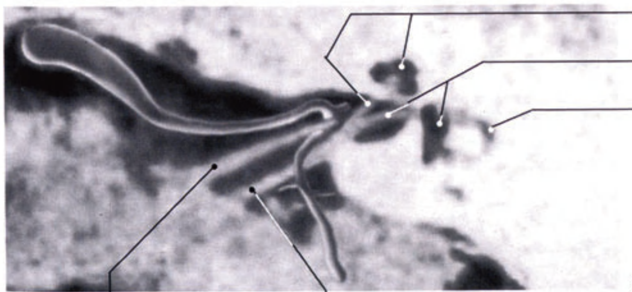




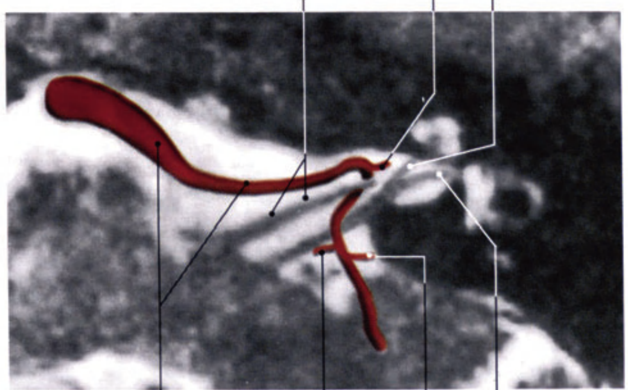


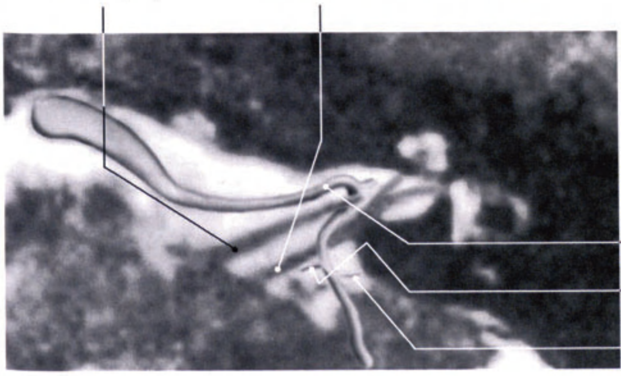


Basilar artery (*large, straight arrow*)
labyrinthine artery (*small, double arrows*)
inferior anterior cerebellar artery (*small arrow*)
facial nerve (VII) (*medium, straight arrow*)
nervus intermedius (VIIb) (*double, medium arrows*)
vestibulocochlear nerve (VIII) (*double arrowheads*)
inferior vestibular (VIII) (*curved arrow*)
cochlear nerve (VIII) (*large arrow*)
Cochlea (*C*); vestibule (*V*)



g





i

(MRI: Dr. J. W. Casselman, A. Z. St Jan, Brugge)

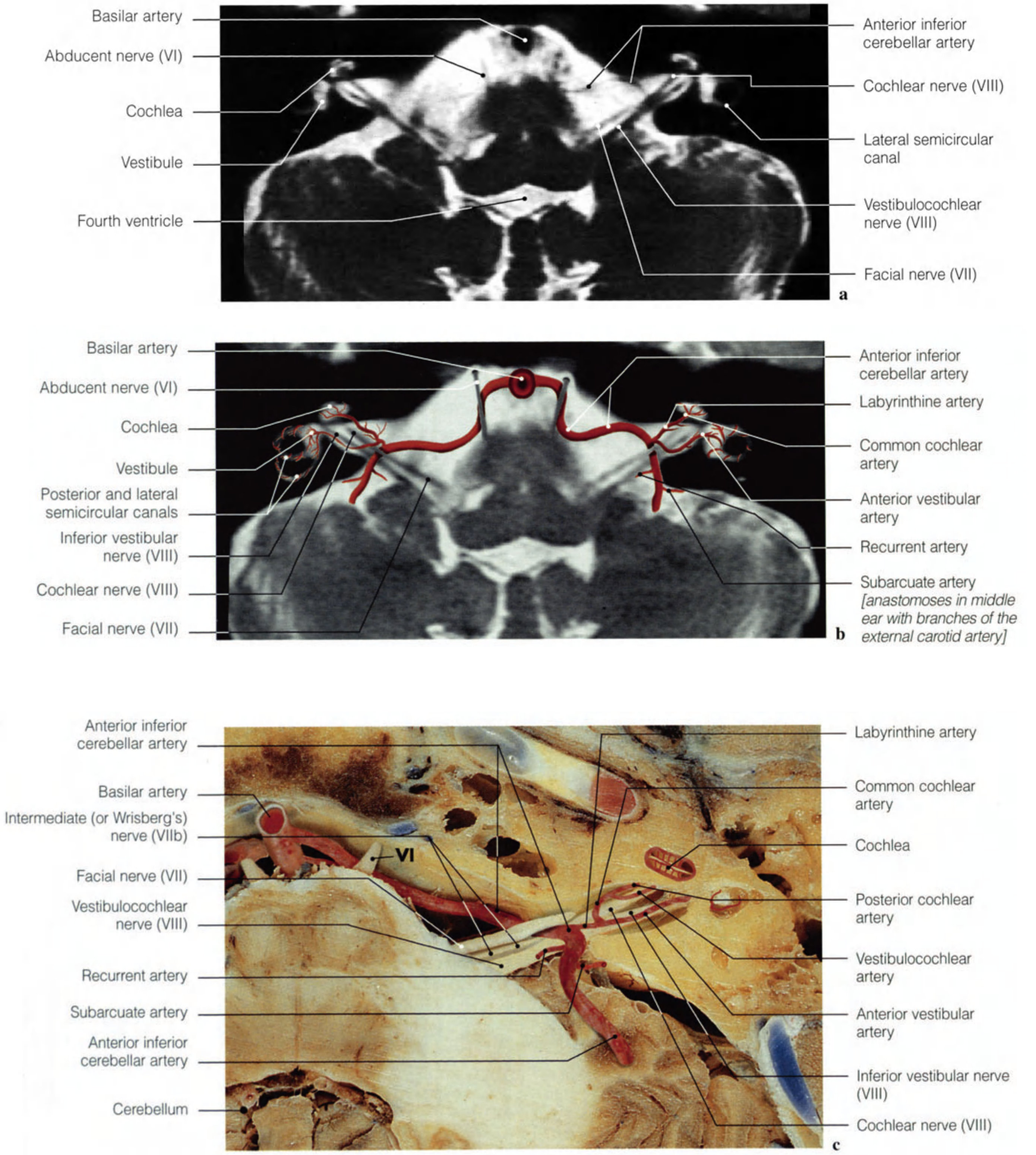
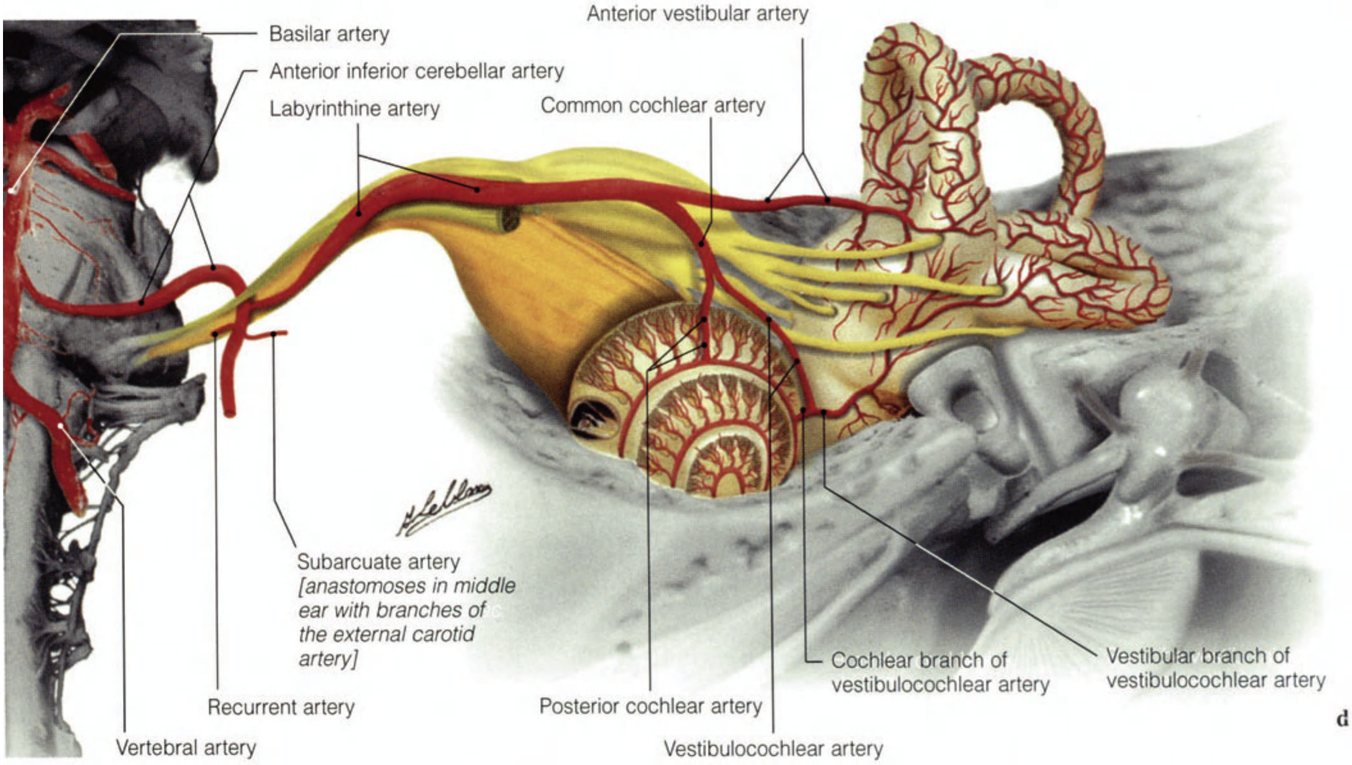
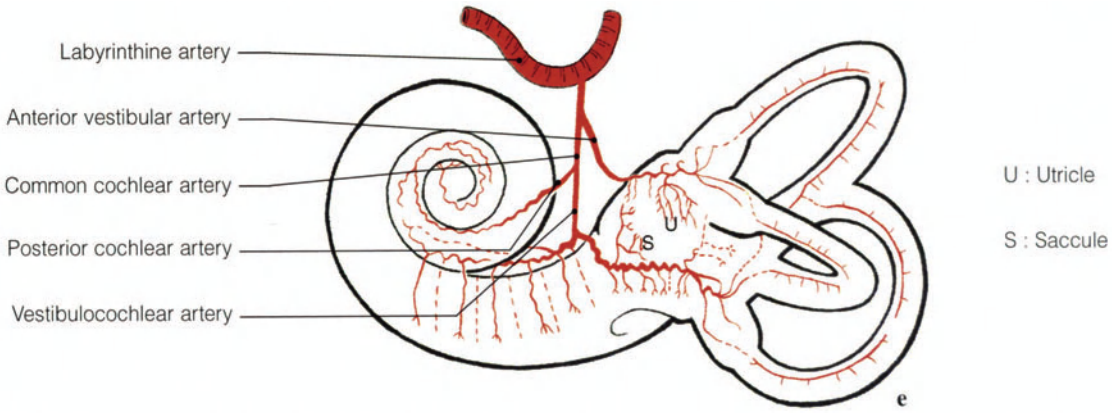


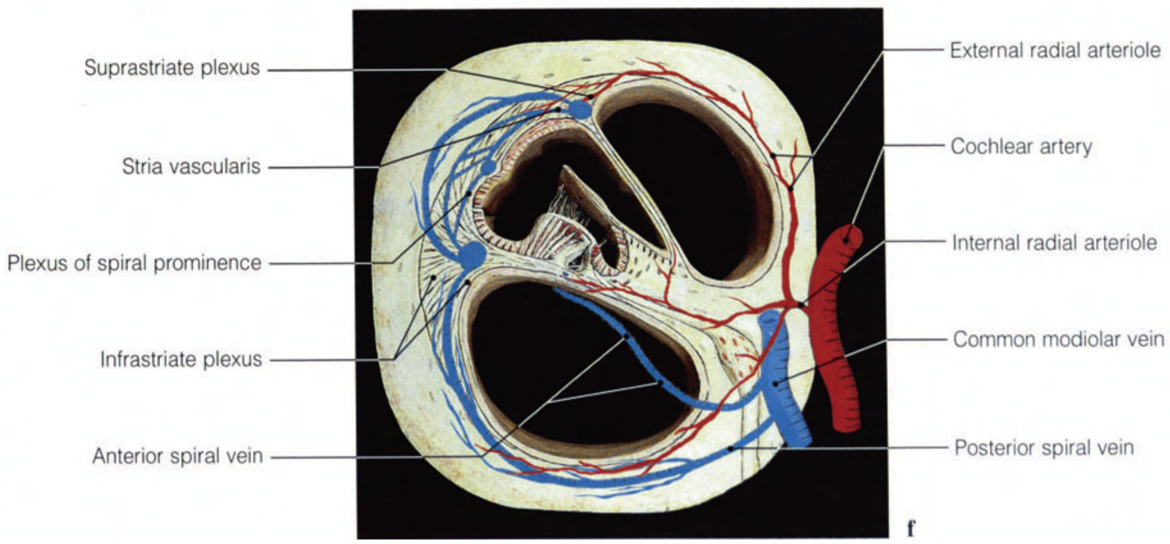
Fig. 24 a–f. MRI views of the cerebellopontine angle at the level of the acoustic and facial nerves; superimposed is a diagram of the anterior inferior cerebellar artery **(a, b)**; anatomical section of the same level **(c)**; diagram of arterial and venous vasculature of the internal ear **(d–f)** (MRI: Prof. Y. S. Cordoliani, Dr. J. L. Sarrazin, Hôpital du Val-de-Grâce, Paris); (anatomical section: Prof. J. P. Francke, Faculty of Medicine, Lille); (diagram **(e)**: Prof. Y. Guerrier, *Anatomie Chirurgicale de l'os temporal de l'oreille et de la base du crâne*, Tome 1, La Simarre, 1988)


Basilar artery
Anterior inferior cerebellar artery
Labyrinthine artery
Anterior vestibular artery
Common cochlear artery
Subarcuate artery
[anastomoses in middle
ear with branches of
the external carotid
artery]
Recurrent artery
Vertebral artery
Posterior cochlear artery
Vestibulocochlear artery
Cochlear branch of
vestibulocochlear artery
Vestibular branch of
vestibulocochlear artery

d


Labyrinthine artery
Anterior vestibular artery
Common cochlear artery
Posterior cochlear artery
Vestibulocochlear artery
S
U
U : Utricle
S : Saccule

e


Suprastriate plexus
Stria vascularis
Plexus of spiral prominence
Infrastriate plexus
Anterior spiral vein
External radial arteriole
Cochlear artery
Internal radial arteriole
Common modiolar vein
Posterior spiral vein

f

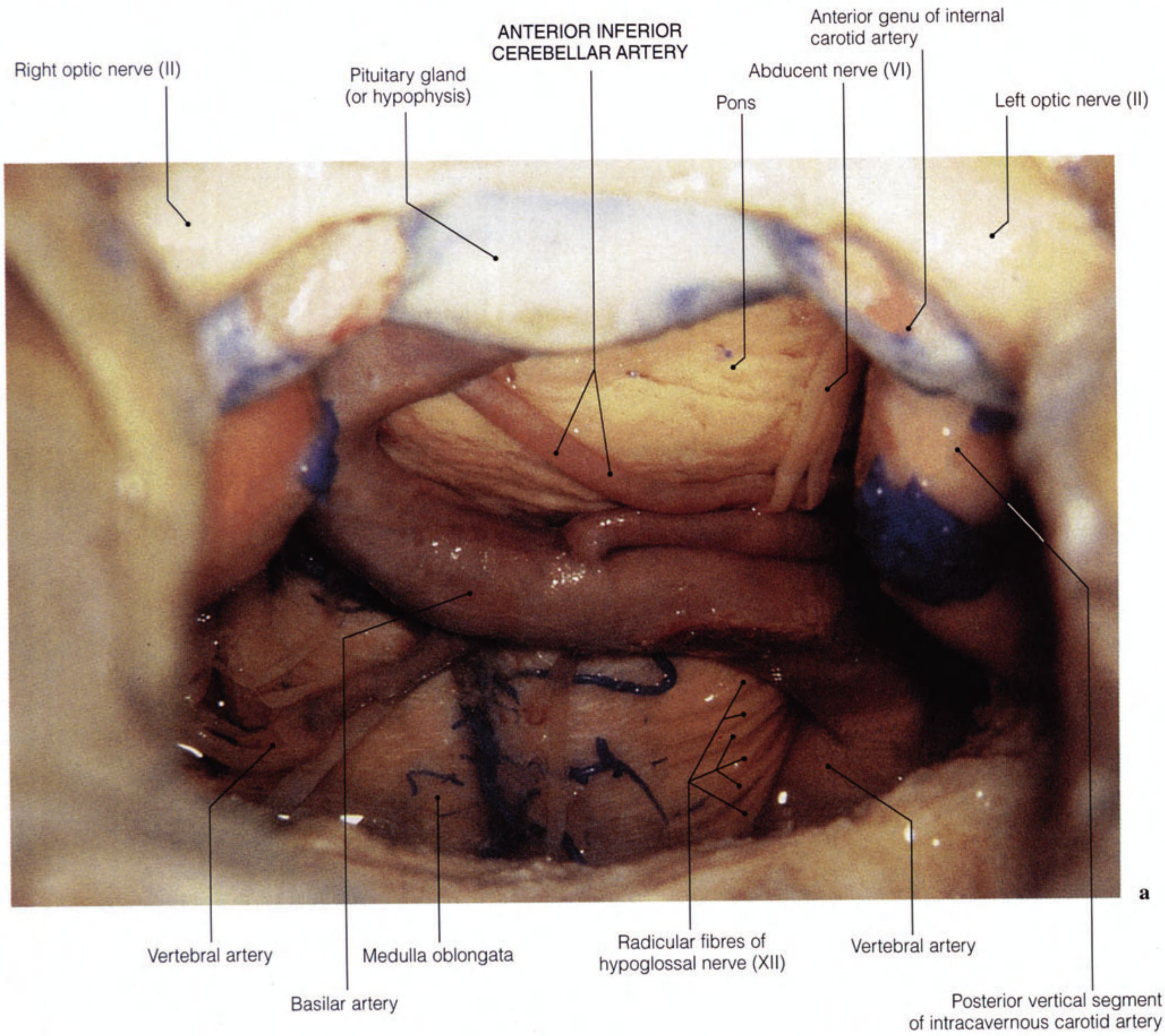


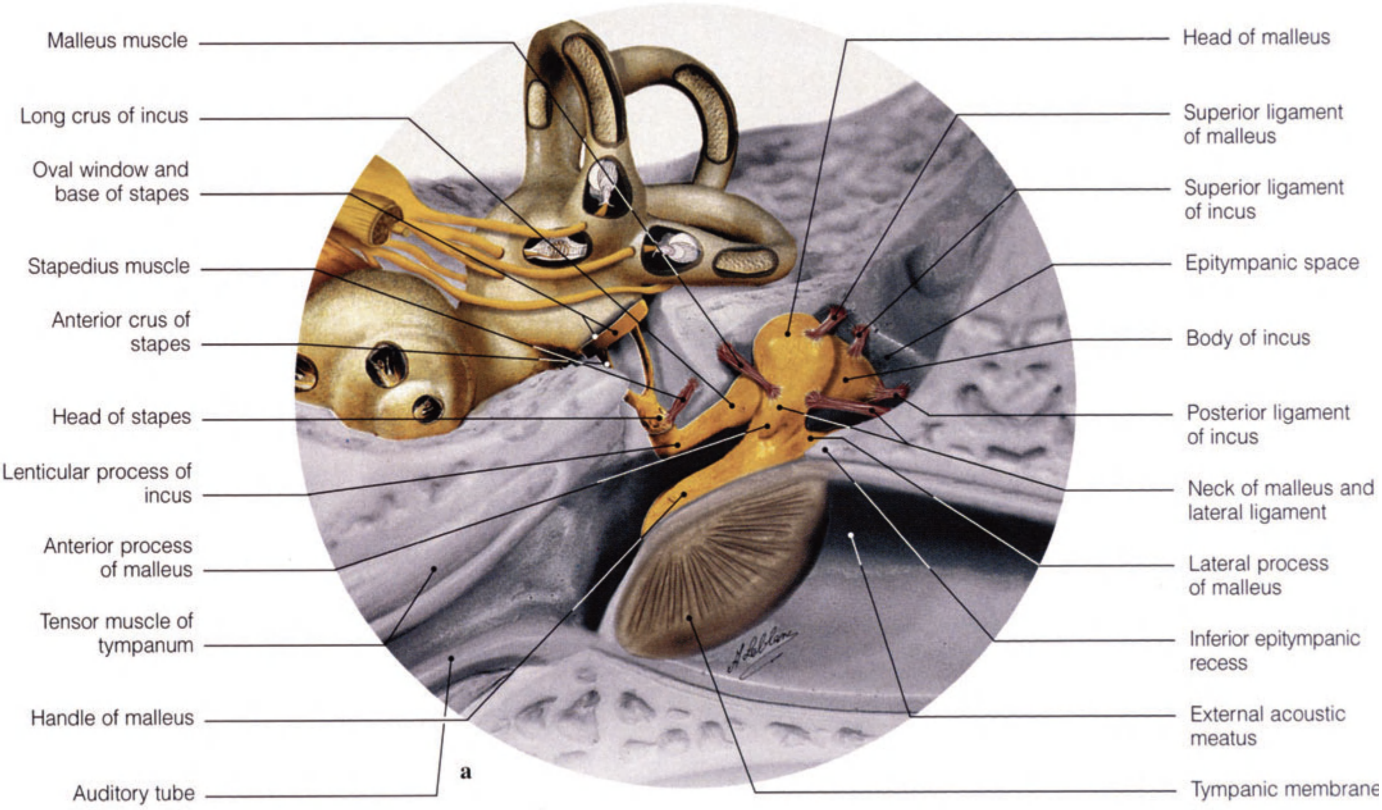
Fig. 25 Frontal anatomical view of the brain stem showing the basilar and anterior inferior cerebellar arteries (Prof. C. Sen, Prof. C. S. Chen, Prof. K. D. Post, *Microsurgical Anatomy of the Skull Base,* Thieme, 1997)

MIDDLE EAR, OSSICULAR CHAIN

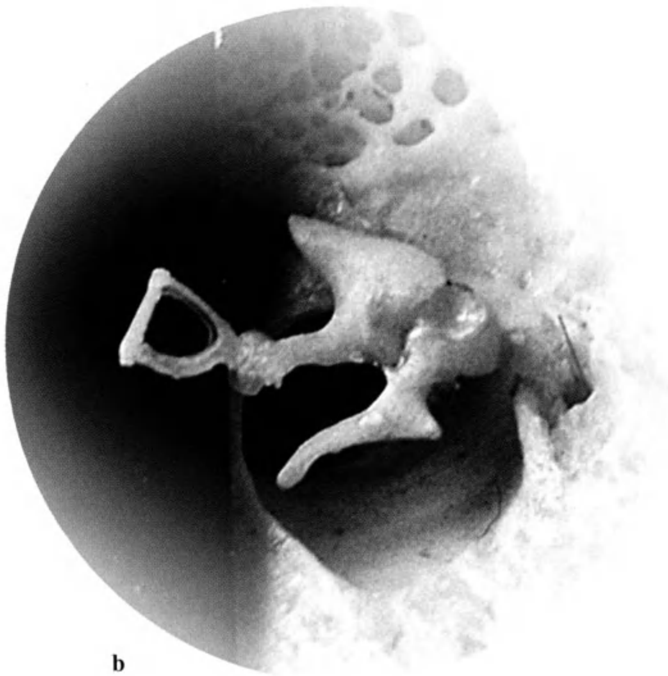
MUSCLES, LIGAMENTS, NASOTUBAL CAVITIES, EPITYMPANIC RECESS

Anatomy, diagrams, and CT views

(Pages 41-47)



a



b

Fig. 26 a, b. Diagram of the auditory ossicles and their ligaments **(a)**; anatomical view of the ossicular chain **(b)**

Middle ear (organ of transmission)

Anatomy

The **middle ear** is a long cavity containing air and formed of three parts:
- the tympanic compartment,
- the auditory tube,
- the mastoid cavities.

The tympanic compartment, hollowed out in the temporal bone, is separated from the external ear by the tympanic membrane and from the internal ear by
- the vestibular window above, corresponding to the vestibule,
- the cochlear window below, corresponding to the scala tympani of the cochlea.

The middle ear communicates with the rhinopharynx via the auditory tube. It is occupied by the chain of auditory ossicles
- the malleus, incus and stapes – which connect the tympanum with the vestibular window (Fig. 29–38).

The **malleus** has a head, a neck, a handle and two processes, one anterior and one lateral (Fig. 31.a–g). The head of the malleus is joined to the body of the incus at the incudomallear articulation.

The **incus** is situated behind the malleus and has a body and two limbs, long and short. It is situated in the attic and its body is flattened lateromedially, its articular surface is adapted to the articular surface of the head of the malleus.

The *short (upper or horizontal) limb* is squat, thick and of a flattened cone shape; its posterior end rests against the notch situated at the antero-inferior angle of the ostium of the *aditus ad antrum.*

The *long (lower) limb* is more slender and longer than the former and initially descends almost vertically behind and medial to the handle of the malleus. Its lower end bends inwards to terminate in a rounded tubercle: the *lenticular process* which articulates with the stapes.

The **stapes** is situated medial to the incus and extends almost horizontally from the lenticular process to the vestibular (oval) window.

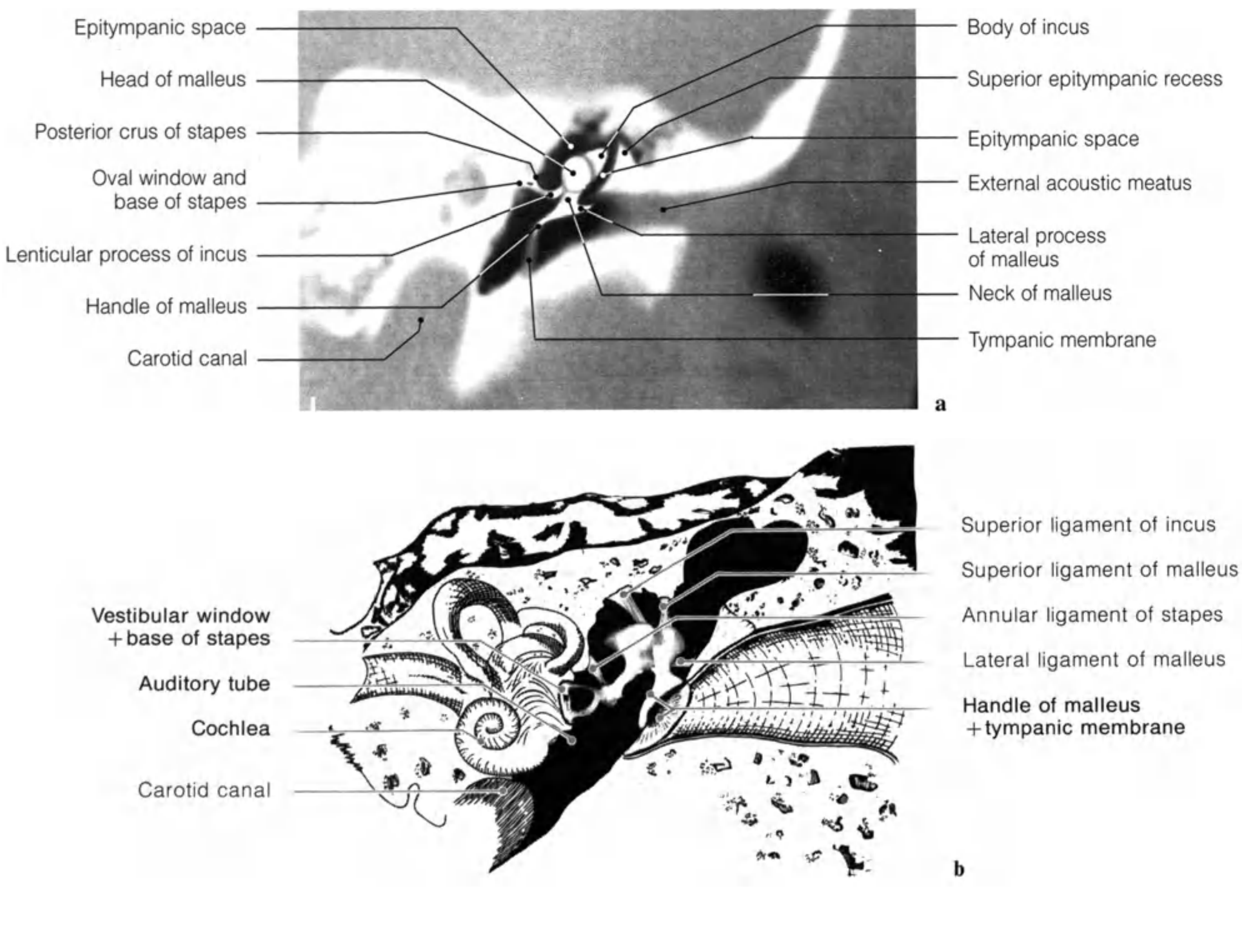
It has a head, a platelike base and two limbs. Laterally, the head is hollowed by a glenoid cavity which articulates with the lenticular process of the incus. The stapes is an oval membrane connected with the vestibular window.

The limbs of the stapes are two: anterior and posterior.

Connections of the ossicles: The ossicles are interconnected by two articulations: the incudomallear and incudostapedial joints.

The **motor muscles of the ossicles** are two in number: the stapedius and the tensor tympani.

Fig. 27 a, b. Computed tomography (CT) of the antro-adito-attical passage and of the incus and base of the stapes; diagram of the middle ear withe the incudomallear and incudostapedial articulations



The *stapedius muscle* occupies a bony canal hollowed in the thickness of the posterior wall of the tympanic box. This stapedial canal is situated in front of the upper part of the facial canal. The muscle is inserted at the posterior side of the head of the stapes.
The *tensor tympani muscle* is contained within the bony canal situated at the upper wall of the bony orifice of the auditory tube (Fig. 4.22; 27.b; 38); it is inserted at the upper end of the handle of the malleus.

Imaging

CLINICAL VARIANTS

Whatever the clinical types of affection of the petrous bone, before carrying out special views it is essential to examine the petrous bone by the classic survey views:
- frontal, with projection of the petrous bones into the orbits,
- sagittal (comparative) view,
- Stenvers-Schüller view,
- Worms-Bretton view,
- Meyer view,
- Hirtz view (Fig. 7.27).

These radiographs must be made symmetrically or comparably, save when investigating for fractures. After assessment of the abnormal or suspect zones in these films and of the clinical picture, special and more appropriate views may be used.

These views will depend on the clinical picture:

1) Otosclerosis of the base of the stapes or tympanosclerosis of the external ear:
Radiographic, tomographic and computed tomographic (CT) studies:
- in Guillen transorbital view,
- in Pöschl-Meyer view,
- in symmetric transorbital frontal view.

These display the antro-adito-attical passage, the whole of the auditory ossicles and the space between the base of the stapes and the vestibular (oval) window (Fig. 27–32).

2) Antral or antro-adito-attical cholesteatoma:
Radiographic and computed tomographic (CT) study of the middle ear, the auditory tube from the aditus ad antrum up to the antrum with the tegmen tympani and the tegmen of the external acoustic meatus to display any possible destruction:
- in Stenvers view,
- in Chaussé III view,
- in Guillen view,
- in Pöschl-Meyer view,
- in the 40° opposed transorbital view.

These views are also advisable to complete examination of the superior bulb of the jugular vein when there is a fracture or a tumour of the jugulare glomus that may have affected or destroyed the roof of the jugular foramen.

3) Intracanalicular acoustic neurinoma or fracture of internal ear:
Tomographic study of internal acoustic meatus:
- in Chaussé IV (50° to 60°) view,
- in Stenvers view,
- in Guillen view,
- in Hirtz view,
- in symmetric frontal view (petrous bones projected in orbits).
- in the prestudied inclined sagittal view.

4) Fracture or dislocation of the ossicles or posttraumatic incudomallear or incudostapedial luxation, or ossicular destruction (antro-adito-attical cholesteatoma):
Radiographic study with tomographic and computed tomographic (CT) sections of ossicles:
- in Pöschl-Meyer view,
- in symmetric frontal view with projection of petrous bones into orbits,
- in Guillen comparative view,
- in the prestudied inclined sagittal view.

TECHNIQUE

Tomographic study of the auditory ossicles and middle ear in prestudied inclined sagittal view:
- The subject is in lateral decubitus, with the head in profile resting on the temporoparietal region and making an angle of 30° to 40° in relation to the median sagittal plane;
- the centreing point is situated at the level of the external acoustic meatus to be examined, which is the furthest from the table;
- a tomographic series is to be made starting from the mastoid process, every 5 mm up to the petrous apex; after having identified the best planes for the ossicles several sections are made at 1 mm intervals.

Displayed: This prestudied view allows display of the chain of ossicles along its longest axis and all its bony components (Fig. 29, 30) as well as the stapes and its base opposite the vestibular (oval) window and the lenticular process of the incus. It makes it possible to study: the carotid canal, the jugular foramen, the ostium introitus, the semicircular canals, the vestibule and cochlea, the facial canal and the sulcus of the chorda tympani, the geniculate ganglion, the hiatuses of the greater and lesser petrosal nerves, the antrum, aditus and external acoustic meatus.

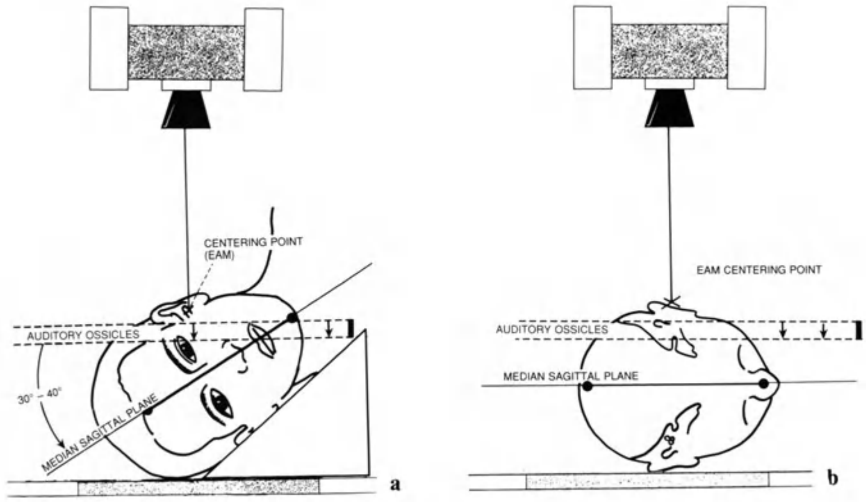


Fig. 28 a, b. Centering diagrams for study of ossicles in prestudied sagittal view

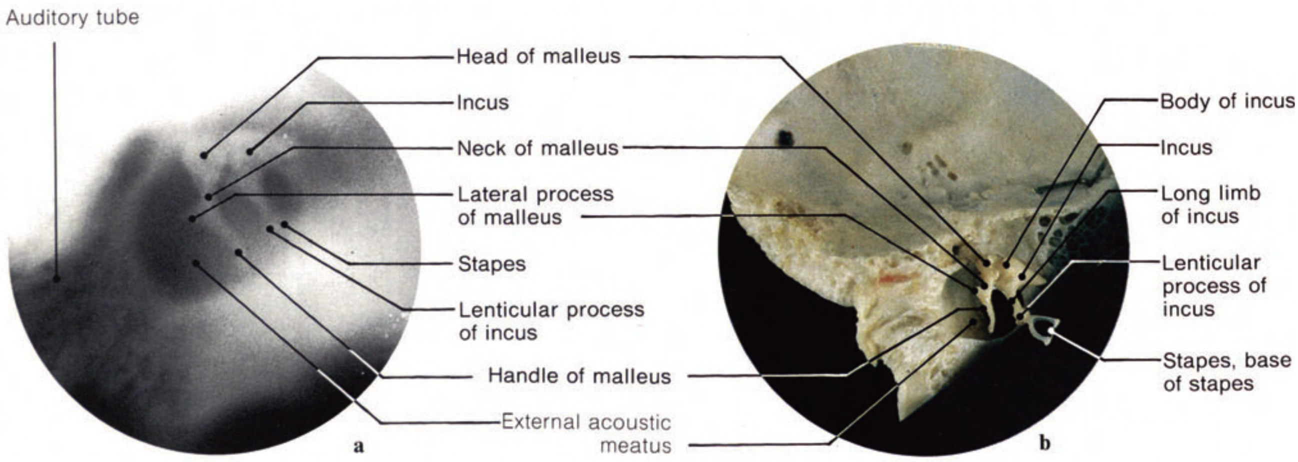


Fig. 29 a Imaging study of anatomic specimen; b view of chain of ossicles in dried bone (sagittal views)

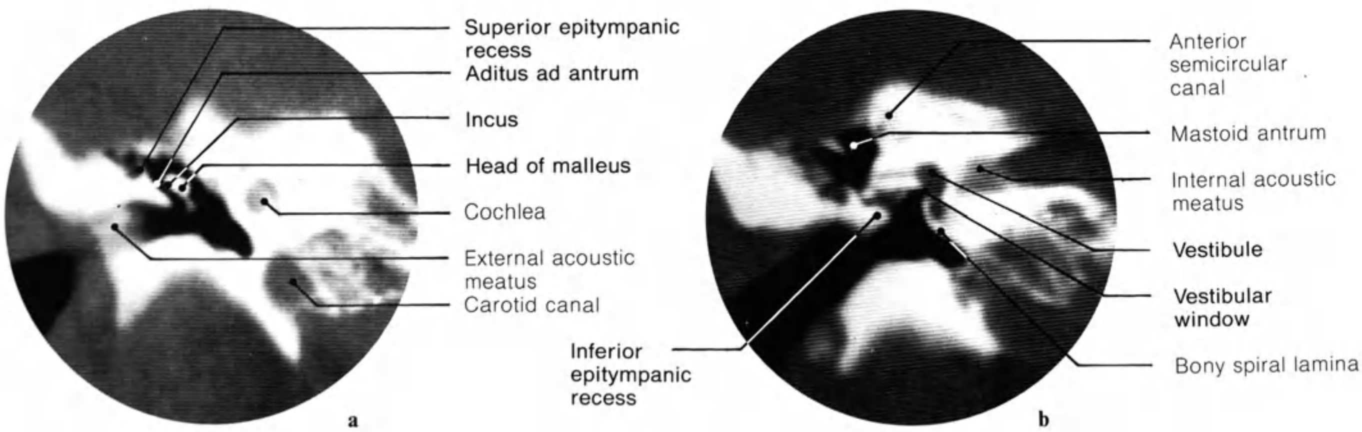


Fig. 30 a, b. CT in varied views; **a** antro-adito-attical passage; **b** vestibular window

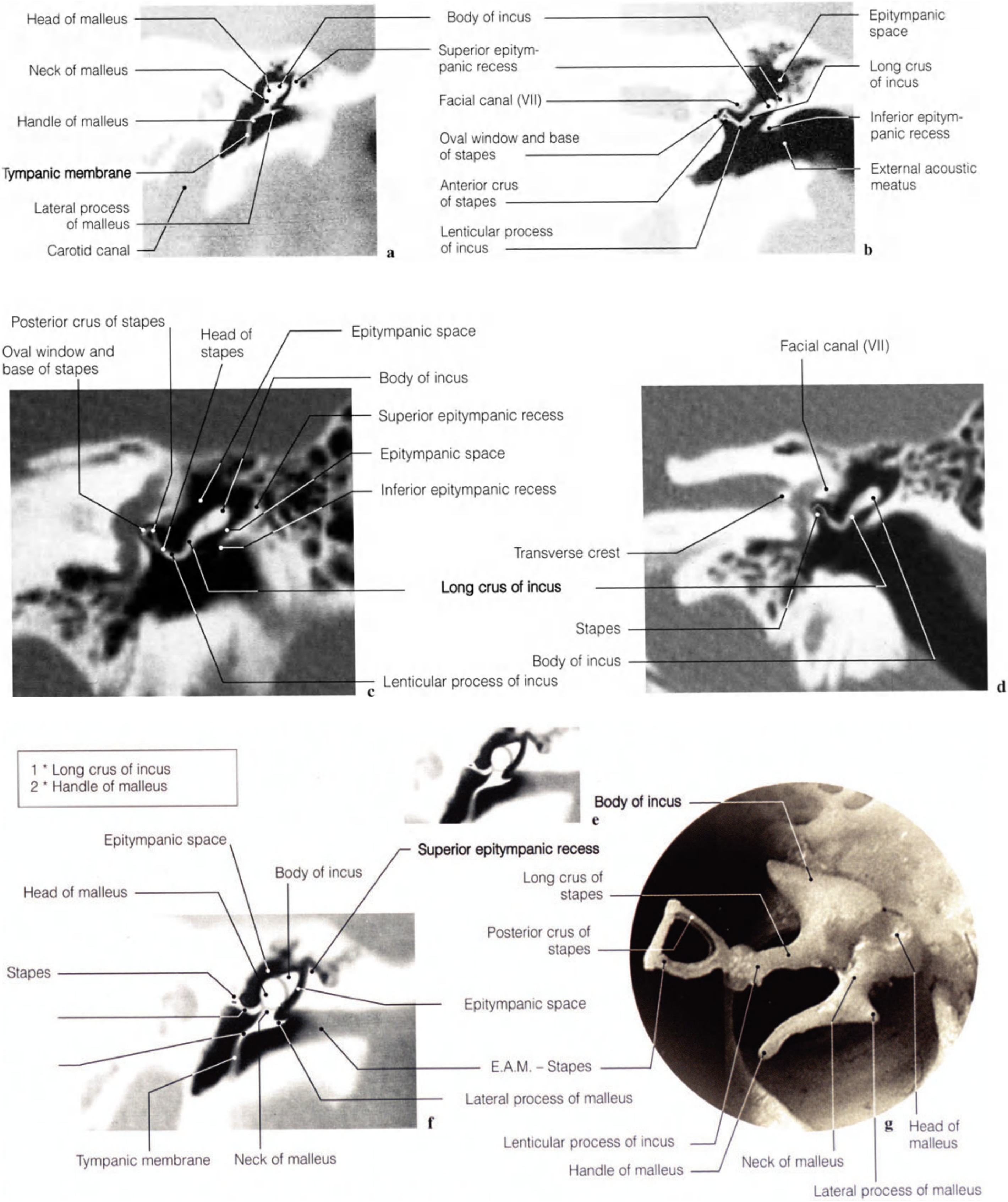


Fig. 31 a–g. CT views of the ossicular chain and the cavity of the middle ear along the axis of the footplate of the stapes and the oval window (CT: Dr. J. W. Casselman, A. Z. St Jan, Brugge; Prof. Y. S. Cordoliani; Dr. J. L. Sarrazin, Hôpital du Val-de-Grâce, Paris)

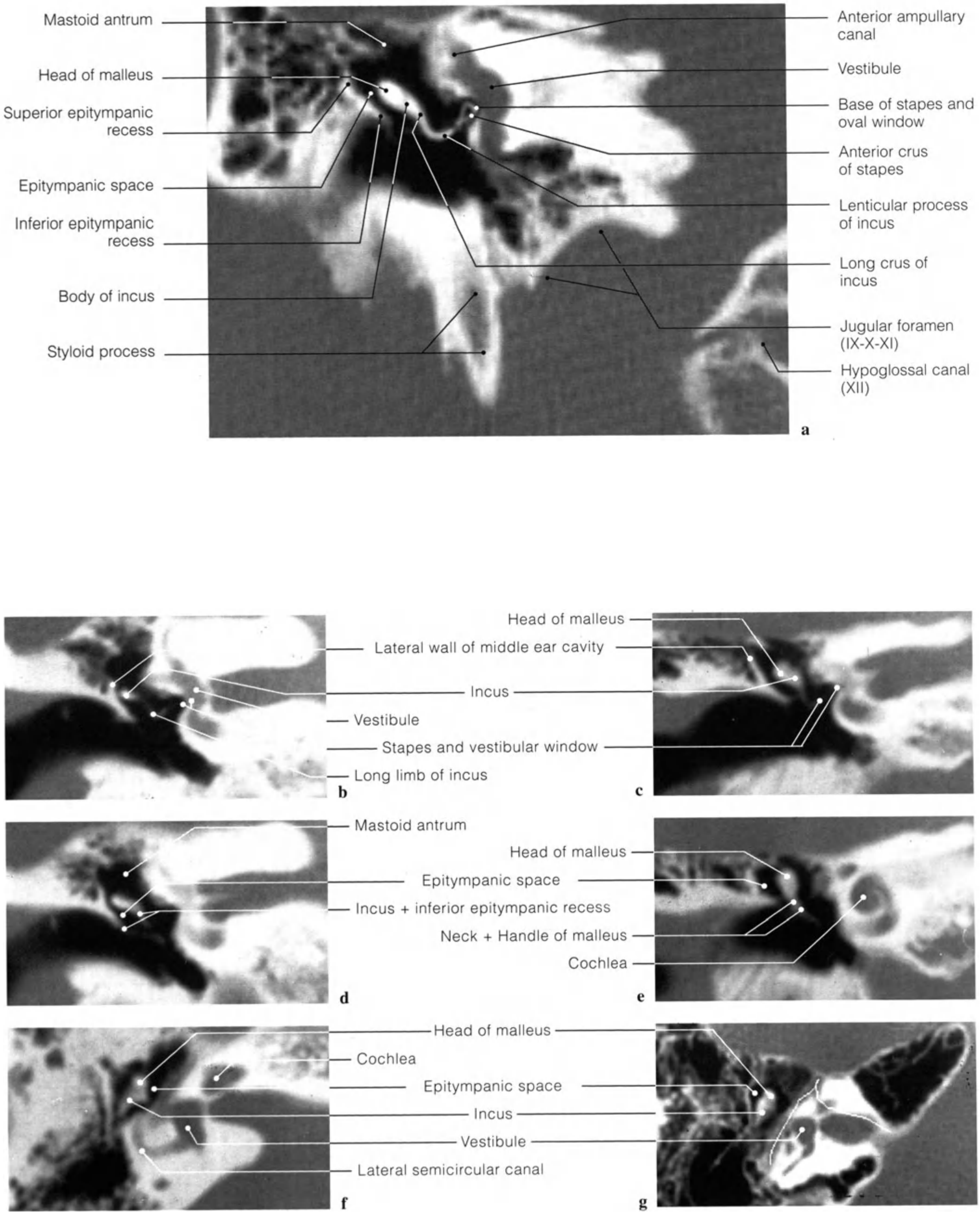


Fig. 32 a–g. CT view of the footplate of the stapes and the oval window (**a**); oblique (**b–e**) and axial (**f, g**) views of the epitympanic space and of the vestibulocochlear pathways

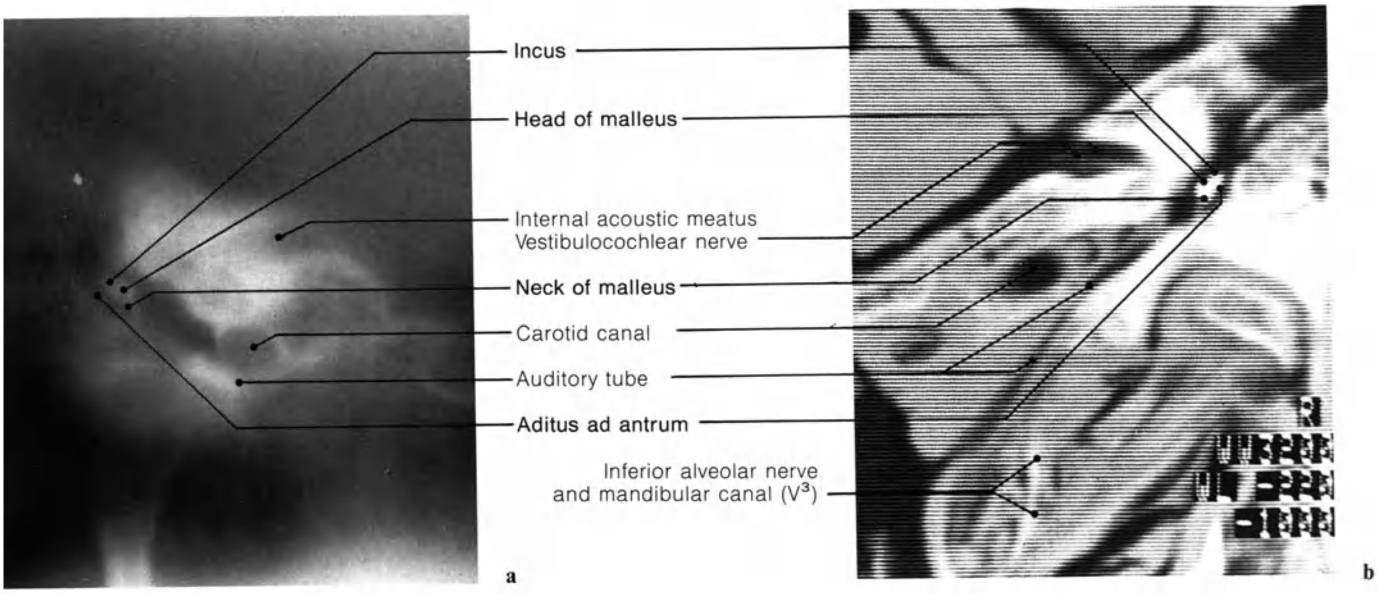


Fig. 33 a Tomographic Guillen view

Fig. 34 b Computed tomographic (CT) Worms-Breton view

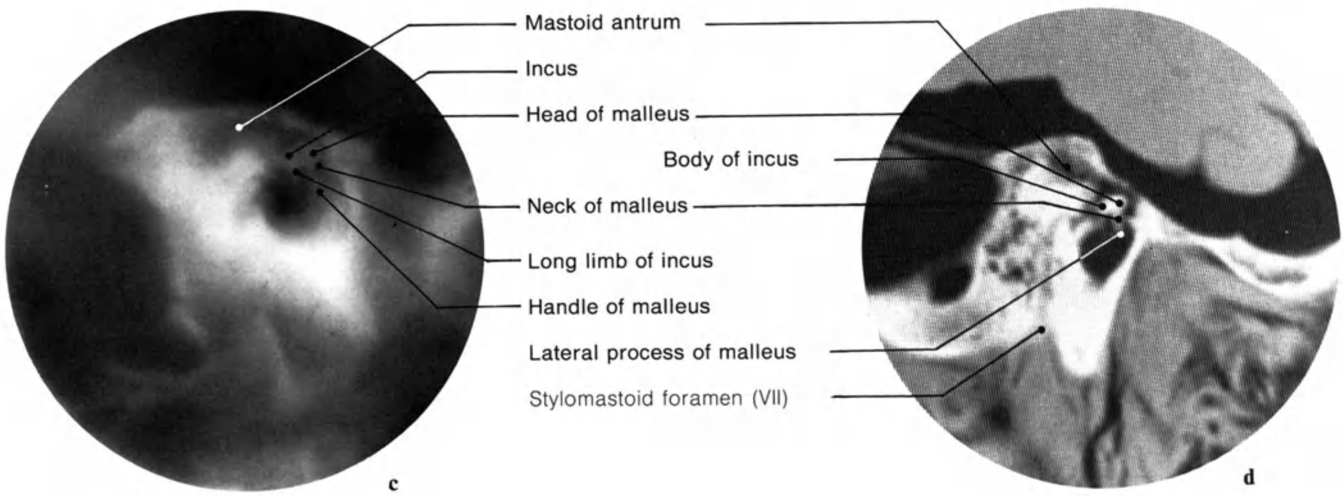


Fig. 35 c, d. Tomography and computed tomography (CT) in prestudied inclined sagittal view

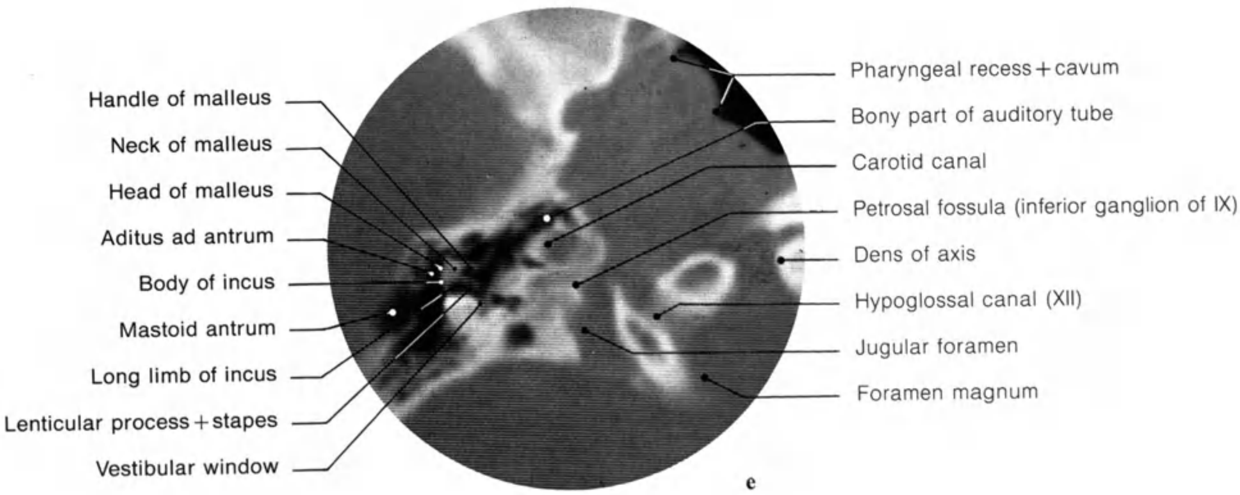


Fig. 36 e Computed tomography (CT) in oblique axial view

AUDITORY TUBE

TYMPANIC AND PHARYNGEAL ORIFICES OF THE AUDITORY TUBE, PHARYNGEAL (or ROSENNMÜLLER'S) RECESS

Anatomy, diagrams, and CT views

Anatomy

The auditory tube is the channel for aeration of the middle ear. It connects the tympanic cavity with the rhinopharynx, from which air enters at every swallowing movement to maintain the balance of pressure in the various part of the tympanic cavity.
The auditory tube lies in front of the cavum, aditus and mastoid antrum. It travels obliquely forwards, downwards and inwards.
The auditory tube consists of two parts, bony behind and fibrocartilaginous in front. It is lined by a mucous membrane (Fig. 1; 34; 37–39).

Imaging

Clinical features

When the canal is obstructed, either by a sarcoma or by tumours of cavum, rhinopharynx, jugular glomus or of the pharyngeal recess, this causes displacement of the tympanic membrane towards the interior of the cavity. The equilibrium on both sides of the membrane no longer exists and the stapes becomes embedded in the vestibular window, so producing diminished hearing acuity, vertigo and severe continuous tinnitus. Investigation of the auditory tube then becomes necessary.

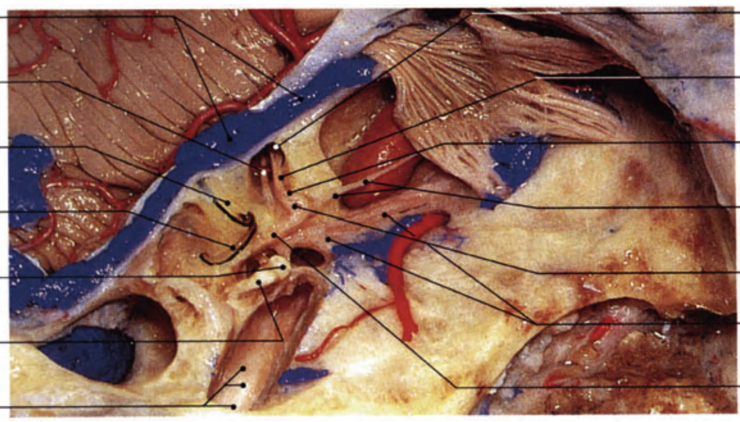


Fig. 37 Axial anatomical section at the level of the labyrinth showing the external and internal acoustic meatuses and the vestibulocochlear and facial nerves (anatomical section: Prof. C. Sen, C. S. Chen, K. D. Post, *Microsurgical Anatomy of the Skull Base,* Thieme, 1997)

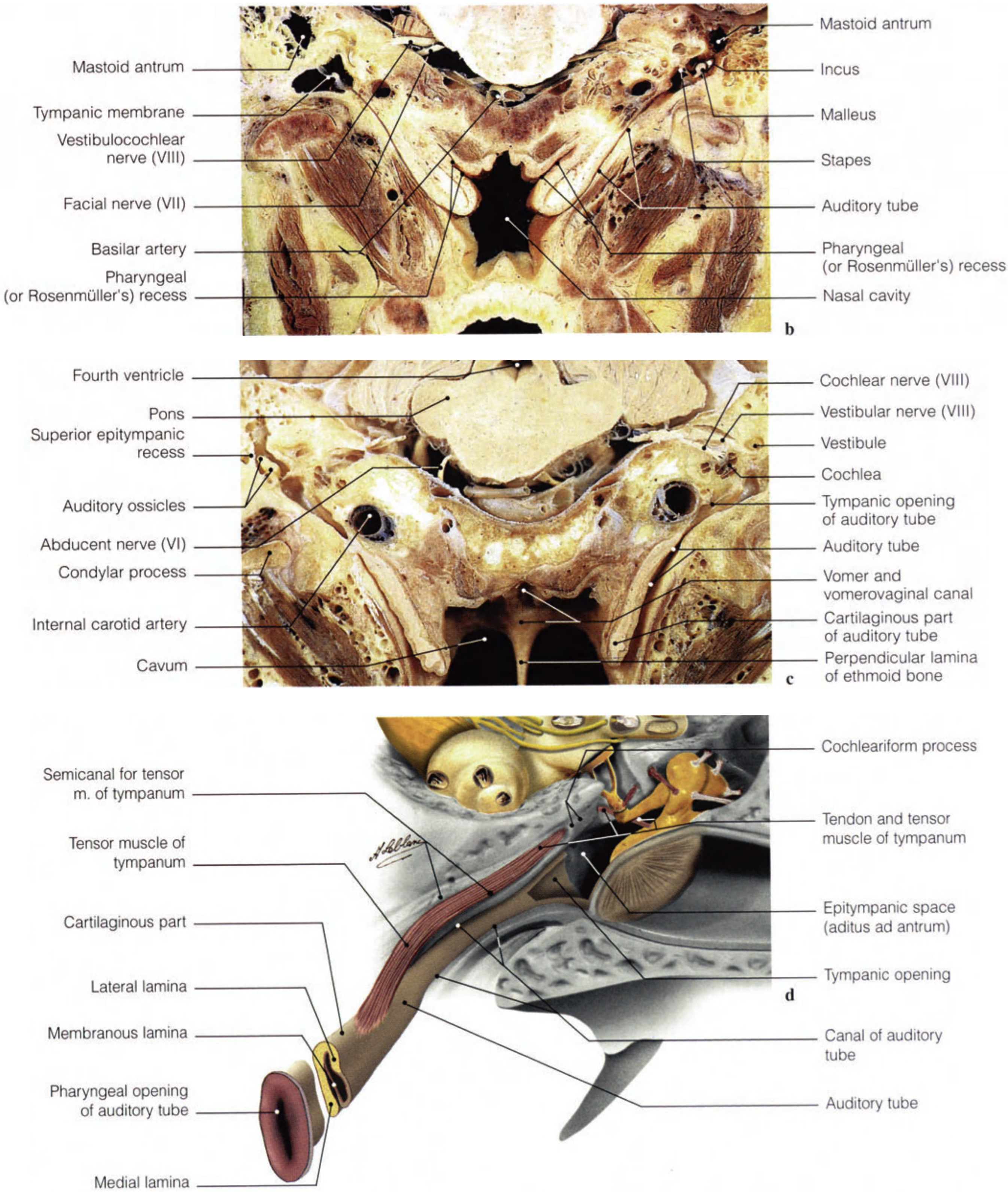


Fig. 38 a–d. CT view **(a)** and anatomical sections **(b, c)** of the auditory tubes and of the epitympanic space; diagrams of the auditory tube from its tympanic ostium to its pharyngeal ostium **(d)**

EXTERNAL EAR
EXTERNAL ACOUSTIC MEATUS
Anatomy, diagrams, and CT views

Anatomy

The external ear is formed of two segments: the auricle and the external acoustic meatus.
The external acoustic meatus is a canal extending from the concha to the tympanic membrane.
The wall of the meatus is cartilaginous and is covered throughout the extent of its internal surface by a skin lining continuous with the skin of the external ear.
The external ear, thanks to its shape and immediate relations, is the receptor organ for sound, which plays a very minimal part in man.

Imaging

CLINICAL FEATURES – INVESTIGATION

In cases of temporal fracture, and if the patient exhibits otorrhagia accompanied by tinnitus with blunted hearing, radiologic examination of the external acoustic meatus is necessary.
It is possible for a temporal fracture to extend into the walls of the external acoustic meatus, involve and displace the inferior epitympanic recess (or wall of the compartment) and produce obstruction of the aditus ad antrum. This fracture may also extend as far as the ossicular chain and produce incudomallear or incudostapedial dislocation; the stapes may be embedded in the vestibular window, producing continuous tinnitus.

Other pathologic conditions of the external acoustic meatus:
- tympanosclerosis,
- an antral and antro-adito-attical cholesteatoma expanding upwards and inferolaterally may, after having destroyed the tegmen tympani, erode the roof of the external acoustic meatus.

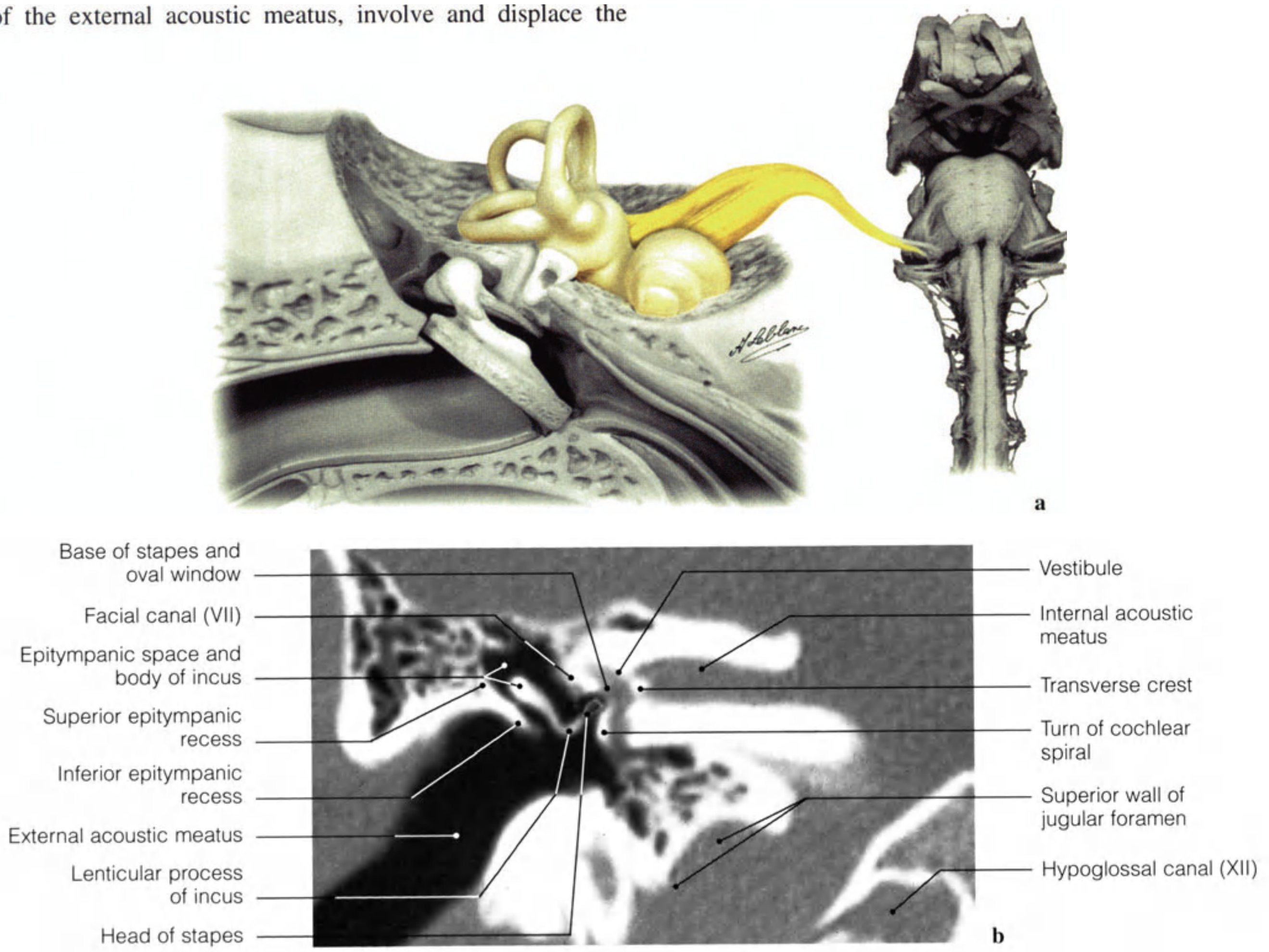


Fig. 39 a, b. CT view and frontal anatomical diagram of the external acoustic meatus

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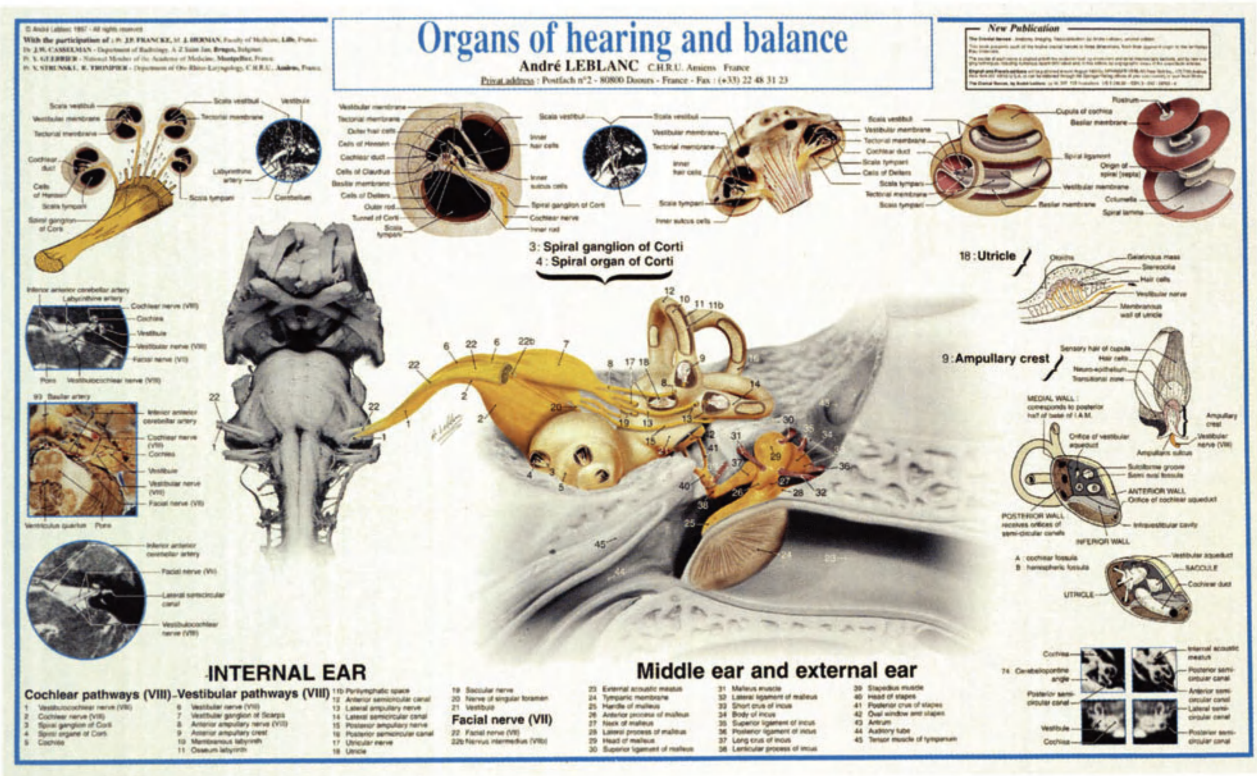

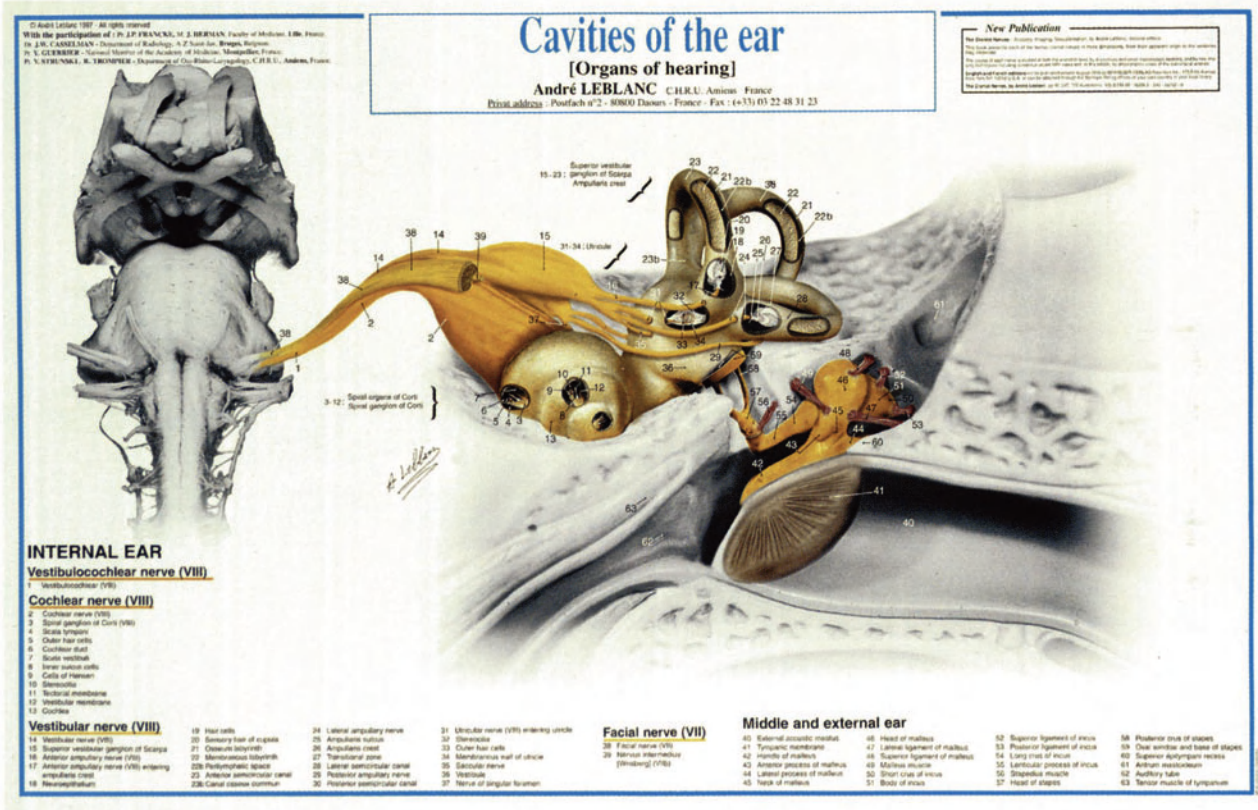

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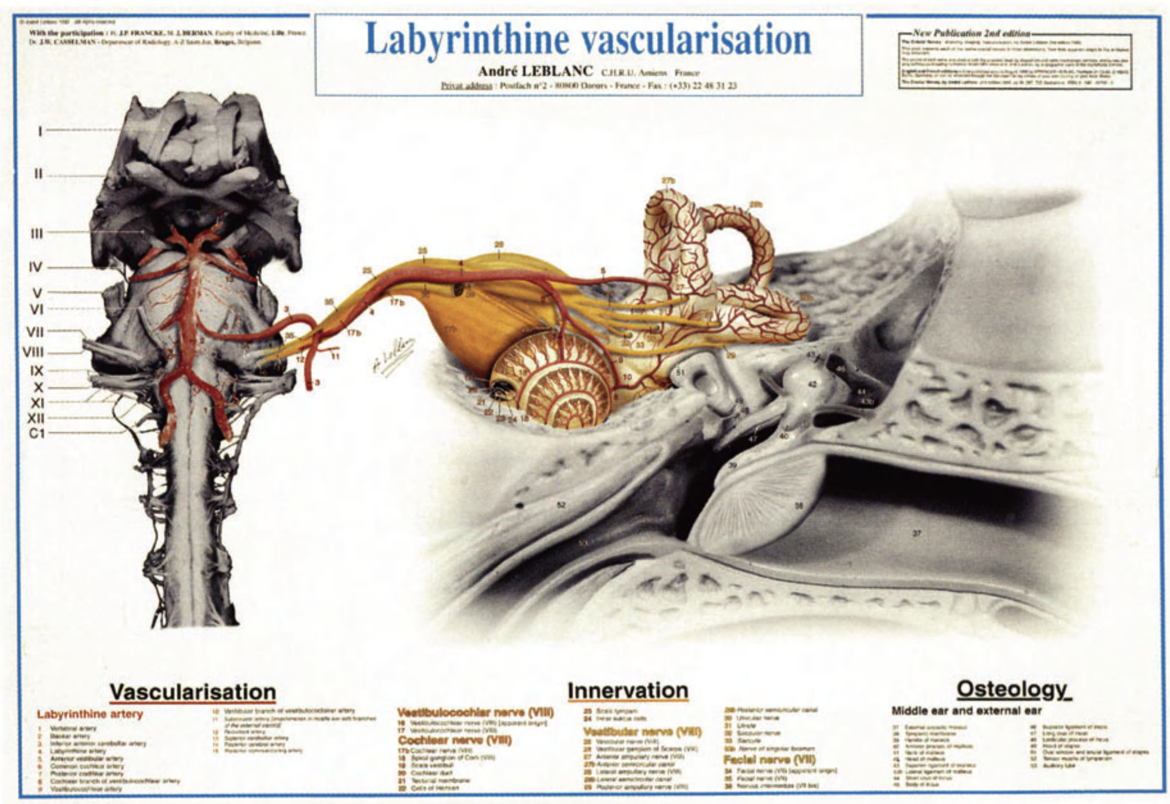

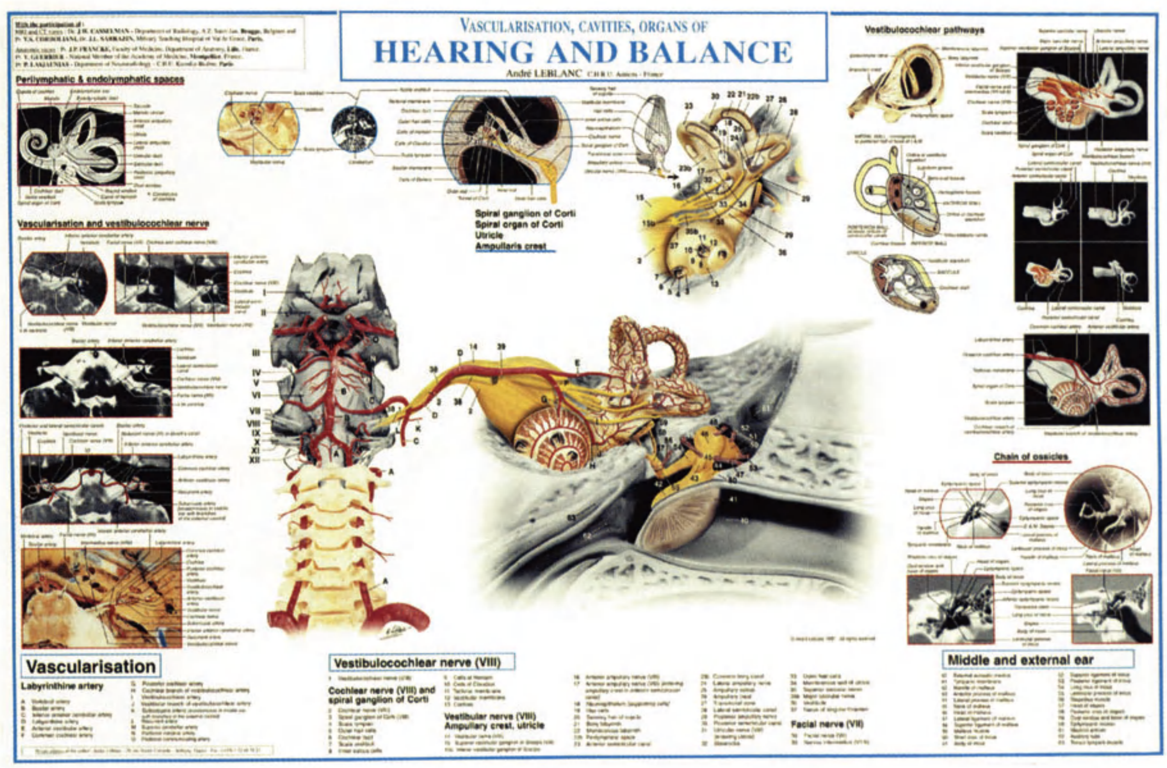

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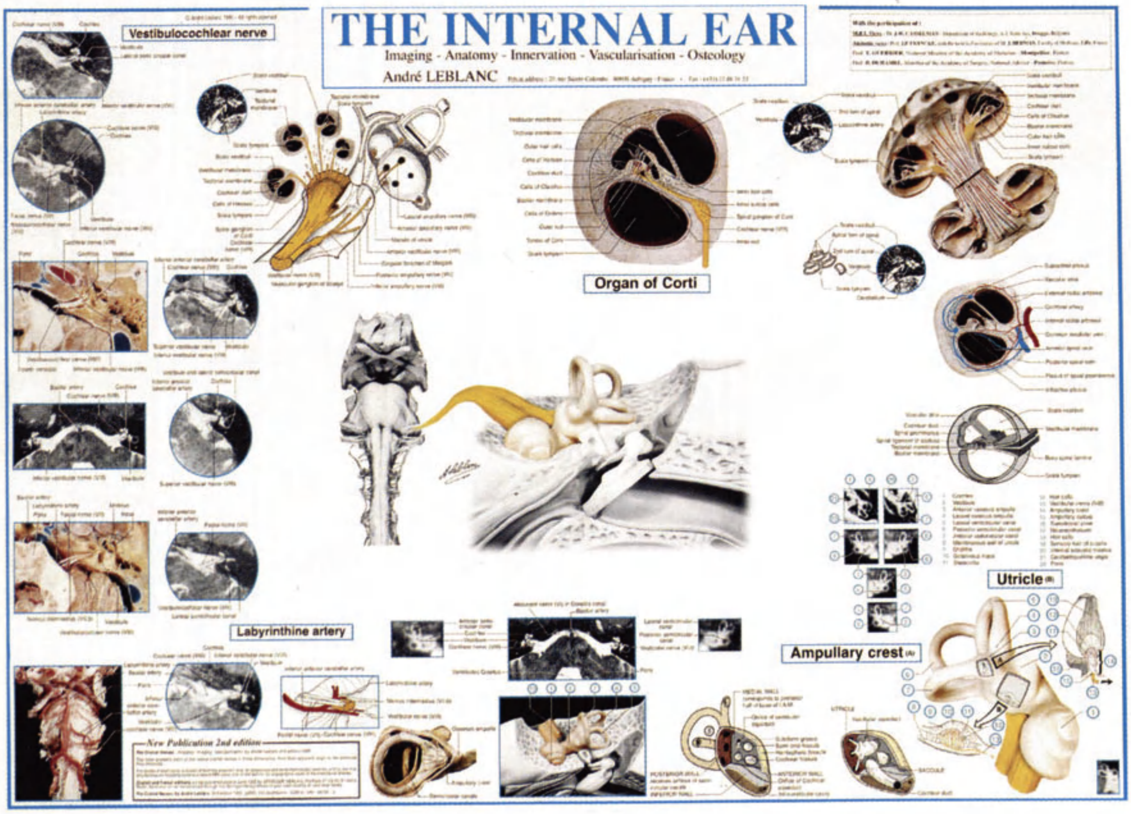

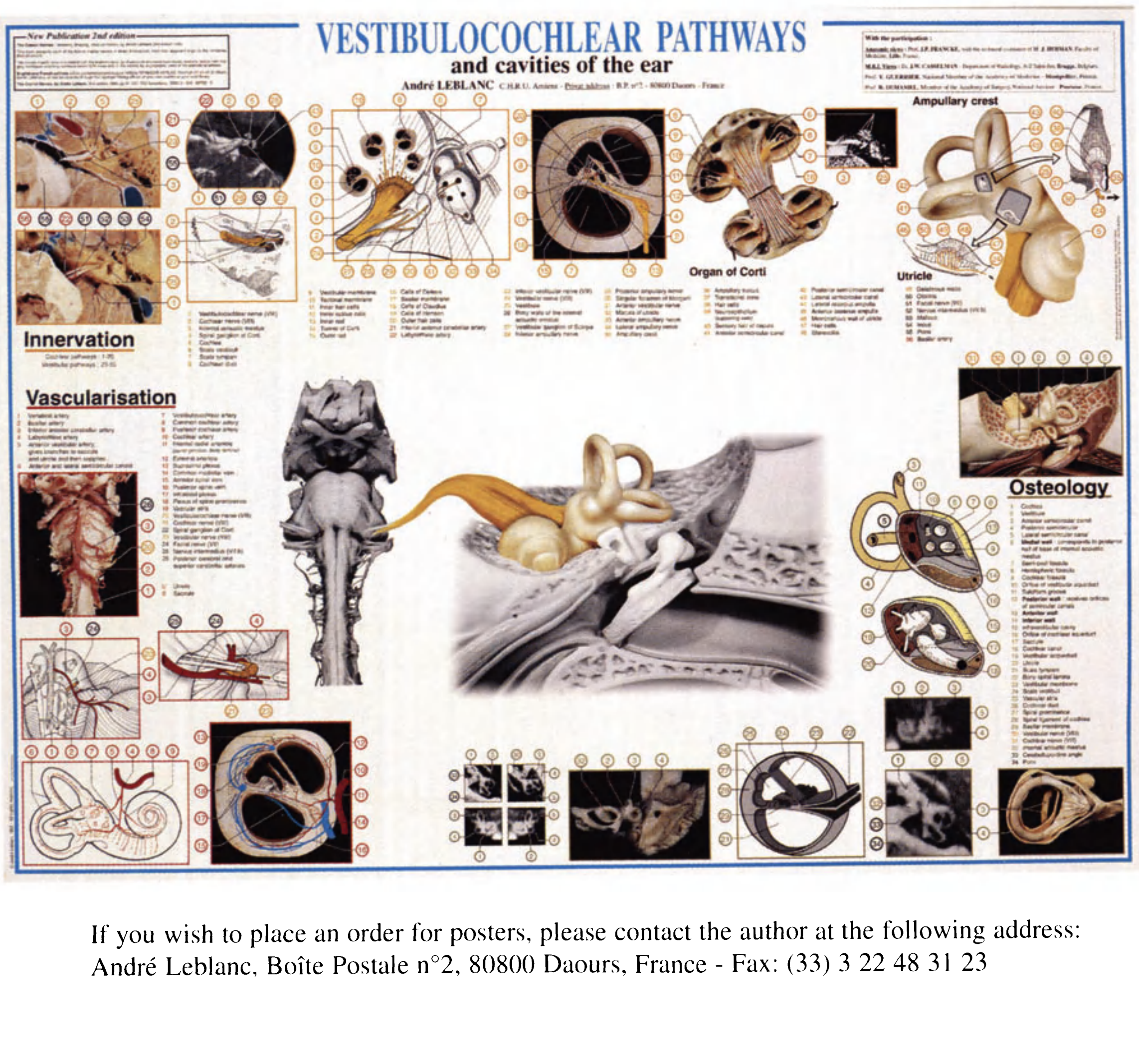

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