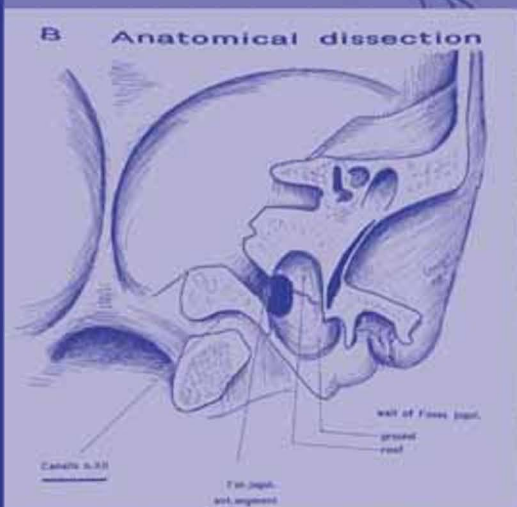
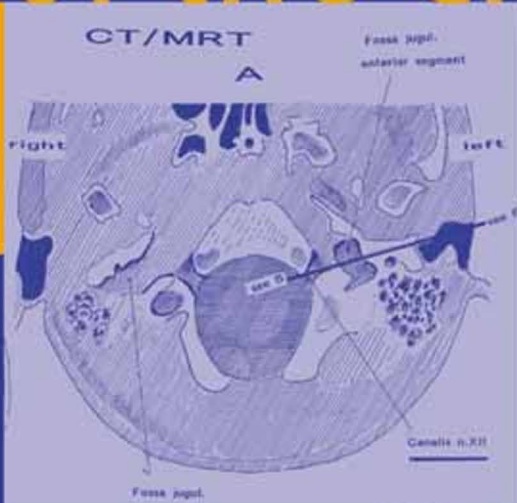


Wolfgang Seeger

# Endoscopic and Microsurgical Anatomy of the Cranial Base



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Wolfgang Seeger

Endoscopic and Microsurgical Anatomy  
of the Cranial Base

In collaboration with  
Jan Kaminsky and Astrid Weyerbrock

SpringerWienNewYork

Prof. em. Dr. med. Wolfgang Seeger  
Department of Neurosurgery, University Hospital Freiburg, Freiburg/Br.,  
Germany

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## Preface

Neuroendoscopic transnasal surgical approaches have become increasingly common for some time, and have started to replace microsurgical techniques in pituitary surgery. Endoscopic transnasal approaches have also been recently used in some neurosurgical centres to reach pre- and retrosellar areas and targets localized in the basal cisterns. One major factor is the localization of the carotid artery between the siphon and aperture externa of the carotid canal at the base of the petrous bone.

The following areas are especially critical:

1. the anterior siphon area
2. the area between the bottom of the sphenoid sinus and the base of Processus pterygoideus
3. the proximity of the carotid canal to the Tuba Eustachii, the labyrinth, Bulbus superior of the internal jugular vein and the facial nerve.

Some segments of the course of the carotid artery are well known but they have rarely been surgical target areas using transnasal approaches to date.

This has changed since the introduction of modern imaging techniques, especially neuronavigation. It has become possible to identify and localize structures of the skull and extra- and intracranial structures in any desired plane.

The study of the anatomy of the skull base should not exclude experience gained in cadaver skull dissections. In contrast to imaging techniques, standard cadaver skull dissections do not permit examination of the above mentioned critical areas of the skull base without destruction of the skull specimen. Therefore it is necessary to also present a representative variety of skull preparations, which this book seeks to do.

The most important blood vessels and nerves passing the bony foramina, foveae and fissures have been labelled by colour. As this book is based on a collection of skulls, rare or unknown anatomical variants may be illustrated which are commonly not or only rarely found in anatomical atlases or standard medical textbooks. One example of a rare anatomic variant is the variability of the foramen spinosum and the adjacent Spina angularis, which are covered by the Tuba auditiva and the origins of M. tensor and the levator veli palatini. These variants might gain some relevance for neuronavigation and endoscopy because of the closeness of A. meningea media and the transitional area between the Pars ossea and Pars cartilaginea tubae.

The author owes a particular debt of gratitude to the chairs of the departments of neurosurgery in Freiburg (Prof. Zentner) and Giessen (Prof. Böker), and to the director of the neurosurgical department in Zwickau (Prof. Warnke), and their coworkers, especially PD Dr. Kaminsky (Freiburg), Dr. Nestler, Dr. Preuss, and the oto-rhino-laryngologist PD Dr. Bockmühl (Giessen).

Dr. Astrid Weyerbrock has carefully revised and edited the manuscript.

The author is grateful to Ms. E. Rotermond, Professor Zentner's secretary, for the typing and layout of the text.

I would especially like to thank the Springer Verlag Wien New York for its continuous support and cooperation and excellent publication of my books for over 3 decades.

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**CHAPTER I**  
**SURVEY**  
(Figs. 1 to 8)

## Overview (Figs. 1 to 5)

**The following figures illustrate the anatomical base of transnasal endoscopic routes but not according to conventional anatomical views.**

For better understanding, it is useful to give an overview of the well known anatomy as shown in Figs. 1 to 5.

## Topography of the endoscopic routes (Figs. 6 to 8)

The routes can be divided into five segments:

Cavum nasi and paranasal sinuses

Foramen sphenopalatinum and adjacent structures

Foramen lacerum and adjacent structures

Pyramis (petrous bone)

Area of Clivus

### Cavum nasi and paranasal sinuses

Unusual and nearly unknown routes of CSF leaks are important, which occur more frequently in extended transnasal endoscopy (Castelnuovo P, Locatelli D, 2007).

Other aspects of the transnasal routes are well known from pituitary surgery.

### Foramen sphenopalatinum and adjacent structures

Foramen sphenopalatinum is located at the bony connection of the anterior inferior segment of Sinus sphenoidalis, Meatus nasi medius, and Fossa pterygopalatina. Its dorsal margin corresponds to the anterior Apertura of Canalis pterygoideus.

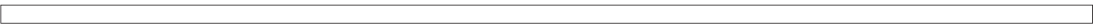
### Foramen lacerum

Its anterior margin corresponds to the posterior Apertura of Canalis pterygoideus. The Canalis penetrates the base of Processus pterygoideus (for definition of the course of the carotid artery between Sinus sphenoidalis and Foramen lacerum). Canalis pterygoideus is an important landmark at surgery, as it defines the course of the carotid artery ...

### Pyramis (petrous bone)

Anterior area: A. carotis int. and its relationship to Tuba and A. meningea media

Posterior area: A. carotis int. and its relationship to Labyrinth, Tuba, Foramen jugulare and Canalis n. hypoglossi.



**SURVEY** (Figs. 1 to 8)

Fig. 1

Overview



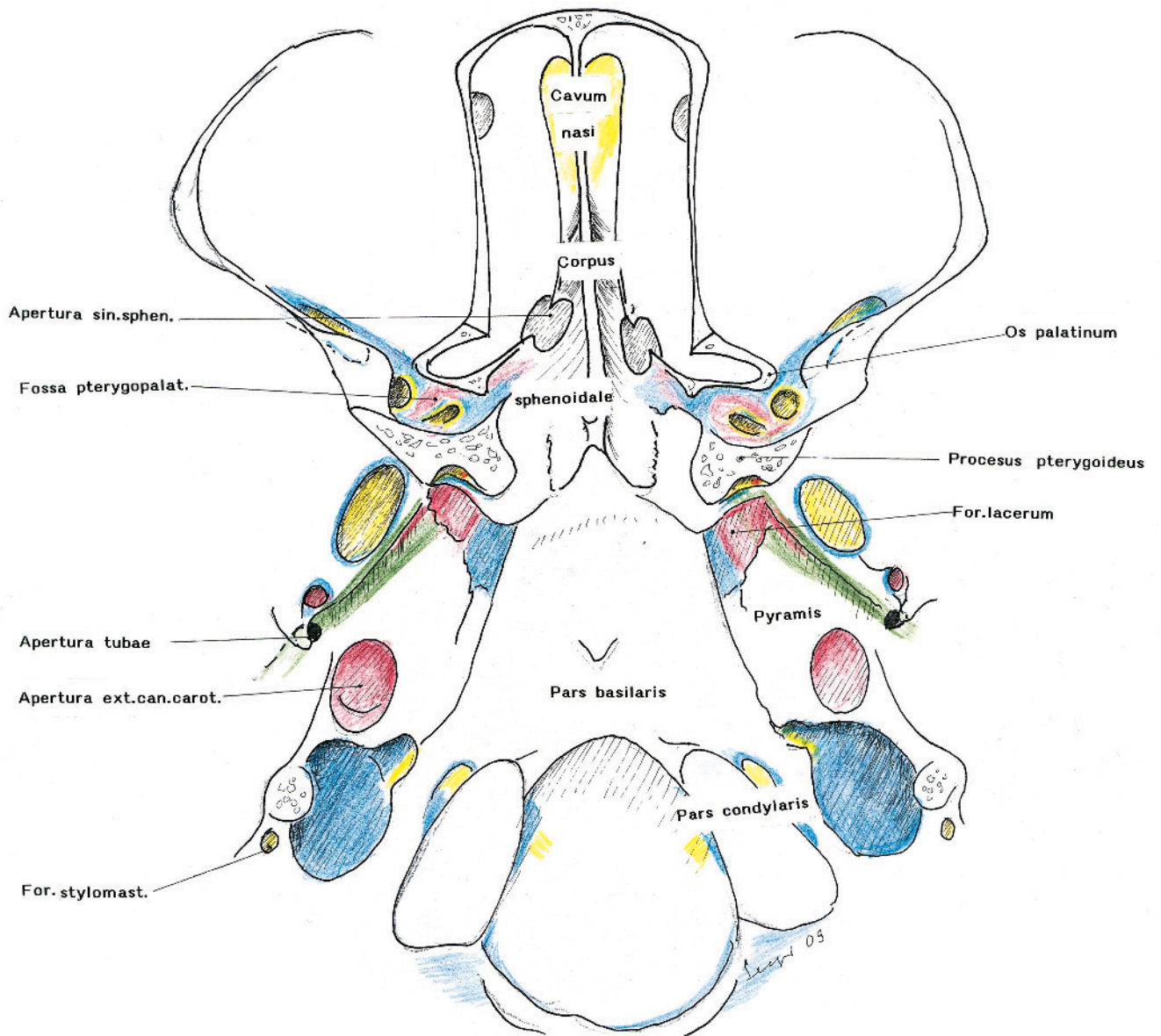
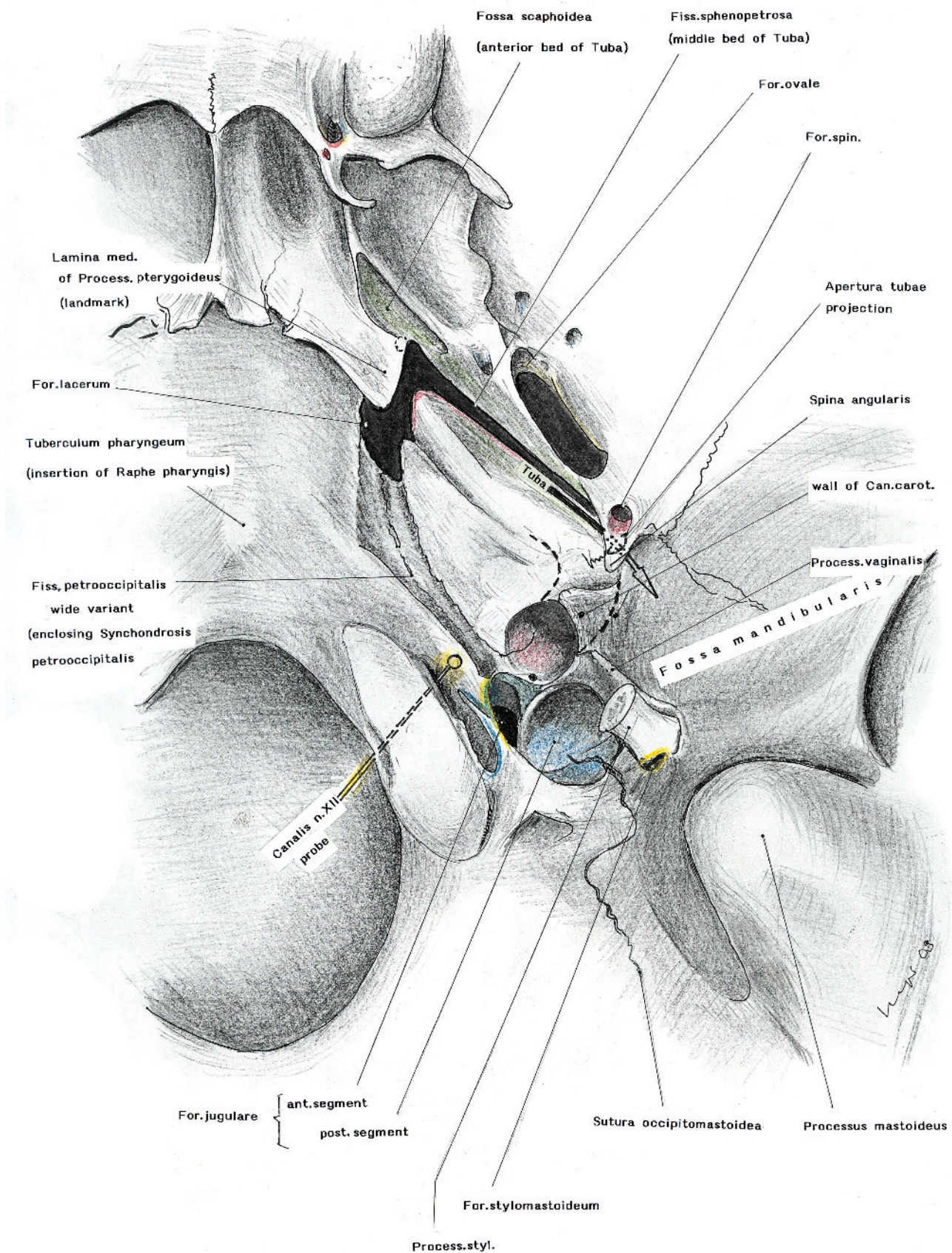




Fig. 2

Cranial base. Extracranial medial area





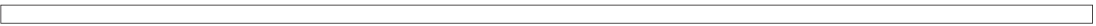


Fig. 3

Addendum to Fig. 2  
Cranial nerves and blood vessels, schematic



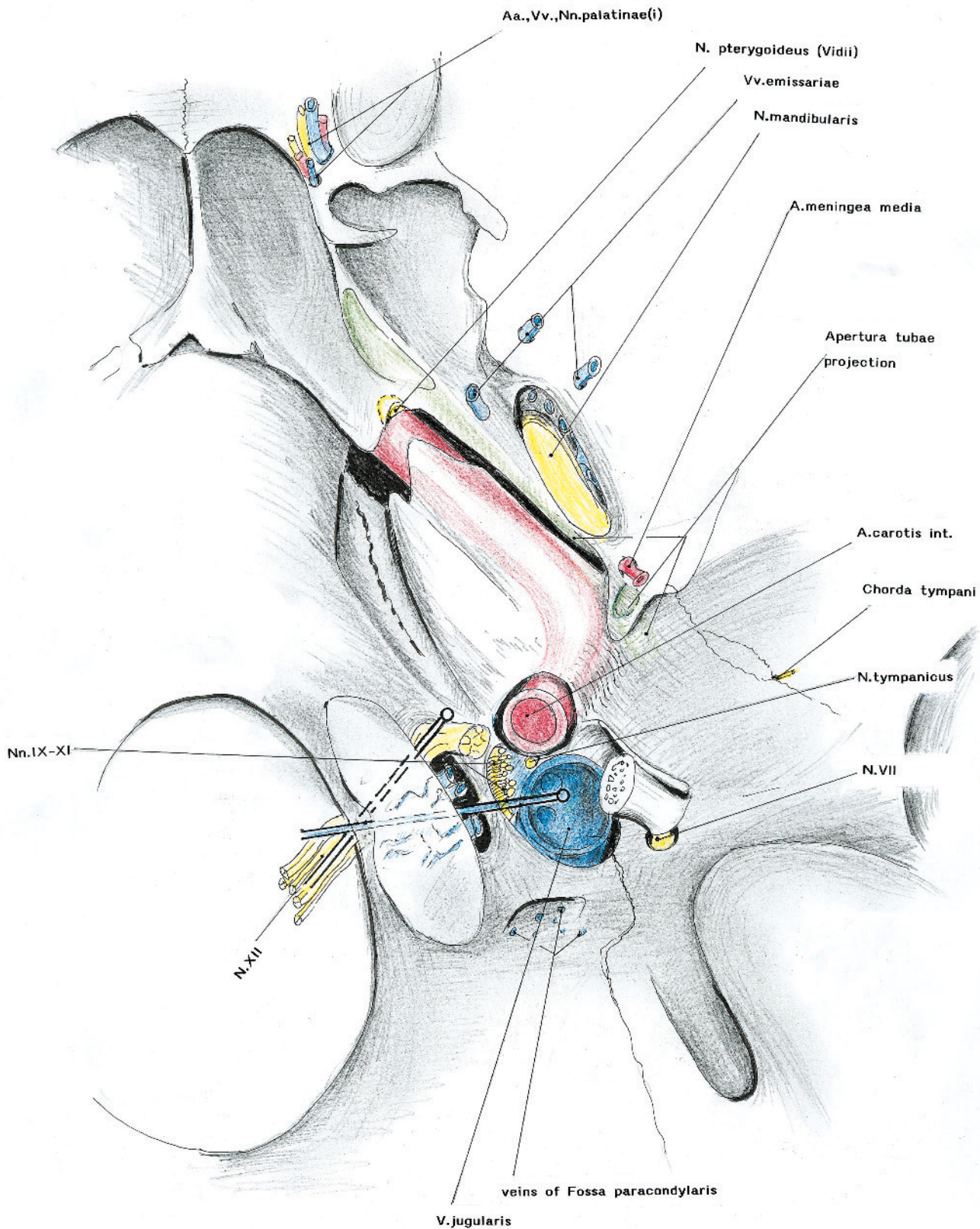
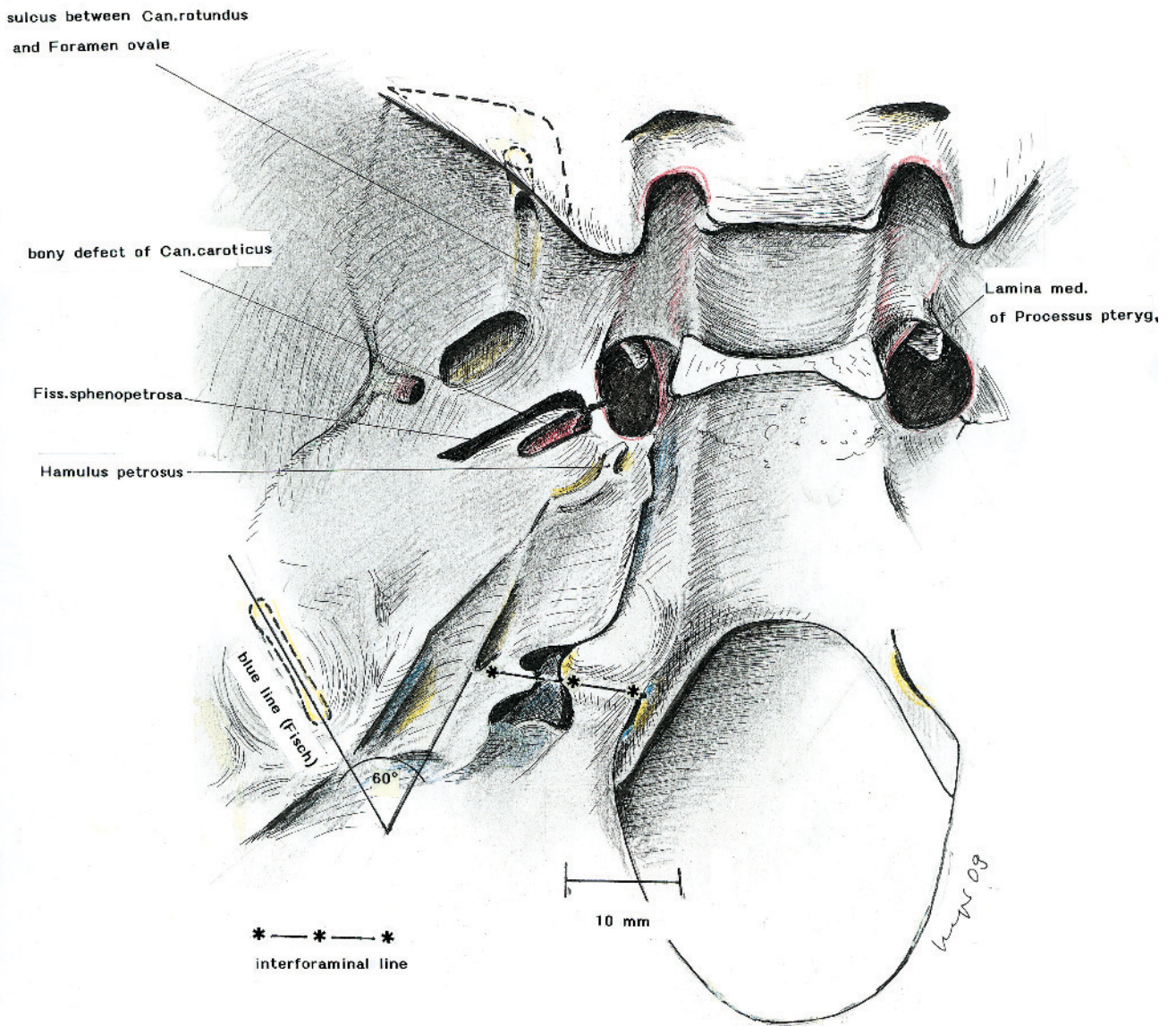




Fig. 4

Skull base. Intracranial medial area.



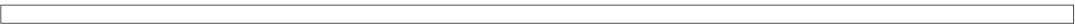


Fig. 5

Addendum to Fig. 4  
Cranial nerves and blood vessels, schematic



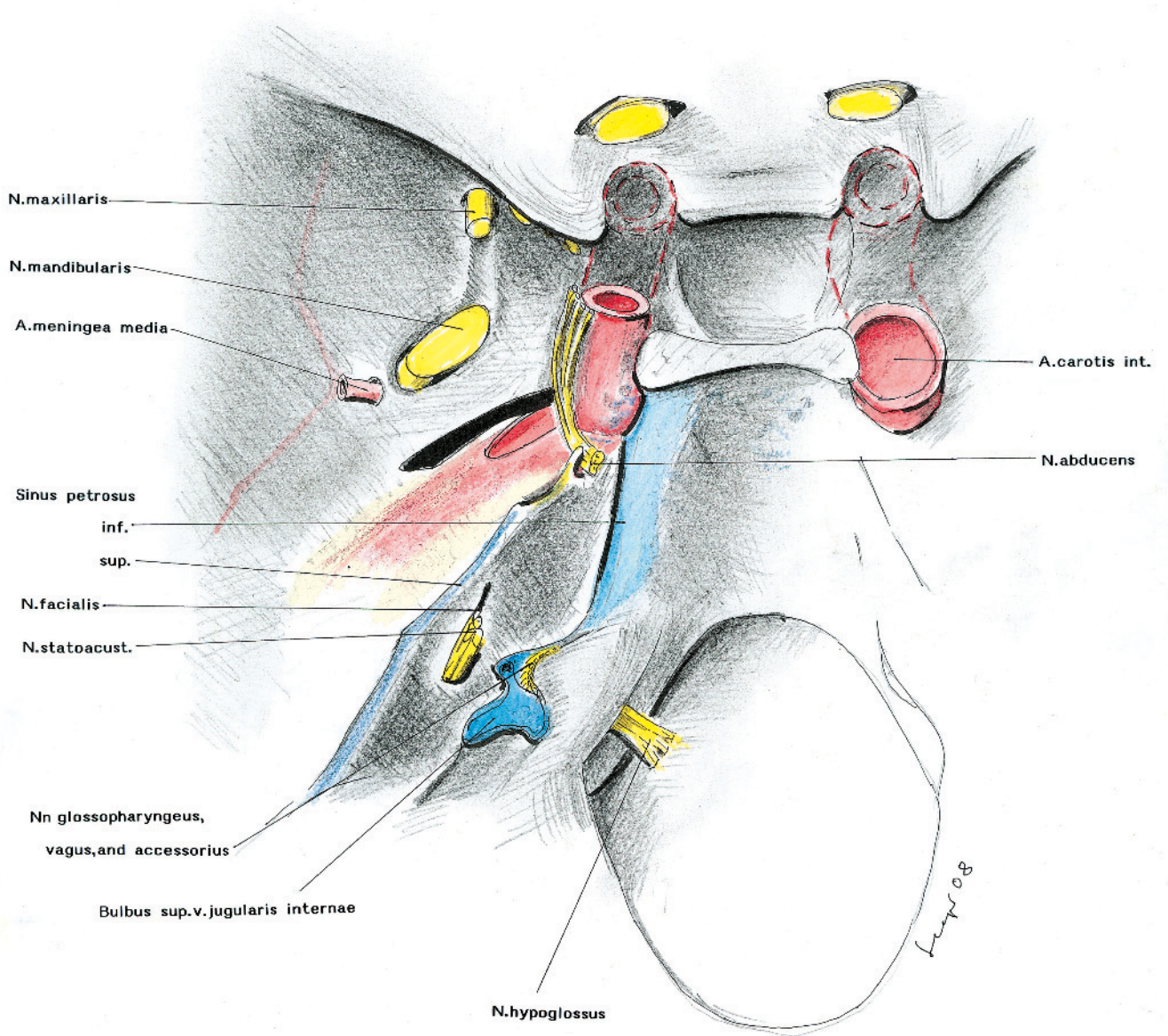


Fig. 6

Cadaver skull dissection for better understanding of transnasal endoscopic approaches

The upper areas of Cavum nasi and Orbita are transected. The base of Processus pterygoideus is transected to illustrate the relationship of Cavum nasi (dorsal area of Choana) to the roof of Foramen sphenopalatinum and Fossa pterygopalatina. These are located anterior to Processus pterygoideus.

Foramen lacerum is located posterior to Processus pterygoideus. Fossa pterygopalatina and the area of Foramen lacerum (+ Apertura int. of Canalis caroticus) are connected by Canalis pterygoideus (Vidii) (projection, dotted).

The middle and inferior segment of Pyramis (Pars petrosa of the temporal bone) contain structures which are located close to the Labyrinth.



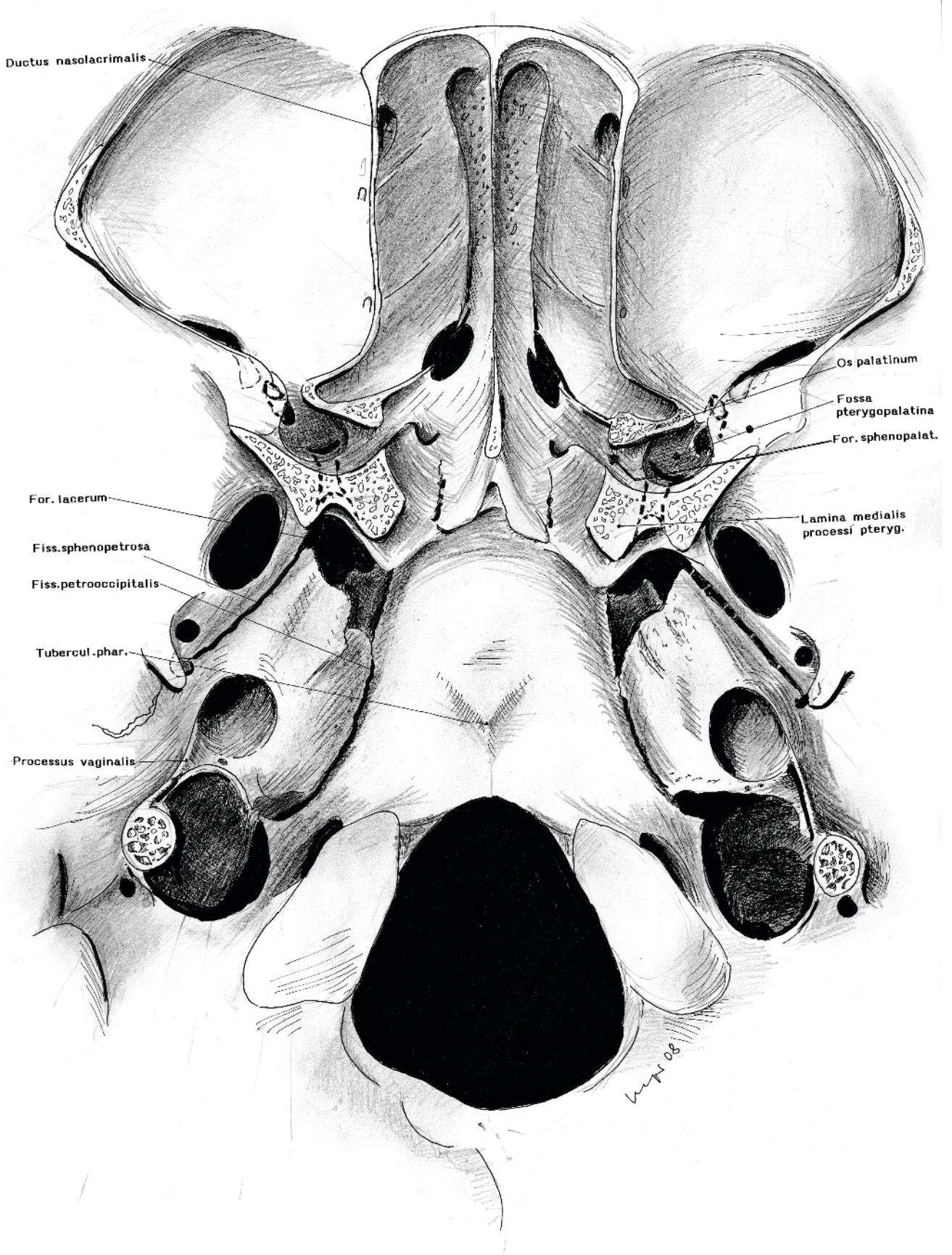


Fig. 7

Roof at Foramen sphenopalatinum and surrounding structures.  
Sectional magnification of Fig. 3, slightly modified.

Foramen sphenopalatinum is located between Fossa pterygopalatina and Cavum nasi. Its posterior limit area is Os palatinum. It is partially or completely fused with Processus pterygoideus. The base of Processus pterygoideus is interposed between Foramen sphenopalatinum and Foramen lacerum.

The Processus-ptyerygoideus-Corpus-sphenoidale-bloc (merged perinatally) contains Canalis pterygoideus (Vidii) (dotted). It connects the anterior margin of Foramen lacerum (area of the carotid artery) to Fossa pterygopalatina.

**Canalis pterygoideus is an important landmark for the endoscopic visualization of A. carotis interna from the lateral wall of Sinus sphenoidalis to Foramen lacerum, Apertura interna of Canalis caroticus, and to all segments of Canalis caroticus.\***

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\* according to Kassam, Snyderman et al (2005), and according to the surgical experiences of Kaminsky, Freiburg/Br., personal communication 2009.



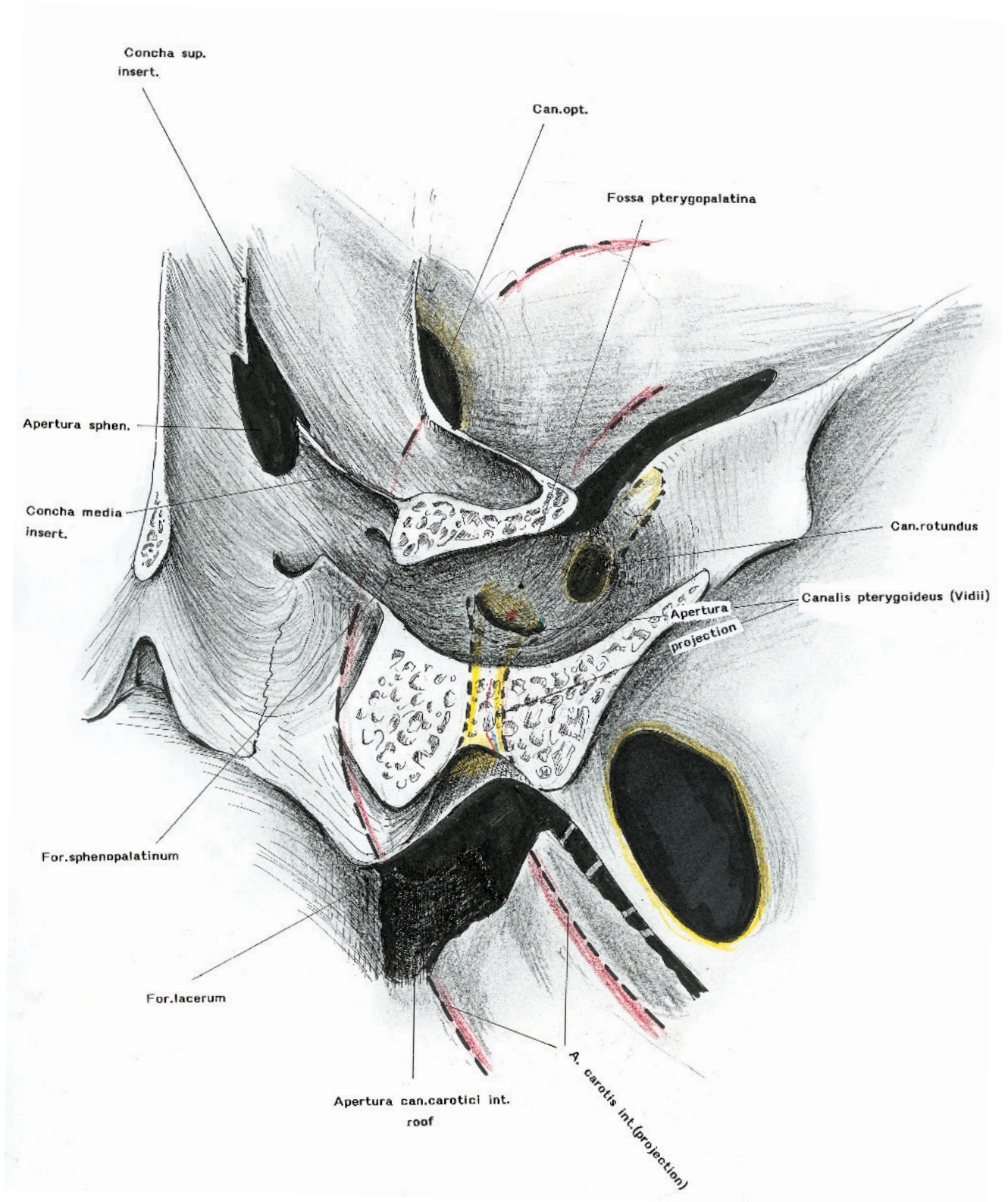
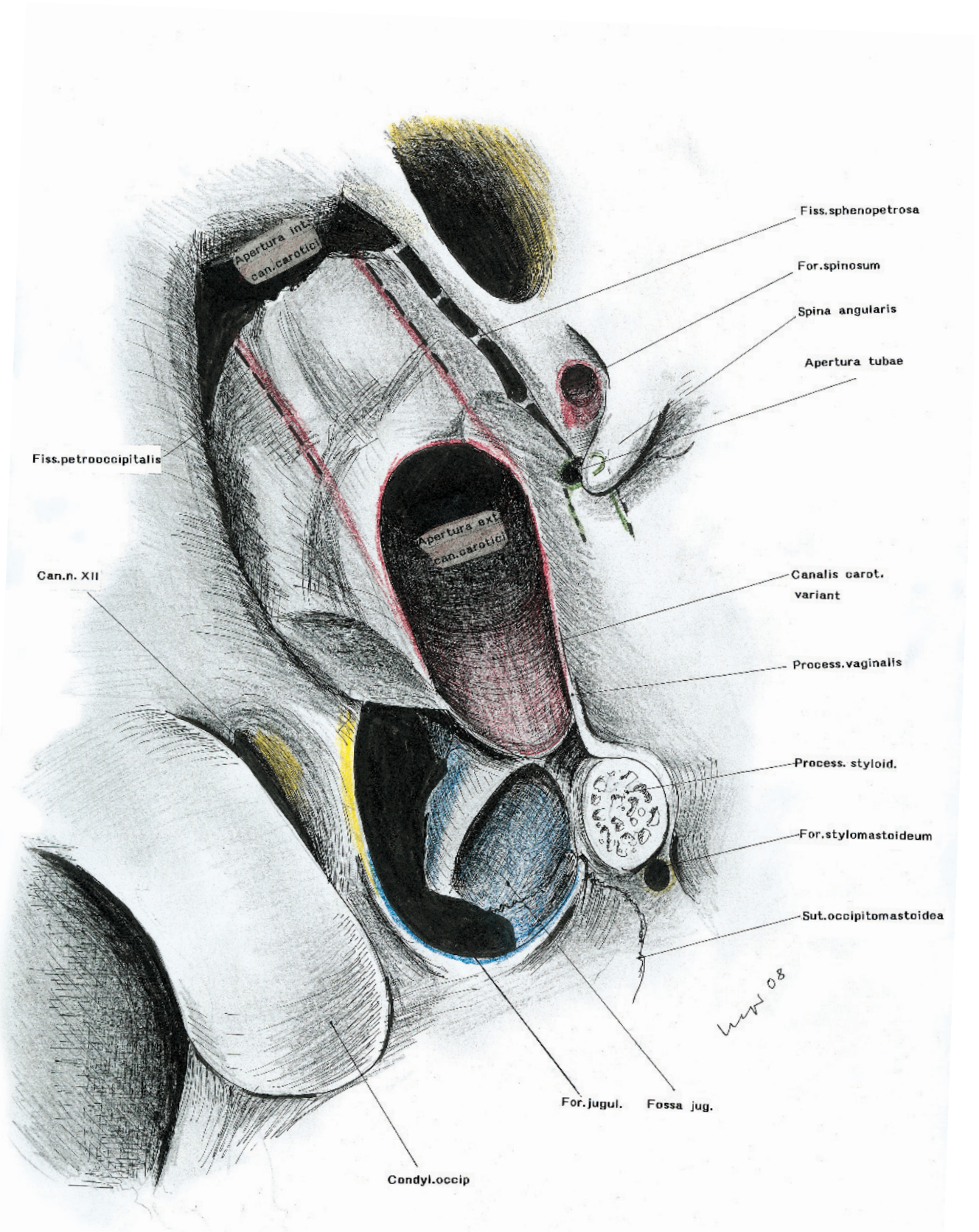


Fig. 8

Addendum to Fig. 7

Course of A. carotis int. between Apertura interna and ext. of Canalis caroticus.  
Variant of Apertura ext.





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**CHAPTER II**  
**CAVUM NASI AND**  
**FOSSA PTERYGOPALATINA**  
**(Figs. 9 to 17)**

## Overview (Figs. 9 and 10)

The superior transnasal routes for endoscopy are Cavum nasi, Sinus sphenoidalis, the roof of Os ethmoidale, and Sella turcica.

The inferior transnasal routes for endoscopy are Cavum nasi, Sinus sphenoidalis, Cavum nasi inferior and Fossa pterygopalatina, along A. carotis interna.

## Cavum nasi (Fig. 10)

The route crossing Meatus nasi medius is well known in pituitary surgery. Connections to paranasal sinuses and Ductus nasolacrimalis are responsible for infections and CSF leaks.

## Hiatus maxillaris (Fig. 11)

It is usually located at Infundibulum ethmoidale, anterior to Bulla ethmoidalis. Bulla ethmoidalis is the largest ethmoid cell. Additional fenestrations may be present as bony gaps around Bulla ethmoidalis. If Mucosa is fenestrated at these points, additional Hiati maxillaris may be visible. These may present further entry zones for infections of Sinus maxillaris.

## Other paranasal sinuses (Fig. 12)

All paranasal sinuses are draining to Meatus nasi superior or medius. Meatus nasi inferior is separate and only drains Ductus nasolacrimalis. Besides the well known routes of CSF leaks via the paranasal sinuses, other routes must taken in consideration, which were rare in the past, but are more common today.

Atypical CSF leaks through the roof of Orbita

Usually CSF leaks at the orbital roof are draining into Sinus frontalis. Atypical extensions of the anterior or posterior ethmoid cells into the orbital roof may present atypical routes of CSF leaks.

Pneumatization of the anterior clinoid process is well known.

CSF leaks may occur after conventional and endoscopic surgery. Its route may be a connection to posterior ethmoid cells or to Sinus sphenoidalis between Canalis opticus and Planum sphenoidale (duplication of the roof of Canalis opticus), as described by Lang (1981) and by Seeger (2003).

CSF leaks from Canalis rotundus

to Sinus sphenoidalis are possible, because the wall of Canalis rotundus and the Sulcus between Foramen ovale and Canalis rotundus are segments of the wall of Sinus sphenoidalis (Seeger 2000)

## **Foramen sphenopalatinum and Fossa pterygopalatina (Figs. 13 to 19)**

### **Foramen sphenopalatinum**

This foramen is interposed between the posterior segment of Meatus nasi medius, the inferior segment of Sinus sphenoidalis, and the medial segment of Fossa pterygopalatina (Fig. 14)

### **Fossa pterygopalatina**

This fossa extends from Foramen sphenopalatinum to Fissura orbitalis inferior (roof of Fossa pterygopalatina).

Apertura anterior of Canalis pterygoideus (Vidii) is located at the dorsal margin of Foramen sphenopalatinum. Apertura externa of Canalis rotundus is located lateral to it.

## **Vessels and nerves of the area of Foramen sphenopalatinum**

Fossa pterygopalatina contains the terminal branches of

### **A. maxillaris**

Branches in Fossa pterygopalatina

Aa. palatinae, Rr. alveolares, A. meningea media, branches to Canalis rotundus and Canalis infraorbitalis, a branch to Canalis pterygoideus, A. sphenopalatina

Branches medial to Foramen sphenopalatinum:

A. sphenopalatina is the main branch. It divides into Rr. nasales mediales and laterales

### **Veins: Plexus pterygoideus**

### **Nerves:**

N. maxillaris and N. canalis pterygoidei (a combination of N. petrosus profundus and N. petrosus superficialis)

**CAVUM NASI AND FOSSA PTERYGOPALATINA (Figs. 9 to 17)**

Fig. 9

Overview

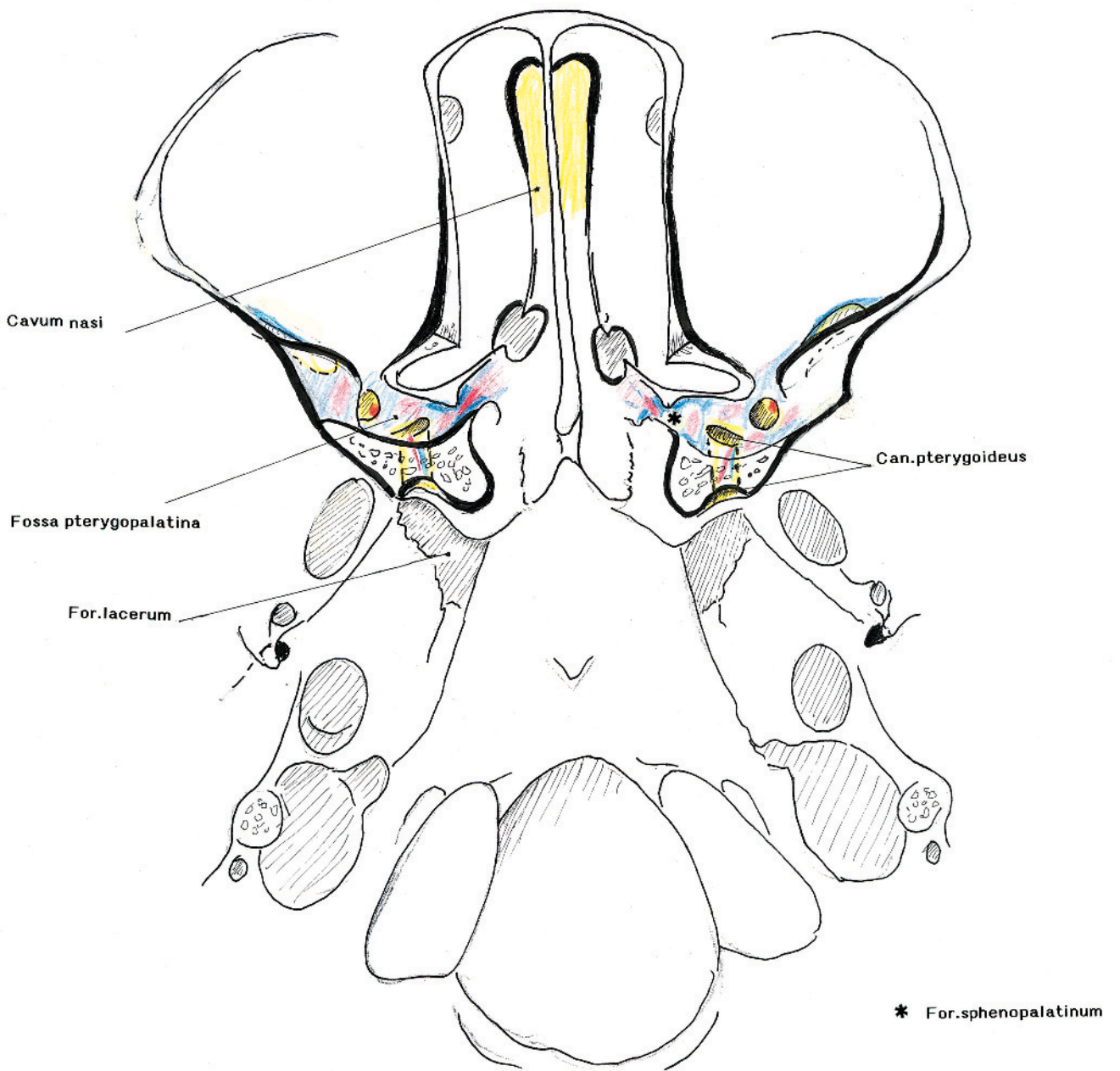


Fig. 10

Wall of Cavum nasi

- A** Bony structures
- B** Relief of Mucosa

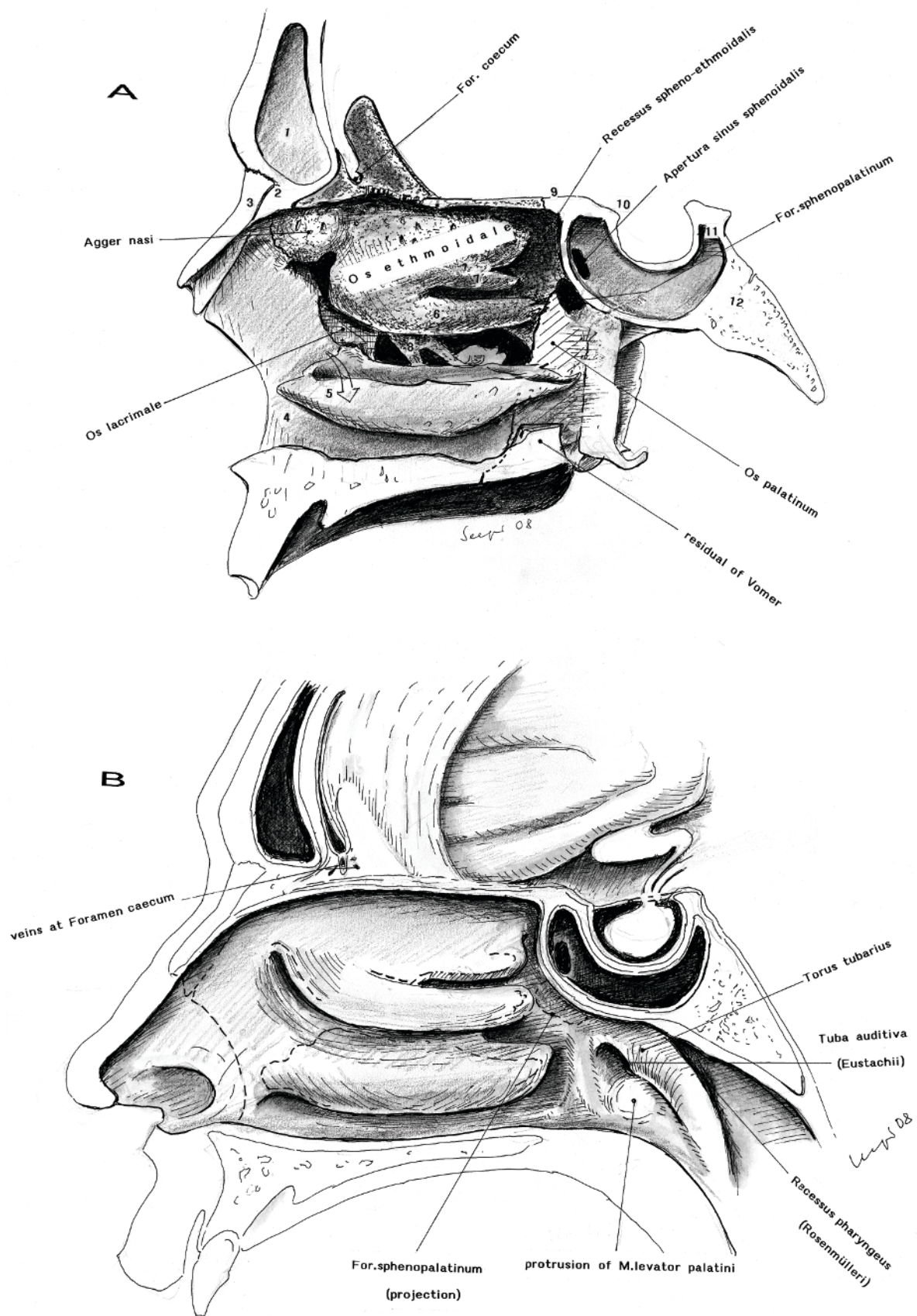


Fig. 11

Outside of the wall of Cavum nasi, segment of Sinus maxillaris and Orbita

### Abbreviations

- 1 Os nasale
- 2 Processus front. maxillae
- 3 Os lacrimale
- 4 Foramen ethmoidale ant.
- 5 Lamina perpendicularis
- 6 Foramen ethmoidale post.
- 7 Os palatinum, Processus orbitalis
- 8 Canalis opticus
- 9 Processus clinoideus ant.
- 10 Probe in Foramen sphenopalatinum
- 11 Canalis rotundus
- 12 Canalis pterygoideus (Vidii)
- 13 Processus pterygoideus, Lamina lat.
- 14 as 13, between Ala major (transected) and 10
- 15 Os palatinum, vertical portion
- 16 Os palatinum, Processus pyramidalis
- 16 a) probe in Canalis palatinus major
- 17 Maxilla, Facies orbitalis
- 18 Spina trochlearis
- 19 Corpus sphenoidale, orbital wall of Sinus sphenoidalis
- 20 Fissura orbitalis sup., medial-basal ground
- 21 probe in Canalis rotundus (lateral from 22)
- 22 probe in Canalis pterygoideus (Vidii), see 12 in A
- 23 Concha media, processus of its: Processus maxillaris
- 24 Concha media, Processus maxillare
- 25 Fontanellae
- 26 Concha media, Processus ethmoidalis
- 27 Processus uncinatus
- 28 Hiatus semilunaris
- 29 insertion of Concha inf. (projection)
- 30 Ductus nasolacrimalis (projection)
- 31 Processus uncinatus (as 27)
- 32 Infundibulum ethmoidale (projection)
- 33 Hiatus semilunaris as 28
- 34 Processus uncinatus, connection to 35
- 35 Concha media, connection to Processus uncinatus
- 36 Bulla ethmoidalis, bulging into Sinus maxillaris
- 37 Insertion of Concha media (projection)
- 38 posterior Fontanella
- 39 Concha media, Processus maxillaris



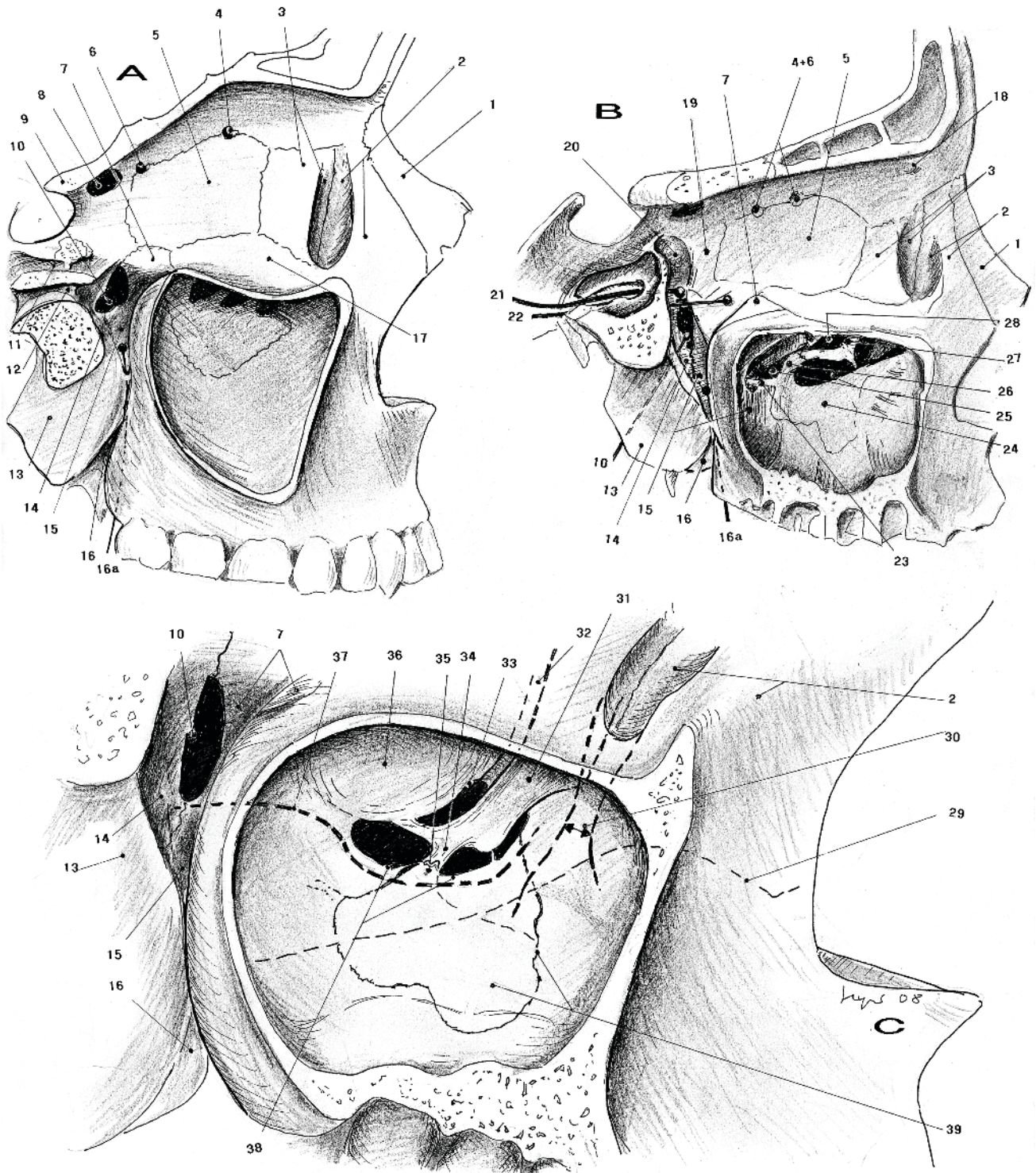


Fig. 12

Connections of paranasals to Cavum nasi

**Abbreviations**

- 1 Processus clinoideus anterior
- 2 Foramen opticum
- 3 bulging of Canalis opticus
- 4 Recessus sphenothmoidalis of Meatus nasi superior
- 5 Concha nasalis media (cut)
- 6 Fossa sacci lacrimalis (projection)



Connections of Sinus paranasales to Meati nasales  
(arrows)

- a from Sinus sphenoidalis
- b from Cellulae ethmoidales postt.
- c from Cellulae ethmoidales antt.(here:from Bulla ethmoidalis)
- d from Sinus frontalis (here:double), Cellulae ethmoidales antt., and Sinus maxillaris

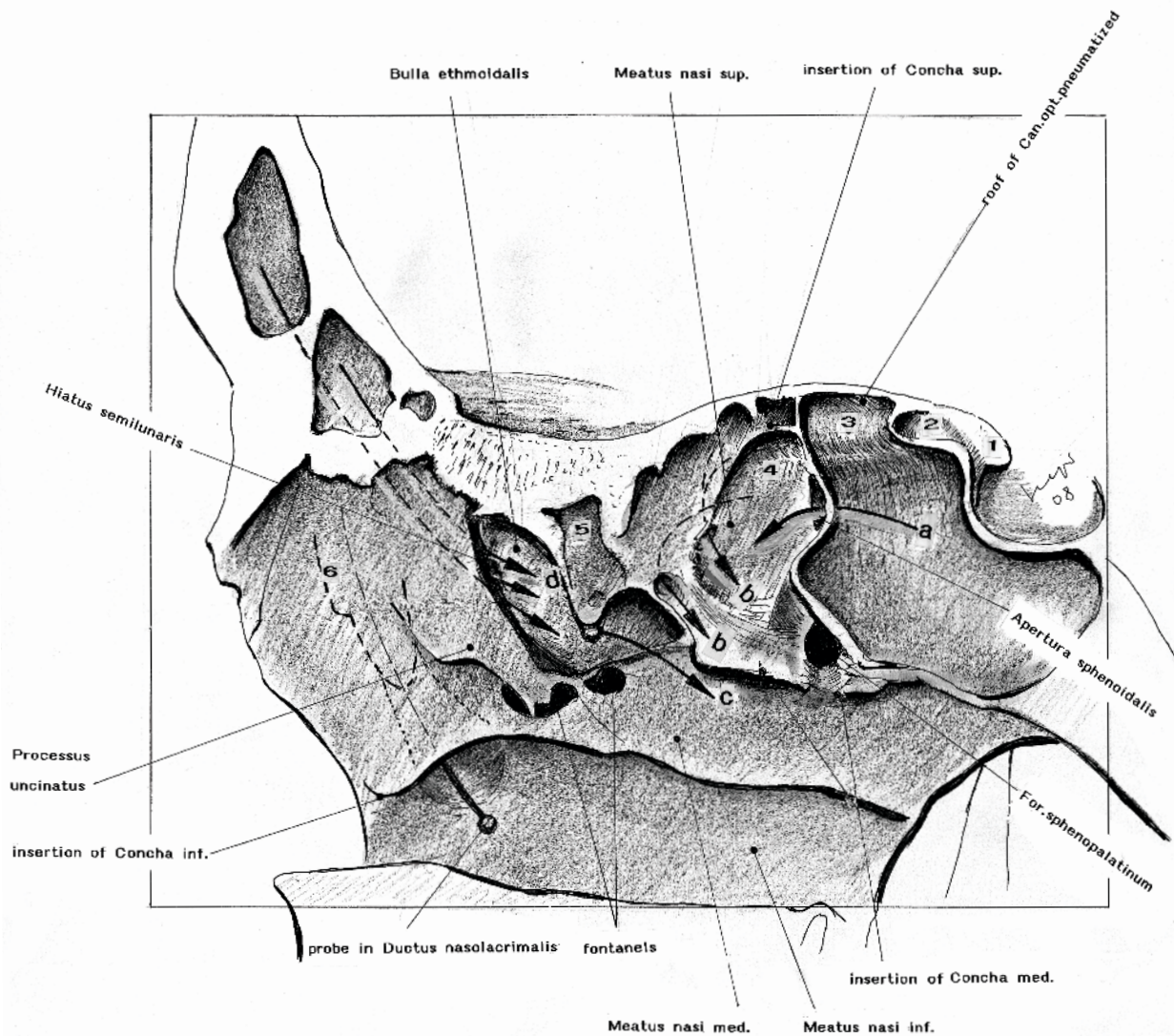
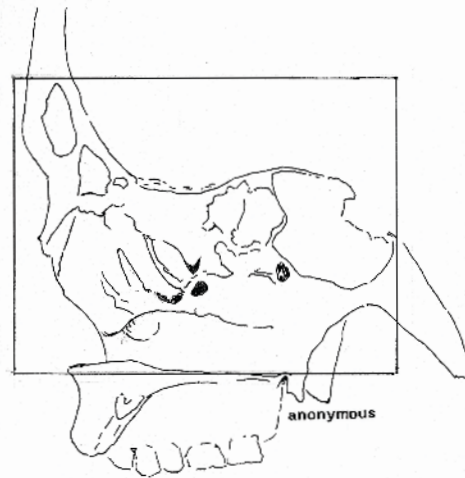


Fig. 13

Choana and surrounding structures

I a: Canales pterygoidei (projections). Course parallel or slightly convergent.

I b: Canales rotundi (projections). Course divergent.

II: Foramen ovale and Canalis rotundus

**Abbreviations:**

- 1 Foramen spinosum
- 2 Ala major
- 3 Os zygomaticum
- 4 Foramen palatinum majus
- 5 Os palatinum, Processus pyramidalis
- 6 Hamulus pterygoideus
- 7 Ala vomeris
- 8 Concha nasalis media
- 9 bony gap for Synchondrosis sphenoccipitalis (child)

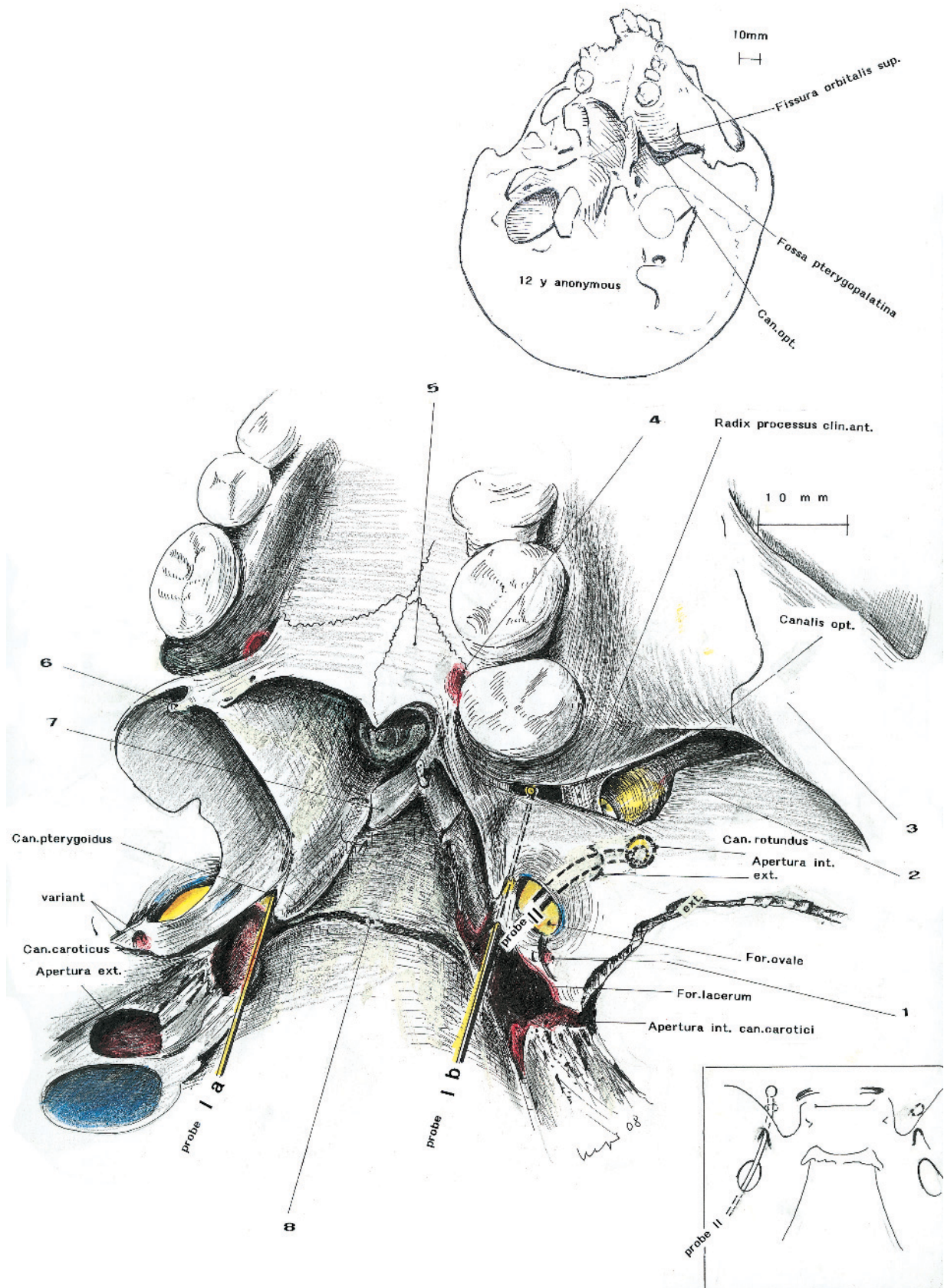


Fig. 14

Continuation of Fig. 13

Os ethmoidale is resected –a-, Os palatinum and Processus pterygoideus are transected –c- and –d-

- a) Lamina papyracea
- b) Transection between a and c
- c) Transection of Os palatinum, close to Tuber maxillare
- d) Transection of the base of Processus pterygoideus







Fig. 15

Fossa pterygopalatina and Foramen sphenopalatinum

**A** Usual findings

**B** Variant

**Abbreviations**

- 1 Fissura tympanomastoidea
- 2 Fossa mandibularis, post. segment
- 3 Porus acusticus ext., anterior wall
- 4 Os palatinum (Pars orbitalis)
- 5 Os palatinum, connecting Tuber maxillare and Processus pterygoideus
- 6 Processus pterygoideus, Lamina lateralis

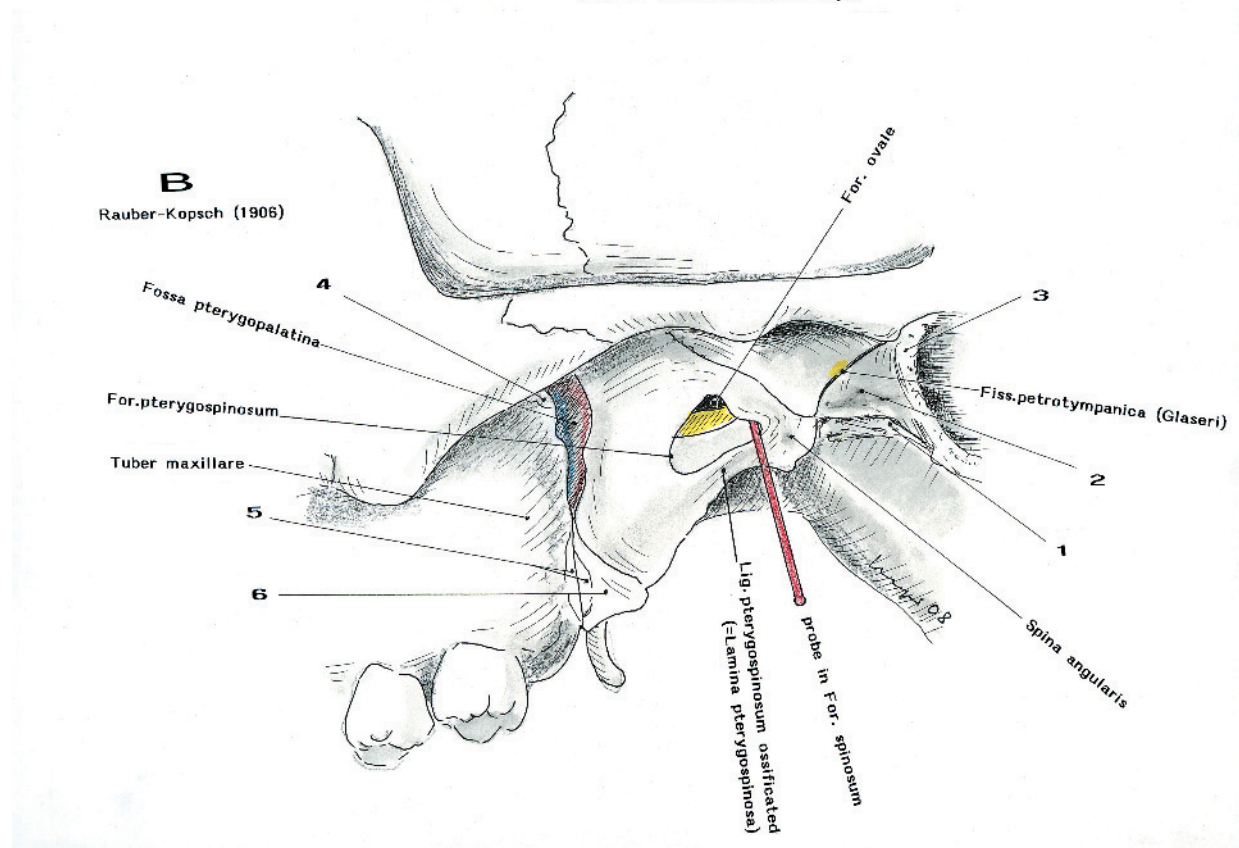
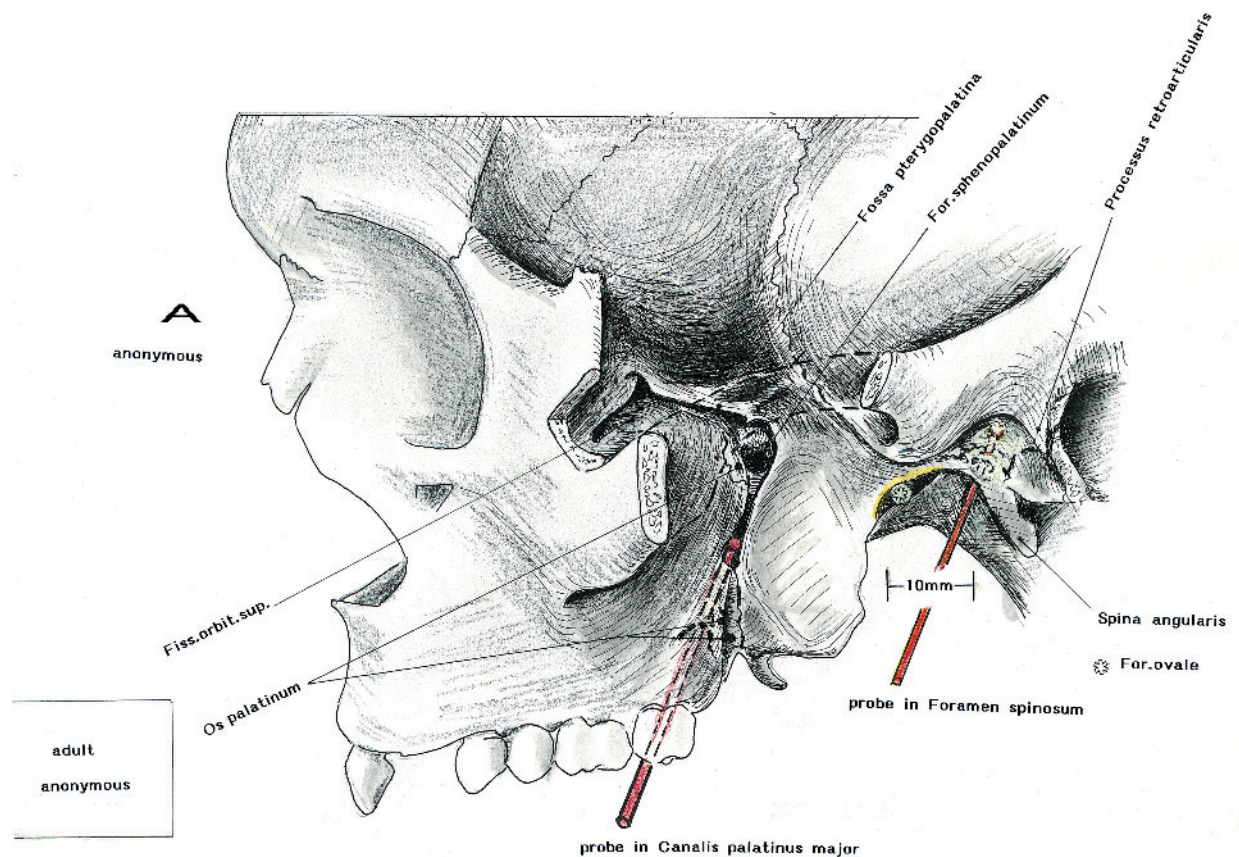


Fig. 16

Fissura orbitalis inf. (and sup.) and Fossa pterygopalatina

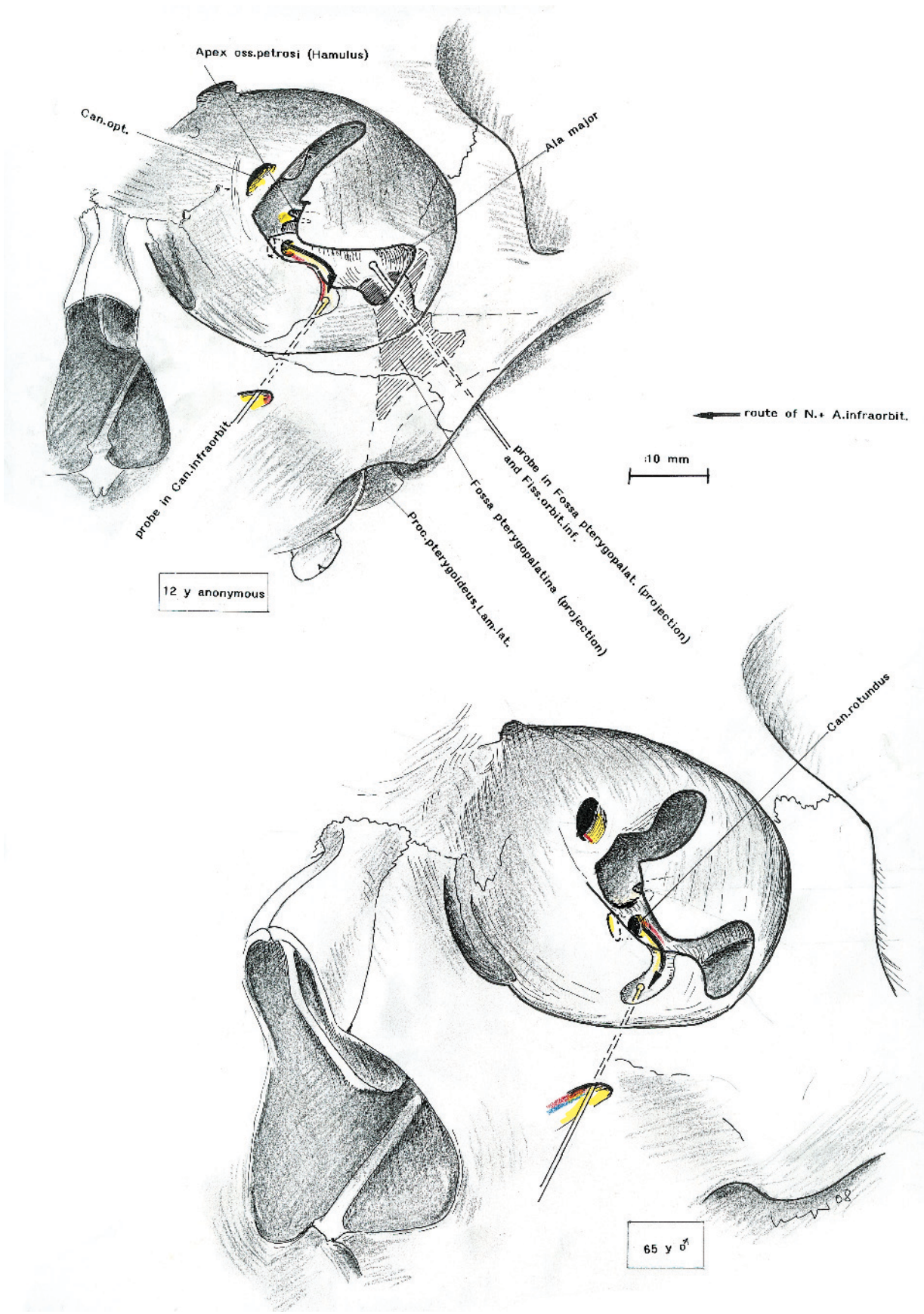




Fig. 17

Fissura orbitalis inferior and Fossa pterygopalatina

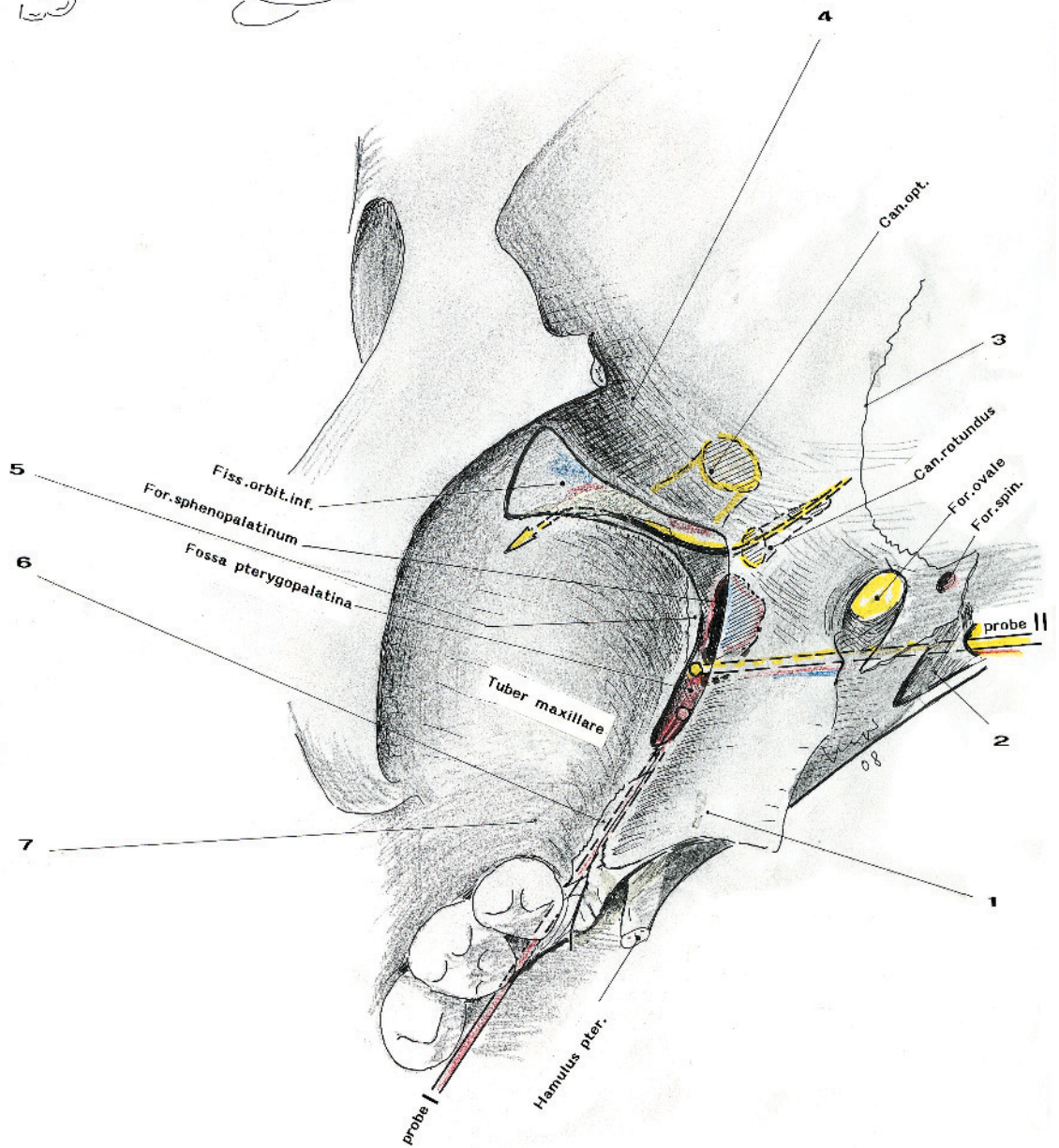
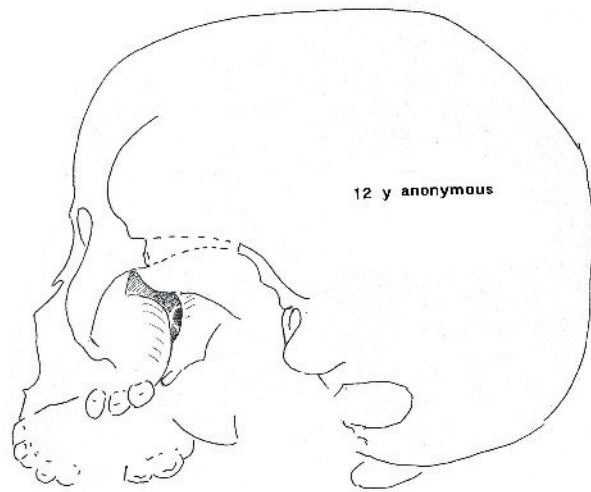
Probe I: Canalis palatinus major (A.+V. palatinus/a major and N. palatinus ant.)

Probe II: Canalis pterygoideus Vidii (N. pterygoideus and A.+V. pterygoideus/a)

Arrow: Course of N. maxillaris (A. + V. infraorbitalis).

**Abbreviations**

- 1 Processus pterygoideus, Lamina lateralis
- 2 Fossa scaphoidea (adherent to the distal segment of Tuba)
- 3 Sutura squamosa
- 4 Ala major, Facies temporalis
- 5 Os palatinum
- 6 Os palatinum, Pars verticalis-Pars horizontalis (Processus pyramidalis), transition
- 7 Tuber maxillare





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**CHAPTER III**  
**SINUS SPHENOIDALIS AND**  
**FOSSA PTERYGOPALATINA**  
(Figs. 18 to 34)

## Overview (Figs. 18 to 20)

**Sinus sphenoidalis is enclosed by Corpus sphenoidale. Corpus sphenoidale and Pars basilaris of the occipital bone are merged with Os basilare in adults.**

In children and adolescents and many mammals, both segments of Os basilare are connected by Synchondrosis sphenooccipitalis.

## Sinus sphenoidalis (Figs. 19 and 20)

It is enclosed by Corpus sphenoidale, which is merged with the adjacent segments of the sphenoid bone since the perinatal period of life. Outside structures cause inward bulging of the walls of the sinus (Fig. 20), Fig. 20 presents a widening of the sinus. A bulging of Canalis opticus and of the siphon area of the carotid artery can be observed easily. The optocarotid recess divides both structures. The walls of Canalis rotundus and Canalis pterygoideus can be penetrated by a fine needle, if the wall of the sinus is very thin-walled. The relief of the sinus is better recognized, if a light source is positioned behind the anatomical dissection.

### Widening of adjacent structures (Figs. 27, 28, and 33).

Widenings of the sinus to Orbita were presented before, and in Fig. 33, further widenings in Fig. 33. Rare widenings include pneumatizations of Ala major, far lateral from Canalis rotundus. The roof of Canalis opticus may be doubled by a connection of the sinus to a pneumatized Processus clinoideus anterior. It may be combined with a pneumatization of the root of Processus clinoideus ant., which connects the sinus to the clinoid process inferior to Canalis opticus.

## Area between Sinus sphenoidalis and Foramen lacerum (Figs. 19 to 34)

### Anterior wall of Sinus sphenoidalis

Apertura sinus sphenoidalis is interposed between the insertions of Concha superior and Concha media (Fig. 30). Recessus sphenooethmoidalis (roof of Meatus nasi superior) is located superior to Apertura sphenoidalis.

### Foramen sphenopalatinum (Figs. 23 to 25)

Its upper margin is the flat shape of the anterobasal wall of Sinus sphenoidalis at its transition to the roof of Fossa pterygopalatina (\* in Fig. 23). Foramen sphenopalatinum is interposed between the vertical segment of Os palatinum and the base of Processus pterygoideus (Figs. 23 to 25)

### Fossa pterygopalatina (Figs. 22 to 26, and 28 to 33)

The central area of its roof represents Apertura externa of Canalis rotundus, between the base of the insertion of Os palatinum and the base of Processus pterygoideus, lat-

eral to Apertura ant. of Canalis pterygoideus (see probe and arrow in Fig. 23, and Fig. 30).

**Canalis pterygoideus penetrates the base of Processus pterygoideus. It connects the roof of Fossa pterygopalatina to the anterior shape of Foramen lacerum.**

At the level of the anterior Apertura of Canalis pterygoideus, A. carotis int. is located at the inside of the skull base, at the coronal level of Dorsum sellae. This area is located close to the lumen of the sinus. It is defined after widening of the well known approaches to Sella. This area is illustrated by the cadaver skull dissection in Fig. 28 (see Sulcus caroticus, colored). Drilling of the base of Processus pterygoideus along Canalis pterygoideus reveals the carotid artery between its siphon and Foramen lacerum, close to Apex pyramidis. Apex encloses Apertura int. of Canalis caroticus.

### Foramen lacerum and its contents (Figs. 23 to 31)

Foramen lacerum lies between the base of Processus pterygoideus, Ala major, Apex pyramidis (enclosing Apertura int. of the carotid channel) and the bony bloc of Os basillare, at the level of Synostosis (Synchondrosis) sphenoccipitalis. Its extra- and intracranial shapes are incongruent and variable (Figs. 1 to 7). A carotis int. fills Foramen lacerum. It is covered by chondroid layers and ligaments. No bony structure is interposed between the external and internal shape of the cranial base. Between the anterior margin of Foramen lacerum and the posterior clinoid process, the artery bends in a steep course, distant to the external shape of the cranial base, along the wall of Sinus sphenoidalis (Fig. 21).

**SINUS SPHENOIDALIS AND FOSSA PTERYGOPALATINA (Figs. 18 to 34)**

Fig. 18

Overview

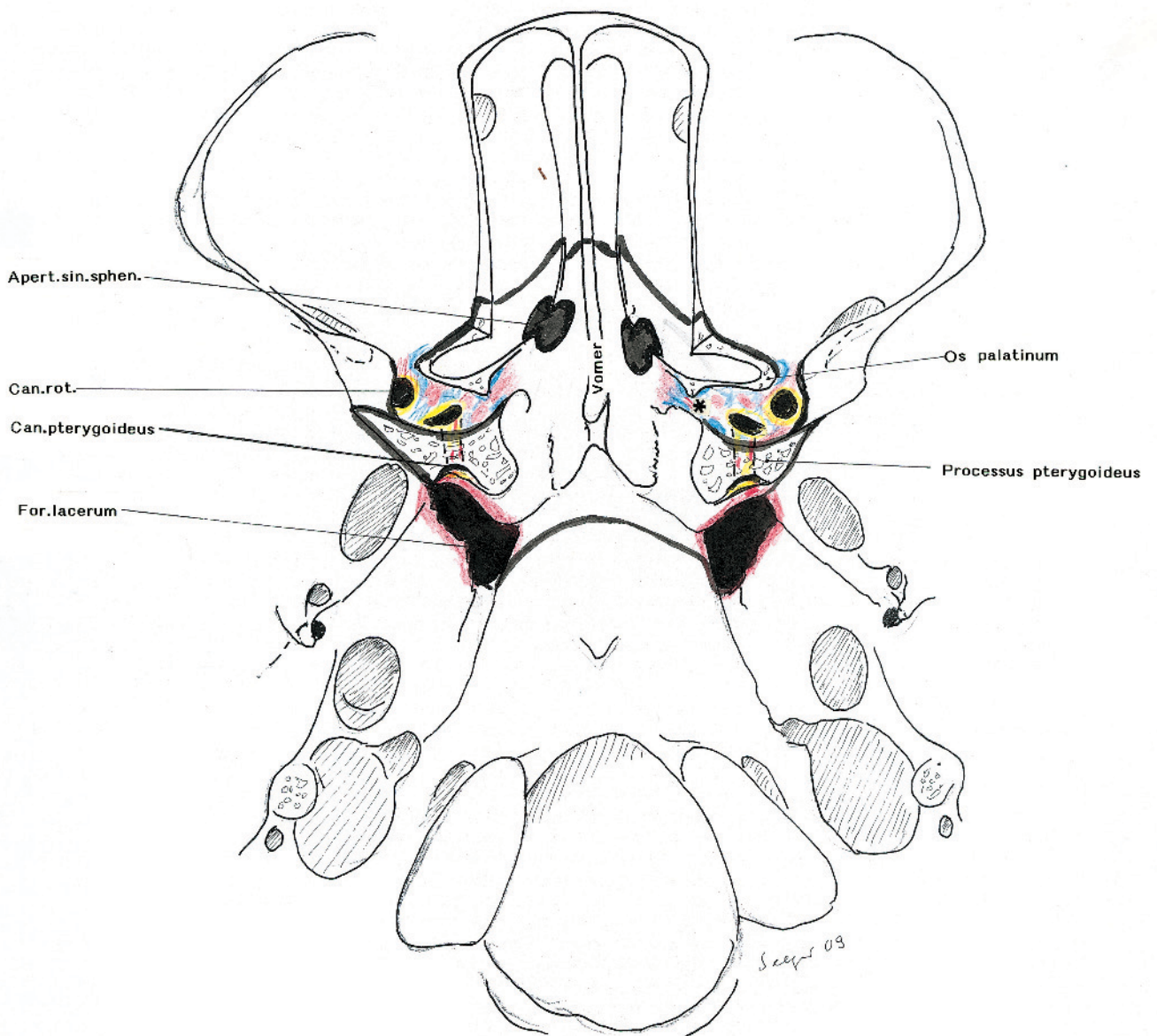




Fig. 19

Os sphenoidale

- A.** According to Rauber-Kopfsch (1907), anterior view direction  
**B.** As A, posterior view direction  
**A'** Similar to A, cadaver skull dissection, sectional enlargement  
**B'** Similar to B, cadaver skull dissection, sectional enlargement  
**A''** and **B''** anatomical sketches for topograms

#### Abbreviations

- |    |  |
|----|--|
| 1  | Crista sphenoidalis (Alae vomeris removed) |
| 1' | Alae vomeris (projection)                  |
| 2  | anterior wall of Sinus sphenoidalis        |
| 3  | Apertura sinus sphenoidalis                |
| 4  | Canalis pterygoideus Vidii, Apertura ant.  |
| 4' | Canalis pterygoideus Vidii, Apertura post. |
| 5  | Canalis rotundus, Apertura ant.            |
| 5' | Canalis rotundus, Apertura post.           |
| 6  | Ala major, Facies infratemporalis          |
| 7  | Ala major, Facies orbitalis                |
| 8  | Fissura orbitalis superior                 |
| 9  | Planum sphenoidale                         |
| 10 | Fossa scaphoidea                           |
| 11 | Ala major, Facies cerebralis               |
| 12 | Sulcus caroticus                           |
| 13 | Dorsum sellae                              |
| 14 | Corpus sphenoidale                         |
| 15 | Fossa cranii media (projection)            |
| 16 | Ala major, Facies infratemporalis          |
| 17 | Processus pterygoideus, Lamina medialis    |

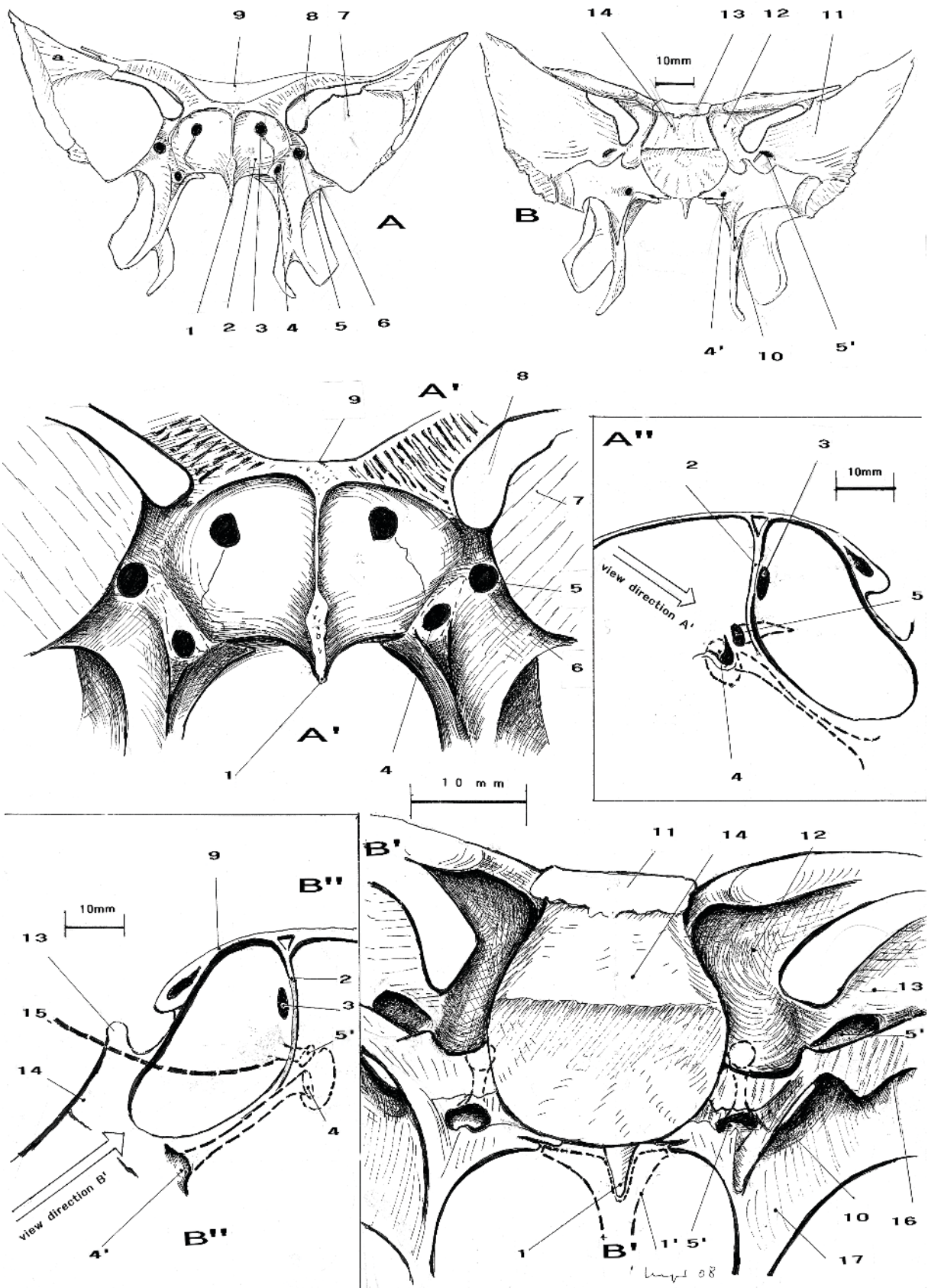


Fig. 20

Sinus sphenoidalis, wall

Thin walled sinus (common variant). The bulging of the wall by A. carotis int. is accentuated. Walls of Canalis rotundus and Canalis pterygoideus removed.

#### Abbreviations

- 1 Meatus nasi sup.
- 2 Concha sup.
- 3 atypical Cella ethmoidalis between Apertura sinus sphenoidalis and Planum sphenoidale
- 4 atypical supraoptic widening of Sinus sphenoidalis
- 5 optic nerve prominence (Divitis et al, 2006)
- 6 carotid protuberance
- 7 Tuberculum sellae
- 8 Processus clinoideus ant.
- 9 Curvatura post. of A. carotis int. (here: prominent to Sinus sphenoidalis)
- 10 Foramen lacerum (may be located close to the posterior-lateral wall of the sinus)
- 11 Apertura int. of Canalis caroticus
- 12 Apertura posterior of Canalis pterygoideus (Vidii)
- 13 Lamina med. of Processus pterygoideus
- 14 Lamina lat. of Processus pterygoideus
- 15 insertion of Concha nas. inf.
- 16 root of Ala major
- 17 Apertura ext. of Canalis rotundus
- 17a Apertura int. of Canalis rotundus
- 18 insertion of Concha nas. med.
- 19 Apertura ant. of Canalis pterygoideus (Vidii)
- 20 Canalis rotundus, opened

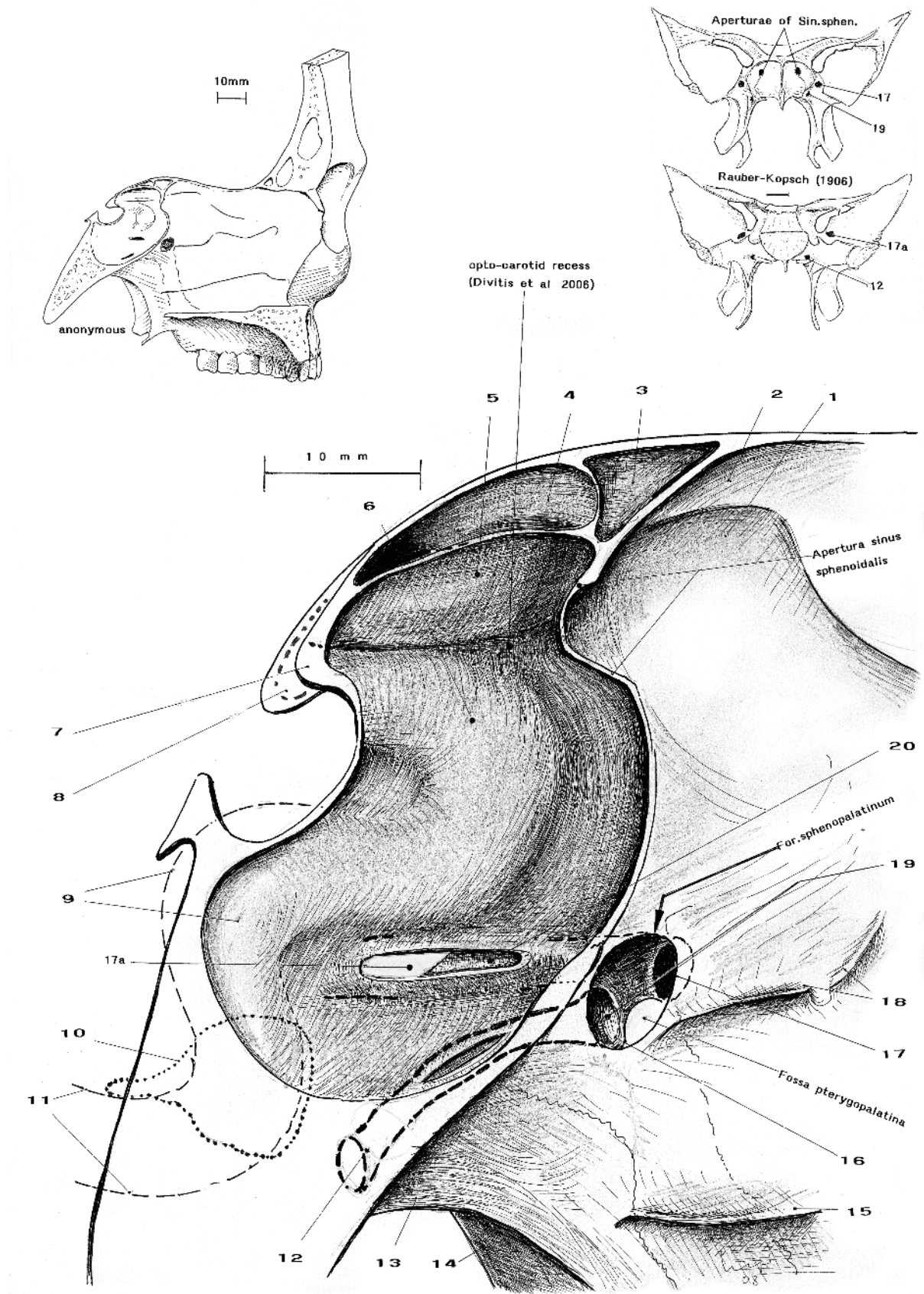


Fig. 21

Addendum for Fig. 20  
Cranial nerves and blood vessels



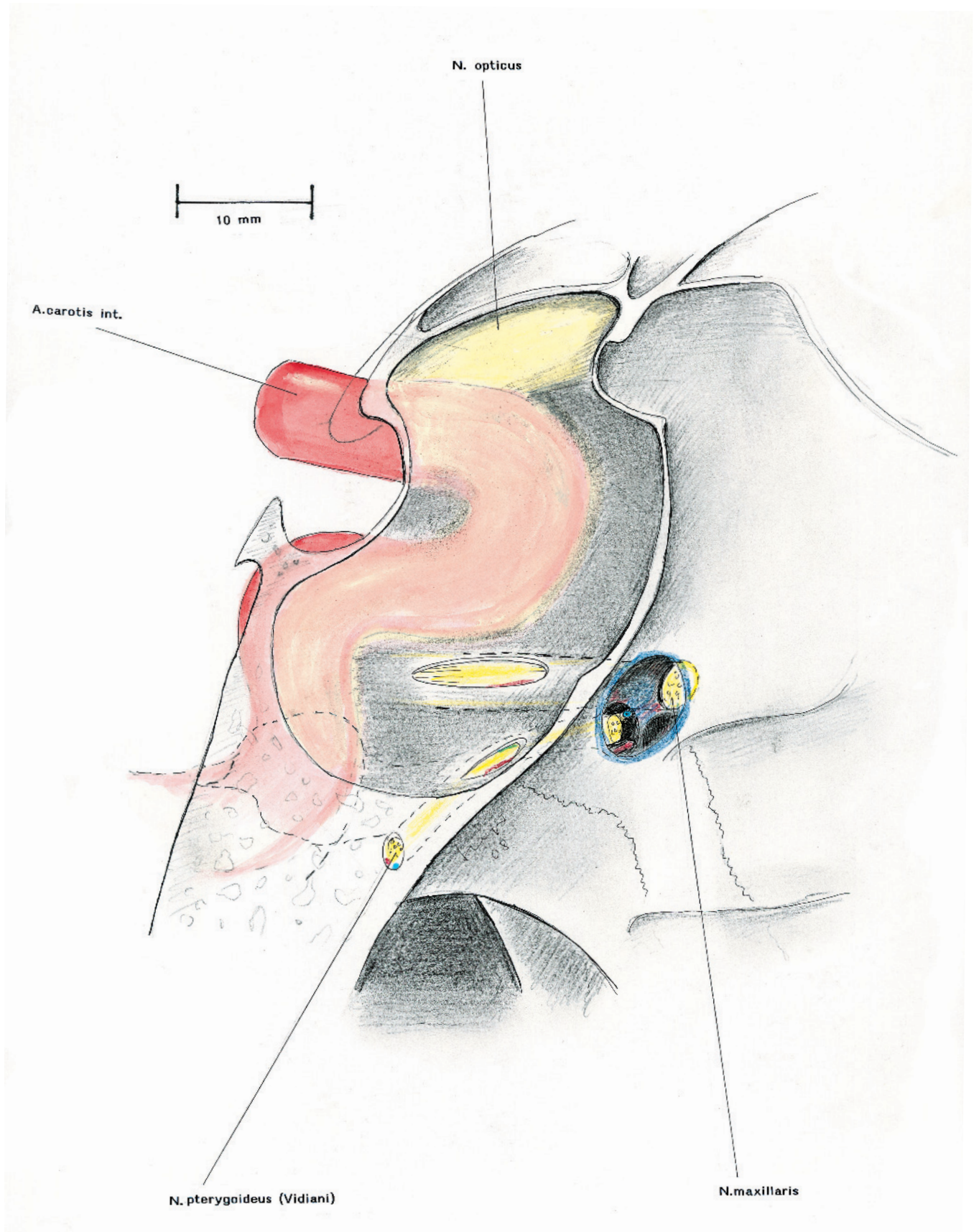


Fig. 22

Sinus sphenoidalis and roof of Foramen sphenopalatinum. Overview

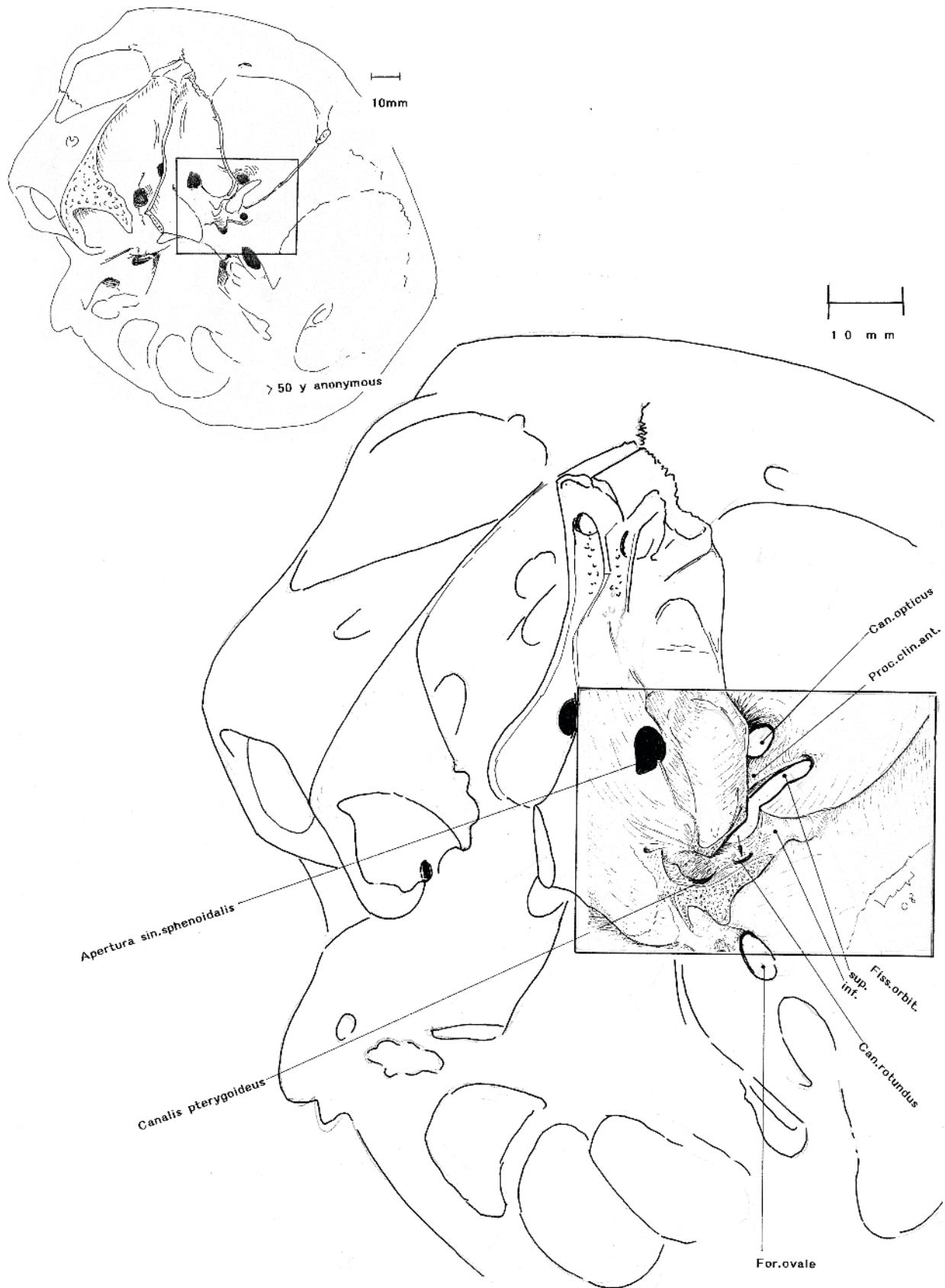


Fig. 23

Continuation of Fig. 22. Sectional enlargement



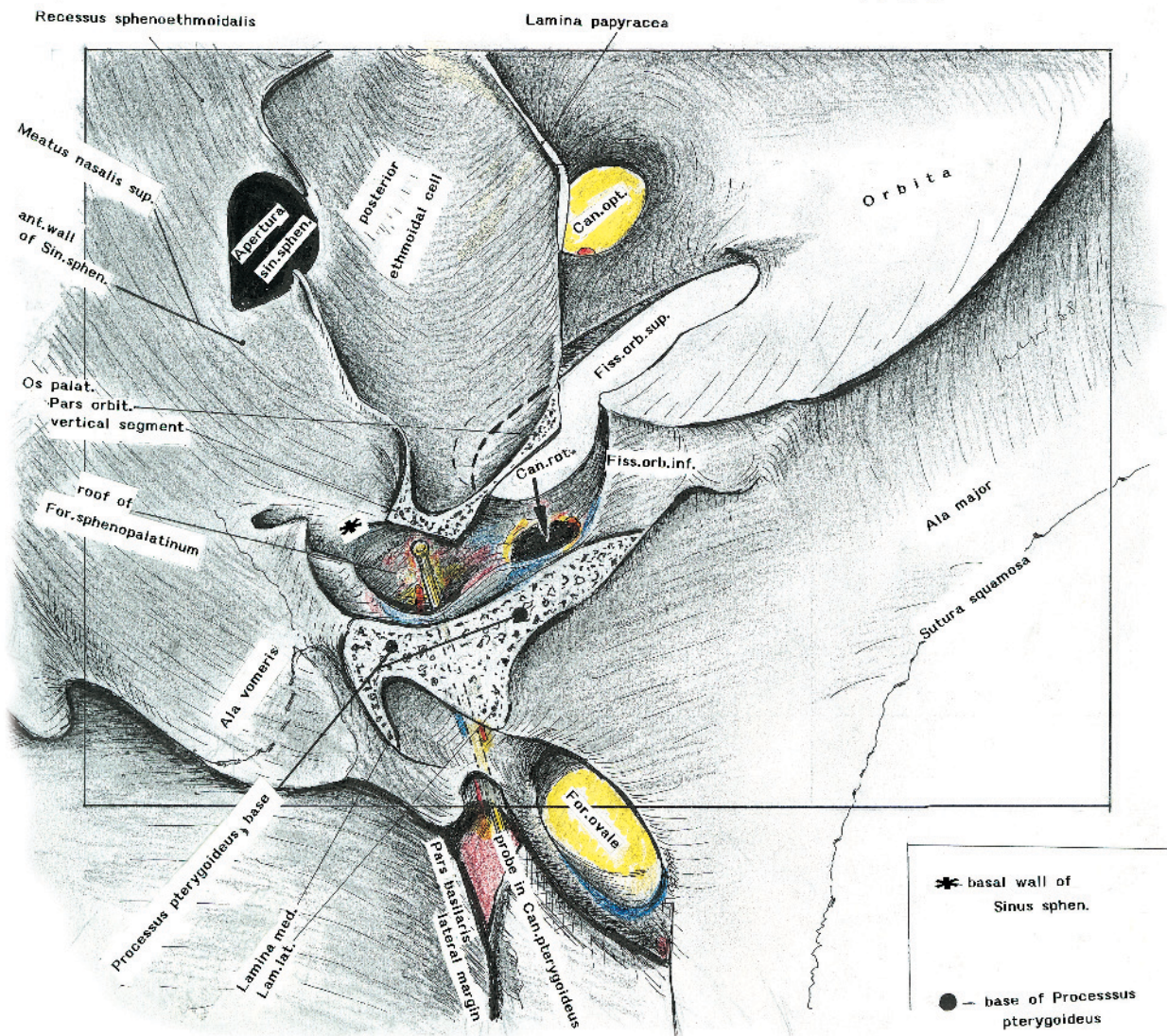
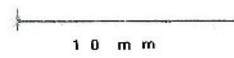
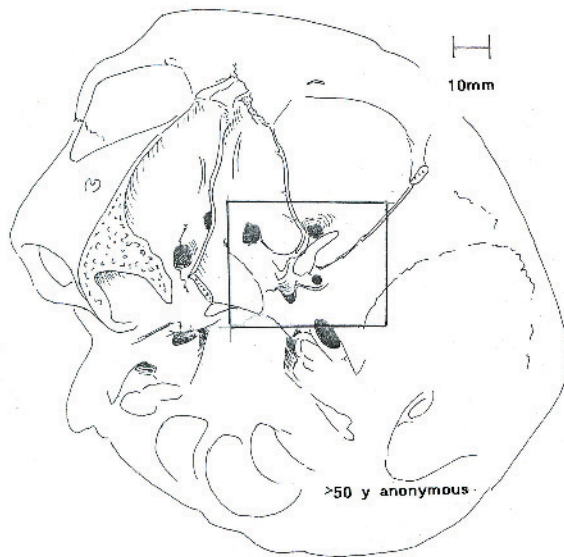




Fig. 24

After resection of the left anterior wall of Sinus sphenoidalis

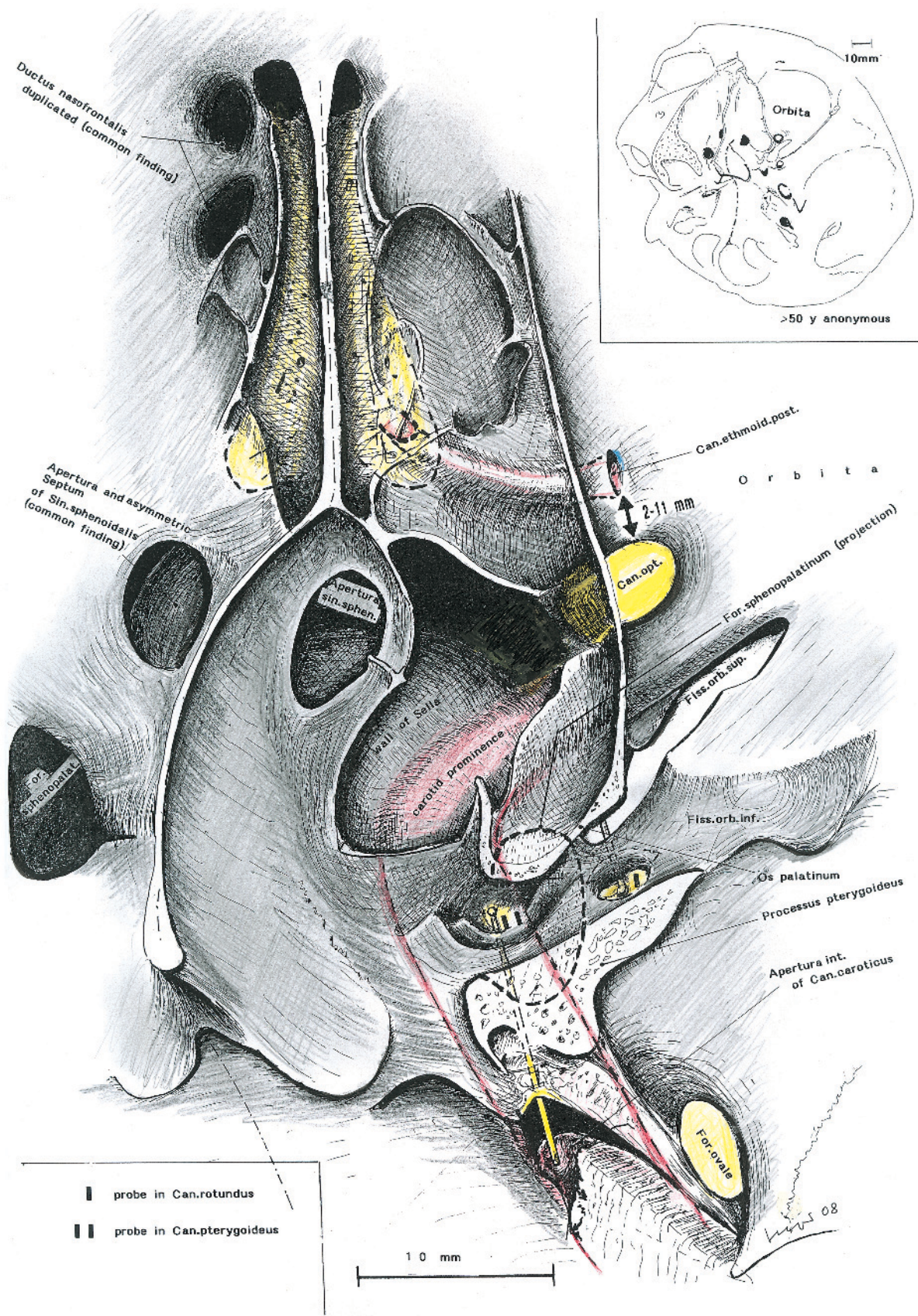


Fig. 25

Resection continued. Sectional enlargement



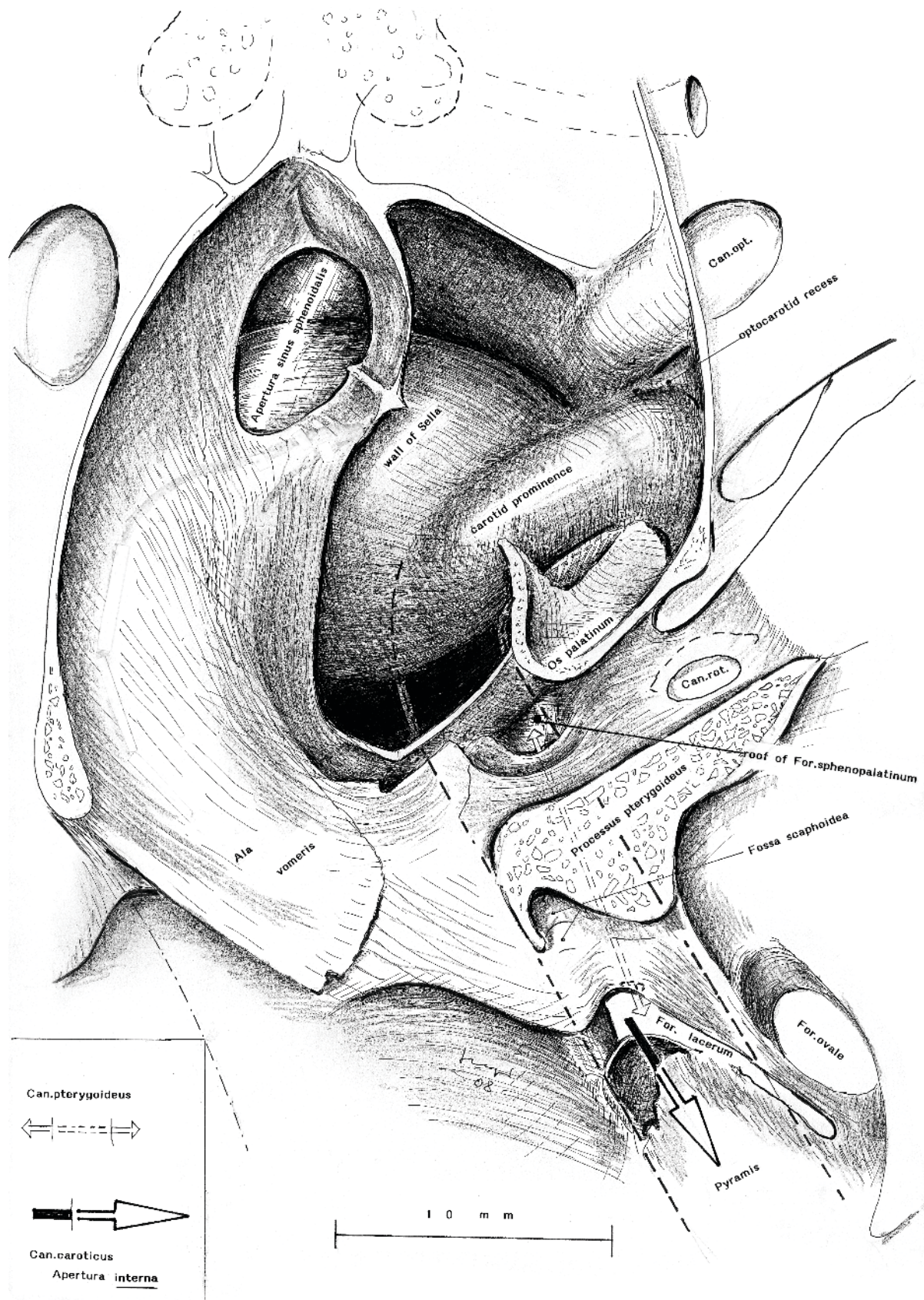




Fig. 26

Addendum for Fig. 25

Note close distance between A. (and V.) ethmoidalis post. and Canalis and N. opticus  
(common finding)



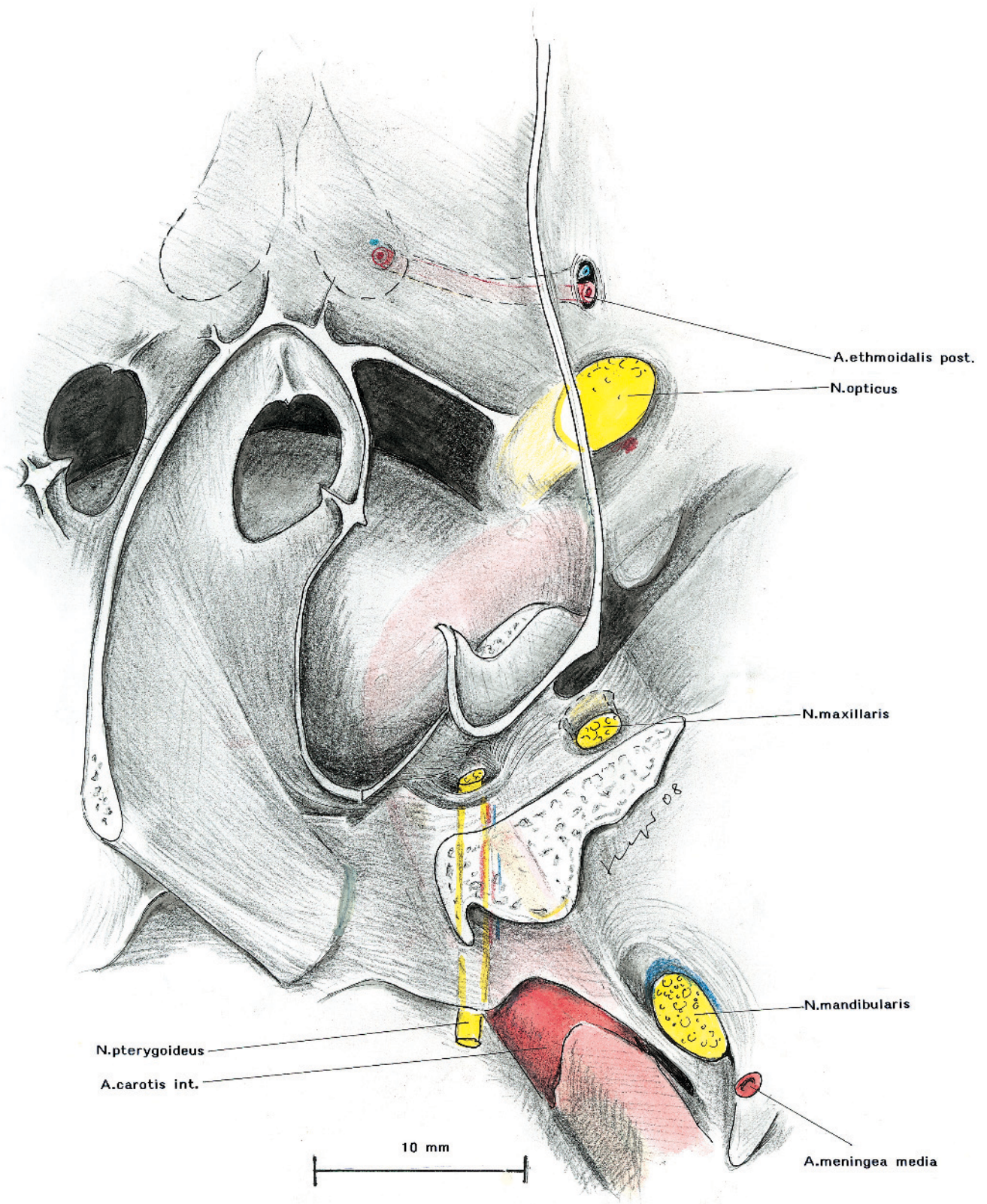


Fig. 27

Sinus sphenoidalis. Possible width.



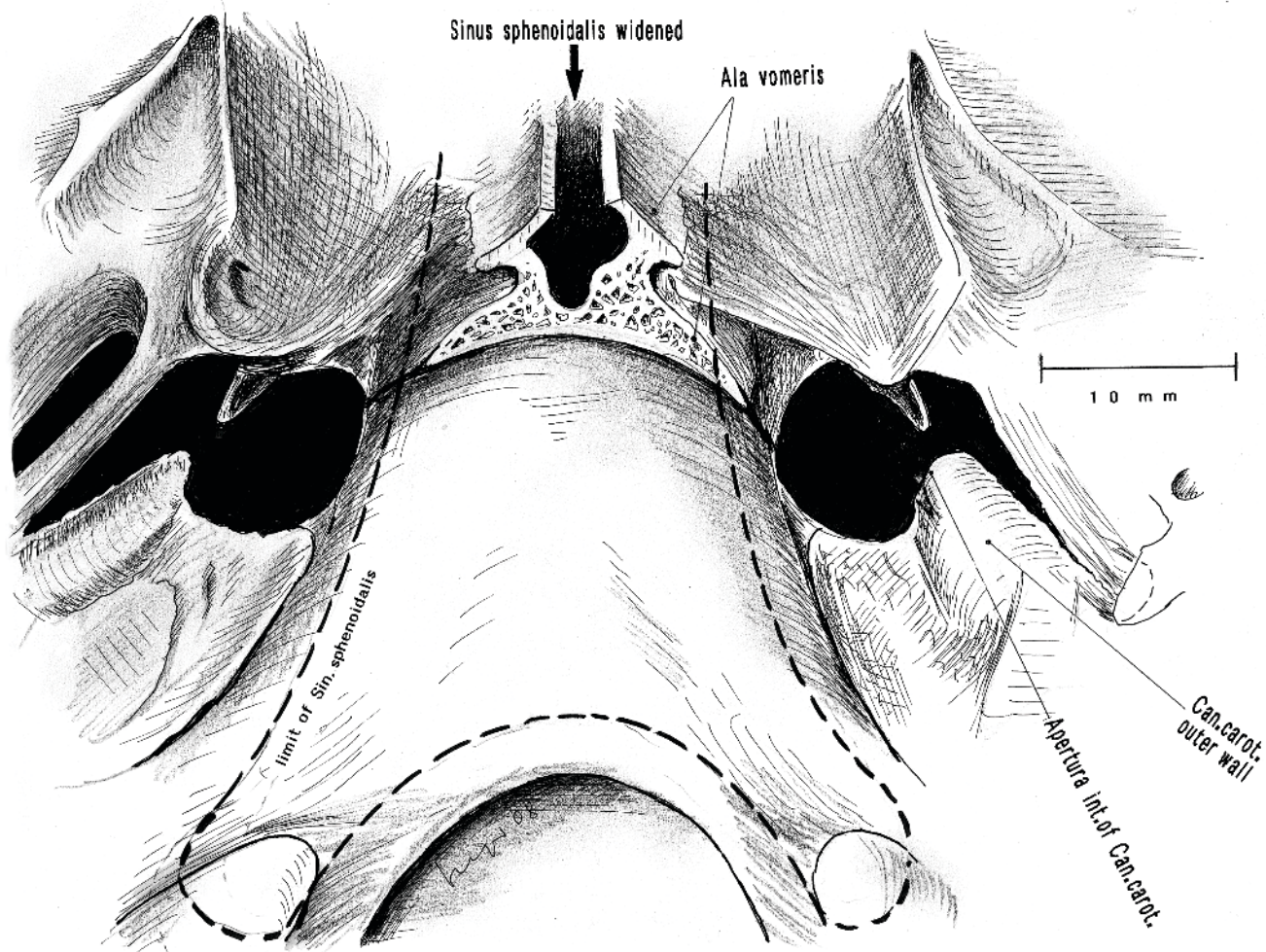


Fig. 28

View into a wide variant of Sinus sphenoidalis.

1. Apertura interna of Canalis caroticus
2. Foramen lacerum
3. Sulcus caroticus

Arrow: Course of A. carotis int.

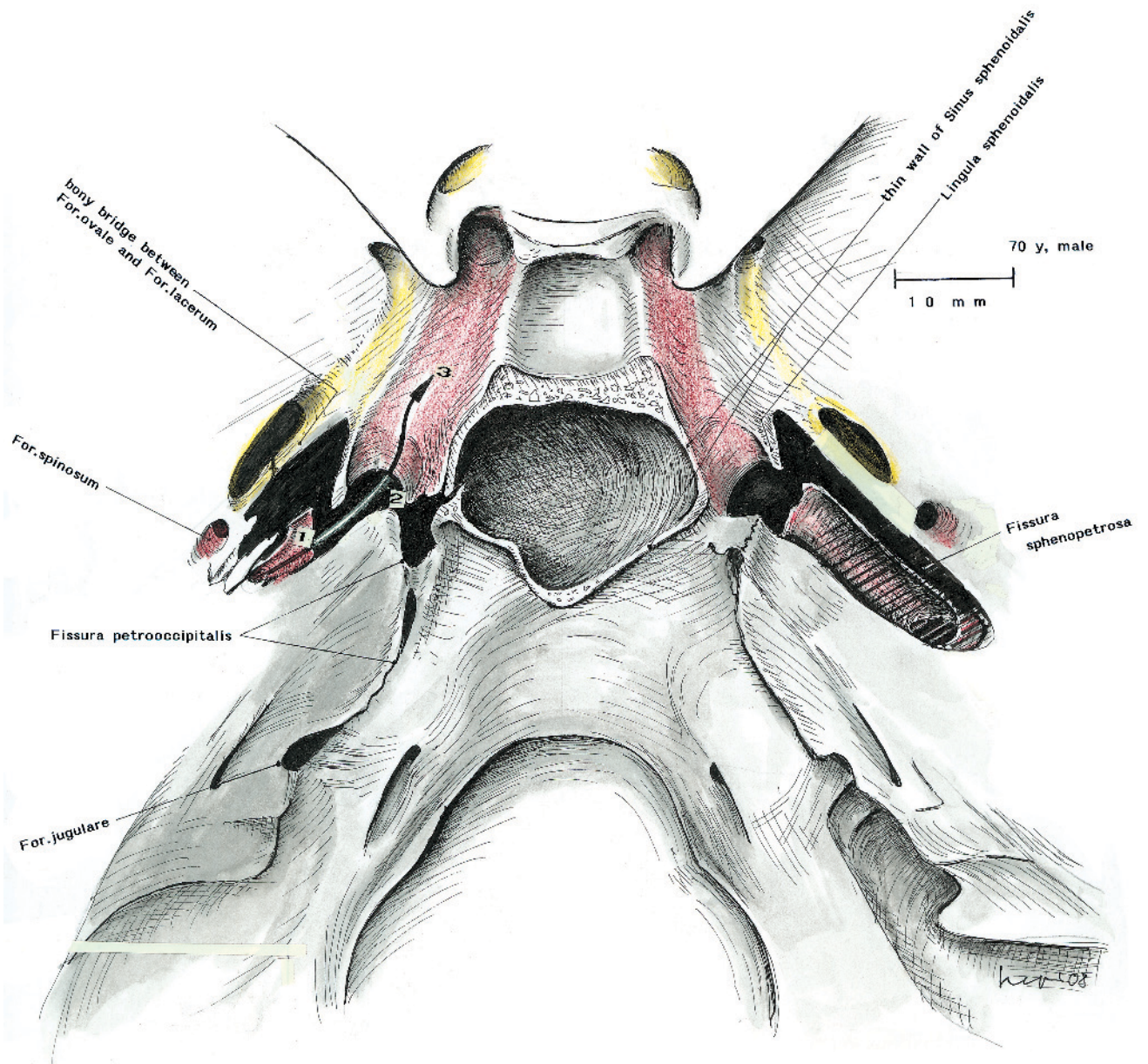
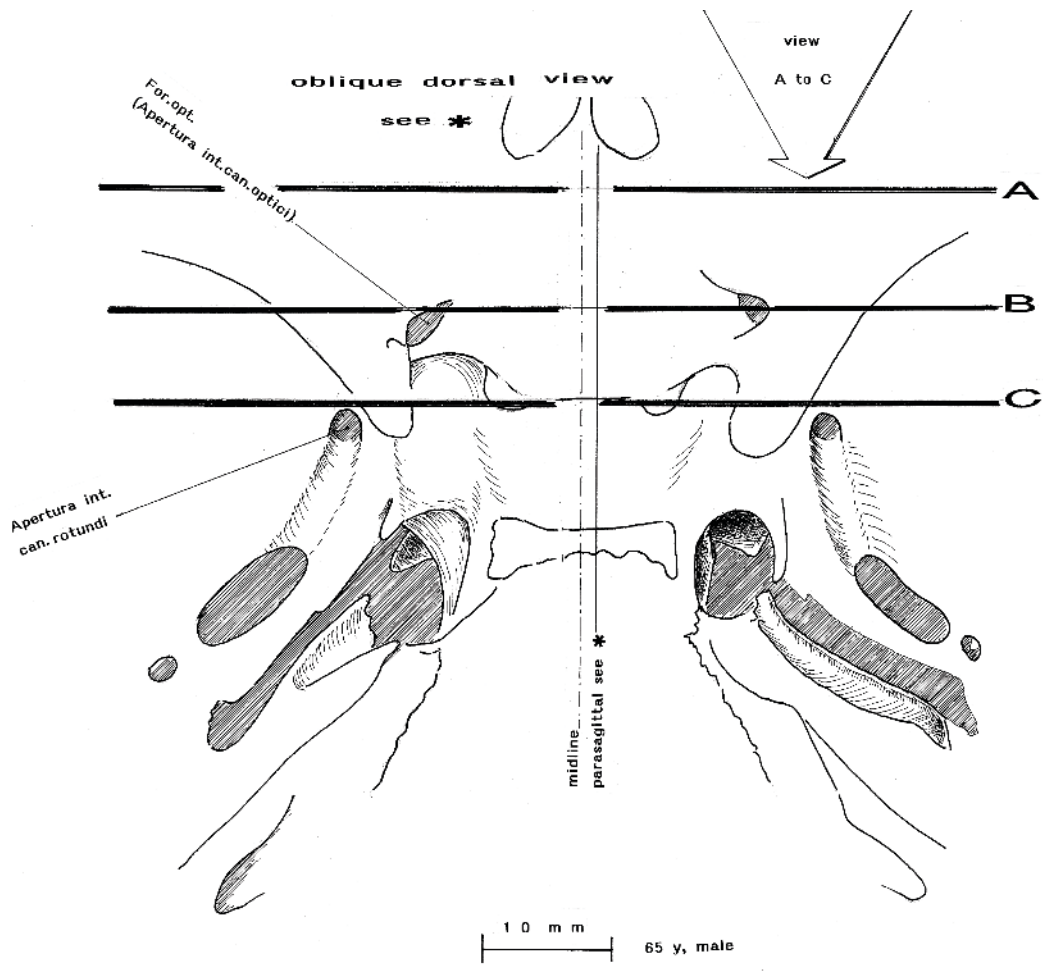




Fig. 29

Sinus sphenoidalis

Topogram for Figs. 30 and 31



\* parasagittal  
transection  
Septum sphenoidale omitted

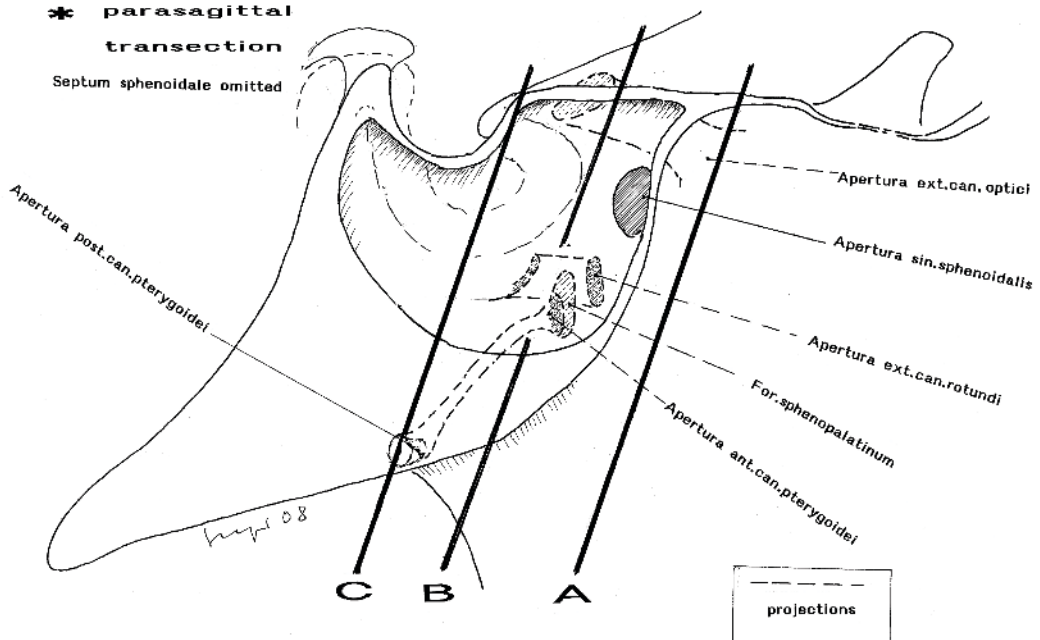
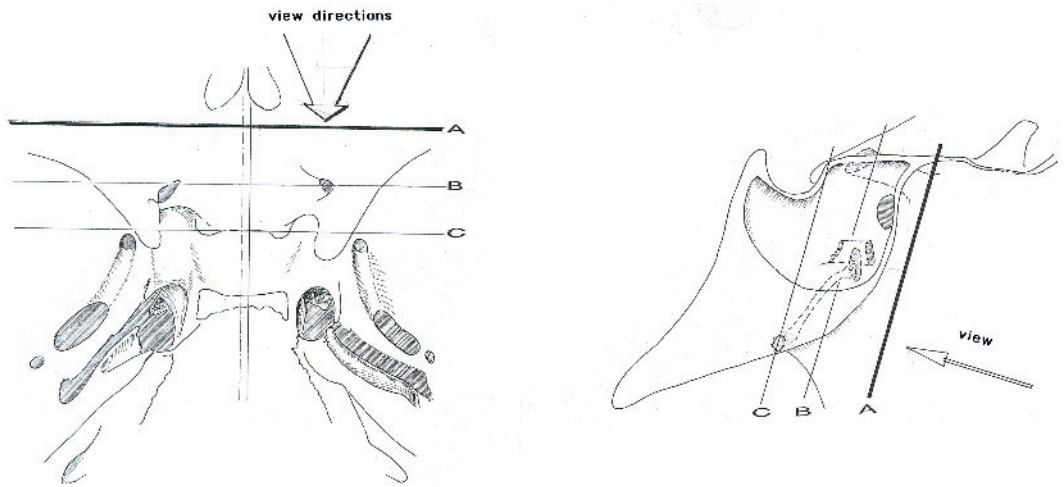


Fig. 30

Sinus sphenoidalis

A Vertical transection at the level of Recessus sphenothmoidalis



A

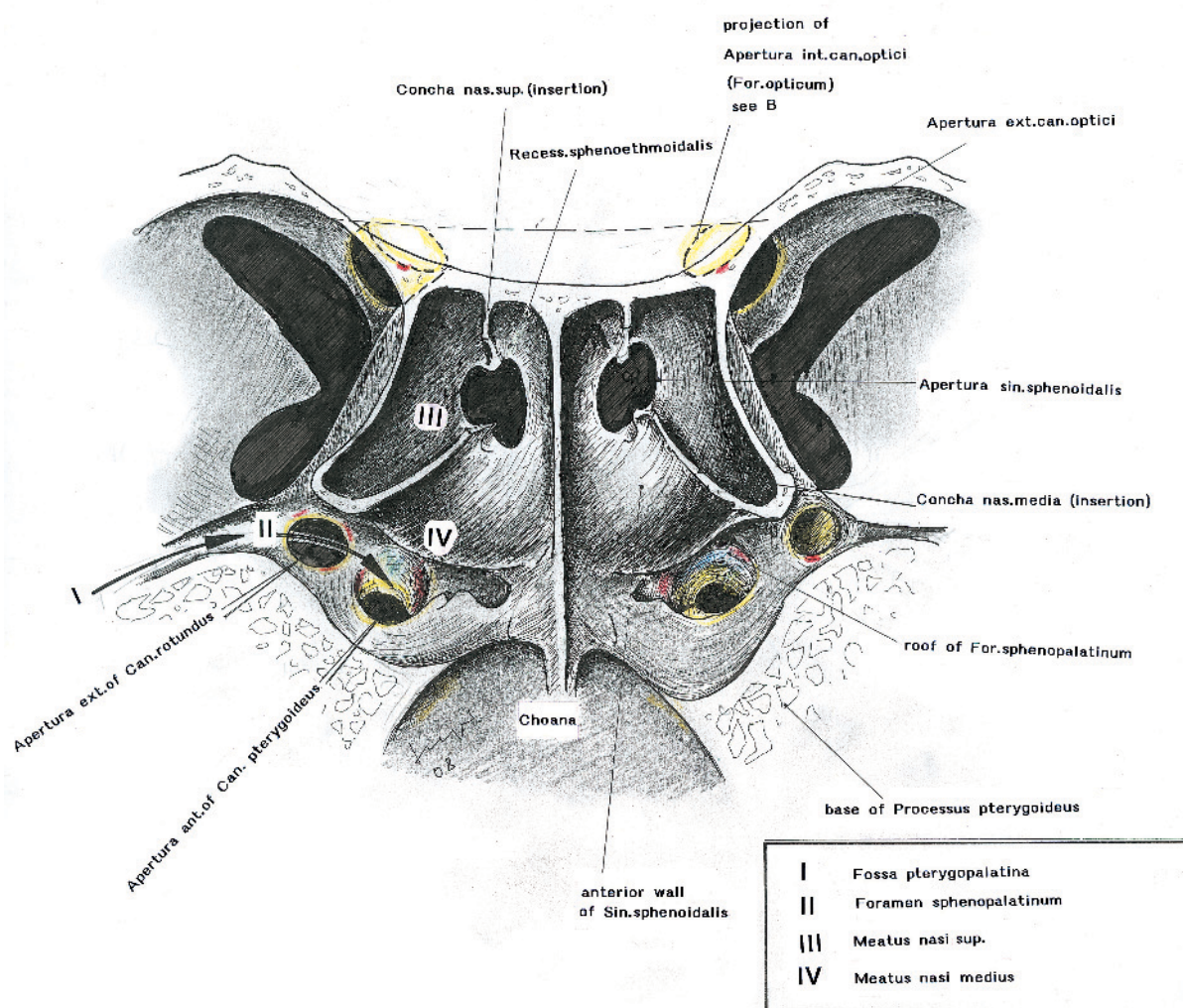


Fig. 31

Continuation of Fig. 30

- B** Vertical transection at the level of For. opticum and posterior to Foramen sphenopalatinum
- C** Vertical transection at the level of Tuberculum sellae and at the anterior margin of Foramen lacerum.



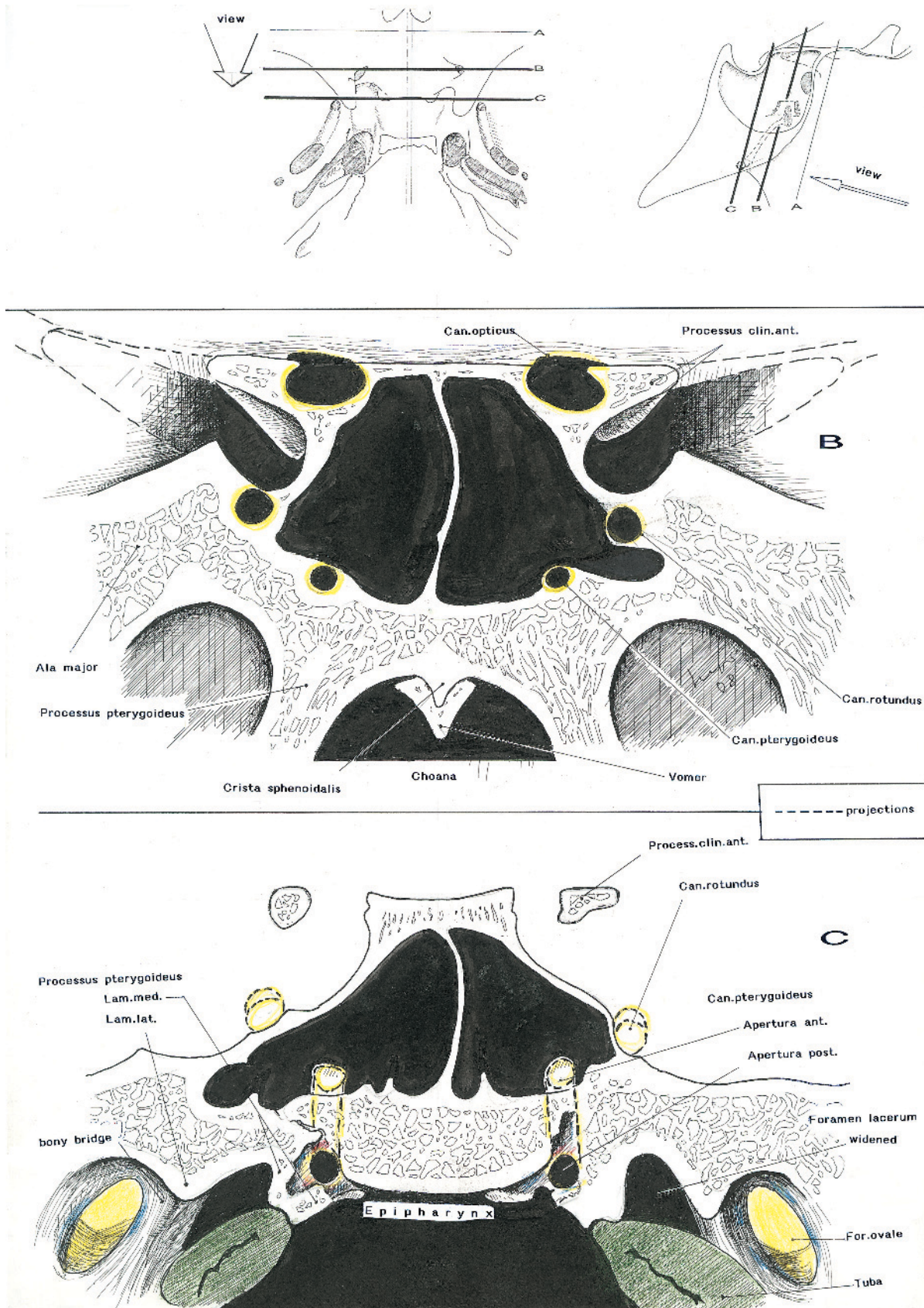


Fig. 32

Sinus sphenoidalis. Its roof is removed. Os basilare is transected.

**Abbreviations**

- 1 medial basal segment of Fissura orbitalis (located immediately lateral from the knee of Curvatura ant. of A. carotis int.)
- 2 Processus clinoides ant.
- 3 Canalis opticus
- 4 Concha nasalis sup., beyond Apertura sphenoidalis
- 5 Meatus nasi superior beyond Apertura sphenoidalis
- 6 as 3
- 7 Foramen ovale
- 8 fenestrated wall of Sinus sphenoidalis
- 9 bony ridges of the floor of Sinus sphenoidalis
- 10 as 9
- 11 Apex of the petrous bone
- 12 Apertura int. of Foramen rotundum



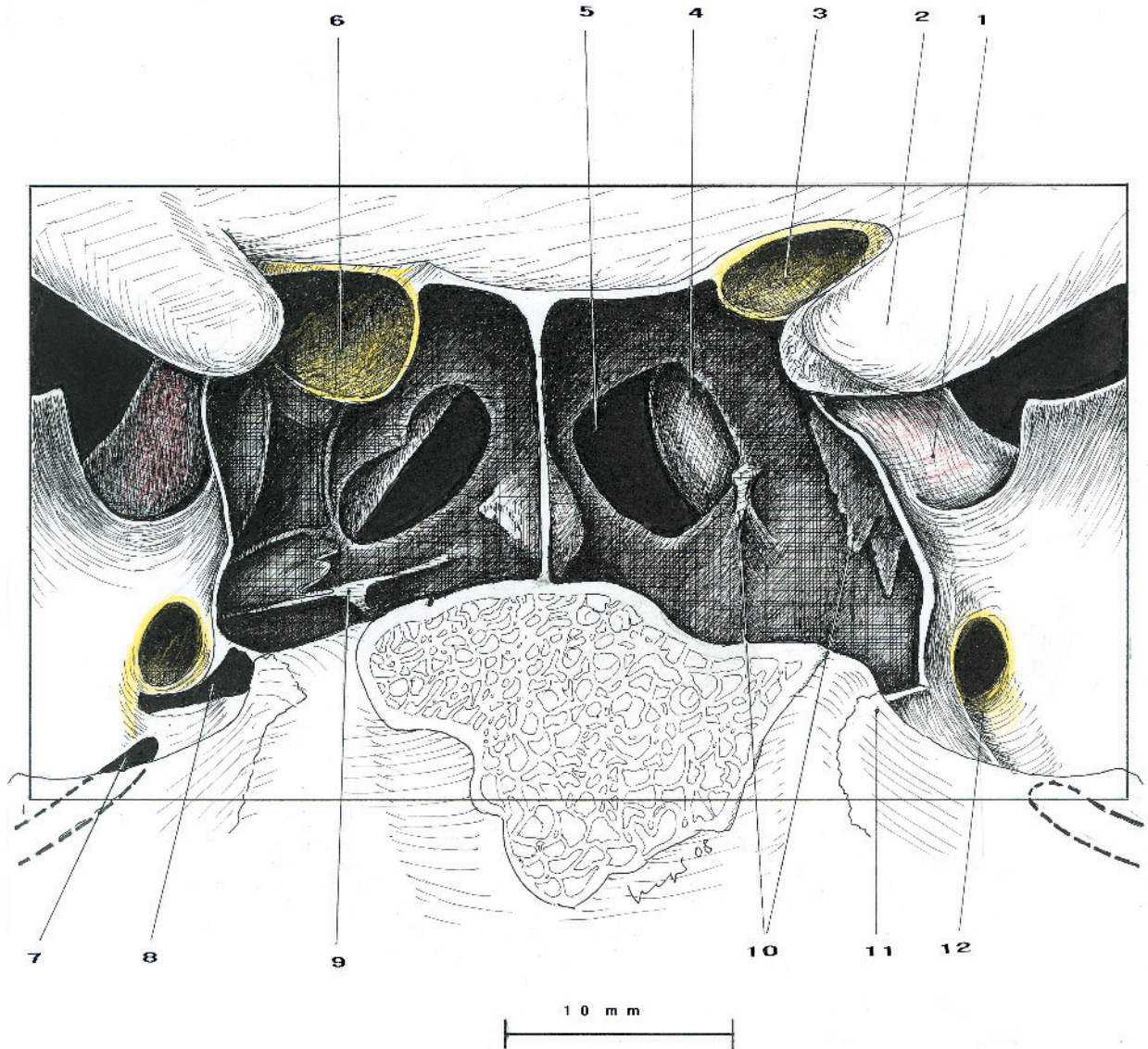
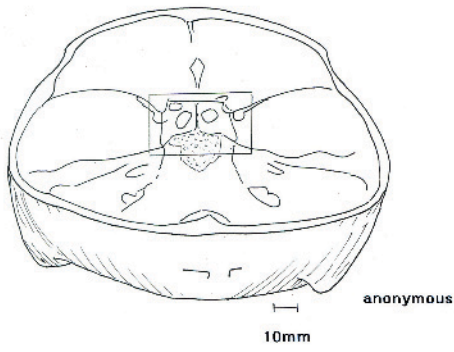


Fig. 33

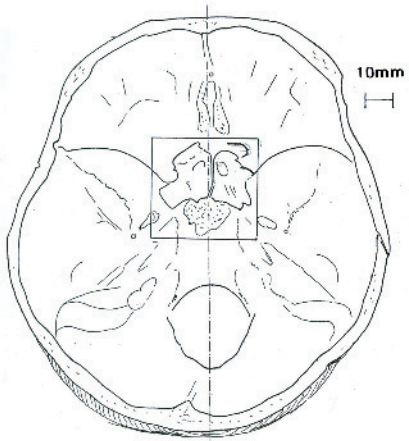
Continuation of Fig. 32

A leftsided pneumatization is depicted in this cadaver skull dissection. This type of variant may be connected to a widened Sinus sphenoidalis or to a widened posterior ethmoid cell (Lang 1981, p 457). These connections may present as extensions of a pneumatized roof of Processus clinoideus anterior or as a pneumatization and bony duplication of the roof of Canalis opticus, or both. This is demonstrated in Fig. 20.

**Abbreviations**

- 1 Apex of the petrous bone
- 2 Foramen ovale
- 3 Lamina medialis of Processus pterygoideus beyond Foramen lacerum
- 4 bony sulcus between Canalis rotundus and Foramen ovale, variable 4a as 4, fenestrated
- 5 Foramen opticum
- 6 Sulcus chiasmatis
- 7 Apertura sinus sphenoidalis
- 8 Canalis opt.
- 9 Septum of Sinus sphenoidalis





anonymous

+++++ Canalis rotundus projection

+++++

--- pneumatization of Processus clinoides ant. projection

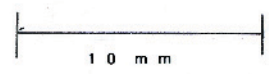
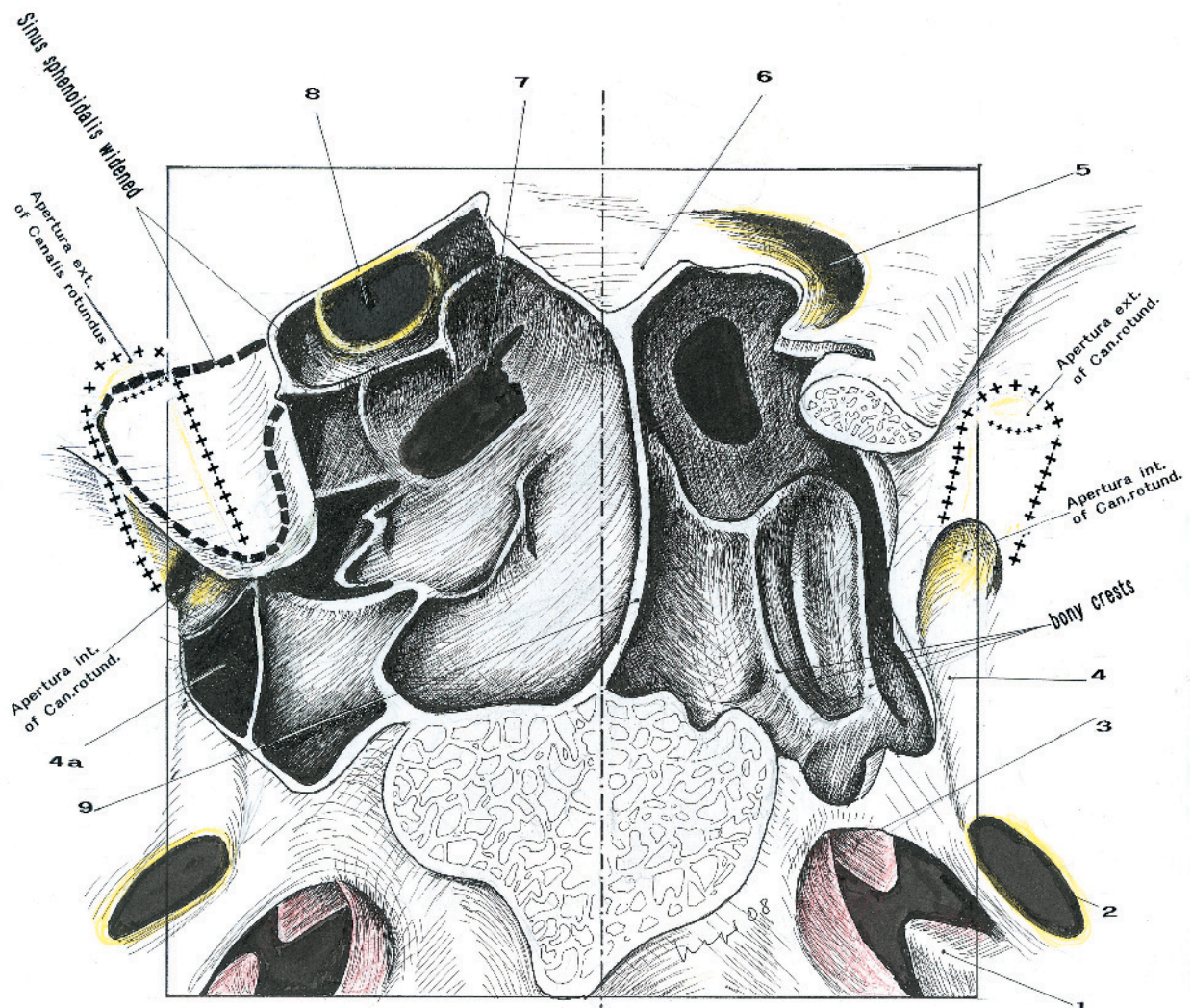
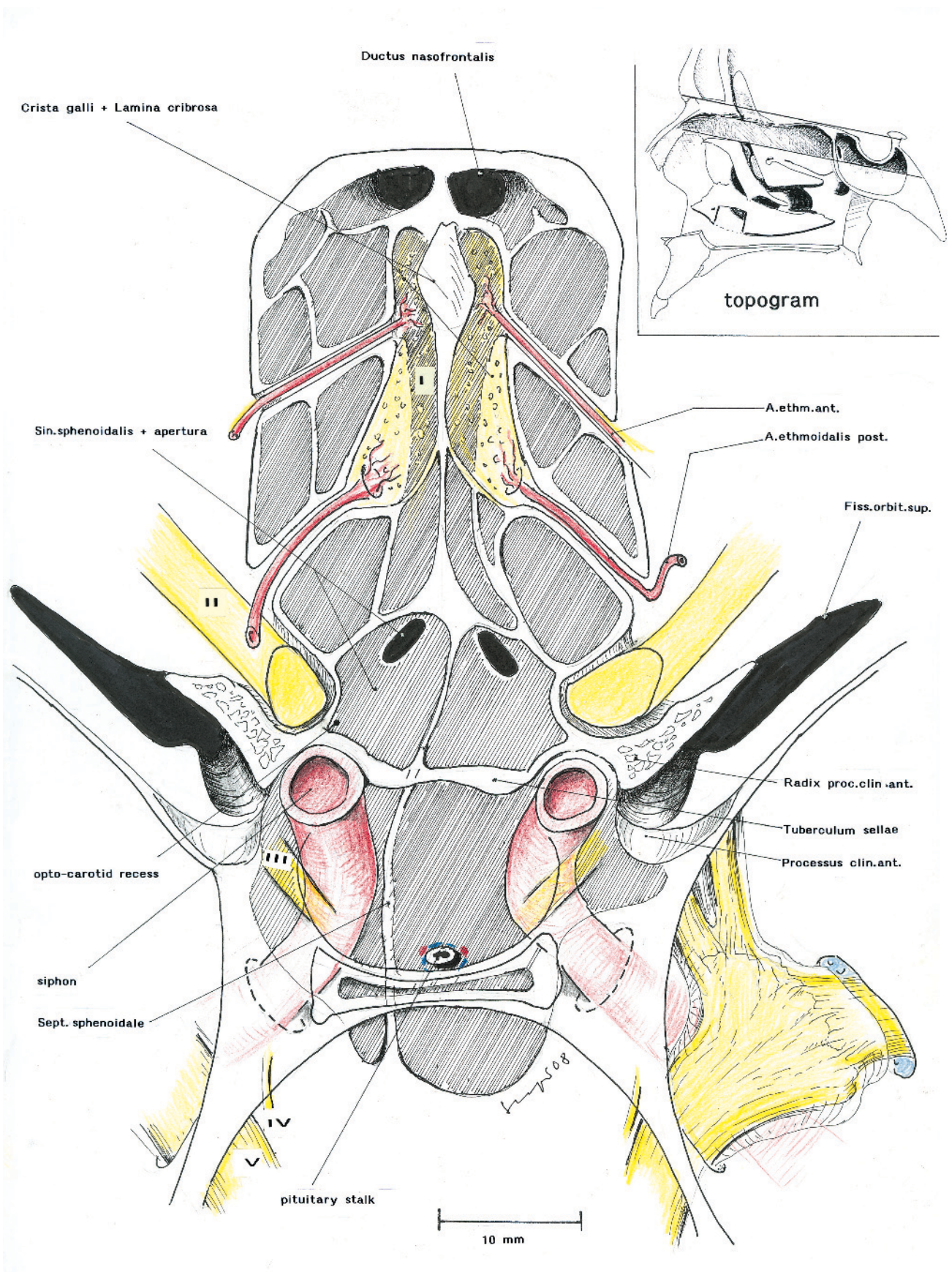


Fig. 34

Axial transection of Cavum nasi, Sinus sphenoidalis and surrounding structures.  
Schematic presentation.





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**CHAPTER IV**  
**TUBA AUDITIVA (EUSTACHII)**  
**(Figs. 35 to 40)**

## Overview (Figs. 35 und 36)

**Tuba auditiva is divided into Pars cartilaginea and Pars ossea.**

**Pars cartilaginea is located extracranially, Pars ossea is enclosed by Pyramis**

The long course of Tuba extends from its Orificium at Pharynx to its Ostium at Cavum tympani. The entrance of Pars cartilaginea at Pyramis is called Apertura tubae. Here Tuba is narrowed (Isthmus tubae). Between this point and Cavum tympani, the thin-walled fine Semicanalus musculotubarius encloses M. tensor tympani (upper segment) and Tuba (inferior segment).

### Pars cartilaginea

Orificium tubae is located in the axial level of Concha inferior. The posterior wall of Tuba, Torus tubarius, is located between Orificium and Recessus pharyngeus (Rosenmuelleri). The bony bed of Tuba begins caudally at Fossa scaphoidea. This is a small triangular fovea at the dorsal base of Lamina medialis of Processus pterygoideus, anterior to Foramen lacerum. At Foramen lacerum, Tuba and A.carotis int. are separated by cartilaginous and fibrous layers. Posterior to Foramen lacerum the Tuba is running along its extracranial bed, Fissura sphenopetrosa, parallel to the intrapetrosal (pyramidal) course of A. carotis int. (Fig. 37). Fissura sphenopetrosa often presents as a wide gap, which forms an extension of Foramen lacerum into a lateral-posterior direction. It may extend to the Spina angularis-Apertura-tubae-complex. The gap of Fissura sphenopetrosa may connect to the longitudinal dorsal gap of Canalis caroticus. Tuba and A. carotis int. are interposed between the extra- and intracranial surface of the cranial base. Due to this proximity inexact punctures of Foramen ovale may be dangerous! Foramen ovale is located close to Tuba. If Tuba is punctured (instead of Foramen ovale), injury to A. carotis interna is possible with consecutive hematotympanon. This was a well known complication in the past, in electrocoagulation of Ganglion Gasseri (Schenk and Seeger, 1968). Foramen spinosum is located lateral to Tuba. The extracranial segment of A. meningea media and Mm.tensor and levator veli palatinae, which originates from Tuba and from Spina angularis are in close proximity. They may mask Apertura tubae (Fig. 50, see chapter 5).

### Pars ossea (C in Fig. 37, and Fig. 40)

Apertura tubae of Pyramis is covered by Spina angularis of Ala major and palatinal muscles, close to Foramen spinosum and its content, A. meningea media. The distance between to the Apertura externa of the carotid channel is variable.

Tuba crosses the bending segment of the carotid channel at its dorsal point, close to Apertura tubae.

**TUBA AUDITIVA (EUSTACHII)** (Figs. 35 to 40)

Fig. 35

Overview

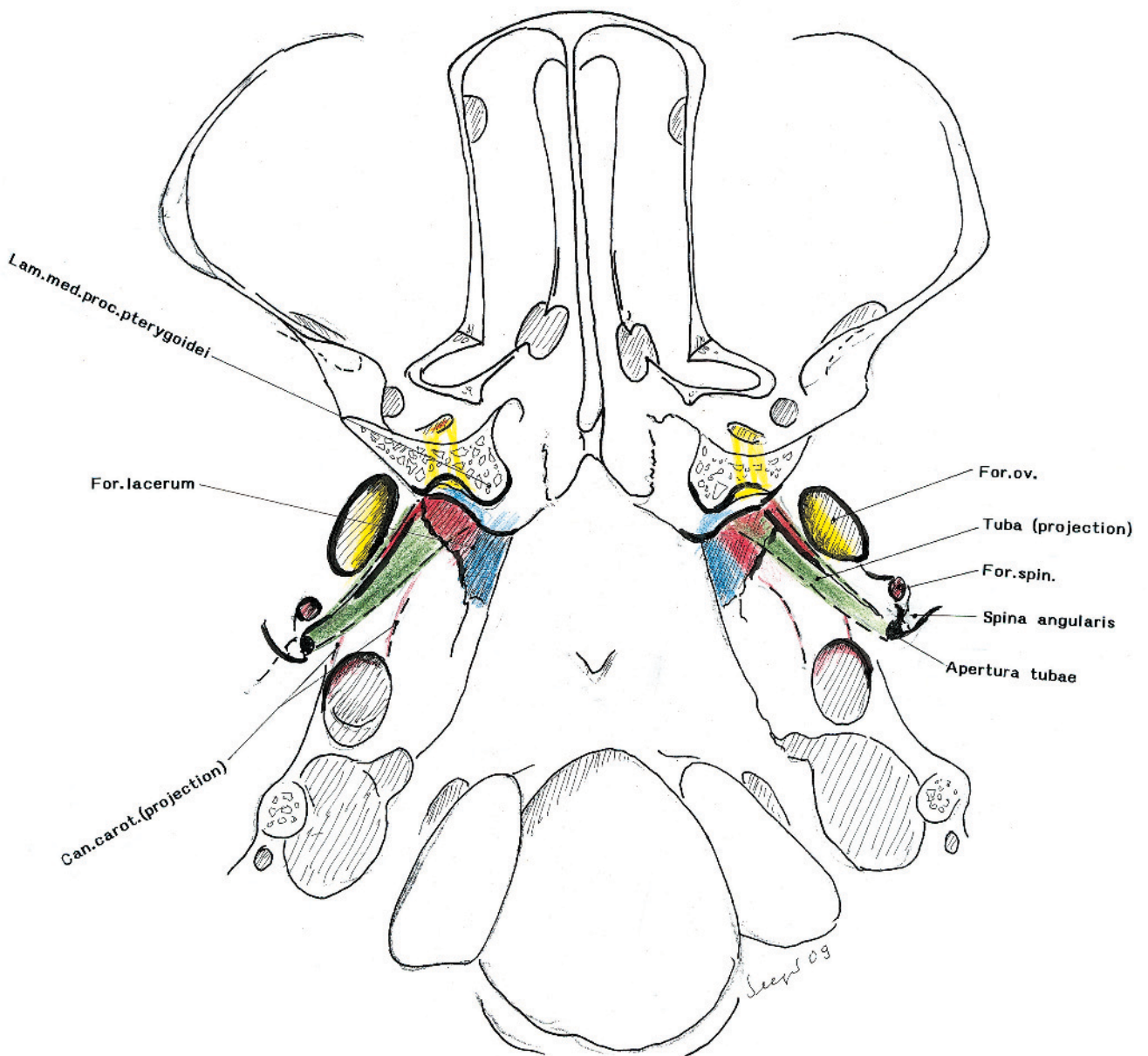




Fig. 36

Tuba auditiva (Eustachii), overview

- A** Schematic illustration
- B** Basal view according to Spalteholz (1907). Details added.  
Pars cartilaginea tubae split and everted (arrows)

**Abbreviations**

- 1 Tunica mucosa tubae auditivae (Eustachii)
- 2 Pars membranacea
- 3 Pars cartilaginea
- 4 M. levator veli palatini
- 5 M. tensor veli palatini
- 6 M. tensor tympani
- 7 Meatus acusticus ext., Pars ossea

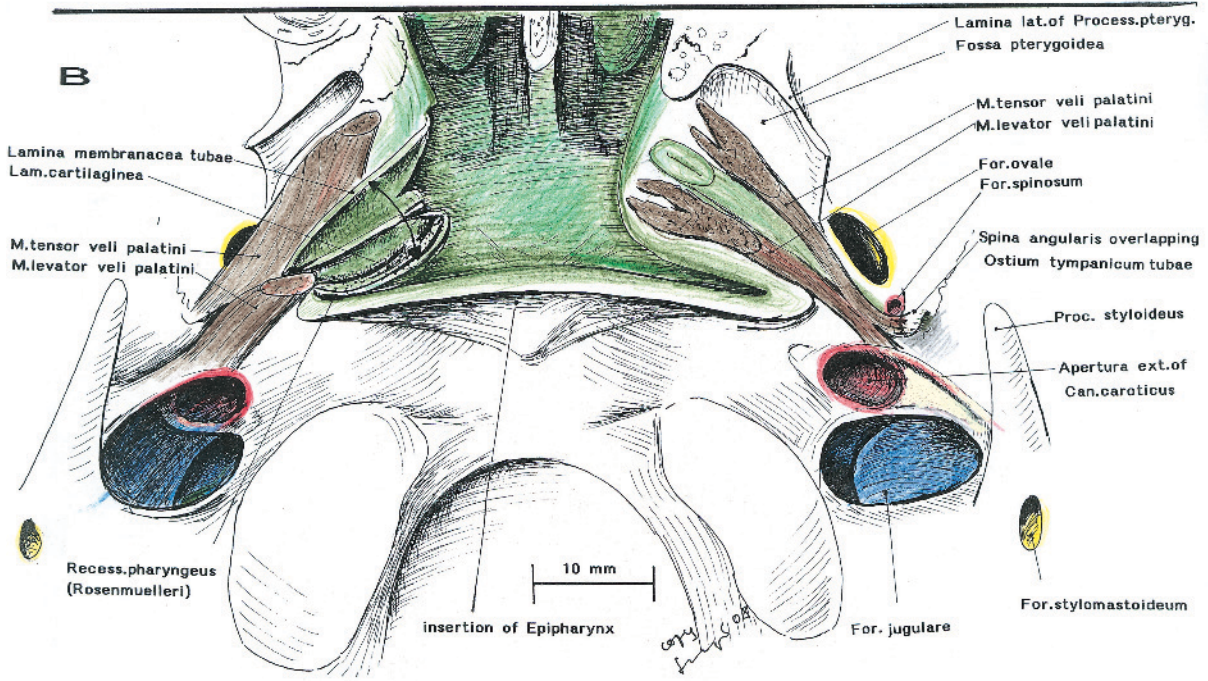
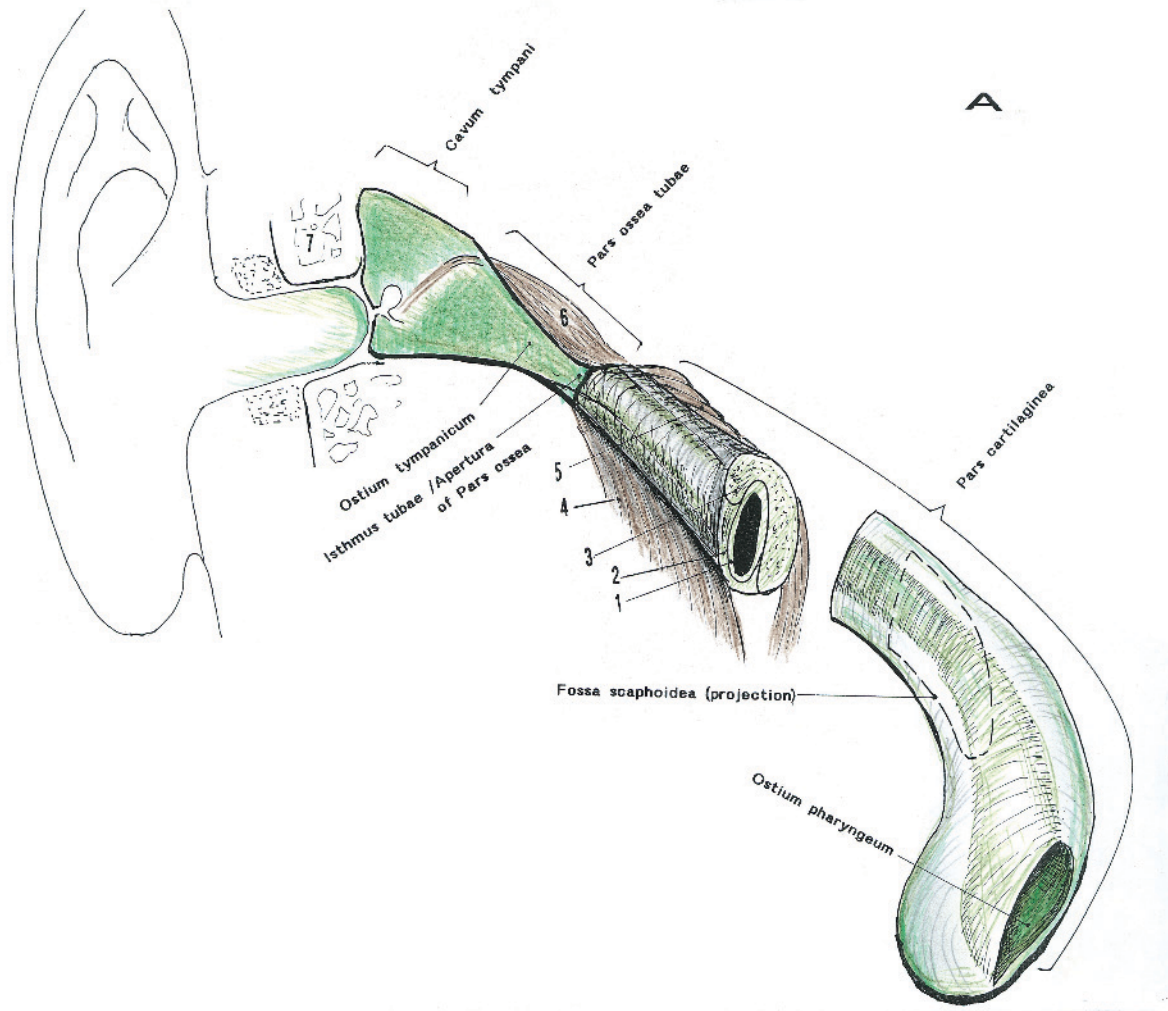


Fig. 37

Tuba auditiva (Eustachii), details

- A** Transectional planes A1 to A4
- B** Locations of A1 to A4
- C** Apertura tubae

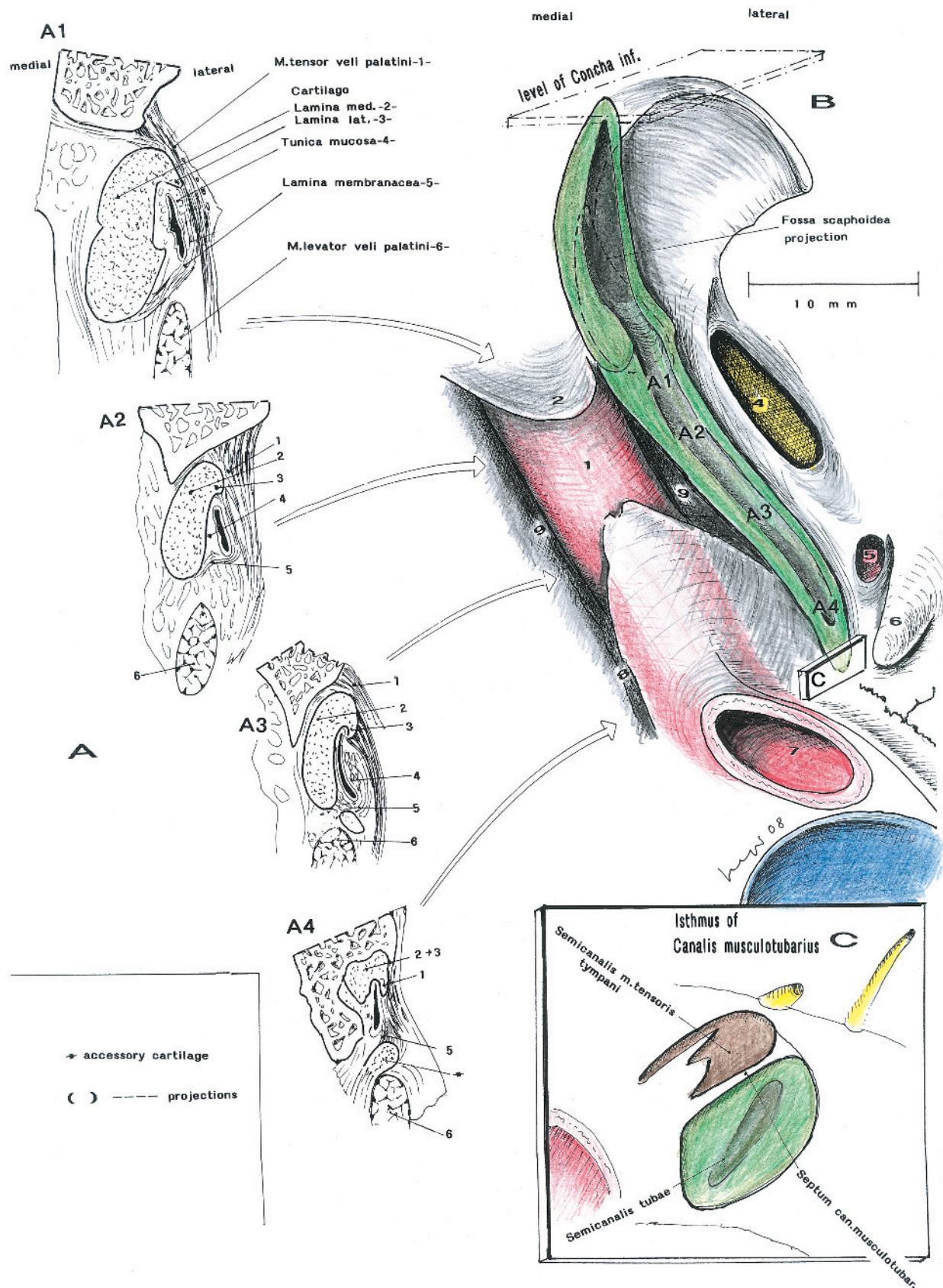




Fig. 38

Tuba, topographical relationship to Epipharynx and to anterior segment (orificium) of Tuba at the level of Concha inf. According to Spalteholz (1906, p 504), modified.

**Landmarks**

- 1 Vomer
- 2 Processus vaginalis (see Chapter 5)
- 3 Os petrosum
- 4 Sulcus petrosus inf.
- 5 Clivus
- 6 Pars basilaris

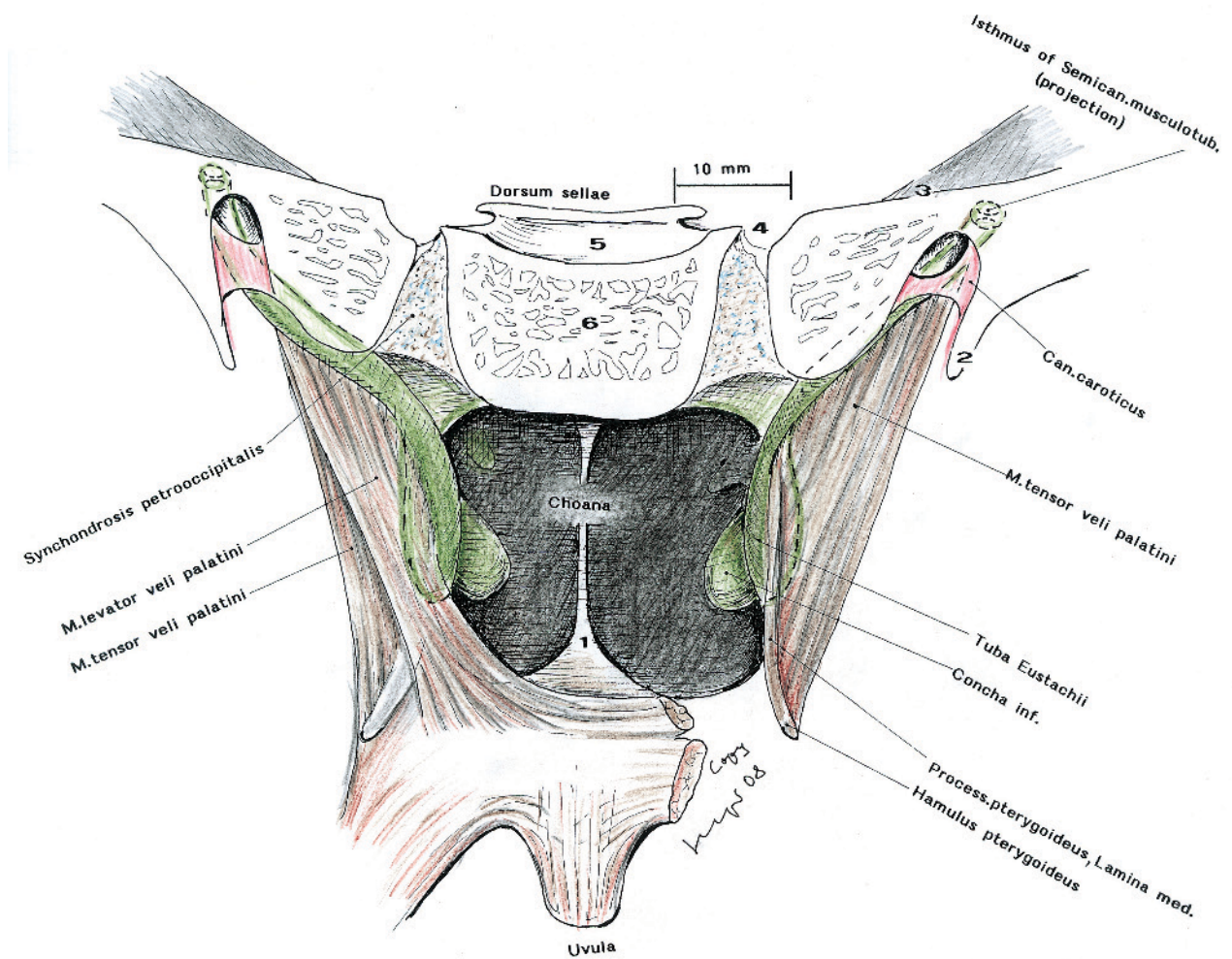
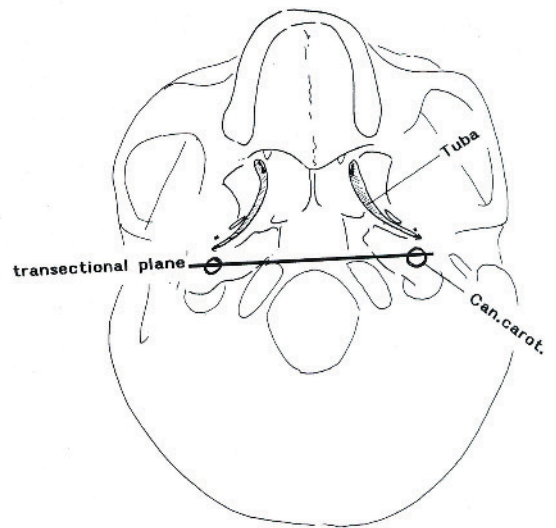
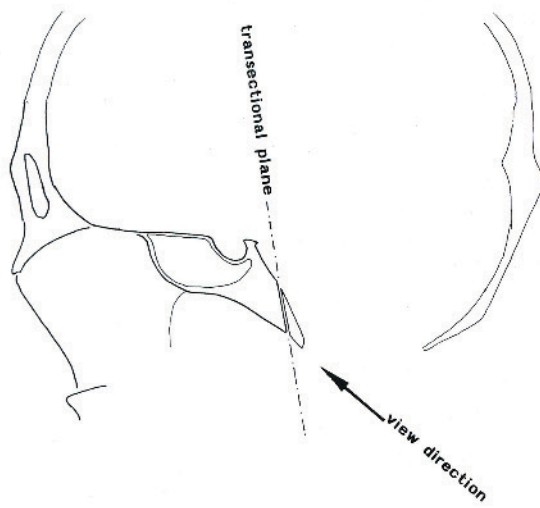


Fig. 39

Continuation of Fig. 38

- A** Bed of Tuba
- B** Proximal segment of Tuba
- C** Overview

**Abbreviations**

- 1 Condylus occipitalis
- 2 Processus styloideus
- 3 Vagina of Processus styloideus
- 4 Porus acusticus ext.
- 5 Fossa mandibularis and Fissura petrotympanica Glaseri
- 6 Tuberculum articulare of Os temporale
- 7 Fossa pterygopalatina
- 8 spine between Facies temporalis and infratemporalis of Ala major of Os sphenoidale
- 9 Fossa pterygoidea

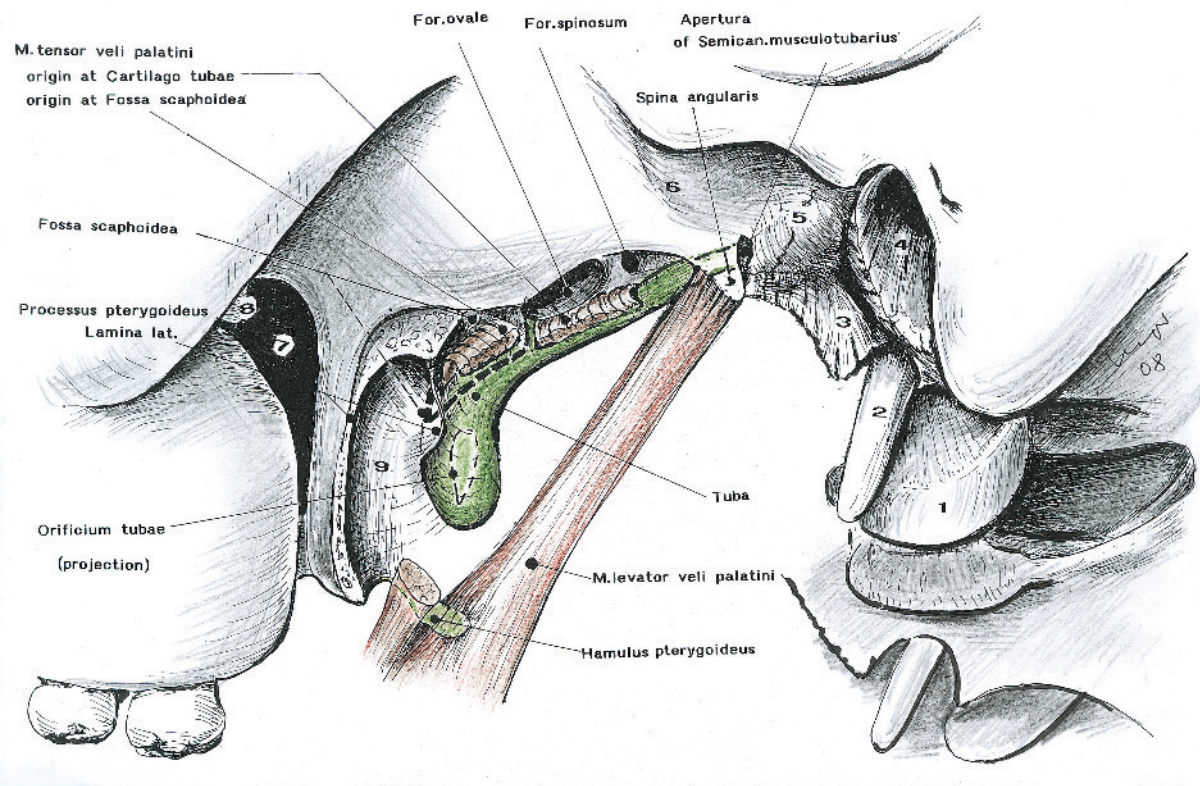
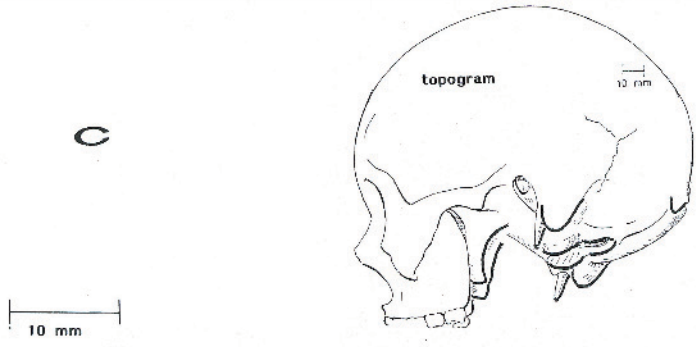
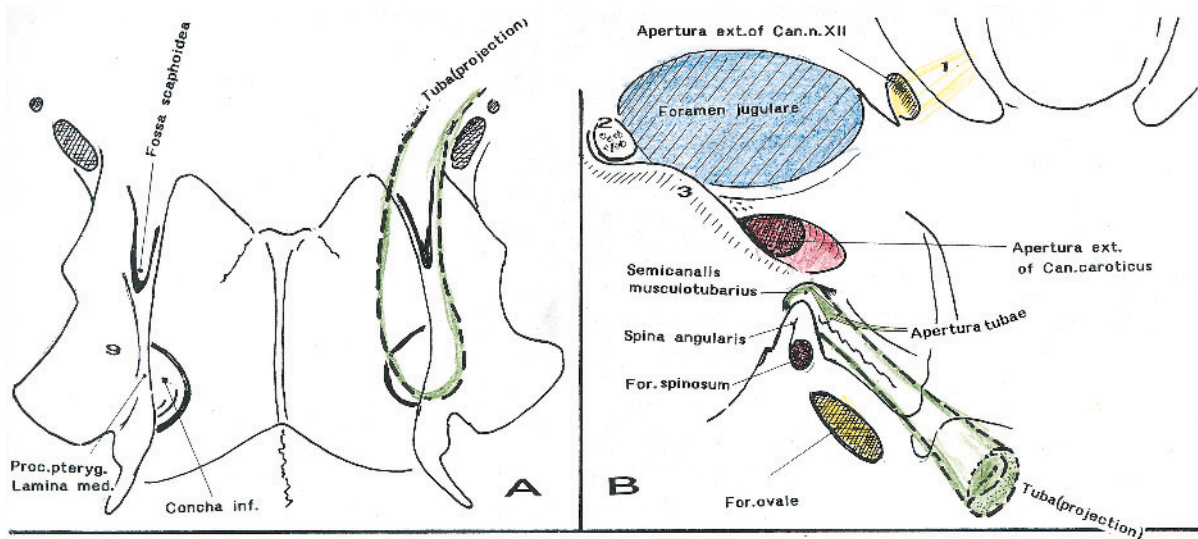




Fig. 40

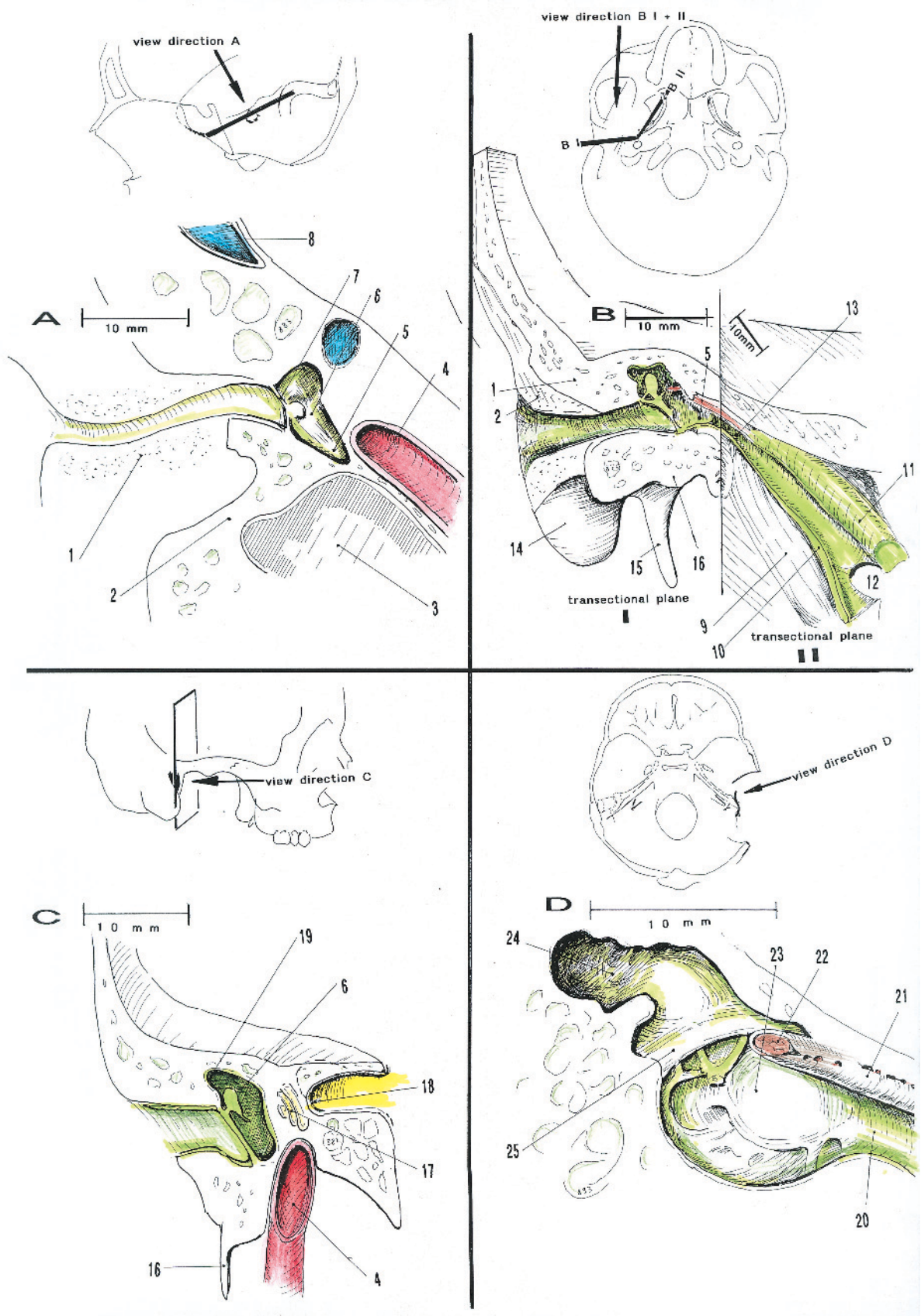
Tuba auditiva, Pars ossea.

Historical cadaver head and skull dissections, according to Spalteholz (1907, 803ff, 810), slightly modified

- A** Horizontal transection
- B** Vertical coronal and vertical oblique transections combined
- C** Coronal transection
- D** Sagittal presentation of Cavum tympani, medial wall

#### Abbreviations

1. Pars cartilaginea of Meatus acusticus ext.
  2. Meatus acusticus ext., Pars ossea
  3. temporobasal cerebral cortex
  4. A. carotis int.
  5. Ostium tympanicum tubae
  6. Cavum tympani
  7. Membrana tympani
  8. Sinus sigmoideus
  9. M. levator veli palatinae
  10. Tuba Eustachii, Pars membranacea
  11. Tuba Eustachii, Pars cartilaginea
  12. Ostium pharyngeum tubae
  13. Isthmus tubae
  14. Processus mastoideus
  15. Processus styloideus
  16. Processus vaginalis
  17. Cochlea
  18. Fundus of Meatus acusticus int.
  19. Recessus epitympanicus
  20. as 5, Semicanalus tubarius
  21. Semicanalus muscularis
  22. M. tensor tympani
  23. Promontorium
  24. Antrum tympanicum
  25. Outer wall of Canalis n. facialis,
- Between 24 and 35: Recessus epitympanicus



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- Spalteholz W (1906) Handatlas der Anatomie des Menschen, Bd. 3, pp 502-509, p 803, p 810, p 819, p 822. Hirzel, Leipzig
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**CHAPTER V**  
**PYRAMIS (PETROUS BONE,**  
**PARS PETROSA PLUS PARS TYMPANICA)**  
**(Figs. 41 to 63)**



## Overview (Figs. 41 to 43)

The exact outline of Pars petrosa and Pars tympanica is given by sutures in childhood  
**The pyramis resembles an irregular shaped pyramid with 3 planes and edges.**  
**Facies posterior and anterior pyramidis are located on the inside of the skull base.**  
**Facies inferior is located on the outside of the skull base.**

## Pyramis, schematic drawing (Figs. 42 and 43)

### Facies posterior pyramidis (Fig. 42)

Central structures are Porus and Meatus acusticus internus. Margo sup. pyramidis, Fissura petrooccipitalis and Apex pyramidis forms the logs of pyramis. The base of Pyramis is not exactly defined (Fig. 42). Margo sup. pyramidis extends from Foramen lacerum to Sulcus sigmoideus (close to the sinus knee). Fissura petrooccipitalis extends from Foramen lacerum to the anterior margin of Foramen jugulare. At the base of Foramen jugulare, a fine suture separates Pyramis from Os occipitale. Foramen jugulare consists of a medial portion, which is a segment of the occipital bone, and a lateral portion, which is a segment of Pyramis.

The lateral margin of Foramen jugulare is divided into a small anterior and a wider posterior segment. They are divided by a small protrusion, Processus intrajugularis. This is not yet recognized as an exact neuronavigatory landmark.

### Facies anterior pyramidis (Fig. 43)

The main structures are located on the margins. These are the horizontal segment of Canalis caroticus, Apertura tubae and adjacent structures of the sphenoid bone. These structures are located close to Fissura sphenopetrosa, between Ala major and Pyramis. Eminentia arcuata encloses Ductus semicircularis superior.

### Facies inferior pyramidis (Fig. 43)

Its main structures are Apertura ext. of the carotid channel, Foramen jugulare, and Foramen stylomastoideum. Fissura sphenopetrosa and Fissura petrooccipitalis form the borders. Processus vaginalis encloses the lateral walls of the Foramina of the carotid channel and of Foramen jugulare-Fossa jugularis. Fossa jugularis is bulging into Pyramis enclosing Bulbus superior venae jugularis. Processus styloideus is interposed between Fossa jugularis and Processus vaginalis. Fissura sphenopetrosa is a wide and deep rim, which is the bed of Tuba.

## Course of Canalis caroticus (Figs. 42 and 43)

It starts at the Apertura int., which encloses Apex pyramidis and Apertura externa, close to Foramen lacerum. The channel makes an oblique bending into a laterodorsal direction. This segment is located close to the anterior segments of Labyrinth and Meatus acusticus int. and ext. The anterior course of the carotid channel is running almost horizontally, excentric dorsolateral located in the middle and apical segment of Pyramis. This horizontal segment is enclosed by a spongious bony bloc of Pyramis, which doesn't contain other essential structures.

## **Dorsal and basal axis of Pyramis (Figs. 44, 45, 47 and 48)**

The dorsal axis of pyramis is the most important for surgery. But axis and superior margin of Pyramis are incongruent. This is irrelevant for surgery if other landmarks are available. For transnasal endoscopy it may be useful to define a straight-lined basal extracranial axis along *Facies inferior pyramidis*. This is achieved by connecting Foramen stylomastoideum to the posterior edge of the base of Lamina medialis of Processus pterygoideus. This edge protrudes to the anterior margin of Foramen lacerum (Fig. 48). The angle of this axis to the biforaminal line (between both Foramina stylomastoidea) varies between 44° and 55° (Fig. 44). A possible asymmetry of the cranial base should be taken into consideration (see B in Fig. 44).

## **Cadaver skull dissections (Figs. 45 to 63)**

### **Apex pyramidis, *Facies posterior*, anterior and inferior (Fig. 45)**

The transectional plane of Fig. 45 presents the excentric dorsolateral position of the carotid channel and the spongy substance of the other segments of the pyramis.

### ***Facies posterior pyramidis* (Fig. 46)**

Hamulus pyramidis and *Impressio trigemini* are located close to the apex. *Fissura petrooccipitalis* is small in contrast to this fissure at *Facies inferior pyramidis*.

### ***Facies anterior pyramidis* (Fig. 47)**

Hamulus pyramidis and *Impressio trigemini* are located at the superior margin of Pyramis between *Facies anterior* and *posterior*.

Fisch's blue line defines *Meatus acusticus int.* for supratentorial surgical approaches.

### ***Facies inferior pyramidis* (Figs. 48 to 50)**

From a basal perspective the projection of *Canalis caroticus* follows the basal axis of Pyramis. Other projections of *Canalis caroticus* are seen in Figs. 51 and 52.

## **Variants of Pyramis (Figs. 53 to 56)**

Variants and normal findings may be mixed, dependent on different views (Fig. 53). Variable dorsolateral gaps of *Canalis caroticus*, often combined with a widening of *Fissura sphenoccipitalis*, are common findings. They are more relevant for supratentorial surgical approaches than for transnasal endoscopy. During supratentorial surgical approaches the bony wall of *Canalis caroticus* doesn't protect the artery from surgical manipulations as it does during medial basal approaches.

The bending of *Canalis caroticus* may be steep or flat (Fig. 55). The relationship of Labyrinth to *Canalis caroticus* depends on the degree of bending. Further variants are shown at the extracranial shape of the cranial base (Figs. 54 to 56). The variability in

distance and types of Spina angularis, A. meningeal media and others may be relevant for defining of Apertura tubae, which is located in the depth, enclosed by the other structures.

## **Structures adjacent to Labyrinth (Figs. 60 to 63)**

According to the well known anatomy of Pars tympanica and Labyrinth, the adjacent structures of Labyrinth are illustrated here.

### **Relationship of Canalis caroticus to the labyrinth bloc**

#### **Anterior area of the Labyrinth bloc (Fig. 60)**

Fig. 60 presents a steep type of Canalis caroticus. Its lateral wall is crossed by Tuba. The carotid canal is located dorsal and parallel to Tuba.

A flat bending of the carotid canal results in a longer distance to Pars ossea tubae to the anterior segments of the Labyrinth (basal area of Cochlea) and to Meatus acusticus int. In this anatomical setting Cochlea and Meatus acusticus int. may be more relevant as neuronavigatory landmarks than the bending of the carotid canal.

#### **Area of Labyrinth, Apertura ext. can. carotici and of Fossa jugularis (Figs. 60 to 63)**

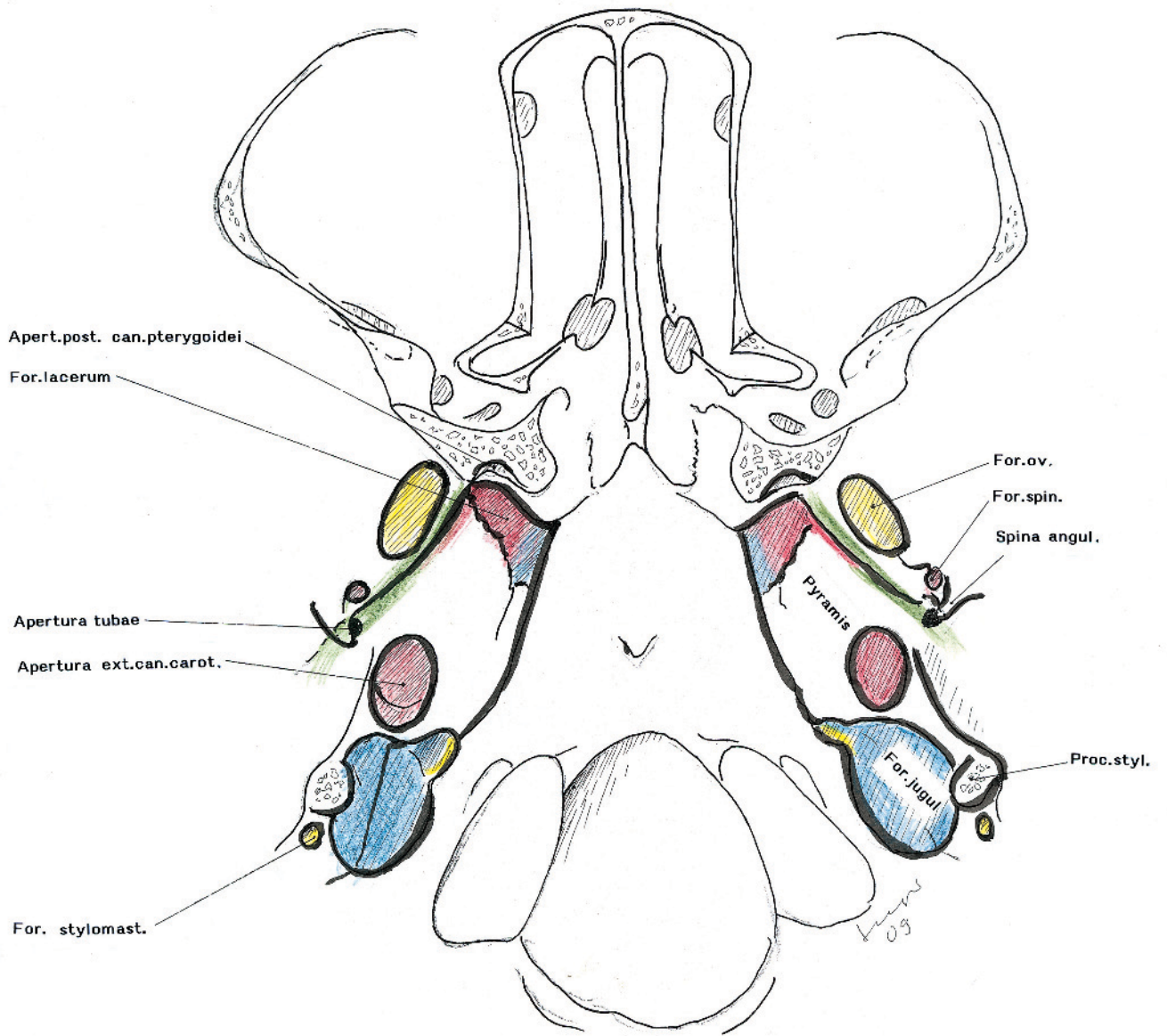
This area is located posterior to Apertura externa of the carotid canal. Labyrinth, the base of Meatus acusticus ext. and int., and the Fallopian channel are located close to each other (Fig. 60). This short distance is further illustrated in transectional planes. Fig. 62 shows the short distance between Canalis caroticus and Cochlea. Note the short distance between Bulbus sup. v. jugularis (Fossa jugularis) and Cavum tympani at B in Fig. 61, and the discrete bulging of the wall of Cavum tympani by Processus styloideus -15- of Fig. 63.

**PYRAMIS (PETROUS BONE)** (Figs. 41 to 63)

Fig. 41

Overview





**SIMPLIFIED PRESENTATION OF PARS PETROSA (PYRAMIS-SEGMENT)**  
(Figs. 42 and 43)

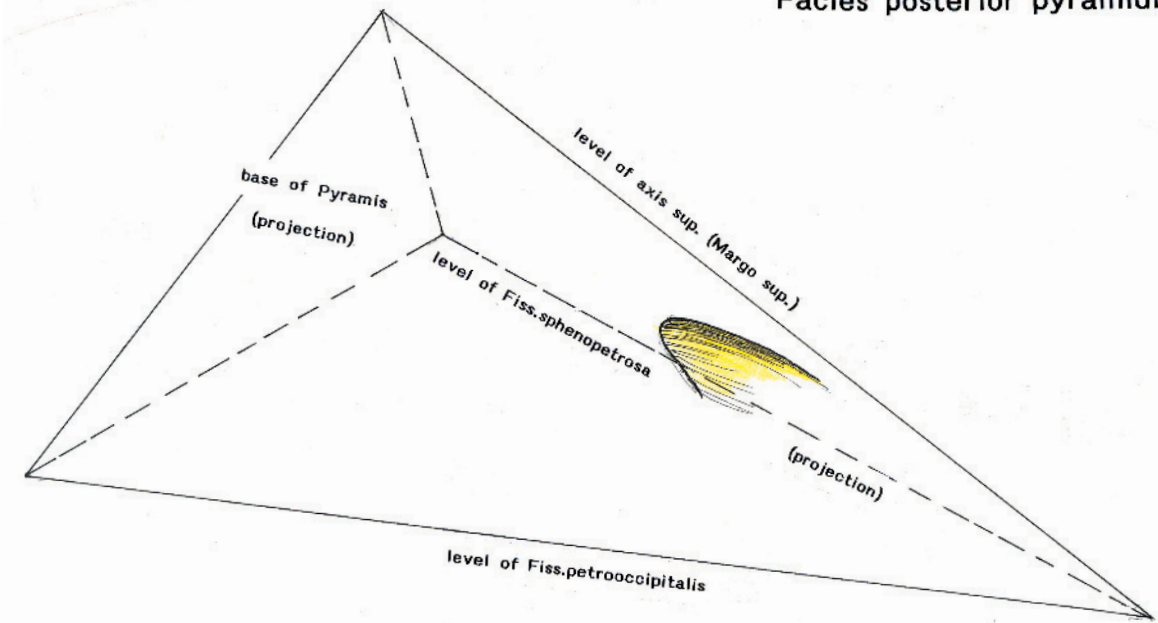
Fig. 42

**A** Intracranial posterior shape of Pyramis. Projections of other shapes and some essential structures added

**Abbreviations**

- 1 Apex pyramidis
- 2a Impressio trigemini
- 2b course of Sulcus (Sinus) petrosus sup.
- 3 Porus acusticus int.
- 4 Apertura ext. ductus endolymphatici at Fossa sacculi
- 5 Sulcus (Sinus) sigmoideus
- 6 Foramen jugulare, posterior segment enclosing Bulbus sup. of V. jugularis
- 7 Processus intrajugularis
- 8 Foramen juglare, anterior segment enclosing Nn. IX to XI
- 9 Processus styloideus
- 10 Processus vaginalis of 9
- 11 Apertura ext. of Canalis caroticus
- (11) as 11, projection
- (12) oblique vertical segment of Canalis caroticus, projection
- (13) Curvatura of Canalis caroticus, projection
- (14) oblique horizontal segment of Canalis caroticus, projection
- (15) Area of Apertura int. of Canalis caroticus at Foramen lacerum, projection
- 16 Area of Sulcus (Sinus) petrosus inferior

Facies posterior pyramidis



A

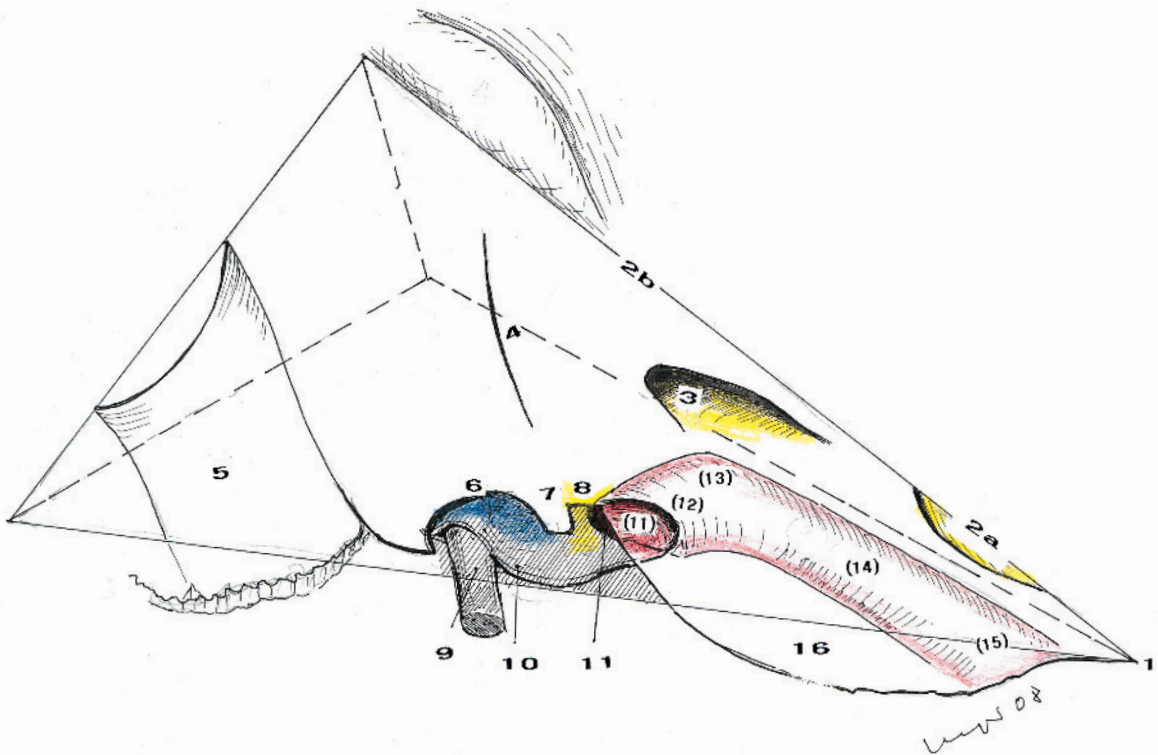


Fig. 43

Continuation of Fig. 42

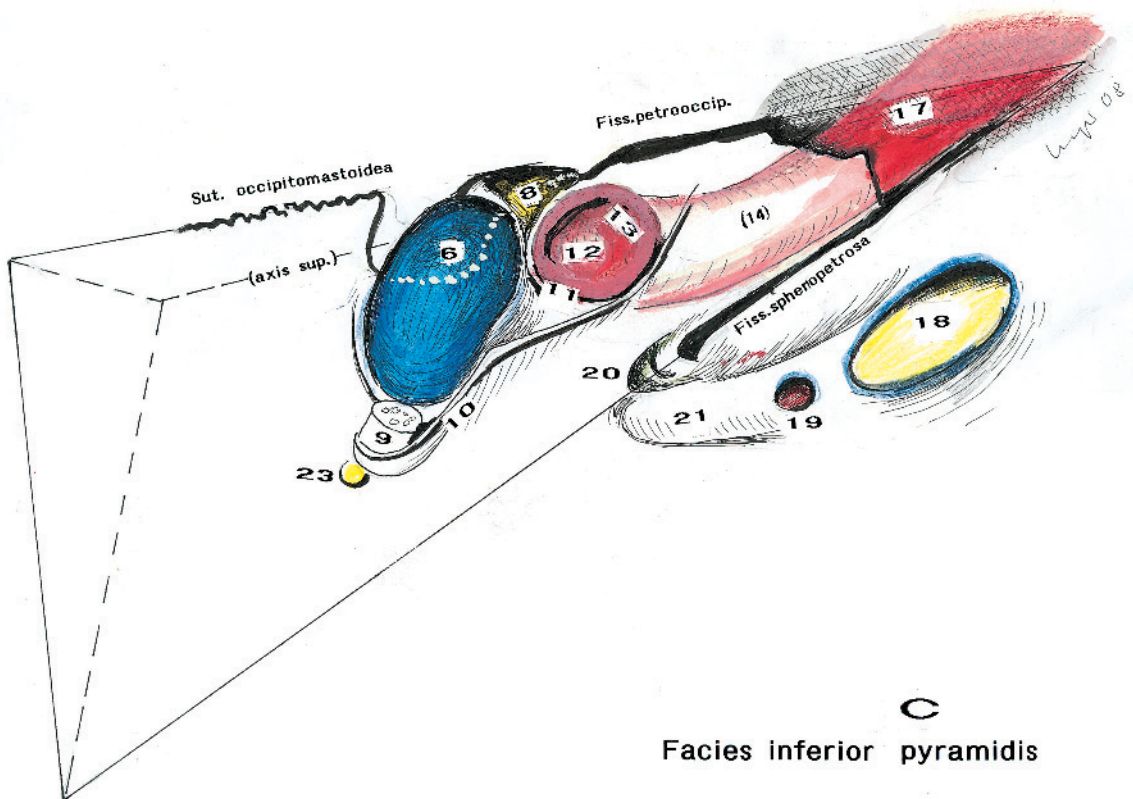
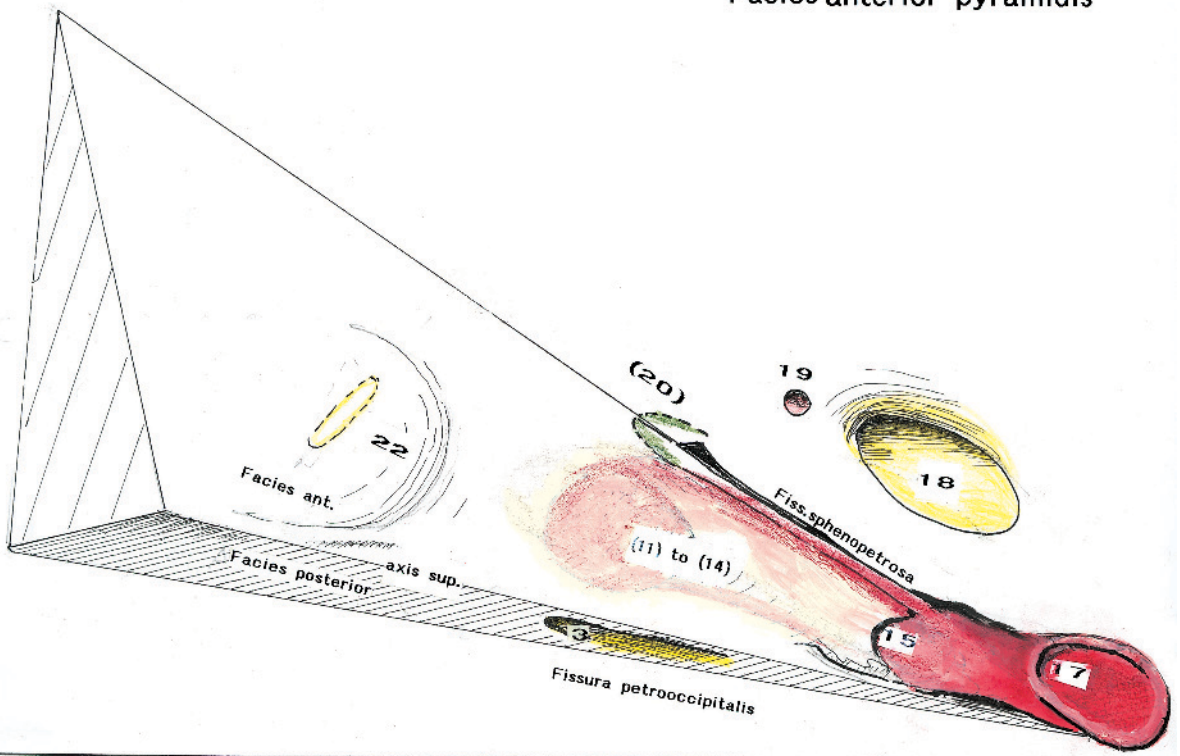
- B** Intracranial anterior shape of Pyramis
- C** Extracranial inferior shape of Pyramis

**Abbreviations**

- 15 Area of Apertura interna canalis carotici
- 16 see Fig. 33
- 17 Foramen lacerum
- 18 Foramen ovale of Os sphenoidale
- 19 Foramen spinosum of Os sphenoidale
- (20) Apertura tubae (projection)
- 21 Spina angularis of Os sphenoidale
- 22 Eminentia arcuata (enclosing Ductus semicircularis sup., dotted)
- 23 Foramen stylomastoideum (enclosing N. facialis)



**B**  
Facies anterior pyramidis



**C**  
Facies inferior pyramidis

Fig. 44

Inferior axis of Pyramis

This axis is different from the conventional axis along the superior margin between Facies anterior and posterior pyramidis.

This inferior axis of pyramis connects Foramen stylomastoideum to the base of Lamina medialis of Processus pterygoideus. Its variations are minimal, if the connection of both Foramina stylomastoidea is positioned exactly vertical to the midline. If the cranial base is asymmetric, this should be taken into consideration (see example D)

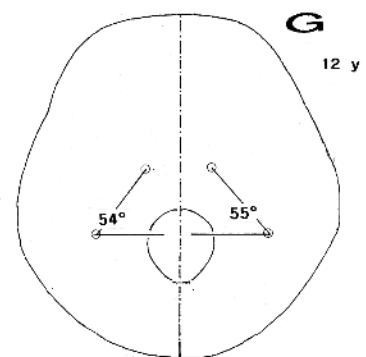
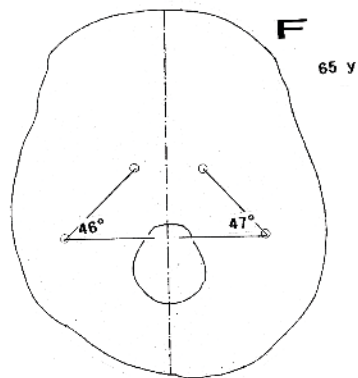
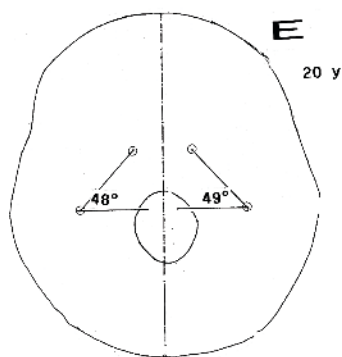
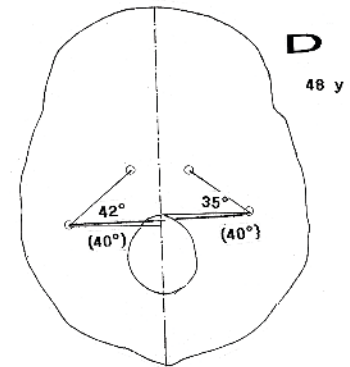
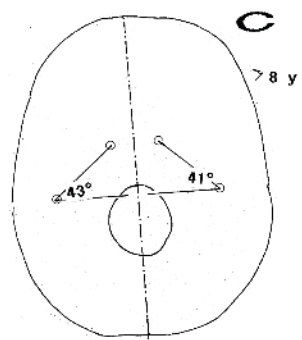
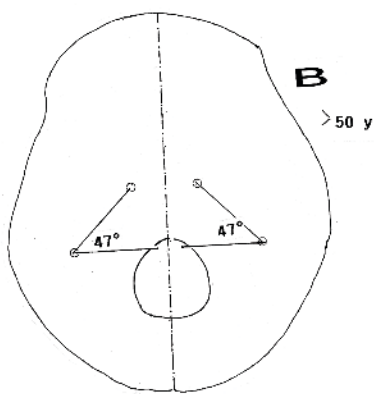
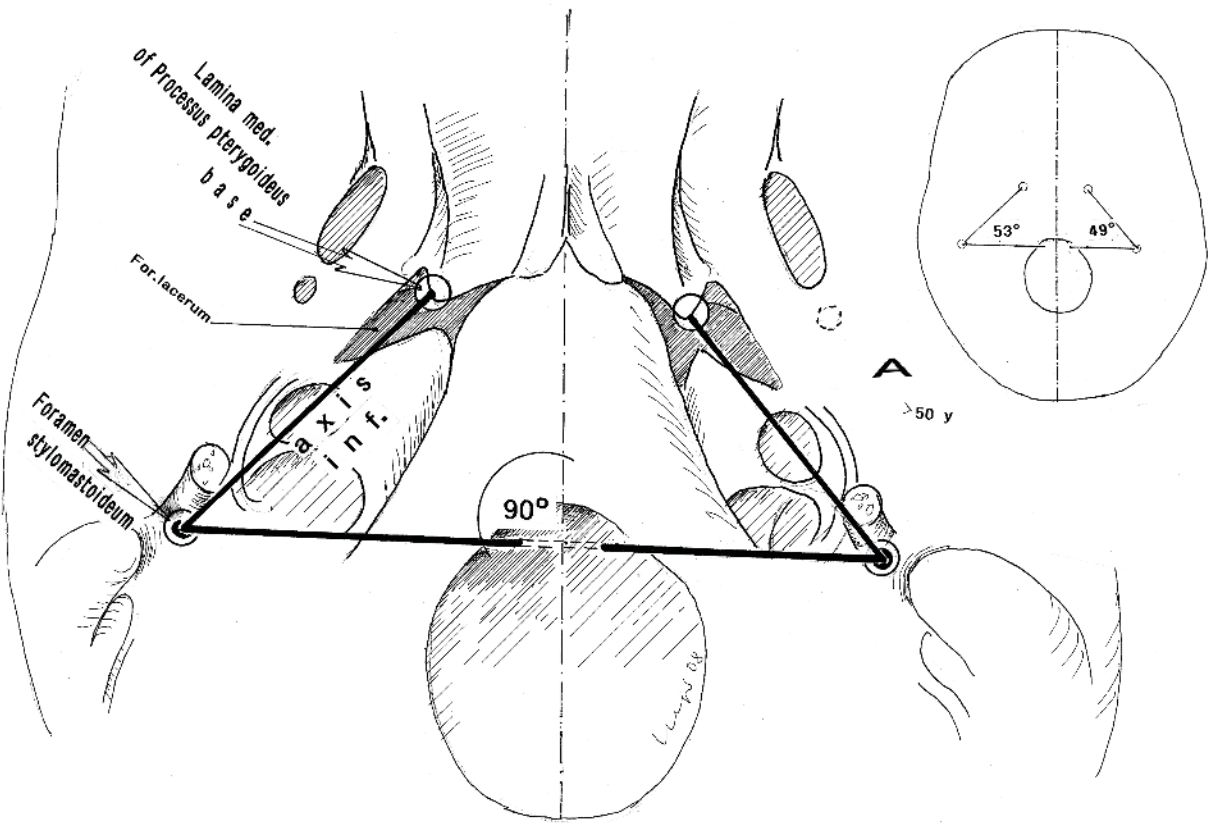


Fig. 45

Apex of the triangular Pyramis and Canalis caroticus

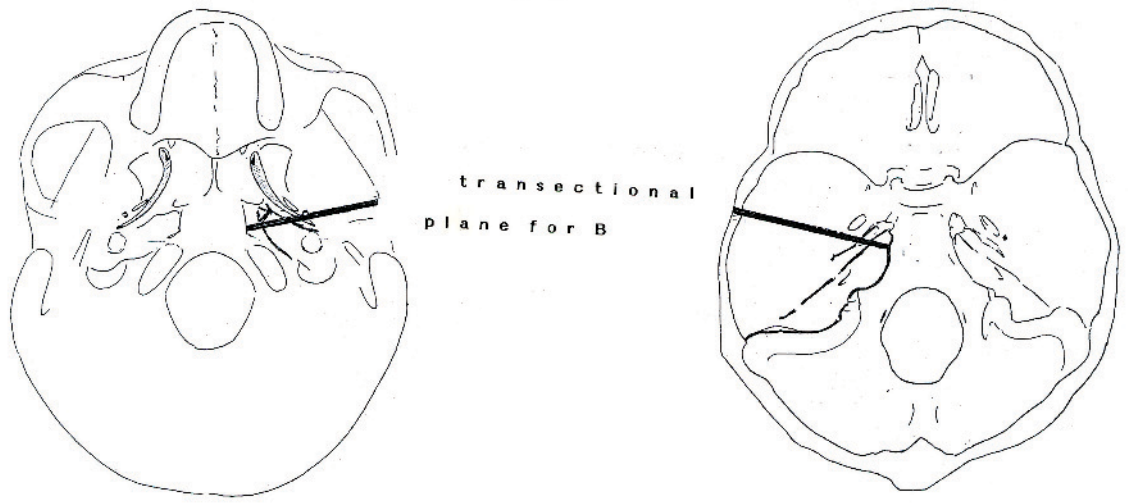
- A** Topogram
- B** Pyramis and adjacent structures

**Abbreviations**

- 1 Apex pyramidis
- 2 transectional plane
- 3 A. carotis int.
- 4 Tuba auditiva (Eustachii)
- 5 A. meningea media
- 6 Foramen ovale
- 7 defect and thin wall of Canalis caroticus
- 8 defect and thin wall of the ground of Fissura sphenopetrosa



A



B

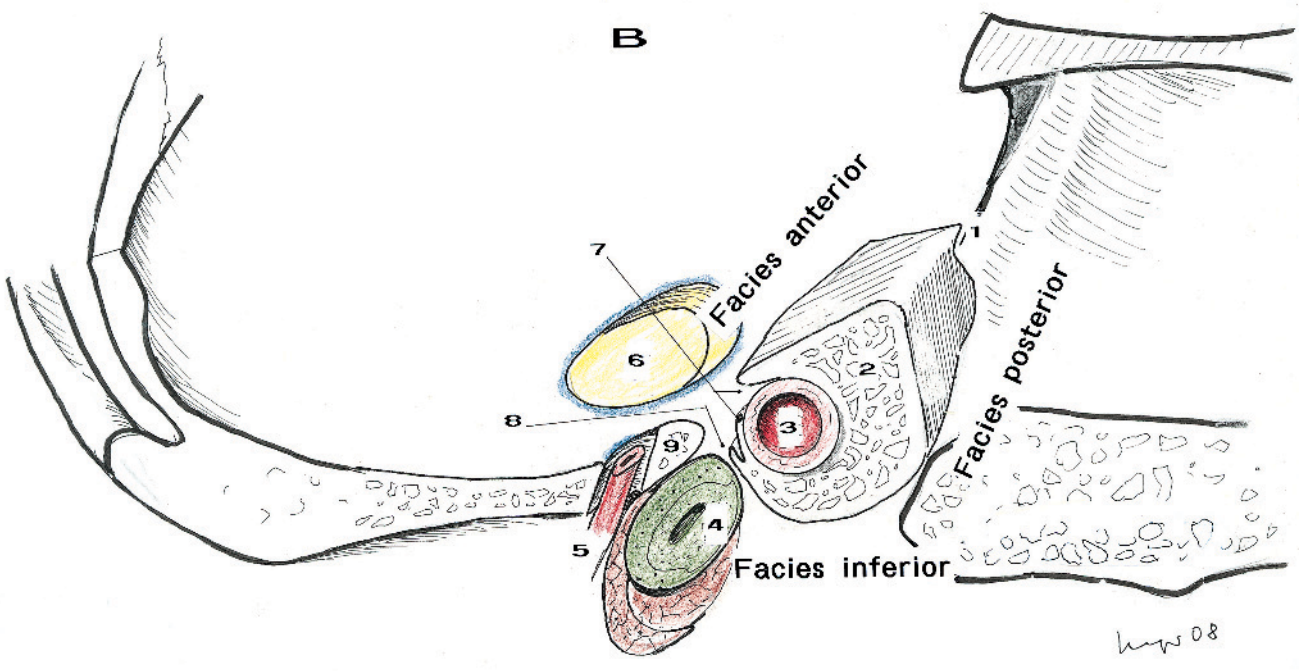


Fig. 46

Facies posterior pyramidis and surrounding structures.  
Labyrinth, Meatus acusticus int. and Canalis caroticus transparent or dotted.

**Abbreviations**

- 1 Impressio trigemini
- 2 Sulcus petrosus sup.
- 3 Eminentia arcuata
- 4 Porus acusticus int.
- (5) Fundus of Meatus acusticus int.
- (6) Cochlea, inferior margin

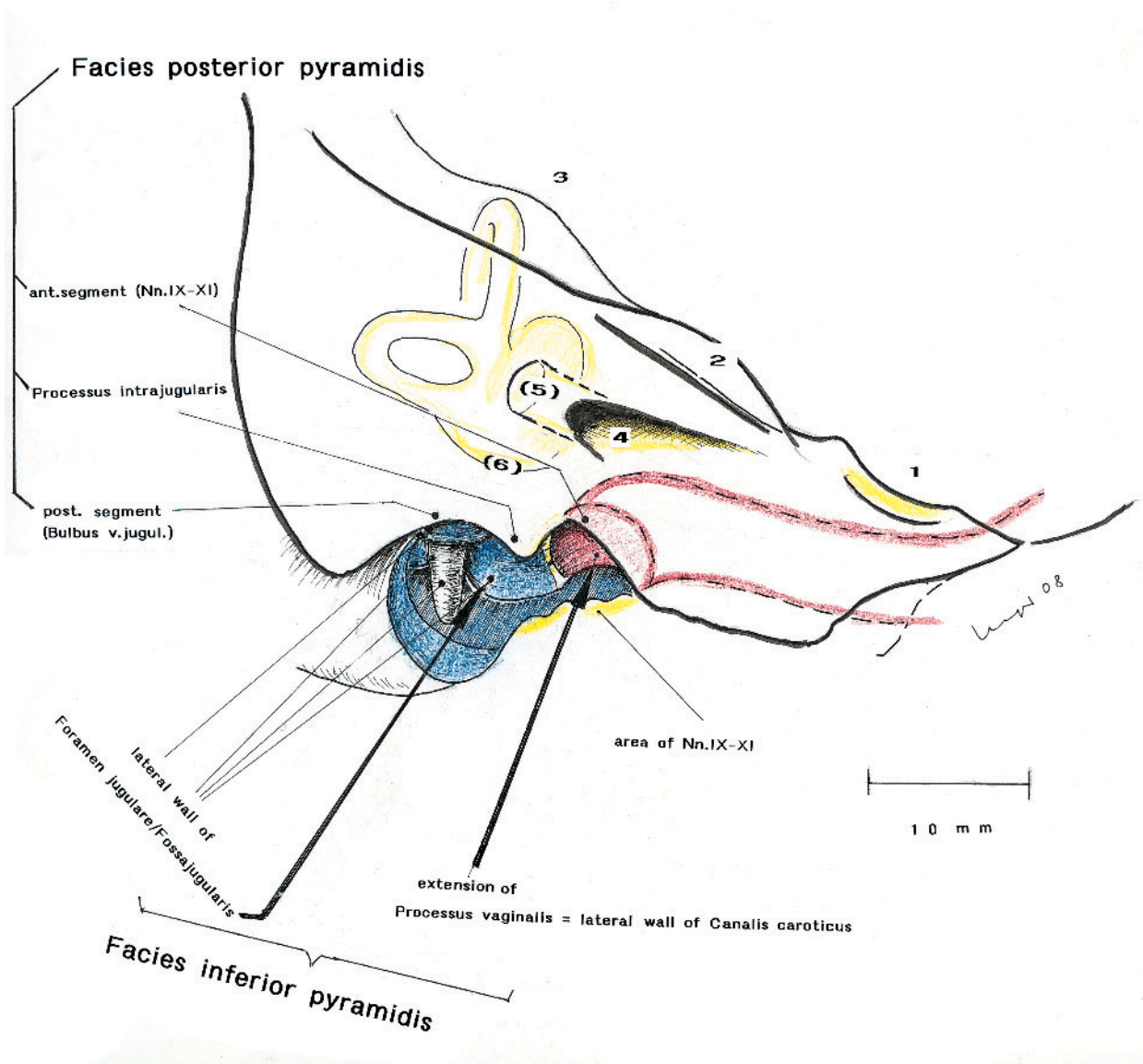
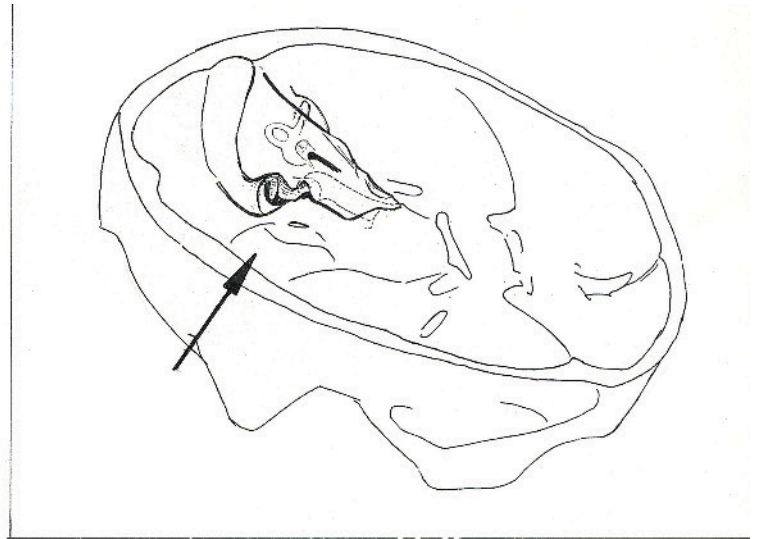


Fig. 47

Facies anterior and posterior pyramidis and surrounding structures

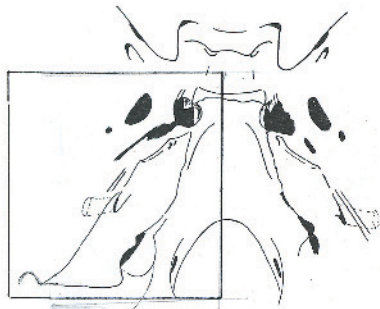
Contents and dorsal axis added.

The axis is different from the superior margin of Pyramis

Oblique projection of Facies posterior pyramidis

For blue line see text.





48 y, female

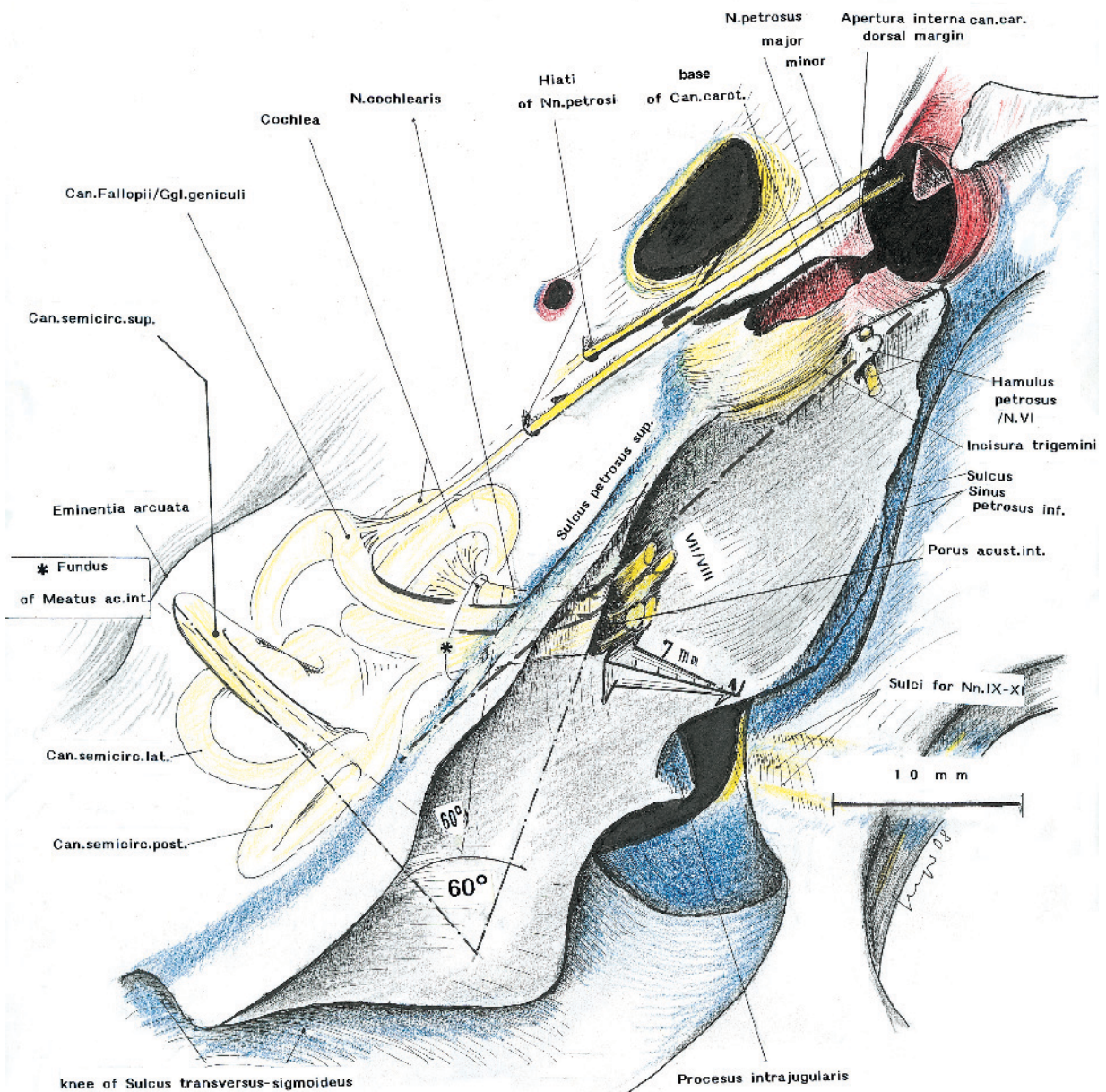
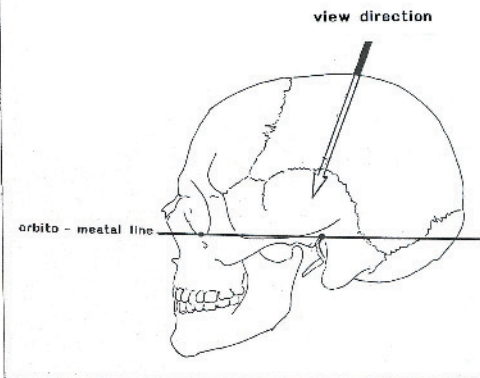


Fig. 48

Facies inferior pyramidis and surrounding structures.  
Inferior axis added



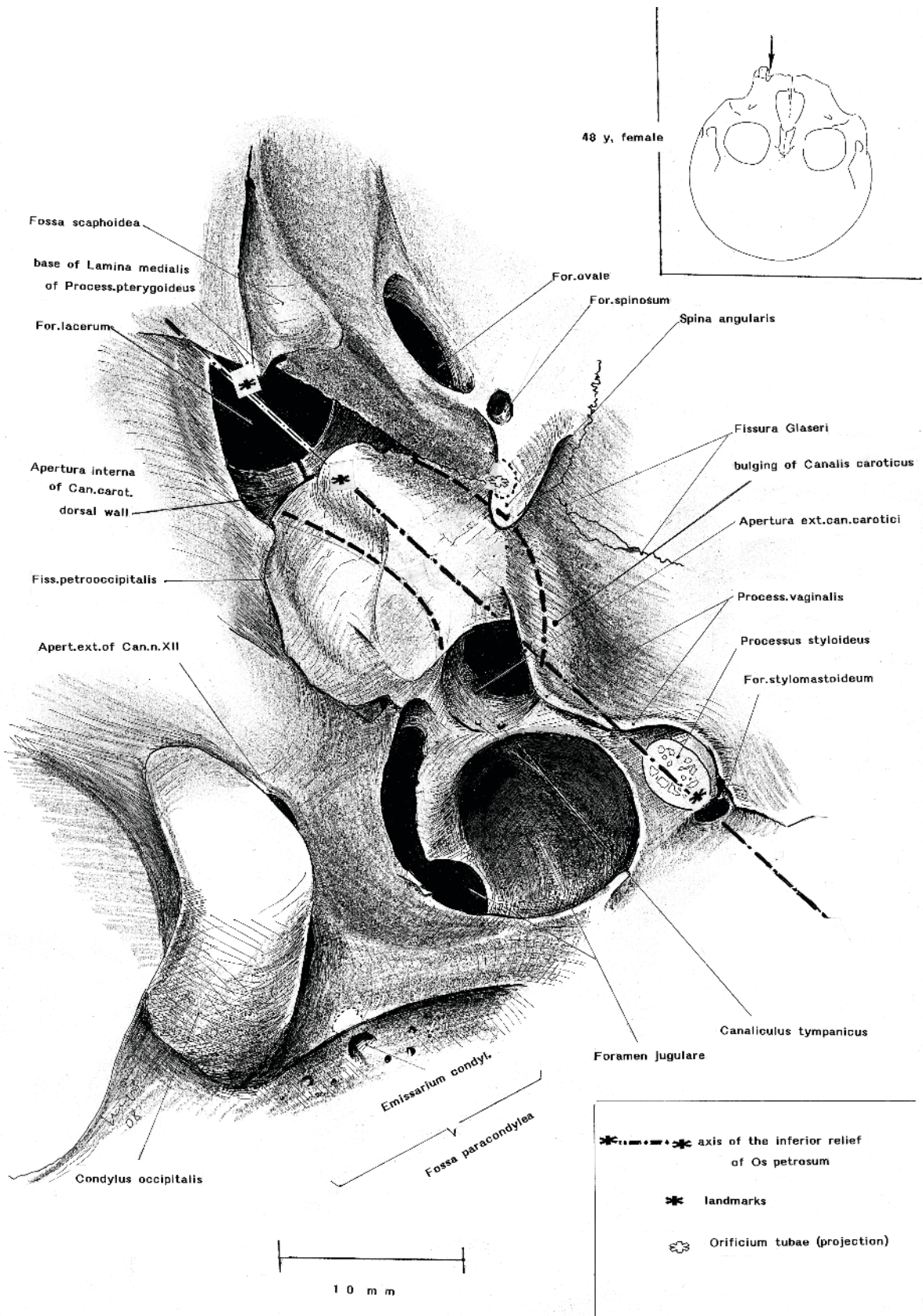
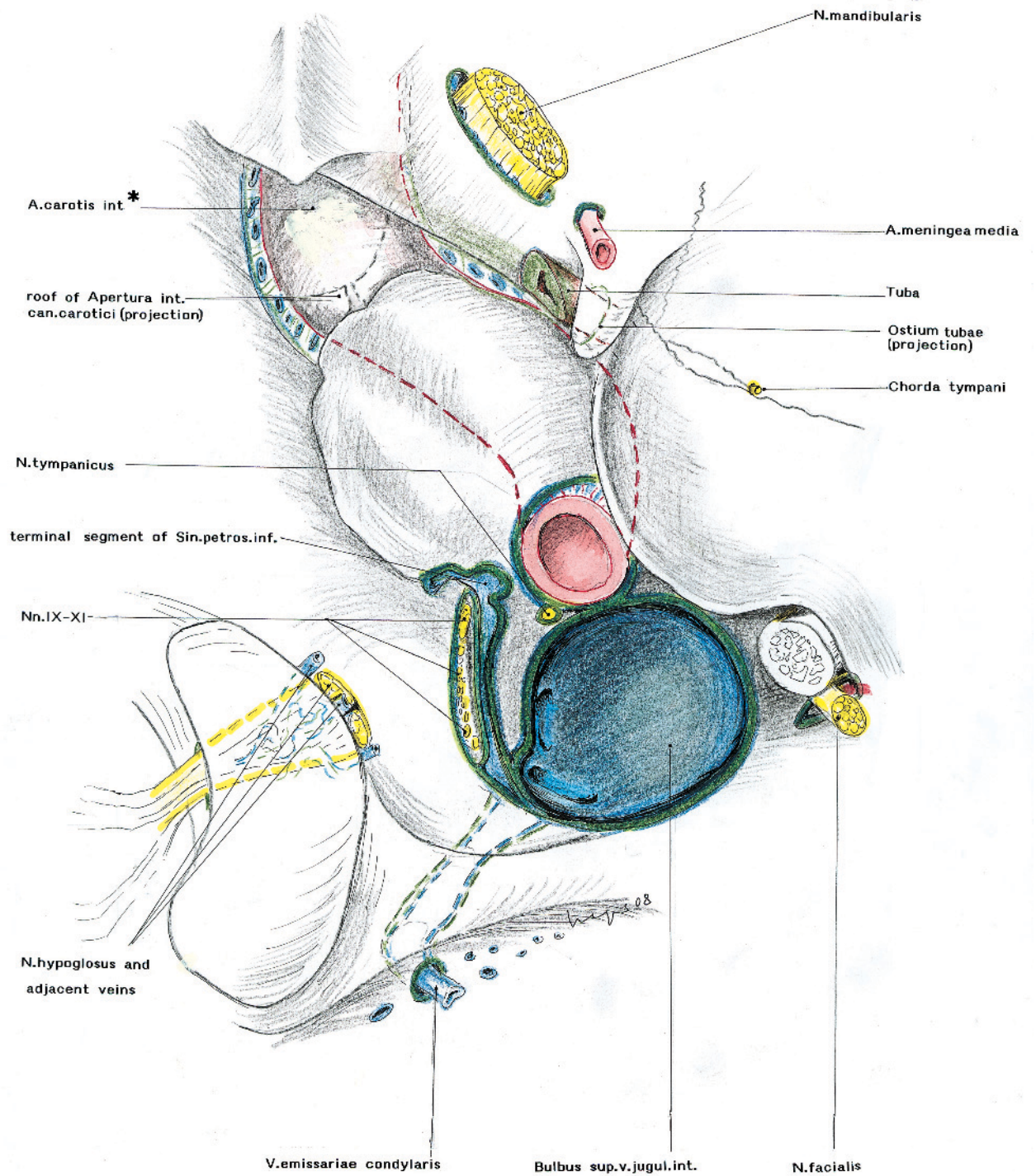


Fig. 49

Addendum to Fig. 48  
Nerves and blood vessels added



\* Enchondrosis sphenopetrosa omitted

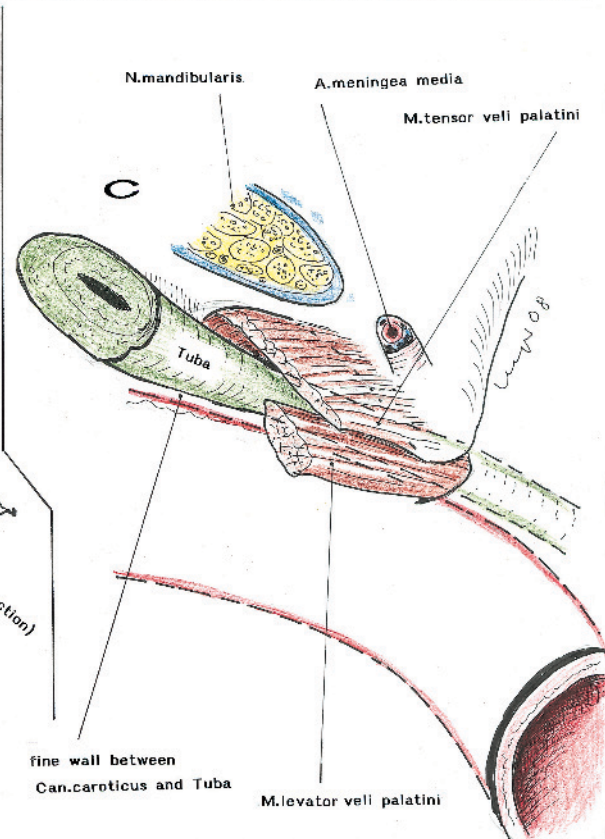
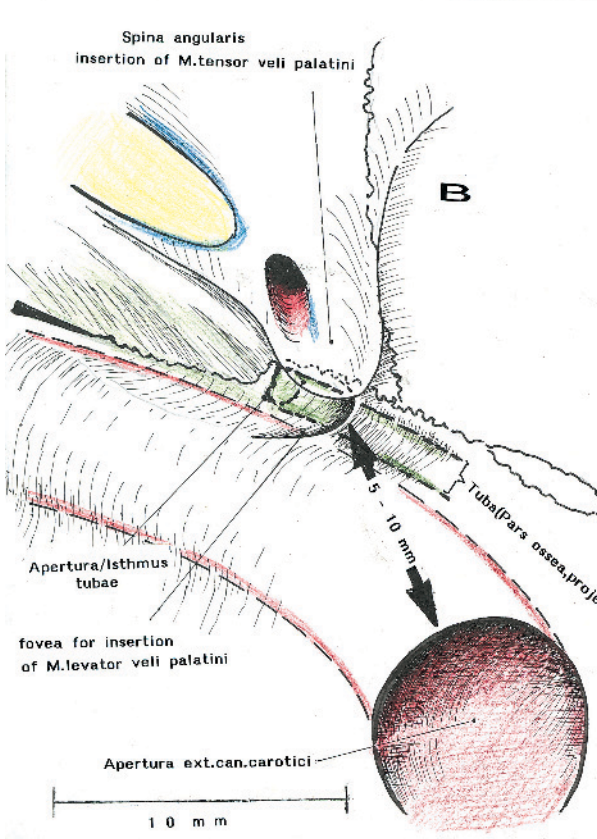
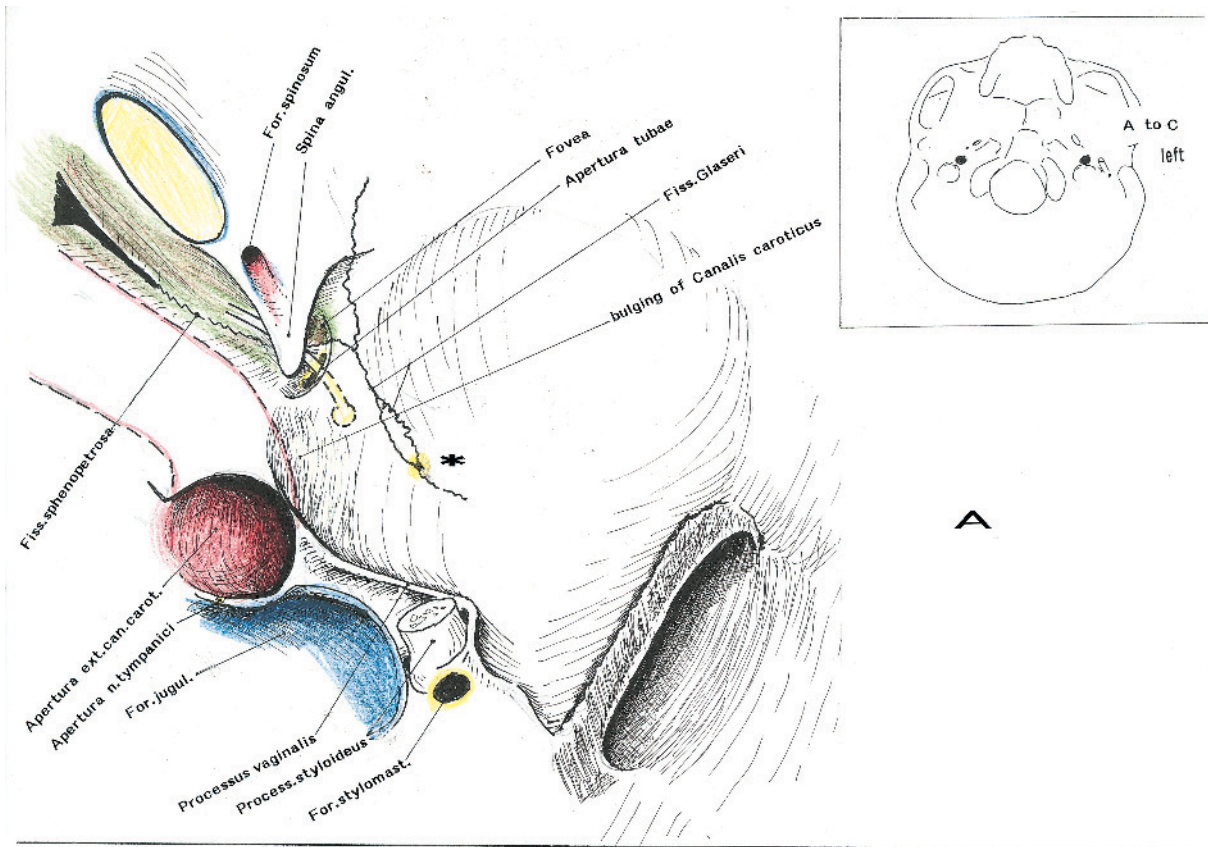


Fig. 50

Facies inferior pyramidis, posterior segment

Note the short distance between all segments.

- A** Apertura tubae and Fissura/Sutura sphenopetrosa (bed of Tuba)
- B** As A, sectional enlargement
- C** Tuba and its adjacent muscles



**VARIABLE VIEW. A CAROTIS INT. ADDED (PROJECTIONS)**

(Figs. 51 and 52)

Fig. 51

**Abbreviations**

- 1 Fossa paracondyloidea
- 2 Fossa biventerica
- 3 margin of Foramen jugulare
- 4 Foramen stylomastoideum
- (4) projection
- 5 Processus styloideus
- 6 Processus vaginalis
- 7 Apertura externa canalis carotici
- 8 Fossa mandibularis
- 9 Apertura of Tuba to Semicanalisis musculotubarius
- 10 Spina angularis
- 11 Foramen spinosum
- 12 Tuberculum articulare
- 13 Sulcus tubarius at Fissura sphenopetrosa
- 14 Foramen lacerum
- 15 outer surface of the wall of Canalis caroticus
- 16 Os basilare, medial margin of Foramen lacerum
- 17 base of Lamina medialis processu pterygoidei
- 18 Alae vomeris
- 19 Apertura externa canalis nervi hypoglossi
- 20 Apertura interna canalis nervi hypoglossi
- 21 Foramen ovale
- 22 Lamina lateralis processu pterygoidei

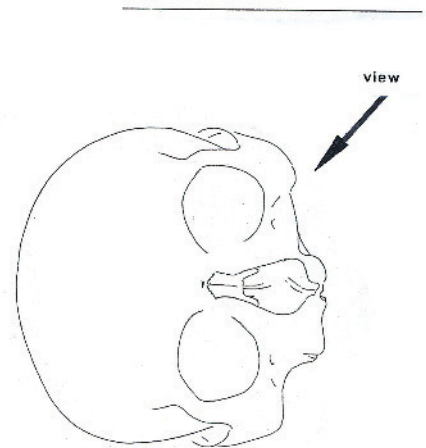
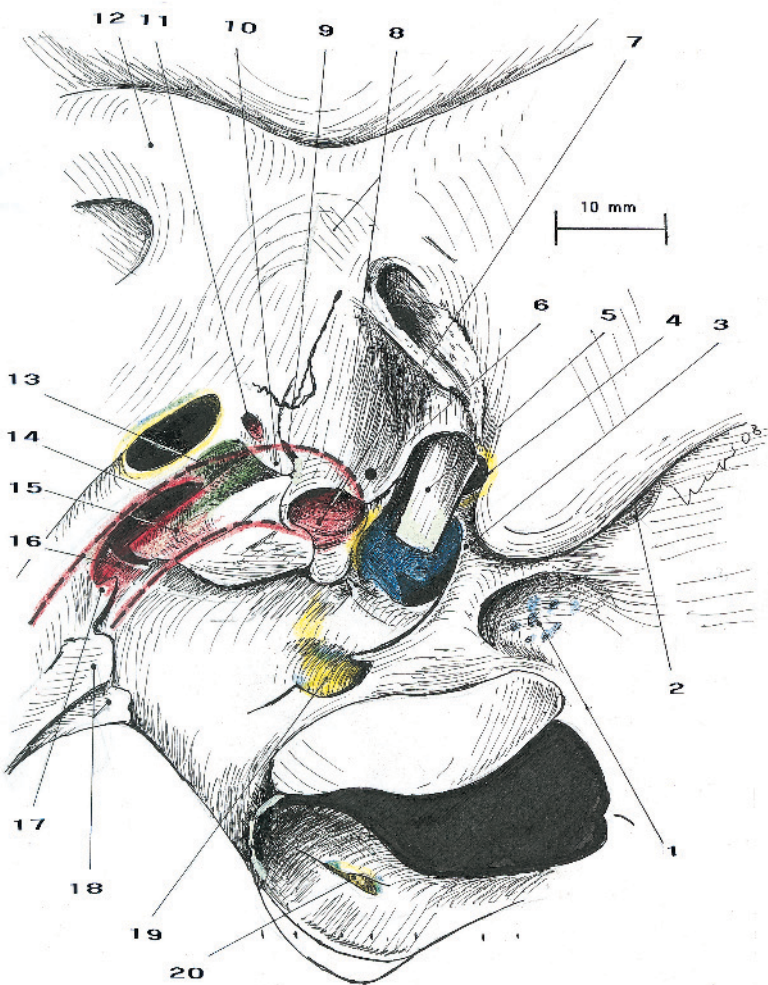
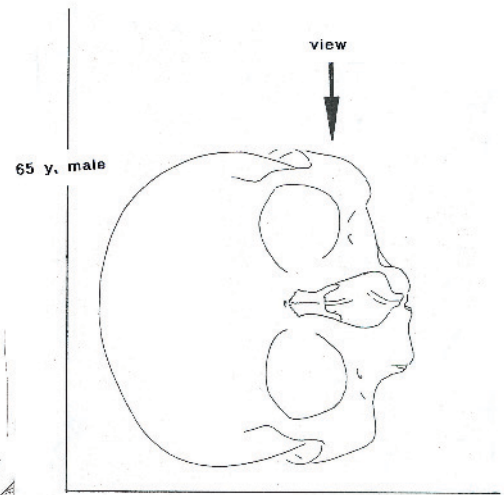
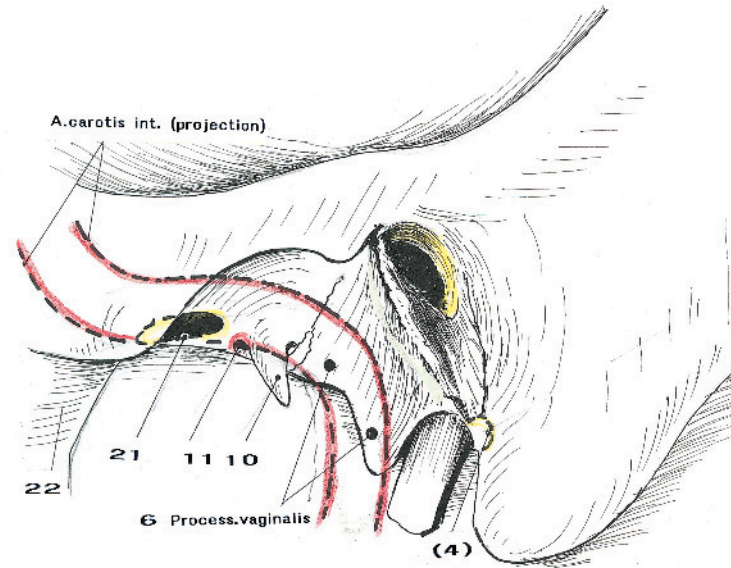




Fig. 52

Oblique view from the contralateral side  
Condylus occipitalis overlaps Apertura ext. of Canalis n. XII

**Abbreviations**

- 1 Apertura interna nervi hypoglossi
- 2 Condylus occipitalis
- 3 Emissarium condylare
- 4 Foramen jugulare
- 5 Processus styloideus
- 6 Foramen stylomastoideum
- 7 Processus vaginalis
- 8 Processus mastoideus
- 9 Porus acusticus externus
- 10 Fissura petrotympanica Glaseri (contains Chorda tympani)
- 11 Sutura sphenosquamosa
- 12 Spina angularis
- 13 Foramen spinosum
- 14 Foramen ovale
- 15 Foramen lacerum
- 16 gap for Synchondrosis sphenoccipitalis at infancy
- 17 Corpus sphenoidale
- 18 Pars basilaris ossis occipitalis

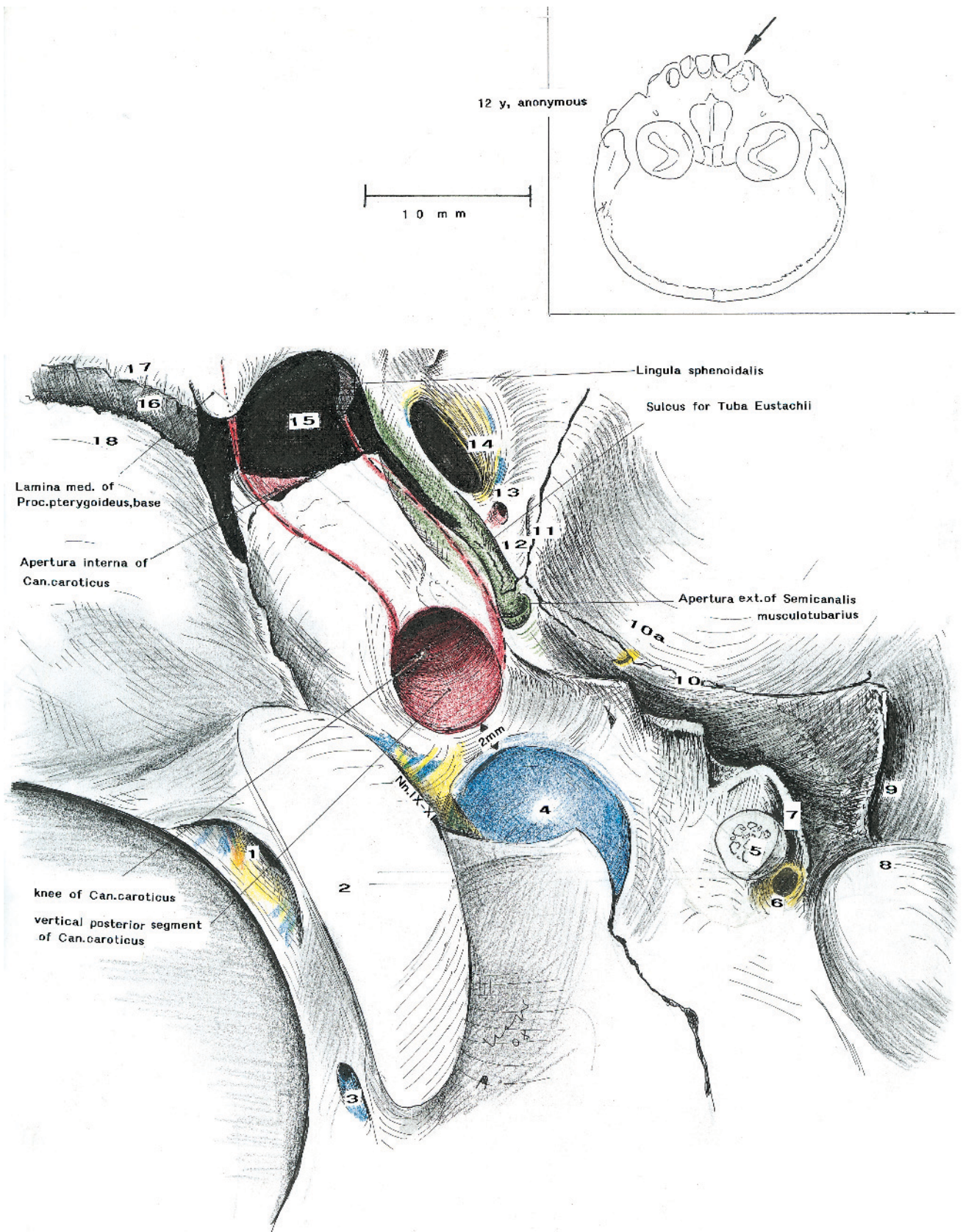


Fig. 53

Variant and possible errors depending on the perspective  
Illustrated by cadaver skull dissections

- A** Normal finding
- A'** As A, oblique view
- B** Variant. View as A

**Abbreviations**

- 1 Processus mastoideus
- 2 Foramen stylomastoideum
- 3 Processus styloideus
- 4 Processus vaginalis
- 5 Apertura ext. canalis carotici
- 6 Foramen jugulare
- 7 Apertura of Pars ossea tubae (schematic)
- 8 Fissura (Synchondrosis) sphenopetrosa
- 9 Spina angularis
- 10 Foramen spinosum
- 11 Foramen ovale
- 12 Fissura (Synchondrosis) petrooccipitalis (schematic)
- 13 Canaliculus tympanicus
- 14 Processus intrajugularis

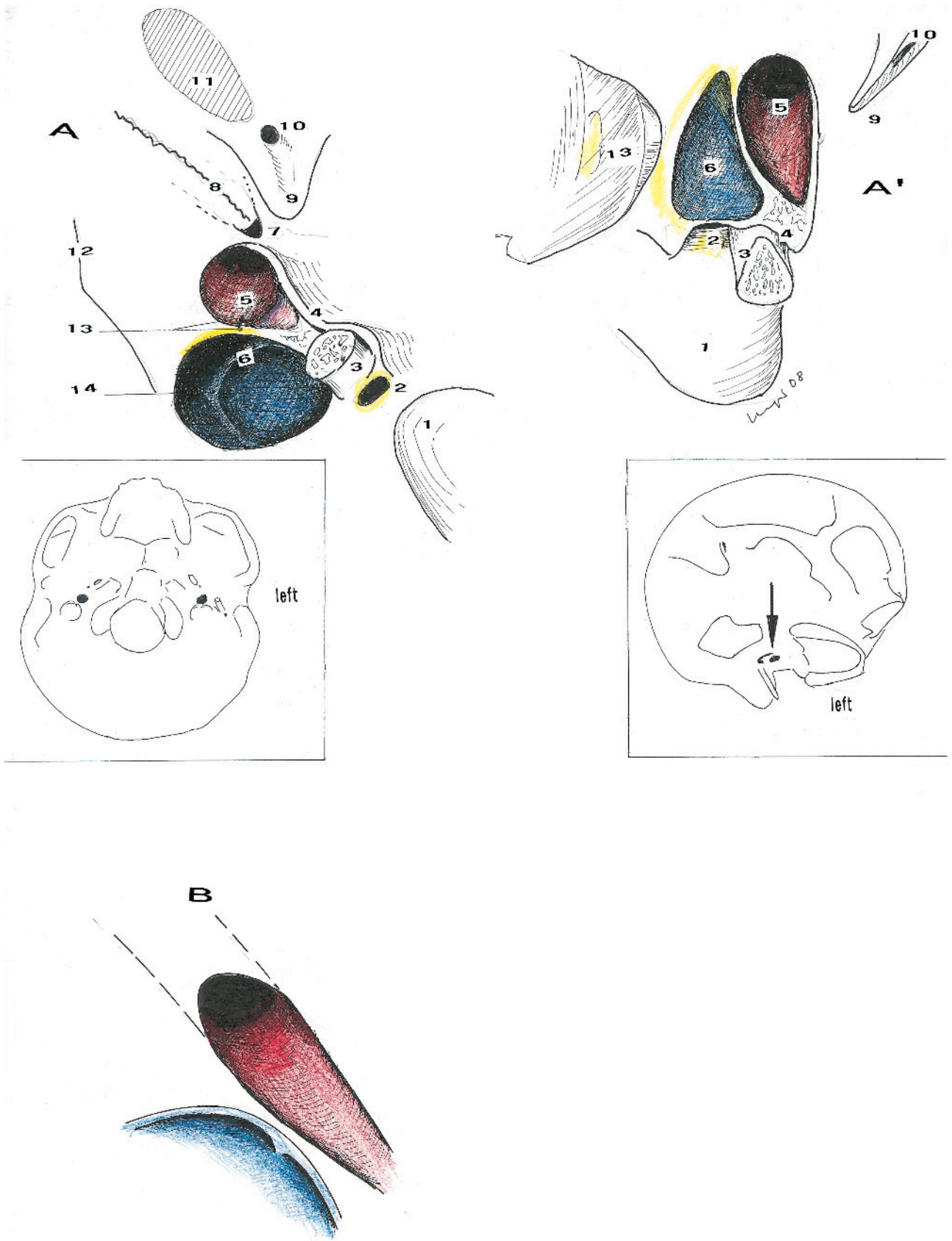




Fig. 54 and Fig. 55

Variants between Facies inferior pyramidis and Ala major

Foramen ovale

exostoses (see 3 in A and B)

Foramen spinosum

communicating to Fissura sphenopetrosa (4 at B)

Spina angularis

Hypoplasia (B, D, and E)

Apertura tubae

overlapped by Spina angularis: arrow in C and (14) in E

overlapped by an exostosis of Pyramis (B)

no overlap (arrow in A, 14 in D)

Apertura externa canalis carotici

long distance to Apertura tubae (light arrows in B)

short distance to Apertura tubae in C and E

Processus vaginalis

lateral to Processus styloideus, common finding (13 in D)

medially to Processus styloideus (rare variant, 13 in E)

small overlap of Apertura canalis carotici (13 in E)

wide overlap of Apertura externa canalis carotici (13 in E')

Bending of Canalis caroticus

steep course, common finding (D')

flat, rare variant (E and E')

#### Abbreviations

- 1 Glaser's fissure
- 2 Spina angularis
- 3 Exostosis
- 4 Sutura/Fissura sphenopetrosa
- 5 Foramen spinosum (5) absent
- 6 Foramen ovale
- 7 Emissaria
- 8 Apertura externa canalis carotici
- 9 Processus styloideus
- 10 Foramen stylomastoideum
- 11 Foramen jugulare
- 12 bony fovea
- 13 Processus vaginalis
- 14 Apertura tubae
- (14) overlap

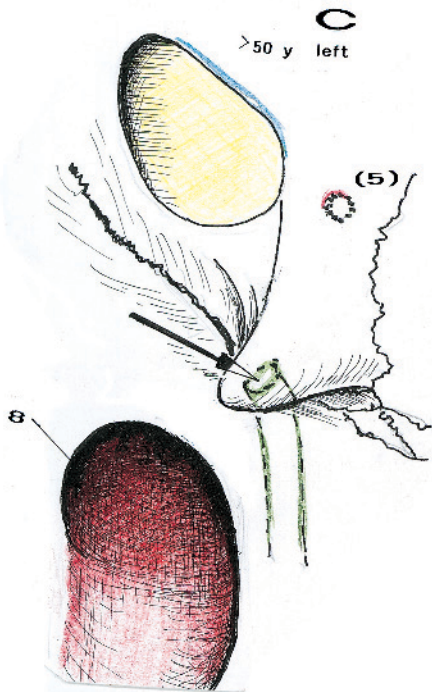
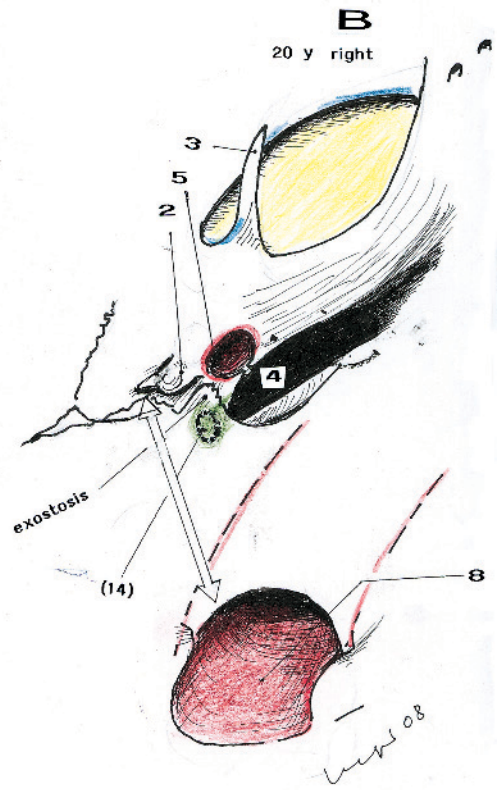
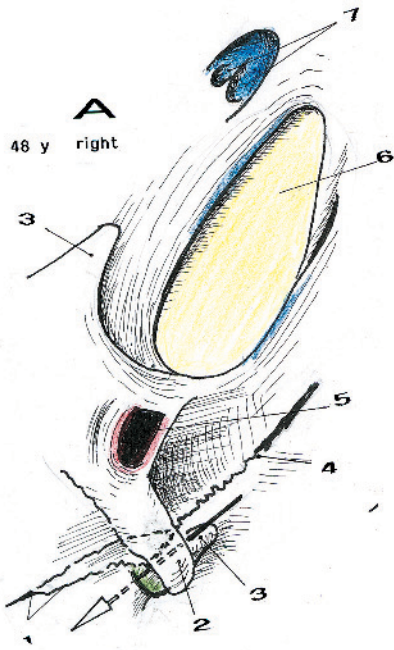
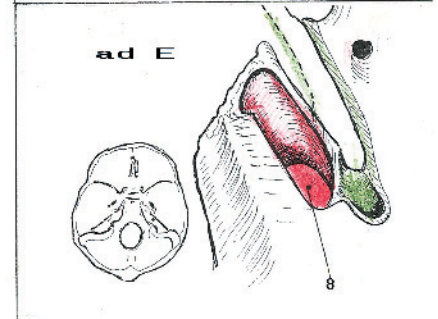
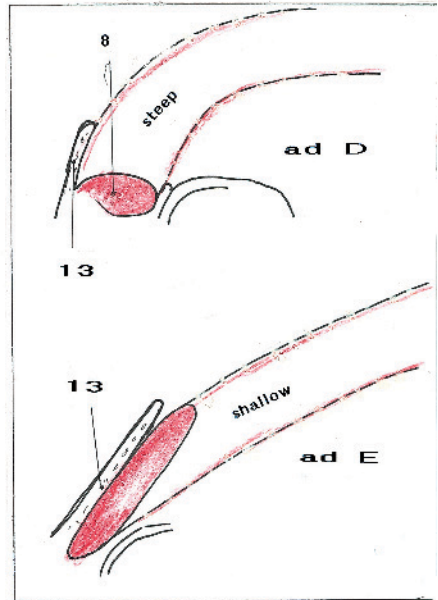
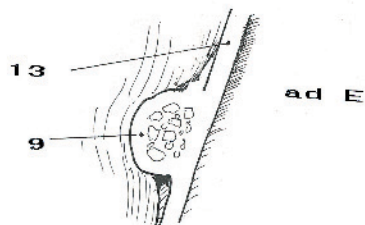
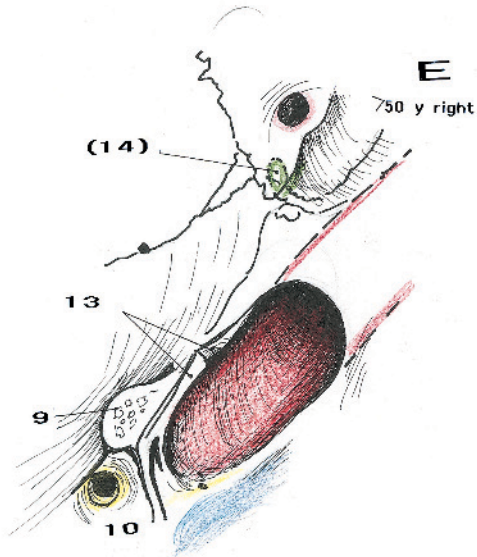
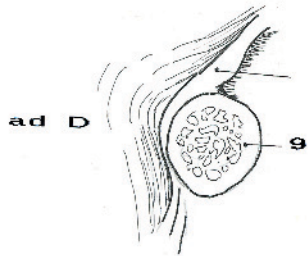
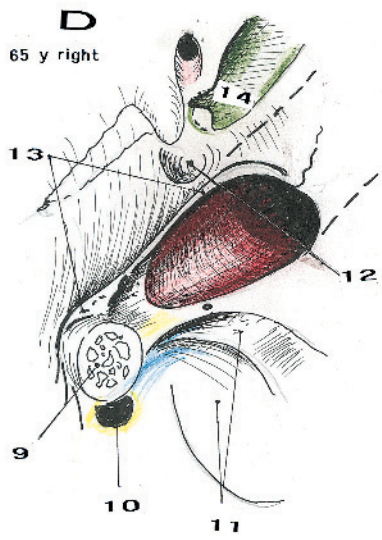


Fig. 54 and Fig. 55

Variants between Facies inferior pyramidis and Ala major



*W. 1908*



Fig. 56

Addendum to Figs. 54 and 55  
 Area of Spina angularis and Processus vaginalis

- A** Spina angularis singular, merged with an exostosis of Pyramis -5a-, Both overlap Apertura tubae. Arrow: Course of Tuba. Processus vaginalis overlaps Apertura ext. of Can. caroticus
- B** Doubled Spina angularis. Both components overlap Apertura tubae
- C** Elongated Spina angularis. Partial overlap of Apertura tubae by an elongated Processus vaginalis
- D** Spina angularis similar to C. Overlapping Foramen spinosum  
 Note the difference of Processus vaginalis in C and D

Processus vaginalis was called “Vagina of Processus styloideus” in the past. But it encloses not only the lateral circumference of Apertura int. of Apertura ext. of the carotid channel. Today it is called Processus vaginalis

**Abbreviations**

- 1 Foramen ovale
- 2 Foramen spinosum
- 3 Sutura (Fissura) sphenopetrosa
- 4 bony Fovea
- 5a) Exostosis of Pyramis
- 5b) Exostosis of Ala major
- 6 Apertura ext. canalis carotici
- 7 Fissura Glaseri
- 8 Foramen stylomastoideum
- 9 Processus styloideus

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\* arrow: Course of Tuba

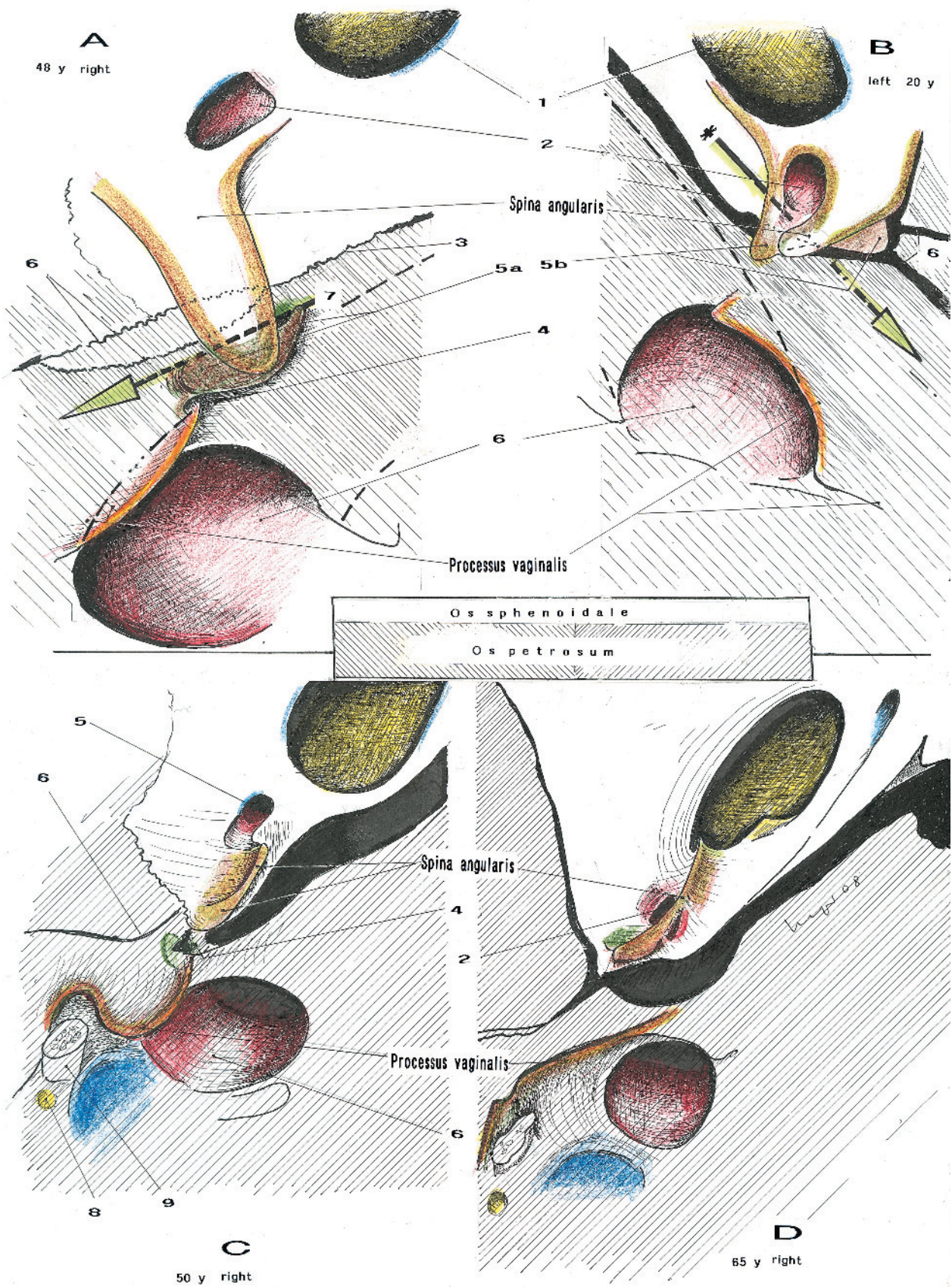


Fig. 57

Transection of the Pyramis at the bending segment of Canalis caroticus. Its relationship to Tuba auditiva.

- A** Posterior part of the dissection. The highest point of the carotid canal is not yet reached
- B** Anterior part of the dissection. Relationship of Canalis caroticus and Apertura tuba marked by dots.



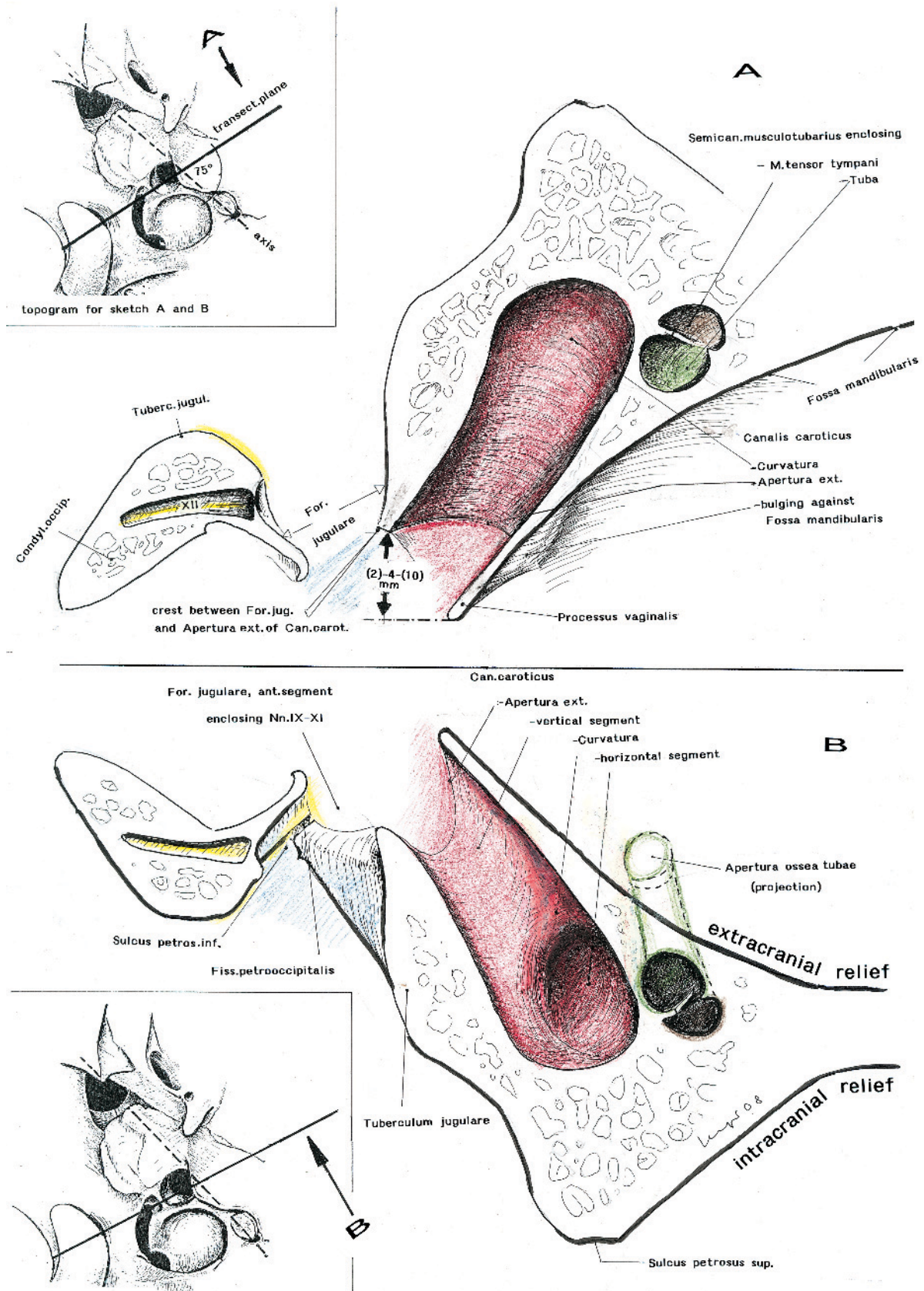




Fig. 58

Horizontal segment of Canalis caroticus

- A** Transectional level of B (arrows). Canalis caroticus dotted.
- B** Transectional plane of Apex pyramidis, enlarged  
Thin walled dorsolateral segment of Canalis caroticus resected

**Abbreviations**

- 1 Fossa jugularis
- 2 Foramen stylomastoideum
- 3 as 5
- 4 Processus styloideus, variant
- 5 Processus vaginalis
- 6 Fissura Glaseri
- 7a) Canalis caroticus
- b) Canalis caroticus, distal (horizontal) segment
- 8 Apertura tubae
- 9 Fissura sphenopetrosa
- 10 Spina angularis
- 11 Foramen spinosum
- 12 Foramen ovale
- 13 Canalis caroticus, close to Apertura int.
- 14 base of Lamina medialis processu pterygoidei
- 15 Foramen lacerum
- 16 Tuberculum pharyngeum
- 17 Fissura petrooccipitalis
- 18 Canalis nervi hypoglossi

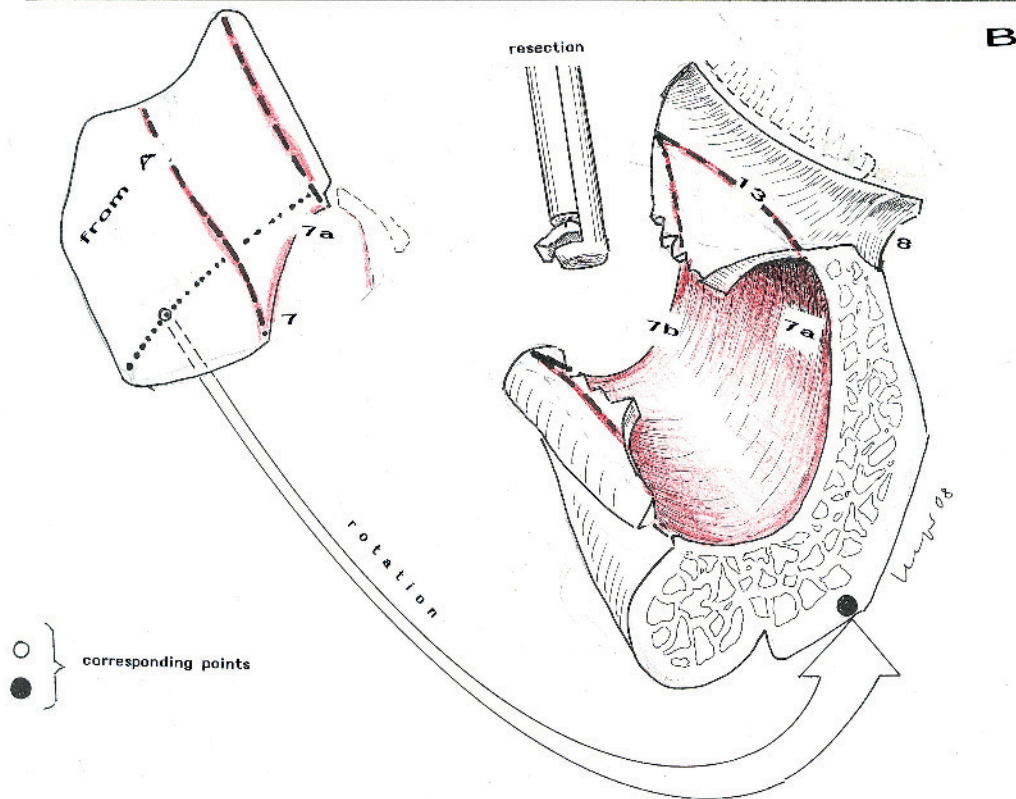
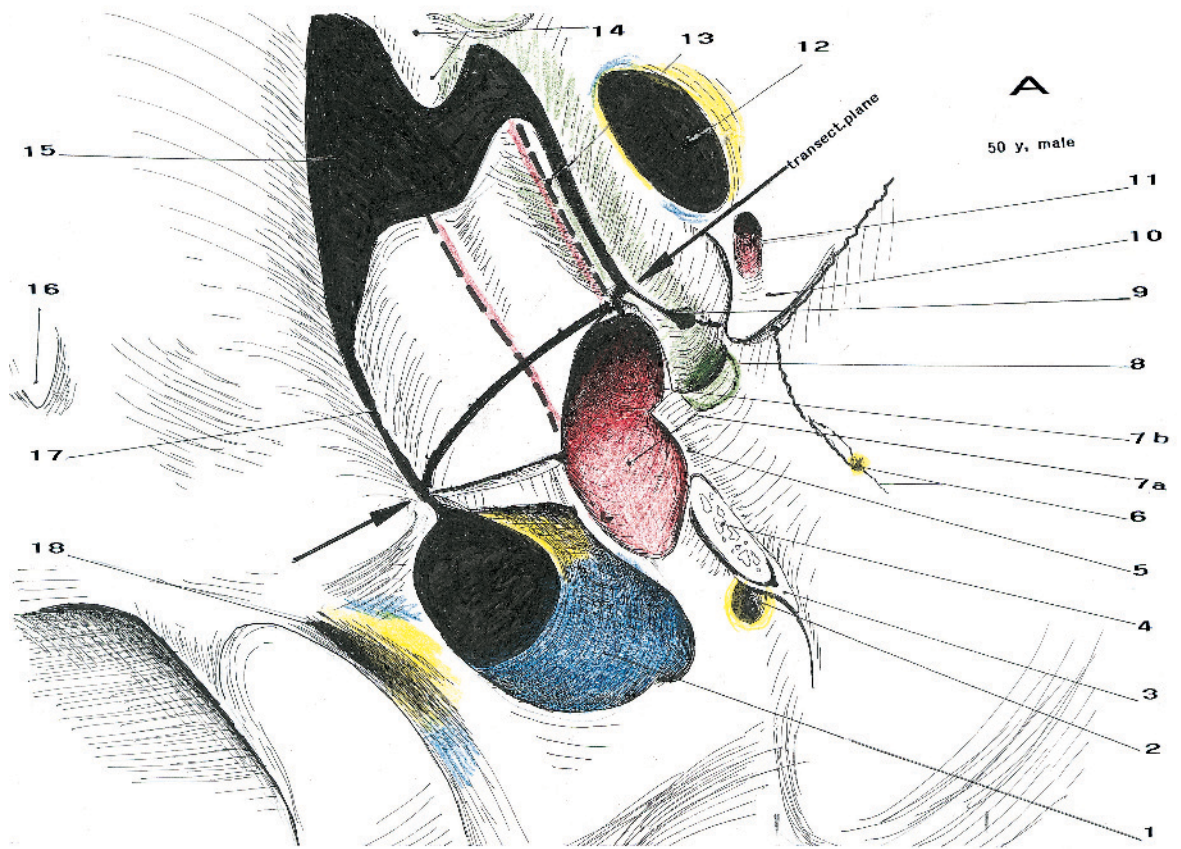
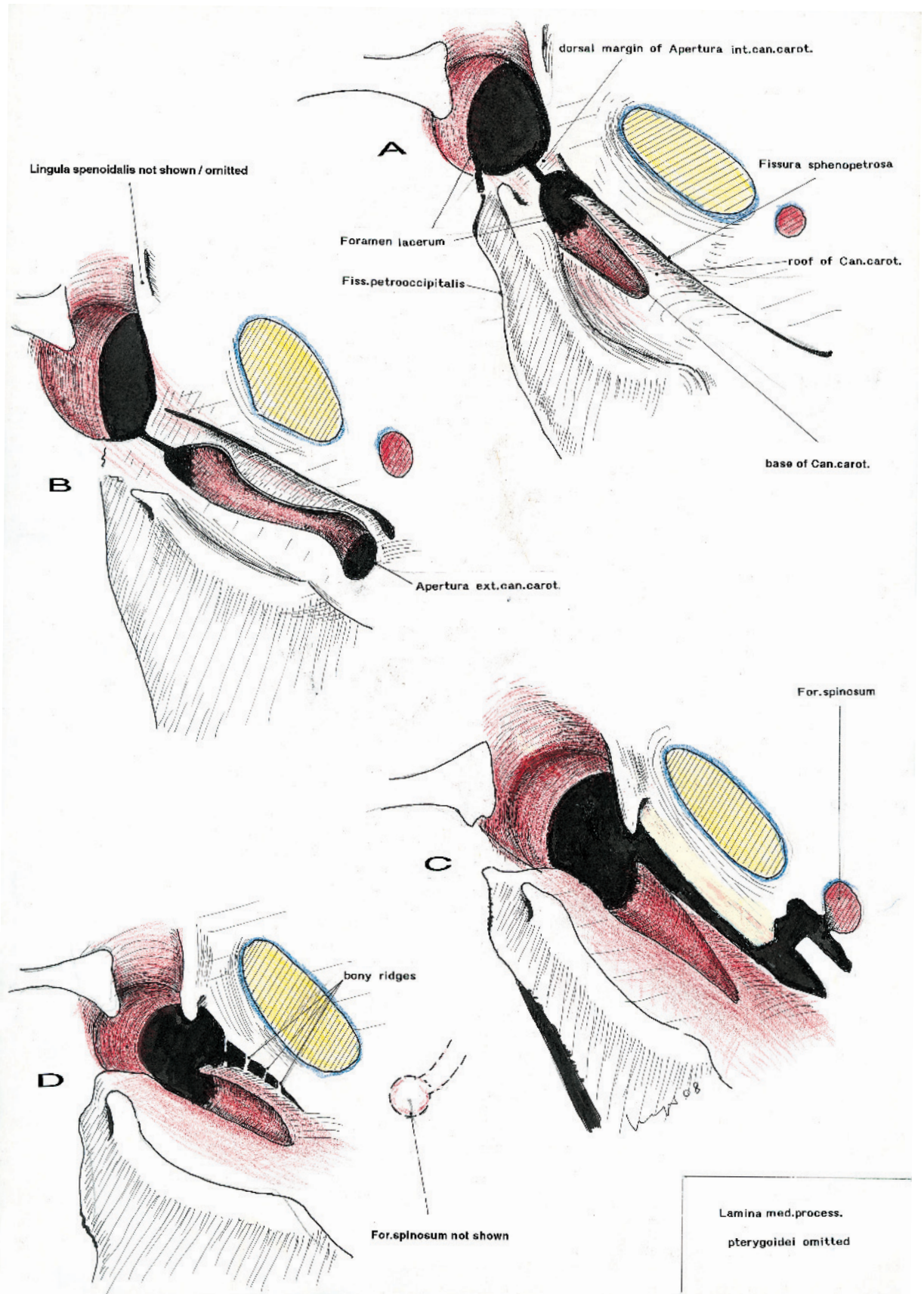


Fig. 59

Horizontal segment of Canalis caroticus, variants

- A and B** Closed dorsal wall at Apertura int. canalis carotici. Common variant
- C** Widening of Fissura sphenopetrosa. Foramen spinosum enclosed by the fissure
- D** Usual findings at Canalis caroticus and Fissura sphenopetrosa. Foramen spinosum not shown (Lang, 1979) For. surgical aspects see Seeger, 2003, pp 112 ff





**CONTENTS OF PYRAMIS, TRANSECTIONAL PLANES**  
(Figs. 60 to 63)

Fig. 60

Overview

- A** Transparent presentation according to the historic metallic cast B
- B** Copy of the cast of Siebenmann, presented in Rauber-Kopsch (1908) vol. 6, p 1017

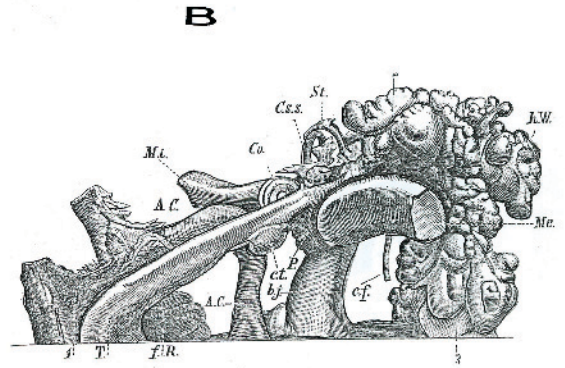
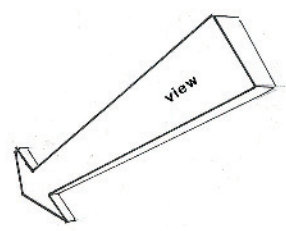
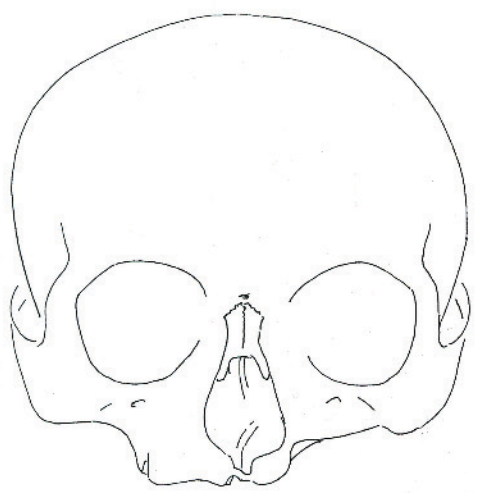
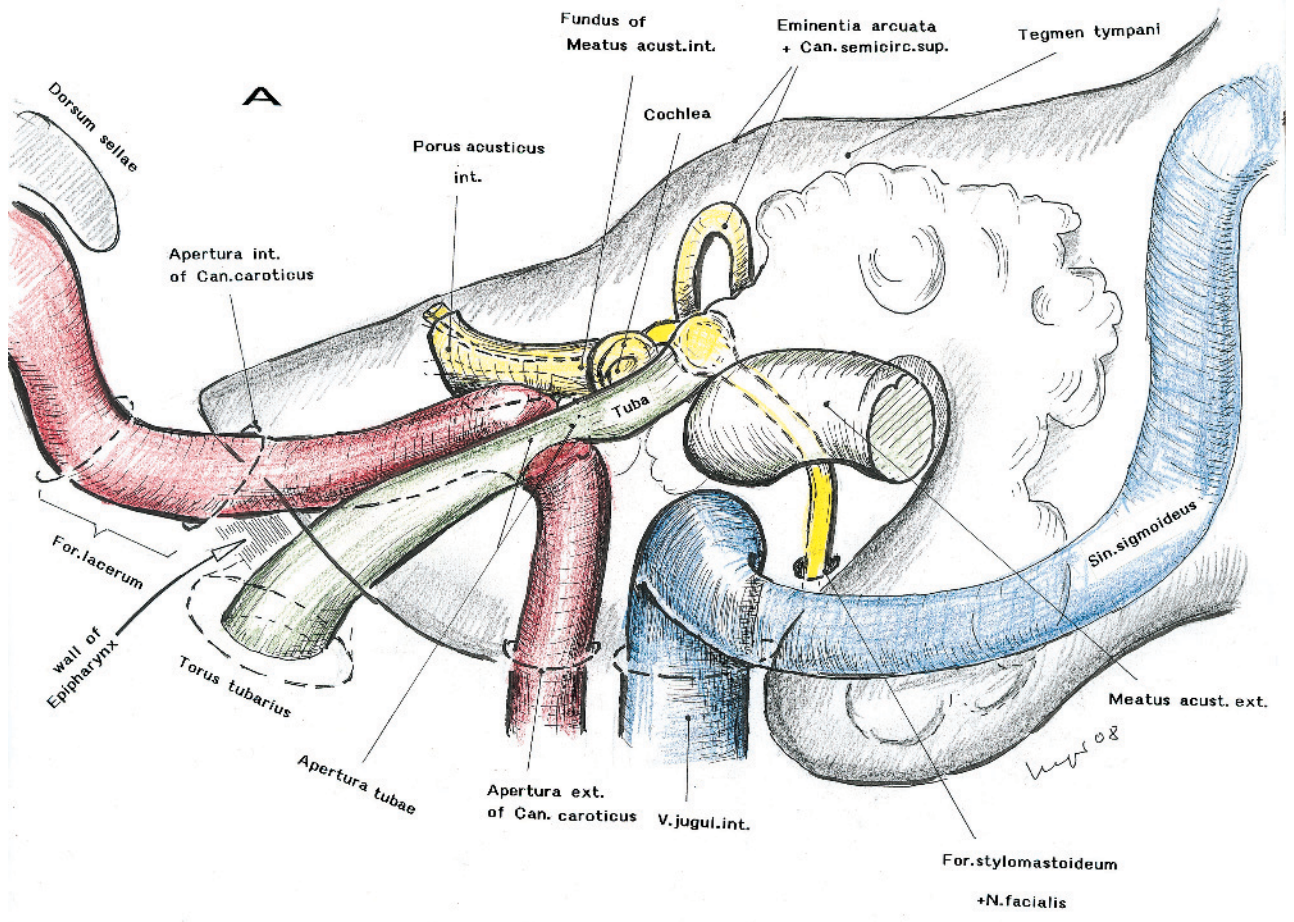


Fig. 1056.

Metallausguß des linken Schläfenbeins des Erwachsenen. (F. Siebenmann.)

Fig. 61

- A** Vertical transection of the petrous bone, parallel to the upper margin, along the level of Canalis n. facialis (Fallopian). According to a historical cadaver skull dissection (Spalteholz, 1907, p 12), modified.
- B** Horizontal transection of the petrous bone at the axis of Meatus acusticus externus. The horizontal segment of Canalis caroticus is known, as well as the upper area of Fossa jugularis, and its contents. According to a historical cadaver head dissection (Spalteholz, 1906, p 803), modified.

**Abbreviations**

- 1 probe in Apertura inf. canaliculi tympanici
- 2 distal end of probe
- 3 canal of N. petrosus minor (location of Jakobson's anastomosis between N.IX-N.tympanicus-N.petrosus minor)
- 4 Semicanalisis m. tensoris tympani, lateral wall
- 5 begin of Semicanalisis m. tensoris tympani
- 6 Promontorium and Tuba Eustachii

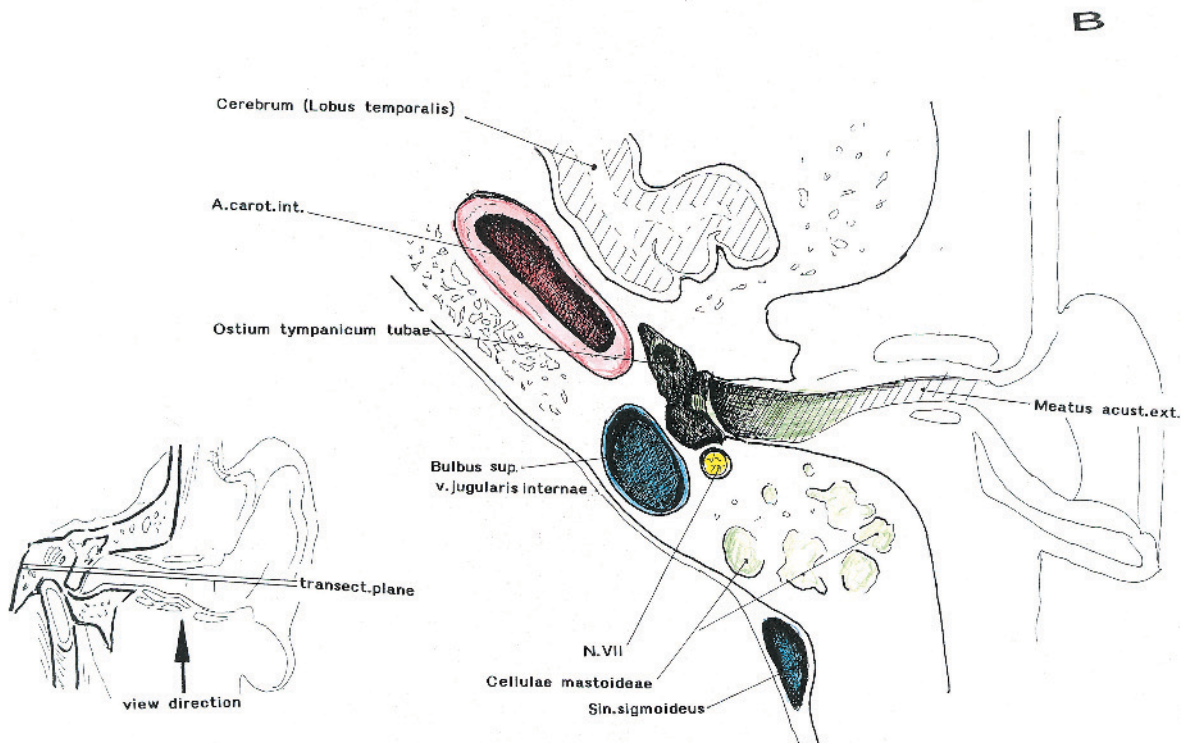
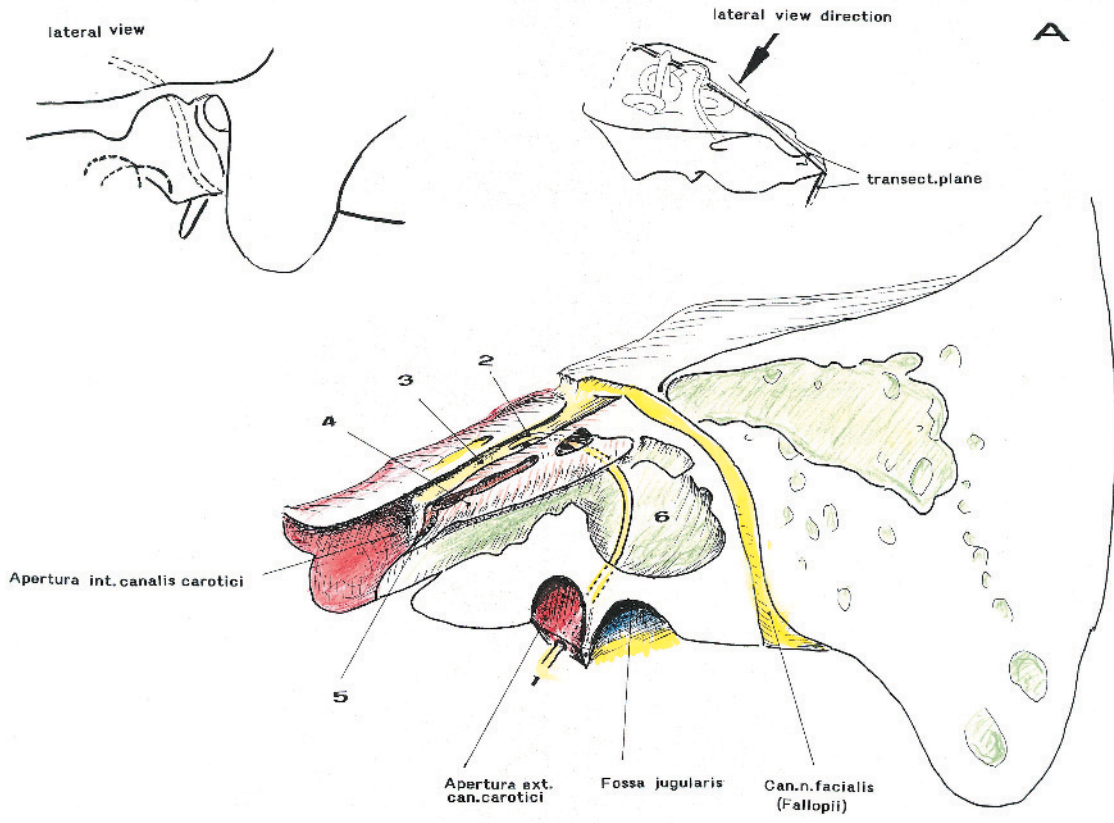




Fig. 62

Vertical transection of Pyramis perpendicular to its longitudinal axis, at the level of Modiolus, Meatus acusticus int., and the bending segment of Canalis caroticus. Note the proximity to the base of Cochlea and the Fundus of Meatus acusticus int. The fallopian channel is located posterior to this transectional plane.

According to a cadaver skull dissection of Spalteholz (1906, p 822), modified.

**Abbreviations**

- 1 Area cochleae of Fundus meati acustici interni
- 2 Canalis spiralis modioli
- 3 Modiolus
- 4 Canalis longitudinalis modioli
- 5 Sulcus n. petrosi majoris
- 6 Sulcus n. petrosi minoris
- 7 Lamina spiralis secundaria

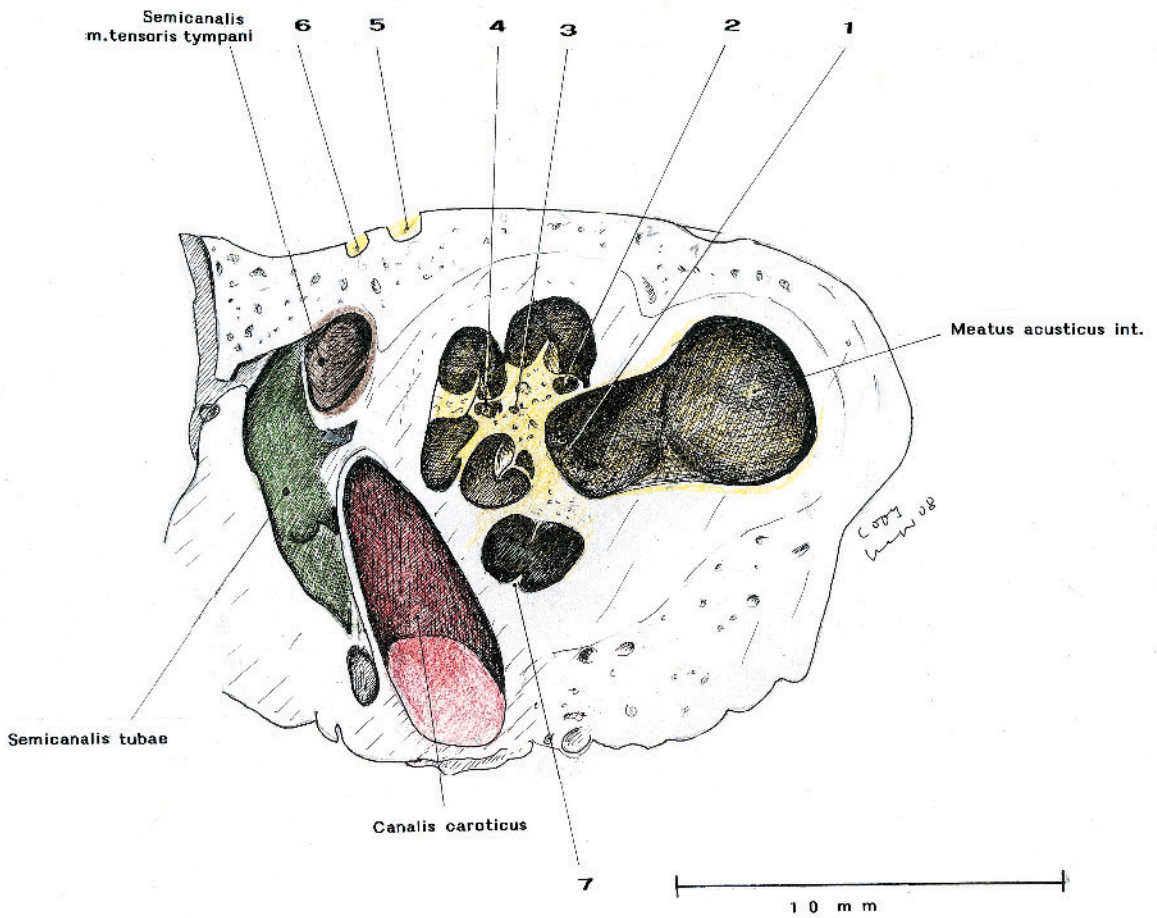
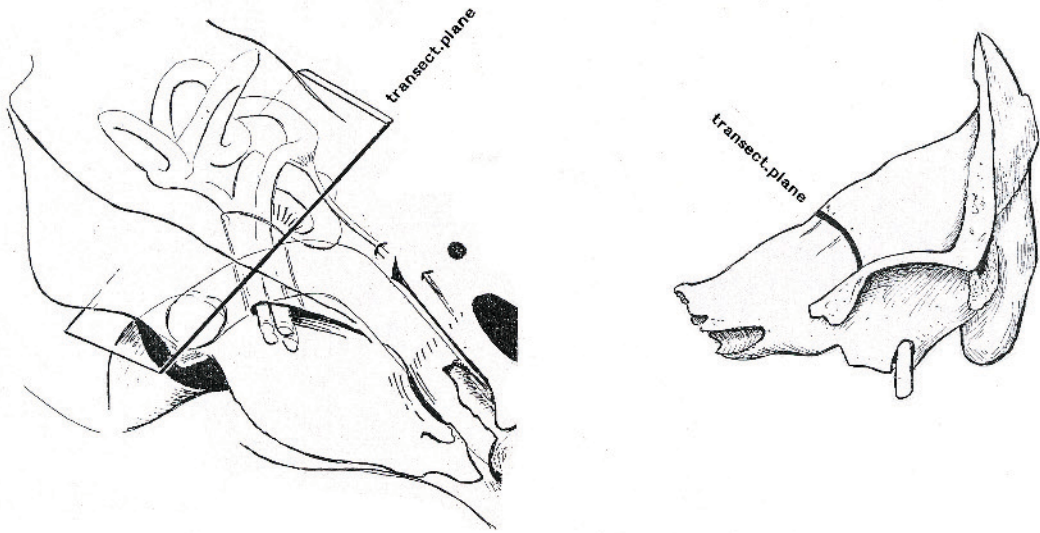


Fig. 63

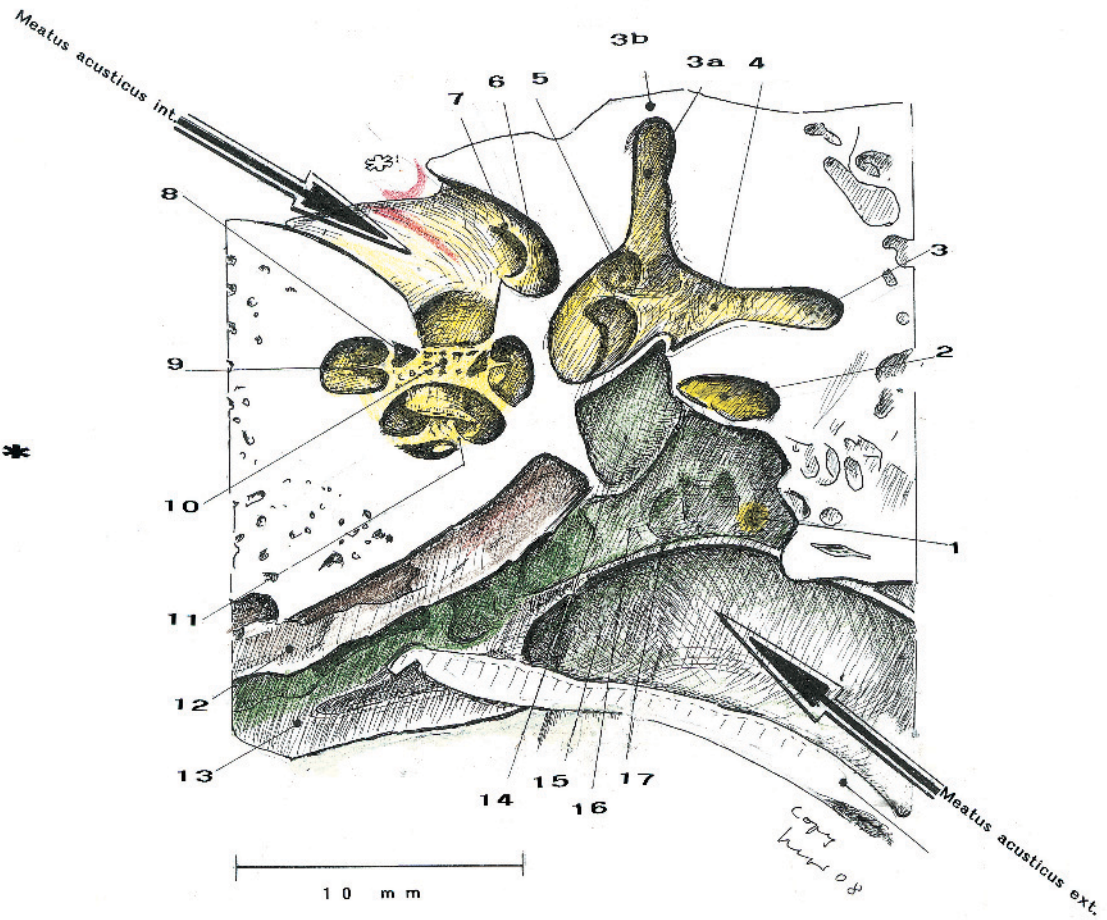
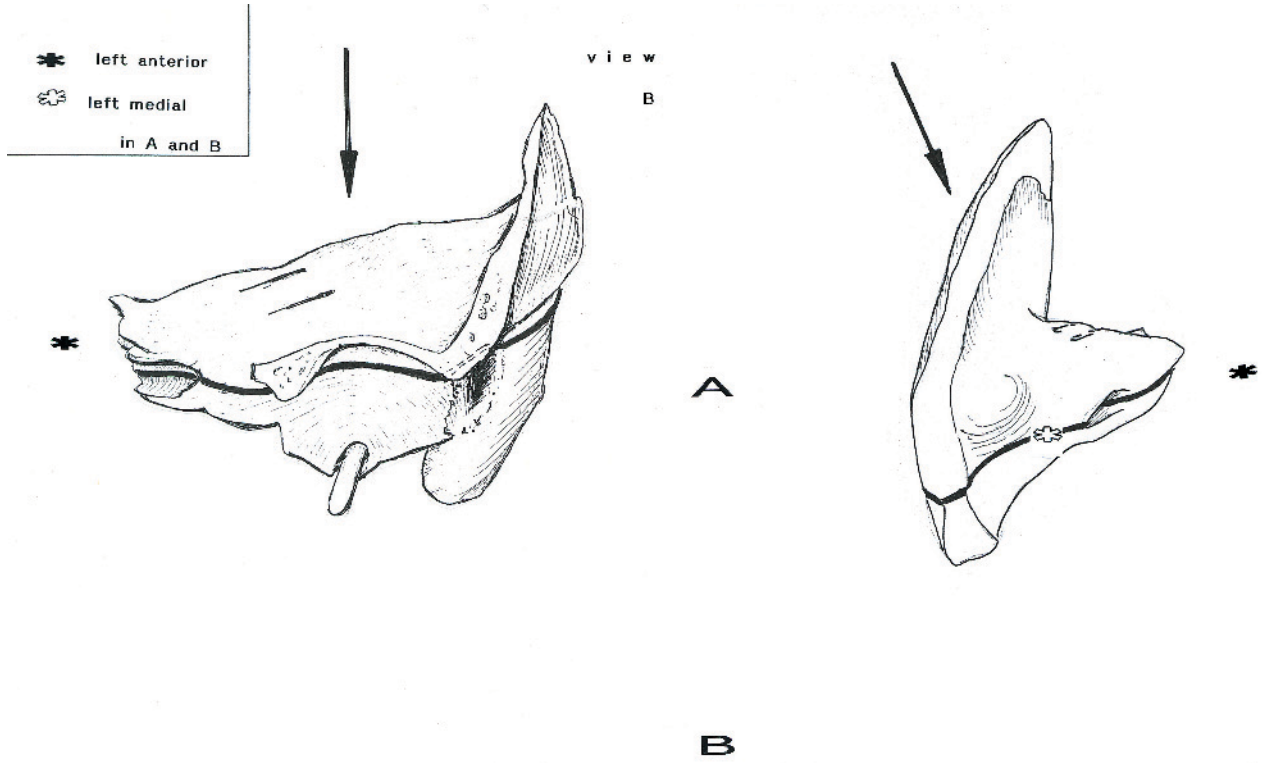
Horizontal transectional plane parallel to the illustration of B in Fig. 51, at the level of Modiolus, of Canalis semicircularis lateralis, of the upper segment of Meatus acusticus ext., and the axis of Meatus acusticus int.

M. tensor tympani is transected longitudinally and dorsally, Tuba is transected longitudinally and basally.

According to a cadaver skull dissection of Spalteholz (1906, p 819), modified.

#### Abbreviations

- 1 Apertura tympanica canaliculi cochleae
- 2 Canalis n. facialis (Fallopil)
- 3 Canalis semicircularis lateralis
  - a) Canalis semicircularis sup.
  - b) Eminentia arcuata
- 4 Ampulla lat.
- 5 Ampulla post.
- 6 Area vestibularis sup.
- 7 Crista transversa
- 8 Canalis spiralis modioli
- 9 Lamina spiralis ossea
- 10 Modiolus
- 11 Lamina modioli
- 12 Semicanalil m. tensoris tympani
- 13 Semicanalil tubae and its Cellula pneumatica
- 14 Promontorium
- 15 Prominentia styloidea
- 16 bony wall between Tympanon and Foramen jugulare
- 17 Sulcus tympanicus





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**CHAPTER VI**  
**CLIVUS AREA AND PARS CONDYLLARIS**  
**(Figs. 64 to 70)**

## Overview (Figs. 64 and 65)

In clinical terminology, Clivus means **Clivus Blumenbachii** and its underlying bony segment between the posterior limit of the roof of Choana and the anterior margin of Foramen occipitale and the bony bloc of the Foramen jugulare-condylar-complex

### Components of the Clivus area

Clivus Blumenbachii is the intracranial medial plane between Dorsum sellae and the anterior margin of Foramen occipitale (anatomical nomenclatura).

The clinical defining includes 3 segments:

- Its small rostral segment is the caudal part of **Corpus sphenoidale**. Corpus sphenoidale is the central part of Os sphenoidale enclosing Sinus sphenoidalis. It is connected to the large caudal segments by Synchrondrosis sphenoccipitalis in children and adolescents (Fig. 3), and it merges with
- **Pars basilaris** of the occipital bone in adults.

Merging of Corpus sphenoidale to adjacent components of the sphenoid bone occurs at the early years of life, earlier than merging of Corpus sphenoidale and Pars basilaris. The caudal-lateral component of the so-called Clivus is **Pars condylaris**. It connects to Pars basilaris and to Squama occipitalis (tabular portion, Gray, ed. 1974) at the same period as the components of the sphenoid bone, earlier than Corpus sphenoidale and Pars basilaris of the occipital bone.

## Phylogenetic, ontogenetic and dysontogenetic aspects (Fig. 66)

Lesions of the Clivus area are today more relevant than in the past, especially in endoscopic transnasal surgery. Dysontogenetic tumors, Clivus chondromas and Clivus chordomas are the most important entities. These tumors originate from phylo- and ontogenetic residuals, which form Synchrondrosis sphenoccipitalis. This is a chondroid layer, which covers a component of Chorda dorsalis, similar to intervertebral discs.

Synchrondrosis in children and adolescents also plays a role in neuronavigation (Fig. 66).

## Basal extracranial Clivus area (Figs. 66 to 68)

Fissura petrooccipitalis is the lateral border of Pars basilaris of the occipital bone. This wide deep bony gap is filled and flattened by Enchondrosis petrooccipitalis, as demonstrated in Fig. 38.

The lateral border of the condylar segment of the occipital bone is formed by Foramen jugulare and its Fossa (medial shapes). The lateral boundary is Pyramis. The extension of Fissura petrooccipitalis is a fine suture at the base of Fossa jugularis, which is the starting point of Sutura occipitomastoidea. Bony dysplasias may be relevant for surgery.

Bony structures forming

- Pars condylaris (bilateral)
- Pars basilaris
- Pars squamosa (tabular part, Gray ed. 1974)

These components are similar to the Atlas-Dens-complex in newborns. Atlas and occiput may merge partially or completely. An occipital vertebra may develop from components of the occipital bone, partially or completely. These variants are well known in neurosurgery because these variants may result in brainstem compressions.

These variants help to understand the variability of Foramen jugulare as presented by Helms (1978). Some examples of cadaver skull dissections are shown in Fig.68.

### **Dorsal intracranial Clivus area (= Clivus Blumenbachii plus condylar part) (Figs. 4, 5, and 65)**

In its intracranial contour, Fissura petrooccipitalis is flat and small in contrast to the extracranial shape. But there the flat Sulcus petrosus inf. is located (Fig. 77). Sinus petrosus inf. is wider than its bony sulcus. Before entering Bulbus sup. v. jugularis it divides into branches, especially at the medial area of the anterior segment of Foramen jugulare. The cranial nerves IX to XI are located medially to it. V. emissaria condylaris connects the venous branches of Fossa paracondylaris to Bulbus sup. v. jugularis internae. Cranial nerves are separated from the surrounding veins by arachnoid tunnels. These are extensions of cisternal CSF spaces similar to CSF spaces around other craniospinal nerves.

The Tuberculum jugulare-condylar-bloc is located posterior-laterally to the Clivus. It encloses Canalis n. hypoglossi and its numerous venous branches and venous emissaries (Figs. 69 and 70).



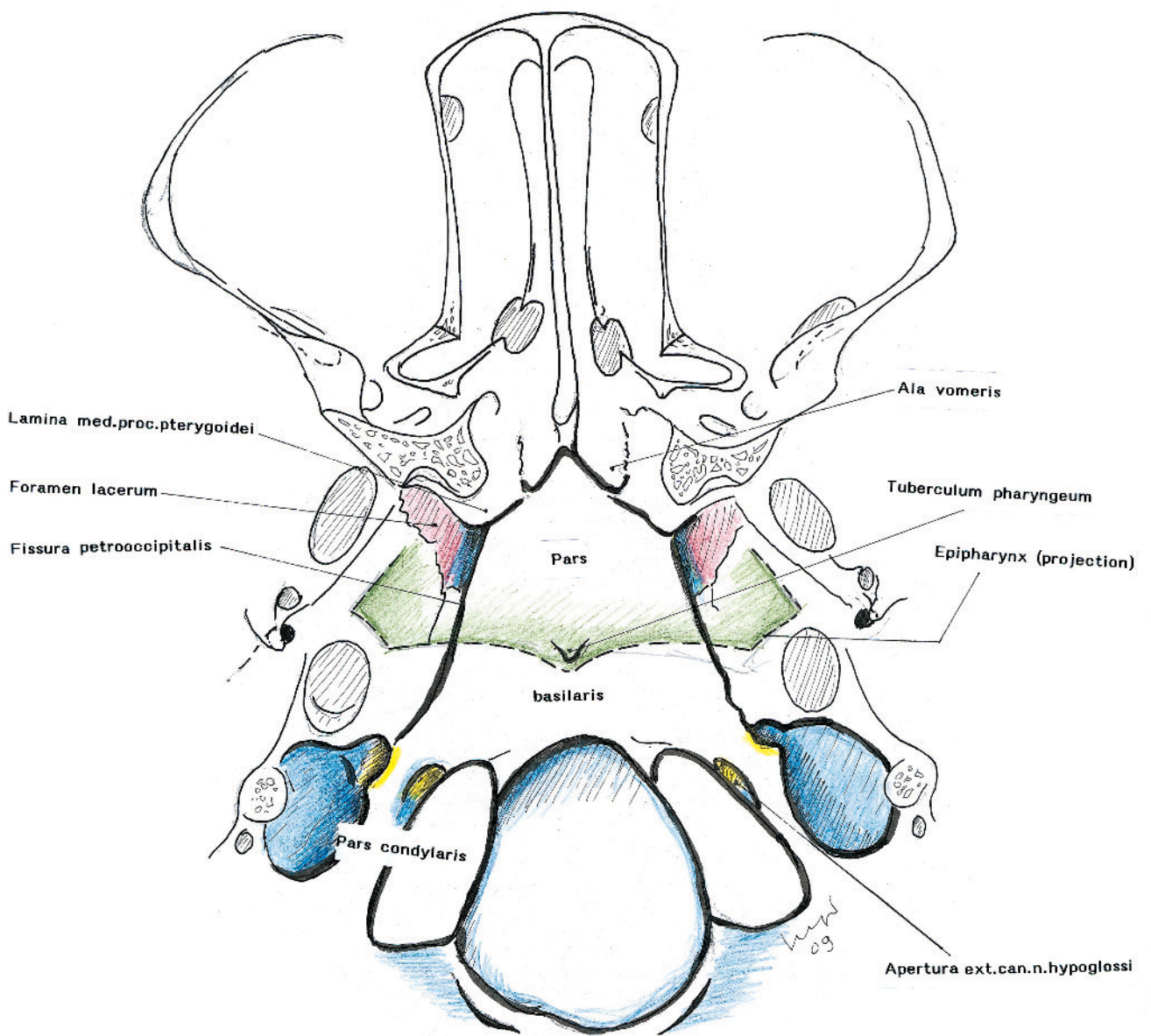
**CLIVUS AREA AND PARS CONDYLLARIS** (Figs. 64 to 70)

Fig. 64

Basal bony bloc below Clivus

- segment of Corpus sphenoidale posterior to the roof of Choana
- Pars basilaris of Os occipitale below Clivus

Pars condylaris of Os occipitale



\* For.sphenopalatinum

Fig. 65

Clivus Blumenbachii and Pars condylaris

- segment of Corpus sphenoidale (postsellar segment)
- Pars basilaris of Os occipitale

Pars condylaris of Os occipitale

- Tuberculum jugulare-condylar-bloc

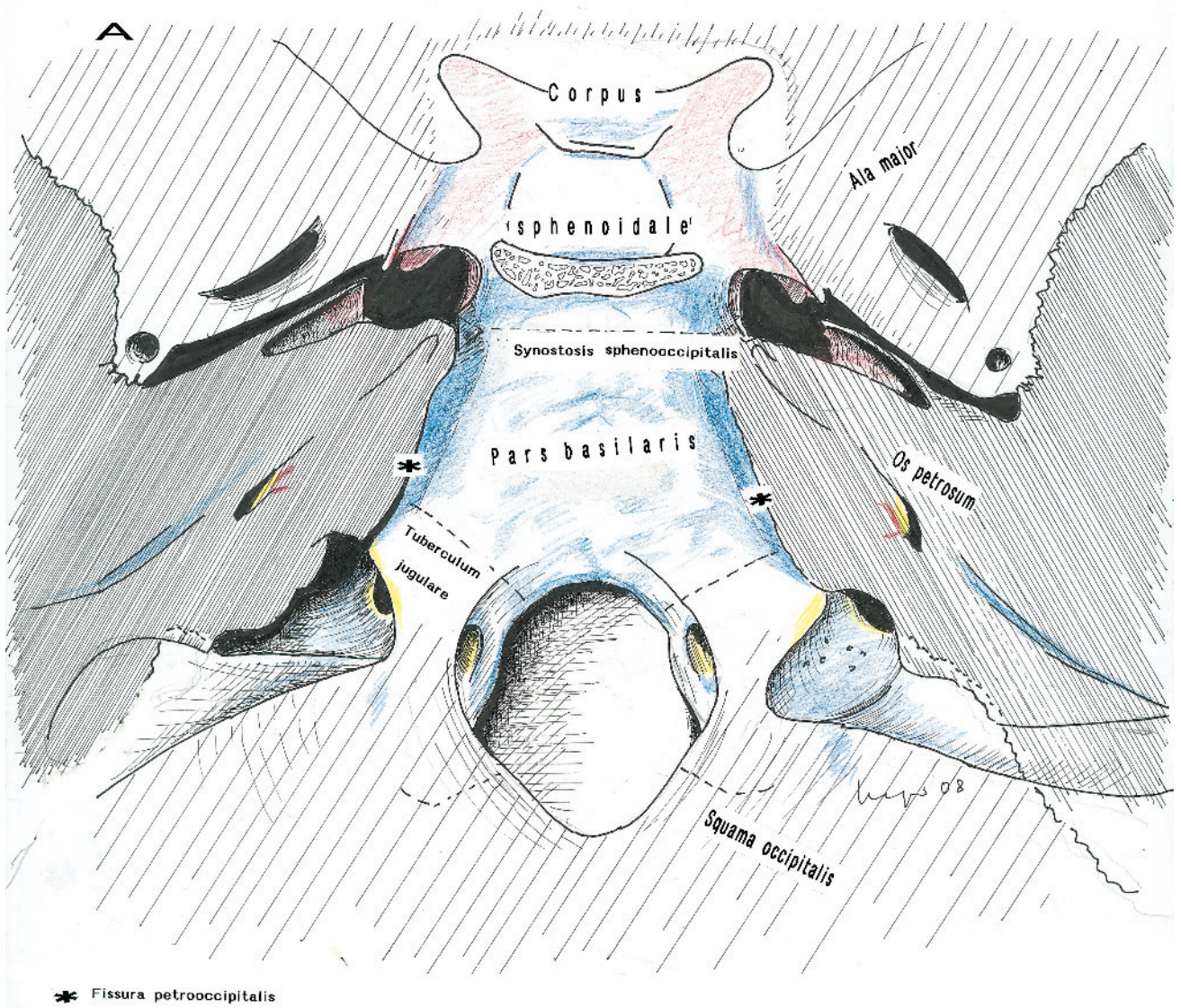




Fig. 66

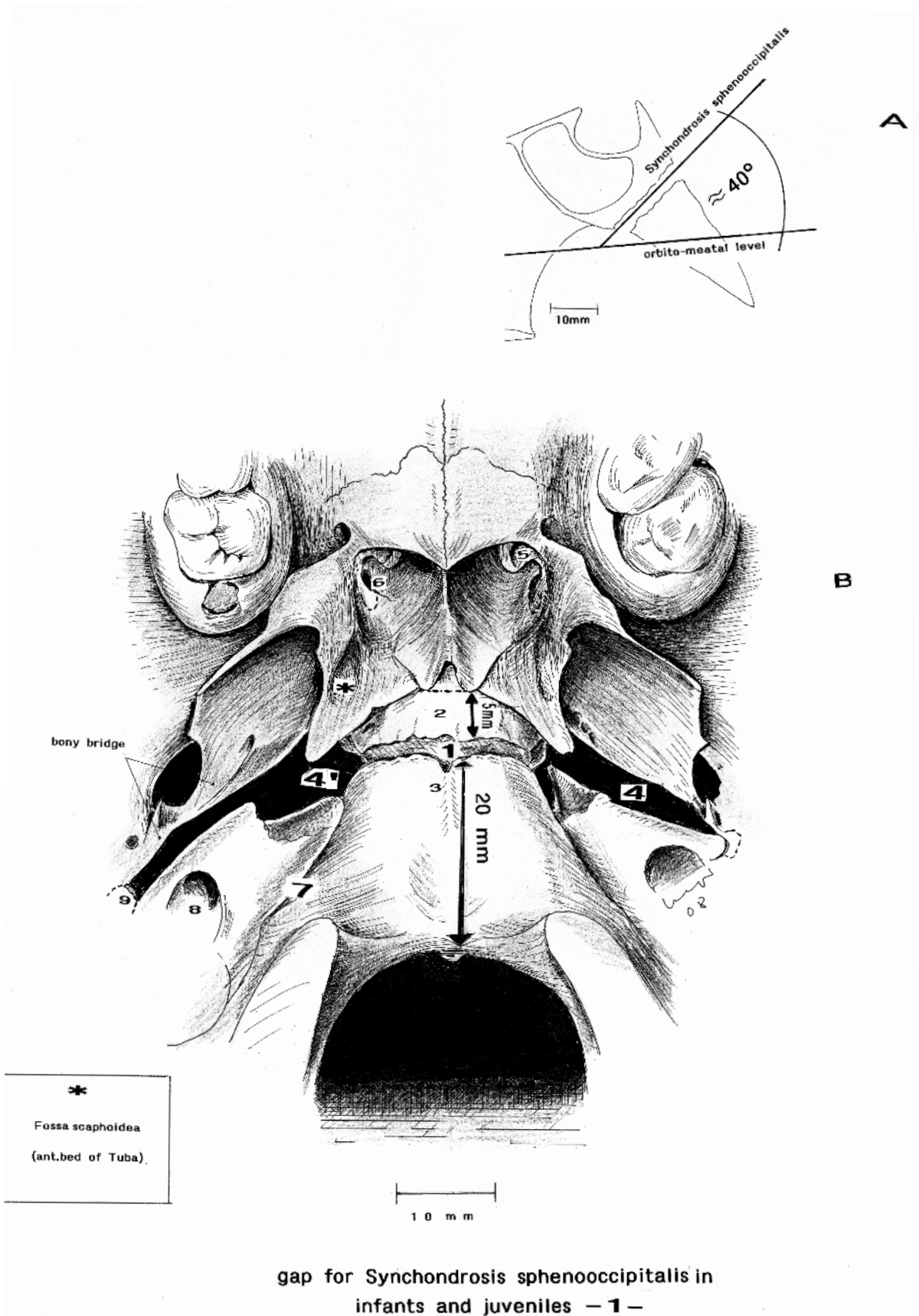
Skull base of a child (12 years)

**A** Synchondrosis can be used as a neuronavigatory landmark

**B** Cranial base, sphenoidal and occipital segments of the bony bloc forming Clivus

**Abbreviations**

- 1 bony gap, usual finding before puberty
- 2 Corpus sphenoidale
- 3 Pars basilaris of the occipital bone
- 4 and 4' Fissura sphenopetrosa a wide; usual finding in children and often in adults
- 5 Concha inferior
- 6 Foramen sphenopalatinum
- 7 Fissura petrooccipitalis
- 8 Apertura externa canalis carotici
- 9 Apertura tubae (projection)



gap for *Synchondrosis sphenoccipitalis* in infants and juveniles - 1 -

Fig. 67

Foramen jugulare and surrounding structures

- A** Overview
- B** Sectional enlargement

**Abbreviations**

- 1 Foramen ovale
- 2 Foramen spinosum
- 3 Sutura petrosquamosa
- 4 Fissura petrotympanica
- 5 Apertura externa canalis carotici
- 6 Porus acusticus externus
- 7 Processus styloideus cut
- 8 Foramen stylomastoideum
- 9 Fossa jugularis
- 10 Processus mastoideus
- 11 Sutura occipitomastoidea
- 12 Fossa paracondyloidea
- 13 Condylus occipitalis
- 14 Foramen occipitale
- 15 Apertura externa canalis nervi hypoglossi
- 16 Fissura petrooccipitalis
- 17 Apertura tubae
- 18 Fissura sphenopetrosa
- 19 Processus vaginalis
- 20 as 11
- 21 Processus paracondyloideus
- 22 Processus intrajugularis
- 23 connection of Processus paracondyloideus to Condylus occipitalis
- 24 posterior segment of Foramen jugulare (for V. jugularis interna)
- 25 anterior segment of Foramen jugulare (for cranial nerves-medially-, and for ramifications of Sinus petrosus inf.-laterally-)



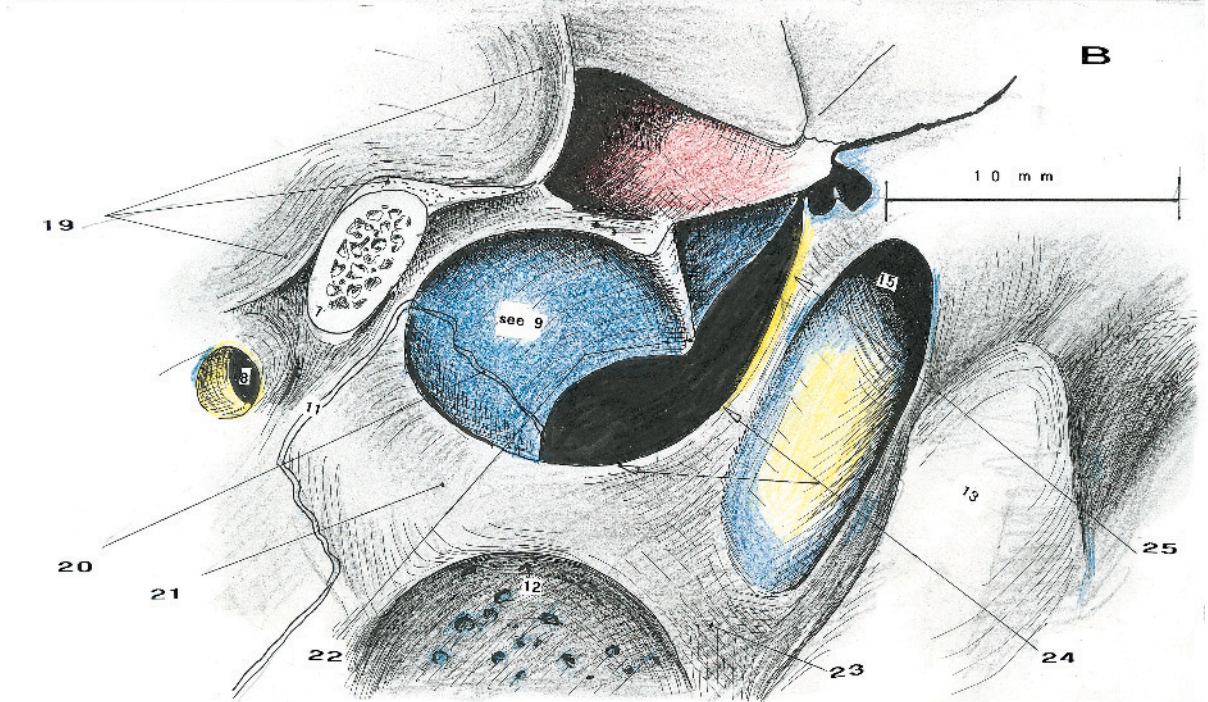
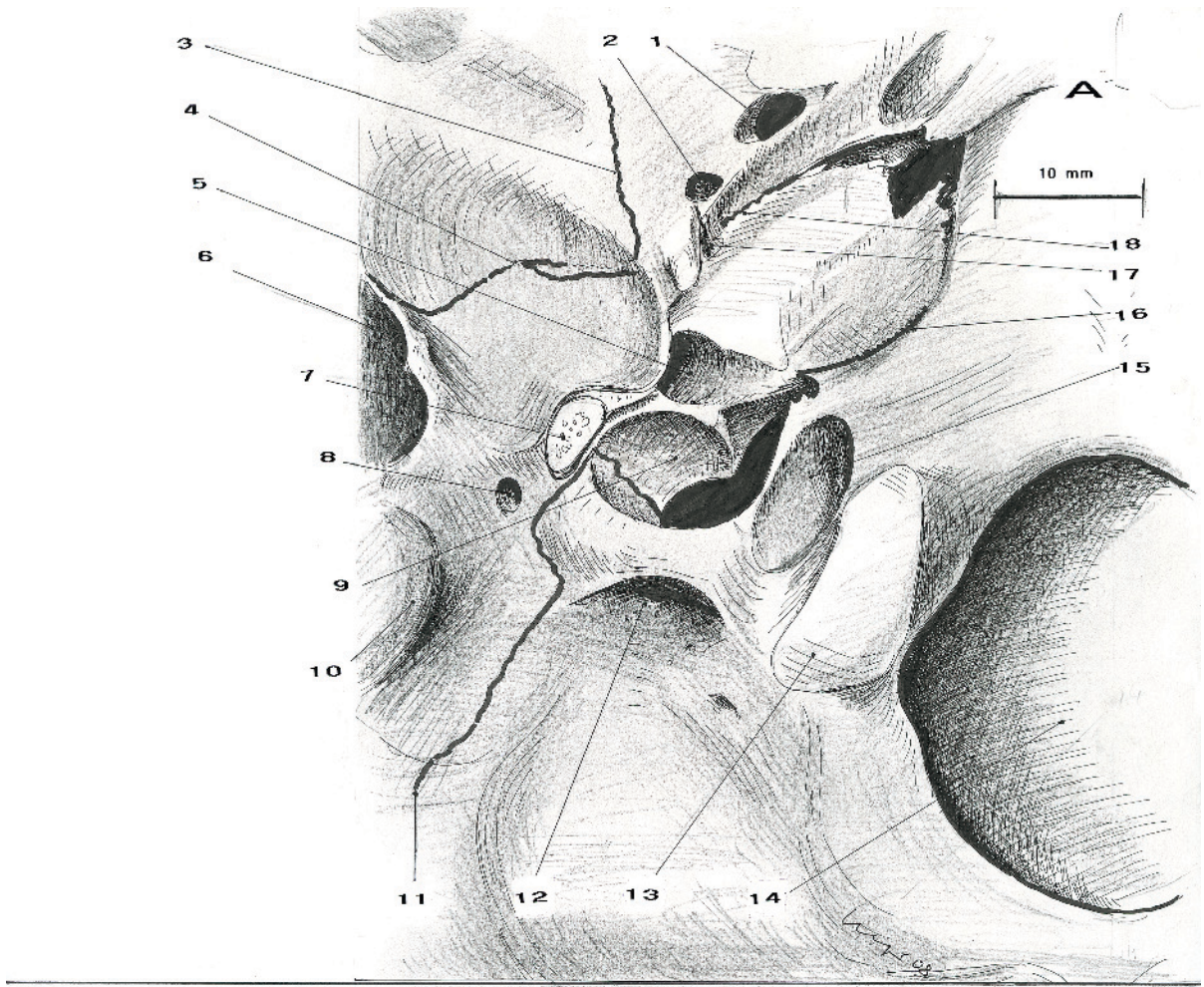




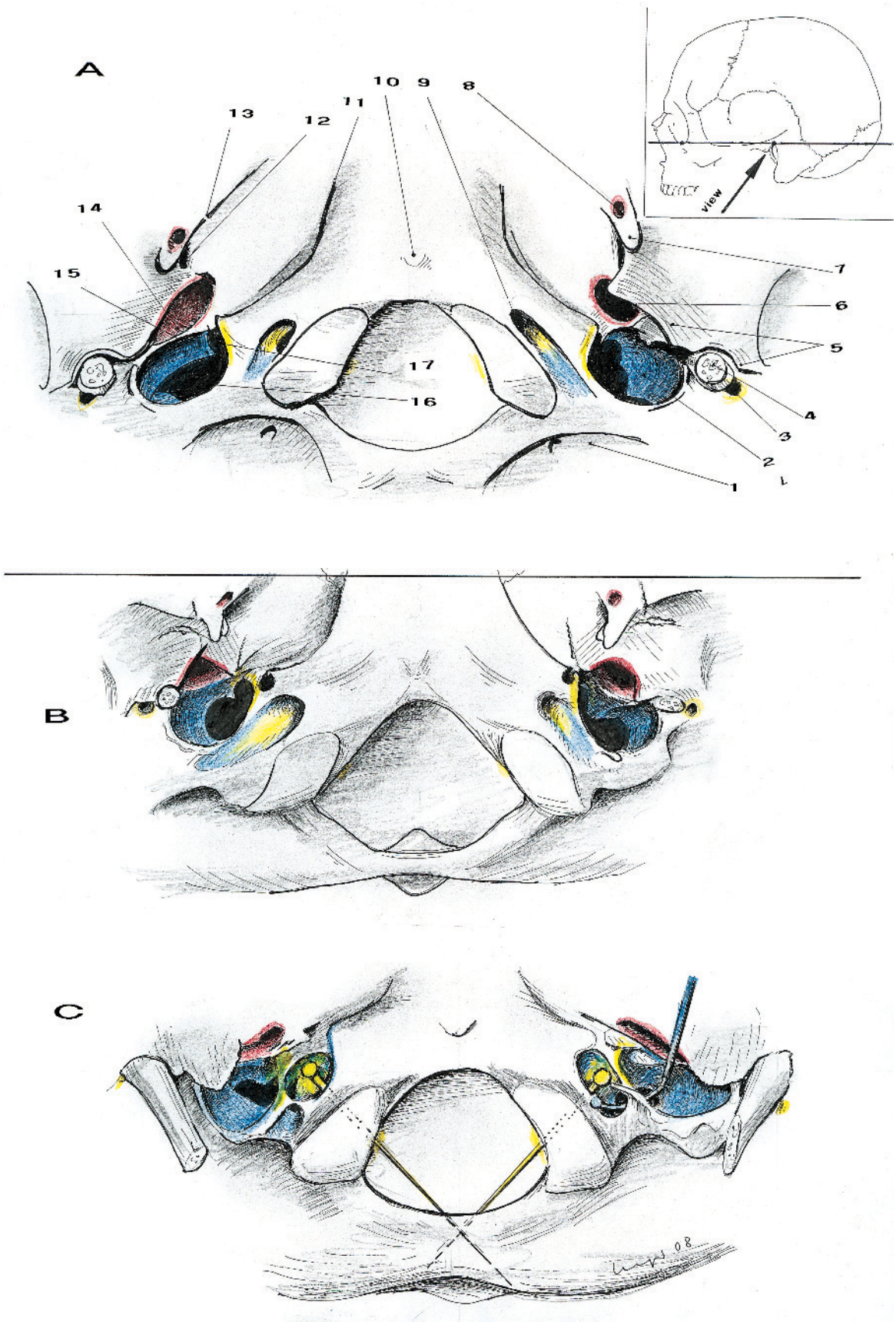
Fig. 68

Addendum to Fig. 67. – Examples

- A** 20 y, female. Tuberculosis. Chronic high venous pressure.
- B** 48 y, female. Close relationship of Processus styloideus to Foramen jugulare (usual finding)
- C** 65 y, male. Senile atrophy. Probes in Canales n. hypoglossi. Bony defect between Fossa jugularis and Apertura ext. n. hypoglossi on the left side (see probe).

**Abbreviations**

- 1 Fossa paracondyloidea
- 2 Fossa jugularis
- 3 Foramen stylomastoideum
- 4 Processus styloideus
- 5 Processus vaginalis
- 6 Apertura ext. canalis carotici
- 7 Spina angularis
- 8 Foramen spinosum
- 9 Apertura ext. canalis n. hypoglossi
- 10 Tuberculum pharyngeum
- 11 Fissura (Synchondrosis) petrooccipitalis
- 12 Apertura of Pars ossea tubae
- 13 Fissura (Synchondrosis) sphenopetrosa
- 14 roof of Apertura ext. canalis carotici
- 15 Processus intrajugularis
- 16 Foramen jugulare, posterior segment, enclosing Bulbus sup. v. jugul. internae
- 17 Foramen jugulare, anterior segment, enclosing cranial nerves IX to XI



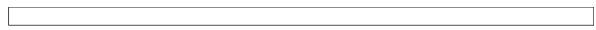


Fig. 69

Common variant

Probes: Venous channels are connecting Canalis n. hypoglossi to Foramen and Fossa jugularis)



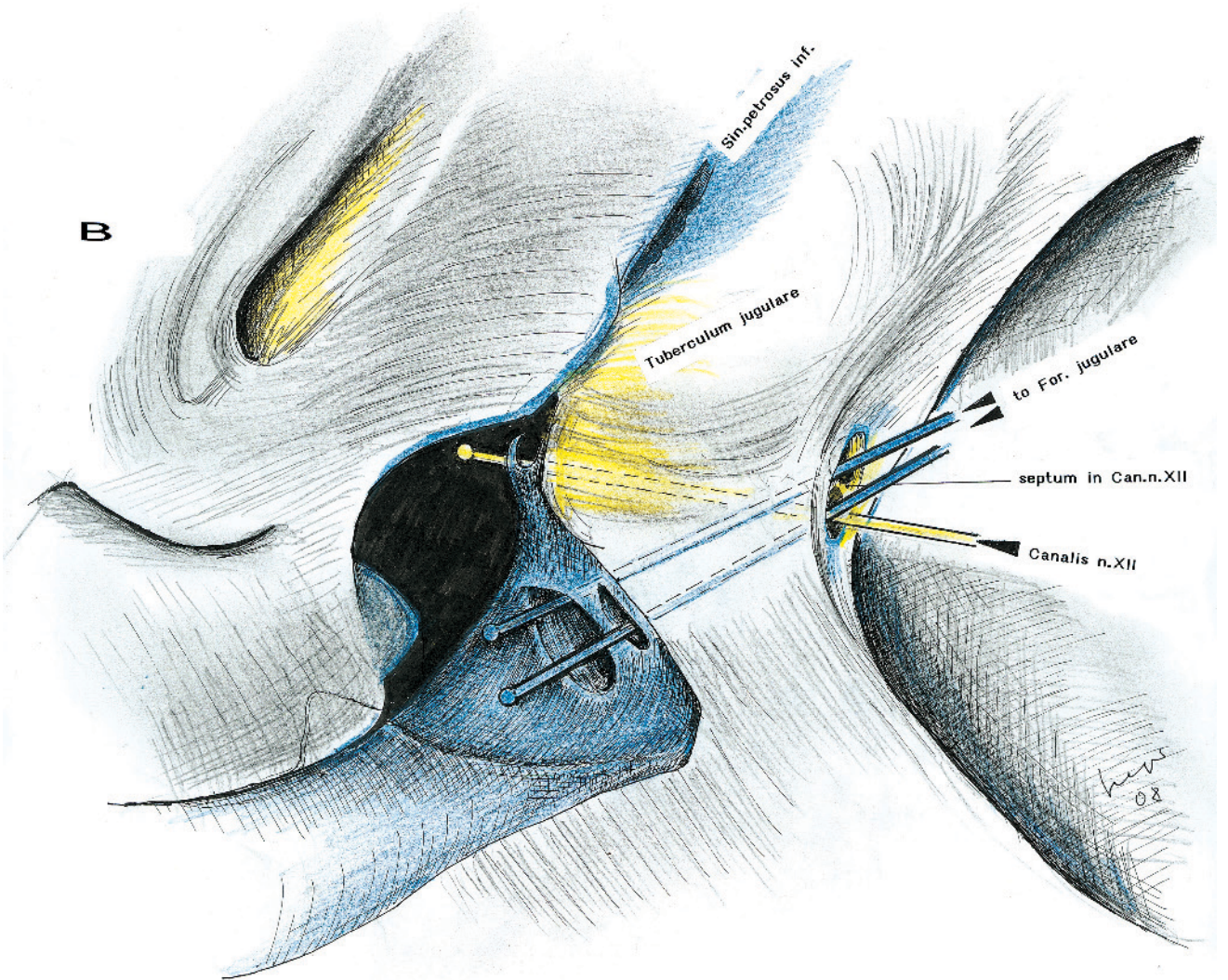
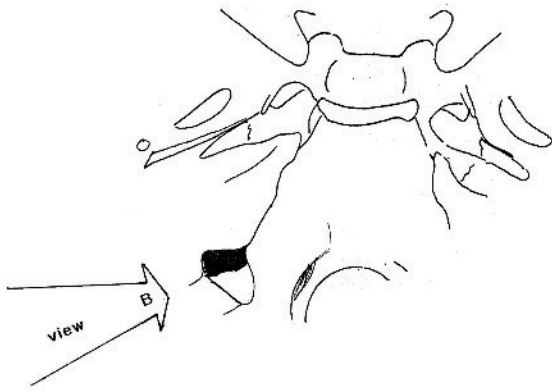




Fig. 70

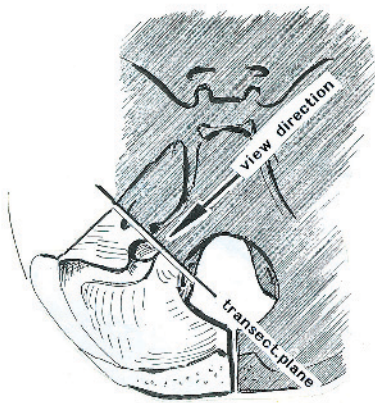
Interforaminal cadaver skull transection

At this transectional plane the following structures are located on one straight line:

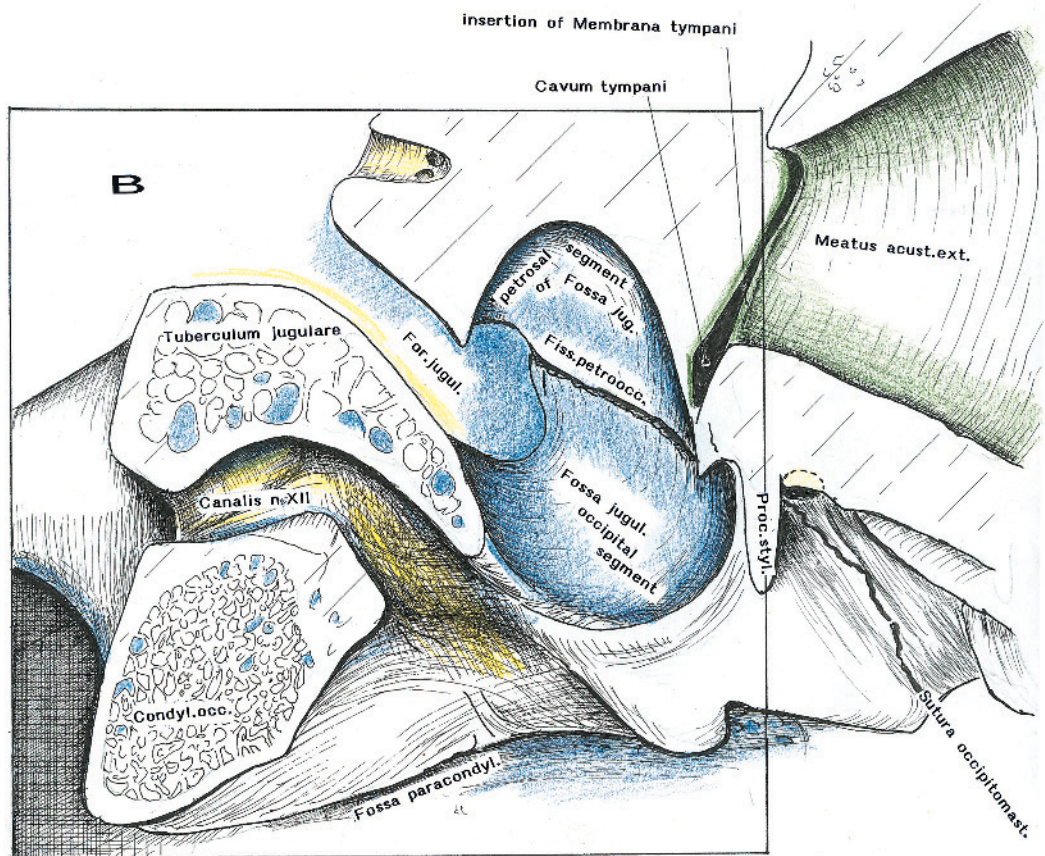
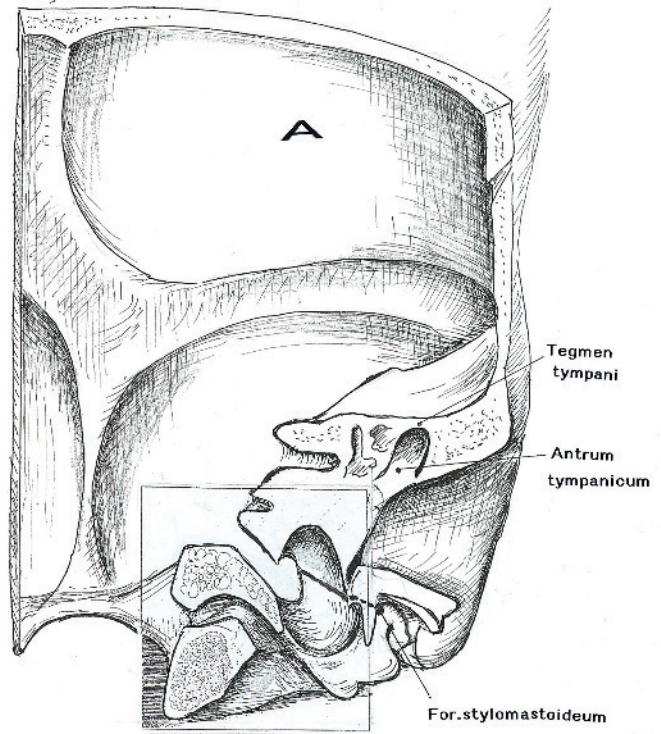
- posterior margin of Porus acusticus int.
- anterior segment of Foramen jugulare (not visible on CT in many cases)
- anterior margin of Apertura int. of Canalis n. hypoglossi

**A** Overview

**B** Sectional enlargement



topogram



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**CHAPTER VII**  
**SPECIAL SURGICAL ASPECTS. EXAMPLES**  
(Figs. 71 to 79)



## Planning strategies (Figs. 71 to 77)

### Imaging techniques (Figs. 71 to 74)

A cadaver skull transection at the level of the interforaminal line connecting For. acust. int. – For. jugulare – Apertura int. n. XII (see Fig. 70) was merged with MRT/CT-slices, for a better understanding of the asymmetric slices. These inconsistencies may occur by incorrect positioning of the head or by asymmetries of the head and skull.

### Measurements (Figs. 75 to 77)

Anatomical landmarks may be unclear. Distance estimations may be useful for orientation, especially for defining the margins of Os basilare and of the condylar part.

### Dural penetration point of N. abducens (Figs. 76 and 77)

A further problem is the neuronavigatory definition of the dural penetration point of N. abducens. This area is located close to some essential structures (Fig. 76)

It is crucial to identify in skull base surgery, especially of petroclival meningiomas. The tumor usually masks the nerve along its intradural-transstumoral course. Identification of the nerve is easier during an anterior than an posterior surgical approach, as in transnasal endoscopy. Before the nerve enters the lateral wall of the cavernous area of the carotid artery, it crosses Hamulus pyramidis. Hamulus is an inconstant landmark. It is distant to the dural penetration point. The position of this point is given to Fig. 77.

## Transnasal routes (Figs. 78 and 79)

A. carotis int. is the most important structure to identify in basal endoscopic approaches. Along the midline, approaches are less dangerous than lateral to it, except in the area of the carotid siphon. The anatomy of the siphon is well known from pituitary surgery. The next difficult segment is the carotid course to Foramen lacerum. This part of A. carotis int. is located more medially than other segments of the carotid artery. The endoscopic approach from Apertura nasi to the contralateral Apertura ext. of the carotid canal, is shown in Figs. 78 and 79. Foramen lacerum is located close to a straight lined direction. Foramen lacerum is the only area at the skull base where the artery crosses without a bony envelope, as it is usually given by the sphenoid bone and by the carotid channel of Pyramis. Therefore Canalis pterygoideus (Vidii) is used in modern endoscopy as an important landmark (Kassam, Snyderman et al. 2005). The canal connects the posterior basal segment of the wall of Sinus sphenoidalis to the area of Foramen lacerum and Apertura int. of the carotid canal. The nerve of Canalis pterygoideus (Vidii) – N.petrosus – should be spared.

**SPECIAL SURGICAL ASPECTS. EXAMPLES.**

(Figs. 71 to 79)

**PLANNING STRATEGIES. IMAGING TECHNIQUES. EXAMPLES.**

(Figs. 71 to 74)

Fig. 71

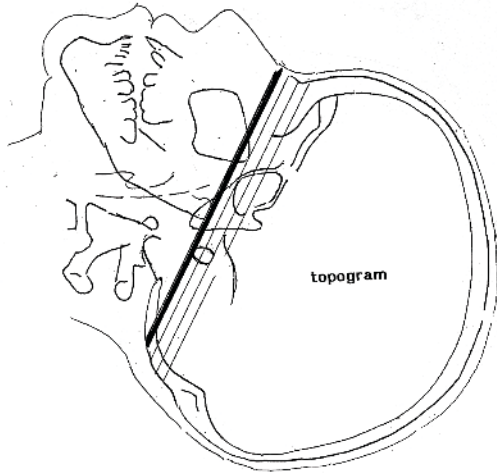
Imaging techniques. Topographical overview

**A** Craniospinal area

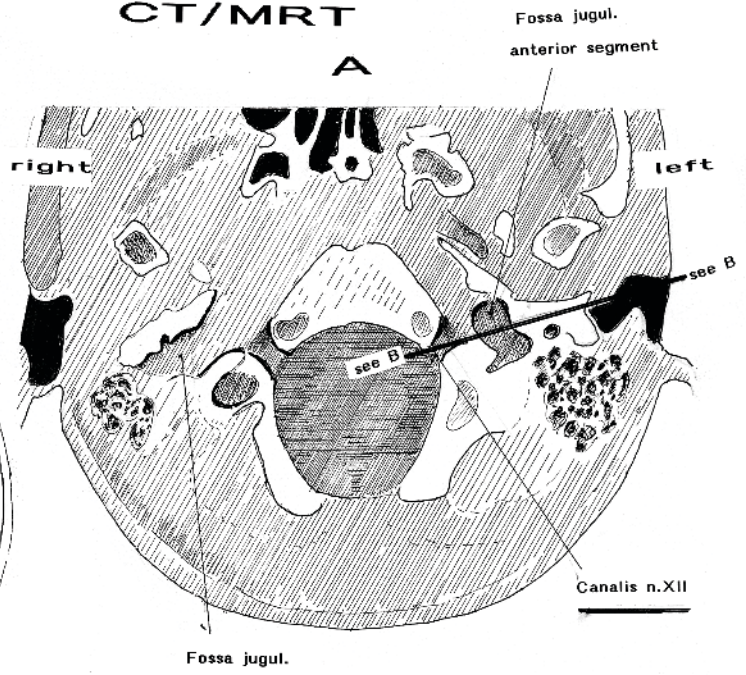
**B** Interforaminal cadaver skull dissection according to Fig. 70

guiding structures

Canalis nn.XII



CT/MRT



B Anatomical dissection

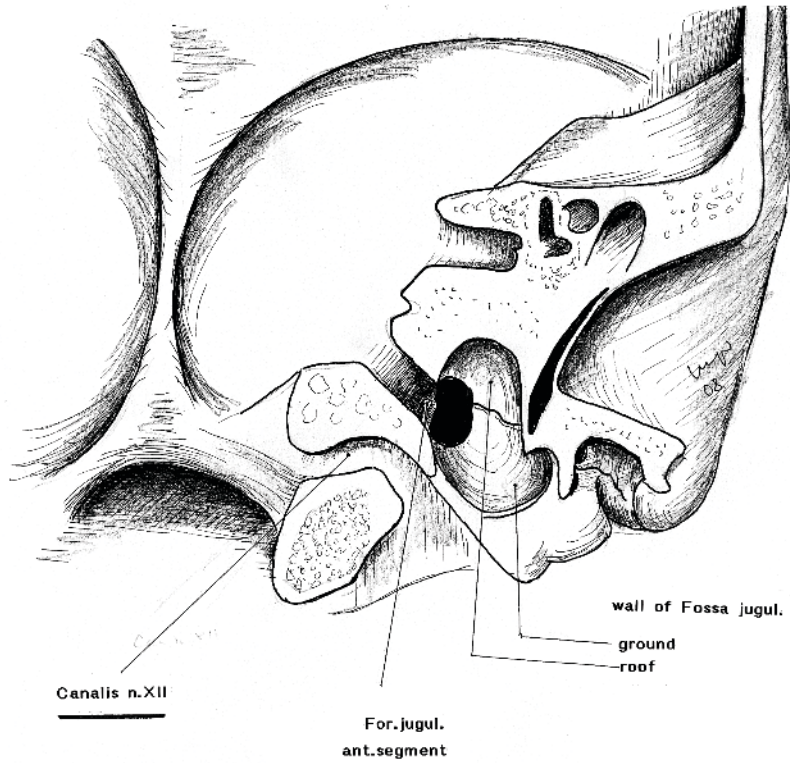


Fig. 72

Continuation of Fig. 71

Right Canalis nervi hypoglossi present, as in Fig. 71

Left canal not present

- A** CT/MRT, transectional level B indicated in  
**A' and A''** Sectional enlargements of A  
**B** Cadaver skull transection

#### Abbreviations

- 1 Apertura interna canalis n. hypoglossi
- 2 Canalis n. hypoglossi
- (2) projection
- 3 Foramen occipitale
- 4 Fossa jugularis
- 5 Foramen jugulare, anterior segment
- 6 as 4, and Foramen jugulare, posterior segment
- 7 Canalis caroticus
- (7) Apertura ext. canalis carotici, projection indicates
- 8 Meatus acusticus ext.
- 9 Cavum tympani
- 10 Tuberculum jugulare
- 11 Condylus occipitalis
- 12 Processus styloideus and Foramen stylomastoideum
- 13 Capitulum mandibulae
- 14 Meatus acusticus internus
- 15 Cellulae mastoideae



guiding structure  
right Canalis n.XII

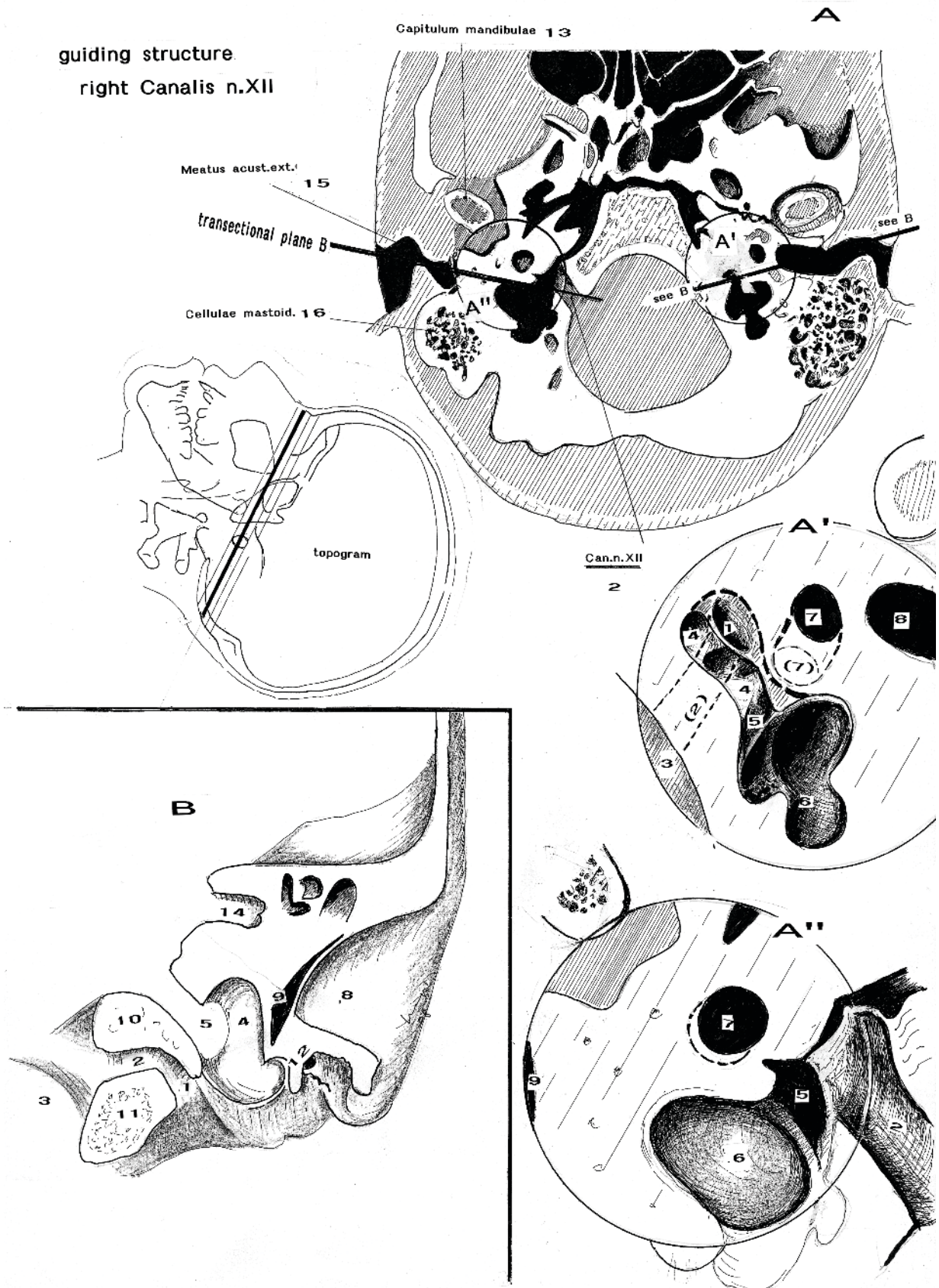
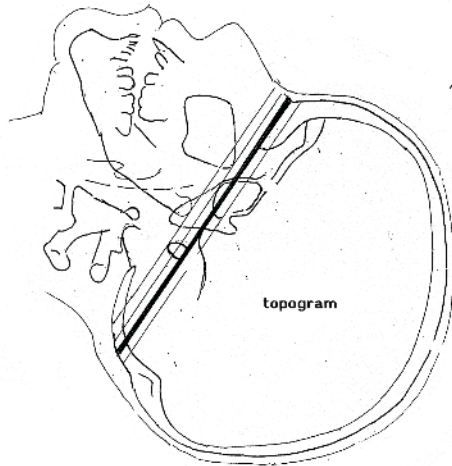


Fig. 73

Continuation of Fig. 72  
Different illustration of Capitulum mandibulae,  
Cochlea, Foramen jugulare, Processus mastoideus, on the right and left side, in Figs. 72  
and 73

guiding structures

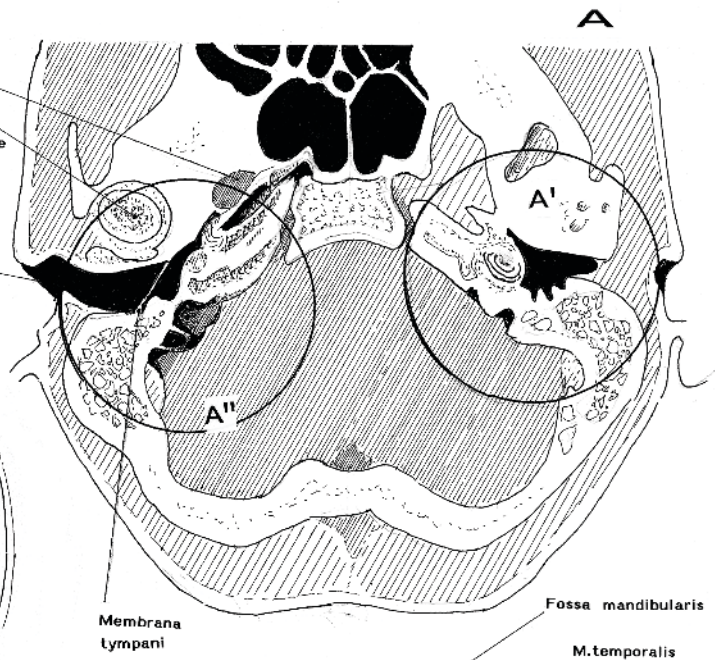
left Cochlea  
left roof of  
For./Fossa jugul.



For. ovale

Capitulum mandibulae

Meatus acust. ext.



intracran. space

Cochlea

For./Fossa jugularis  
roof

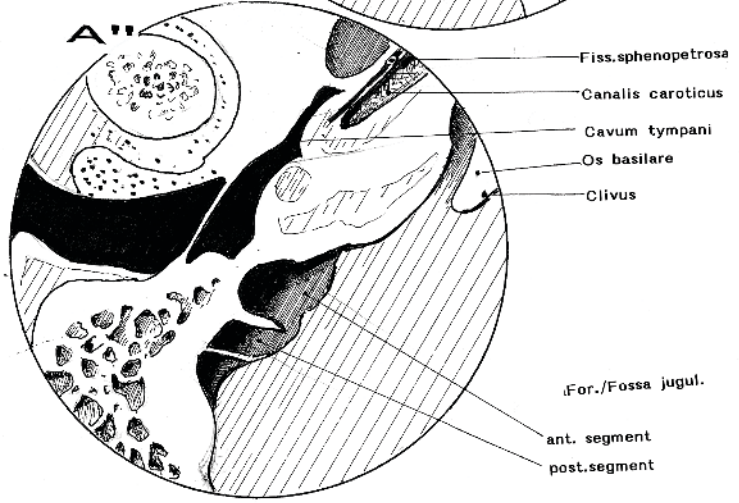
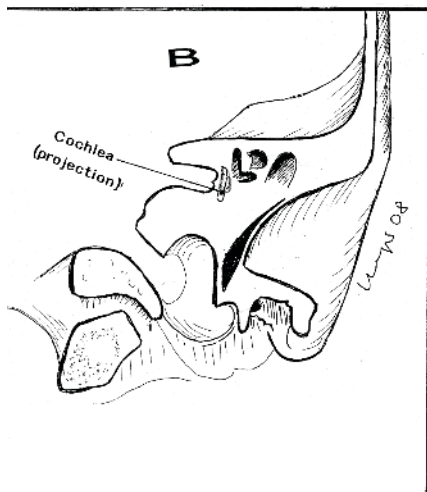
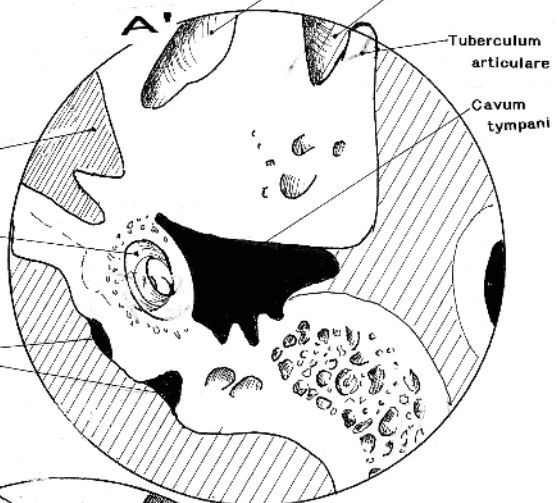


Fig. 74

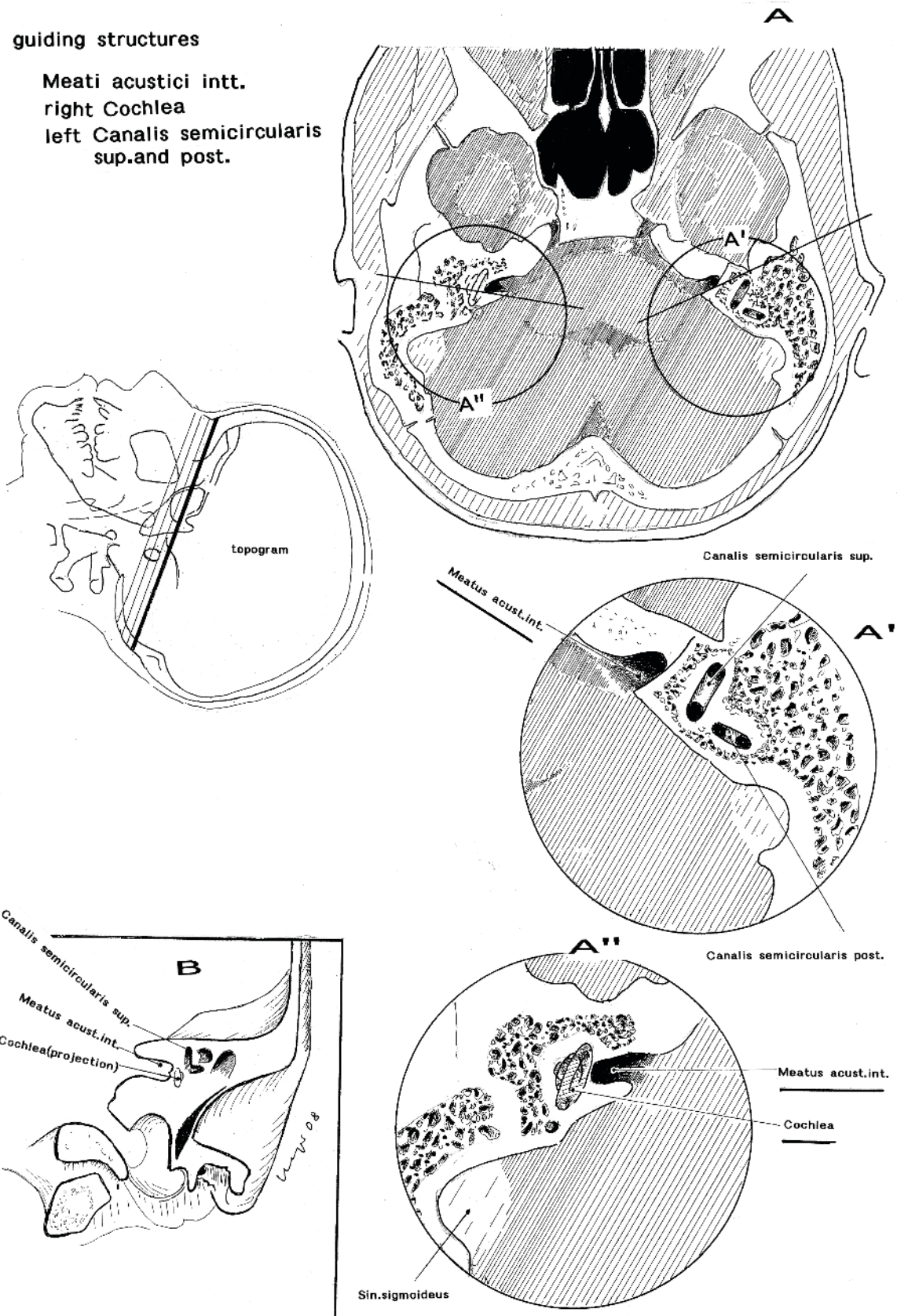
Continuation of Fig. 73

Different illustrations of Cochlea, Ducti semicirculares, and Meatus acusticus internus on the right and left side, in Figs. 73 and 74.



guiding structures

Meati acustici intt.  
right Cochlea  
left Canalis semicircularis  
sup.and post.



**MEASUREMENTS** (Figs. 75 to 77)

Fig. 75

Clivus area, underlying structures included.  
Condylar-Tuberculum jugulare-complex.  
Measurements based on 8 cadaver skull-dissection.

**A and A'** Intracranial shape  
**B and B'** Extracranial shape

a 16–18 mm  
b 20–25 mm  
c 45 mm  
d 50–55 mm  
e 15–20 mm  
f 25–35 mm

poc Synchronosis petrooccipitalis

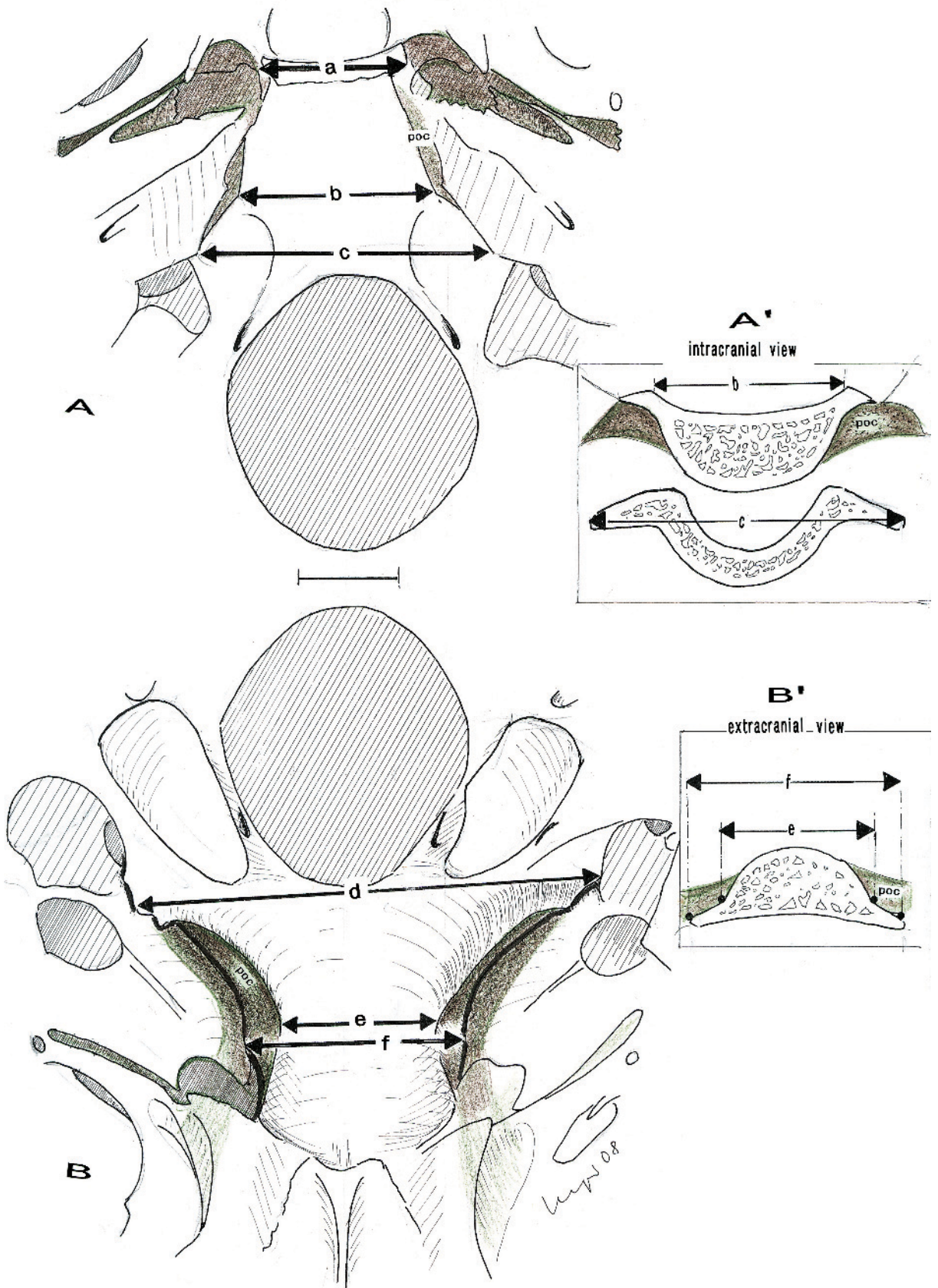


Fig. 76

Addendum to Fig. 75

Short distance of Canalis caroticus (A. carotis int.) to Fissura sphenopetrosa (bed of Tuba auditiva) and to Foramen ovale (N. mandibularis)  
Enlargement of Sinus petrosus inf.



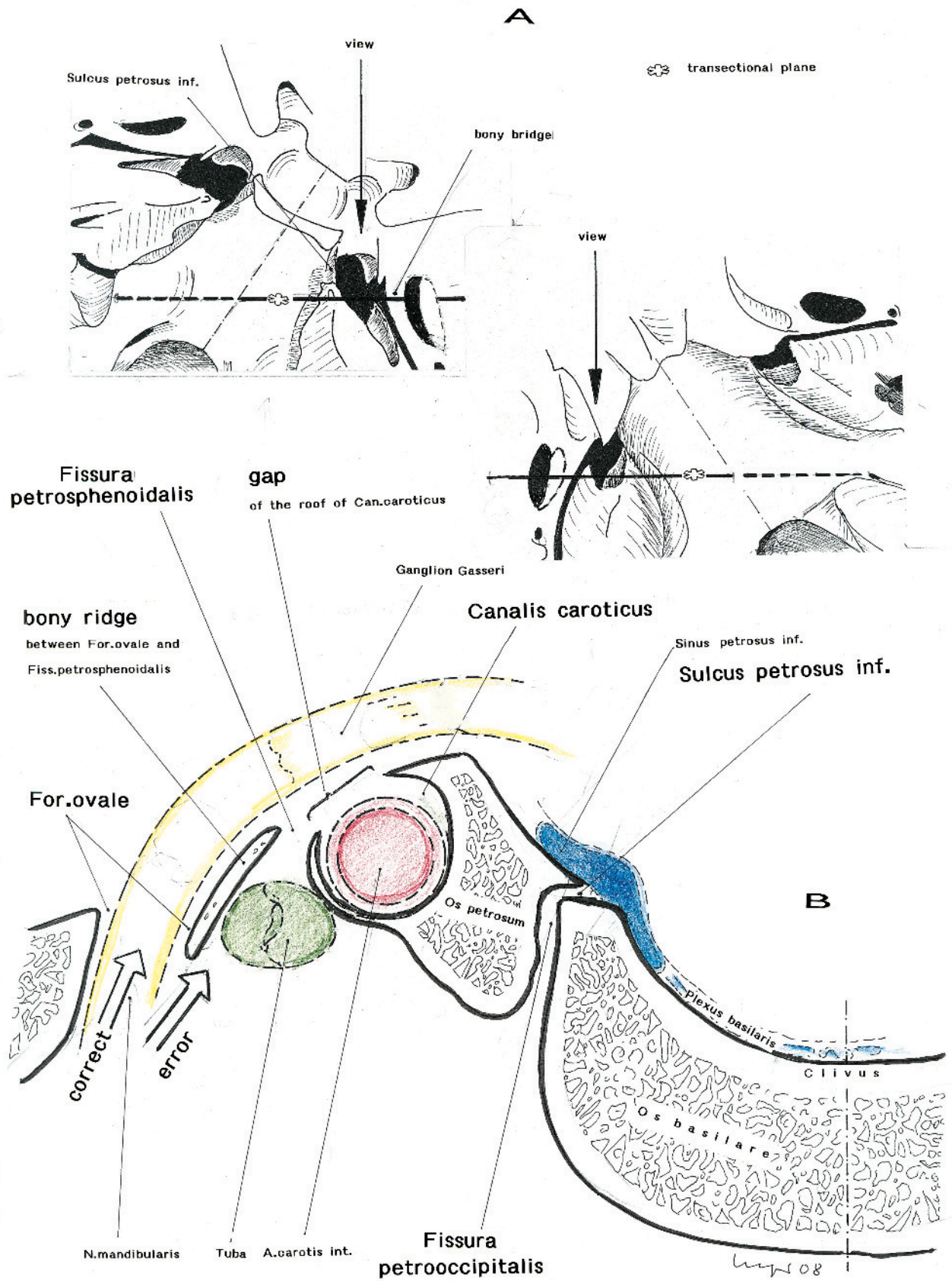
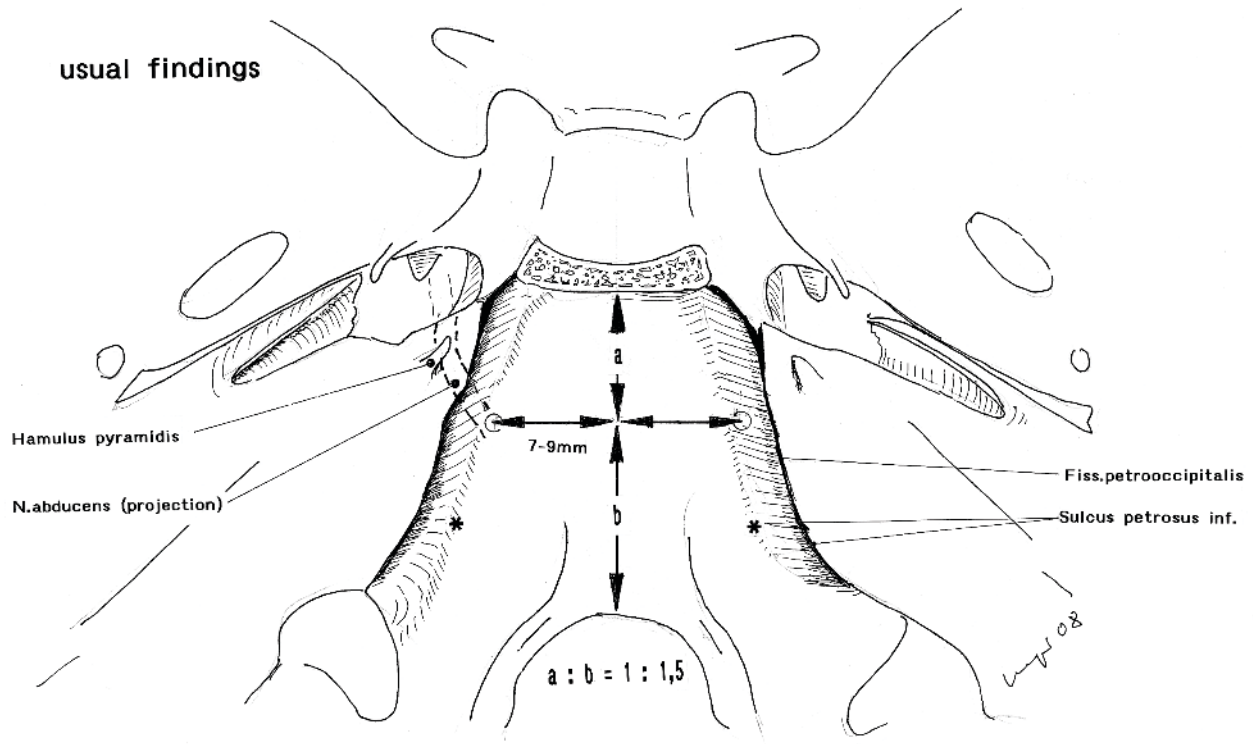


Fig. 77

Dural penetration point of N. abducens

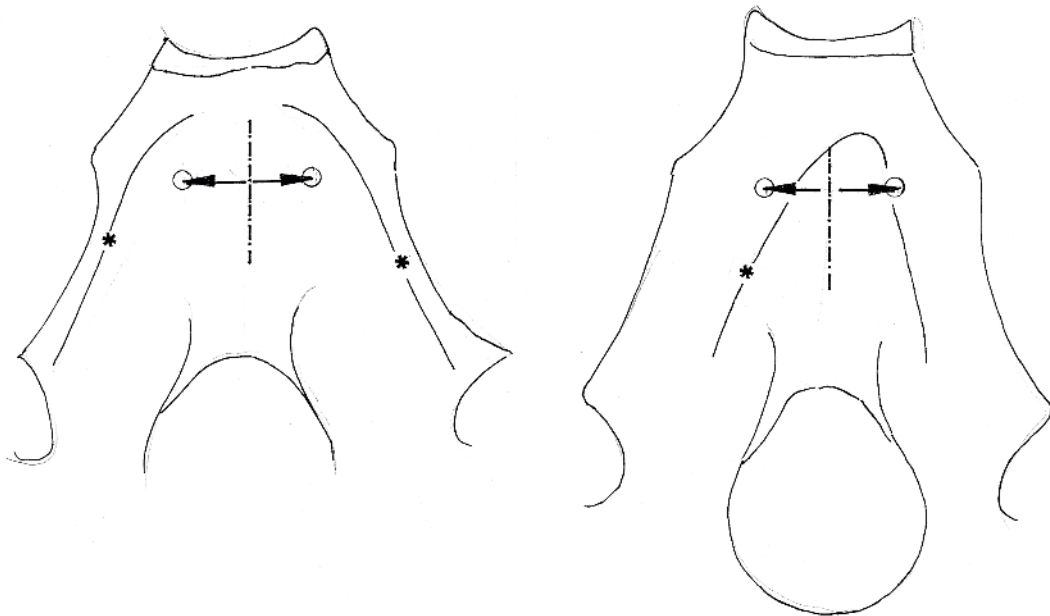
The penetration point is often located at the medial margin of Sulcus petrosus inf. The sulcus is often flattened or variable. The length of Clivus varies between 3 and 4 cm but the relationship of segments a and b are 1 : 1,5. The distance to the midline is 7 – 9 mm. These measurements are useful for defining neuronavigatory landmarks.

usual findings



\* medial border area of Sulcus (not Sinus) petrosus inf.

○ dural exit area of N. abducens



extreme variants of Sulcus petrosus inferior

Fig. 78

Endoscopic transnasal route  
Anatomical model

Approach to the contralateral medial margin of Apertura externa canalis carotici. The medial margin of Foramen lacerum (according to the medial margin of the carotid artery) is crossed by the endoscopic route. Asymmetries of the skull base must be taken into consideration.

a and b: distances from to the midline for the definition of asymmetries. Asymmetric variant in B3 of Fig. 79

**Abbreviations**

- 1 Spina angularis (and Ostium tubae)
- 2 Foramen spinosum
- 3 Foramen ovale



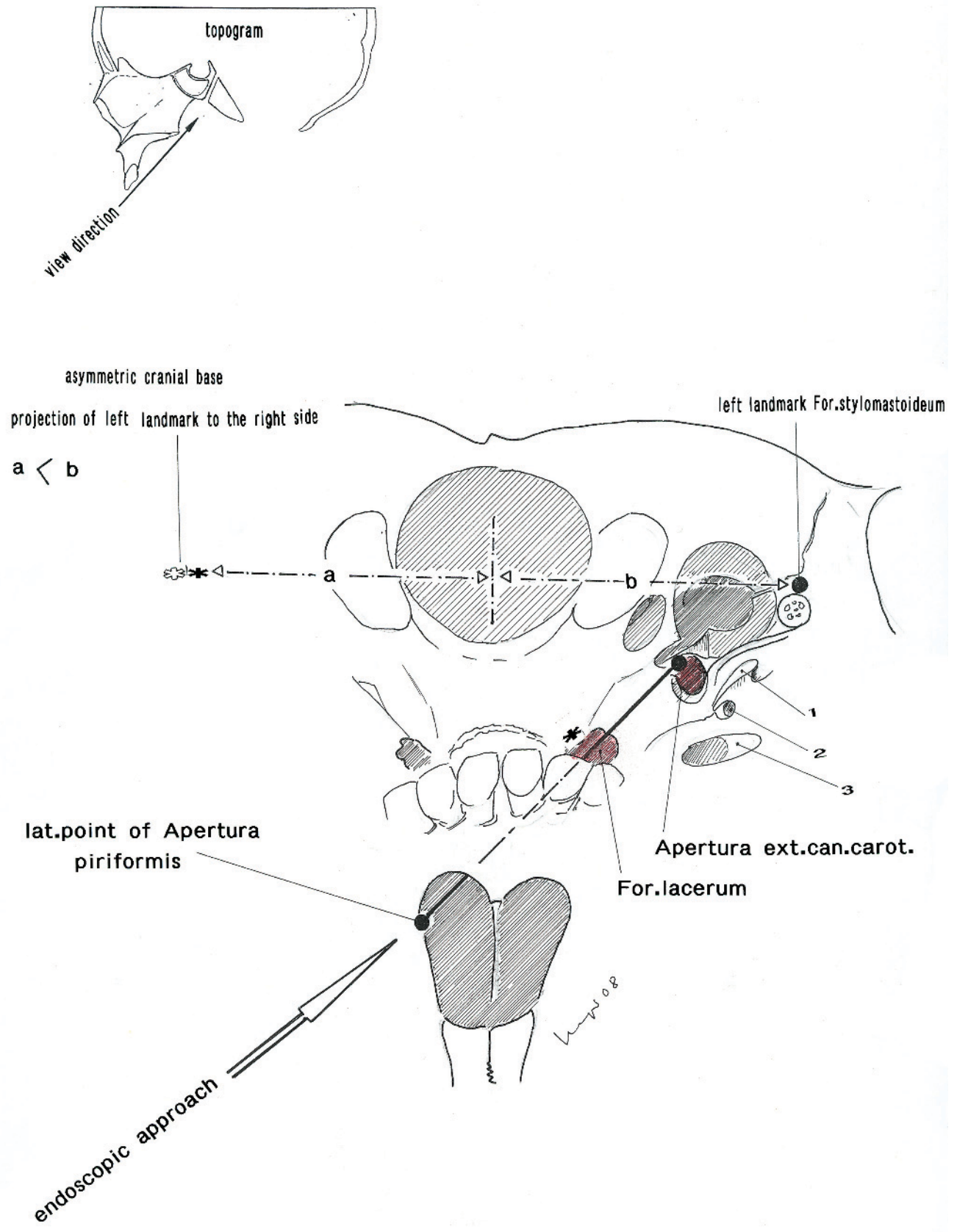
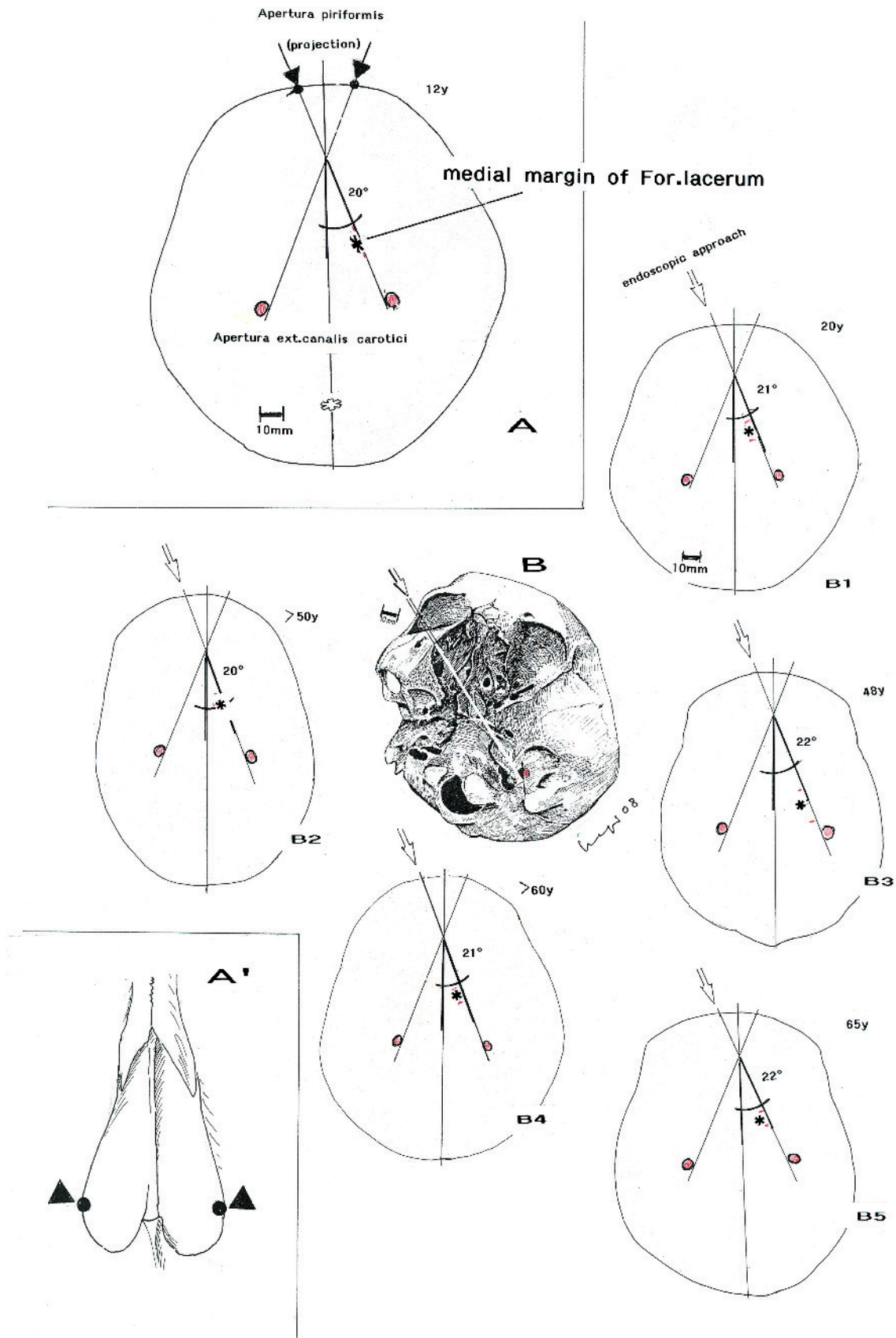


Fig. 79

Addendum for Fig. 78

**A** As Fig. 78

**B to B4** further cadaver skull dissection



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