THE ANTERIOR AND MIDDLE CRANIAL BASE

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KEY WORDS: Anterior fossa, Cranial base, Cranial nerves, Infratemporal fossa, Microsurgical anatomy, Middle fossa, Nasal cavity, Orbit, Paranasal sinuses, Pterygopalatine fossa, Skull base, Surgical approaches

Neurosurgery 51[Suppl 1]:273–302, 2002 DOI: 10.1227/01.NEU.0000028087.76279.41 www.neurosurgery-online.com

OVERVIEW

No part of the cranial base is immune to surgical pathology or to its use as a pathway to access lesions in the intra- or extracranial spaces. Tumors and many other lesions can involve any of the intracranial fossae, and can appear in the paranasal sinuses, nasal cavity, infratemporal and pterygopalatine fossae, orbit, and in the retropharyngeal and craniocervical regions (*Fig. 6.1*). Managing these lesions requires an extensive knowledge of the cranial base and its intra- and extracranial relationships. This chapter provides a concise review of the cranial base, focusing largely on the anterior and middle cranial base; the Millennium issue of *Neurosurgery* focused on the posterior cranial fossa (8). The chapters that follow provide a more focused review of the orbit, sella, and cavernous sinus.

The skull is divided into the cranium and the facial skeleton. The cranium is divided into the calvarium and the cranial base. The cranial base has an endocranial surface, which faces the brain, and an exocranial surface, which faces the nasal cavity and sinuses, orbits, pharynx, infratemporal and pterygopalatine fossae, and the parapharyngeal and infrapetrosal spaces (*Fig. 6.2*). Both surfaces are connected by canals, foramina, and fissures through which numerous neural and vascular structures pass. Both the endocranial and exocranial cranial base surfaces are divided into anterior, middle, and posterior parts, each of which have a central and paired lateral portions. On the intracranial side, the three parts correspond to the anterior, middle, and posterior cranial fossae (*Figs. 6.2* and *6.3*). On the endocranial side, the border between the anterior and middle cranial bases is the sphenoid ridge joined medially by the chiasmatic sulcus, and the border between the middle and posterior cranial bases is formed by the petrous ridges joined by the dorsum sellae and posterior clinoid processes. On the exocranium side, the anterior and middle cranial bases are divided at the level of a transverse line extending through the pterygomaxillary fissures and the pterygopalatine fossae at the upper level and the posterior edge of the alveolar process of the maxilla at a lower level. Medially, this corresponds to the anterior part of the attachment of the vomer to the sphenoid bone. The middle and posterior cranial bases are separated by a transverse line crossing at or near the posterior border of the vomer-sphenoid junction, the foramen lacerum, carotid canal, jugular foramen, styloid process, and the mastoid tip. The osseous structures, their foramina and fissures, canals and their muscular, and neural and vascular relationships are described in this chapter.

ANTERIOR CRANIAL BASE

Endocranial Surface

The anterior endocranial surface, formed by the ethmoid, sphenoid, and frontal bones, is divided into medial and lateral portions (*Figs. 6.3–6.5*). The medial part, covering the upper nasal cavity and the sphenoid sinus, is formed by the crista galli and the cribriform plate of the ethmoid bone anteriorly and the planum of the sphenoid body posteriorly. The lateral part, which covers the orbit and the optic canal, is formed by the frontal bone and the lesser wing of the sphenoid bone, which blends medially into the anterior clinoid process (*Figs. 6.3* and *6.4*). The foramen caecum in the midline serves as the site of passage of an emissary vein and the cribriform plate is pierced by the filaments of the olfactory nerve. The optic canal transmits the optic nerve and the ophthalmic artery. The anterior cranial base faces the frontal lobes with the gyri recti medially and the orbital gyri laterally, along with the branches of the anterior cerebral arteries medially and middle cerebral arteries laterally.

Exocranial Surface

On the exocranial side, the anterior cranial base is divided into a medial part related to the ethmoidal and sphenoid sinuses with the nasal cavity below, and a lateral part that corresponds to the orbit and maxilla (*Figs. 6.2, 6.6, 6.7,* and *6.8*) (2). The ethmoid bone forms the anterior and middle thirds and the sphenoid body forms the posterior third of the medial part. The ethmoid is formed by the cribriform plate, with the olfactory fila traveling through it, the perpendicular plate that joins the vomer in forming the nasal septum, and two lateral plates located in the medial walls of the orbits. The lateral plates separate the lateral wall of the nasal cavity and the orbit. The superior turbi-

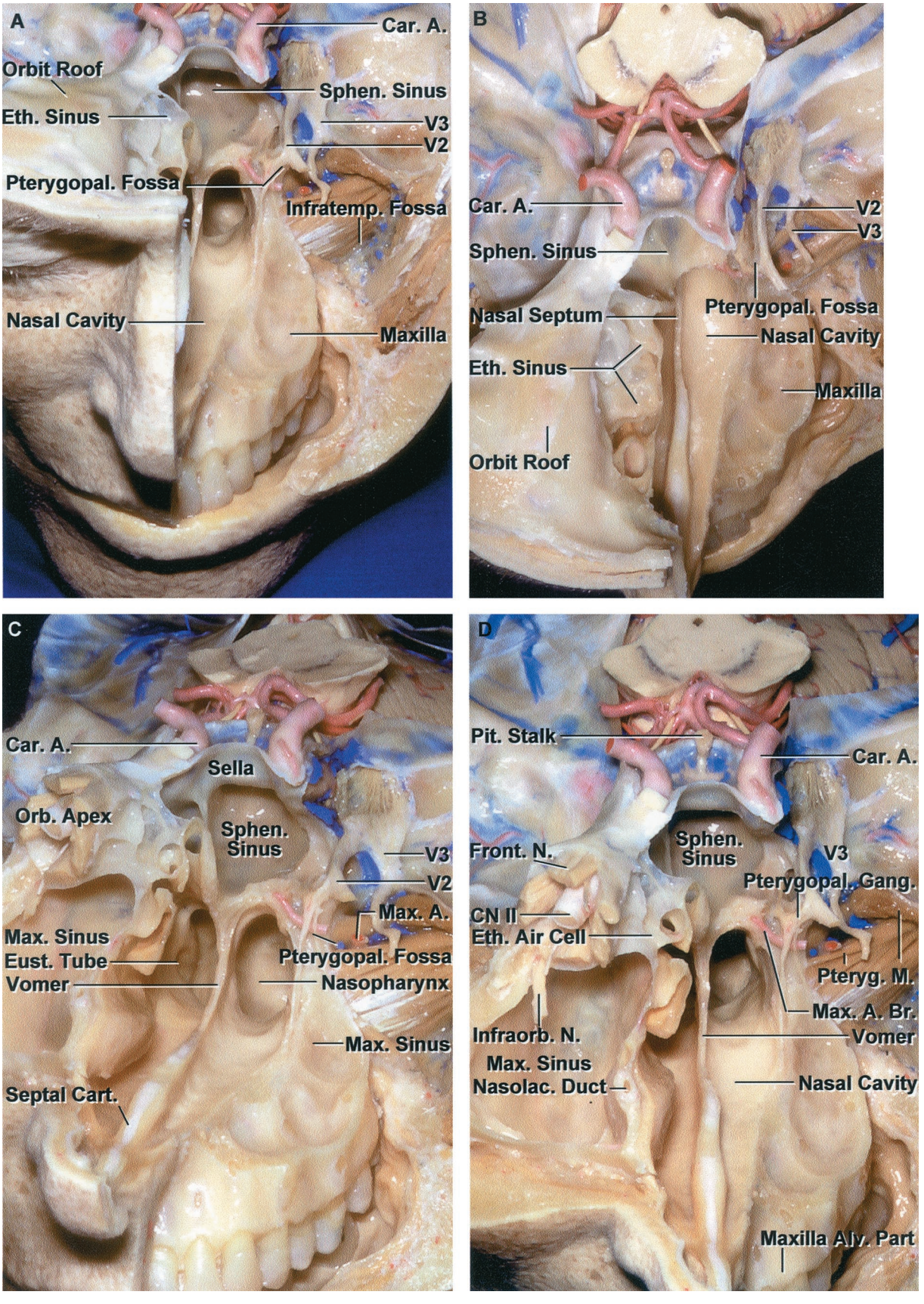

FIGURE 6.1.

nate, an appendage of the ethmoid bone, projects into the superior part of the nasal cavity. The body of the sphenoid bone harbors the sphenoid sinus just below the planum sphenoidale, with the anterior orifices located above the superior turbinate. The orbital roof is formed by the lesser sphenoid wing and by the orbital plate of the frontal bone; the lateral wall is formed by the greater sphenoid wing and the zygomatic bone; the inferior wall is formed by the zygomatic, maxillary, and palatine bones; and the medial wall is formed by maxillary, lacrimal, and ethmoid bones (9). The main foramina of the region are the anterior and posterior ethmoidal foramen located in the superomedial orbital wall, transmitting the anterior and posterior ethmoidal nerves and arteries; the supraorbital and supratrochlear notches or foramina, transmitting the arteries and nerves of the same name; and the optic canal, through which the optic nerve and ophthalmic artery pass (*Figs. 6.4, 6.5,* and *6.7*). The superior orbital fissure is located between the lesser and greater wing of the sphenoid bone on the lateral side of the optic canal. The inferior orbital fissure, located between the greater sphenoid wing behind and the maxillary and palatine bones anteriorly, is closed by a fibrous tissue and orbital muscle. Covered with periorbita and filled with a great amount of fat, the orbit is divided into an anterior space where the globe lies and a posterior space that shelters the nerves, vessels, and muscles behind the globe (4). The annular tendon of Zinn, a fibrous ring that surrounds the central part of the superior orbital fissure and the optic canal, gives attachment to the superior, medial, inferior, and lateral rectus muscles (*Figs. 6.3* and *6.4*). The superior oblique attaches above the annular tendon and the inferior oblique arises from the inferomedial orbital wall just behind the rim. The oculomotor foramen, located inside the annular tendon and through which the oculomotor nerve passes, is located between the upper and lower attachment of the lateral rectus muscle. Just before passing through the superior orbital fissure and the oculomotor foramen in the annular tendon, the oculomotor nerve divides into an upper division supplying the superior rectus and levator muscles and a lower division to the medial and inferior rectus and inferior oblique muscles. The oculomotor nerve gives rise to the parasympathetic motor root to the ciliary ganglion that lies lateral to the optic nerve. The abducens nerve passes through the oculomotor foramen and enters the medial surface of the lateral rectus muscle. The ophthalmic nerve divides just behind the annular tendon into lacrimal and frontal nerves that pass outside the annular tendon, and the nasociliary nerve that passes through the annular tendon. The ophthalmic nerve gives rise to the long ciliary nerves and the sensory root to the ciliary ganglion; the former conveys the sympathetic pupillomotor fibers and the latter conveys corneal sensation. The trochlear nerve passes above and outside the superomedial edge of the annular tendon. The optic nerve passes superior and medial from the globe to reach the optic canal and divides the retro-orbital space into medial and lateral parts. The main arterial supply to the orbit is by the ophthalmic artery and its branches. This artery courses below the optic nerve in the optic canal, crosses to the lateral side of the nerve at the orbital apex, and then courses from lateral to medial above the optic nerve. The main branches are the central retinal artery and the lacrimal, ciliary, ethmoidal, supraorbital, and dorsal nasal arteries, plus numerous muscular branches. The main venous drainage of the orbit is through the superior and inferior ophthalmic veins that exit the orbit by passing outside the annular tendon and through the superior orbital fissure. The lacrimal gland, located in the superolateral part of the orbit, receives its sensory innervation from the lacrimal nerve and its parasympathetic and sympathetic innervation from the greater

FIGURE 6.1. *Anterior and middle cranial base.* A, *on the left side, the floor of the anterior fossa and the upper portion of the maxilla have been removed to expose the structures deep to the anterior and middle cranial fossa. The frontal, ethmoidal, and sphenoid sinuses and the nasal cavity lie below the medial part of the anterior cranial base. The orbit and maxilla are located below the lateral part of the anterior cranial base. The sphenoid sinus and sella are located in the medial part of the middle cranial base, and the infratemporal and pterygopalatine fossa are located below the lateral part of the middle cranial base. The carotid arteries pass upward on the medial part of the middle cranial base and are intimately related to the sphenoid and cavernous sinuses. The infratemporal fossa, which contains branches of the mandibular nerve, pterygoid muscles, pterygoid venous plexus, and maxillary artery, is located below the middle cranial base and greater sphenoid wing. The alveolar process of the maxilla, which encloses the roots of the upper teeth, has been preserved on the left side. The maxillary nerve enters the pterygopalatine fossa, which is located medial to the infratemporal fossa between the posterior wall of the maxilla and the pterygoid process of the sphenoid bone.* B, *superior view of the anterior and middle cranial base. The infratemporal fossa is located posterolateral to the maxilla. The right ethmoid air cells are exposed on the medial side of the right orbit. The nasal cavity extends upward between the ethmoidal sinuses.* C, *oblique anterior view. The facial structures on the right side have been removed to expose the orbital apex located above the maxillary sinus. The walls of the right maxillary sinus form the floor of the orbit, much of the lateral wall of the nasal cavity, and the anterior wall of the pterygopalatine and infratemporal fossa. On the left side, the mandibular nerve enters the infratemporal fossa. The maxillary nerve enters the pterygopalatine fossa, which is located in the lateral wall of the nasal cavity and contains the maxillary nerve, pterygopalatine ganglion, and terminal branches of the maxillary artery.* D, *anterior view. The orbital apex is located above the pterygopalatine fossa. The frontal branch of the ophthalmic nerve passes along the roof of the orbit, and the infraorbital branch of the maxillary nerve courses in the floor of the orbit. The posterior ethmoid air cells are located medial to the orbital apex. The vomer forms the posterior part of the nasal septum and attaches to the maxilla and palatine bones below and to the body of the sphenoid bone above. The sphenoid sinus is located in the middle cranial base below the sella turcica. The upper brainstem is seen in the posterior part of the exposure.* A., *artery;* Alv., *alveolar;* Br., *branch;* Car., *carotid;* Cart., *cartilage;* CN, *cranial nerve;* Eth., *ethmoid;* Eust., *eustachian;* Foss., *fossa;* Front., *frontal;* Gang., *ganglion;* Infraorb., *infraorbital;* Infratemp., *infratemporal;* M., *muscle;* Max., *maxillary;* N., *nerve;* Nasolac., *nasolacrimal;* Orb., *orbital;* Pit., *pituitary;* Pteryg., *pterygoid;* Pterygopal., *pterygopalatine;* Sphen., *sphenoid.*

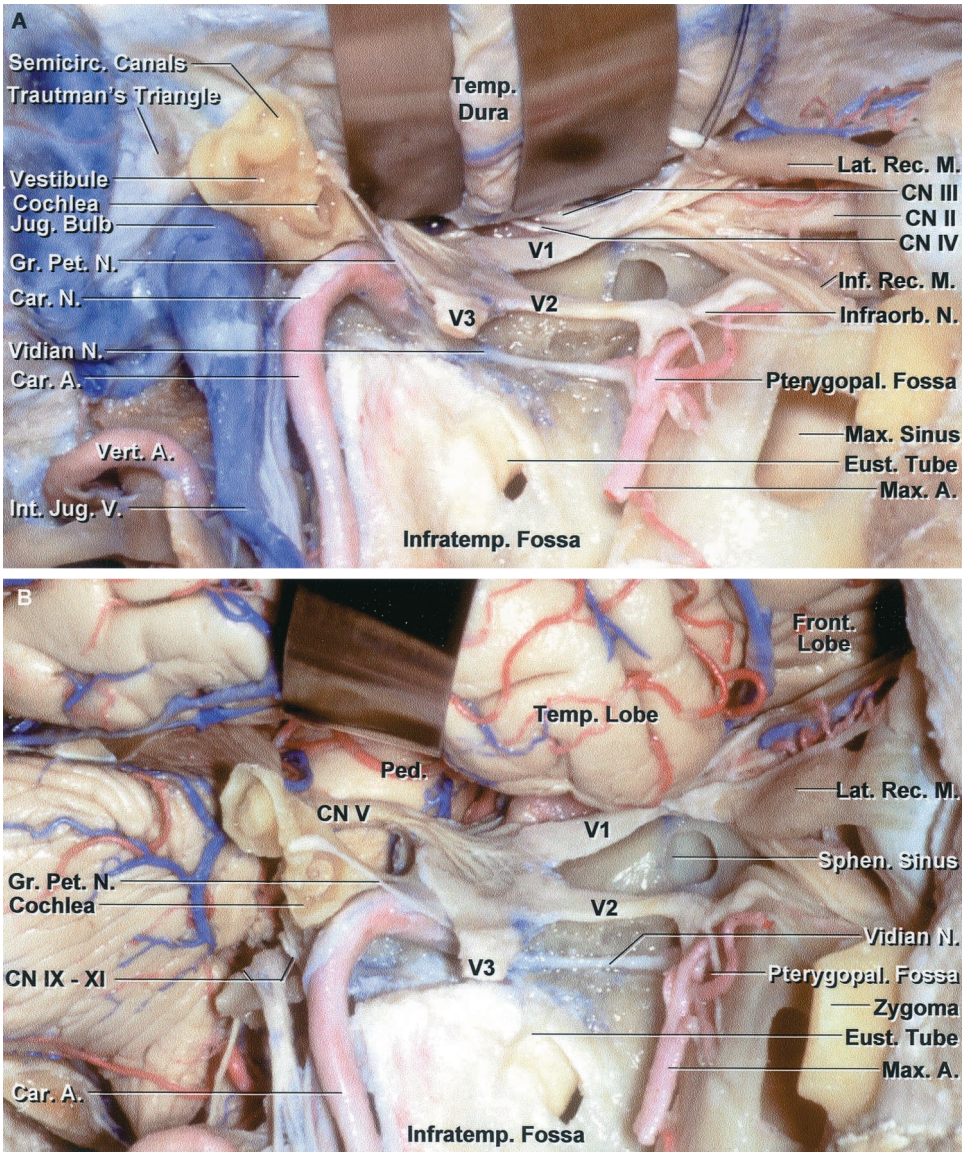

FIGURE 6.2. *Lateral view of the anterior, middle, and posterior cranial base.* A, *the bone and structures lateral to the orbit, infratemporal, and pterygopalatine fossa, and the parapharyngeal space and petrous part of the temporal bone have been removed to expose the structures below the anterior, middle, and posterior cranial base. The orbit and maxillary sinus are located below the anterior cranial base. The infratemporal and pterygopalatine fossae and the parapharyngeal space are located below the middle cranial base, and the suboccipital area is located below the temporal and occipital bones. The first trigeminal division is related to the upper part of the orbit. The second trigeminal branch is related to the lower part of the orbit and maxilla. The mandibular nerve exits the cranium through the foramen ovale and enters the infratemporal fossa. The pterygoid and levator and tensor veli palatini muscles have been removed to expose the eustachian tube and its opening into the nasal pharynx. The lateral part of the temporal bone has been removed to expose the cochlea, vestibule, and semicircular canals. The petrous carotid passes upward and turns medially below the cochlea. The sigmoid sinus turns downward under the semicircular canals and vestibule where the jugular bulb is located. The segment of the vertebral artery passing behind the atlanto-occipital joint is located below the posterior cranial base.* B, *the dura has been opened to show the relationships of the frontal and temporal lobes and the cerebellum to the cranial base. The orbit is exposed below the frontal lobe. The pterygopalatine and infratemporal fossae and the temporal bone are located below the temporal lobe. The jugular bulb and internal jugular vein have been removed to show Cranial Nerves IX through XII exiting the jugular foramen.* A., *artery;* Car., *carotid;* CN, *cranial nerve;* Eust., *eustachian;* Front., *frontal;* Gr., *greater;* Inf., *inferior;* Infraorb., *infraorbital;* Infratemp., *infratemporal;* Int., *internal;* Jug., *jugular;* Lat., *lateral;* M., *muscle;* Max., *maxillary;* N., *nerve;* Ped., *peduncle;* Pet., *petrosal;* Pterygopal., *pterygopalatine;* Rec., *rectus;* Semicirc., *semicircular;* Sphen., *sphenoid;* Temp., *temporal;* V., *vein;* Vert., *vertebral.*

FIGURE 6.3. *Osseous relationships of the anterior and middle cranial base.* A, *on the endocranial surface, the anterior and middle cranial base corresponds to the anterior and middle fossae. The anterior part of the cranial base is separated from the middle fossa by the sphenoid ridge and the chiasmatic sulcus. The middle cranial base is separated from the posterior cranial base by the dorsum sellae and the petrous ridges. The upper surface of the anterior cranial base is formed by the frontal bone, which roofs the orbit; the ethmoid bone, which is interposed between the frontal bones and is the site of the cribriform plate; and the lesser wing and anterior part of the body of the sphenoid, which forms the posterior part of the floor of the anterior fossa. The upper surface of the middle cranial base floor is formed by the greater sphenoid wing and posterior two-thirds of the sphenoid body anteriorly and the upper surface of the temporal bone posteriorly. The posterior part of the cranial base is formed by the temporal and occipital bones. The cribriform plate, sella, and clivus are located in the medial part of the cranial base. The lateral part of the cranial base is located above the orbits, pterygopalatine and infratemporal fossae, and the subtemporal and lateral part of the suboccipital areas.* B, *exocranial surface of the cranial base. This surface is more complicated than the endocranial surface. It is not demarcated into three well-defined fossae as is the endocranial surface. The exocranial surface is formed by the maxilla, the zygomatic, palatine, sphenoid, temporal, and occipital bones, and the vomer. The maxilla, orbits, and nasal cavity are located below the anterior fossa. The anterior part of the hard palate is formed by the maxilla and the posterior part is formed by the palatine bone. The anterior part of the zygomatic arch is formed by the zygoma and the posterior part by the squamosal part of the temporal bone. The mandibular fossa on the lower surface of the temporal squama is located below the posterior part of the middle fossa. The vomer attaches to the lower part of the body of the sphenoid and forms the posterior part of the nasal septum.* C, *anterior view. The orbital rim is formed by the frontal bone, zygoma, and maxilla. The roof of the orbit is formed by the frontal and sphenoid bones; the lateral wall by the greater sphenoid wing and the zygomatic bone; the*

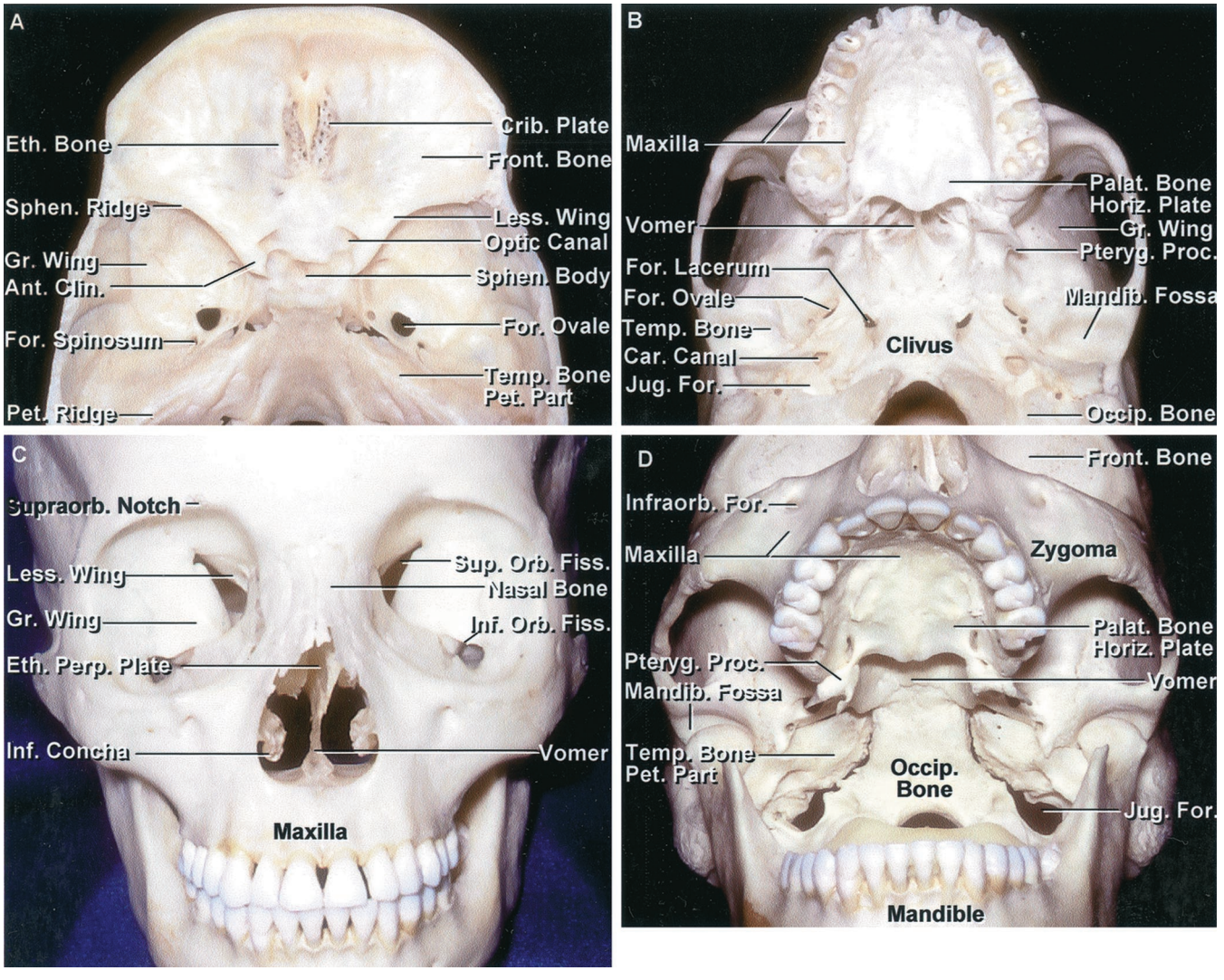

FIGURE 6.3. *Continued*

floor by the maxilla, except for a small part of the posterior floor formed by the palatine bone; and the medial wall of the orbit by the maxilla and lacrimal and ethmoid bones. The nasal bone is interposed above the anterior nasal aperture between the maxillae. The nasal cavity is located between the ethmoid bones above and the maxillae, palatine bones, and sphenoid pterygoid process below. It is roofed by the frontal and ethmoid bones and the floor is formed by the maxillae and palatal bones. The osseous nasal septum is formed by the perpendicular ethmoid plate and the vomer. The inferior concha is a separate bone, and the middle and superior conchae are appendages of the ethmoid bone. The orbit opens through the superior orbital fissure into the middle fossa and through the inferior orbital fissure into the pterygopalatine and infratemporal fossae. D, *anteroinferior view of the cranial base. The anterior part of the hard palate is formed by the maxillae and the posterior part is formed by the horizontal plate of the palatine bone. The vomer forms the posterior part of the nasal septum and divides the posterior nasal aperture in the midline. The infratemporal fossa is located below the greater sphenoid wing. The clivus is formed above by the body of the sphenoid bone and below by the basal part of the occipital bone. The petrous apex is interposed between the greater sphenoid wing and the clival part of the occipital bone. The mandibular condyles are set in the mandibular fossa, located below the posterior part of the middle fossa on the inferior surface of the squamosal part of the temporal bone.* E, *the cranial base is formed, in the lateral view, from anterior to posterior, by the maxilla and the frontal, zygomatic, sphenoid, temporal, and occipital bones. The zygomatic and frontal bones form the lateral part of the orbital rim. The pterion on the greater sphenoid wing marks the lateral end of the sphenoid ridge. The keyhole, a burr hole that exposes the dura of the anterior fossa and the periorbita in its depth, is located just above the frontozygomatic suture, behind the superior temporal line. The zygomatic arch is formed by the zygomatic bone and the squamosal part of the temporal bone. The condylar fossa, in which the mandibular condyle sits, is positioned above on the lower surface of the squamosal part of the temporal bone and posteriorly on the tympanic part of the temporal bone. The lower end of the pterygoid process unites with the posterior maxilla, but above, the process separates from the maxilla to create the pterygomaxillary fissure, which opens medially into the pterygopalatine fossa.* F, *inferior view of a cross extending through the maxillae. The maxilla, which contains a large air-filled sinus, forms the anteromedial wall of the infratemporal fossa, the anterior wall of the pterygopalatine fossa, the lateral wall of the nasal cavity, the anterior portion of the hard palate, and much of the floor of the orbit. The pterygopalatine fossa is located between the pterygoid process and the posterior maxillary wall. The nasal septum is formed anteriorly and above by the perpendicular ethmoid plate and posteriorly and below by the vomer.* G, *the right half of the maxilla and zygomatic arch has been removed. The inferior orbital fissure is located between the greater sphenoid wing and the maxilla. The right orbital roof and ethmoid air cells have been preserved. The right pterygoid process has been removed at its junction with the sphenoid body. The roof of the vidian canal, which extends through the base of the pterygoid process, has been preserved.* H, *anteroinferior view of the cranial base. The midline of the cranial base is formed, from anterior to posterior, by the frontal, ethmoid, sphenoid, and* *(Legend continues on next page.)*

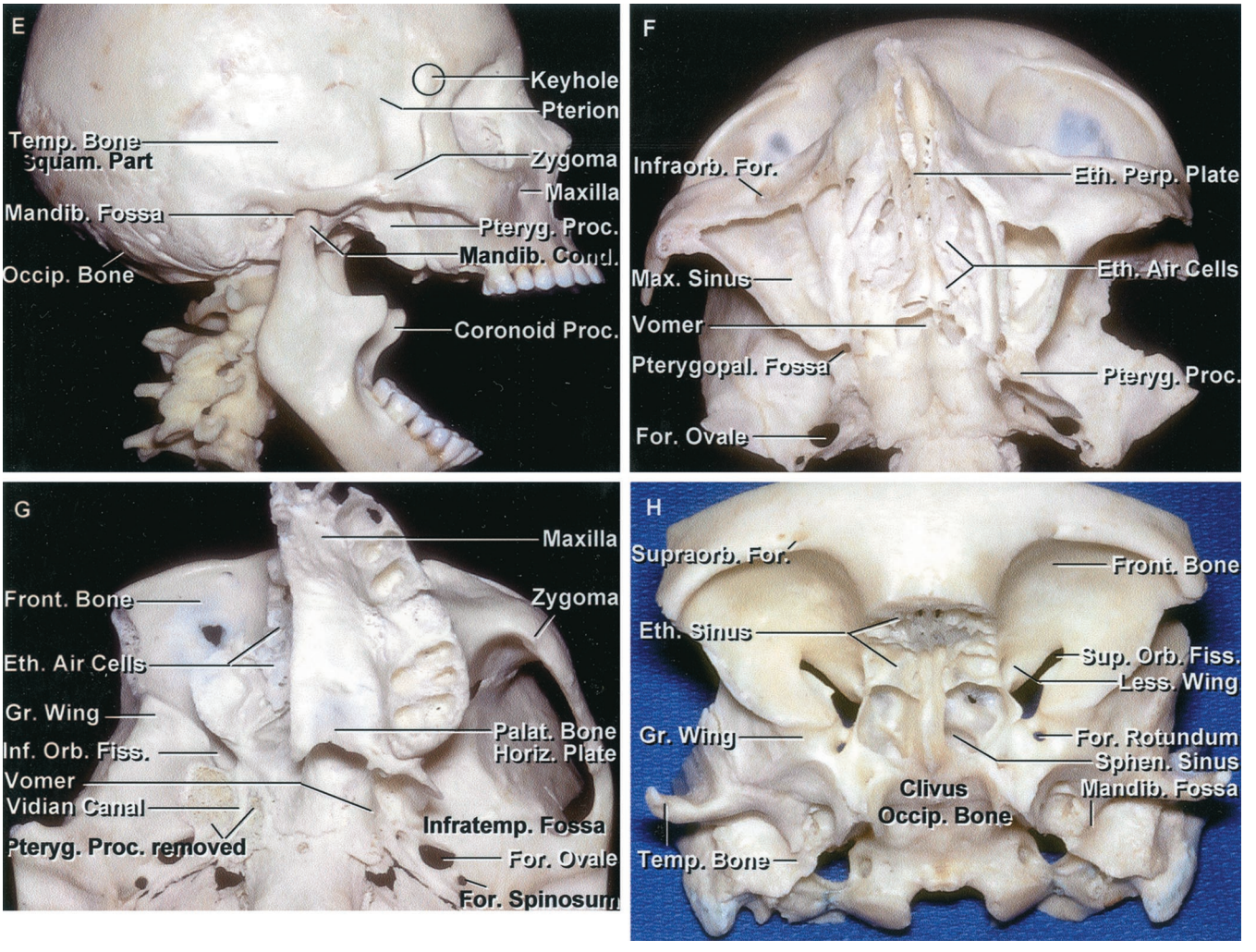

FIGURE 6.3. *Continued*

occipital bones. The roof the orbit is formed by the frontal bone and lesser sphenoid wing. The ethmoidal sinuses are located anterior to the sphenoid sinus between the orbits. I, *lateral view of the pterygomaxillary fissure. The pterygomaxillary fissure is located between the posterior maxillary wall and the pterygoid process. The pterygomaxillary fissure opens from the infratemporal fossa into the pterygopalatine fossa. The mandibular fossa is formed above by the squamosal part of the temporal bone and posteriorly by the tympanic part of the temporal bone, which also forms the anterior and lower wall of the external auditory meatus.* J, *anterior view through the maxillary sinus. The anterior and posterior walls of the maxillary sinus have been removed to expose the pterygoid process, which forms the posterior wall of the pterygopalatine fossa. The lower part of the superior orbital fissure is seen through the upper part of the maxillary sinus. The foramen rotundum opens into the pterygopalatine fossa and is separated from the superior orbital fissure by the maxillary strut. The vidian canal opens through the pterygoid process below the medial to the foramen rotundum.* K, *anterior view of a cranium sectioned through the posterior part of the ethmoid and maxillary sinuses. The ethmoidal sinuses are located anterior to the sphenoid body and sphenoid sinus. The part of the posterior wall of the maxilla forming the anterior wall of the pterygopalatine fossa has been preserved. The perpendicular plate of the palatine bone forms the medial wall of the pterygopalatine fossa. The ethmoidal sinus overlaps the lateral margin of the sphenoid ostia. The superior orbital fissure is located between the lesser and greater sphenoid wing and sphenoid body. The infratemporal fossa is located below the greater wing of the sphenoid. The temporal fossa, which contains the temporalis muscle, is located between the greater wing and the zygomatic arch.* L, *the posterior wall of the maxilla and ethmoidal sinuses have been removed to expose the sphenoid sinus and pterygopalatine fossa. The lateral wing of the sphenoid sinus extends laterally into the pterygoid process below the foramen rotundum. Septae divide the sphenoid sinus. The vidian canal opens through the base of the pterygoid process into the pterygopalatine fossa.* M, *the osseous cross section has been extended posteriorly to just in front of the superior orbital fissure. The optic strut extends from the base of the anterior clinoid to the sphenoid body and separates the optic canal from the superior orbital fissure. The foramen rotundum is located below the medial part of the superior orbital fissure. The vidian canal opens into the pterygopalatine fossa below and medial to the foramen rotundum.* N, *posterior view of the specimen in* K *showing the anterior part of the middle fossa from behind. The superior orbital fissure is positioned below the lesser sphenoid wing. The optic strut extends from the base of the anterior clinoid to the sphenoid body and separates the optic canal from the superior orbital fissure. The greater wing extends laterally to form part of the floor and anterior and lateral wall of the middle fossa. The medial and lateral pterygoid plates project backward from the pterygoid process. The horizontal plate of the palatine bone forms the posterior part of the hard plate. The posterior opening into the vidian canal is located above the medial pterygoid plate and extends forward through the pterygoid process at its junction with the shenoid body.* Ant., *anterior;* Car., *carotid;* Clin., *clinoid;* Cond., *condyle;* Crib., *cribriform;* Eth., *ethmoid;* Fiss., *fissure;* For., *foramen;* Front., *frontal;* Gr., *greater;* Horiz., *horizontal;* Inf., *inferior;* Infraorb., *infraorbital;* Infratemp., *infratemporal;* Jug., *jugular;* Lat., *lateral;* Less., *lesser;* Mandib., *mandibular;* Max., *maxillary;* Med., *medial;* Occip., *occipital;* Orb., *orbital;* Palat., *palatine;* Perp., *perpendicular;* Pet., *petrosal;* Post., *posterior;* Proc., *process;* Pteryg., *pterygoid;* Pterygomax., *pterygomaxillary;* Pterygopal., *pterygopalatine;* Sphen., *sphenoid;* Squam., *squamosal;* Sup., *superior;* Supraorb., *supraorbital;* Temp., *temporal.* *(Figure continues on next page.)*

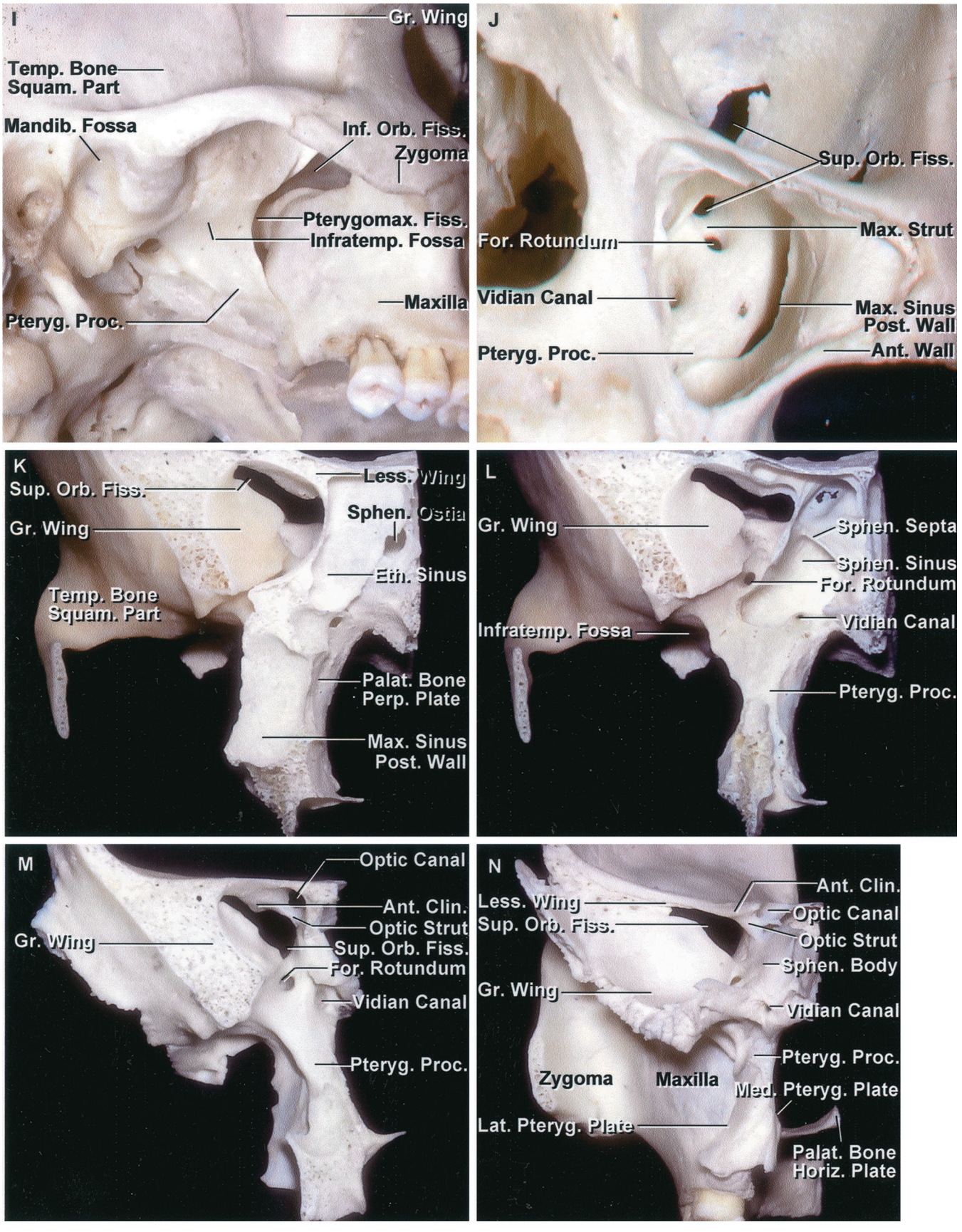

FIGURE 6.3. *Continued*

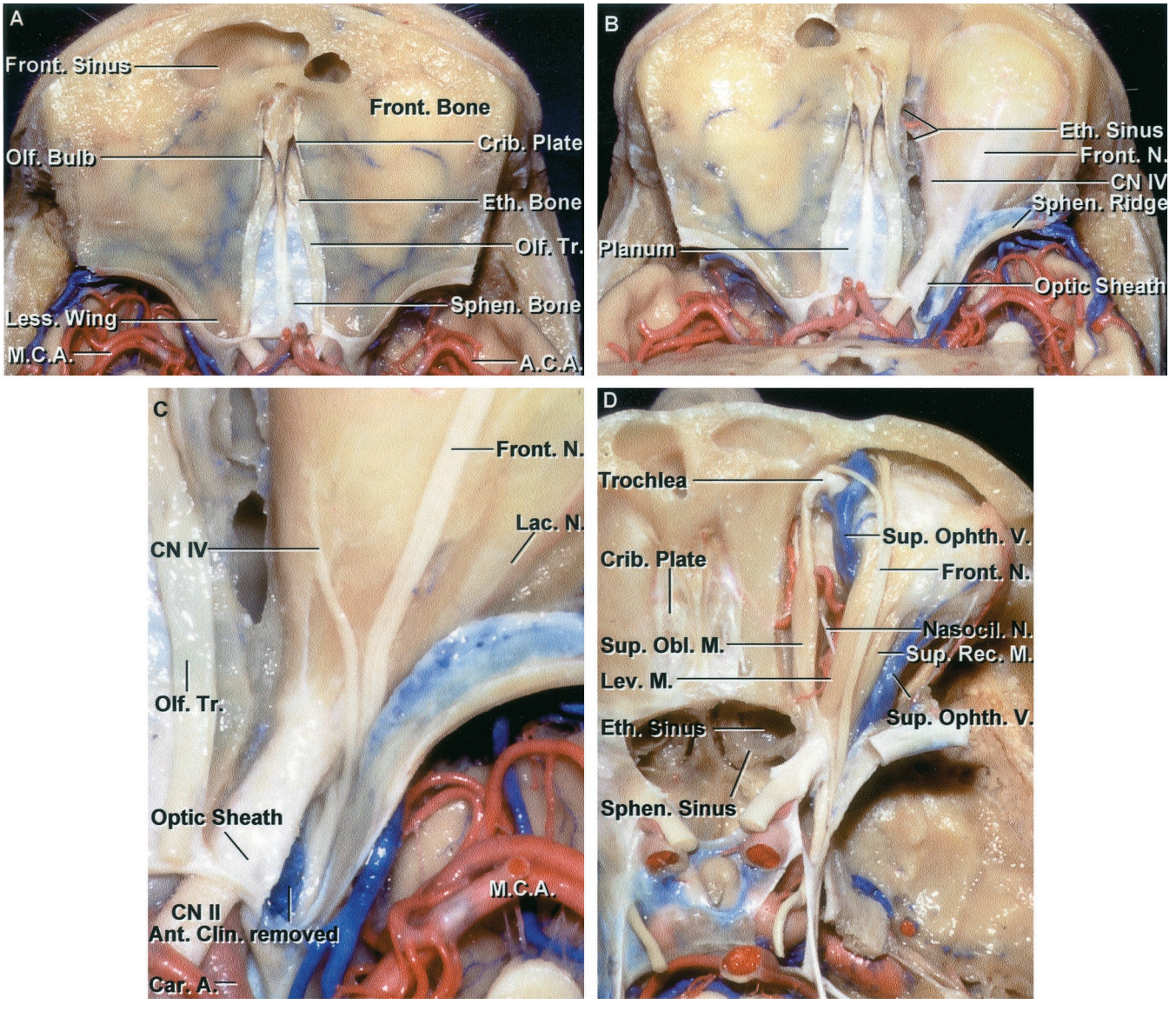

FIGURE 6.4. *Anterior fossa, orbit, and perinasal sinuses.* A, *superior view. The anterior cranial fossa is formed by the frontal, ethmoid, and sphenoid bones. The frontal bone splits anteriorly into two laminae, which enclose the frontal sinus. The ethmoid bones, which contain the ethmoid air cells and are the site of the crista galli and cribriform plate, are interposed between the frontal bones. Posteriorly, the frontal and ethmoid bones join the sphenoid bone, which encloses the sphenoid sinus and has the pituitary fossa on its upper surface. The olfactory bulbs and tracts have been preserved.* B, *the roof of the right orbit has been removed to expose the periorbita. The right anterior clinoid process and roof of the optic canal have been removed to expose the optic nerve enclosed within the optic sheath as it passes through the optic canal to reach the orbital apex.* C, *the frontal, trochlear, and lacrimal nerves can be seen through the periorbita. The trochlear nerve crosses above the orbital apex to reach the superior oblique muscle.* D, *the orbital fat has been removed and the sphenoid sinus opened. The frontal branch of the ophthalmic nerve courses above the levator muscle. The ophthalmic artery, nasociliary nerve, and superior ophthalmic vein are located medially in the anterior part of the orbit and cross between the optic nerve and superior rectus muscle to be situated on the lateral side of the optic nerve at the orbital apex.* E, *enlarged view. The superior oblique muscle has been retracted medially to expose the anterior and posterior ethmoidal branches of the ophthalmic artery and nasociliary nerve entering the anterior and posterior ethmoidal canal. The trochlea of the superior oblique muscle is attached to the superomedial margin of the orbit just behind the orbital rim. The frontal nerve divides into supraorbital and supratrochlear branches.* F, *the levator and superior rectus muscle have been retracted posteriorly to expose the nasociliary nerve, ophthalmic artery, and superior ophthalmic vein passing above the optic nerve.* G, *superior view of the anterior fossa in another specimen. The nasal cavity, sphenoid sinus, and orbit have been unroofed. The dura has been removed from the roof and lateral wall of the cavernous sinus. The medial strip below the anterior cranial base is formed, from anterior to posterior, by the frontal, ethmoidal, and sphenoid sinuses. The orbital fat has been removed to expose the intraorbital structures. The frontal nerve courses above the levator muscle. The trochlear nerve passes above the annular tendon to reach the superior oblique muscle. The trochlea of the superior oblique muscle is attached in the superomedial part of the anterior orbit. The lacrimal nerve courses above the lateral rectus muscle. The ophthalmic artery and superior ophthalmic vein are seen in the interval between the levator and superior oblique muscle. The anterior and posterior eth-*

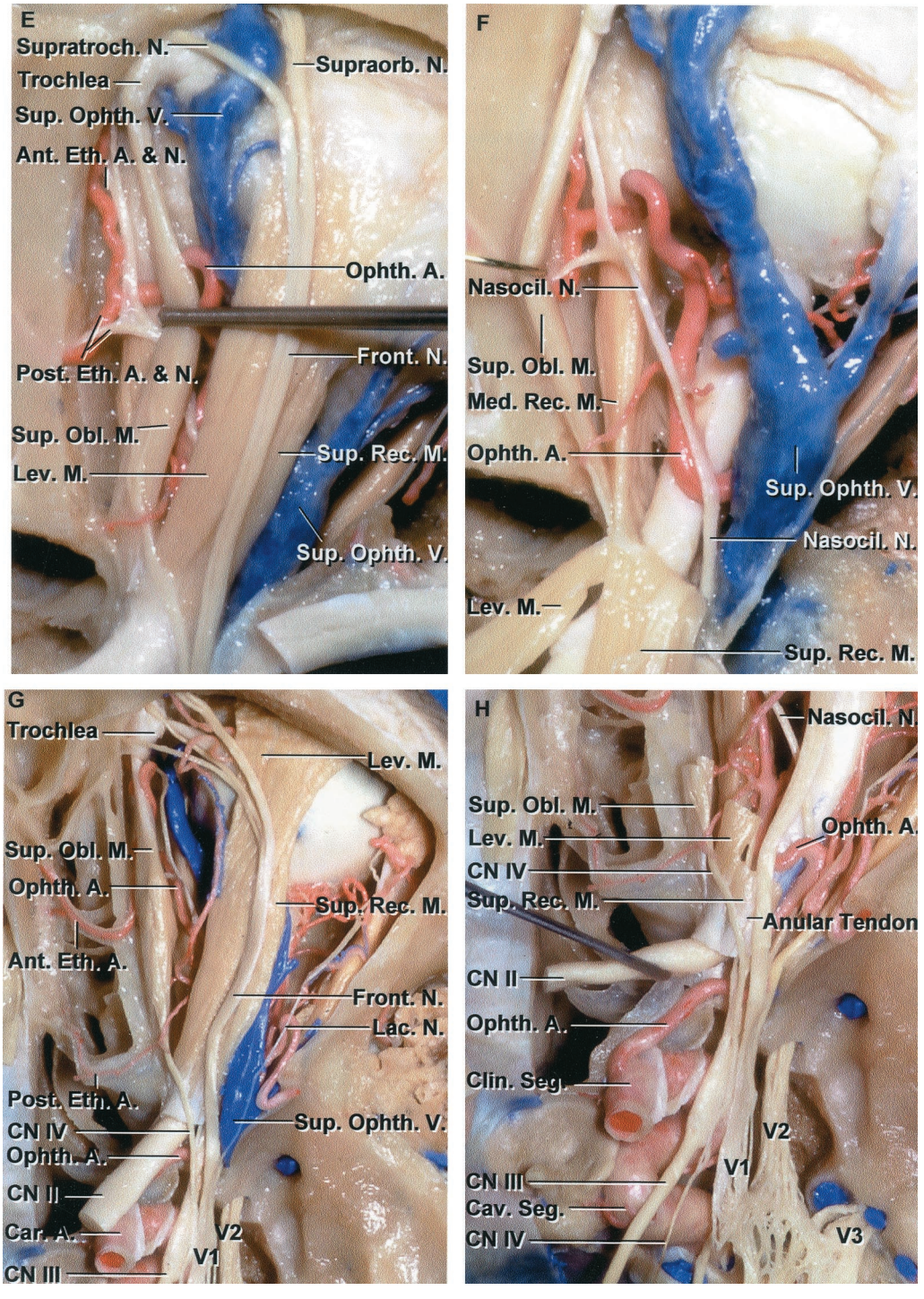

FIGURE 6.4. *Continued*
moidal branches of the ophthalmic artery course through the anterior and posterior ethmoidal canals. H, enlarged view of cavernous sinus, superior orbital fissure, and orbital apex. The superior oblique, levator, and superior rectus muscles have been removed. The ophthalmic artery and nasociliary nerve enter the orbital apex on the lateral side of the optic nerve and cross between the optic nerve and superior rectus muscle to reach the medial part of the orbit. The optic nerve has been elevated to expose the ophthalmic artery, which courses through the optic canal on the lower side of the optic nerve and enters the orbital apex on the lateral side of the optic nerve. The ophthalmic artery then crosses medially between the optic nerve and superior rectus muscle, as does the nasociliary nerve. The maxillary nerve exits the foramen rotundum to enter the pterygopalatine fossa, and the mandibular nerve exits the foramen ovale to enter the infratemporal fossa. A., *artery;* A.C.A., *anterior cerebral artery;* Ant., *anterior;* Car., *carotid;* Cav., *cavernous;* Clin., *clinoid;* CN, *cranial nerve;* Crib., *cribriform;* Eth., *ethmoid, ethmoidal;* Front., *frontal;* Lac., *lacrimal;* Less., *lesser;* Lev., *levator;* M., *muscle;* M.C.A., *middle cerebral artery;* Med., *medial;* N., *nerve;* Nasocil., *nasociliary;* Obl., *oblique;* Olf., *olfactory;* Ophth., *ophthalmic;* Post., *posterior;* Rec., *rectus;* Seg., *segment;* Sphen., *sphenoid;* Sup., *superior;* Supraorb., *supraorbital;* Supratroch., *supratrochlear;* Tr., *tract;* V., *vein.*

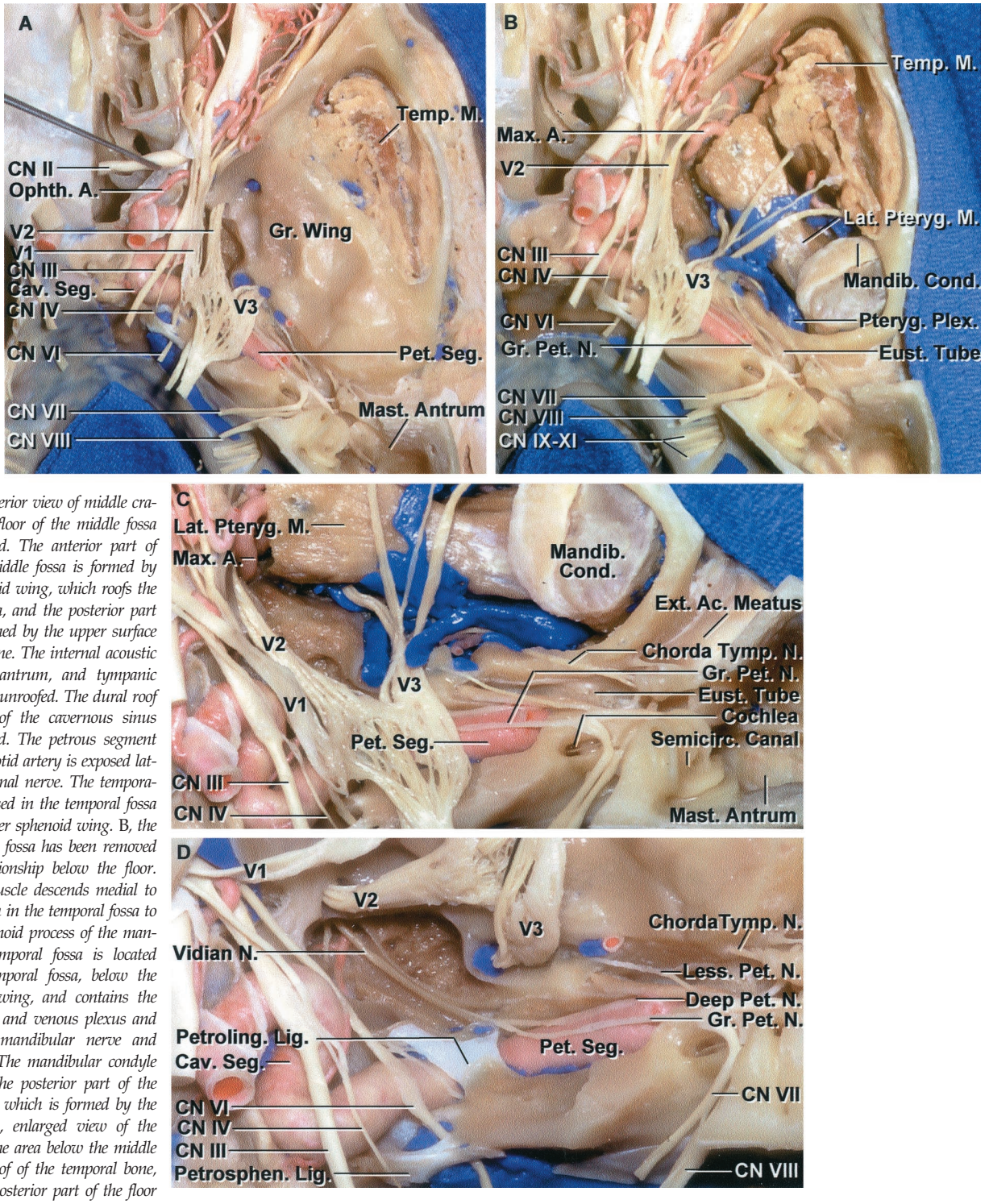

FIGURE 6.5. *Superior view of middle cranial base.* A, *the floor of the middle fossa has been preserved. The anterior part of the floor of the middle fossa is formed by the greater sphenoid wing, which roofs the infratemporal fossa, and the posterior part of the floor is formed by the upper surface of the temporal bone. The internal acoustic meatus, mastoid antrum, and tympanic cavities have been unroofed. The dural roof and lateral wall of the cavernous sinus have been removed. The petrous segment of the internal carotid artery is exposed lateral to the trigeminal nerve. The temporalis muscle is exposed in the temporal fossa lateral to the greater sphenoid wing.* B, *the floor of the middle fossa has been removed to show the relationship below the floor. The temporalis muscle descends medial to the zygomatic arch in the temporal fossa to insert on the coronoid process of the mandible. The infratemporal fossa is located medial to the temporal fossa, below the greater sphenoid wing, and contains the pterygoid muscles and venous plexus and branches of the mandibular nerve and maxillary artery. The mandibular condyle is located below the posterior part of the middle fossa floor, which is formed by the temporal bone.* C, *enlarged view of the posterior part of the area below the middle fossa floor. The roof of the temporal bone, which forms the posterior part of the floor of the middle fossa, has been opened to expose the mastoid antrum, eustachian tube, semicircular canals, cochlea, the nerves in the internal acoustic meatus, and the mandibular condyle.* D, *the trigeminal nerve has been reflected forward. The abducens nerve passes below the petrosphenoid ligament and through Dorello's canal. The petrous segment of the carotid passes below the petrolingual ligament to enter the cavernous sinus. The greater petrosal nerve is joined by the deep petrosal branch of the carotid sympathetic plexus to form the vidian nerve, which passes forward in the vidian canal, which has been unroofed. The lesser petrosal nerve arises from the tympanic branch of the glossopharyngeal nerve, which passes across the promontory in the tympanic nerve plexus and regroups to cross the floor of the middle fossa, exiting the cranium to provide parasympathetic innervation through the otic ganglion to the parotid gland. The tensor tympani muscle and eustachian are layered, with the former above the latter, along and separated from the anterior surface of the petrous carotid by a thin layer of bone.* A., *artery;* Ac., *acoustic;* Cav., *cavernous;* CN, *cranial nerve;*

and deep petrosal nerves. The petrosal nerves join to form the vidian nerve that enters the pterygopalatine ganglion, which sends branches to the zygomatic nerve that anastomoses with the lacrimal nerve to reach the gland.

MIDDLE CRANIAL BASE

Endocranial Surface

The endocranial surface of the middle portion of the middle cranial base, formed by the sphenoid and temporal bones, has medial and lateral parts (*Figs. 6.2, 6.3, 6.5,* and *6.9*). The medial part is formed by the body of the sphenoid bone, the site of the tuberculum sellae, pituitary fossa, middle and posterior clinoid processes, the carotid sulcus, and the dorsum sellae (*Fig. 6.8*). The lateral part is formed by the lesser and greater sphenoid wings, with the superior orbital fissure between them (*Figs. 6.3* and *6.5*). The lesser wing is connected to the body of the sphenoid bone by an anterior root, which forms the roof of the optic canal, and by a posterior root, also called the optic strut, which forms the floor of the optic canal and separates the optic canal from the superior orbital fissure (*Fig. 6.3*). The greater wing forms the largest part of the endocranial surface of the middle fossa, with the squamosal and the petrosal parts of the temporal bone completing this surface. The superior orbital fissure transmits the oculomotor, trochlear, ophthalmic, and abducens nerves, a recurrent meningeal artery, and the superior and inferior ophthalmic veins (5). The maxillary and mandibular nerves pass through the foramen rotundum and ovale, both located in the greater wing of the sphenoid. The not infrequently occurring sphenoidal emissary foramen, located anteromedial to the foramen spinosum, gives passage to a vein connecting the cavernous sinus and the pterygoid venous plexus. The upper surface of the petrous bone is grooved along the course of the greater and lesser petrosal nerves (*Fig. 6.5*) (6). The carotid canal extends upward and medially and provides passage to the internal carotid artery and carotid sympathetic nerves in their course to the cavernous sinus. The posterior trigeminal root reaches the middle fossa and the impression on the upper surface of the petrous bone where Meckel's cave and the semilunar ganglion sit. The roof of the carotid canal opens below the trigeminal ganglion near the distal end of the carotid canal (*Figs. 6.5, 6.6,* and *6.9*). The arcuate eminence approximates the position of the superior semicircular canal. A thin lamina of bone, the tegmen tympani, roofs the area above the middle ear and auditory ossicles on the anterolateral side of the arcuate eminence. The internal auditory canal can be identified below the floor of the middle fossa by drilling along a line approximately 60 degrees medial to the arcuate eminence, near the middle portion of the angle between the greater petrosal nerve and arcuate eminence (*Fig. 6.5*). The petrous apex, medial to the internal acoustic meatus, is free of important structure.

The middle cranial base can be divided into a lateral portion, containing the middle cranial fossa and the upper surface of the temporal bone, and a medial portion, the sellar and the parasellar region, where the pituitary gland and cavernous sinus are located (*Figs. 6.3* and *6.8*). The basal temporal lobe, formed by the parahippocampal, occipitotemporal, inferotemporal gyri, and uncus and supplied by branches of the anterior choroidal, posterior cerebral, and middle cerebral arteries, rests on the middle fossa floor. The cavernous sinus, situated between two layers of dura, is formed by an outer layer facing the brain, and an inner or periosteum layer, covering the bone of the middle fossa (3). The inner layer splits into two parts when it reaches the cavernous sinus; one invests the nerves and forms the inner layer of the lateral wall, and the medial layer faces the sphenoid body and forms the medial wall of the sinus. The same inner layer invests the oculomotor, trochlear, and ophthalmic nerves and the distal part of the abducens nerve in their course through the lateral wall of the cavernous sinus. The internal carotid artery, with its vertical posterior bend, horizontal anterior bend, and clinoidal segments, runs inside the cavernous sinus. The clinoidal segment of the internal carotid artery is between the distal and proximal dural rings and is covered by a layer of dura, which forms a collar, the carotid collar, around the artery (11). In a previous study, we found that the venous plexus, forming the cavernous sinus, extends through the lower ring, inside the collar of dura, and around the clinoid segment to the level of the upper ring. The meningohypophyseal trunk, with its tentorial, inferior hypophyseal, and dorsal meningeal branches, and the inferolateral trunk, also called the artery of the inferior cavernous sinus, arise from the intracavernous carotid artery. The proximal abducens nerve passes through Dorello's canal, located below the petrosphenoid ligament, and receives sympathetic branches from the internal carotid nerve, which pass to the ophthalmic nerve to enter the orbit.

The main venous afferents to the cavernous sinus are the superior and inferior ophthalmic veins and the sphenoparietal sinus (*Figs. 6.4* and *6.7*). Several venous compartments, named according to their relationship to the cavernous carotid artery, empty mainly into the basilar and superior and inferior petrosal sinuses, or, by way of the foramina in the middle fossa floor, into the pterygoid venous plexus (10). The sella houses the pituitary gland and is partially closed above by the diaphragma sellae. Anterolateral to the diaphragm, the carotid cave, a dural depression at the level of the distal dural ring, extends downward medial to the initial intradural segment of the internal carotid artery. The tensor tympani muscle and the eustachian tube cross medial to the foramen spinosum, below the floor of the middle fossa, and anterior to the horizontal segment of the petrous carotid (*Fig. 6.5*). The greater petrosal nerve crosses the area above and parallel to the petrous carotid artery, laterally joins the geniculate ganglion, and medi-

Cond., *condyle;* Eust., *eustachian;* Ext., *external;* Gr., *greater;* Lat., *lateral;* Less., *lesser;* Lig., *ligament;* M., *muscle;* Mandib., *mandibular;* Mast., *mastoid;* Max., *maxillary;* N., *nerve;* Ophth., *ophthalmic;* Pet., *petrosal;* Petroling., *petrolingual;* Petrosphen., *petrosphenoid;* Plex., *plexus;* Pteryg., *pterygoid;* Seg., *segment;* Semicirc., *semicircular;* Temp., *temporalis;* Tymp., *tympani.*

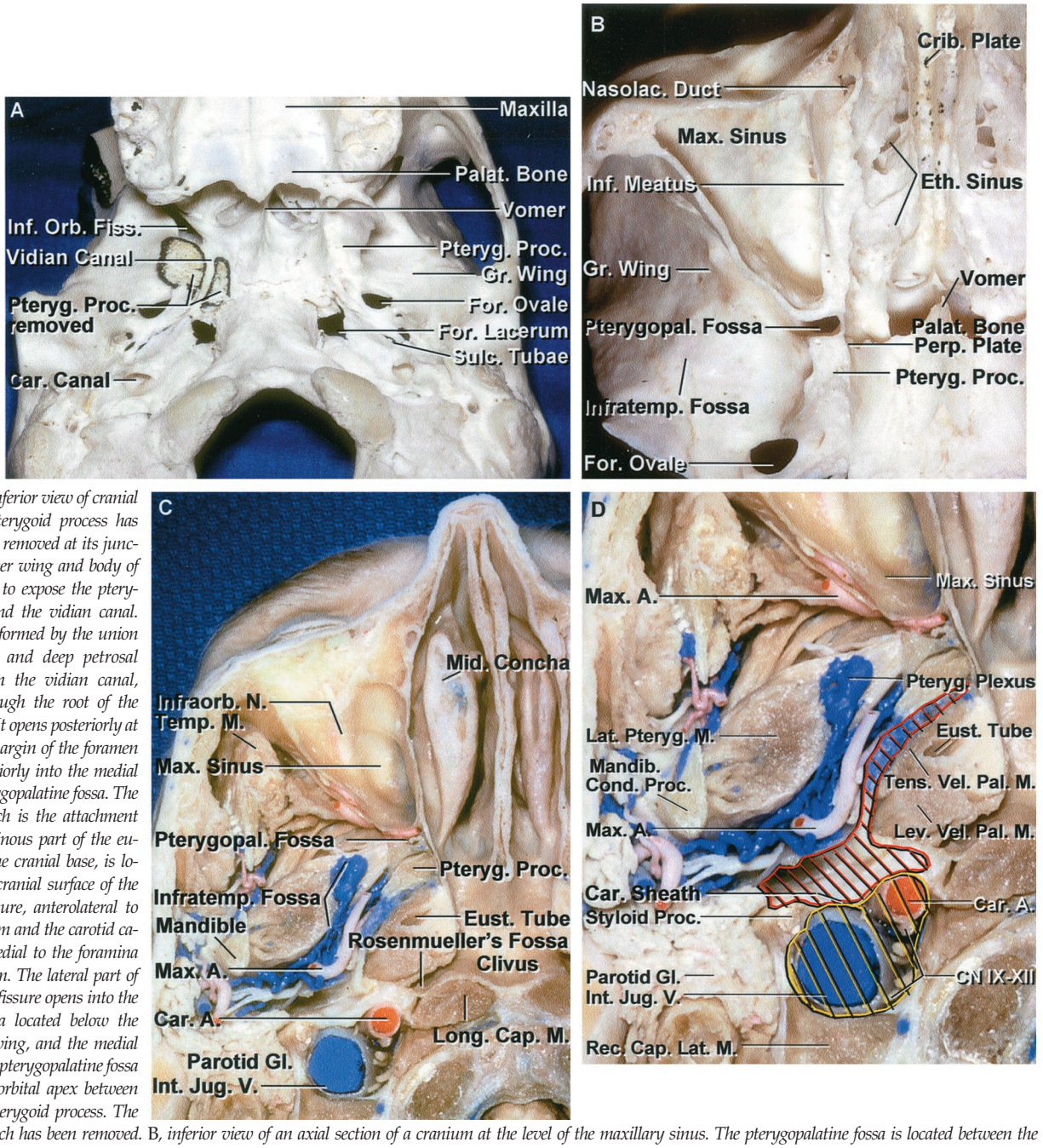

FIGURE 6.6. A, *inferior view of cranial base. The right pterygoid process has been sectioned and removed at its junction with the greater wing and body of the sphenoid bone to expose the pterygopalatine fossa and the vidian canal. The vidian nerve, formed by the union of the superficial and deep petrosal nerves, courses in the vidian canal, which passes through the root of the pterygoid process. It opens posteriorly at the anterolateral margin of the foramen lacerum and anteriorly into the medial portion of the pterygopalatine fossa. The sulcus tubae, which is the attachment site of the cartilaginous part of the eustachian tube to the cranial base, is located on the extracranial surface of the sphenopetrosal fissure, anterolateral to the foramen lacerum and the carotid canal, and posteromedial to the foramina ovale and spinosum. The lateral part of the inferior orbital fissure opens into the infratemporal fossa located below the greater sphenoid wing, and the medial part opens into the pterygopalatine fossa located below the orbital apex between the maxilla and pterygoid process. The right zygomatic arch has been removed.* B, *inferior view of an axial section of a cranium at the level of the maxillary sinus. The pterygopalatine fossa is located between the posterior wall of the maxillary sinus and the pterygoid process. The roof of the maxillary sinus forms the floor of the orbit. The infratemporal fossa is located below the greater wing of the sphenoid and opens medially into the pterygopalatine fossa. The medial wall of the pterygopalatine fossa is formed by the perpendicular plate of the palatine bone, which has an opening, the sphenopalatine foramen, through which branches of the maxillary artery and nerve reach the nasal cavity. The ethmoid air cells are located medial to the orbit.* C, *inferior views of an axial section of the cranial base. The infratemporal fossa is surrounded by the maxillary sinus anteriorly, the mandible laterally, the pterygoid process anteromedially, and the parapharyngeal space posteromedially. It contains the mandibular nerve and maxillary artery and their branches, the medial and lateral pterygoid muscles, and the pterygoid venous plexus. The posterior nasopharyngeal wall is separated from the lower clivus by the longus capitis, and the nasopharyngeal roof rests against the upper clivus and floor of the sphenoid sinus.* D, *enlarged view with highlighting of the pre-* (red) *and poststyloid* (yellow) *compartments of the parapharyngeal space. The styloid diaphragm, formed by the anterior part of the carotid sheath, separates the parapharyngeal space into pre- and poststyloid parts. The prestyloid compartment, a narrow fat-containing space between the medial pterygoid and tensor veli palatini muscle, separates the infratemporal fossa from the medially located lateral nasopharyngeal region containing the tensor and levator veli palatini and the eustachian tube. The poststyloid compartment, located behind the prestyloid part, contains the internal carotid artery, internal jugular vein, and the Cranial Nerves IX through XII.* E, *some of the lateral pterygoid muscle has been removed to expose the branches of the mandibular nerve in the*

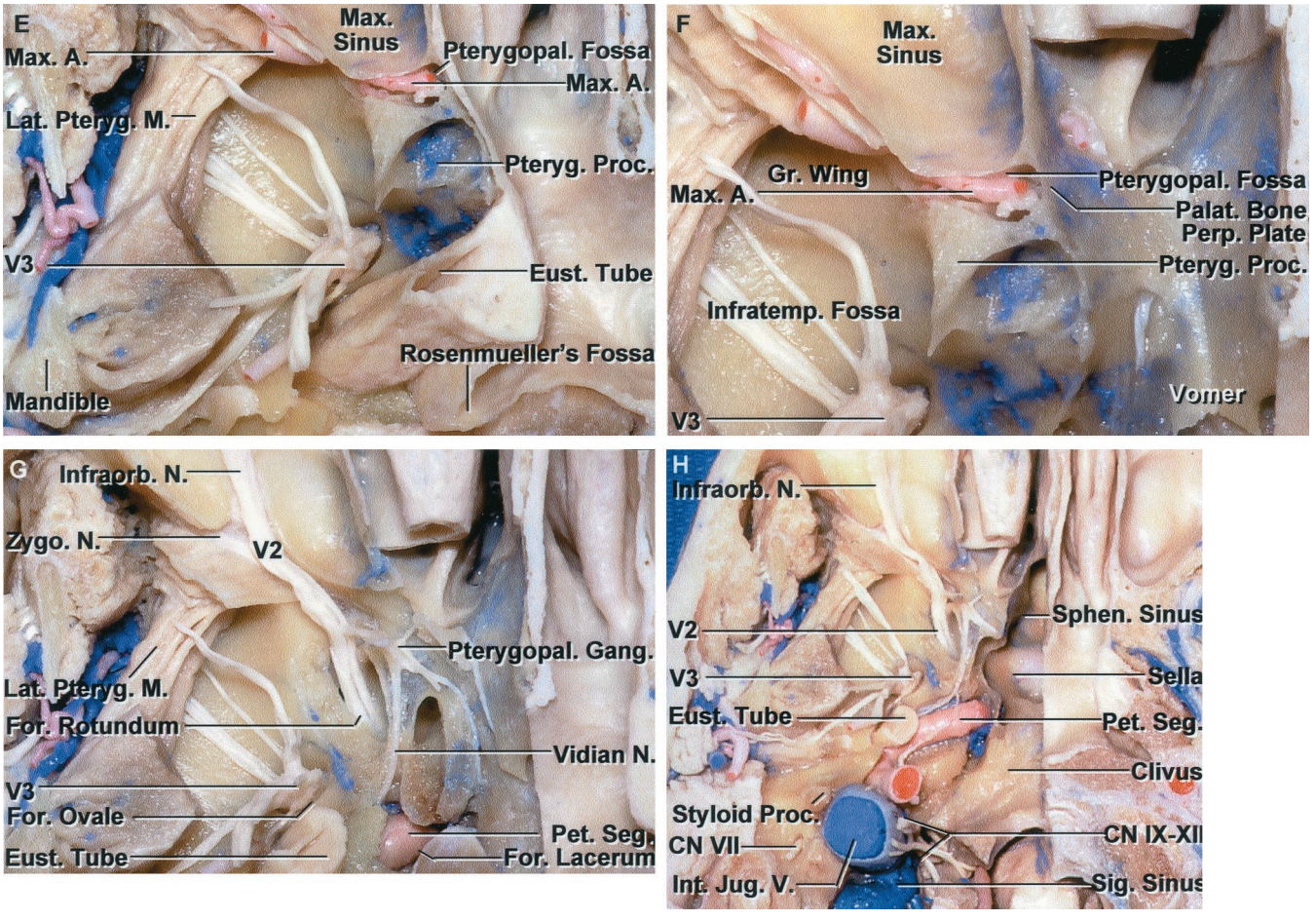

FIGURE 6.6. *Continued*
infratemporal fossa. The lower part of the pterygoid process has been removed to expose the maxillary artery in the pterygopalatine fossa. The pharyngeal recess (fossa of Rosenmüller) projects laterally from the posterolateral corner of the nasopharynx below the foramen lacerum. F, *enlarged view. The pterygopalatine fossa is located between the posterior maxillary wall anteriorly, the sphenoid pterygoid process posteriorly, the perpendicular plate of the palatine bone medially, and the infratemporal fossa laterally. The medial part of the eustachian tube has been removed.* G, *the pterygoid process has been removed to expose the maxillary nerve passing through the foramen rotundum to enter the pterygopalatine fossa, where it gives rise to the infraorbital and zygomatic nerves and communicating rami to the pterygopalatine ganglion. The vidian nerve exits the vidian canal and joins the pterygopalatine ganglion. The terminal part of the petrous carotid is exposed above the foramen lacerum.* H, *enlarged view of the region of the carotid canal and jugular foramen. The bone below the carotid canal has been removed to expose the petrous carotid. The deep portion of the parotid gland has been removed to expose the facial nerve at the styloid foramen. The sigmoid sinus hooks downward from the posterior fossa and opens into the internal jugular vein. A portion of the occipital condyle has been removed to expose the hypoglossal nerve joining the nerves exiting the jugular foramen to pass downward in the carotid sheath. The styloid process and facial nerve at the stylomastoid foramen are located on the lateral side of the internal jugular vein. The right half of the floor of the sphenoid sinus has been removed to expose the sella.* A., *artery;* Cap., *capitis;* Car., *carotid;* CN, *cranial nerve;* Cond., *condylar;* Crib., *cribriform;* Eth., *ethmoid;* Eust., *eustachian;* Fiss., *fissure;* For., *foramen;* Gang., *ganglion;* Gl., *gland;* Gr., *greater;* Inf., *inferior;* Infraorb., *infraorbital;* Infratemp., *infratemporal;* Int., *internal;* Jug., *jugular;* Lat., *lateral, lateralis;* Lev., *levator;* Long., *longus;* M., *muscle;* Max., *maxillary;* Mid., *middle;* N., *nerve;* Nasolac., *nasolacrimal;* Orb., *orbital;* Pal., *palatini;* Palat., *palatine;* Perp., *perpendicular;* Pet., *petrosal;* Plex., *plexus;* Proc., *process;* Pteryg., *pterygoid;* Pterygopal., *pterygopalatine;* Rec., *rectus;* Seg., *segment;* Sig., *sigmoid;* Sphen., *sphenoid;* Sulc., *sulcus;* Temp., *temporalis;* Tens., *tensor;* V., *vein;* Vel., *veli;* Zygo., *zygomatic.*

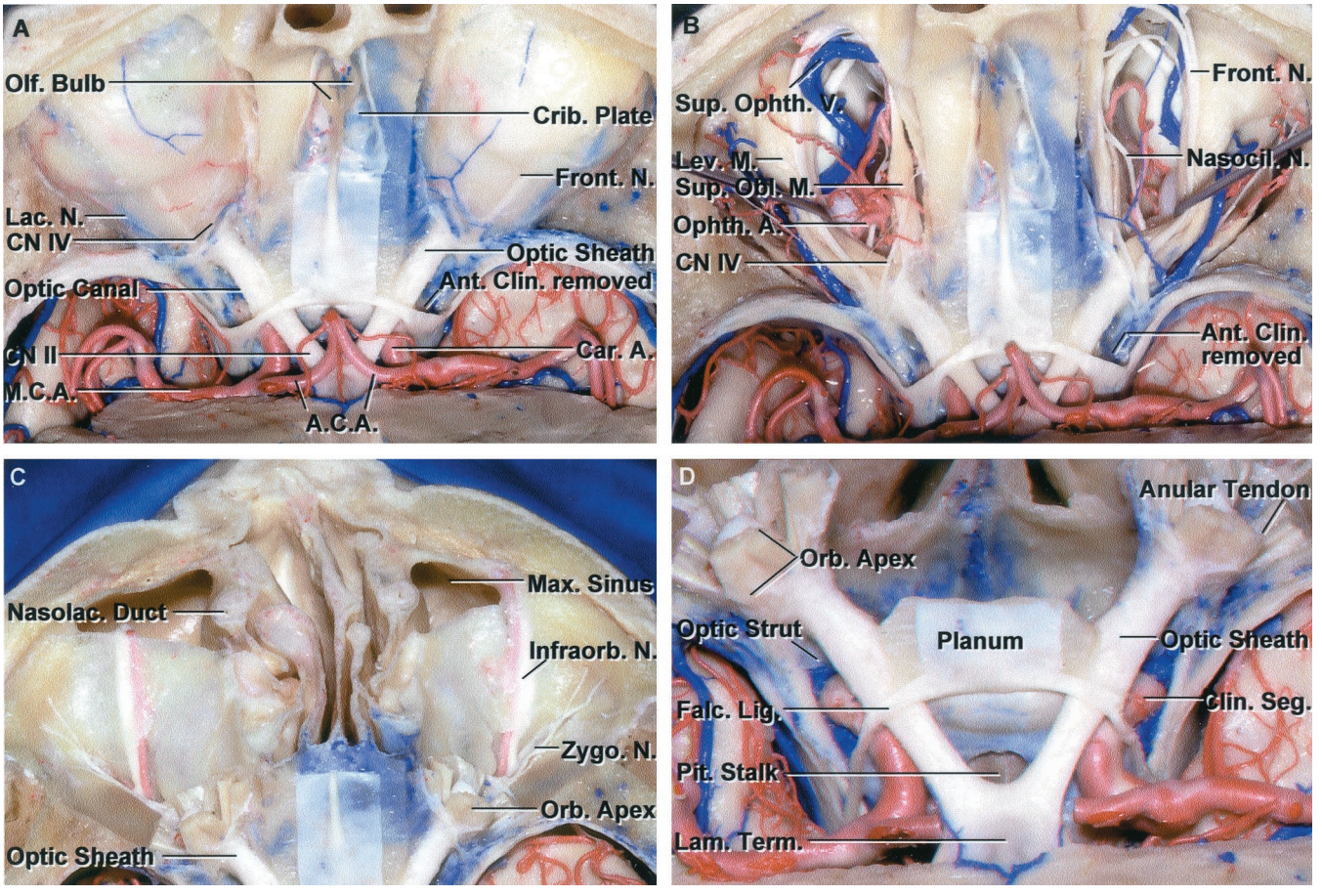

FIGURE 6.7. *Superior view of the anterior cranial base.* A, *both orbits have been unroofed to expose the periorbita. The optic canals have been unroofed and the anterior clinoids removed to expose the optic nerves, which are enclosed in the optic sheath within the optic canal. The frontal, trochlear, and lacrimal nerves can be seen through the periorbita. The roof of the ethmoidal sinuses and the olfactory bulbs sitting on the cribriform plate have been preserved. The anterior cerebral arteries course above the optic chiasm.* B, *the intraorbital fat has been removed and the levator and superior rectus muscles have been retracted laterally to expose both globes, ophthalmic arteries, superior ophthalmic veins, and nasociliary nerves.* C, *the orbital contents have been removed to expose the lateral wall and floor of the orbit. The maxillary sinuses are exposed below the orbital floors. The maxillary nerves give rise to the infraorbital nerve, which courses along the floor of the orbit to reach the cheek, and the zygomatic nerve, which courses along the lateral wall of the orbit to reach the malar eminence and temple.* D, *enlarged view. The optic nerves are enclosed within the optic sheath as they course through the optic canal. The annular tendon, from which the rectus muscles arise, surrounds the optic nerve and medial portion of the superior orbital fissure. Removal of the anterior clinoid exposes the clinoid segment of the carotid artery. The optic strut, which separates the optic canal and superior orbital fissure, has also been removed. The segment of anterior cerebral arteries passing above the chiasm has been removed to expose the lamina terminalis. The falciform dural fold extends across the optic nerve at the entrance into the optic canal.* A., *artery;* A.C.A., *anterior cerebral artery;* Ant., *anterior;* Car., *carotid;* Clin., *clinoid;* CN, *cranial nerve;* Crib., *cribriform;* Falc., *falciform;* Front., *frontal;* Infraorb., *infraorbital;* Lac., *lacrimal;* Lam., *lamina;* Lev., *levator;* Lig., *ligament;* M., *muscle;* Max., *maxillary;* M.C.A., *middle cerebral artery;* N., *nerve;* Nasocil., *nasociliary;* Nasolac., *nasolacrimal;* Obl., *oblique;* Olf., *olfactory;* Ophth., *ophthalmic;* Orb., *orbital;* Pit., *pituitary;* Seg., *segment;* Sup., *superior;* Term., *terminalis;* V., *vein;* Zygo., *zygomatic.*

FIGURE 6.8. *Structures below the medial part of the anterior and middle cranial fossae.* A, *midsagittal section of the anterior and middle cranial base to the right of the nasal septum. The area below the medial part of the anterior cranial fossa is formed by the frontal and ethmoidal sinuses and the nasal cavity. The nasal cavity is divided into the inferior, middle, and superior meatus and the sphenoethmoidal recess by the inferior, middle, and superior cochlea. The inferior meatus is located below the inferior turbinate, and the sphenoethmoidal recess, into which the sphenoid sinus opens, is located above the superior turbinate. The central part of the middle cranial base is formed by the body of the sphenoid bone, which contains the sphenoid sinus and sella with the pituitary gland. The cribriform plate is located in the roof of the nasal cavity. The nasopharynx and the opening of the eustachian tube are located below the sphenoid sinus.* B, *some of the mucosa has been removed from the concha. The inferior concha is a separate bone attached to the maxilla. The middle and superior concha are appendages of the ethmoid bone. The carotid artery courses along the lateral margin of the sphenoid sinus. The prominence within the sphenoid sinus, formed by the superior orbital fissure, is located anterior to the intracavernous carotid, and the prominence overlying the maxillary nerve is located below the intracavernous carotid.* C, *the middle and superior turbinates have been removed to expose the ostia of the maxillary and frontal sinuses. Both open into the middle meatus below the middle turbinate. The nasolacrimal duct opens below the inferior concha. Rosenmüller's fossa is*

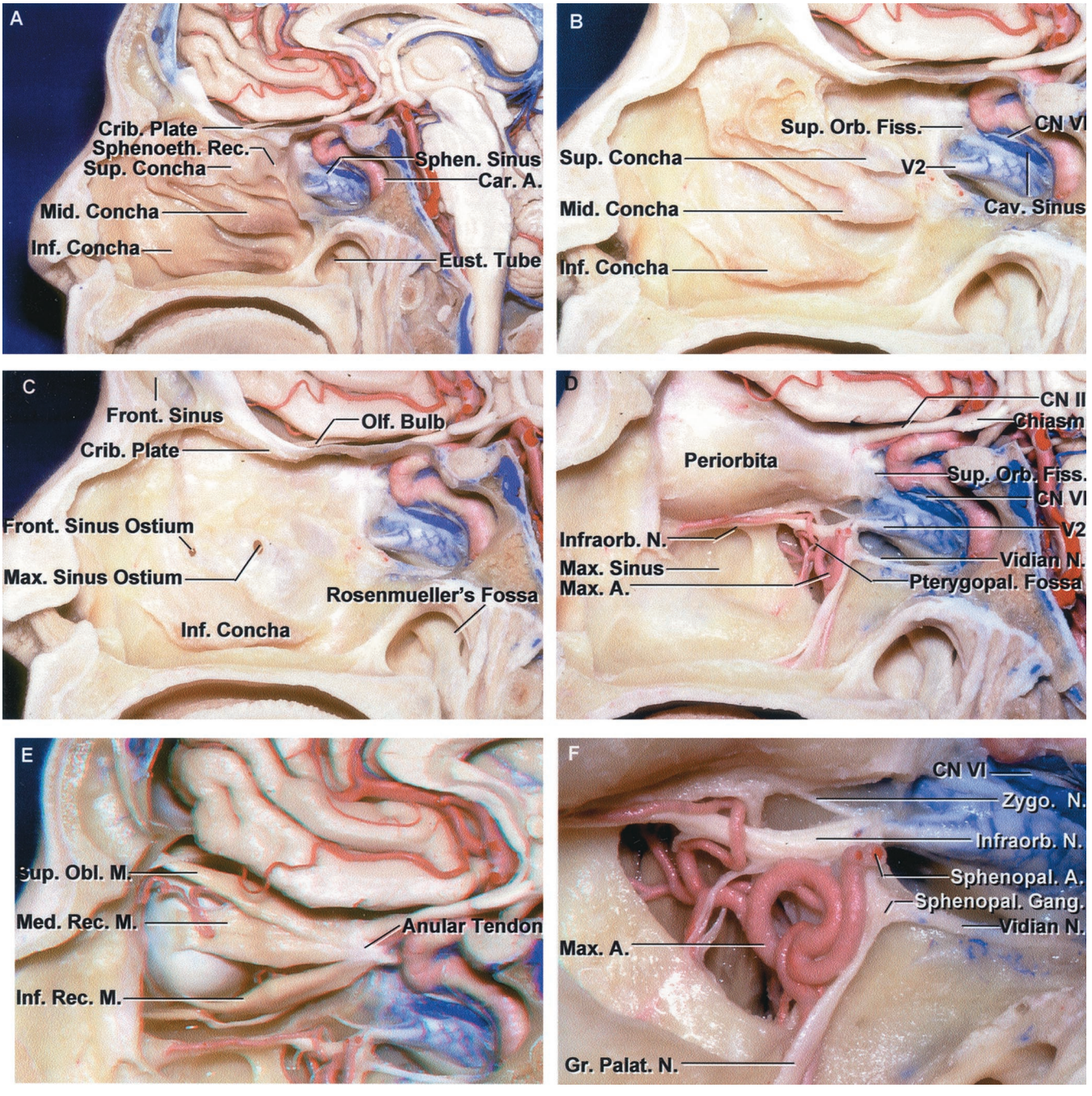

FIGURE 6.8. *Continued*

located behind the eustachian tube. D, *the medial wall of the maxillary sinus and the ethmoid air cells have been removed to expose the orbit. The optic nerve enters the orbit above the superior orbital fissure. The maxillary nerve exits the foramen rotundum to enter the pterygopalatine fossa. The vidian nerve passes through the vidian canal and enters the posterior margin of the sphenopalatine ganglion in the pterygopalatine fossa. The floor of the anterior cranial fossa forms much of the roof of the orbit, and the maxillary sinus forms most of the floor of the orbit. The abducens nerve is seen below the intracavernous segment of the internal carotid artery. The pterygopalatine fossa is located anterior to the sphenoid sinus and below the orbital apex.* E, *the intraorbital fat has been removed to expose the superior oblique and medial and inferior rectus muscles.* F, *enlarged view of the pterygopalatine fossa. The maxillary nerve exits the foramen rotundum to enter the pterygopalatine fossa, where it gives rise to the infraorbital, zygomatic, and palatine nerves and communicating rami to the pterygopalatine ganglion. The vidian nerve exits the vidian canal to enter the pterygopalatine ganglion. The pterygopalatine fossa contains branches of the maxillary nerve, the junction of the vidian nerve with the pterygopalatine ganglion, and terminal branches of the maxillary artery.* A., *artery;* Car., *carotid;* Cav., *cavernous;* CN, *cranial nerve;* Crib., *cribriform;* Eust., *eustachian;* Fiss., *fissure;* Front., *frontal;* Gang., *ganglion;* Gr., *greater;* Inf., *inferior;* Infraorb., *infraorbital;* M., *muscle;* Max., *maxillary;* Med., *medial;* Mid., *middle;* N., *nerve;* Obl., *oblique;* Olf., *olfactory;* Orb., *orbital;* Palat., *palatine;* Pterygopal., *pterygopalatine;* Rec., *recess, rectus;* Sphen., *sphenoid;* Sphenoeth., *sphenoethmoid;* Sphenopal., *sphenopalatine;* Sup., *superior;* Zygo., *zygomatic.*

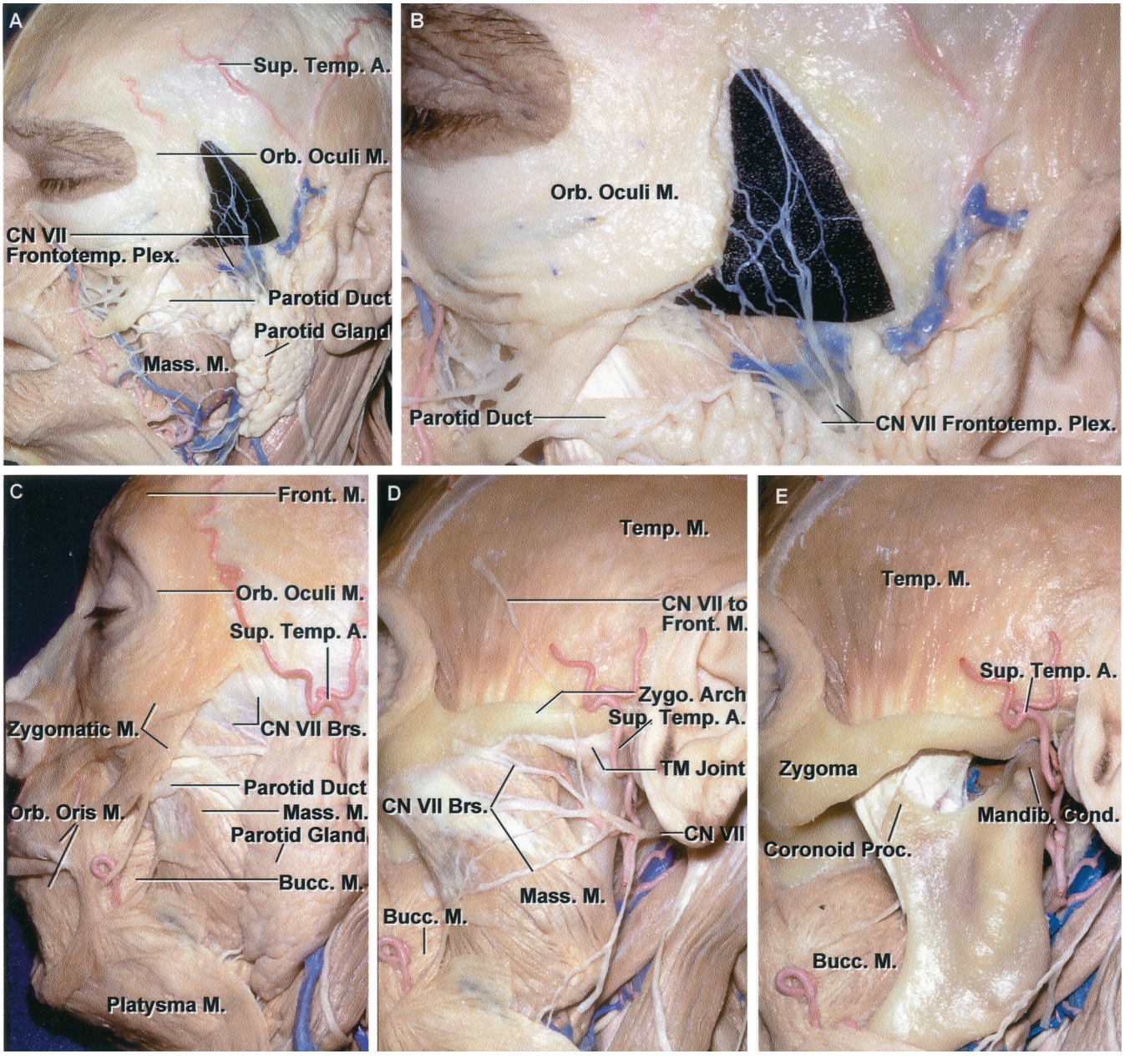

FIGURE 6.9. A, *the branches of the facial nerve, which form a fine plexus in the fat pad overlying the temporalis fascia and are directed to the orbicularis oculi and frontalis muscle, have been dissected free and a small piece of black material placed deep to their fine branches to highlight this neural network in the fat pad.* B, *enlarged view of the facial nerve plexus innervating the orbicularis oculi and frontalis muscle.* C, *lateral view of the structures superficial to the anterior and middle cranial base. The frontotemporal and zygomatic branches of the facial nerve are exposed anterior to the parotid gland. The orbicularis oculi surrounds the orbit, and the frontalis muscle extends upward from the superior orbital rim. The levators of the lip and zygomaticus muscles are located in front of the maxilla. The orbicularis oris surrounds the mouth and the buccinator muscle surrounds the oral cavity deep to the masseter muscle. The parotid duct crosses the masseter muscle. The superficial temporal artery divides into anterior and posterior branches. The parotid gland has been removed to show the branches of the facial nerve.* D, *the parotid gland has been removed to expose the facial nerve exiting the stylomastoid foramen. The facial nerve branch to the frontalis muscle has been preserved in the dissection and has been laid back against the temporalis muscle to show it crossing the zygomatic arch in its course to the forehead. The superficial temporal artery passes deep to the facial nerve in front of the ear.* E, *the masseter muscle has been removed to expose the temporalis muscle inserting on the coronoid process. The buccinator muscle, which surrounds the oral cavity, is situated on the deep side of the masseter muscle.* F, *the coronoid process and lower part of the temporalis muscle have been removed to expose the deep temporal branches of both the maxillary artery and mandibular nerve passing upward along the greater sphenoid wing and temporal squama to enter the deep side of the temporalis muscle. The lateral pterygoid muscles extend backward from the pterygoid process and greater wing of the sphenoid to insert along the mandibular condyle and temporomandibular joint.* G, *a craniotomy has been performed to expose the floor of the middle fossa, and the lateral wall of the orbital has been removed to expose the extraocular muscles. The mandibular condyle has been removed and the pterygoid muscles reflected to expose the mandibular nerve at the foramen ovale. The pterygopalatine fossa is located behind the maxilla. The floor of the orbit and the upper part of the maxilla have been removed to expose the nasal cavity.* H, *enlarged view after resection of the floor of the middle fossa*

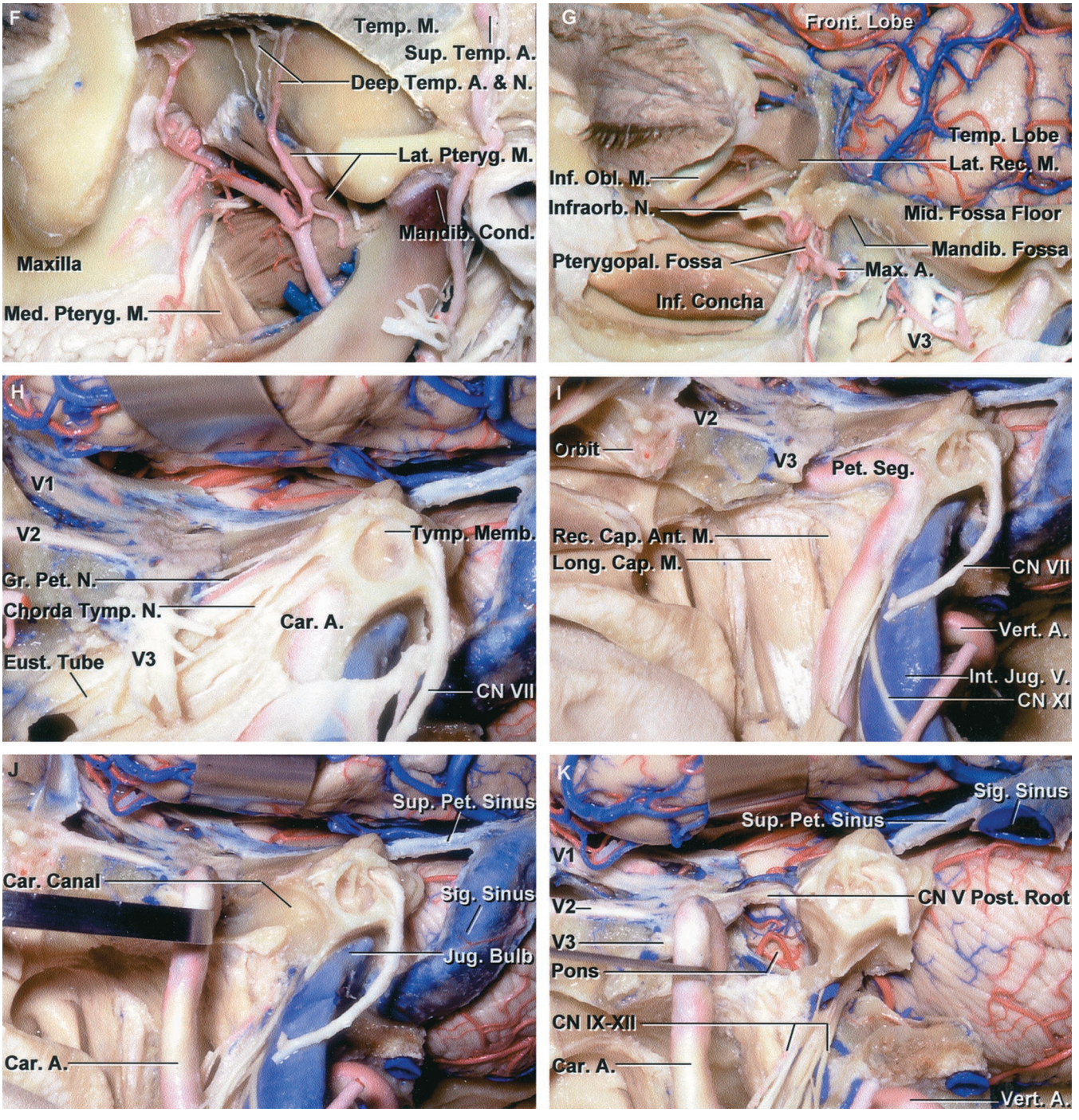

FIGURE 6.9. *Continued*
and the external auditory canal to expose the tympanic membrane and the mandibular nerve below the foramen ovale. The mastoid segment of the facial nerve has been preserved. The greater petrosal nerve crosses above the petrous carotid. The tensor tympani muscle and eustachian tube are layered along the anterior margin of the petrous carotid. I, *the eustachian tube and tensor tympani have been resected to expose the upper cervical and petrous carotid. The nasopharyngeal mucosa has been opened to expose the longus capitis and rectus capitis anterior muscles.* J, *the carotid artery has been reflected forward out of the carotid canal. This exposes the petrous apex in front of the jugular foramen on the medial side of the internal carotid artery.* K, *the petrous apex has been drilled and the dura opened below the trigeminal nerve to expose the upper anterior part of the posterior cranial fossa. A segment of the internal jugular vein and jugular bulb have been resected to expose the IXth through XIIth cranial nerves below the jugular foramen and hypoglossal canal.* A., *artery;* Ant., *anterior;* Brs., *branches;* Bucc., *buccinator;* Cap., *capitis;* Car., *carotid;* CN, *cranial nerve;* Cond., *condyle;* Coron., *coronoid;* Eust., *eustachian;* Front., *frontal;* Frontotemp., *frontotemporal;* Gr., *greater;* Inf., *inferior;* Infraorb., *infraorbital;* Int., *internal;* Jug., *jugular;* Lat., *lateral;* Long., *longus;* M., *muscle;* Mandib., *mandibular;* Mass., *masseter;* Max., *maxillary;* Med., *medial;* Memb., *membrane;* Mid., *middle;* N., *nerve;* Obl., *oblique;* Orb., *orbital;* Pet., *petrosal;* Plex., *plexus;* Post., *posterior;* Proc., *process;* Pteryg., *pterygoid;* Pterygopal., *pterygopalatine;* Rec., *rectus;* Seg., *segment;* Sig., *sigmoid;* Sup., *superior;* Temp., *temporal, temporalis;* TM, *temporomandibular;* Tymp., *tympani, tympanic;* V., *vein;* Vert., *vertebral;* Zygo., *zygomatic.*

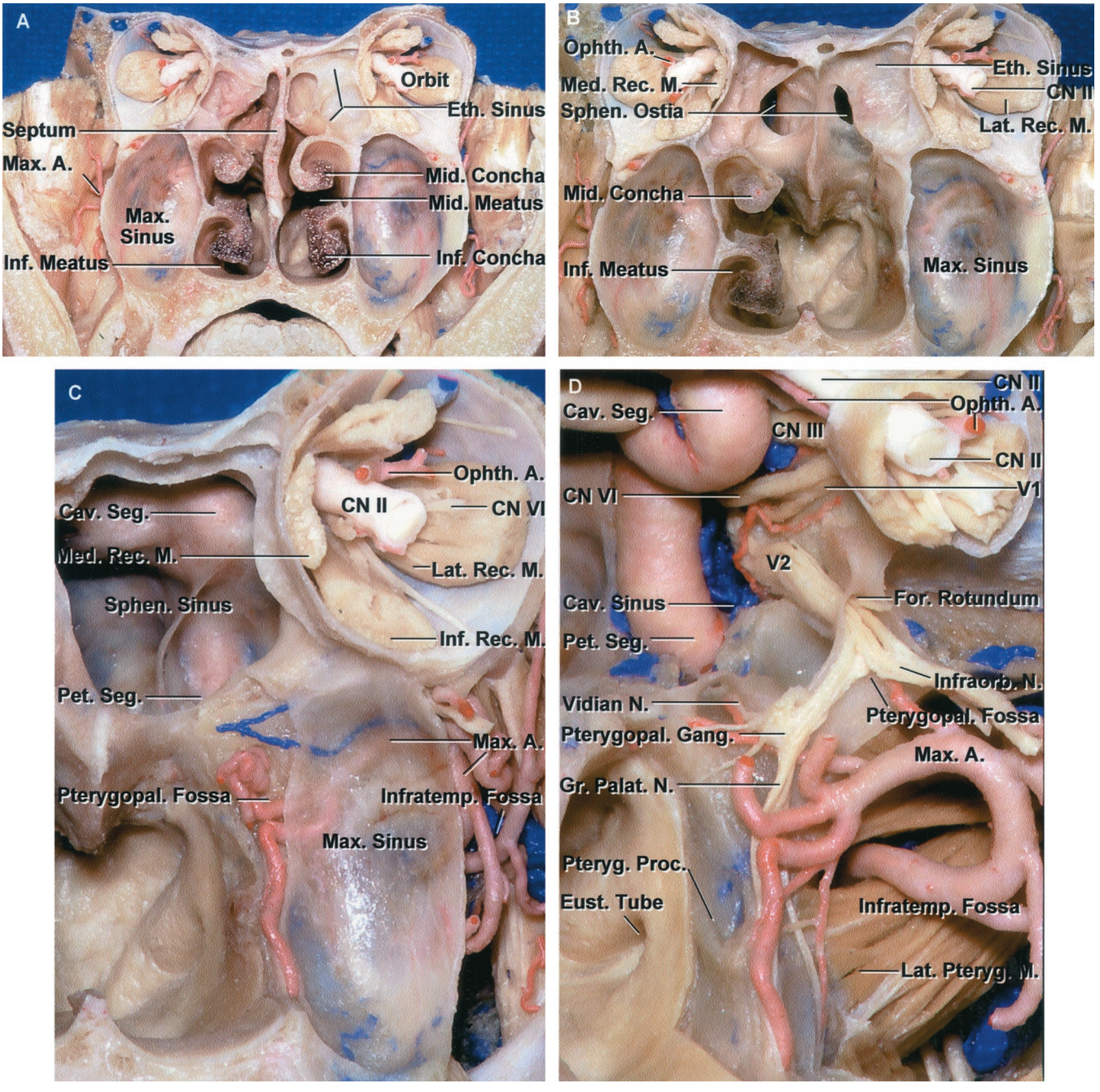

FIGURE 6.10. A, *anterior view of a coronal section, anterior to the sphenoid sinus, through the nasal cavity, orbits, and maxillary sinuses. The upper part of the nasal cavity is separated from the orbits by the ethmoidal sinuses. The lower part of the nasal cavity is bounded laterally by the maxillary sinuses. The middle concha projects medially from the lateral nasal wall at the junction of the roof of the maxillary and ethmoidal sinuses. The posterior ethmoid air cells are located in front of the lateral part of the sphenoid sinus.* B, *the middle and inferior nasal conchae on the left side and the nasal septum and the posterior ethmoidal sinuses on both sides have been removed to expose the posterior nasopharyngeal wall, the anterior aspect of the sphenoid body, and the sphenoid ostia. The posterior ethmoid air cells overlap the lateral margin of the sphenoid ostia.* C, *enlarged view showing the relationships of the nasal cavity, pterygopalatine and infratemporal fossae, orbit, and sphenoid sinus. The nasopharynx is located below the sphenoid sinus. The pterygopalatine fossa is located in the lateral wall of the nasal cavity behind the upper part of the maxillary sinus and below the orbital apex. The posterior maxillary wall is so thin that the maxillary artery coursing in the pterygopalatine fossa can be seen through the bone. The sphenopalatine branch of the maxillary artery passes through the sphenopalatine foramen to reach the walls of the nasal cavity and the sphenoid face.* D, *the posterior wall of the maxillary sinus has been removed to expose the pterygopalatine and infratemporal fossae and*

ally joins the deep petrosal branch of the carotid sympathetic nerves to form the vidian nerve, which enters the pterygopalatine ganglion (*Figs. 6.2, 6.5,* and *6.6*). The lesser petrosal nerve runs anterior to the greater petrosal nerve and exits the cranium, passing through the foramen spinosum to join the otic ganglion. The cochlea is situated below the floor of the middle cranial fossa, at the apex of the angle between the greater petrosal and labyrinthine segment of the facial nerve.

Exocranial Surface

The exocranial surface of the middle cranial base is also divided into central and lateral parts (*Figs. 6.2, 6.3, 6.6,* and *6.9*). The central part encompasses the sphenoid body and the upper part of the basal (clival) part of the occipital bone and corresponds to the sphenoid sinus and the nasopharynx. The lateral part is formed by the greater sphenoid wing, the petrous, tympanic, and squamous parts of the temporal bone, the styloid process, and the zygomatic, palatine, and maxillary bones. The medial and lateral parts are separated by a parasagittal plane passing through the medial pterygoid plate. The foramen lacerum is located at the union of the sphenoid, occipital, and petrous bones and is enclosed on its lower side by fibrocartilaginous tissue to form the inferior wall of the carotid canal. Structures transversing the lateral part include the carotid artery in the carotid canal, the glossopharyngeal, vagus, and accessory nerves in the jugular foramen, the third trigeminal division in the foramen ovale, the middle meningeal artery in the foramen spinosum, and the facial nerve in the facial canal. The pterygomaxillary fissure is the lateral opening of the pterygopalatine fossa into the infratemporal fossa. The glenoid fossa harbors the mandibular condyle. The roof of the fossa is divided into anterior and posterior parts by the squamotympanic fissure, along which the chorda tympani passes.

The area below the middle portion includes the infratemporal fossa, parapharyngeal space, infrapetrosal space, and pterygopalatine fossa (*Figs. 6.6,* and *6.9–6.11*). The boundaries of the infratemporal fossa are the middle pterygoid muscle and the pterygoid process medially, the mandible laterally, the posterior wall of the maxillary sinus anteriorly, the greater wing of the sphenoid superiorly, and the medial pterygoid muscle joining the mandible and the pterygoid fascia posteriorly. The fossa opens into the neck below. The infratemporal fossa contains the branches of mandibular nerve, the maxillary artery, and the pterygoid muscles and venous plexus. The mandibular nerve, after exiting the foramen ovale, lies anterolateral to the otic ganglion and divides immediately into its terminal branches: the pterygoid, buccal, masseteric, and temporal branches along the superior wall of the fossa; the inferior alveolar and the lingual branches, after being joined by the chorda tympani, descend between both pterygoid muscles; and the auriculotemporal branch with the maxillary artery course between the mandible and the sphenomandibular ligament. The auriculotemporal nerve carries the parasympathetic innervation of the parotid gland, which travels through the tympanic branch of the glossopharyngeal nerve that forms the lesser petrosal nerve, to reach the otic ganglion before joining the auriculotemporal nerve. The maxillary artery, which arises as a terminal branch of the external carotid artery with the superficial temporal artery, is divided into three segments. The first, or mandibular segment, passes between the sphenomandibular ligament and the mandibular neck and gives rise to the deep auricular, anterior tympanic, middle meningeal, accessory middle meningeal (enters through the foramen ovale) and the inferior alveolar artery. The second, or pterygoid segment, courses through the middle of the infratemporal fossa and gives rise to the posterosuperior alveolar, infraorbital, masseteric, pterygoid, temporal, and buccal branches. The third, or pterygopalatine segment, courses in the fossa of the same name. The pterygoid venous plexus connects through the middle fossa foramina and inferior orbital fissure with the cavernous sinus and empties into the retromandibular and facial veins.

The pterygopalatine fossa is located between the maxillary sinus in the front, the pterygoid process behind, the palatine bone medially and the body of the sphenoid bone above (*Figs. 6.3, 6.6, 6.10,* and *6.11*). The fossa opens laterally through the pterygomaxillary fissure into the infratemporal fossa and medially through the sphenopalatine foramen to the nasal cavity. Both the foramen rotundum for the maxillary nerve and the pterygoid canal for the vidian nerve open through the posterior wall of the fossa formed by the sphenoid pterygoid process. The palatovaginal canal carrying the pharyngeal nerve and artery and the greater and lesser palatine canals conveying the greater and lesser palatine arteries open into the pterygopalatine fossa. The inferior orbital fissure, across which the orbital muscle stretches, lies in front of the pterygopalatine fossa. The fossa contains branches of the maxillary nerve, vidian nerve, the pterygopalatine ganglion, and the pterygopalatine segment of the maxillary artery. The maxillary nerve passes through the foramen rotundum to enter the fossa and, after giving communicating rami to the pterygopalatine ganglion, divides into the posterosuperior alveolar, infraorbital, and zygomatic nerves. The zygomatic nerve, in addition to its sensory fibers, carries the parasympathetic fibers from the pterygopalatine ganglion to the lacrimal gland. The vidian (nerve of the pterygoid canal) ends in the pterygopalatine ganglion, which sends rami to the maxillary nerve and gives

the internal carotid artery and nerves coursing through the cavernous sinus. The maxillary artery passes through the infratemporal fossa and enters the pterygopalatine fossa, where it gives rise to branches that follow the branches of the maxillary nerve. Some of these arteries course along the sphenoid face where careful hemostasis during transsphenoidal surgery reduces the need for nasal packing after transsphenoidal operations. The maxillary nerve exits the foramen rotundum to enter the pterygopalatine fossa, where it gives rise to the infraorbital and greater palatine nerves and communicating rami to the pterygopalatine ganglion. The eustachian tube opens into the nasopharynx along the posterior edge of the medial pterygoid plate. A., *artery;* Cav., *cavernous;* CN, *cranial nerve;* Eth., *ethmoid;* Eust., *eustachian;* For., *foramen;* Gr., *greater;* Inf., *inferior;* Infraorb., *infraorbital;* Infratemp., *infratemporal;* Lat., *lateral;* M., *muscle;* Max., *maxillary;* Med., *medial;* Mid., *middle;* N., *nerve;* Ophth., *ophthalmic;* Palat., *palatine;* Pet., *petrosal;* Proc., *process;* Pteryg., *pterygoid;* Pterygopal., *pterygopalatine;* Rec., *rectus;* Seg., *segment;* Sphen., *sphenoid.*

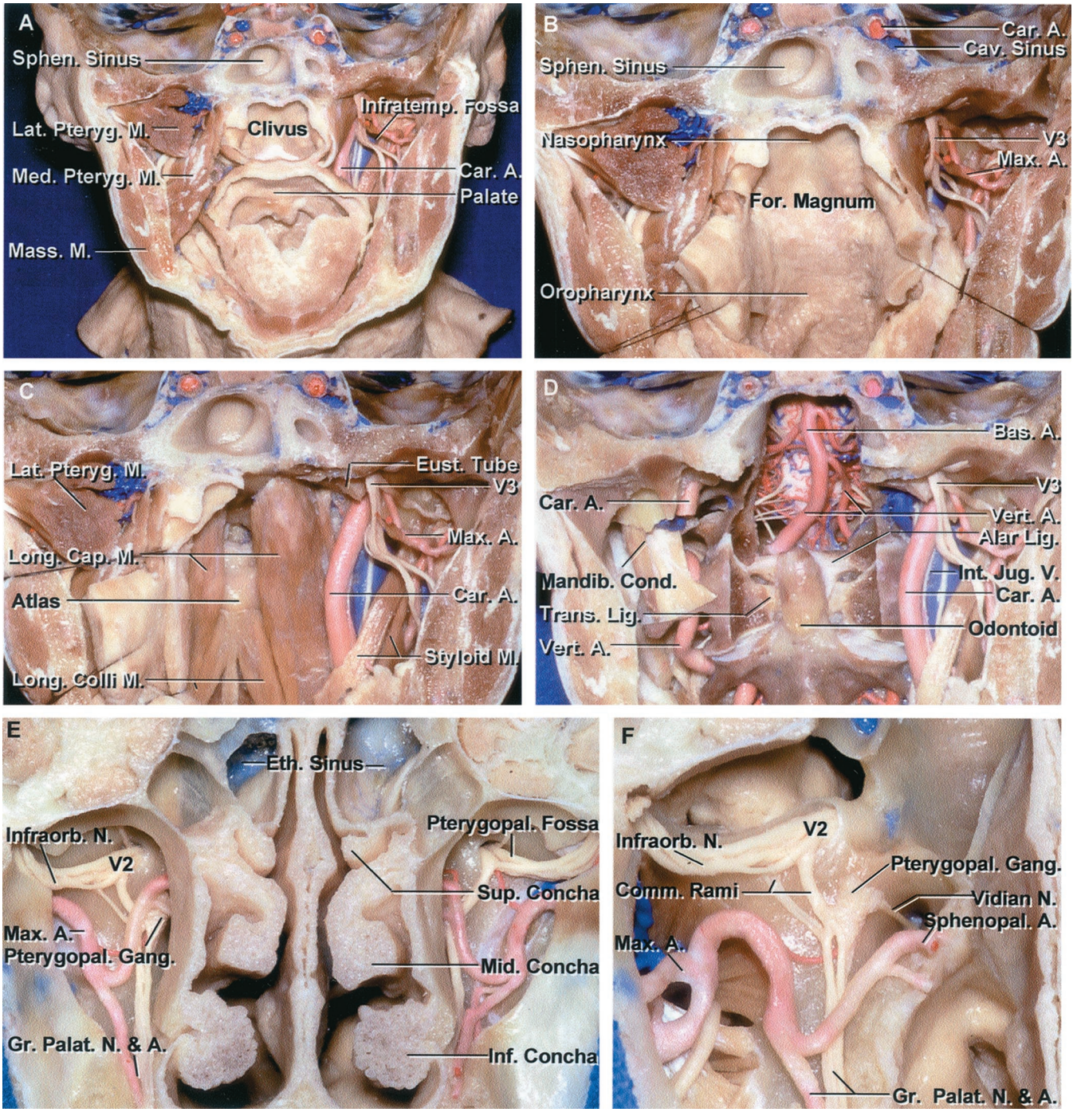

FIGURE 6.11. *Anterior view. Stepwise dissection of a cross section showing the relationships below the middle cranial base.* A, *the soft palate, which has been preserved, is located at the level of the foramen magnum. The infratemporal fossa, located below the greater sphenoid wing and middle cranial fossa, contains the pterygoid muscles, maxillary artery, mandibular nerve branches, and the pterygoid venous plexus, and opens posteriorly into the area around the carotid sheath, as shown on the left side.* B, *enlarged view. The soft palate has been divided in the midline, and the leaves reflected laterally. The atlanto-occipital joints and the foramen magnum are located at approximately the level of the hard palate. The anterior arch of C1 and the dens are located behind the oropharynx, and the clivus is located behind the nasopharynx and sphenoid sinus. The prominence over the longus capitis and the anterior arch of C1 are seen through the pharyngeal mucosa.* C, *the mucosa lining the posterior pharyngeal wall has been reflected to the right, exposing the longus capitis that attaches to the clivus and the part of the longus colli that attaches to the anterior arch of C1. The left eustachian tube has been divided.* D, *the clivus and anterior arch of C1 have been removed. The dura has been opened to expose the vertebral and basilar arteries. The dens has been preserved. The structures in the right infratemporal fossa and a segment of the right carotid artery and mandible have been removed to expose the right vertebral artery*

rise to the greater and lesser palatine and pharyngeal nerves and nasal branches. The third part of the maxillary artery enters the fossa and divides into its terminal lesser and greater palatine, sphenopalatine, vidian, and pharyngeal branches.

The parapharyngeal space lies between the structures in the pharynx wall medially, the medial pterygoid muscle and the parotid fascia laterally, and the styloid fascia investing the styloglossus, stylopharyngeal, and stylohyoid muscles posteriorly (*Fig. 6.6*). In its upper medial wall, the eustachian tube, covered below by the tensor and levator veli palatine muscles, runs from the tympanic cavity to the pharyngeal wall. This is predominantly a fat-filled space, but also contains pharyngeal branches of the ascending pharyngeal and facial arteries and branches from the glossopharyngeal nerve.

The last of the four spaces below the middle fossa is the infrapetrosal space, also referred to as the poststyloid part of the parapharyngeal space. It is located behind the styloid fascia, below the petrous bone, and medial to the mastoid process (*Figs. 6.2*, *6.6*, and *6.9*). Among the foramina in the area connecting the intra- and extracranial spaces is the jugular foramen containing the jugular bulb and lower end of the inferior petrosal sinus. It also contains branches of the ascending pharyngeal artery, the glossopharyngeal, vagus, and accessory nerves, and the opening of the carotid canal through which the carotid artery and the carotid sympathetic nerves pass. Two tiny foramina located between the jugular foramen and carotid canal carry the tympanic branch of the glossopharyngeal nerve and the auricular branch of the vagus nerve. The stylomastoid foramen, conveying the facial nerve and the stylomastoid artery, opens between the mastoid tip and styloid processes. The main fissure in the area is the petroclival fissure on the upper and lower side of which courses the inferior petrosal sinus and the inferior petroclival vein, respectively. The main nerves of the area are the glossopharyngeal nerve coursing below the styloglossus muscle, the vagus nerve descending between the internal carotid artery and the jugular vein, and the accessory nerve passing lateral to the jugular vein on its way to the sternocleidomastoid muscle. The facial nerve runs to the parotid gland, where it divides into cervicofacial and temporofacial trunks. The hypoglossal nerve, after exiting the hypoglossal canal, descends between the carotid artery and the jugular vein, turning anteriorly across the lateral wall of the artery below the level of the digastric muscle. The main arteries in the area are the internal carotid artery and its cervical and petrous segments. The branches of the petrous segment are the caroticotympanic and vidian arteries. The ascending pharyngeal artery ascends medial to the carotid artery, giving meningeal branches that pass through the hypoglossal canal and jugular foramen, as well as pharyngeal branches. The occipital artery passes posteriorly on the medial side of the posterior belly of the digastric muscle. The veins in the area are the internal jugular vein, which receives drainage from the inferior petrosal sinus, and the venous plexus of the hypoglossal canal outside the jugular foramen. The main structures in the area are the styloglossus, stylopharyngeal, and stylohyoid muscles, the digastric nerve, and the stylomandibular ligament.

The medial part of the temporal bone is constituted mainly by the internal auditory canal, the carotid canal, and the petrous apex. Laterally, within the petrous part of the temporal bone on the medial side of the mastoid antrum, lies the semicircular canals and vestibule enclosed within the otic capsule (*Fig. 6.5*).

The tympanic segment of the facial nerve passes below the lateral semicircular canal, and the mastoid segment descends to the stylomastoid foramen. The vestibule (vestibular cavity), which communicates with both ends of the semicircular canals, is situated medial to the lateral semicircular canal and below the superior semicircular canal. The aditus of the mastoid antrum opens into the tympanic cavity, which contains the malleus, incus, and stapes, the chorda tympani and tympanic nerve, and the tensor tympani and stapedius muscles. The tympanic cavity is limited laterally by the tympanic membrane, medially by the bone over the cochlea, and opens anteriorly into the eustachian tube. The arteries feeding the area arise from the stylomastoid, anterior tympanic, petrosal, and caroticotympanic arteries. Posterolateral to the otic capsule, anterior to the sigmoid sinus, and inferior to the superior petrosal sinus lies the presigmoid dura, referred to as Trautmann's triangle, under which the endolymphatic sac sits.

POSTERIOR CRANIAL BASE

The endocranial surface of the posterior cranial base corresponds to the floor of the posterior fossa and area around the foramen magnum (*Figs. 6.2* and *6.3*). It is formed by the sphenoid, temporal, and occipital bones. Medially, it is formed by the dorsum sellae, basilar (clival) portion of the

ascending between the C2 and C1 transverse processes. E, *cross section through the ethmoidal and maxillary sinuses and the nasal cavity in front of the posterior maxillary wall. The posterior wall of the maxillary sinus has been removed to expose the pterygopalatine fossa and ganglia on both sides. The maxillary nerves enter the pterygopalatine fossa by passing through the foramen rotundum. The maxillary arteries enter the pterygopalatine fossa from laterally by passing through the pterygomaxillary fissure and give rise to its terminal branches in the pterygopalatine fossa. Another branch enters the greater palatine canal with the greater palatine nerves.* F, *enlarged view of the pterygopalatine fossa. The vidian nerve exits the vidian canal to enter the pterygopalatine ganglion, which receives communicating rami from the maxillary nerve. The sphenopalatine branch passes through the sphenopalatine foramen to enter the lateral nasal cavity.* A., *artery;* Bas., *basilar;* Cap., *capitis;* Car., *carotid;* Cav., *cavernous;* Comm., *communicating;* Cond., *condyle;* Eth., *ethmoid;* Eust., *eustachian;* For., *foramen;* Gang., *ganglion;* Gr., *greater;* Inf., *inferior;* Infraorb., *infraorbital;* Infratemp., *infratemporal;* Int., *internal;* Jug., *jugular;* Lat., *lateral;* Lig., *ligament;* Long., *longus;* M., *muscle;* Mandib., *mandibular;* Mass., *masseter;* Max., *maxillary;* Med., *medial;* Mid., *middle;* N., *nerve;* Palat., *palatine;* Pteryg., *pterygoid;* Pterygopal., *pterygopalatine;* Sphen., *sphenoid;* Sphenopal., *sphenopalatine;* Sup., *superior;* Trans., *transverse;* V., *vein;* Vert., *vertebral.*

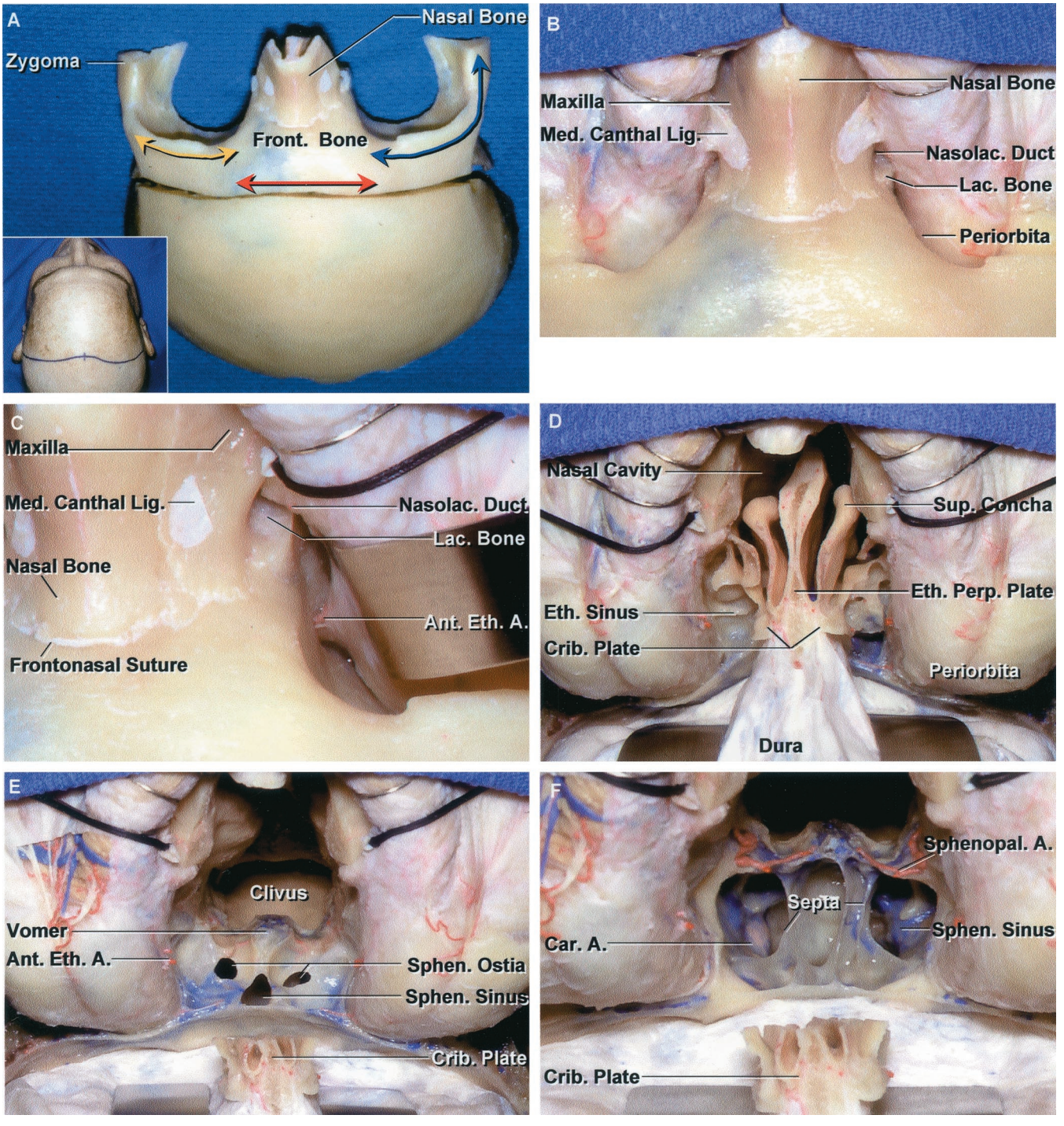

FIGURE 6.12. A–F, *relationships in the transbasal and extended frontal approaches.* A, *the* inset *shows the bicoronal scalp incision. A large bifrontal craniotomy and a fronto-orbitozygomatic osteotomy have been completed. The osteotomized segment may extend through the nasal bone and from one to the other lateral orbital rims, as shown. However, for most lesions, a more limited bone flap and osteotomy will suffice and can be tailored as needed to deal with the involvement of the cranial base, nasal cavity, paranasal sinuses, or orbit. For an orbital lesion, an orbitofrontal craniotomy, elevating only the superior orbital rim* (yellow arrows) *and orbital roof, is all that is needed. For a cavernous sinus or unilateral lesions of the anterior or middle fossa, an orbitozygomatic osteotomy will usually suffice* (blue arrow). *For a clival lesion, a more limited bifrontal approach* (red arrow) *will suffice.* B, *the periorbita has been separated from the walls of the orbit in preparation for the osteotomies. Division of the medial canthal ligament is not necessary for most lesions, but may be required for lesions extending into the lower nasal cavity or orbit. The ligaments should be re-approximated at the end of the operation.*

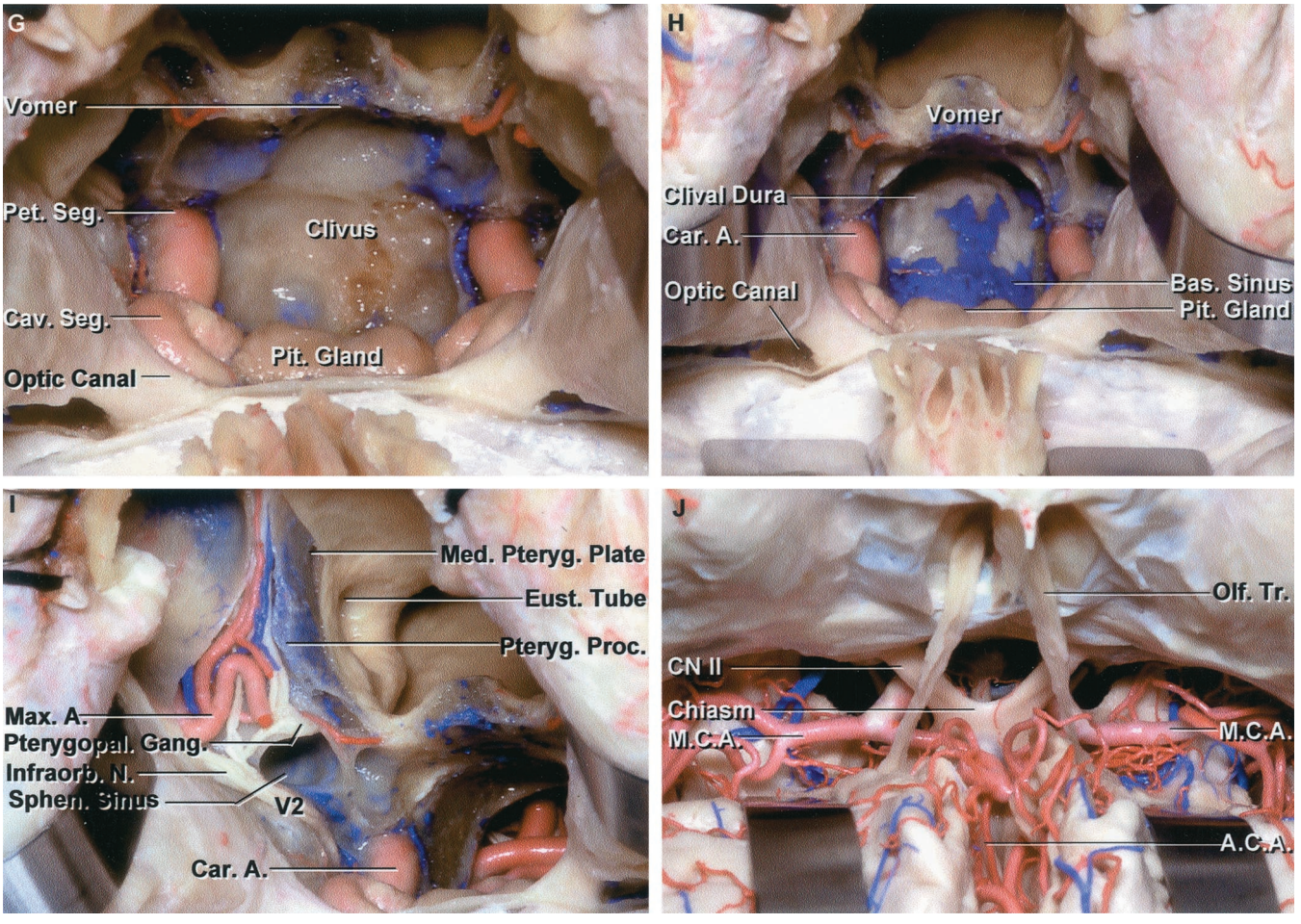

FIGURE 6.12. *Continued*
C, *the right medial canthal ligament has been divided and the orbital contents retracted laterally to expose the nasolacrimal duct and the anterior ethmoidal branch of the ophthalmic artery at the anterior ethmoidal foramen.* D, *the osteotomies have been completed and the frontal dura elevated. The dura remains attached at the cribriform plate. The upper parts of both orbits are exposed.* E, *an osteotomy around the cribriform plate leaves it attached to the dura and olfactory bulbs, a maneuver that has been attempted to preserve olfaction but has not been commonly successful. The anterior face of the sphenoid sinus and both sphenoid ostia are exposed between the orbits.* F, *the sphenoid sinus has been opened to expose the septa within the sinus. The sphenopalatine arteries cross the anterior face of the sphenoid.* G, *the septa within the sphenoid sinus, the sellar floor, and the lateral sinus wall have been removed to expose the intracavernous carotid, pituitary gland, and optic canals.* H, *the clivus has been opened to expose the dura facing the brainstem. The basilar sinus, which interconnects the posterior parts of the cavernous sinus, is situated between the layers of dura on the upper clivus.* I, *the exposure has been extended laterally by opening the medial and posterior wall of the maxillary sinus to expose the branches of the maxillary nerve and artery in the pterygopalatine fossa, located behind the posterior maxillary wall. The posterior wall of the pterygopalatine fossa is formed by the pterygoid process. The maxillary nerve enters the pterygopalatine fossa where it gives rise to the infraorbital nerve, which courses along the floor of the orbit and to the palatine nerves, which descend to the palatal area. The eustachian tube opens into the nasopharynx by passing along the posterior edge of the medial pterygoid plate. The lateral wing of the sphenoid sinus extends laterally below the maxillary nerve.* J, *the frontal dura has been opened and the frontal lobes elevated to expose the olfactory and optic nerves and the internal carotid and anterior and middle cerebral arteries.* A., *artery;* A.C.A., *anterior cerebral artery;* Ant., *anterior;* Bas., *basilar;* Car., *carotid;* Cav., *cavernous;* CN, *cranial nerve;* Crib., *cribriform;* Eth., *ethmoid, ethmoidal;* Eust., *eustachian;* Front., *frontal;* Gang., *ganglion;* Infraorb., *infraorbital;* Lac., *lacrimal;* Lig., *ligament;* Max., *maxillary;* M.C.A., *middle cerebral artery;* Med., *medial;* N., *nerve;* Nasolac., *nasolacrimal;* Olf., *olfactory;* Perp., *perpendicular;* Pet., *petrosal;* Pit., *pituitary;* Proc., *process;* Pteryg., *pterygoid;* Pterygopal., *pterygopalatine;* Seg., *segment;* Sphen., *sphenoid;* Sphenopal., *sphenopalatine;* Sup., *superior;* Tr., *tract.*

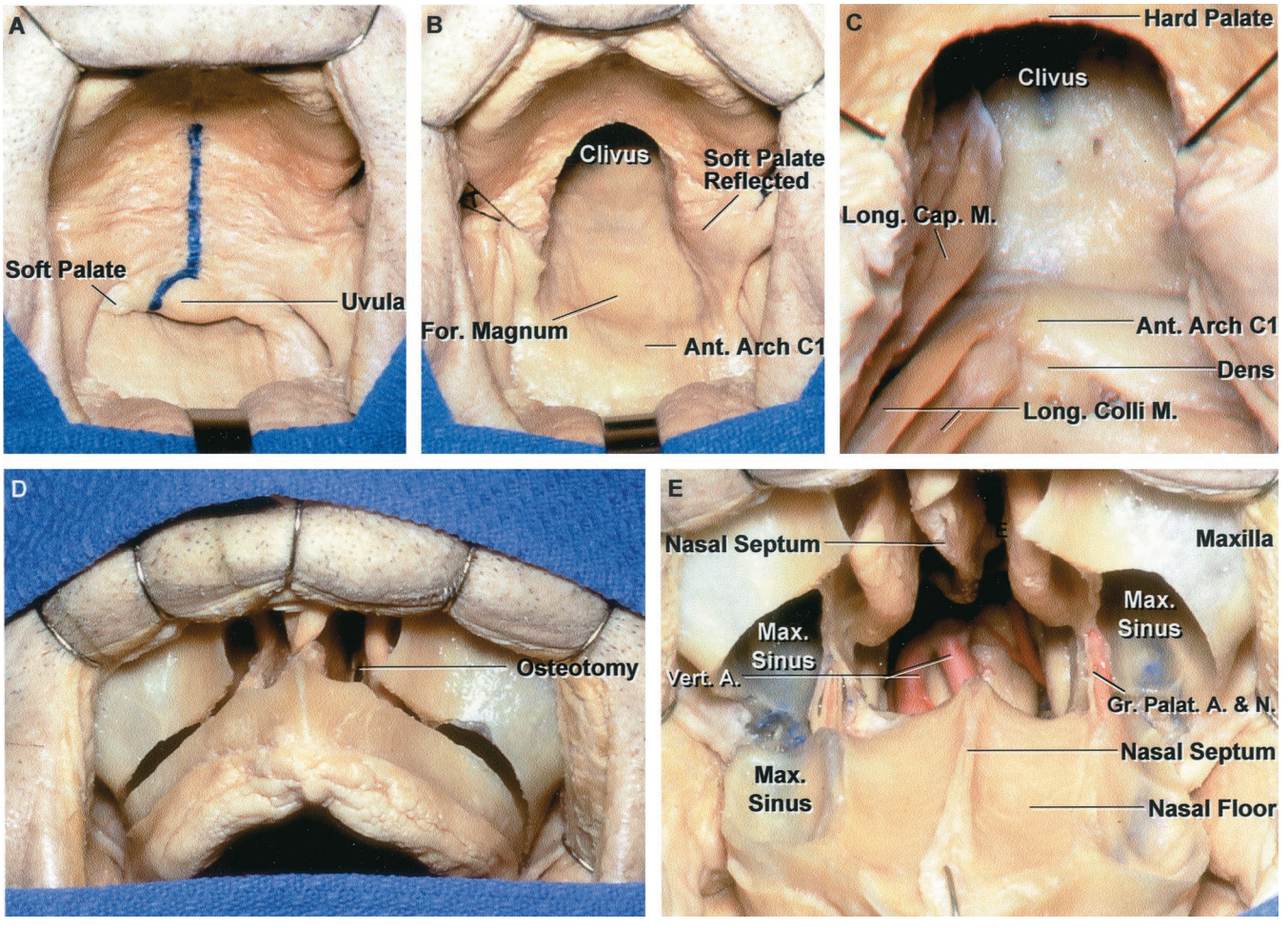

FIGURE 6.13. A, *anterior view through the open mouth. The soft palate, which extends backward from the hard palate, will block the view of the upper clivus. An incision has been outlined in the midline of the soft palate.* B, *the soft palate has been divided to expose the mucosa lining the lower clivus.* C, *the pharyngeal mucosa has been opened in the midline and the left longus capitis and longus colli have been reflected laterally.* D, *the transverse maxillary (Le Fort I) osteotomy extends through the maxillary sinus above the apex of the teeth and below the infraorbital canals.* E, *the lower maxilla has been displaced downward. A clival window and vertebral arteries are seen through the exposure.* A., *artery;* Ant., *anterior;* Cap., *capitis;* For., *foramen;* Gr., *greater;* Long., *longus;* M., *muscle;* Max., *maxillary;* N., *nerve;* Palat., *palatine;* Vert., *vertebral.*

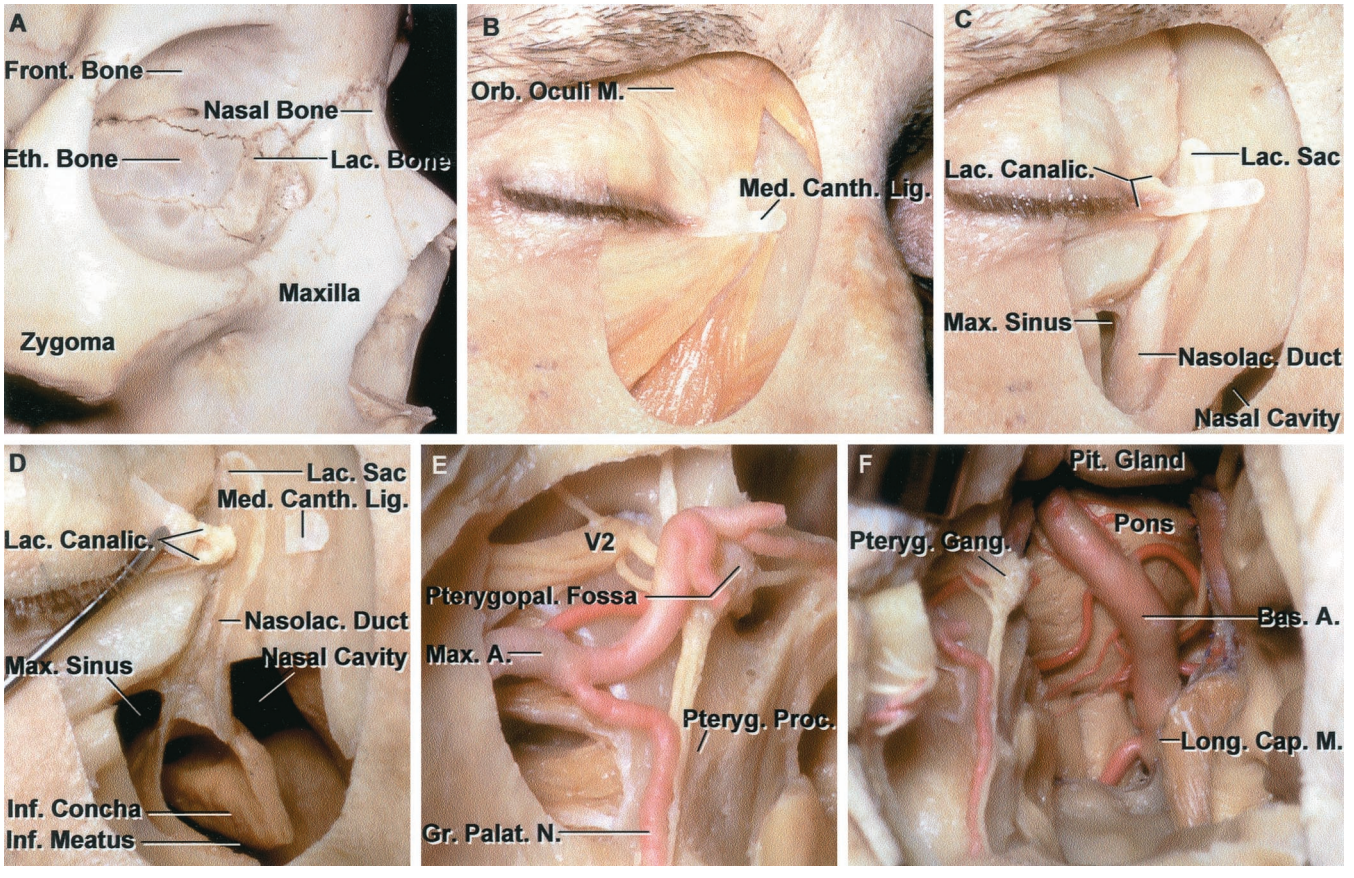

FIGURE 6.14. *Relationships of the medial orbit.* A, *the medial part of the orbital rim is formed by the frontal bone and maxilla. The anterior part of the nasolacrimal canal is formed by the maxilla and the posterior part by the lacrimal bone, which joins the ethmoid bone posteriorly and the frontal bone above.* B, *the medial part of the orbicularis oculi muscle has been exposed. The anterior band of the medial canthal ligament, which crosses in front of the lacrimal sac, is attached to the frontal process of the maxilla medially and to the superior and inferior tarsi laterally.* C, *the medial part of the orbicularis oculi muscle and some of the maxilla have been removed to expose the lacrimal sac, nasolacrimal duct, and a small part of the nasal cavity and maxillary sinus.* D, *the anterior band of the medial canthal ligament has been reflected laterally to expose the superior and inferior lacrimal canaliculi joining the lacrimal sac. Additional maxilla has been removed to expose the nasal cavity and inferior turbinate medially and the maxillary sinus laterally. The nasolacrimal duct opens into the inferior nasal meatus.* E, *some of the posterior and medial wall of the maxillary sinus has been removed to expose the pterygopalatine fossa, which contains the maxillary nerve and artery and their branches and the pterygopalatine ganglion.* F, *the approach has been directed through the nasal cavity medial to the pterygopalatine ganglion and fossa to the clivus, which has been opened to expose the basilar artery.* A., *artery;* Bas., *basilar;* Canalic., *canaliculi;* Cap., *capitis;* Eth., *ethmoid;* Front., *frontal;* Gang., *ganglion;* Gr., *greater;* Inf., *inferior;* Lac., *lacrimal;* Lig., *ligament;* Long., *longus;* M., *muscle;* Max., *maxillary;* Med., *medial;* N., *nerve;* Nasolac., *nasolacrimal;* Orb., *orbital;* Palat., *palatine;* Pit., *pituitary;* Proc., *process;* Pteryg., *pterygoid, pterygopalatine;* Pterygopal., *pterygopalatine.*

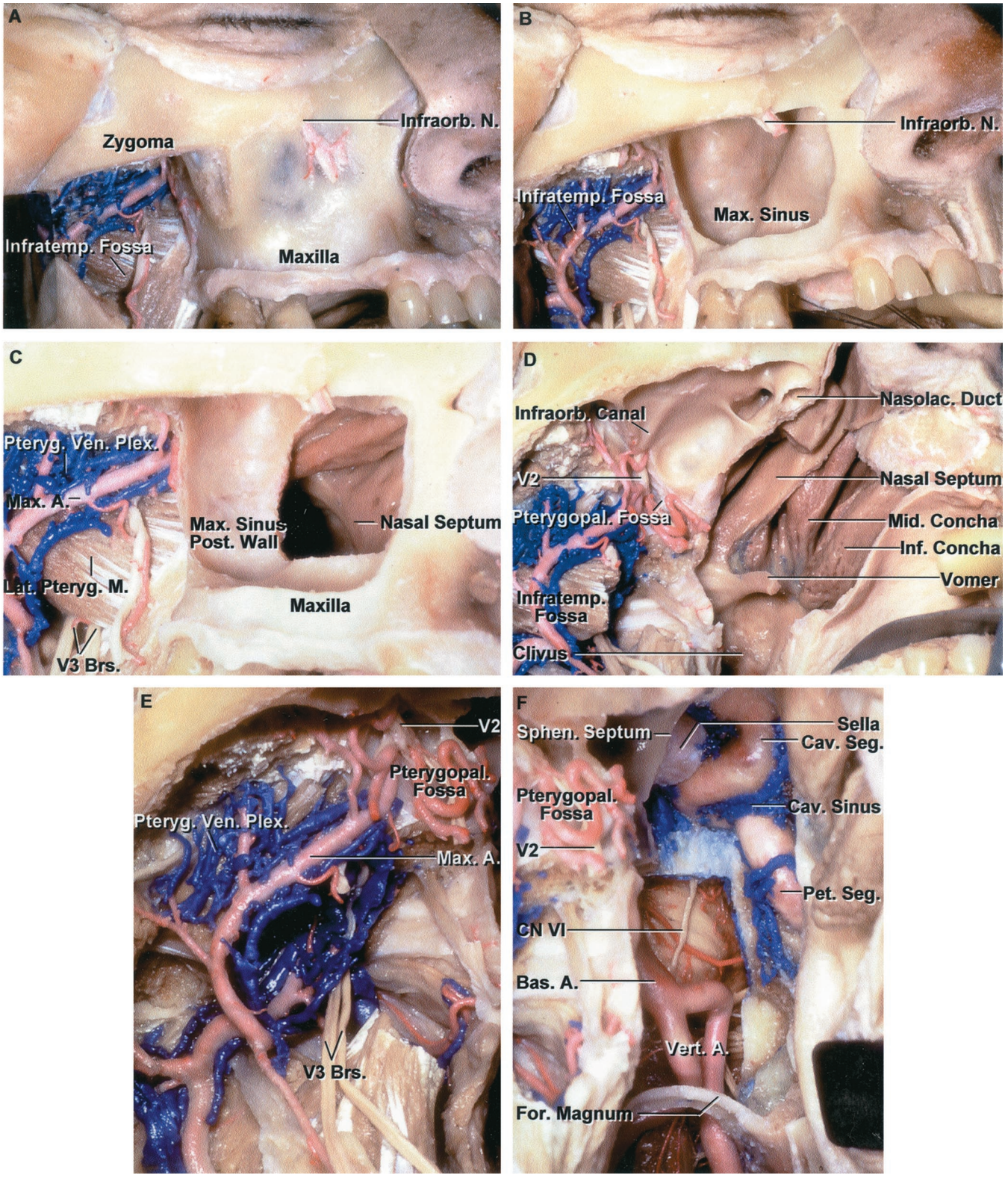

FIGURE 6.15.

occipital bone, and the foramen magnum. Laterally, the endocranial surface is formed by the posterior surface of the temporal and occipital bones, with the petro-occipital fissure and the jugular foramen lying between the occipital and temporal bones.

This exocranial surface is divided into central and lateral portions. The center portion is formed by the basal (clival) part of the occipital bone, which slopes upward from the foramen magnum and the occipital condyles, lateral to its lower portion at the anterolateral margin of the foramen magnum. Lateral to the condyle lies the jugular process of the occipital bone, which forms the posterior edge of the jugular foramen and connects the squamosal and basal parts of the occipital bone. The relationships in the cranial base are not reviewed in detail in this issue; they were covered in the Millennium issue of *Neurosurgery* (8).

DISCUSSION

With the development of the combination of micro-operative techniques and cranial-base surgery, it has become possible to access all parts of the cranial base. Approaches to the posterior fossa, including the foramen magnum, clivus, and approaches directed through the temporal bone, were reviewed in the Millennium issue of *Neurosurgery* (8). The anterior and middle cranial base offers the possibility of numerous approaches from above or below, or as combined procedures.

Lesions involving the medial parts of the anterior and middle cranial base can be accessed through an intracranial or subcranial route, or a combination of the two routes. From above, the transcranial-transbasal approach, involving a bifrontal craniotomy with preservation of the supraorbital rim, can be used to access the ethmoidal and sphenoid sinuses, sella, and clivus in the medial part of the cranial base, plus the adjacent lateral part of the anterior cranial base (7). Extending the transcranial-transbasal approach by removing the supraorbital rims provides greater access to the frontal, ethmoid, and sphenoid sinuses, medial orbit, nasal cavity, and clivus (*Fig. 6.12*). The supraorbital osteotomy can be tailored to include not only the midline and adjacent part of the supraorbital rims, but can include the area extending from one lateral orbital rim to the other, so that the lateral wall and roof of the orbits plus the roof of the nasal cavity can be elevated in a single osteotomy. However, it is important that the approach be tailored to the site, size, and nature of the pathology. A limited orbitofrontal approach, in which only the superior orbital rim is elevated in conjunction with a small frontal bone flap, provides access to the orbit and intracranial area around the optic canal. A further extension of the approach involving an osteotomy of the superior orbital rim is the orbitozygomatic craniotomy in which the superior and lateral orbital rims are elevated in conjunction with a frontotemporal bone flap. The orbitozygomatic approach is selected for lesions involving the lateral orbital wall and superior orbital fissure, cavernous sinus, middle fossa, and paraclinoid area. The orbitozygomatic approach can be extended further posteriorly by elevating the zygomatic arch with the osteotomy to access the middle and infratemporal fossae. A more strictly localized approach to the middle cranial base would be through a preauricular subtemporal approach in which a temporal or frontotemporal craniotomy is combined with an extradural middle fossa exposure to access the internal auditory canal. This approach is used for removal of small acoustic neuromas or removal of the petrous apex (anterior petrosectomy) for exposure of the clivus and upper part of the posterior fossa including the upper trunk and apex of the basilar artery. The approach, directed through the middle fossa floor lateral to the internal acoustic meatus with exposure or removal of the semicircular canals, thus completing a middle fossa translabyrinthine approach, provides an extended middle fossa exposure of the posterior fossa.

The anterior and middle cranial base can also be approached from below. The most localized of the approaches

FIGURE 6.15. A–C, *transmaxillary exposure of the cranial base.* A, *in this dissection, a midfacial soft tissue flap has been reflected laterally to expose the anterior surface of the right maxilla. The operative approach to the maxillary sinus is more commonly performed using a sublabial incision in the gingivobuccal margin rather than through an incision on the face. The approach can be completed without dividing the infraorbital nerve, but in this dissection, it was divided below the infraorbital foramen. The nerve, if divided, can be resutured at the time of closing. The infratemporal fossa, which is situated below the greater sphenoid wing, has been exposed by removing the coronoid process of the mandible and a narrow wedge of zygoma.* B, *the anterior wall of the maxillary sinus has been removed. The roof of the maxillary sinus forms the majority of the floor of the orbit. The infratemporal fossa contains the pterygoid muscles, mandibular nerve, maxillary artery, and the pterygoid venous plexus.* C, *the medial and lateral walls of the maxillary sinus have been opened, but the posterior part of the sinus wall, which forms the anterior wall of the pterygopalatine fossa, has been preserved. Removing the medial wall of the sinus exposes the nasal cavity, turbinates, and nasal septum. The maxillary artery crosses the lateral pterygoid muscle to reach the pterygopalatine fossa, which is located behind the upper part of the posterior wall of the maxillary sinus and below the orbital apex.* D, *the posterior wall of the maxillary sinus has been removed to expose the pterygopalatine fossa and orbital floor. The pterygopalatine fossa is located below the orbital apex and the posteromedial part of the inferior orbital fissure. The maxillary nerve enters the pterygopalatine fossa by passing through the foramen rotundum. The maxillary nerve gives rise to the infraorbital nerve, which passes forward in the infraorbital canal in the sinus roof and orbital floor.* E, *enlarged view of infratemporal and pterygopalatine fossae. Distally, the maxillary artery enters the pterygopalatine fossa, which is located in the lateral wall of the nasal cavity below the orbital apex.* F, *the exposure has been directed medially through the nasal cavity to the clivus, which has been opened to expose the vertebral and basilar arteries and the front of the brainstem. The exposure has been extended upward by opening the sphenoid sinus and exposing the left intracavernous carotid. The margin of the foramen magnum has been preserved.* A., *artery;* Bas., *basilar;* Brs., *branches;* Cav., *cavernous;* CN, *cranial nerve;* For., *foramen;* Inf., *inferior;* Infraorb., *infraorbital;* Infratemp., *infratemporal;* Lat., *lateral;* M., *muscle;* Max., *maxillary;* Mid., *middle;* N., *nerve;* Nasolac., *nasolacrimal;* Pet., *petrosal;* Plex., *plexus;* Post., *posterior;* Pteryg., *pterygoid;* Pterygopal., *pterygopalatine;* Seg., *segment;* Sphen., *sphenoid;* Ven., *venous;* Vert., *vertebral.*

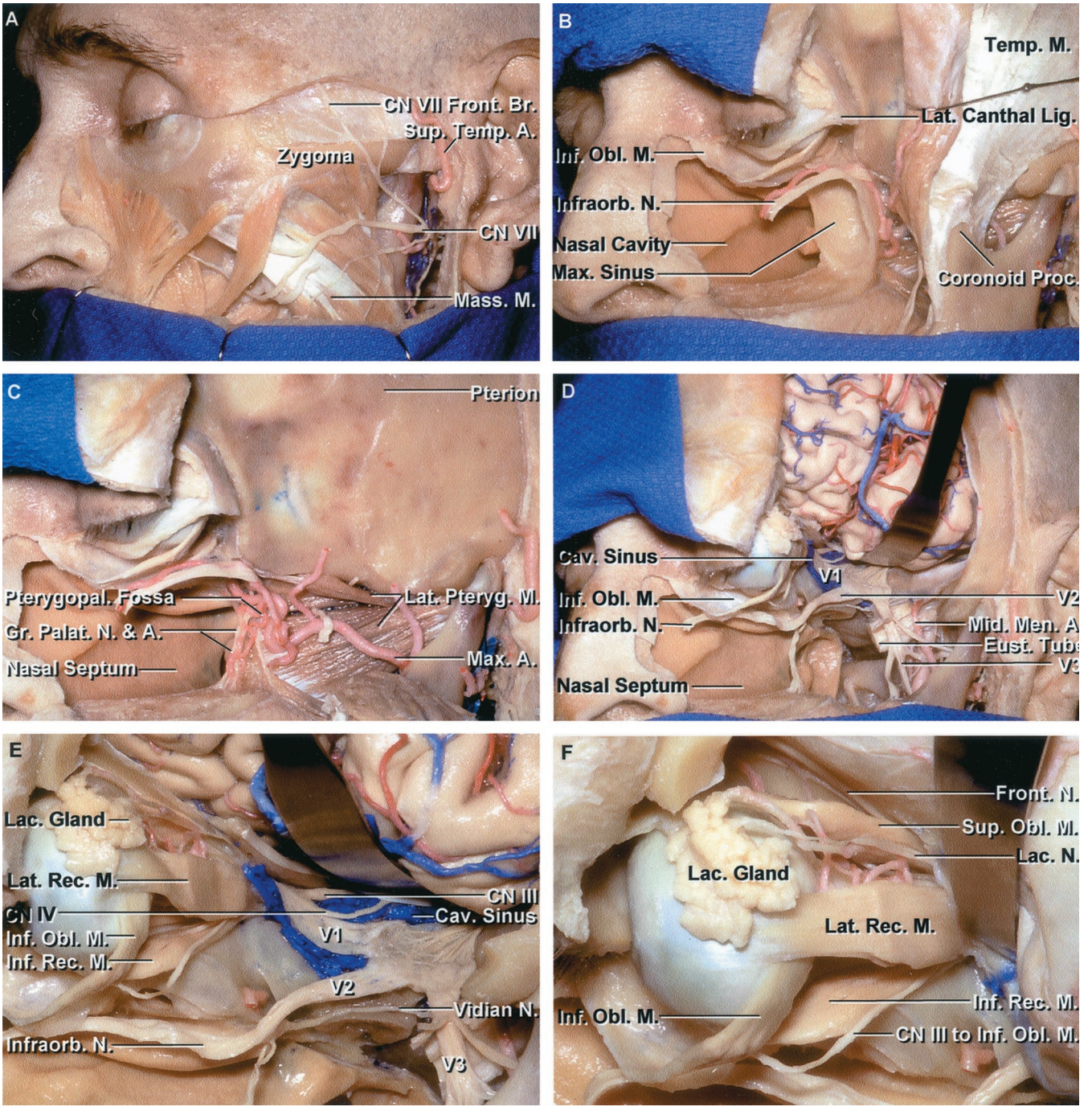

FIGURE 6.16. *Upper subtotal maxillotomy. Exposure obtained with mobilization of the upper part of the maxilla.* A, *this approach uses paranasal, lower conjunctival, transverse temporal, and preauricular incisions. In the usual approach, the cheek flap is elevated as a single layer using subperiosteal dissection. In this dissection, the layers of the cheek flap were dissected separately to illustrate the structures in the flap. The facial muscles and branches of the facial nerve are exposed. The parotid gland has been removed. The frontal branch of the facial nerve crosses the middle portion of the zygomatic arch. If facial nerve branches are transected in the approach, they are tagged in preparation for reapproximation at closure.* B, *a hemicoronal scalp incision and reflection of the temporalis muscle exposes the lateral orbital rim. The cheek flap containing the facial muscles, branches of the facial nerve, parotid gland, and masseter muscle have been reflected inferiorly to the level of the maxillary attachment of the buccinator muscle. The orbital, maxillary, and zygomatic osteotomies have been completed and the lower half of the orbital rim, the anterior, medial, and lateral walls of the maxillary sinus, and the zygomatic arch have been reflected. The lower horizontal cut, located at the Le Fort I level, extends above the apical dental roots and hard palate and along the inferior nasal meatus medially. The maxillotomy, at this stage, does not include the posterior maxillary wall or cross the greater and lesser palatine canals. The lat-*

from below is the transsphenoidal approach that can be performed either through a sublabial incision, a small incision along the side of the nasal septum, or as an endonasal or endoscopic approach directed through the nasal cavity between the nasal concha and septum (*Fig. 6.8*). Another relatively focal midline subcranial exposure is the transoral approach, which can be tailored to reach not only the clivus and upper cervical spine, but can be extended with division of the soft palate or removal of a part of the hard palate to access the sphenoid sinus superiorly or the midcervical levels below, if combined with midline transection of the tongue, mandible, or both (*Fig. 6.13*). The area below the anterior and middle cranial base can also be approached through a lateral rhinotomy incision, along the side of the nose, so that the nose can be reflected to provide access to the nasal cavity, medial orbit, the maxillary, ethmoidal, and sphenoid sinuses, and the clivus (*Fig. 6.14*). The transmaxillary approaches, either unilateral or bilateral as with the Le Fort osteotomy, can be used to provide access to the anterior and middle part of the lateral cranial base (*Figs. 6.13–6.15*). All of the central cranial base back to the foramen magnum can be accessed using the Le Fort I maxillotomy extending through the maxilla bilaterally above the dental apices and below the infraorbital canals with down-fracture of the maxillae (*Fig. 6.15*). If greater exposure is needed, the down-fractured bimaxillary segment can be divided in the midline, and the maxillae reflected laterally. There is also the possibility of using a unilateral upper or lower subtotal transmaxillary approach to access the anterior and middle cranial base (1, 2). In the lower subtotal maxillotomy approach, the portion of one maxilla located below the infraorbital canal is folded down into the floor of the mouth, thus providing access to the nasal cavity medially, the pterygopalatine fossa posteriorly, and infratemporal fossa posterolaterally (*Fig. 6.15*). The portion of the route directed through the nasal cavity can be used to reach the medial wall of the orbit and the paranasal sinuses, clivus, and upper cervical region. Another variant of the transmaxillary approach is the upper subtotal maxillotomy, in which one maxilla above the dental apex and including the orbital floor and lateral wall is mobilized to provide access to the parapharyngeal space, orbit, and upper part of the infratemporal fossa (*Fig. 6.16*) (1, 2). The upper maxillotomy approach can be combined with a frontotemporal craniotomy to yield intracranial access similar to that obtained with an orbitozygomatic craniotomy in addition to that obtained with the upper maxillotomy.

A preauricular infratemporal approach, using a preauricular skin incision, can also be used to access the middle cranial base, and infratemporal fossa and upper cervical carotid, plus the clivus and structures on the anterior side of the jugular foramen and foramen magnum (*Fig. 6.9*). The mandibular condyle can be displaced downward or resected to gain access to the upper cervical segment of the internal carotid artery and can be combined with a craniotomy to expose the middle fossa floor. The approach allows the petrous carotid to be reflected forward out of the carotid canal after resection of the eustachian tube and tensor tympani. After reflecting the carotid artery forward out of the carotid canal, the petrous apex on the medial side of the carotid canal can be removed for exposure of the upper medial part of the posterior fossa.

Because these lesions do not strictly adhere to the anatomic subdivisions of the cranial base, variations of the transcranial, subcranial, and combined approaches must often be innovatively combined for tumors of the cranial base that extend along the intracranial and subcranial structures and along the foramina and fissures in the cranial base. The approaches can be combined to provide access to virtually all of the anterior, middle, and posterior cranial base and should be tailored accurately so that they are not overly extensive and yet are sufficient to deal optimally with the pathology in a manner achieving the least disfiguring and most cosmetically and therapeutically acceptable results.

eral nasal wall was included with the maxillotomy to expose the nasal cavity. The infraorbital nerve, which crosses the orbital floor, may be preserved for reconstruction. C, *the posterior wall of the maxillary sinus has been removed to expose the pterygopalatine fossa and the palatine nerves and arteries. The base of the coronoid process was divided, and the temporalis reflected downward to expose the lateral pterygoid muscle and maxillary artery in the infratemporal fossa.* D, *a frontotemporal bone flap has been elevated, the dura covering the frontal and temporal lobes and lateral wall of the cavernous sinus have been opened, and the temporal lobe has been elevated. The pterygoid muscles, the pterygoid process and plates, and the part of the middle fossa floor formed by the greater sphenoid wing have been removed to expose the nerves passing through the foramina rotundum and ovale. The eustachian tube is exposed behind the mandibular nerve and the middle meningeal artery.* E, *magnified view of the cavernous sinus, superior orbital fissure, and orbit. The oculomotor, trochlear, and ophthalmic nerves course through the lateral wall of the cavernous sinus. The ophthalmic nerve sends its branches along the upper part of the orbit. The maxillary nerve exits the foramen rotundum and passes through the pterygopalatine fossa, where it gives rise to the infraorbital nerve that courses along the floor of the orbit. The mandibular nerve passes through the foramen ovale and sends its branches through the infratemporal fossa. The vidian nerve passes forward in the vidian canal below the maxillary nerve to join the pterygopalatine ganglion in the pterygopalatine fossa.* F, *enlarged view of the orbital exposure. The lacrimal gland sits on the superolateral margin of the globe. The lacrimal nerve courses above the lateral rectus muscle. The inferior oblique muscle passes below the attachment of the inferior rectus muscle and upward between the globe and lateral rectus muscle to insert on the globe near the tendon of insertion of the superior oblique muscle.* A., *artery;* Br., *branch;* Cav., *cavernous;* CN, *cranial nerve;* Eust., *eustachian;* Front., *frontal;* Gr., *greater;* Inf., *inferior;* Infraorb., *infraorbital;* Lac., *lacrimal;* Lat., *lateral;* Lig., *ligament;* M., *muscle;* Mass., *masseter;* Max., *maxillary;* Men., *meningeal;* Mid., *middle;* N., *nerve;* Obl., *oblique;* Palat., *palatine;* Proc., *process;* Pteryg., *pterygoid;* Pterygopal., *pterygopalatine;* Rec., *rectus;* Sup., *superior;* Temp., *temporal, temporalis.*

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Figure from D'Agoty Gautier's Essai d'anatomie, en tableaux imprimés. *Paris, 1748.*