CHAPTER 5

NASAL CAVITIES AND PARANASAL SINUSES

PARVIZ JANFAZA, WILLIAM W. MONTGOMERY, AND SALAH D. SALMAN

THE EXTERNAL NOSE

Anatomic Landmarks (Fig. 5.1)

- Apex (nasal tip): free angle.
- Nasion: midline point at which the nasal bones join the frontal bone.
- Rhinion: inferior point of the midline suture between the nasal bones where they meet the upper lateral cartilages.
- Root: upper attachment of the nose at the forehead.
- Nares: two elliptical openings into the nasal cavities.
- Columella: midline nasal soft tissue anterior to the septum separating the two nares.
- Vibrissae (hairs): help filter particles from inspired air.
- Dorsum of nose: ridge formed by the union of the lateral surfaces of the nose in the midline.
- Nasolabial angle: formed between the lip and the base of the columella.
- Nasofacial angle: junction between the nose and face.

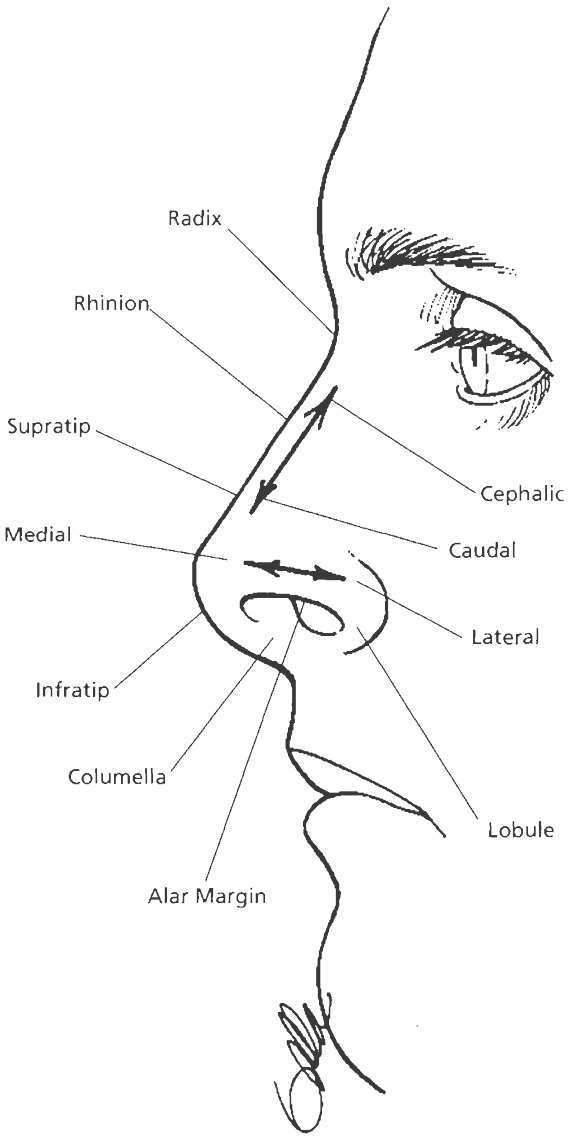


FIG. 5.1. Anatomic landmarks of the external nose. (From Cheney ML. *Facial Surgery: Plastic and Reconstructive.* Baltimore: Williams & Wilkins Publishers, 1997, with permission.)

- Bridge of nose: anterior surface of the nose formed by the nasal bones.
- Alae nasi: wings of the nose, which are rounded eminences at the inferior ends of the lateral nasal surfaces of the nose.

Nasal Bony Framework (Figs. 5.2 and 5.3)

- Is pyramidal in shape.
- Consists of two nasal bones that articulate with the nasal process of the frontal bone superiorly and with the ascending processes of the maxilla laterally (See Chapter 1, Fig. 1.1).
- These bones are thicker superiorly than inferiorly.
- They fuse superiorly with the thick bone of the glabella. The depression at this point is known as the nasofrontal angle and is referred to as the *nasion.*
- The piriform aperture is bounded by these bones and the alveolar processes of the maxilla. The alveolar processes merge in the midline to form the anterior nasal spine to which the cartilaginous septum is attached.
- Their medial articular surfaces are wider because each extends inferiorly and posteriorly into the nasal cavity to form a crest. This crest forms part of the septum and articulates with:
  - Spine of the nasal process of the frontal bone
  - Perpendicular plate of the ethmoid bone
  - Septal cartilage of the nose
- Their lower borders are beveled on their inner surfaces and articulate with the upper lateral nasal cartilages, which project superiorly 2 to 10 mm posterior to the nasal bones and are attached to them by dense connective tissue.

SURGICAL IMPLICATIONS

The development of the nasal bones from membranous primordium may explain their predictable behavior as grafts. Absorption of free grafts of nasal bone or cartilage is unusual, unlike the significant dissolution of cancellous bone grafts from the iliac crest.

- The *lacrimal groove* is located in the posterolateral border of the frontal process of the maxilla and in the lacrimal bone.

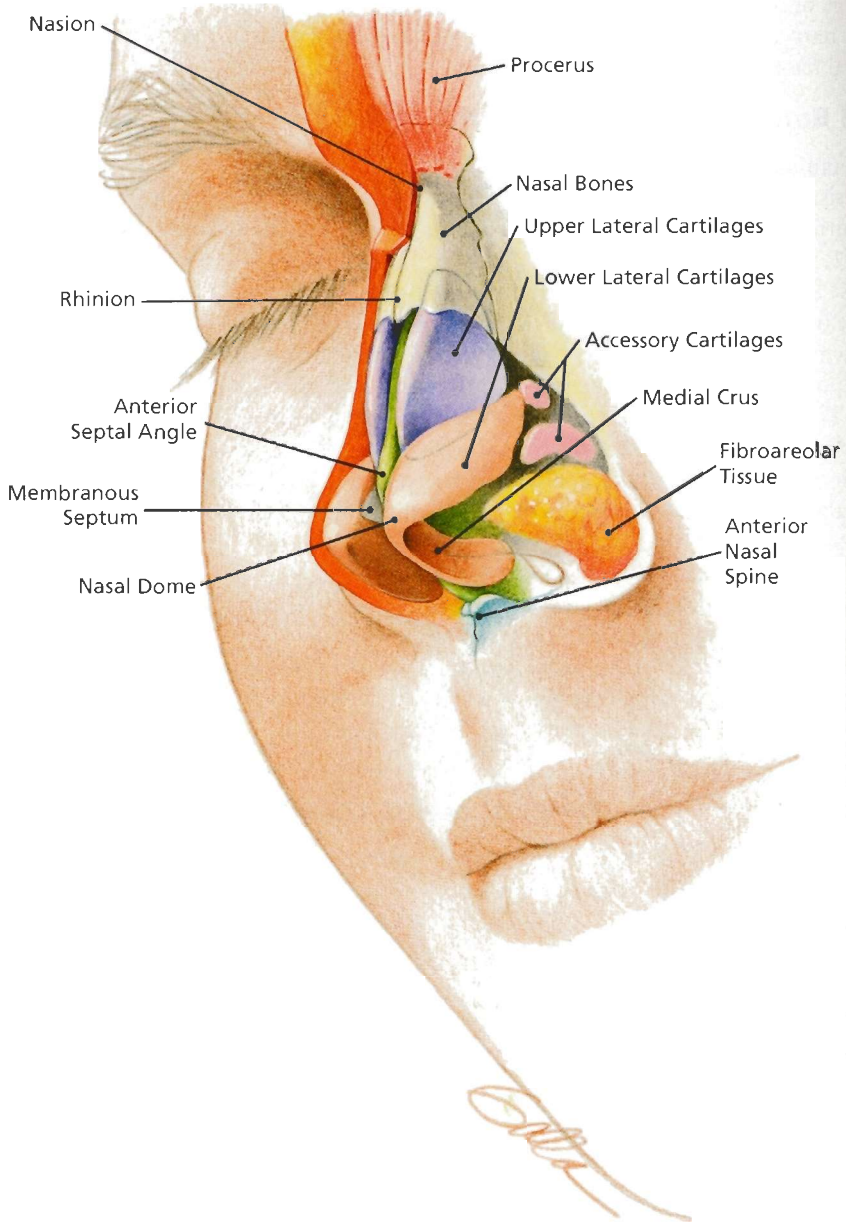
SURGICAL IMPLICATIONS

In a lateral nasal osteotomy, injury of the lacrimal groove and its contents is rare unless the osteotome is angled in an extremely posterior direction.

SURGICAL IMPLICATIONS

It is important to note that true fusion between the internasal, the nasomaxillary, and the nasofrontal sutures is rare. Fractures of these bones have the following characteristics:

1. They develop in the thinner portion of the bones.
2. Ossification of the callus is minimal, and healing is by fibrous union.
3. Fractures occur during osteotomy and are therefore associated with communication along old fracture lines.
4. Frequently, the anterior ethmoidal nerve and vessels produce longitudinal markings in the nasal bone that may be interpreted as fracture lines on nasal x-ray films; in general, fractures of the nasal bones are transverse.



A

FIG. 5.2. A: Nasal skeleton. (Modified from Cheney ML. *Facial Surgery: Plastic and Reconstructive*. Baltimore: Williams & Wilkins Publishers, 1997, with permission.)

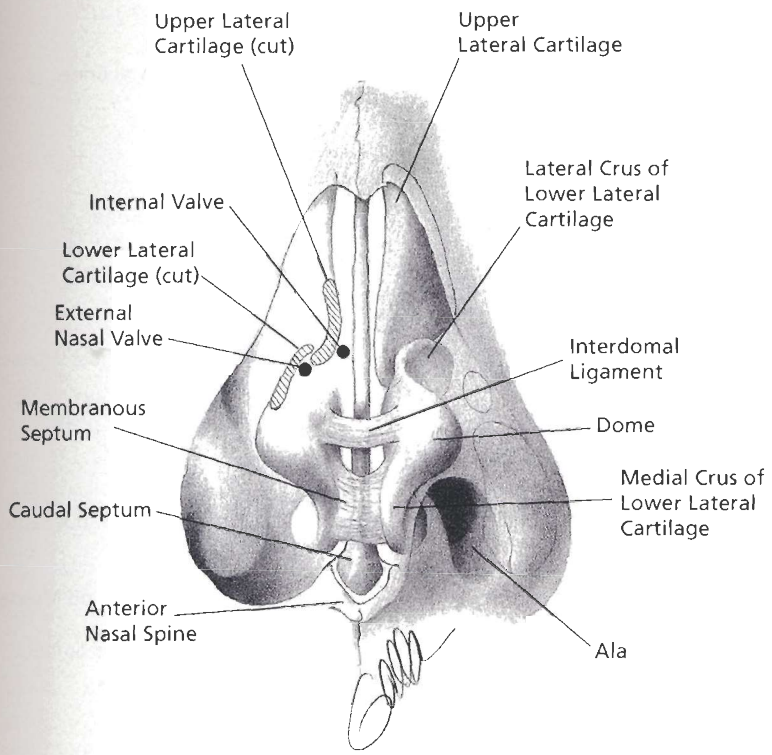


FIG. 5.2. *(continued)* **B:** Nasal cartilages and nasal valve. (Modified from Cheney ML. *Facial Surgery: Plastic and Reconstructive.* Williams & Wilkins Publishers, 1997, with permission.)

Nasal Cartilages (Fig. 5.2)

Upper Lateral (Triangular) Nasal Cartilage

- The base of the triangle (the superior posterior edge) is thin and articulates with the nasal and the maxillary bones for several millimeters.
- The lateral and inferior border is thin and curves laterally, overlapping the superior border of the lower lateral cartilage.
- The medial border of the triangle is thick superiorly, where it is continuous with the septal cartilage, and inferiorly, where it forms a free edge lateral to the midline of the nose. This thickness forms the nasal hump along with the nasal bone.
- The cartilaginous bridge is made by the union of the upper lateral cartilages. Below this, the anterior border of the septum is solely responsible for the normal projection of the nose.

Lower Lateral Cartilages

- Are also known as the greater alar or lobular cartilages.
- Form the shape of the nasal tip and maintain the patency of the nostrils.
- Each comprises a medial and a lateral crus.

Lateral Crus

- Is a variable extension posterolateral into the ala but is always connected to the maxilla by a lateral continuation of the fibrous membrane, which forms the posterolateral portion of the ala and several lesser alar cartilages are embedded in it.
- The two lateral crura diverge in the supratip region, leaving a triangular space between them.
- The dorsum of the nose in the septal area is supported only by the septal cartilage, subcutaneous tissue, and the thickness of the overlying skin.

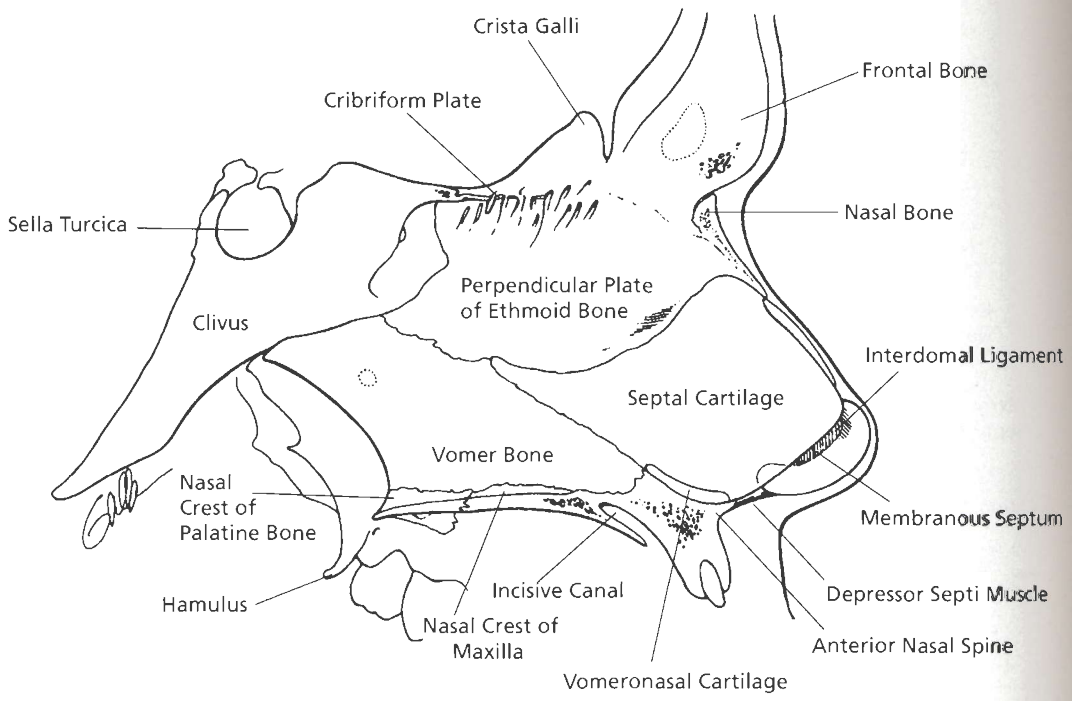


FIG. 5.3. Nasal septum.

> ***SURGICAL IMPLICATIONS***
>
> The angle between the septum and the upper lateral cartilage is important during respiration. Obstruction of this angle by scar tissue or trauma may produce symptoms of nasal obstruction.

Nasal Valve (Fig. 5.2B)

- The lower lateral (alar) cartilage overlaps on the lower border of the upper lateral cartilage.
- Nasal muscles hinge the alar cartilage laterally during inspiration, opening the nostrils.

> ***SURGICAL IMPLICATIONS***
>
> The upper and the lower lateral cartilages are obviously of great importance both in achieving aesthetic results and in maintaining nasal physiology during rhinoplasty. A surgeon should be conservative in trimming the alar cartilage, especially at its inferior extremity. After removal of the nasal hump, the upper lateral cartilages are trimmed flush with the septal dorsum so that the anatomic relationships of the triangle are carefully established.

SURGICAL IMPLICATIONS

The articulation between the caudal edge of the upper lateral cartilage and the lower lateral cartilage is important both anatomically and surgically. It is the site of the intercartilaginous incision during rhinoplasty.

Dion et al. (1978) found the following articular variations:

1. Interlocked (scroll) (52%): the lower border of the upper lateral cartilage turns laterally and upward. The concave surface of the lower lateral cartilage turns medially and caudally to interlock with the upper lateral cartilage.
2. End to end (17%): the cartilages meet end to end.
3. Overlapping (20%): similar to interlocked but with less turns of the edges.
4. Opposed (11%): the edge of the lower lateral cartilage is deep to the edge of the upper lateral cartilage.

Medial Crus

- Is more slender than the lateral crus and continuous with it at the apex of the nose.
- The curve between medial and the lateral crura forms the lateral portion of the apex.
- Extends inferiorly and posteriorly in the free edge of the nasal septum.
- The medial crura are loosely joined to each other and to the inferior border of the septal cartilage by connective tissue.
- At their posterior free borders, they turn slightly laterally.

Nasal Septum (Fig. 5.3)

Components

- Posterosuperiorly: perpendicular plate of the ethmoid.
- Anteriorly:
  - Septal cartilage
  - Membranous septum
  - Medial crus of the greater alar cartilage
- Posteroinferiorly:
  - Vomer
  - Crest of maxillary bone
  - Crest of the palatine bone

Perpendicular Plate of the Ethmoid

- Forms the upper one-third or more of the nasal septum.
- Unites superiorly with the cribriform plate of the ethmoid bone.
- Articulates with
  - Anterosuperiorly: frontal and nasal bones
  - Posteriorly: crest of the sphenoid bone
  - Posteroinferiorly: vomer
  - Anteroinferiorly: septal cartilage

Vomer

- Is the posteroinferior portion of the nasal septum.
- Articulates with
  - Superiorly: body of the sphenoid bone and the perpendicular plate of the ethmoid

Inferiorly: nasal crest of the maxilla and the palatine bones
Anteriorly: septal cartilage

- The nasal spine of the frontal bone and the crests of the maxillary and the palatine bones contribute small portions of the septum.

Septal (or Quadrangular) Cartilage

- Is continuous with the upper lateral cartilages toward the bridge of the nose.
- Is the sphenoidal process of the septal cartilage between the vomer and the perpendicular plate of the ethmoid bone.

SURGICAL IMPLICATIONS

Connective tissue lies between the perichondrium and the periosteum, but most of the fibers of each pass around the edge of the cartilage or the bone and are continuous with the opposite side. Therefore, when the mucoperichondrium is raised in septal surgery, both perichondrium and periosteum must be cut at the borders of the cartilage.

The looser connective tissue between the bone and the cartilage may sometimes contain fat and provides the mobility of the septal cartilage (Fig. 5.4). This joint allows the base of the cartilage to rotate as the cartilage is flexed, therefore decreasing the danger of fracture and permitting marked deviation of the septum without dislocation.

The articulation of the nasal cartilage inferiorly to the vomer and the maxilla may form horizontal "premaxillary wings." These lateral projections make elevation of the mucoperichondrium particularly difficult. To minimize injury to the nasal mucosa over the premaxillary wings, the perichondrium and the periosteum are elevated separately above and below the wings (tunnel technique).

Mobile Membranous Septum (Fig. 5.2B)

- Its inferior portion, the columella, is supported by the medial crura of the greater alar cartilages.
- The columella is connected by a membrane to the lower border of the septal cartilage. This membrane with its covering skin is called the membranous septum, which is a portion of the mobile septum.
- The terms *mobile* and *membranous* septum are often used synonymously.

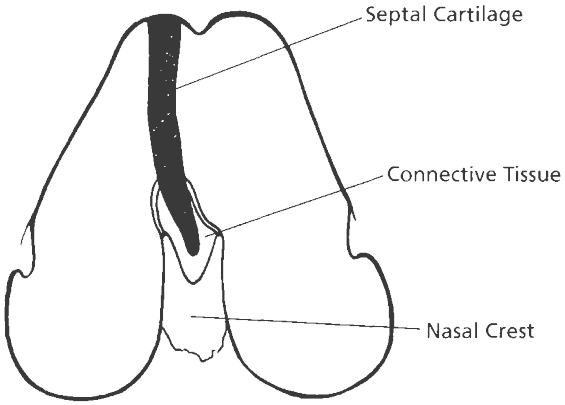


FIG. 5.4. Flexible articulation between the septal cartilage and the nasal crest.

SURGICAL IMPLICATIONS

A "deviated septum" often involves the perpendicular plate, the nasal crests of the maxilla and the palatine bone, and, rarely, the vomer.

A cartilaginous saddle nose, in contrast to a bony saddle nose caused by syphilis, is due to depression of the dorsum of the nose. It may be caused by the following:

1. Excessive removal of septal cartilage, which weakens the normal support in this area
2. Traumatic fracture of the septum
3. Septal hematoma or abscess, because the blood supply of septal cartilage is provided by the covering perichondrium
4. Tuberculosis, relapsing polychondritis, Wegner's granuloma

A fracture of the anterior nasal spine may be complicated by septal hematoma. A hematoma should be drained bilaterally: anteriorly in one nasal cavity and posteriorly in the opposite side. A rubber drain should be placed, as well as bilateral nasal packing to reappose the perichondrium to the septum.

Vomeronasal Cartilage (Fig. 5.3)

- Is a small bar of cartilage located along the inferior border of the septal cartilage on either side.
- A small opening in the mucous membrane leads to the rudimentary vomeronasal organ of Jacobson. In some animals, this organ is connected to the olfactory nerve and bulb.
- In humans, it usually is a simple short tubular sac 2 to 6 mm long covered by epithelium that continues with that of the nasal cavity proper.

Nerve Supply of the Nasal Septum (Fig. 5.5)

- Anterior ethmoidal nerve.
- Maxillary branches from the pterygopalatine (sphenopalatine) ganglion.

Blood Supply of the Nasal Septum (Fig. 5.5)

- Sphenopalatine artery.
- Anterior and posterior ethmoidal arteries.
- Facial artery.
- Coronary artery branch of the superior labial artery to Little's area of the septum.

Lobule of the Nose (Fig. 5.1)

- Comprises:
  - Tip
  - Ala
  - Columella
  - Membranous septum
- The entire lobule is movable.

SURGICAL IMPLICATIONS

The skin of the lobule is important in rhinoplasty for the following reasons:

It is thicker than the upper two-thirds of the nasal skin.
It contains more skin appendages.
Trimming of the skin and subcutaneous tissue frequently results in secondary deformity such as notching and depressions.

Soft Tissues of the Nose

Skin

- Is loosely attached over the upper cartilages and the nasal bones but is closely adherent to the alar cartilages and the tip.
- Skin of the tip and alae contains more sebaceous glands than that over the lateral cartilages.
- Pitanguy (1965) described a subcutaneous "ligament" closely identified with the dorsal skin in the supratip area, particularly in nonwhites.
- Arterial, venous, and neural supplies to the nasal skin are located in a superficial plane.

SURGICAL IMPLICATIONS

This ligament becomes important in surgical thinning of the soft tissue of the nasal tip during rhinoplasty.

SURGICAL IMPLICATIONS

Surgical elevation of the nasal skin should be done in the plane just superficial to the underlying bony and cartilaginous nasal skeleton to prevent injury to the blood supply and to the nasal muscles. Excessive damage to the nasal muscles causes unwanted immobility of the nose during facial expression, so called mummified nose.

Muscles of the Nose (Fig. 5.6)

- Are arranged in two overlapping layers.
- All are innervated by CN VII (facial nerve).

Procerus Muscle

- Is a continuation of the frontal muscle onto the nose.
- Is attached to the nasal bones and the upper lateral cartilages.
- Action: shortens or elevates the nose.

Levator Muscle of the Upper Lip and Ala of the Nose

- Its lower portion is known as the angular muscle.
- Action: shortens the nose and dilates the nostril.

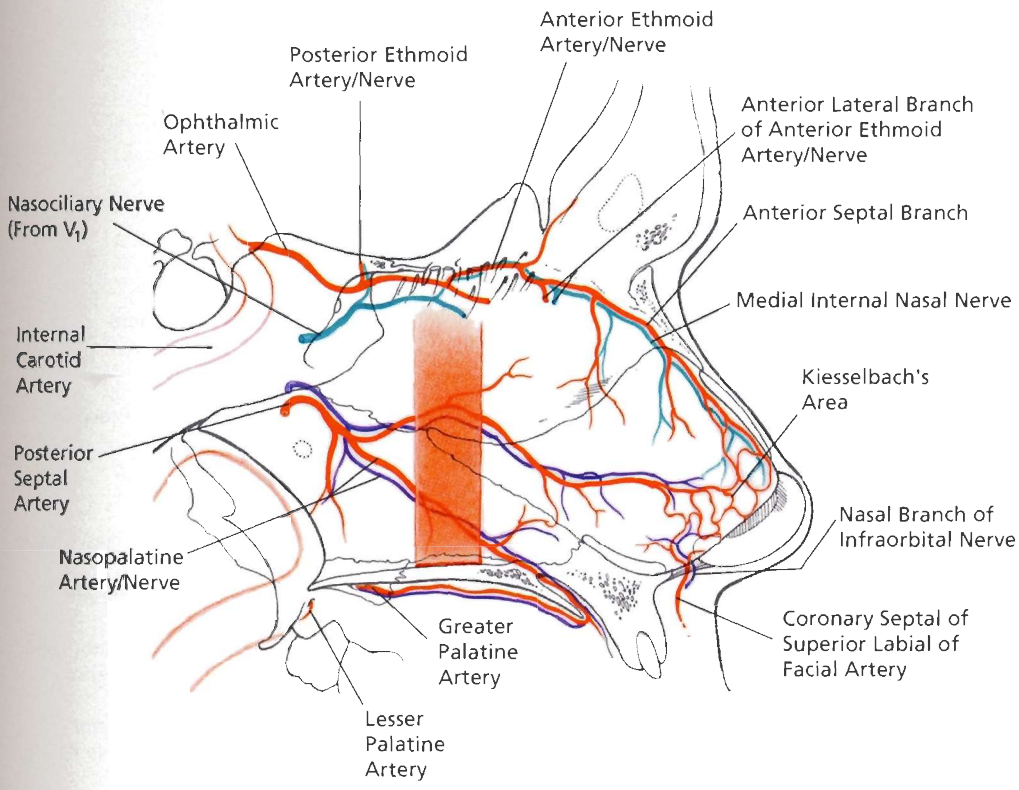


FIG. 5.5. Nerves and blood supply of the nasal septum.

Alar Part of the Nasal Muscle and Depressor Septi Nasi Muscle

- Depress and lengthen the nose.
- Dilate the nostrils.

Zygomatic Muscles

- Exert a pulling effect on the orbicularis oris muscle, which activates many muscles of the lower nose supplying an external but direct influence on nasal motion.

Transverse Part of the Nasal Muscle

- Compresses, lengthens, and contracts the nose.
- Alar cartilages provide support to keep the nostrils open in the resting position.

Depressor Septi Nasi Muscle

- During deep inspiration, the orbicularis oris muscle contracts the lip, and the depressor septi nasi muscle (in conjunction with the zygomatic muscle) tenses the membranous septum and the columella. By this action, the internal nares are narrowed, and negative intranasal pressure increases around the tense columella and the membranous septum. The internal nares then dilate and allow air to enter the nasal cavity.

SURGICAL IMPLICATIONS

Occasionally, the muscles of the nose are surgically severed to prevent plunging of the nasal tip during facial motion, as well as exaggerated dilation of the nostrils.

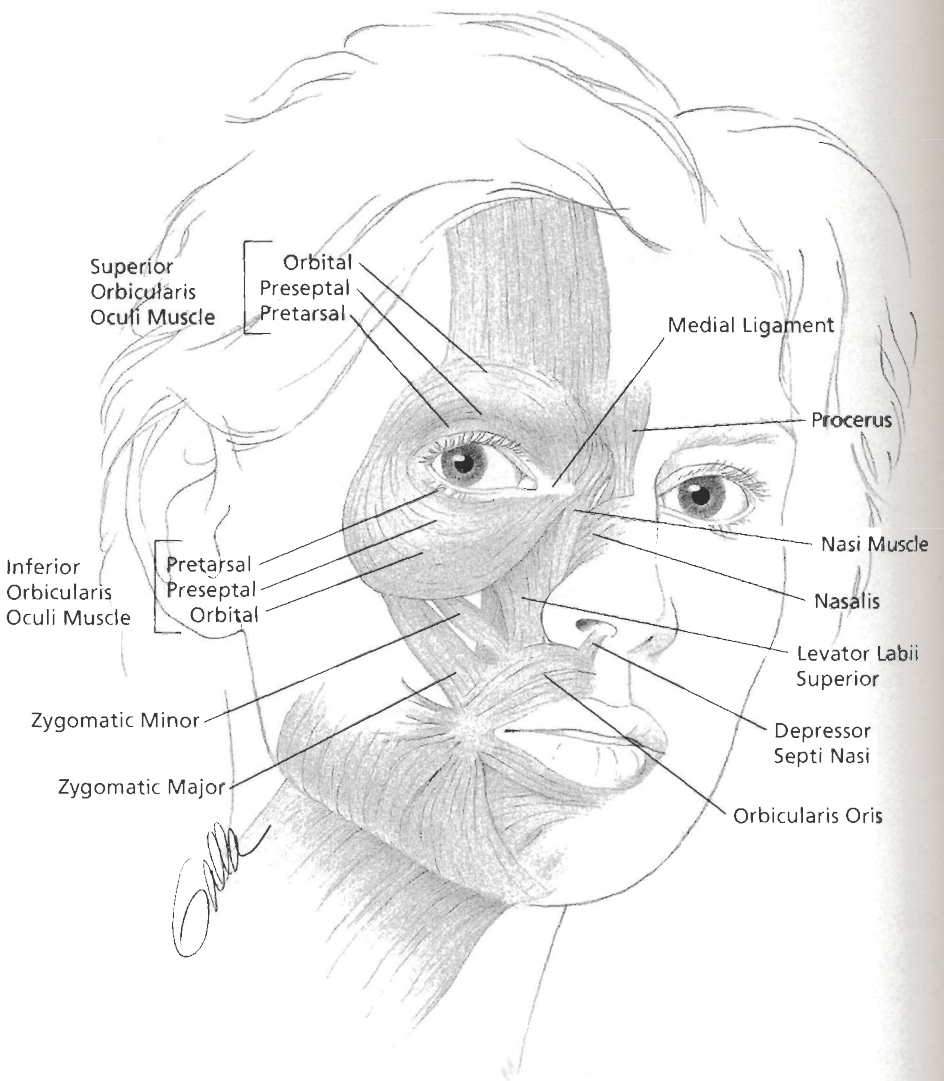


FIG. 5.6. Muscles of the nose. (From Cheney ML. *Facial Surgery: Plastic and Reconstructive.* Williams & Wilkins Publishers, 1997, with permission.)

Blood Supply of the External Nose (Fig. 5.7)

Arteries

- Origin: lateral nasal branch from the angular (upper part of the facial or external maxillary) artery.

Dorsal Nasal Artery

- Is a branch of the ophthalmic artery.
- Course: pierces the orbital septum superior to the medial palpebral ligament and passes inferiorly on the side of the nose.
- Anastomoses with the nasal branch of the facial or the angular artery.
- Provides a branch to the lacrimal sac.

Infraorbital Artery

- Is a branch from the internal maxillary artery.

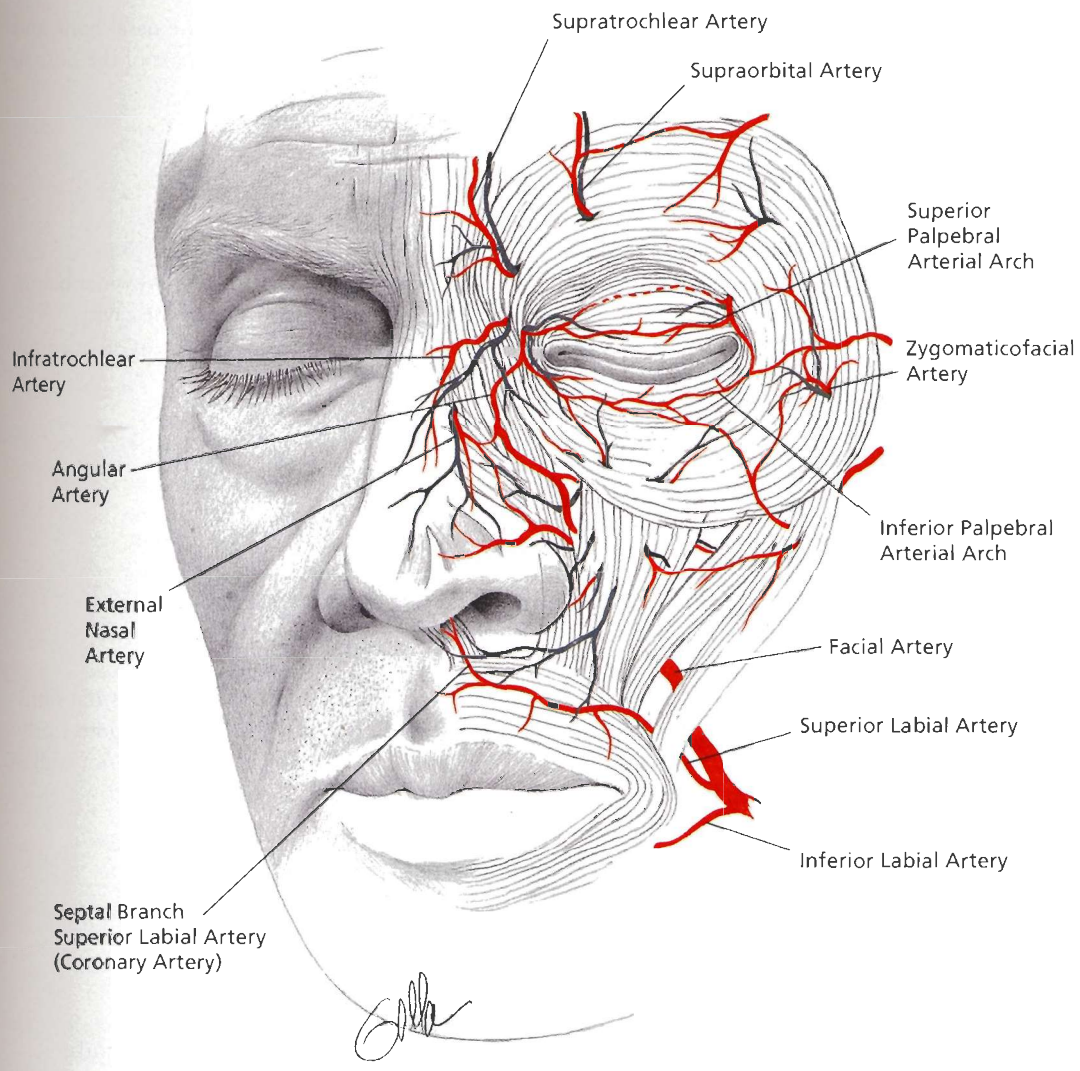


FIG. 5.7. Blood supply of the external nose. (From Cheney ML. *Facial Surgery: Plastic and Reconstructive.* Williams & Wilkins Publishers, 1997, with permission.)

- Provides blood to the side of the nose.

External Nasal Artery

- Is a terminal branch of the anterior ethmoidal artery.
- Emerges between the nasal bone and the upper lateral cartilage.
- Supplies the skin along the dorsum to the apex.

Veins

- Angular vein.
- Ophthalmic vein (see danger area of the face Chapter 1, page 29).

Nerve Supply to the External Nose (Fig. 5.7)

- *Supratrochlear and infratrochlear branches of the ophthalmic nerve* supply the skin of the root, the bridge, and the upper portion of the side of the nose.
- *Infraorbital branch of the maxillary nerve* supplies the skin on the side of nearly the lower half of the nose.

- *External nasal branch of the anterior ethmoidal nerve* exits between the nasal bone and the lateral nasal cartilage to supply the skin over the dorsum of this part of the nose to the tip.

THE NASAL CAVITY (FOSSA) (FIG. 5.8A)

- Comprises paired cavities separated by the nasal septum.
- In frontal section, is roughly triangular in shape, being narrow above and wider below.
- *Nostrils* or *external nares* refer to the oval-shaped anterior openings of the cavity.
- *Choanae* or *posterior nares* refer to the oval-shaped posterior or nasopharyngeal openings of the cavity.

Walls of the Nasal Cavity

- Medial: septum.
- Lateral: (like the medial) cartilaginous, membranous, and bony structures.
- Floor:
  Anterior three-fourths: palatal process of the maxillary bone
  Posterior one-fourth: horizontal process of the palatine bone
- Roof:
  Anteriorly: nasal bone, nasal spine of the frontal bone, and floor of the frontal sinus
  Midportion: cribriform plate of the ethmoid bone, which is very narrow posteriorly
  Posteriorly, the roof slopes down to the posterior choanae along the anterior wall of the sphenoidal sinus and the body of the sphenoid bone

Vestibule of the Nose

- Is a slight dilation inside the opening of nares.
- Boundaries:
  Medially: medial crus of the lower lateral cartilage
  Laterally: ala and the lateral crus of the greater alar cartilage
- Is covered with skin containing vibrissae (hairs) and sweat and sebaceous glands.
- Extends as a small recess toward the apex of the nose.

Limen Nasi (Limen Vestibuli)

- Is a ridge on the lateral nasal wall.
- Is formed by the lower margin of the upper lateral nasal cartilage.
- Separates the vestibule from the rest of the nasal cavity.
- Coincides with the region where there is a transtion from the skin of the vestibule to the mucous membrane of the remainder of the nasal cavity.

SURGICAL IMPLICATIONS

Intercartilaginous incisions in the nose occur just below the limen nasi, where the nasal cartilages are joined by connective tissue. Because the mucosa is thicker and less easily torn at this mucocutaneous line, the incision for performing a submucous resection septoplasty is usually done here.

Squamous papillomas occur anterior to this line. Inverted papillomas occur posterior to it. Occasionally, a lesion at this mucocutaneous junction shows both types of tumor.

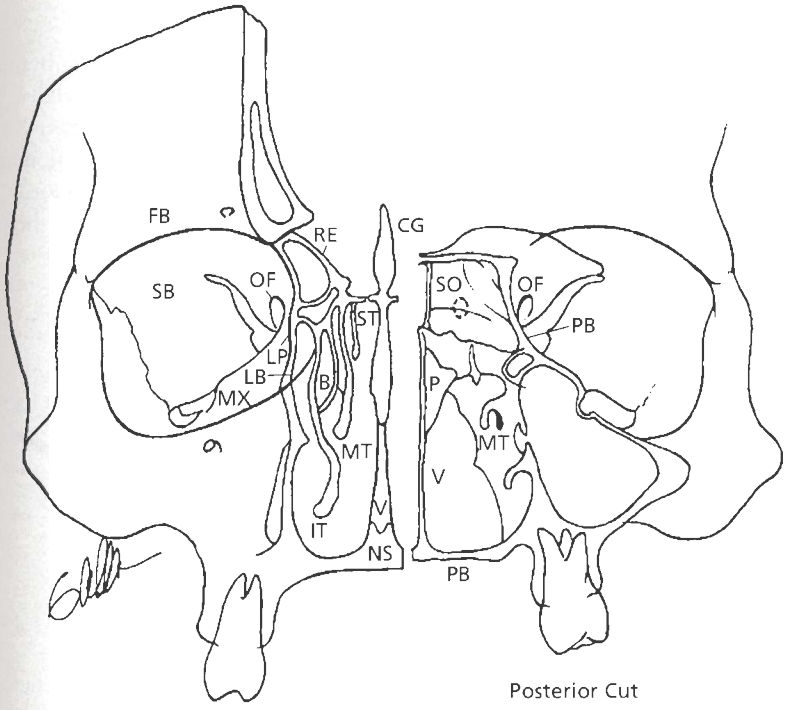
Subdivisions of the Nasal Cavity

Olfactory Region

- Comprises the superior nasal concha and the corresponding opposite septum (olfactory slit).
- Is covered by mucous membrane that
  - Is less vascular (being yellow rather than pink) than the remainder of the nasal mucosa.
  - Is covered by a nonciliated epithelium.
  - Contains the nerve cell bodies that give rise to the olfactory nerve fibers.
  - Contains serous glands (of Bowman).
- Tumors may arise from this olfactory mucosa.
- Olfactory neuroblastomas arise from olfactory nerve cells, and neuroendocrine carcinomas arise from olfactory epithelial cells. Each of these tumors may extend along olfactory nerve fibers through the cribriform plate.

Respiratory Region

- Represents the remainder of nasal cavity.
- Except for the vestibule, the nasal cavity is covered by mucous membrane that is firmly attached to the periosteum.
- The majority of the mucous membrane
  - Is highly vascular
  - Contains many mucous and serous glands
  - Is covered by pseudostratified columnar ciliated epithelium (schneiderian membrane)



FB - Frontal Bone
LB - Lacrimal Bone
MX - Maxilla
PB - Palatine Bone
SB - Sphenoid Bone
OF - Optic Foramen
SO - Sphenoid Sinus Ostium
RE - Roof of Ethmoid
LP - Lamina Papyracea
ST - Superior Turbinate
MT - Middle Turbinate
IT - Inferior Turbinate
P - Perpendicular Plate
V - Vomer
NS - Nasal Spine
CG - Crista Galli
B - Bulla

FIG. 5.8. A: Nasal fossa.

- The mucosa over the medial surfaces of the middle and the inferior turbinates is especially thick and contains a large venous plexus (cavernous plexus of the concha) in the lamina propria, which serve as erectile tissue.
- The function of the nasal respiratory mucosa is to warm and humidify inspired air. When the nasal mucosa is irritated, reflex vasodilation of the vessels causes increased secretion by the nasal glands and may be followed by sneezing. Engorgement and sensation of the nasal cavity is controlled by involuntary stimulation of the autonomic nervous system.

Lateral Nasal Wall (Fig. 5.8B)

- Is formed by three or four conchae (or turbinates), which are projecting scrolls of bone covered by mucous membrane.
- Conchae are named from below upward as the inferior, the middle, and the superior or supreme conchae.
- *Meatus* refers to air spaces located beneath and lateral to the conchae.
- The three turbinates converge toward each other posteriorly. The remaining nasal cavity posterior to them is called the *nasopharyngeal meatus.*
- Anterior to the inferior and middle turbinates and above the limen nasi lie the following:

  Agger nasi: a bulge located between the middle turbinate and the dorsum of the nose, which, in humans, marks the location of ethmoidal (agger nasi) air cells and is a landmark for locating the lacrimal sac

  Olfactory sulcus: a passage located above the agger nasi that extends to the olfactory portion of the nasal cavity

  Atrium of the middle meatus: a shallow depression located below and posterior to the agger nasi that leads to the middle meatus; it is situated above and anterior to the attachment of the inferior turbinate

Inferior Turbinate and Inferior Meatus

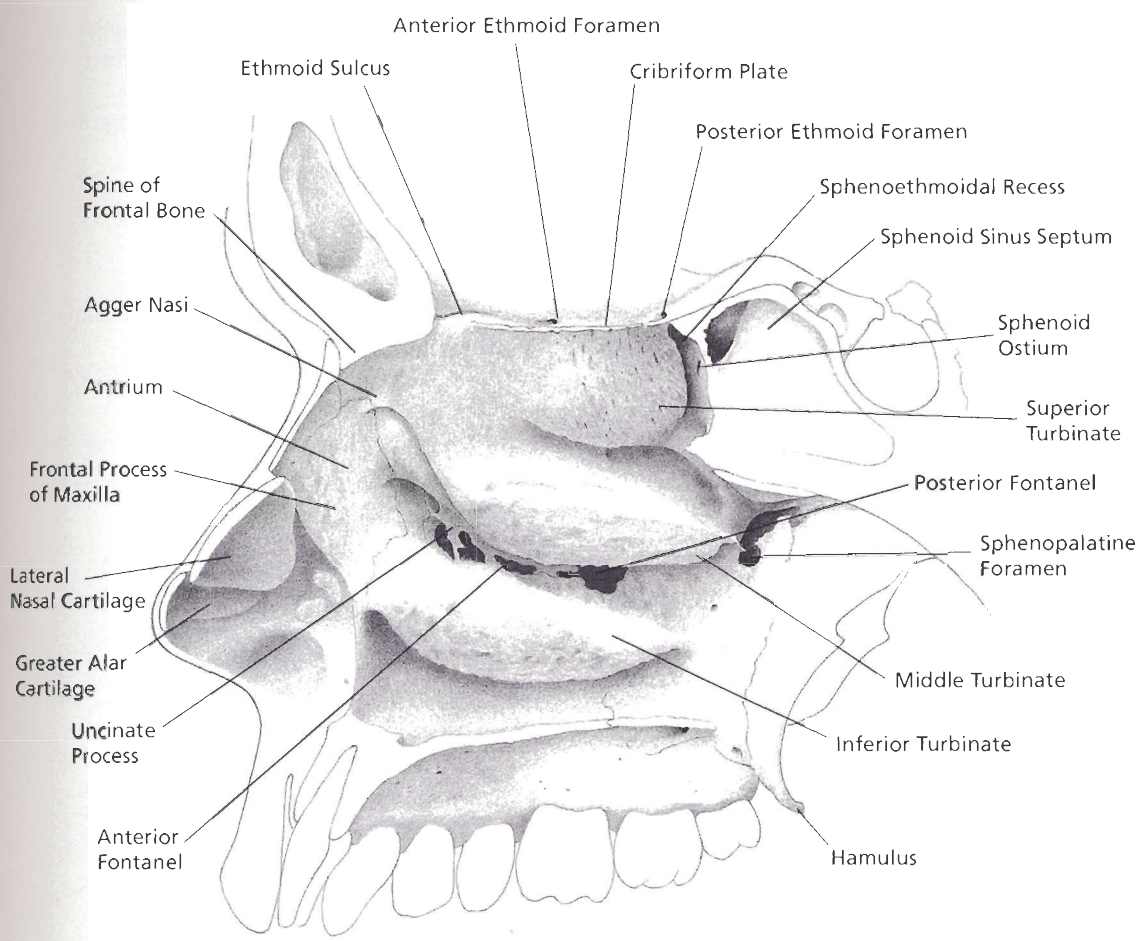
- The inferior nasal turbinate is a separate bone covered by thick mucous membrane.
- Its sagittal arch causes the inferior meatus to narrow anteriorly and posteriorly.
- The inferior turbinate and meatus are both wider and higher at their midpoints.
- The *nasolacrimal opening (valve of Hasner)* is usually found in the anterior portion of the lateral wall of the inferior meatus just below the border of the inferior turbinate.
- When the opening is slit-like, it is protected by a fold of mucous membrane, the plica lacrimalis or valve of Hasner.

SURGICAL IMPLICATIONS

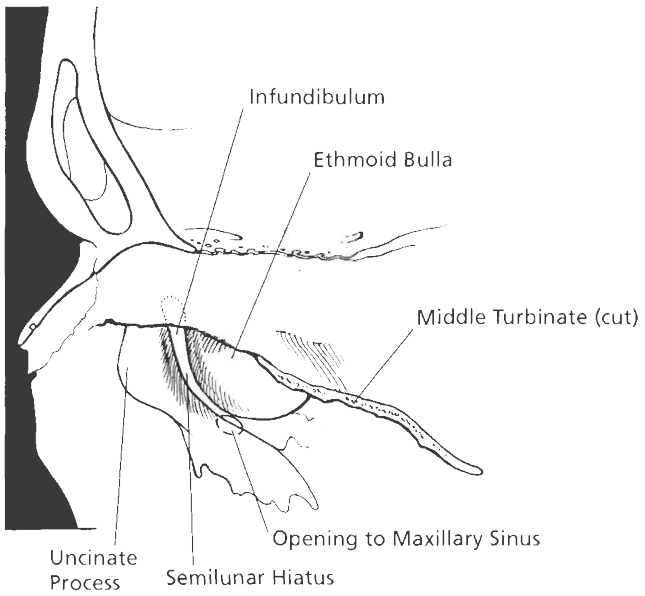
Inferior meatal antrostomy or maxillary sinus irrigation should be performed as far back as possible to prevent injury to this ostium. The bone is thicker around the nasolacrimal duct. Inferior meatal punctures should go through the thinner bone posteriorly.

Middle Turbinate and Middle Meatus

- The middle nasal turbinate is a portion of the ethmoid bone.
- Its anterior end attaches along a line running nearly vertically upward to join the other turbinates at an angle or genu.
- The *concha bullosa* is a pneumatized portion of the middle turbinate continuous with ethmoidal air cells.
- A *paradoxical* middle turbinate is convex laterally rather than medially.



B



C

FIG. 5.8. ***(continued)*** **B:** Lateral nasal wall. **C:** Clefts and spaces of the lateral nasal wall.

- The most superior portion of the *middle meatus* is situated inferior to the genu and is known as the *frontal recess,* where ostia of the frontal sinus and some of the anterior ethmoidal cells are located.
- The descending ramus of the middle meatus extends from the frontal recess posteroinferiorly and contains
  - Ethmoidal bulla
  - Uncinate process
  - Semilunar hiatus
- *Ethmoidal bulla:*
  - Is a rounded projection of the lateral wall of the middle meatus situated under the middle turbinate.
  - Consists of one or more ethmoidal cells referred to as the bulla ethmoidal cells.
  - These cells open on or superior to the bulla.
- The *suprabullar recess (or furrow)* is located above the bulla, between it and the attachment of the base of the middle turbinate.

Superior Turbinate

- Is approximately one-half the length of the middle turbinate.
- Starts at about the middle of the lower turbinates and becomes continuous with them posteriorly.
- The *sphenoethmoidal recess* lies between the superior or the supreme turbinate and the anterior surface of the body of the sphenoid bone.

Supreme Turbinate and Supreme Meatus

- Are present unilaterally or bilaterally in 60% of individuals.
- The ostium of the posterior ethmoidal cell opens into the supreme meatus, when present, in about 75% of individuals.

Clefts and Spaces of the Lateral Nasal Wall (Fig. 5.8C)

Semilunar Hiatus

- Is a slit-line opening bounded
  - Superiorly by the bulla
  - Inferiorly by a sharp ridge of bone called the uncinate process.

Ethmoidal Infundibulum

- Is a space extending from the semilunar hiatus downward and posteriorly between the lateral nasal wall and the uncinate process.
- The following open into it:
  - Anterior ethmoidal cells (infundibular cells)
  - Maxillary sinus ostium, whose accessibility therefore depends mainly on the depth of the infundibulum and on the closeness with which the uncinate process hugs the lateral wall
- Boundaries:
  - Anteroinferiorly: uncinate process of the ethmoid bone
  - Posterosuperiorly: ethmoidal bulla
  - Medially: lateral surface of the uncinate process
  - Laterally: from posterior to anterior:
    - Lamina papyracea of the orbit
    - Ascending frontal process of the maxilla
    - Lacrimal bone anterosuperiorly (rare)

- Becomes continuous with the middle meatus posteriorly.
- Attachments of the uncinate process include
  - Anteriorly: to the above three bones in an acute angle terminating at the infundibulum anteriorly. Therefore, the infundibulum appears to be V-shaped on axial computed tomography (CT).
  - Inferiorly: to the inferior turbinate, leaving two bony defects anterior and posterior to this union:
    - Anterior (or inferior) fontanelle
    - Posterior (or superior) fontanelle
- When the middle turbinate is fractured upward, the bulla, semilunar hiatus, and the posterior edge of the uncinate process can be visualized.
- *Natural ostium of the maxillary sinus:*
  - Is hidden by the uncinate process.
  - Is located in the middle of the floor of the infundibulum.
  - Becomes visible when the inferior portion of the uncinate process is removed.
- The accessory ostia of the maxillary sinus are seen in the anterior or posterior fontanelles.

Frontal Recess

- Is the inferior funnel below the ostium of the frontal sinus.
- The nasofrontal duct enters the anterior end of the middle meatus when the anterior end of uncinate process fuses with the anterior part of the bulla.
- Boundaries:
  - Medially: lateral surface of the most anterior part of the middle turbinate. If the uncinate process turns medially and attaches to the middle turbinate, it forms the medial portion of the frontal recess.
  - Laterally: an anterosuperior extension of the lamina papyracea. If the ethmoidal infundibulum has a terminal recess, then the uncinate process provides a portion of the lateral wall and also forms the floor of the frontal recess in its most anterior aspect.
  - Superiorly: an extension of the ethmoidal foveolae anteriorly. This part of the bone bends superiorly and becomes the posterior wall of the frontal sinus.

Anatomic Relationship of the Frontal Recess and the Ethmoidal Infundibulum

- Depends on the following three variations in the attachment of the uncinate process superiorly (Fig. 5.9)
  - Type I: the superior end of the uncinate process turns laterally and is attached to the lamina papyracea. This attachment forms a pouch superiorly in the ethmoidal infundibulum called the terminal recess (sinus terminalis). The ethmoidal infundibulum is separated from the frontal recess, and the frontal sinus drains medial to the ethmoidal infundibulum.
  - Type II: the upper end of the uncinate process extends superiorly to the roof of the ethmoid or gradually tapers anteriorly.
  - Type III: the upper end of the uncinate process turns medially and attaches to the middle turbinate.

SURGICAL IMPLICATIONS

In types II and III, the frontal sinus and the frontal recess open directly into the ethmoidal infundibulum. This facilitates the spread of infection from the frontal sinus to the other sinuses, particularly the maxillary sinus.

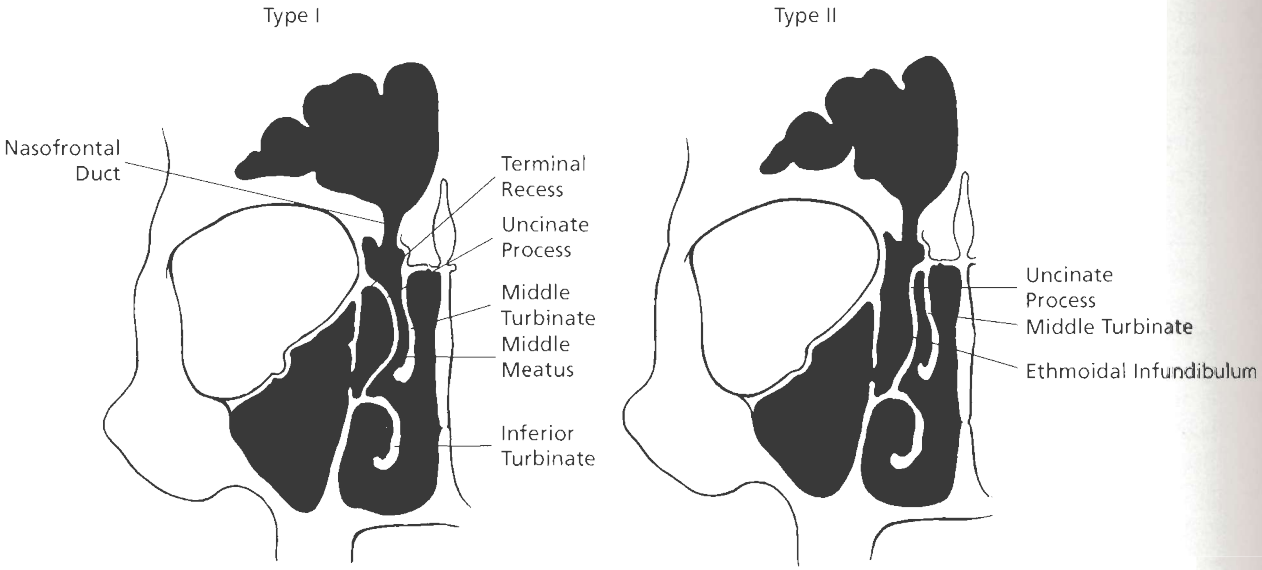


FIG. 5.9. Nasofrontal communication.

Nerves of the Nasal Cavity (Figs. 5.10 and 5.11)

- Include
  - Olfactory nerves
  - Sensory nerves

Nasociliary Nerve

- Is a branch of the ophthalmic division of CN V (trigeminal nerve).
- Arises from the ophthalmic nerve in the lateral wall of the cavernous sinus.
- Enters and traverses the orbit, giving off branches in the orbit and divides into two terminal branches: infratrochlear and anterior ethmoidal nerves.

Infratrochlear Nerve

- Supplies the skin at the medial angle of the eyelid.

Anterior Ethmoidal Nerve

- Leaves the orbit via the anterior ethmoidal foramen with the anterior ethmoidal artery.
- Intracranially, is located anteriorly along the lateral margin of the cribriform plate.
- Leaves the cranium via the ethmoidal slit at the side of the crista galli to reach the nasal cavity.
- Supplies (through the lateral and the medial internal nasal branches) part of the nasal cavity, including
  - Region anterior to the superior turbinate and above the middle turbinate
  - Atrium
  - Anterior ends of the middle and the inferior turbinates, and a corresponding portion of the septum.
- Leaves the nasal cavity between the nasal bone and the lateral nasal cartilage to innervate the skin on the dorsum of the tip of the nose.

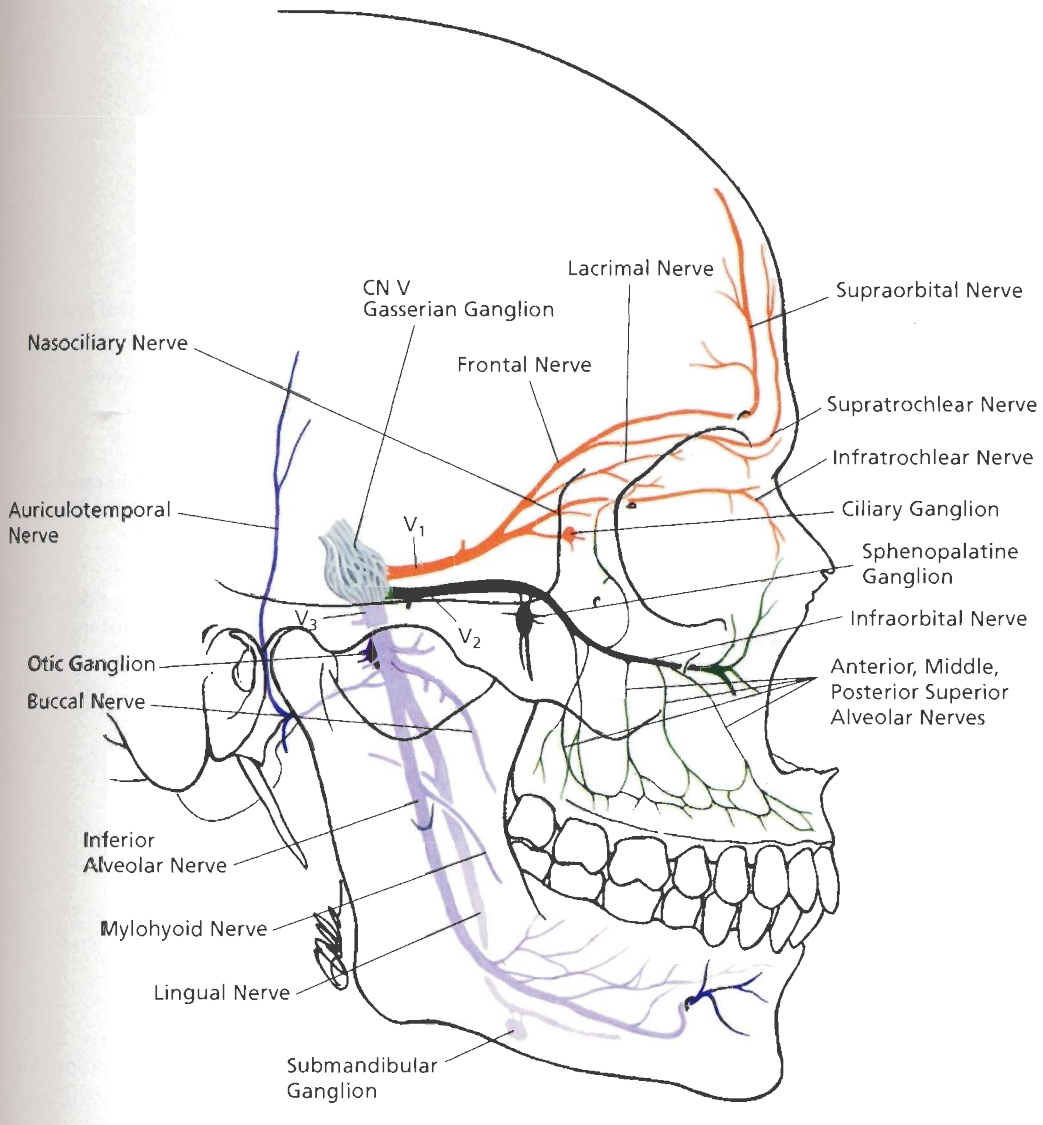


FIG. 5.10. Divisions and branches of CN V (trigeminal). (Modified from Cheney ML. *Facial Surgery: Plastic and Reconstructive*. Williams & Wilkins Publishers, 1997, with permission.)

Maxillary Nerve

Infraorbital (or Terminal) Branch of the Maxillary Nerve

- Supplies
  - Portion of the vestibule of the nose through branches entering by way of the nares and the lateral wall of the nose
  - Anterior part of the inferior meatus
  - Part of the floor of the nasal cavity via the anterior superior alveolar nerve

Main Portion of the Maxillary Nerve

- Comes via the *pterygopalatine (sphenopalatine) ganglion.*
- Pterygopalatine ganglion:
  - Is suspended from the maxillary nerve in the pterygopalatine fossa, which is located immediately lateral to the posterior portion of the nasal cavity.
  - Contains parasympathetic, sympathetic, and sensory nerves.

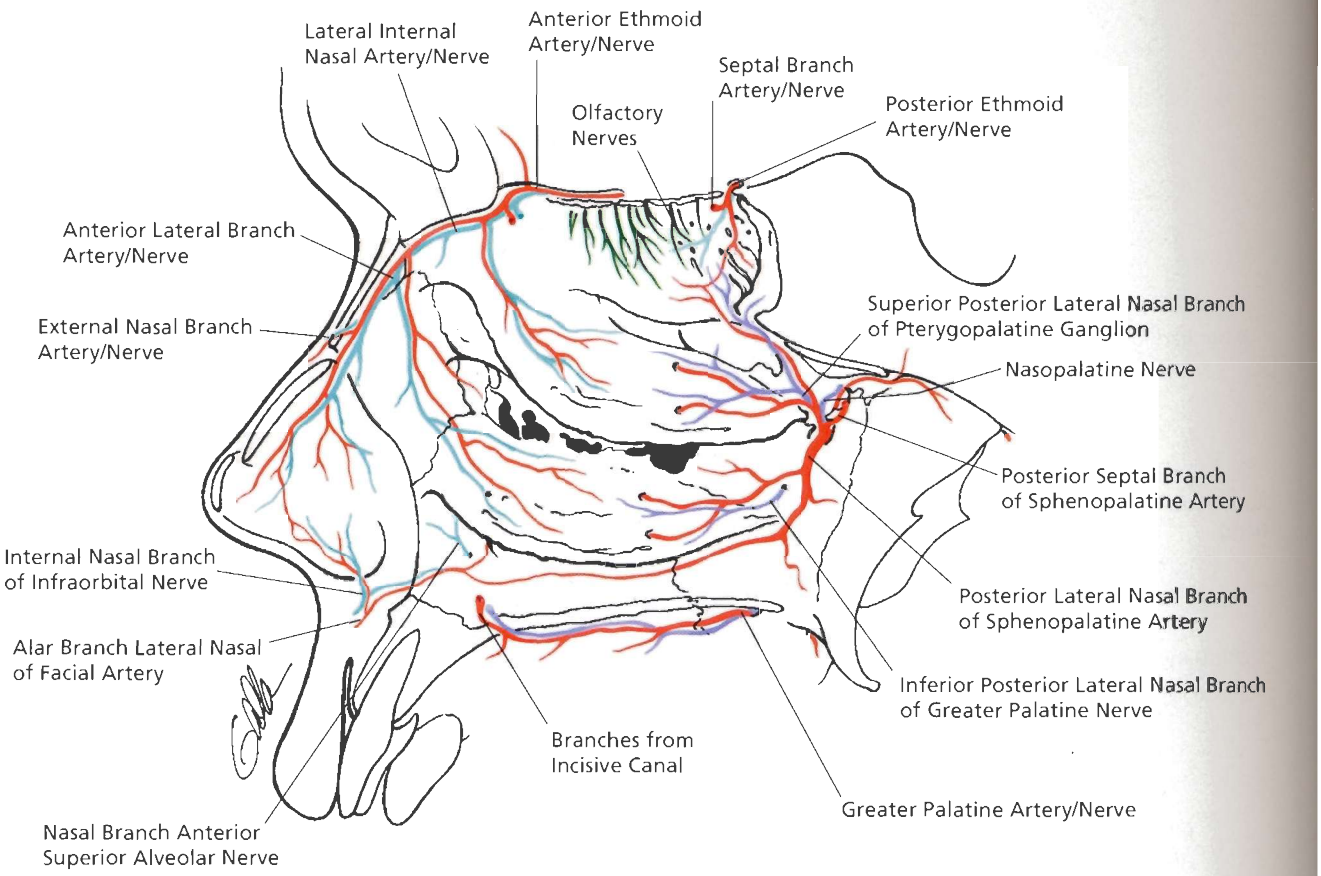


FIG. 5.11. Nerves and arteries of the lateral wall of the nasal cavity.

- The majority of nasal branches from the ganglion pass through the sphenopalatine foramen, which is situated immediately behind the posterior end of the middle nasal turbinate.
- *Branches* of the ganglion include the following.

Lateral Posterior Superior Nasal Branches

- Are small twigs supplying the mucous membrane over the posterior portion of the superior and the middle nasal turbinates and the posterior ethmoidal cells.

Medial Posterior Superior Nasal Branches

- Cross the anterior surface of the sphenoid and the roof of the nasal cavity and the posterior septum.

Nasopalatine Nerve

- Lies between the periosteum and the mucous membrane.
- Unites at the incisive palatine canal with the nasal branch of the anterior superior alveolar nerve.
- Both then pass via the median incisive canals to supply the anterior part of the hard palate and anastomose with the greater (anterior) palatine nerve.

Greater Palatine Branches

- Are derived from the greater palatine nerve passing through the pterygopalatine canal.
- Are small and penetrate the palatine bone to supply the mucous membrane over the posterior portion of the inferior nasal turbinate and the adjacent parts of the middle and inferior meatus.

SURGICAL IMPLICATIONS

The following approaches have been carried out to block the pterygopalatine ganglion and its sensory branches:

Direct injection of the ganglion through its foramen or surrounding thin bone
Lateral, paramandibular approach

Injection superiorly through the greater palatine canal with a short needle to avoid entering orbit. Lidocaine with epinephrine is used to treat posterior epistaxis.

Intranasal and transantral approaches to the ganglion have been described. The transantral approach has been used for vidian neurectomy and ligation of the branches of the third portion of the internal maxillary artery for severe epistaxis.

Terminal Nerves

- Their ganglion cells are embedded in the dura between the crista galli and the olfactory bulb (Brookover, 1914, 1917)
- Reach the nose through the cribriform plate to lie in the septal cartilage.
- Their function is not known, but they are thought to contain sensory and autonomic fibers.

Greater Petrosal Nerve

- Is derived from CN VII.
- Its sensory fibers have their cells of origin in the geniculate ganglion.

Autonomic Innervation (Fig. 5.12)

- The main autonomic (sympathetic and parasympathetic) nerve supply to the nose is derived via the pterygopalatine ganglion and its branches.
- Some sympathetic fibers may reach the nasal cavity via the nasociliary nerve and the terminal nerves.

Parasympathetic Fibers of the Nose

- Are derived from CN VII.

Preganglionic Fibers

- Originate in the superior salivatory nucleus in the medulla oblongata.
- Are located in the nervus intermedius portion of the facial nerve.
- Leave CN VII at the geniculate ganglion with the greater superficial petrosal nerve to the pterygopalatine ganglion.

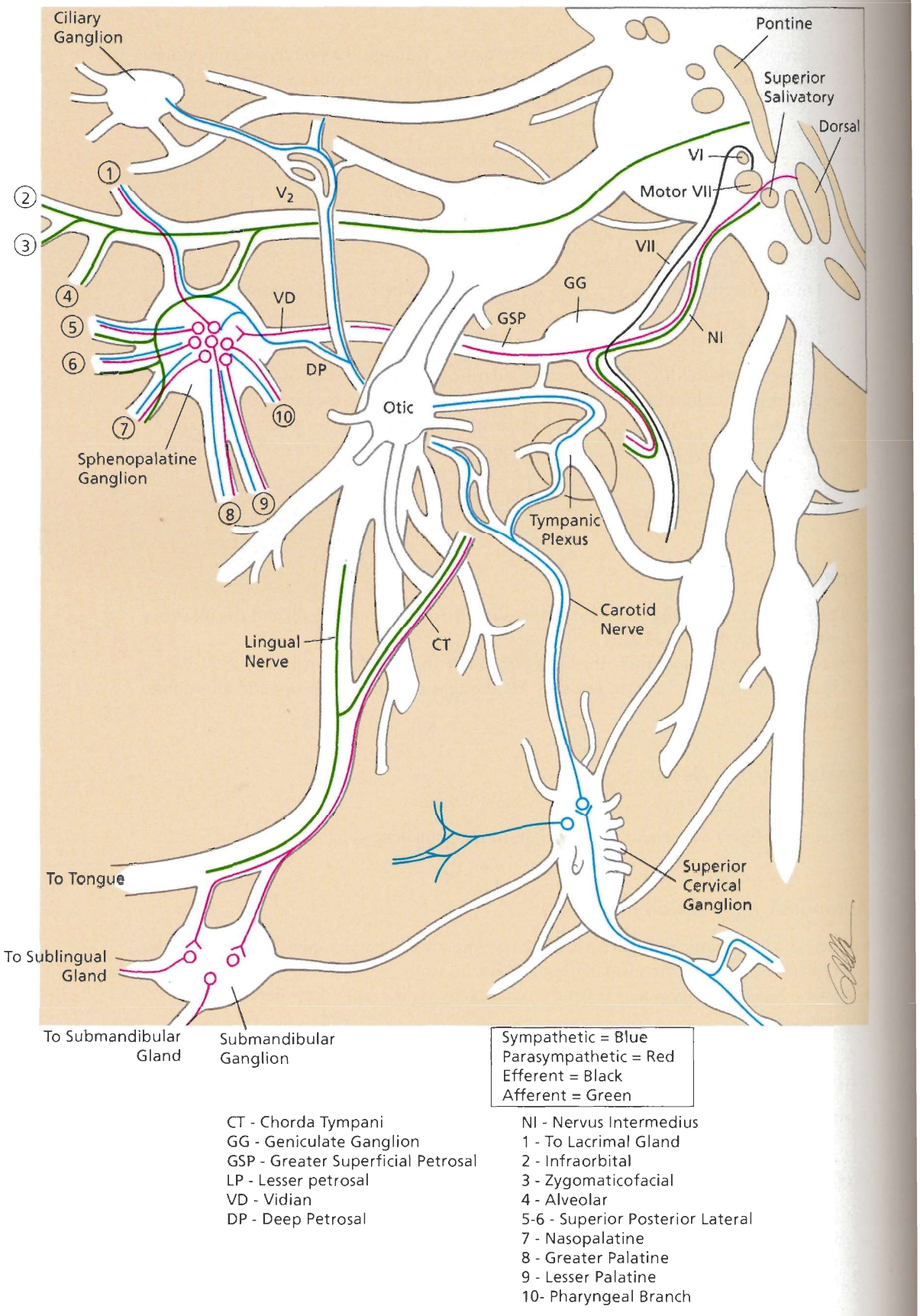


FIG. 5.12. Autonomic innervation of the nasal cavity.

Postganglionic Fibers

- Arise in the ganglion and join sympathetic and sensory fibers.
- The greater superficial petrosal nerve contains both vasodilator and secretory fibers.

Sympathetic Fibers of the Nose

- Originate from the upper thoracic segments of the cord and, occasionally, from the distal cervical segment

Postganglionic Fibers

- Are derived from the superior cervical ganglion.
- Run along the internal carotid artery.
- Leave this plexus as the deep petrosal nerve, which joins the greater superficial petrosal nerve to form the nerve of the pterygoid canal (vidian nerve).
- Run through the pterygopalatine ganglion without synapses.
- Mediate mainly vasoconstriction but may also mediate vasodilation (Larsell and Fenton, 1936).

Blood Supply of the Nasal Cavity (Fig. 5.11)

- Derives from the internal and the external carotid arteries.

Internal Carotid Artery

- The anterior and the posterior ethmoidal arteries leave the ophthalmic artery within the orbit.
- They course via the anterior and the posterior ethmoidal canal, respectively, take an intracranial course, and then turn inferiorly over the cribriform plate.

Anterior Ethmoidal Artery

- Is larger than the posterior artery.
- Supplies the anterior one-third of the lateral wall of the nose and the corresponding portion of the septum.
- Anastomoses with the sphenopalatine artery.
- A terminal branch (external nasal branch):
  Accompanies the external nasal branch of the anterior ethmoidal nerve.
  Exits between the nasal bone and the lateral nasal cartilage to pass on the dorsum of the nose to the nasal tip.

Posterior Ethmoidal Artery

- Supplies
  Superior nasal turbinate
  A portion of the septum

External Carotid Artery

Sphenopalatine Artery

- Passes with the posterior superior nasal nerves through the sphenopalatine foramen and divides into the lateral and septal posterior nasal arteries.

Lateral Posterior Nasal Artery

- Is the larger of the posterior nasal arteries.
- Runs along the middle and inferior turbinates.
- Has a unique location in the middle third of the inferior turbinate:
  The artery of the inferior concha is usually divided.

In the middle third of the turbinate, all branches traverse canals in the turbinate, instead of lying in the mucosa.
Arteries in the canals are surrounded by a venous plexus that drains the erectile tissue of the turbinate. Therefore, dilation of the arteries decreases venous drainage, causing congestion of the mucosa.

Septal Posterior Nasal Artery

- Runs across the face of the sphenoid medially before dividing into branches to the septum.

Descending Palatine Artery

- Is a branch of the third portion of the internal maxillary artery that forms the greater and the lesser palatine arteries accompanying the palatine nerves inferiorly in the palatine canals.
- Supplies
  Lower posterior portion of the nasal cavity
  Soft palate (lesser palatine arteries)
- *Greater palatine artery:*
  Emerges via the greater palatine foramen and passes anteriorly.
  Supplies the hard palate and the inner aspects of the gingiva of the upper teeth.
- A terminal branch:
  Passes superiorly via the incisor fossa and the lateral incisive canal (of Stensen) to supply an inferior part of the nasal cavity.
  Joins Little's area on the septum.

Septal Branch (Coronary Artery) of the Facial Artery

- Is a branch of the superior labial artery branch of the facial artery.
- Supplies the vestibule of the nose and the septum.
- Anastomoses on the anterior portion of the septal cartilage with the septal branch of the sphenopalatine artery.
- Little's area or Kisselbach's plexus is situated in the anterior portion of the nasal septum.
- Includes
  Septal branch of the sphenopalatine artery
  Anterior ethmoidal artery branches
  Greater palatine artery
  Septal branches of the superior labial (coronary) artery

Pharyngeal Branch of the Third Portion of the Internal Maxillary Artery

- Supplies the posterosuperior aspect of the nose and the nasopharynx.

> ***SURGICAL IMPLICATIONS***
>
> Because there are so many anastomoses between vessels supplying the nasal cavity, a recommended approach for severe epistaxis not controlled by other means is embolization of the internal maxillary artery and the ipsilateral facial artery. If angiography shows that an anterior ethmoidal artery is large, the artery can be ligated surgically.

Veins of the Nasal Cavity

- The nasal venous plexus resembles erectile tissue in the turbinates.
- The definitive veins correspond approximately to the arteries:
  Sphenopalatine vein drains via the sphenopalatine foramen into the pterygoid plexus.

Ethmoidal veins drain into the superior ophthalmic vein.
Over the alar cartilages, the nasal plexus is continuous with the subcutaneous plexus of the nose and therefore empties into the facial vein.

Lymphatic Vessels of Nasal Cavity

- From the more anterior portion of the nose, are connected through the nares with lymphatic vessels of the skin.
- Larger vessels pass posterior to the tonsillar region and then directly to the upper deep cervical nodes.
- Most drain into the pharyngeal plexus and then into the retropharyngeal nodes.

THE PARANASAL SINUSES (FIGS. 5.13 TO 5.17)

Development of the Sinuses

- With the exception of the sphenoidal sinus, start to develop as evaginations of the mucosa of the nasal cavity during the third and fourth fetal months.
- The maxillary and the ethmoidal sinuses are of appreciable size at birth but are not filled with air; aeration gradually develops after birth.
- The frontal sinus is a very small diverticulum at birth, and almost all of its development occurs after birth.
- The sphenoidal sinus hardly exists at birth and significant enlargement does not begin until the third year.

Mucosa of the Sinuses

- Usually, consists of pseudostratified columnar ciliated epithelium.
- The direction of flow created by the ciliary beat in all sinuses is toward the ostium; therefore material anywhere within the sinus tends to be carried to the nose.

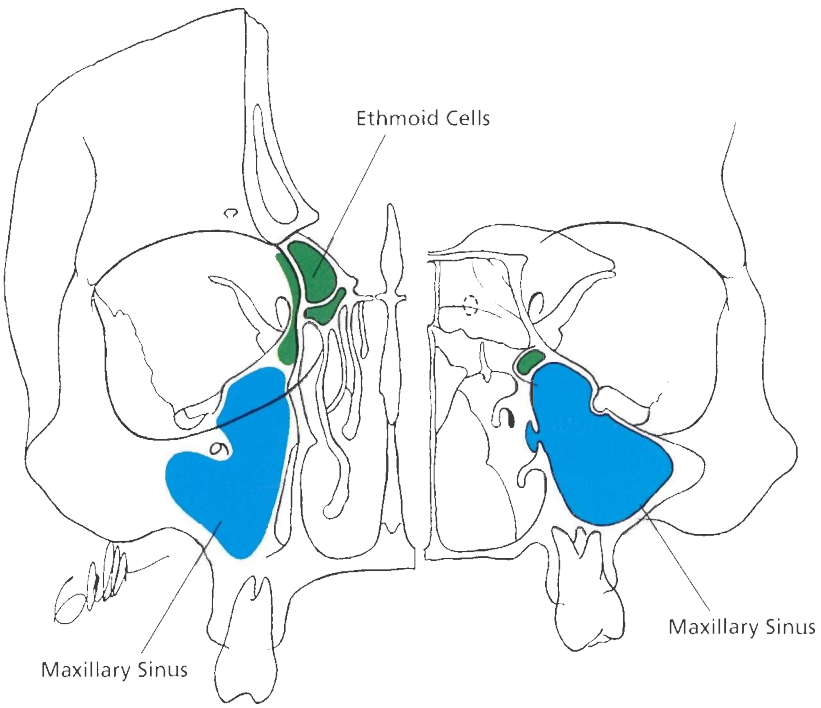


FIG. 5.13. Paranasal sinuses: maxillary and ethmoidal.

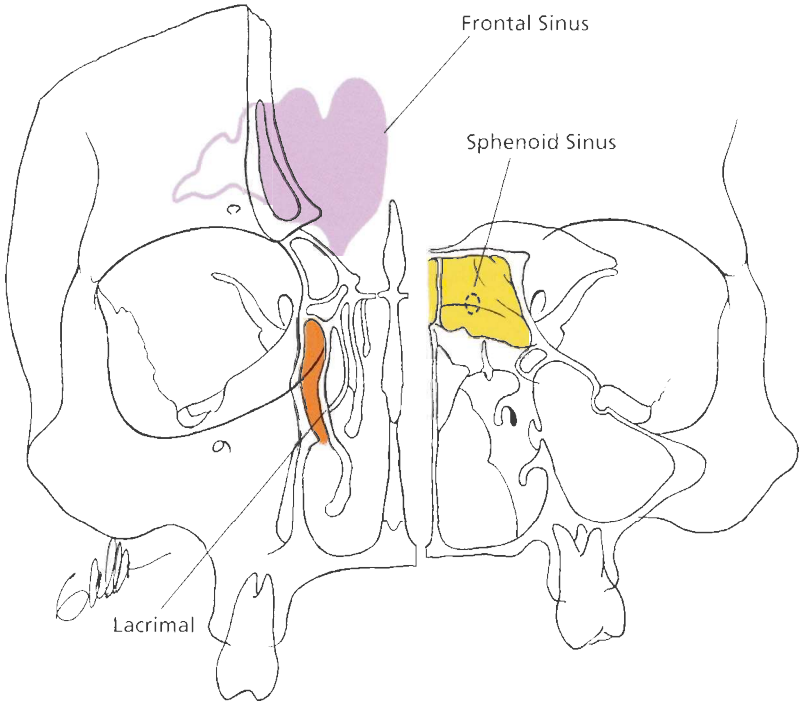


FIG. 5.14. Paranasal sinuses: frontal and sphenoidal.

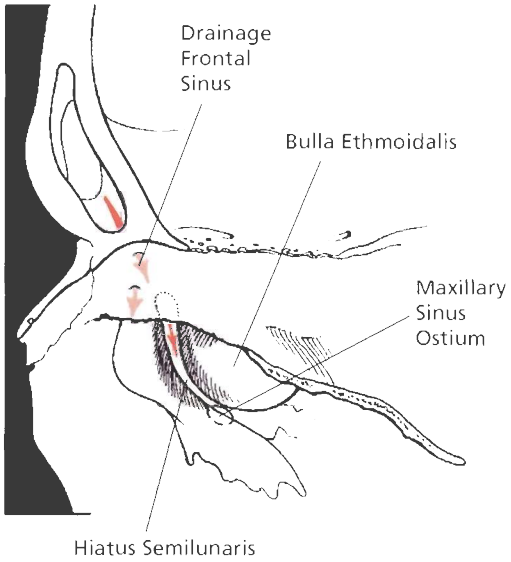


FIG. 5.15. Frontonasal communication.

- Negative pressure created in the sinuses during inspiration also facilitates drainage. In an erect position, ciliary action alone is not sufficient to drain the sinuses (McMurray, 1931).
- The sinuses vary in size and location of their ostia. These variations are of great importance to rhinologists.
- Is thinner and less vascular than the nasal mucosa.
- Although the arterial blood supply of the sinuses is not exclusively limited to the nasal arteries, the main venous drainage is via sinus ostia into the nasal cavity, where their venous plexuses become continuous with those of the nose.

THE FRONTAL SINUS

- Is absent at birth.
- Is fairly well developed by 7 to 8 years of age
- Is fully developed at puberty.
- Average dimensions include
  Height: 3 cm
  Width: 2.5 cm
  Depth: 2.5 cm
  Volume: 6 to 7 ml
- Develops as an outgrowth of the frontal recess, as the anterior ethmoidal cells do.
- More than one sinus on one side has been reported (Fig. 5.17).
- Extension of the anterior ethmoidal cells into the frontal bone may be confused with the sinus.
- May have septa, which partially subdivide the cavity and may interfere with its drainage.
- Normally, has two extensions:
  Upward extension: into the squamous (portion) of the frontal bone
  Posterior extension: into the orbital part of the frontal bone, between the inferior surface of the frontal lobe and the orbital contents
- The two frontal sinuses are frequently unequal in size, in which case the larger sinus may pass across the midline and overlap the other.

SURGICAL IMPLICATIONS

The frontal sinus has important clinical relationships to the anterior cranial fossa posteriorly and to the orbital cavity inferiorly. Infection of the frontal sinus may result in meningitis, epidural abscess, orbital cellulitis, or orbital abscess, most frequently in the lateral orbit. The bone separating the frontal sinus from the roof of orbit and from the anterior cranial cavity is often particularly thin and can easily be penetrated during surgery.

Frontonasal Communication (Fig. 5.15)

- Variations in development, and hence drainage, of the frontal sinus have been described (Schaeffer, 1916).
- The frontal sinus
  Usually develops as an extension of the frontal recess.
  May develop from "frontal pits" in the anterior ethmoidal cells.
  May develop from the frontal extremity of the ethmoidal infundibulum.
- In Kasper's (1936) study of 100 frontal sinuses, the communication was:
  Via the frontal recess rather than the ethmoidal infundibulum in 62%
  Into the ethmoidal infundibulum in 4%
  Above the ethmoidal infundibulum in 34%

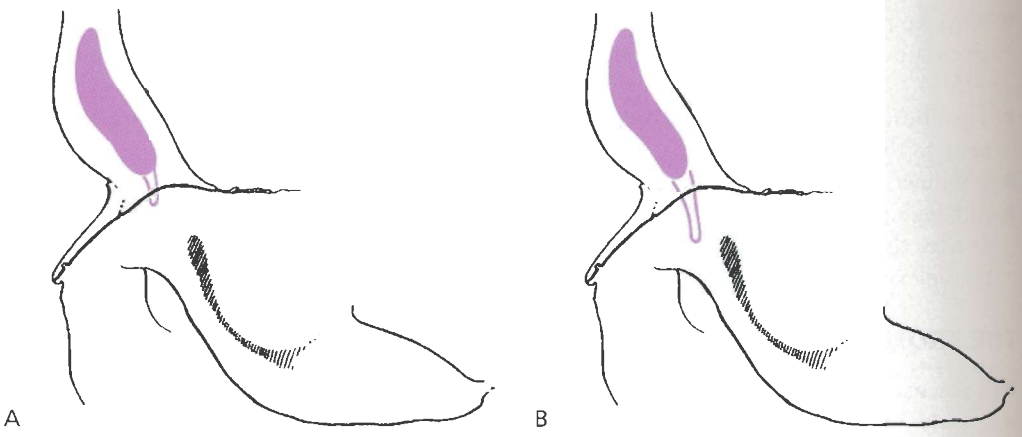


FIG. 5.16. A,B: Variations of nasofrontal communication.

SURGICAL IMPLICATIONS

According to Schaeffer (1916), in approximately 50% of adults, the ethmoidal infundibulum may function as a channel for conducting secretion or infection from the frontal sinus and some of the anterior ethmoidal cells to the maxillary sinus. This occurs either because of the continuity of the frontal sinus with the infundibulum or because of their close relationship.

- Communication between the frontal sinus and the nasal cavity may be via a narrow duct or directly through an ostium (Fig. 5.16).
- In nearly 50% of individuals, air cells extending from the anterior ethmoidal cells may impinge on the frontal sinuses, including the frontal ostium (Van Alyea, 1941a, 1944).
- *Frontal bulla* (Fig. 5.17):
  - Is a convexity on the floor of the frontal sinus.
  - May develop as a result of
    - Encroachment by an anterior ethmoidal cell
    - Encroachment by the opposite frontal sinus
- Its drainage may be impeded by (Van Alyea, 1941a, 1944)
  - Presence of a frontal bulla
  - Blocked middle meatus, usually caused by impingement of the middle concha against the lateral nasal wall

SURGICAL IMPLICATIONS

In 85% of patients the frontal ostium is accessible for irrigation of the frontal sinus via the nose. The reason for this is that the frontal sinus drains directly into the frontal recess in 55% and opens above the infundibulum in 30% (Van Alyea, 1941a, 1944, 1946). Intranasal irrigation of the frontal sinus is used less frequently than in the past. The availability of effective antibiotics has reduced its indications. Traumatic instrumentation of the nasofrontal duct may lead to stenosis.

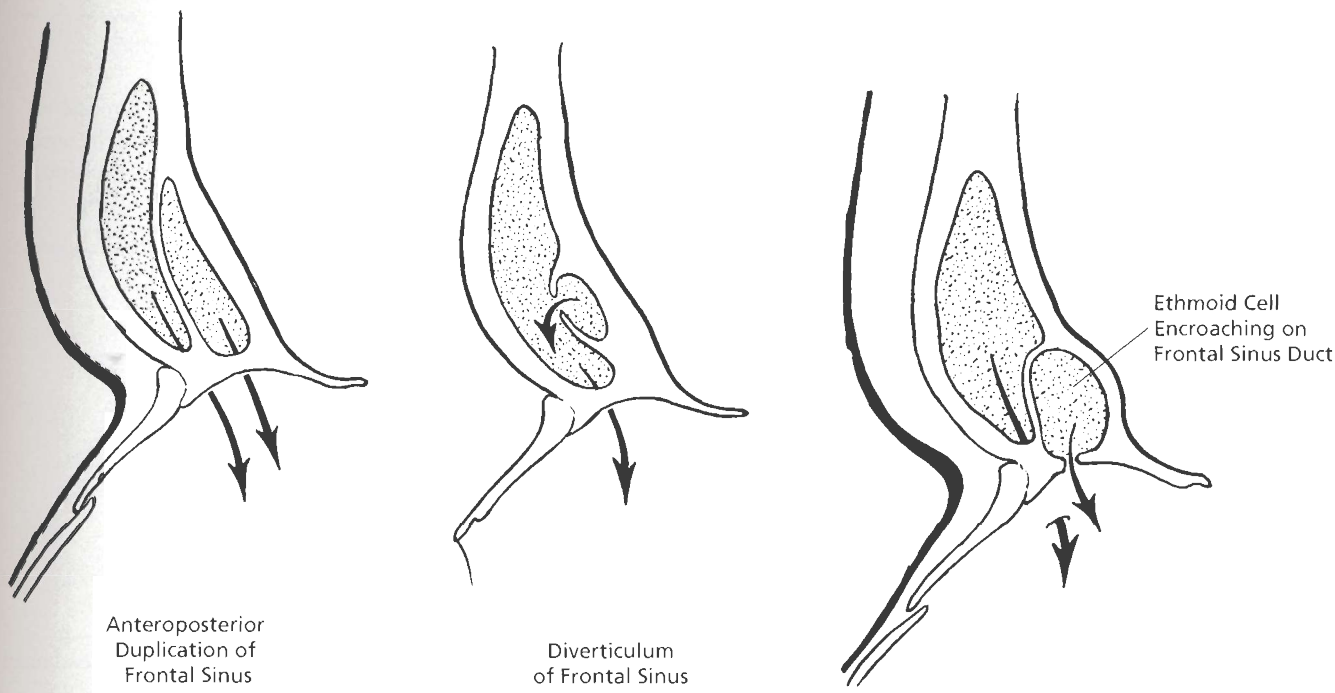


FIG. 5.17. Variations in the frontal sinus and frontal bulla.

Blood Supply and Innervation of the Frontal Sinus

- Are transmitted via the supraorbital foramen or notch.

Supraorbital Artery

- Supplies the diploic space and the frontal sinus via a diploic branch in its course from the orbit to the forehead.

Venous Drainage

- Occurs via the veins of the nose.
- Occurs via a small vein that unites the supraorbital and the superior ophthalmic veins.

> ***SURGICAL IMPLICATIONS***
>
> Communication between the venous drainage of the frontal sinus and that of the other diploic veins and the veins of the scalp, the dura, the meninges, and the brain provides a pathway for spread of infection from the frontal sinus to bone, dura, meninges, and brain (Fig. 5.18).
>
> Osteomyelitis secondary to frontal sinusitis has been called "metastatic" because the areas of osteomyelitis can be discontinuous along the course of these veins.

Nerve Supply

- Derives from the supraorbital branch of the ophthalmic nerve, as it runs over the supraorbital notch.
- A branch goes to the diploë and to the mucous membrane of the frontal sinus in the region of the nasofrontal communication.

SURGICAL IMPLICATIONS

Frontal sinusitis may cause supraorbital pain in the distribution of the ophthalmic nerve to the forehead and to the dura of the anterior cranial fossa. Referred pain from the nose and the more posterior sinuses to the area of the ear and the mastoid process is explained by the shared distribution of CN V and VII.

THE ETHMOID BONE (FIGS. 5.19, 5.20)

- Includes
  - Right and left ethmoidal sinuses
  - Right and left cribriform plates
  - Crista galli and the perpendicular plate in the midline

THE ETHMOIDAL SINUS (FIGS. 5.19 TO 5.31)

- Air cells honeycomb the ethmoid bone between the superior portion of the lateral nasal wall and the medial wall of the orbit.
- Air cells vary in number, with as few as three or up to 18 on each side.
- The average volume of one ethmoidal sinus is 14 ml.
- The ethmoidal cells form a pyramid, with the base situated posteriorly (Mosher, 1929a). The pyramid has the following approximate dimensions:
  - Anteroposteriorly: 4 to 5 cm
  - Height: 2.5 to 3 cm
  - Width: 0.5 cm anteriorly and 1.5 cm posteriorly

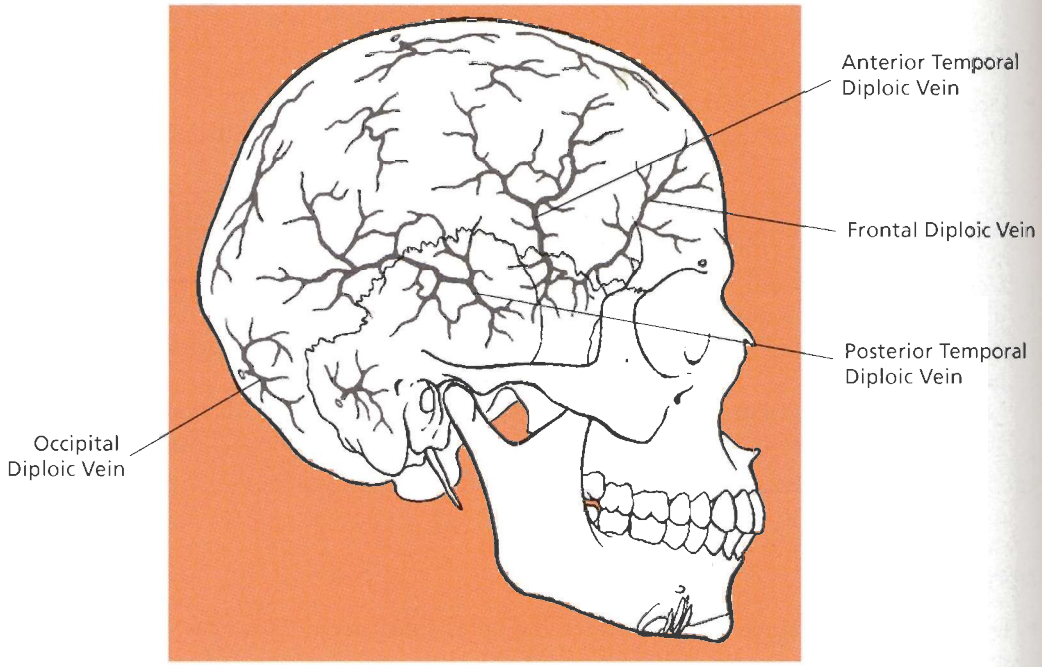
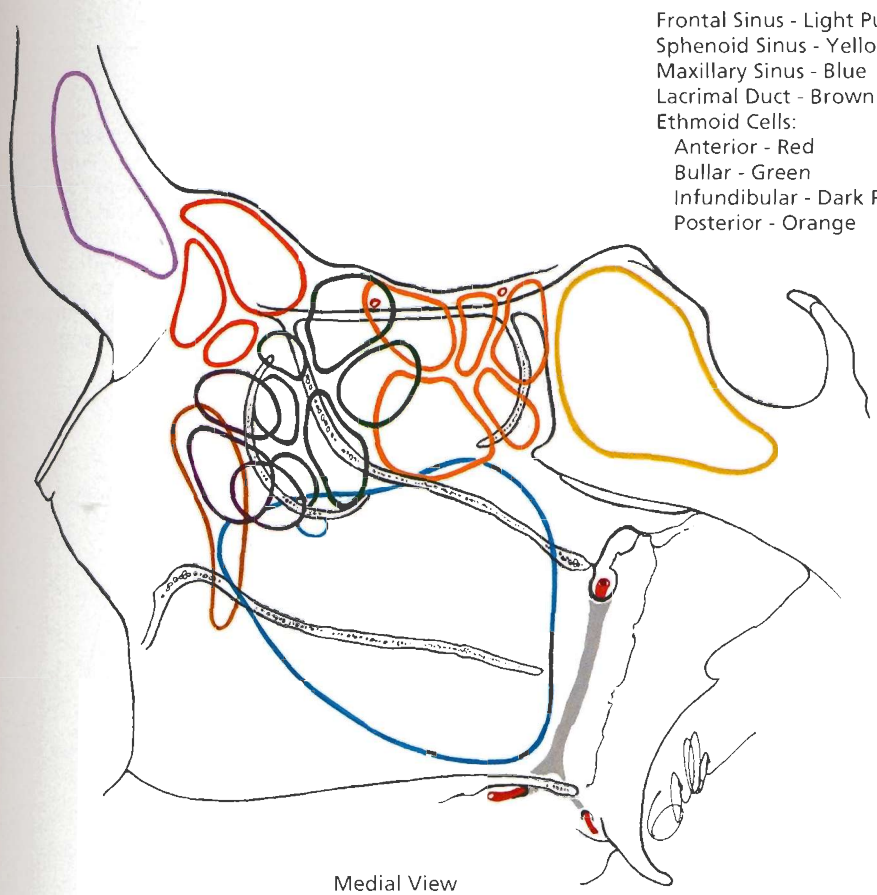
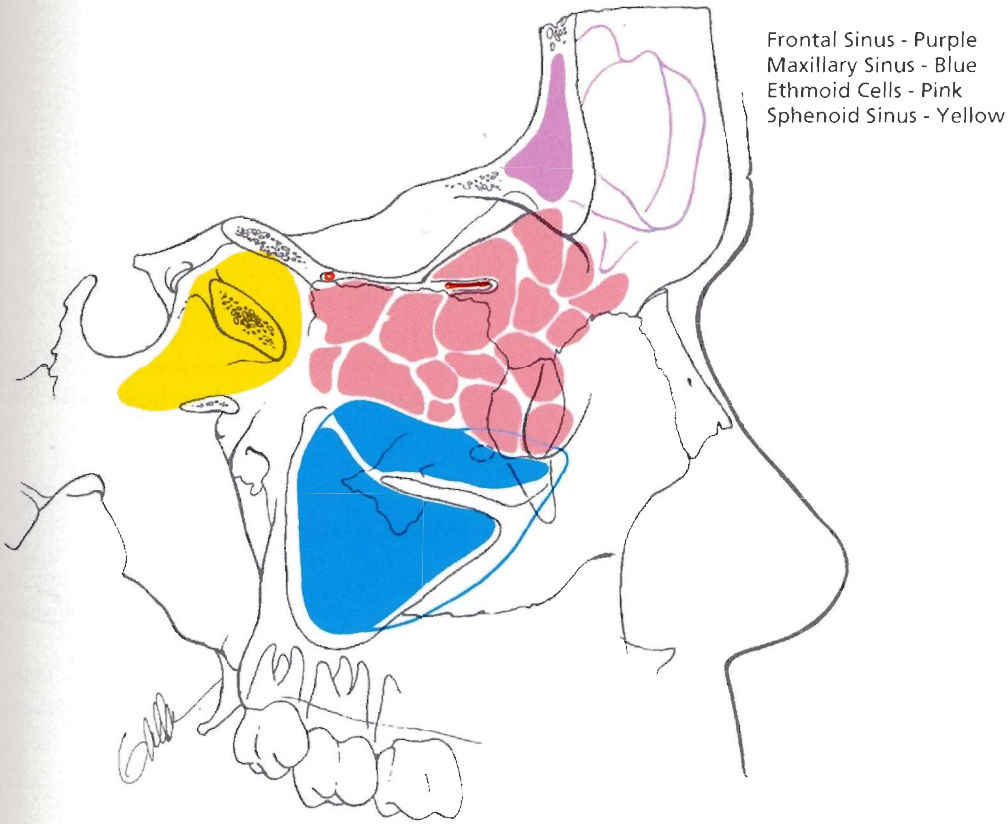


FIG. 5.18. Diploic veins of the skull.



A Medial View



B Lateral View

FIG. 5.19. A: Ethmoid bone and ethmoidal sinuses, medial view. **B:** Ethmoid bone and ethmoidal sinuses, lateral view.

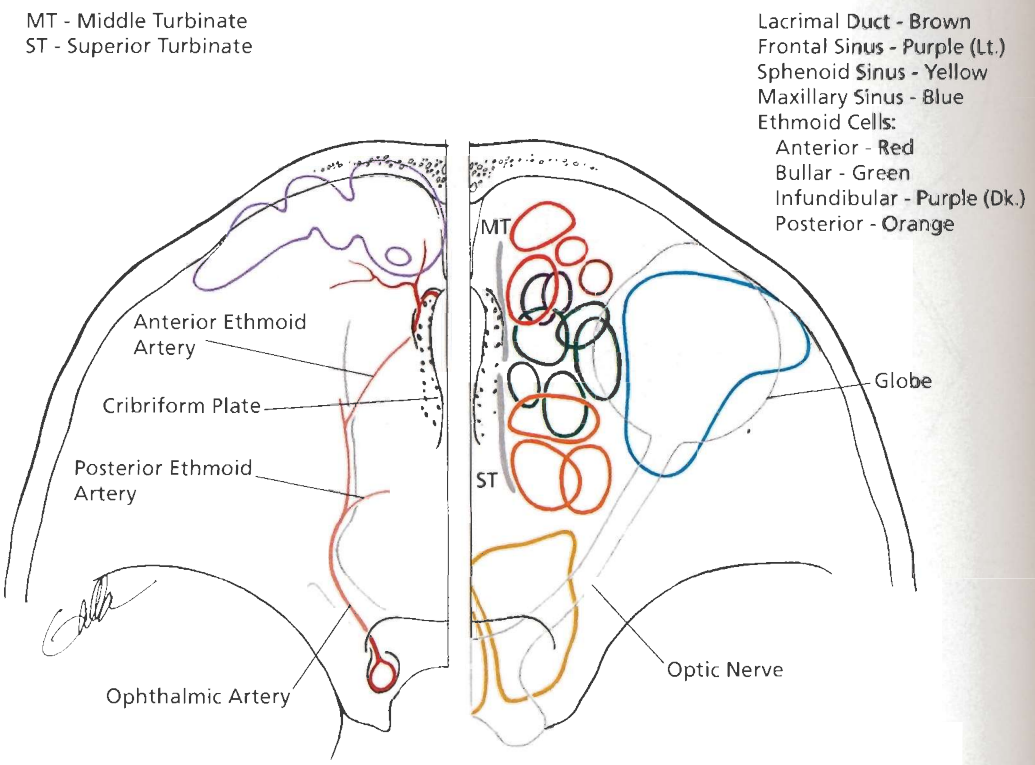


FIG. 5.20. Ethmoidal sinuses, superior view.

- *Locations* of the ethmoidal ostia are variable:
  May originate as diverticula above, on, or below the ethmoidal bulla.
  May be located in any part of the middle meatus, the frontal recess, or the superior meatus.
  May lie above and posterior to the superior nasal concha.
- Ethmoidal cells are *categorized* by their ostia:
  Anterior ethmoidal cells open into the middle meatus. Bullar cells, which open on or above the ethmoidal bulla, are a subgroup (bullar cells) of anterior cells.
  Posterior ethmoidal cells open into the superior or the supreme meatus.
- *Walls* of the cells at the periphery of the ethmoidal labyrinth comprise (Fig. 5.8A):
  Frontal bone: its orbital part completes the superior wall of the ethmoidal air cells as the ethmoidal fovea.

SURGICAL IMPLICATIONS

The ethmoidal fovea is easily penetrated during surgery, which may result in injury to the contents of the anterior cranial fossa. It is continuous with the roof of the sphenoid posteriorly and the posterior wall of the frontal sinus anteriorly.

Dissection along the fovea from posterior to anterior provides a surgical landmark for locating the frontal sinus during endoscopic sinus surgery. The fovea appears more opaque than surrounding bone and has a yellowish tint.

Maxillary bone: completes the inferior ethmoidal cells adjacent to the roof of the maxillary sinus.

SURGICAL IMPLICATIONS

This relationship has been used to perform ethmoidectomy via the maxillary sinus.

Lacrimal bone: completes the lateral wall of the anterior ethmoidal cells.

SURGICAL IMPLICATIONS

The lacrimal bone provides a surgical landmark for locating the anterior ethmoidal cells during external ethmoidectomy.

Sphenoid bone: completes the posterior walls of the posterior ethmoidal cells.
Palatine bone: completes the posterior ethmoidal cells.

- Ethmoidal cells may extend into
  Squama (perpendicular part) of the frontal bone
  Orbital part of the frontal bone
  Maxilla
  Sphenoid bone

Walls of the Ethmoidal Sinus

- *Lateral wall* is the thin lamina papyracea ("paper plate").

SURGICAL IMPLICATIONS

The lamina papyracea may be dehiscent congenitally or after intranasal ethmoidectomy or nasal polypectomy. The lacrimal plate of the lacrimal bone that lies anterior to the lamina and just posterior to the lacrimal fossa is frequently dehiscent.

- During ethmoid surgery, the periorbita may be inadvertently penetrated via these dehiscences. It tends to be very thin and therefore more vulnerable at suture lines.
- Buttressing of the paper plate by the walls of the ethmoidal cells is thought to be the reason why the thicker orbital floor is fractured more often during blunt injury to the orbital contents (orbital blow-out fracture).
- *Medial wall* consists of two or three turbinates: middle, superior, and sometimes supreme.
- *Superior wall* consists of the ethmoidal fovea.

SURGICAL IMPLICATIONS

Cerebrospinal fluid leaks from a fracture or surgery are commonly located in the ethmoidal fovea.

Bony Structures of the Lateral Nasal Wall (Fig. 5.8B)

Agger Nasi

- Develops from the anterior ascending portion of the fetal ethmoturbinal known as the nasoturbinal.

Uncinate Process

- Is a thin bony plate covered by mucosa on its lateral and medial surfaces.
- Develops from the posterior or descending portion of the first fetal ethmoturbinal.
- Its posterosuperior margin
  - Is concave and parallel to the anterior surface of the ethmoidal bulla.
  - Is located in front of the ethmoidal bulla.
- The gap between its posterior margin and the ethmoidal bulla is referred to as *semilunar hiatus.*
- Anteriorly, a space lateral to it is referred to as the *ethmoidal infundibulum.*
- Its posterior end attaches to the perpendicular lamina of the palatine bone and inferiorly to the ethmoidal process of the inferior turbinate
- Anterior margin of the uncinate process attaches to the bony lateral nasal wall and may extend to the lacrimal bone.
- Superior segment:
  - May extend to the base of the skull.
  - May turn laterally and attach to the lamina papyracea.
  - May turn frontally or medially and fuse with the attachment of the middle turbinate

SURGICAL IMPLICATIONS

The common origin of the agger nasi and the uncinate process explains the fact that these structures may not be differentiable in adults.

Ethmoidal Infundibulum

- Derives from the posterior descending part of the fetal first primary furrow between the first and the second ridges or ethmoturbinals.

Frontal Recess

- Forms from the superior ascending part of the first furrow.

Frontal Sinus

- Develops from continuing pneumatization of the frontal recess into the frontal bone.

Frontal Bulla

- Is the extension of an ethmoidal cell into the frontal bone.

SURGICAL IMPLICATIONS

Failure to identify a frontal bulla may result in failure of surgical treatment of frontal or ethmoidal disease.

Middle Turbinate

- Is derived from the second fetal ethmoturbinal.

Superior Turbinate

- Is derived from the third ethmoturbinal.

Supreme Turbinate

- Is derived from fourth and fifth ethmoturbinals.

Middle Meatus

- Is derived from the first primary furrow.

Semilunar Hiatus

- Is derived from the first primary furrow.

Superior Meatus

- Is derived from the second primary furrow.

Supreme Meatus

- Is derived from the third primary furrow.

Ethmoturbinals

- Are ends of bony lamellae.
- Extend through the entire ethmoid, laterally to the lamina papyracea, and superiorly to the lamina cribrosa.

First Lamella

- Is rarely pneumatized.
- Forms the uncinate process.
- May extend to the base of the skull, the middle turbinate, or the lamina papyracea.

Bulla Lamella

- Separates the frontal recess from the anterior ethmoidal cell.
- If intact, extends anteriorly, and the frontal recess becomes narrow.
- Its pneumatization forms the ethmoidal bulla.
- May extend to the base of the skull.

Third Lamella

- Forms the middle turbinate attachment.
- Separates the anterior from the posterior ethmoidal cells.

Fourth Lamella

- Forms the attachment of the superior turbinate.

Fifth Lamella

- Occasionally extends from the small supreme turbinate.

Interturbinal Meatus

- Are the spaces between these lamellae.
- May be partitioned by bony septa to form cells that open into the interluminal meatus by a small ostium.
- These cells may develop in the ethmoidal infundibulum (a remnant of the interluminal meatus), and their number and size dictate the shape of the middle turbinate ground lamella and the sizes of the anterior and the posterior ethmoidal cells.

Medial Wall of the Maxillary Bone

- Is largely dehiscent and is called the maxillary foramen (hiatus maxillaris).
- The *maxillary foramen* is partially covered
  Superiorly: by the ethmoid bone
  Posteriorly: by the ascending process of the palatine bone
  Inferiorly: by the inferior turbinate
- The posterior end of the uncinate process attaches to the ethmoidal process of the inferior turbinate. This attachment divides the maxillary foramen into anterior and posterior areas consisting of periosteum covered by mucous membranes of the nose and the maxillary sinus (membranous area of the lateral nasal wall).
- Because these membranous areas are soft and resemble the soft areas of a newborn's skull, they are called the anterior and the posterior fontanelles.

Ethmoidal Bulla

- Develops from the pneumatization of the bulla lamella.
- Forms the largest cells of the anterior ethmoid.
- Its pneumatization varies:
  Occasionally, it is small or absent (8% to 40%).
  Posteriorly, it may fuse with the lamella of the middle turbinate.
  Superiorly, it may rarely reach the roof of the ethmoid to form the posterior wall of the frontal recess.

THE LATERAL SINUS (FIGS. 5.21 TO 5.26)

- Boundaries:
  Inferiorly: roof of the ethmoidal bulla
  Medially: middle turbinate
  Posteroinferiorly: between the ethmoidal bulla and the ground lamella of the middle turbinate
- The bulla lamella reaches its roof, which is reduced to a cleft between the ethmoidal bulla and the lamella of the middle turbinate that opens into the middle meatus.
- This sickle-shaped cleft is known as the upper semilunar hiatus.

Middle Turbinate

- Its anterosuperior attachment is the maxilla where it bulges anteriorly as the agger nasi.
- Its posterior end attaches to the perpendicular plate of the palatine bone.
- Between its anterior and posterior attachments, may be divided into three portions.

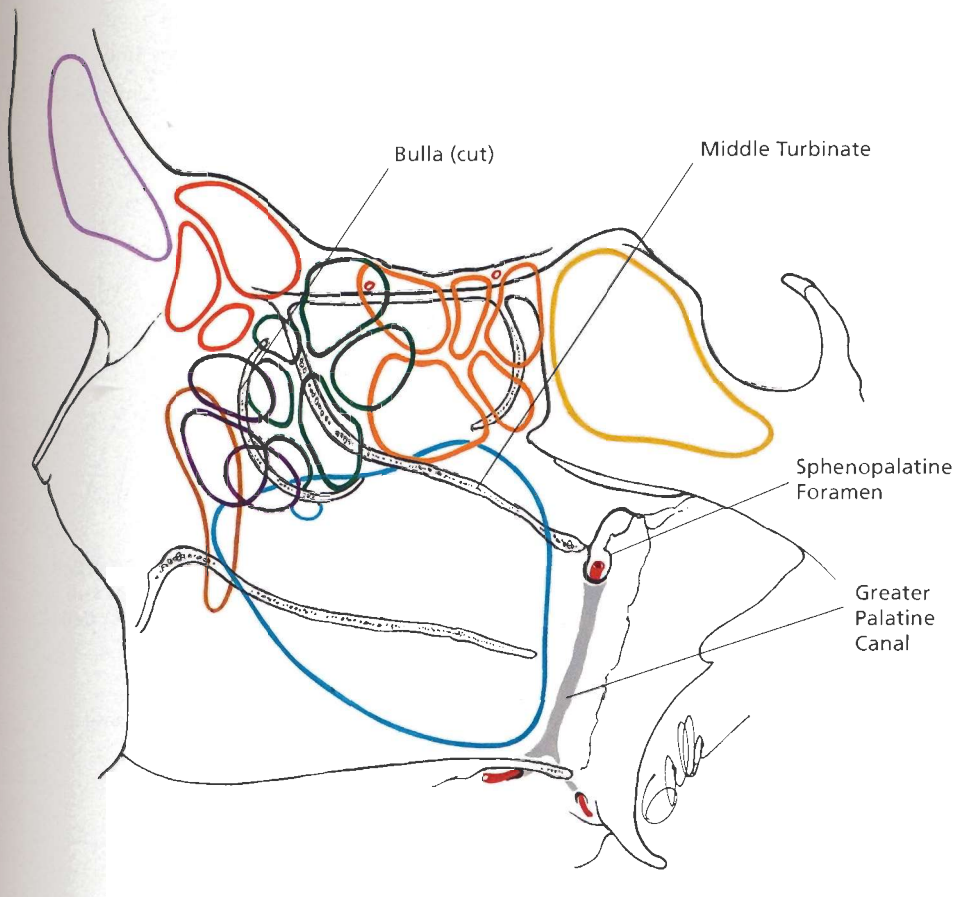


FIG. 5.21. Lateral sinus, parasagittal view.

Anterior One-third

- Is oriented in a vertical (parasagittal) plane.
- Attaches to the lateral edge of the lamina cribrosa of the anterior cranial fossa.

Middle One-third

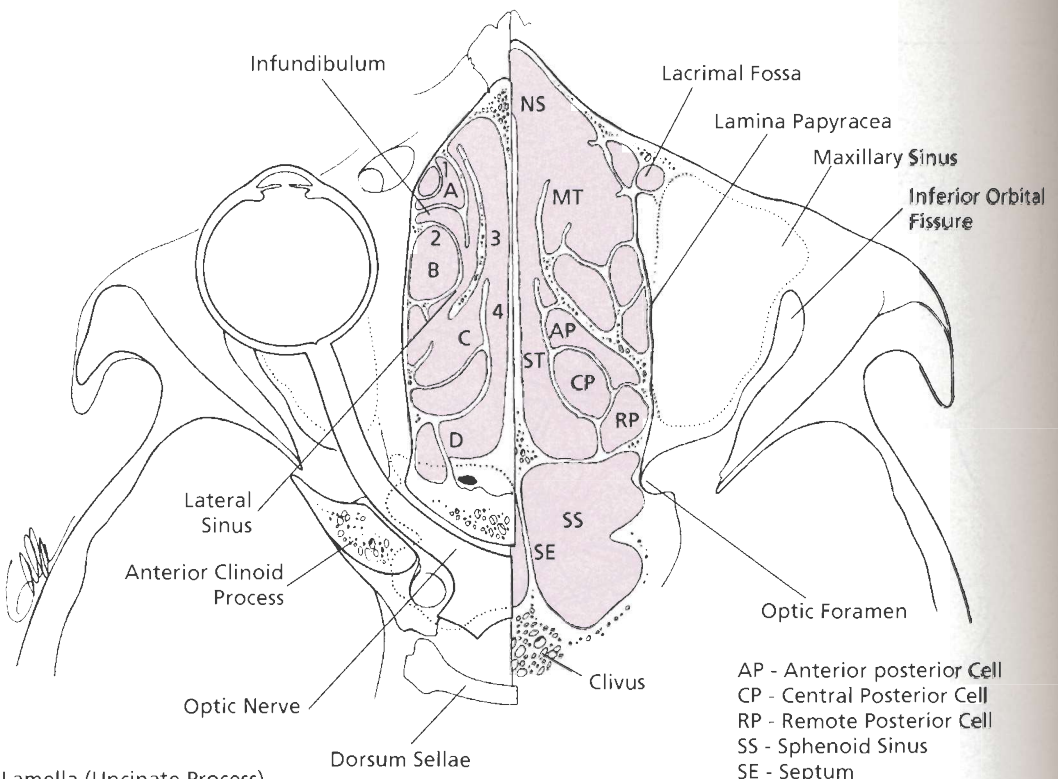
- Turns laterally and attaches to the lamina papyracea in a coronal plane.

Posterior One-third

- Assumes a horizontal position to form the roof the posterior one-third of the middle meatus.
- Attaches to the lamina papyracea or the medial wall of the maxillary sinus.

SURGICAL IMPLICATIONS

These attachments—vertical, frontal, coronal, and horizontal—help stabilize the middle turbinate. When middle turbinate infracture and removal of part of the ground lamella are required, the middle turbinate becomes destabilized and tends to lateralize. This renders ethmoid surgery more difficult to perform and increases the risk of lateral adhesions. Care must be taken therefore not to destabilize the middle turbinate. Some surgeons advocate routine removal of part of the middle turbinate to facilitate surgery and avoid adhesions.



1. First Lamella (Uncinate Process)
2. Bulla Lamella (Bulla Ethmoid)
3. Third Lamella (Middle Turbinate - MT)
4. Fourth Lamella (Superior Turbinate - ST)

A - Uncinate Space
B - Bullar Space
C - Superior Medial Space
D - Sphenoethmoidal Space

FIG. 5.22. Lateral sinus, 2 axial views.

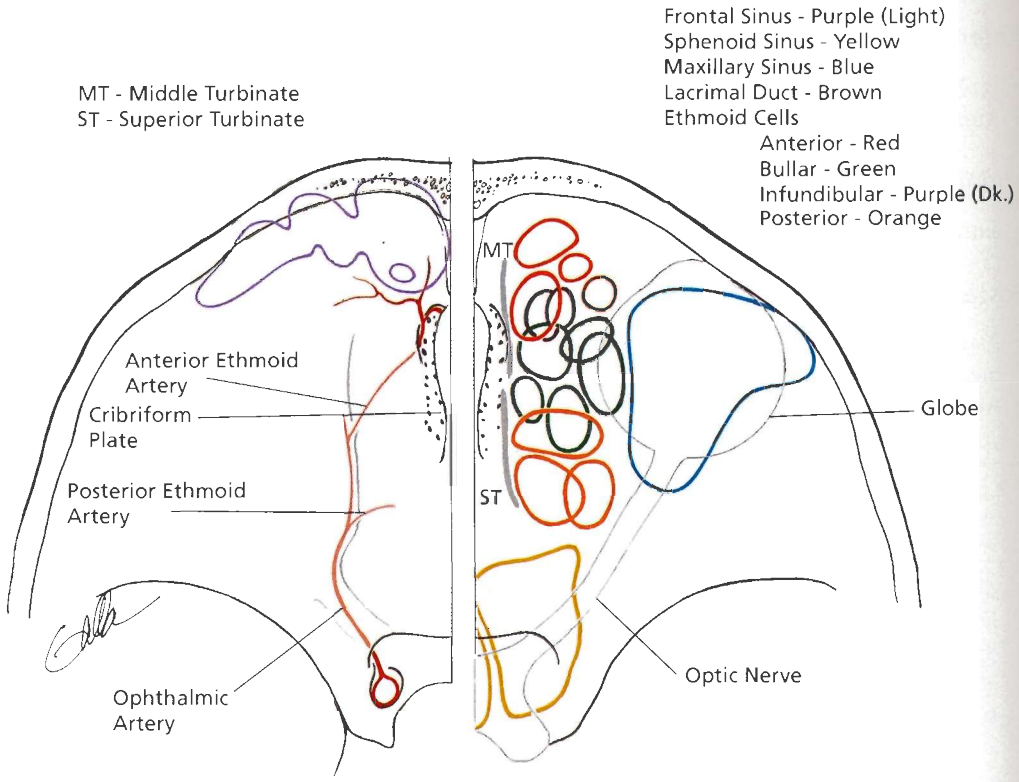


FIG. 5.23. Ethmoidal sinus, axial view.

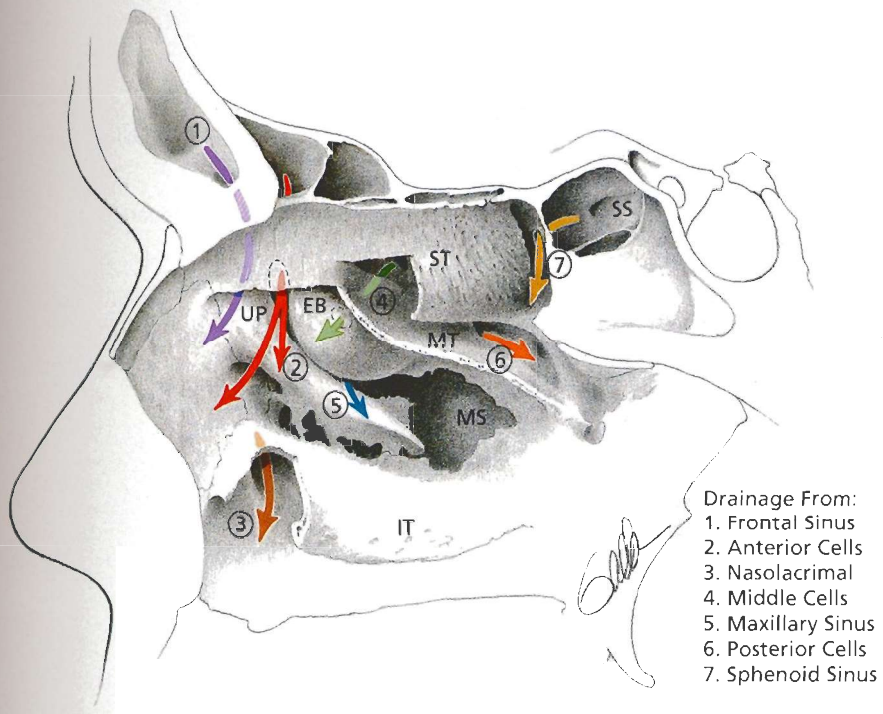


FIG. 5.24. Intranasal drainage from the paranasal sinuses.

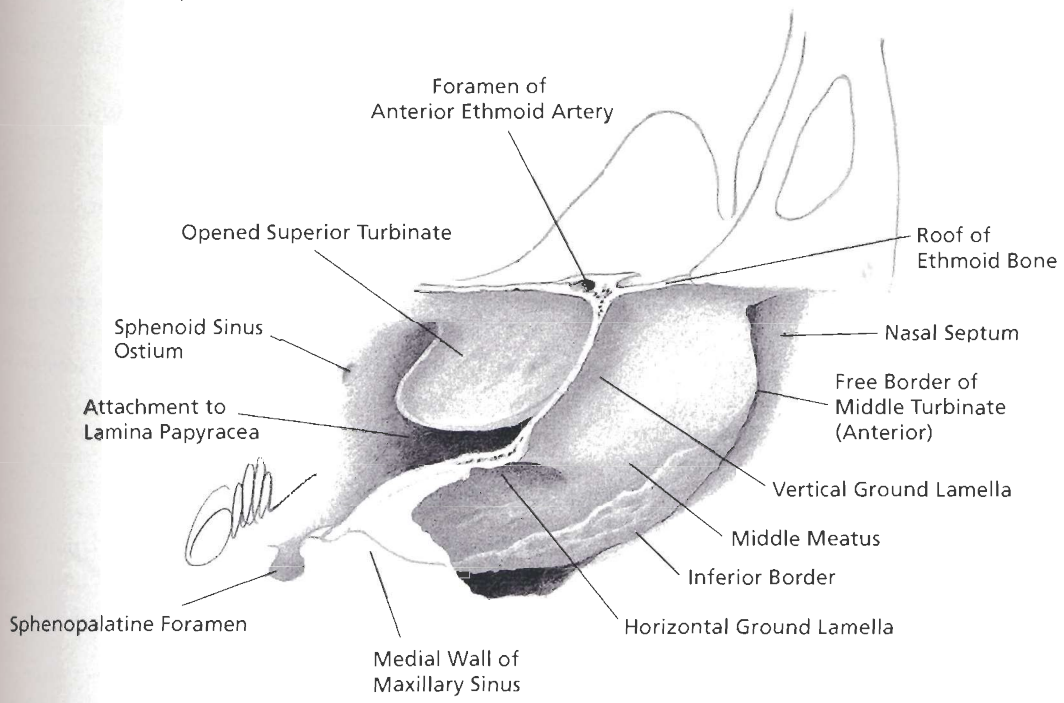


FIG. 5.25. Middle turbinate, lateral view.

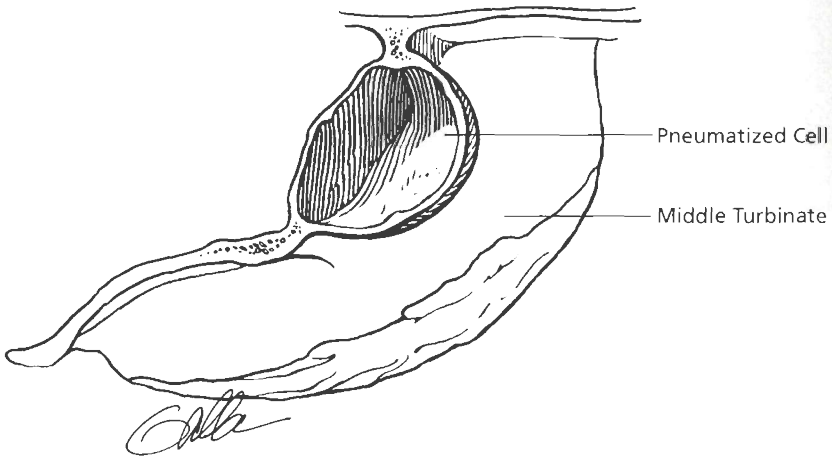


FIG. 5.26. Concha bullosa.

Superior Nasal Meatus

- Is usually shallow.
- If deep, displaces the ground lamella of the middle turbinate forward.
- A posterior ethmoidal cell from it sometimes grows into the bony lamella of the middle turbinate and pneumatizes it, thus forming a so-called concha bullosa, which was described as an interlamellar cell by Grunwald (1925).
- The ground lamella separates the anterior ethmoidal cells from the posterior ethmoidal cells.
- The posterior ethmoidal cells open into the superior or supreme nasal meatus.
- The posterior ethmoidal cells may grow laterally and superiorly over the sphenoidal sinus.
- The optic nerve may bulge on the lateral wall of the Onodi cells or even be surrounded by these cells (Fig. 5.27).
- The internal carotid artery may impinge on the lateral wall of the Onodi cells.
- In the presence of lateral Onodi cells, the anterior wall of the sphenoidal sinus does not lie in a frontal plane but is angled anteromedially to posterolaterally.
- The lateral wall of the posterior ethmoidal cells is formed by the lamina papyracea and may be very thin or dehiscent.

SURGICAL IMPLICATIONS

Preoperative axial and coronal CT sections with bone windows will clarify the relationship of the optic nerve and the carotid artery to the lateral walls of the posterior ethmoidal cells and the sphenoidal sinus. CT will also identify rare variants, such as the optic nerve traversing the posterior ethmoidal cells or the carotid artery devoid of bony covering within the lumen of the sphenoidal sinus. Unfortunately, even 2mm sections may miss small bony dehiscences, which should always be assumed to be present.

Anterior Ethmoidal Cells (Fig. 5.28)

- Are classified into groups according to the location of ostia.

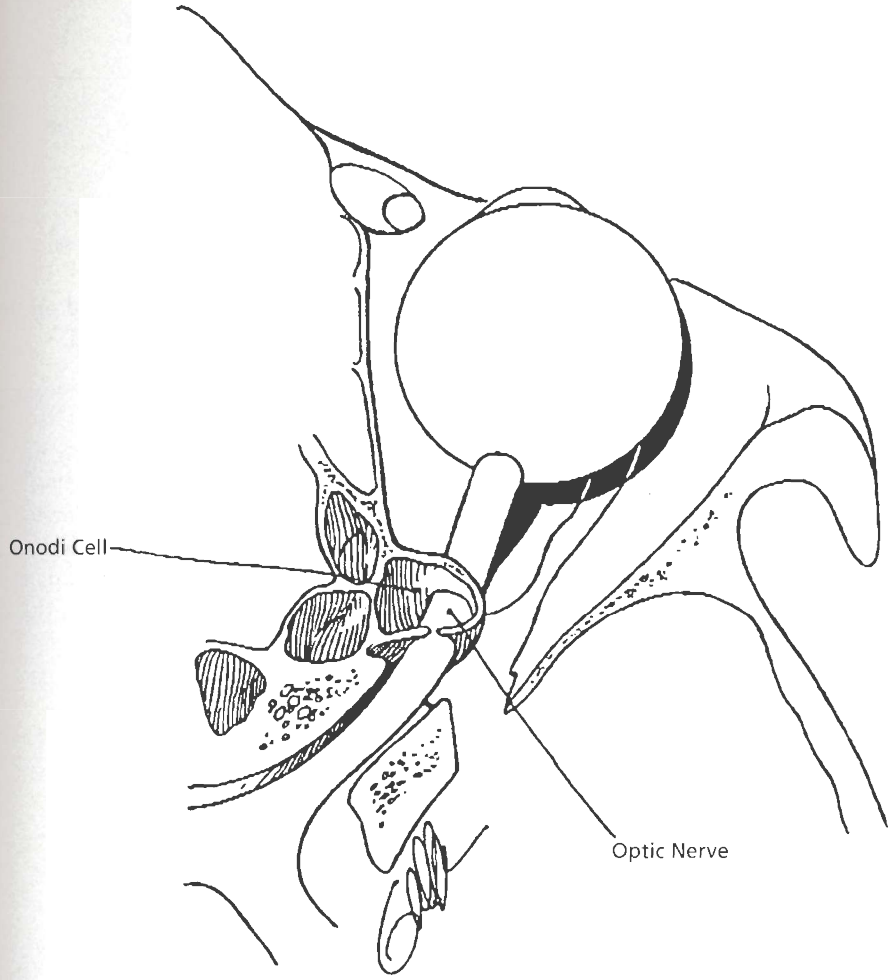


FIG. 5.27. Onodi cell, axial view.

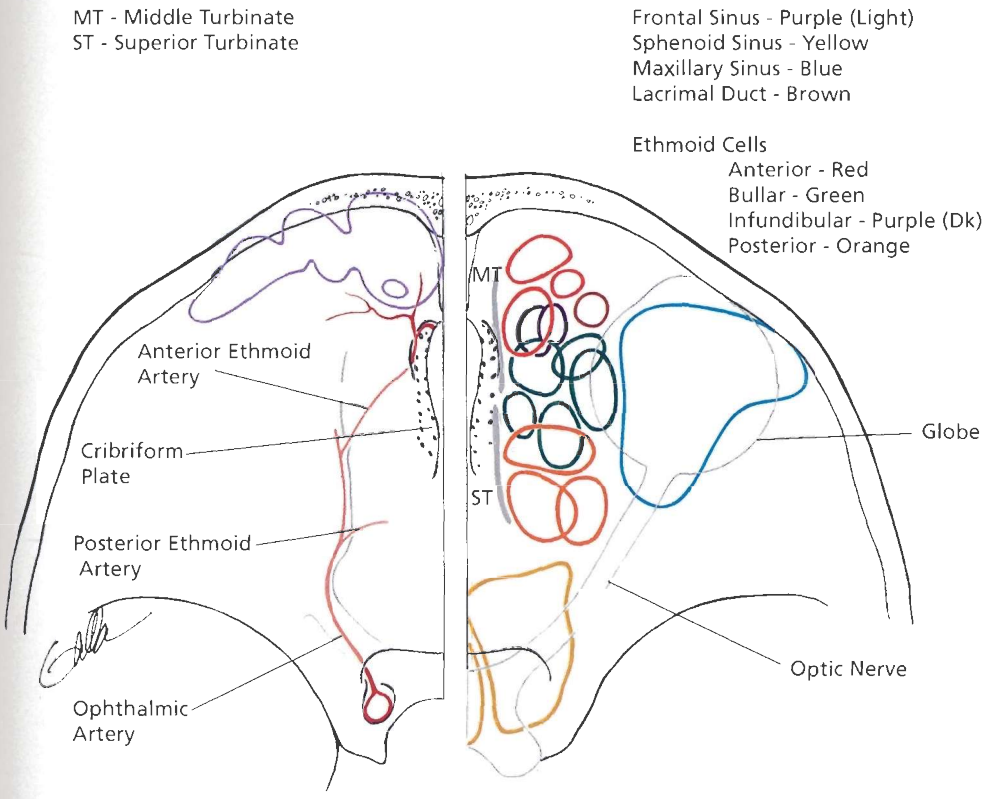


FIG. 5.28. Anterior ethmoidal cells, axial view.

Frontal Recess Cells

- Open into the frontal recess of the middle meatus.
- Number three or four and are associated developmentally with the frontal recess.
- May impinge on the frontal sinus either on its wall or at its ostium.
- Van Alyea (1941a) found 100 specimens in which ethmoidal cells encroached on the frontal sinus (frontoethmoidal or ethmofrontal cells) in 242 specimens studied.

SURGICAL IMPLICATIONS

During endoscopic anterior ethmoidectomy with an angled telescope, the "opening" that is most anterior and medial is usually the frontal sinus. In rare instances, however, ethmoidal cells have been found anterior and even medial to the frontonasal duct. When there is doubt at surgery, a lateral plain film with a curved metallic instrument placed in the questioned opening or CT image guidance will help determine the identify of the ostium.

Infundibular Cells

- Open into the ethmoidal infundibulum.
- Number on average three (range, one to seven) (Van Alyea, 1939).
- The most constant cell is located in the agger nasi (89%) (Van Alyea, 1939).
- In 34%, the agger nasi cell formed the upper termination of the infundibulum.

SURGICAL IMPLICATIONS

The agger nasi cell is frequently opened in endonasal approach to the lacrimal sac.

- May extend to the region of the frontal sinus or overlap with bulla cells.

Bullar (Middle) Cells

- Open into the middle meatus on or above ethmoidal bulla.
- Vary in number, ranging from one to six.
- Are the most constant cells of any of the ethmoid group (Van Alyea, 1939).
- May extend to the region of the maxillary or the frontal sinuses.

Posterior Ethmoidal Cells

- Number from one to seven.
- One or more were found in 96% of subjects (Van Alyea, 1939).
- In 67 of 100 specimens, there was a supreme concha, and in 38 of these one or more posterior cells opened into the supreme meatus.
- Bullar and posterior ethmoidal cells may encroach on each other.
- Infundibular and posterior ethmoidal cells are rarely in contact.
- Posterior cells may extend into the sphenoid bone and the sphenoidal sinus.

SURGICAL IMPLICATIONS

Mosher (1929a) found these cells in 25% of specimens and observed that they were especially likely to be overlooked in the transantral approach to the ethmoidal sinuses.

SURGICAL IMPLICATIONS

Because a thin plate of lamina papyracea separates the ethmoid from the orbit, ethmoid infection may extend to the orbit, causing orbital cellulitis.

SURGICAL IMPLICATIONS

Because one or more posterior ethmoidal cells and the sphenoidal sinus are in close contact with the optic nerve, infection of ethmoidal or sphenoidal sinuses may cause retrobulbar neuritis.

SURGICAL IMPLICATIONS

Axial and coronal CT best demonstrate the position of the optic nerve in relation to the posterior ethmoidal cells and the sphenoidal sinus. This information is important for avoiding damage to the nerve during sinus surgery and in performing optic nerve decompression.

Cases have been reported in which the optic nerve runs unprotected by a bony covering in the posterior ethmoidal cells. Lack of appreciation of this rare anatomic variant explains some cases of blindness following ethmoidectomy.

SURGICAL IMPLICATIONS

The *Haller cell* is an ethmoidal cell that may exist between the maxillary sinus and the floor of the orbit (Fig. 5.29). It usually arises from the posterior cell system. It may impede the drainage tract of the maxillary sinus. The Haller cell is best seen on coronal CT.

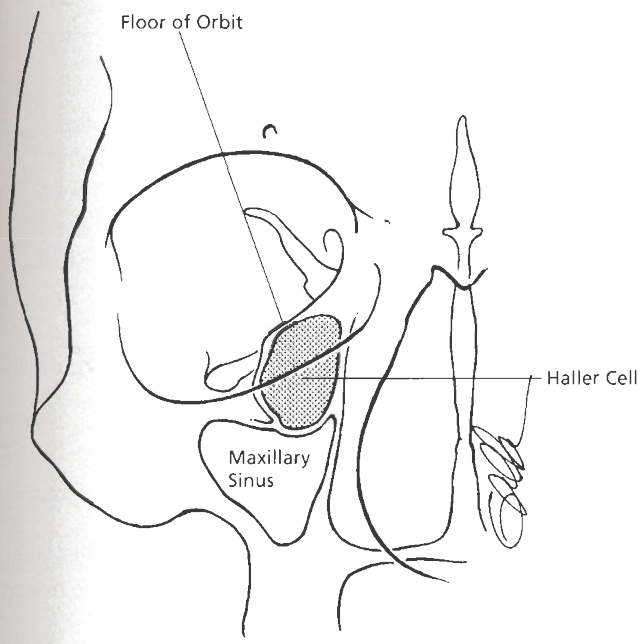


FIG. 5.29. Haller's cells.

Roof of the Ethmoidal Sinuses (Figs. 5.25, 5.30, and 5.31)

- Is covered by the medial edges of the frontal bone, which has small depressions named ethmoidal foveolae.
- The ethmoidal fovea is thicker laterally and attaches to the lateral lamella of the lamina cribrosa, which is less dense and thinner.
- The lateral lamella of the lamina cribrosa forms
  - Lateral border of the olfactory fossa
  - Medial wall of the dome of the ethmoidal sinus

> ***SURGICAL IMPLICATIONS***
>
> The highest point of the roof of the ethmoidal sinuses may be 17 mm above the level of the lamina cribrosa (Fig. 5.30). Coronal CT sections demonstrate the height of the ethmoidal foveae in relation to the cribriform plate and the superior insertion of the middle turbinate.

Blood Supply and Innervation of the Ethmoidal Sinus (Figs. 5.28 and 5.31)

Arterial Supply

- The ethmoidal sinus is supplied from both the external and the internal carotid systems.
- Arteries include
  - Posterior lateral nasal branches of the sphenopalatine artery
  - Anterior ethmoidal artery, which supplies the anterior ethmoidal cells
  - Frontal branch of the supraorbital artery, which supplies the frontal ethmoidal cells
  - Posterior ethmoidal artery, which supplies the posterior ethmoidal cells

Anterior Ethmoidal Artery

- Traverses the orbit, the ethmoidal sinus, and the anterior cranial fossa in its course from the orbit to the olfactory fossa.

> ***SURGICAL IMPLICATIONS***
>
> At the point where the anterior ethmoidal artery enters the anterior cranial fossa, the lateral lamella of the lamina cribrosa is thinner and weaker than the roof of the ethmoidal sinus and is frequently the site of surgical injury causing cerebrospinal fluid leak. A lateral approach to the ethmoidal fovea avoids this dangerous area.

- Origin: ophthalmic artery in the orbit.
- Passes through the anterior ethmoidal foramen, and in the ethmoidal sinus roof may travel through a thin-walled bony canal known as the orbitocranial canal.
- *Orbitocranial canal:*
  - Occasionally, is imbedded in the roof of the ethmoidal sinus.
  - Most often, is connected to the roof by a bony ridge measuring as much as 5 mm in height.
  - Is usually located directly posterior to the point where the roof of the ethmoidal sinus curves anterosuperiorly to create the posterior and the superior borders of the frontal recess.
  - Is usually located anterior to the first ethmoidal cell adjacent to the lamina papyracea.

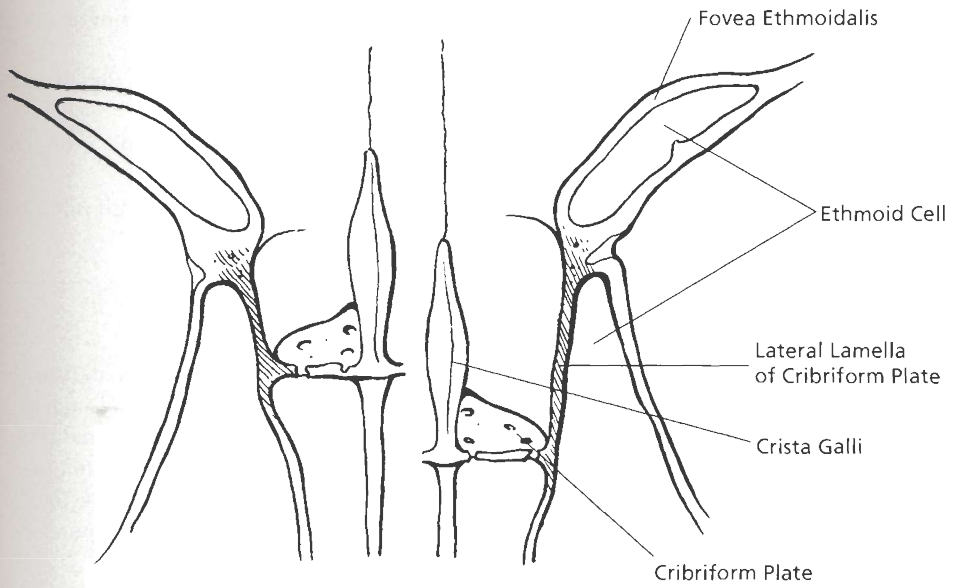


FIG. 5.30. Roof of the ethmoidal sinus.

- If the frontal sinus is absent, usually lies between the first and the second anterior ethmoidal cells that extend laterally to the lamina papyracea (orbitoethmoidal cells).
- Passes diagonally through the ethmoidal sinus and perforates the lateral lamella of the lamina cribrosa at the lateral wall of the olfactory fossa.
- Then curves anteriorly in a groove in the lateral lamella (ethmoidal sulcus) and gives a branch to the anterior meningeal artery.
- Enters the nasal cavity via the cribroethmoidal foramen and the lamina cribrosa.

SURGICAL IMPLICATIONS

The anterior ethmoidal artery does not have great surgical significance in ethmoid surgery because it is usually superior to the ethmoidal fovea and is rarely the source of significant bleeding. It is often seen through a thin fovea or as a bulge in the fovea. When identified, it is usually close to the superior curve of the fovea, which constitutes the posterior wall of the frontonasal connection.

- Has the following *terminal branches* in the nasal cavity:
  Anterior nasal artery, which has superior, lateral, and medial branches
  A posterior branch
  Several small meningeal branches
- These terminal divisions may develop before or after passing through the lamina cribrosa.

Anatomic Variations in the Ethmoidal Sulcus and Anterior Ethmoidal Artery

- Length of the ethmoidal sulcus ranges from (Kainz and Stammberger, 1990)
  3 to 10 mm on the left to
  13 to 16 mm on the right
- Length of the orbitocranial canal varies from (Kainz and Stammberger, 1990)
  4 to 13 mm on the left to
  5 to 25 mm on the right

- Partial or complete bony dehiscences may be present, usually in the inferior aspect of the orbitocranial canal in 40% of individuals.
- In most of its course, the anterior ethmoidal artery is intradural through the olfactory fossa.
- The anterior ethmoidal artery is covered by dura from its entrance into the orbitocranial canal to the olfactory fossa.
- In 75% of individuals, the anterior ethmoidal artery is a single vessel on both sides, and in 15% it is double.

SURGICAL IMPLICATIONS

During endonasal surgery and in head injury, the anterior ethmoidal artery and surrounding bone are subject to fracture, hemorrhages, and dural tears. In head injury, fracture may occur between the thinner lamina cribrosa and its lateral lamella and the thicker surrounding bone. Because the dura is thin and firmly attached, a traction injury may occur in the olfactory fossa, producing a cerebrospinal fluid leak. These fractures may be small and not detectable by CT, and they may cause repeated bouts of meningitis.

The olfactory fibers with their perineurium, which corresponds to the leptomeninges, pass through the subdural space and the dura. The weakest area of the anterior cranial fossa is the lateral lamella of the lamina cribrosa, where the anterior ethmoidal artery passes through the ethmoidal sulcus. When the lateral lamella of the lamina cribrosa is high and thin, it may be injured by blunt head trauma or surgical manipulation at the medial aspect of the roof of the ethmoidal sinus.

The deeper the olfactory fossa is, the thinner and therefore the more vulnerable to surgical injury is its lateral wall. Cerebrospinal fluid leak following ethmoid surgery most commonly occurs at this location. To avoid injury to the lamina cribrosa, a surgeon should stay strictly lateral to the attachment of the middle turbinate and, when operating at the roof of the ethmoid, should identify the anterior ethmoidal artery to protect the lateral lamella of the lamina cribrosa.

Steps for identifying the anterior ethmoidal artery during endonasal surgery include the following:

1. Follow the anterior wall of the ethmoidal bulla superiorly toward the roof of the ethmoidal sinus.
2. If the bulla is attached to the roof of the ethmoidal sinus, the artery is located 1 or 2 mm posterior to this point.
3. If the lamella of the bulla does not reach the roof of the ethmoidal sinus, and hence the frontal recess and lateral sinus are continuous, the artery may be seen in the lateral sinus. During endoscopy, the artery may easily be visualized when the upper semilunar hiatus is wide. More rarely, it may be seen through the frontal recess.

Venous Plexuses of the Ethmoidal Sinus

- Join those of the nasal cavity.

Lymphatic Vessels of the Ethmoidal Sinus

- Ethmoidal cells have only a few lymphatic capillaries.
- Lymphatics pass via the ostia to join those of the nasal mucosa.

Innervation of the Ethmoidal Sinus

- Anterior and middle ethmoidal cells are innervated by the ophthalmic divisions of CN V via the anterior ethmoidal branch of the nasociliary nerve.

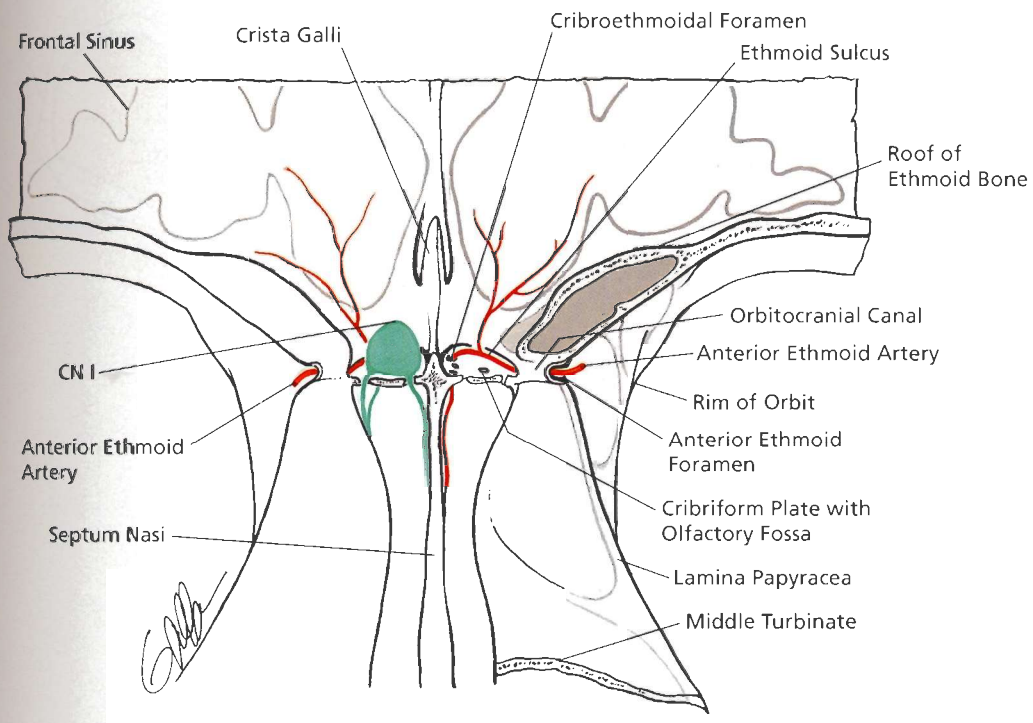


FIG. 5.31. Blood supply and innervation of the ethmoidal sinus.

- When frontal ethmoidal cells are present, the supraorbital branch of the ophthalmic nerve to the frontal sinus may also innervate the anterior ethmoidal cells.
- Posterior ethmoidal cells and adjacent mucous membrane of the superior and the middle nasal conchae are innervated by:
  - Maxillary branch of CN V via the lateral posterior superior nasal branches of the pterygopalatine (sphenopalatine) ganglion
  - Orbital (or ascending) branches of the pterygopalatine ganglion
  - Occasionally, a posterior ethmoidal branch of the nasociliary nerve via the posterior ethmoidal foramen
- Posterior ethmoidal cells are therefore innervated by both the ophthalmic and the maxillary divisions of CN V.

THE SPHENOIDAL SINUS (FIGS. 5.19, 5.20, 5.24, 5.27, AND 5.32 TO 5.37)

- The primordium of the sinus is recognizable as early as the fourth month of fetal life. Pneumatization starts after the third year.
- May extend
  - Into the body of the sphenoid bone
  - To the pterygoid process
  - Into the basilar portion of the occipital bone
  - Into the nasal septum and perpendicular plate of the ethmoid bone
- Right and left sinuses are rarely symmetric in shape or equal in size. The septum between them is usually asymmetric, especially posteriorly. Sometimes overlapping sinuses from the two sides are situated above and below each other, rather than having the expected lateral relationship. The two sinuses rarely communicate with each other.
- Is the most variable in form of any bilateral cavity or organ in the human body.

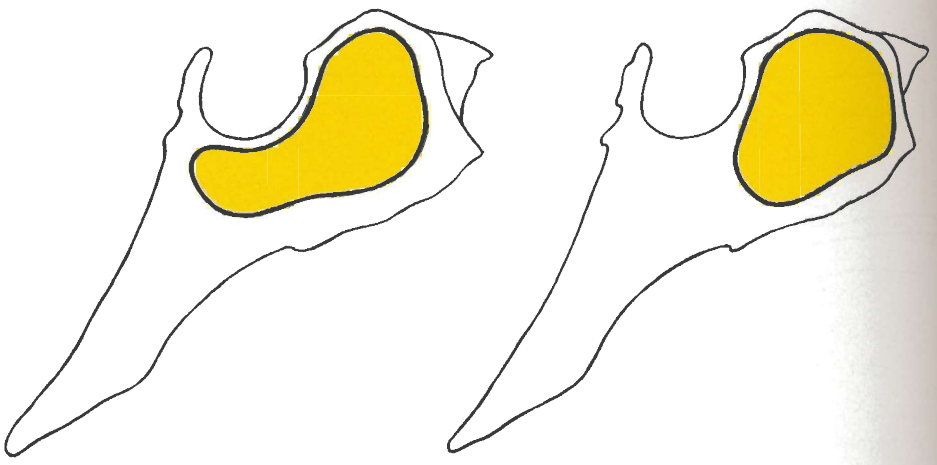


FIG. 5.32. Variations of sphenoidal sinus pneumatization.

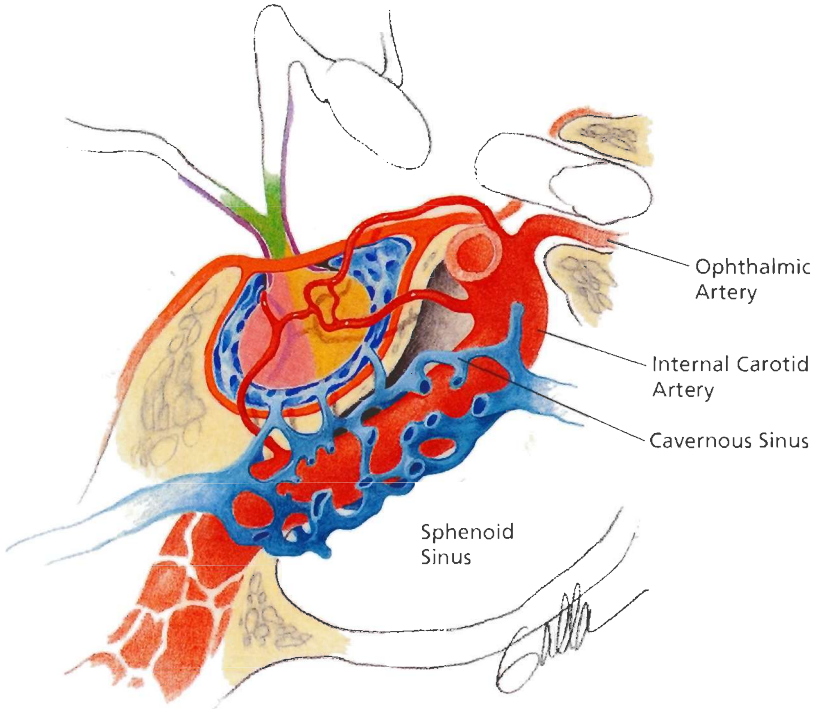


FIG. 5.33. Cavernous sinus.

- Its average dimensions include (Van Alyea, 1941b):
  Length: 4 to 44 mm
  Width: 2.5 to 34 mm
  Height: 5 to 33 mm
  Volume: 7.5 mL

Boundaries

- Is adjacent to the middle cranial fossa and the pituitary gland in the sella turcica.

Superior

SURGICAL IMPLICATIONS

When the sphenoidal sinus expands into the anterior and the posterior clinoid processes, the hypophysis projects markedly into the sphenoidal sinus (Fig. 5.32). Diverticula of the sinus may lie directly against the dura (Schaeffer, 1920). Such dehiscences explain the pathogenesis of encephaloceles and some cases of spontaneous cerebrospinal fluid leaks. The transsphenoidal approach to the pituitary gland carries less morbidity than a classic craniotomy.

Lateral

- Is adjacent to
  Cavernous sinus (Fig. 5.33)
  Internal carotid artery (Fig. 5.34)
  Optic nerve (Fig 5.35)

SURGICAL IMPLICATIONS

The lateral wall of the sphenoidal sinus may be thin and have areas of dehiscence, especially over the internal carotid artery. Special care must be taken if removal of mucosa is required there. A contingency plan should be available in the surgeon's mind if any of these important structures is violated. Spontaneous cerebrospinal fluid leakage from this area is common.

The optic nerve and the carotid artery are more obvious in a well pneumatized sphenoidal sinus.

- If the anterior clinoid is pneumatized, there will be a deep recess directed superolaterally between the prominences of the optic nerve superficially and of the internal carotid artery inferiorly (Figs. 5.35 to 5.37).

Prominence of the Optic Nerve

- Is more rostral from anterior to posterior.
- Usually, gradually disappears toward the posterior wall of the sinus.
- Is present in 40% of individuals.
- The optic nerve may be dehiscent in approximately 6%.

Prominence of the Internal Carotid Artery

- Is present in 65% (Van Alyea, 1941b).
- Rarely, the prominences of both sides almost make contact in the midline.

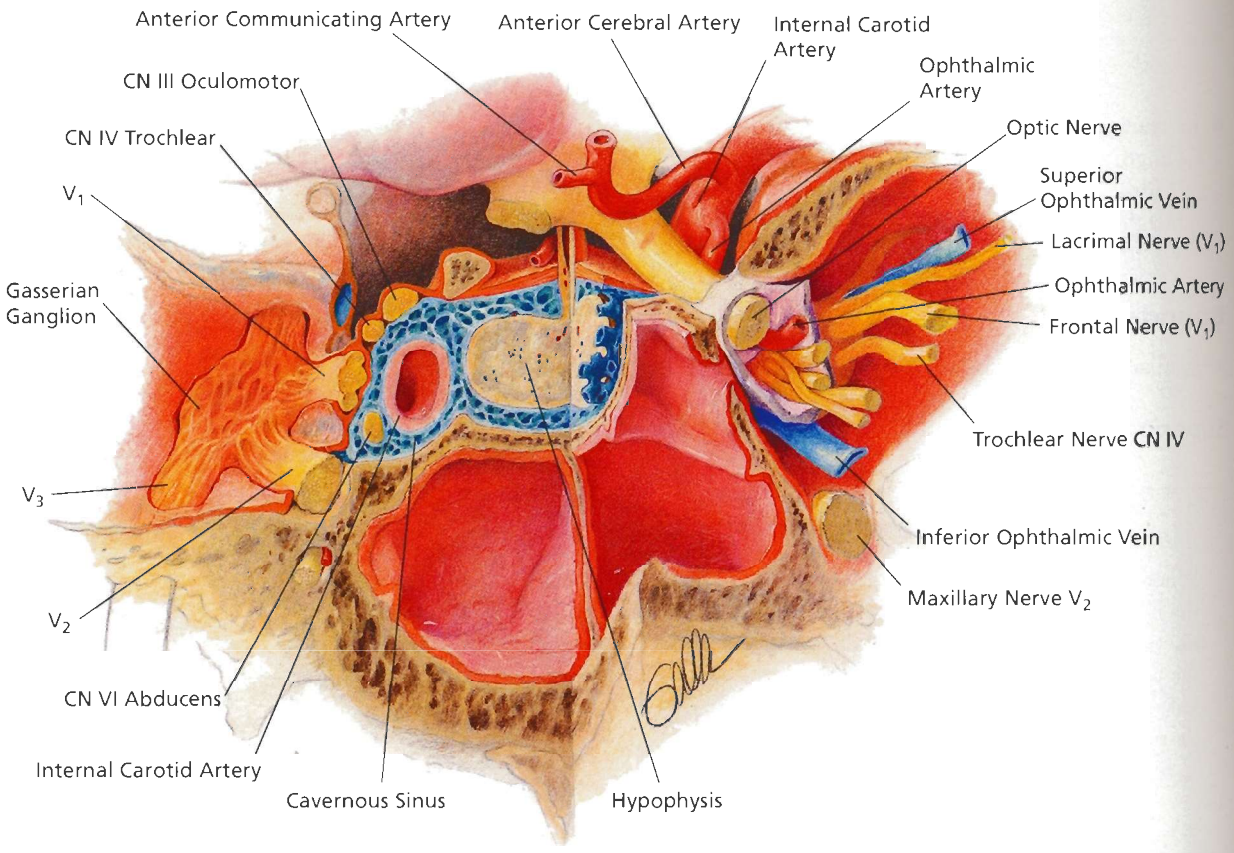


FIG. 5.34. Cavernous and sphenoidal sinus.

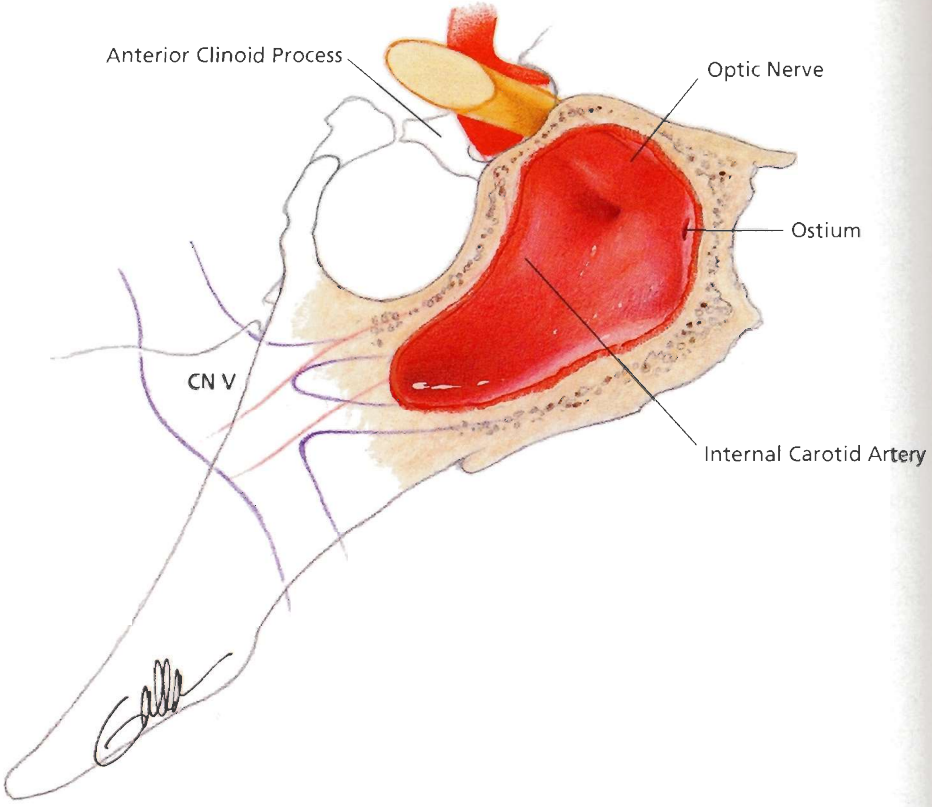


FIG. 5.35. Lateral wall of the sphenoidal sinus.

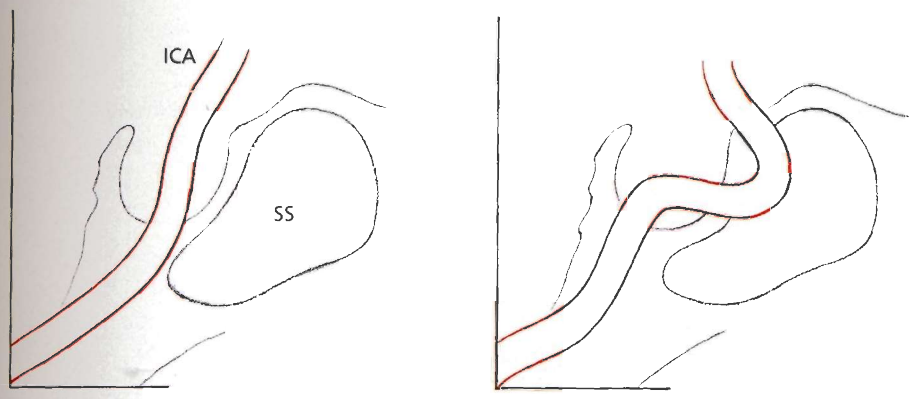


FIG. 5.36. A,B: Variations in the course of the internal carotid artery (ICA) in relation to the sphenoidal sinus (SS).

- The internal carotid artery is dehiscent in 25%.
- Dehiscences are usually small but may be as large as 6 × 10 mm.
- The maxillary division of CN V may also indent the sinus.

Posterior Boundary

- Is adjacent to the part of the posterior fossa containing the pons.

Inferior Boundary

- Is located superior to the roof of the nasopharynx.
- A ridge for the nerve of the pterygoid canal (vidian nerve) is often observed in the floor of the sphenoidal sinus (Dixon, 1937).
- Van Alyea (1941b) found the ridge to be pronounced in 36% of specimens and slight in 12%.
- The thickness of the wall of the sphenoidal sinus varies largely and depends on pneumatization.
- Average thickness is 0.5 mm (Dixon, 1937).
- The inferior wall is usually the thickest.
- The posterior wall, between the sinus and the posterior cranial fossa, may be as much as 1 cm thick.

Anterior Boundary

- The sinus may extend anteriorly to produce a bulge in the wall of the maxillary sinus in 18% of specimens (Van Alyea, 1941b).
- In transethmoidal sphenoidectomy, the posterior (Onodi cell) of the ethmoidal sinus may extend 1.5 cm beyond the front face of the sphenoid.
- Expansion of the posterior ethmoidal cells posteriorly is associated with underdevelopment of the sphenoidal sinus; the posterior ethmoidal cell may lie adjacent to the optic canal.

Ostium of the Sphenoidal Sinus (Fig. 5.8B)

- Regularly opens in the sphenoethmoidal recess, when present.
- Is situated above and behind the superior nasal concha.

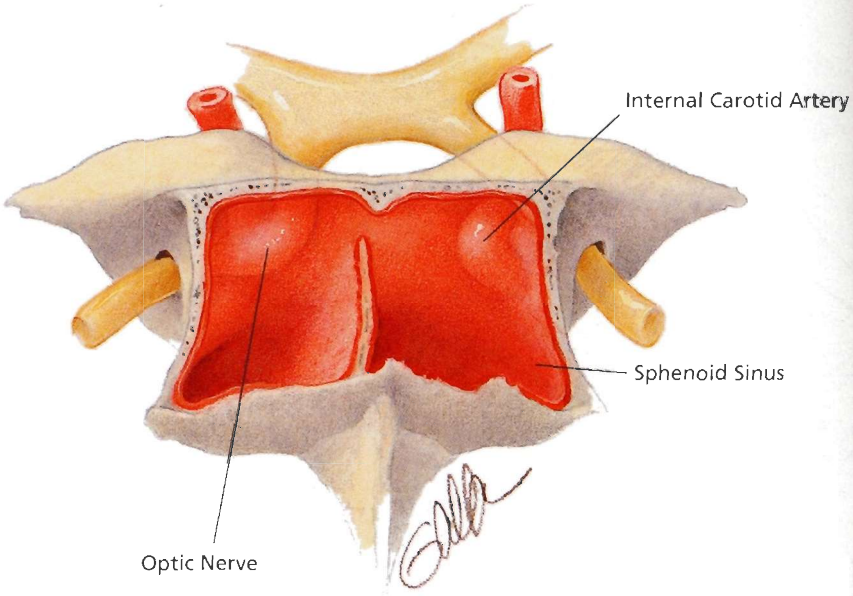


FIG. 5.37. Relation of the optic nerve and the internal carotid artery in the sphenoidal sinus septum.

- Is usually in the posterior wall of the recess, occasionally in its lateral wall.

SURGICAL IMPLICATIONS

The ostium of the sphenoidal sinus may be seen in most patients without a septal deviation if a small endoscope is used. It is adjacent to the posterior part of the septum where the perpendicular plate of the ethmoid attaches to the sphenoidal crest. Surgical excision of the tail of the middle turbinate facilitates this access. As a rule, enlargement of the ostium (sphenoidotomy) is done inferiorly and medially. Lateral enlargement may put the sphenopalatine neurovascular bundle at risk. Superior enlargement puts the os sphenoidale at risk.

In the approach to a petrous apex cyst by way of the sphenoidal sinus, it is best to enter by way of the opposite side to achieve anterior and medial exposure in the ipsilateral sphenoidal sinus.

- Usually, there is one ostium on each side, but occasionally there are two.
- Usually, drainage from the sphenoidal sinus in the standing position is entirely by ciliary action because the ostium is usually located about 1.5 cm above the floor of the sinus.
- Gravity drainage in a prone position may be prevented by septa or spurs partially subdividing the sinus. Dixon (1937) noted septa that were partly bony and partly membranous in 32% of 1,600 specimens. Van Alyea (1941b) found partial septa in 44% of cases.

Intersphenoidal Septum

- Is usually single and rarely multiple.
- Anteriorly, may be in the midline, but posteriorly is rare and may insert on the carotid or the optic prominence.

SURGICAL IMPLICATIONS

Axial CT clearly delineates the posterior insertion of the septum. If it attaches on the carotid or the optic nerve prominence, attempts at resection may lead to catastrophe.

Neural Foramina Adjacent to the Sphenoidal Sinus

- The optic foramen lies between the roots of the lesser wing of the sphenoid bone.
- The foramen rotundum is situated at the root of the greater wing.
- The pterygoid canal lies at the root of the pterygoid process.
- The superior orbital fissure courses between the lesser and the greater wings.
- The palatine vaginal canal lies below the vaginal process.

SURGICAL IMPLICATIONS

Sphenoidal sinusitis can lead to meningitis, CN VI (abducens nerve) palsy, and cavernous sinus thrombosis.

In addition to *pathologic blockage*, the following anatomic variations may interfere with drainage of the sphenoidal sinus and predispose to sinusitis:

Small ostium: less than 2 mm in diameter
Ostium located near the roof of the sinus
Ostium narrowed by a posterior ethmoidal cell
Recesses and septa within the sinus
A narrow sphenoethmoidal recess

Blood Supply and Innervation

- Are similar to those of the posterior ethmoidal cells:
  Sphenopalatine artery
  Posterior ethmoidal artery
  Branches of the pterygopalatine ganglion and sometimes a posterior ethmoidal nerve
- A venous plexus and sparse lymphatic vessels pass via the ostium to join those of the nasal cavity.

THE MAXILLARY SINUS (ANTRUM OF HIGHMORE) (FIGS. 5.38 TO 5.41)

- Is usually the largest of the paranasal sinuses.
- Is a large pyramidal cavity within the body of maxilla.
- Its apex may extend to the zygomatic process or into the zygomatic bone.
- Is first recognizable at 4 months of the fetal life as a shallow groove on the medial surface of the maxillary bone.
- Its average dimensions in adults include
  Height: 33 mm
  Width: 23 mm
  Anteroposterior: 34 mm
  Volume: 15 mL
- Boundaries:
  Anterior (facial): surface of the maxilla
  Posterior: infratemporal fossa

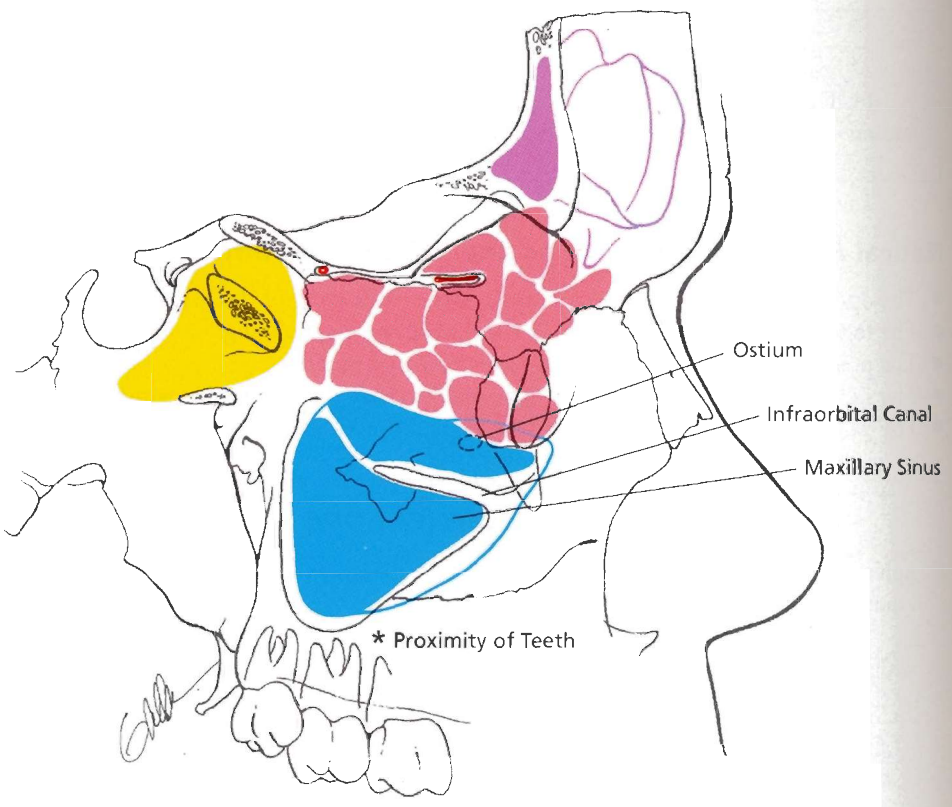


FIG. 5.38. Maxillary sinus.

Medial: lateral wall of the nasal cavity
Superior: floor of the orbital cavity
Inferior: alveolar and palatine processes of the maxilla

- In adults, the floor is 3 to 5 mm below the level of the nasal cavity, whereas in children the floor of the sinus is above or at the level of the floor of the nasal cavity.

SURGICAL IMPLICATIONS

In children, a trocar should not be directed inferiorly when penetrating the sinus through the inferior nasal meatus is attempted.

- The infraorbital nerves and vessels in the superior wall of the sinus and the anterior and the posterior alveolar nerves may be dehiscent.

SURGICAL IMPLICATIONS

Although such dehiscences are rare, injury to the infraorbital neurovascular bundle may occur during surgical instrumentation.

Anatomic Relationship of the Maxillary Sinus and the Teeth

- Are variable, depending on maxillary pneumatization of the alveolar process.

- The maxillary third molars have the most constant relation to the maxillary sinus.

> ***SURGICAL IMPLICATIONS***
>
> An oroantral fistula and maxillary sinusitis may develop after molar extraction because the molar roots may be located within the sinus.

- The canine tooth or the first and the second molars occasionally extend into the sinus.

Ridge and Septa in the Maxillary Sinus

- Larger septa may impede proper drainage of the sinus (Schaeffer, 1910).
- Occasionally, a complete septum divides the sinus into two compartments. One compartment may drain by a small foramen into the other or by an accessory ostium into the nasal cavity.

Innervation and Blood Supply (see Chapter 6, Fig. 6.17)

- Posterior superior alveolar nerves and arteries
- Infraorbital nerves and arteries
- Anterior superior alveolar nerves and arteries
- Superior artery of the inferior concha, which enters through the ostium of the sinus
- Veins and lymphatic vessels of drain via the ostium into the nasal cavity

> ***SURGICAL IMPLICATIONS***
>
> Infection of the maxillary sinus may extend via the infraorbital vein to the cavernous sinus.

Ostium of the Maxillary Sinus (Figs. 5.40 and 5.41)

- Is not ideally located in humans to achieve drainage.
- Is situated on the highest part of the medial wall of the sinus and opens into a narrow ethmoidal infundibulum and not directly into the nasal cavity.
- Teleologically, ostia of the sinus cavities appear properly positioned for gravity drainage in quadrupeds rather than bipeds.
- May be tunnel-shaped and 1 to 22 mm in length (average length, 5.55 mm) (Simon, 1933, 1939), created by the thickness of the infundibulum and sinus mucosa.

Location of the Ostium

- ▸ Usually, opens into the posterior half of the ethmoidal infundibulum (i.e., uncinate groove).
- ▸ Extends posteroinferiorly from the infundibulum proper under cover of the uncinate process.
- ▸ Other locations have been described by Van Alyea (1936) (Fig. 5.39):
  Posterior third of the uncinate groove (72%)
  Posterior tip of the groove rather than under cover of the uncinate process (12%).
  Middle third of the uncinate groove (11%)
  Anterior third of the uncinate groove (6%)

Accessory Ostium

- ▸ Is present in 4% to 30% of individuals.
- ▸ Is most frequently located in the posterior fontanelle of the nasal cavity.

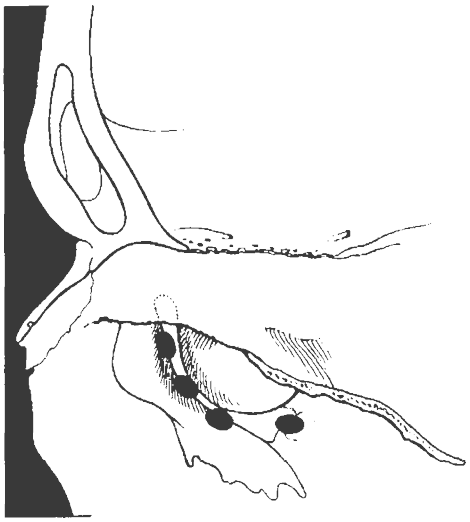


FIG. 5.39. Variations of the maxillary ostium.

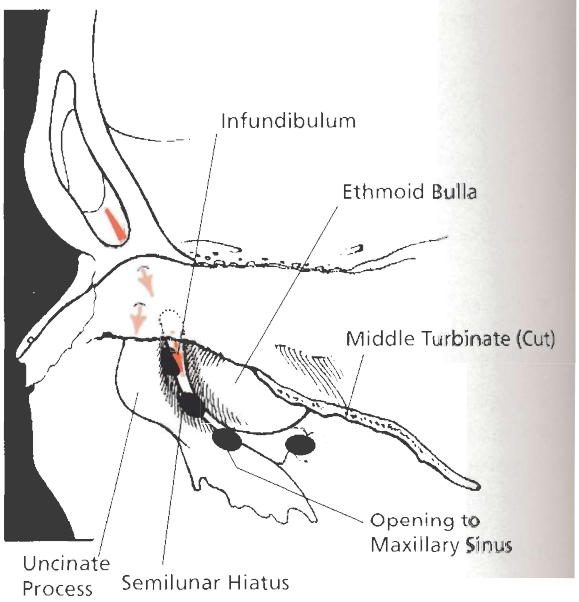


FIG. 5.40. Lateral wall of the middle meatus.

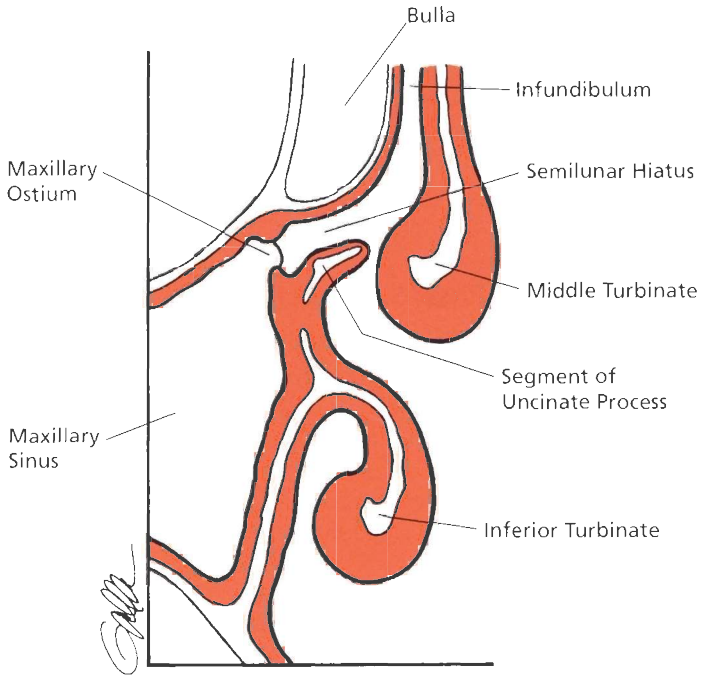


FIG. 5.41. Frontal section of the osteomeatal complex.

SURGICAL IMPLICATIONS

The ostium of the maxillary sinus is usually readily identifiable during endoscopic surgery after the medial infundibular wall (bony uncinate process covered by mucosa medially and laterally) is removed. Sometimes, it is less apparent because it is hidden by a thin mucosal fold. Pressure on the anterior fontanelle causes air bubbles to escape, which helps localize the ostium in difficult cases.

Accessibility of the natural ostium for sinus lavage varies with both its location and the shape of the infundibulum. Sinus lavage can be performed in only 50% of cases (Van Alyea, 1936) and is more often performed through the inferior meatus or the anterior wall than through the natural ostium because the latter is usually not identifiable unless the medial infundibular wall is removed.

SURGICAL IMPLICATIONS

Middle meatal antrostomy, popularized by Stammberger (1986), is performed through the endoscopic endonasal approach.

Inferior meatal lavage is performed by penetrating the lateral wall of the inferior meatus. Because Hasner's valve of the nasolacrimal duct opens anteriorly and highly in the inferior meatus, this wall should be penetrated more than 1 cm behind the anterior attachment of the inferior concha. Because the lateral wall of the inferior meatus is formed by thick bone, the sinus should be punctured high in the meatus. The trocar should be directed to the ipsilateral outer canthus of the eye to avoid accidental injury to the floor of the orbit.

Inferior meatal antrostomy is performed in the lateral wall of the inferior meatus. Because the ciliary action of the sinus mucosa is still toward the natural ostium, the value of dependent drainage through an inferior meatal antrostomy has been challenged by endoscopic surgeons.

THE CANINE FOSSA (SEE CHAPTER 6, FIG. 6.2)

- Is a depression in the anterior wall of the maxilla.
- Extends from infraorbital foramen or the inferior margin of the orbit superiorly to the alveolar process inferiorly.
- The anterior superior alveolar nerves and vessels run in the bony wall between it and the maxillary sinus.

SURGICAL IMPLICATIONS

Inferior meatal antrostomy, as part of a Caldwell-Luc procedure, may function via gravity drainage, but the floor of the sinus may lie below the level of the nasal floor, impeding gravity drainage. Supplementary openings between the nasal cavity and maxillary sinus may actually interfere with the normal physiology of the sinus by interfering with normal ciliary action.

McMurray (1931) believed that a normal accessory ostium may interfere with the drainage of the sinus due to diminution of the normal negative pressure developed in the sinus during inspiration. King (1935) placed radiopaque oil in a patient having a nasoantral window in the inferior meatus and found that the oil flowed, not through the larger artificial window, but through the natural ostium, suggesting that ciliary action is more important than gravity drainage.

THE VARIATIONS IN THE ANATOMY OF THE NOSE AND SINUSES WITH AGE

- *Height of the nasal cavities:*
  Newborn: 18 to 20 mm
  First year: increases by 50%
  Seventh year: increases by 100%
  Maturity: increases by 250% to 300%
- *Anteroposterior length* of the nasal cavities doubles between the first and the seventh years and then grows slowly.
- *Proportions* of the lateral wall of the nasal cavity:
  Newborn: ethmoidal portion two-thirds; maxillary portion one-third
  After second year: ethmoidal portion one-half; maxillary portion one-half
- The *inferior turbinate* is in contact with the floor of the nose at birth, and there is no functional inferior meatus in first 2 years of life.
- *Maxillary sinus dimensions:*

At birth	3 to 4 mm laterally
	8 to 10 mm anteroposteriorly
	3 to 15 mm vertically
At 9 years	25 mm laterally
	18 mm anteroposteriorly
	18 mm vertically

- *Sphenoidal sinus dimensions:*

At birth	Width: 2 to 5 mm
	Length: 2 to 3 mm
	Height: 1.5 to 2 mm
At 4 to 5 years	No significant change
At 8 years	Width: 11 mm
	Height: 8 to 12 mm

- *Frontal sinus dimensions:*
  Not present until 2 to 3 years of age
  Becomes clinically important at 5 to 6 years
- *Ethmoidal sinuses dimensions:*
  A definite sinus space exists at 6 to 7 months of fetal life.
  A sinus is always present and clinically important at birth.
  Dimensions:

Cell group	*At full term*	*At 14 years*
Anterior	5 mm vertically	9 to 16 mm vertically
	2 mm laterally	10 mm laterally
	2 mm anteroposteriorly	5 mm anteroposteriorly
Posterior	5 mm vertically	9 to 15 mm vertically
	4 mm laterally	14 mm laterally
	2 mm anteroposteriorly	8 to 20 mm anteroposteriorly

CHAPTER 6

ORAL CAVITY

PARVIZ JANFAZA AND RICHARD L. FABIAN

The oral cavity is bounded by the lips anteriorly and the oropharyngeal isthmus (faucial isthmus) posteriorly. It is covered by mucous membrane, which is nonkeratinized stratified squamous epithelium. It is divided into the vestibule and the oral cavity proper.

THE LIPS (FIG. 6.1)

- Are mobile structures at the opening of the mouth. Their muscles, glands, and connective tissue are covered externally by skin and internally by mucous membrane.
- The *vermilion zone* is the red part of the lips. Its color is due to a rich vascular bed visible through the thin epithelium.
- The *vermilion border* is the junction between the skin and the vermilion zone.
- The superior lip is bounded laterally by the nasolabial groove. This extends from the ala of the nose to a short distance lateral to the corner of the mouth.
  The *philtrum* (Cupid's bow) is a shallow vertical depression of the upper lip.
  The *labial tubercle* is a fleshy bump in the midportion of the vermilion border just inferior to the philtrum.
  The *labiomental groove* separates the lower lip from the chin. The *labial commissure* is a thin fold of tissue that connects the two lips laterally.
  The *oral fissure* (rim of the mouth) is the area between the upper and lower lips.
- Embryologically, are formed from the median nasal, maxillary, and mandibular processes.

THE VESTIBULE (FIGS. 6.2 AND 6.3)

- Is located between the lips and cheeks and the teeth and gingiva when the teeth are in contact.
- Communicates externally through the oral fissure of the lips and with oral cavity proper through the interdental spaces and the posterior openings of the last molar teeth.
- Laterally, is referred to as the *buccal* vestibule, anteriorly as the *labial* vestibule.
- The mucolabial folds, also called the *fornix,* are the transition point between the vestibular mucosa and gingival mucosa.
- The *incisive fossa* is a shallow depression superior to the incisor teeth in the superior labial vestibule.
- The *canine eminence* is a prominence that extends into the labial vestibule from the alveolar ridge over the root of the canine tooth.
- The *canine fossa* is the shallow depression lateral to the canine eminence.
- The *maxillary tuberosity* lies posterior to the zygomatic process superior to the last molar.

SURGICAL IMPLICATIONS

The proximity of the posterosuperior alveolar nerve to the maxillary tuberosity facilitates localization for local anesthesia and also explains anesthesia in the distribution of this nerve due to an intraoral inflammatory process.

- The parotid duct (Stensen's duct) opens into the buccal vestibule by a small elevated mucosal orifice (the parotid papilla) adjacent to the level of the upper second molar

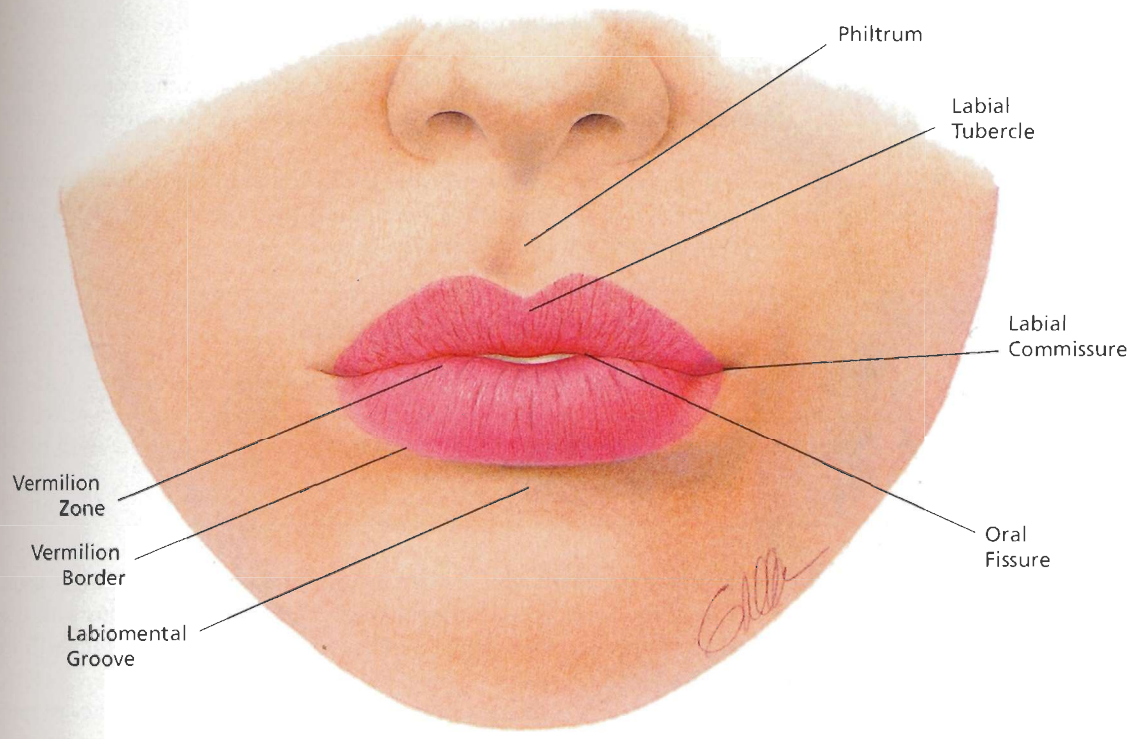


FIG. 6.1. Surface anatomy of the lips.

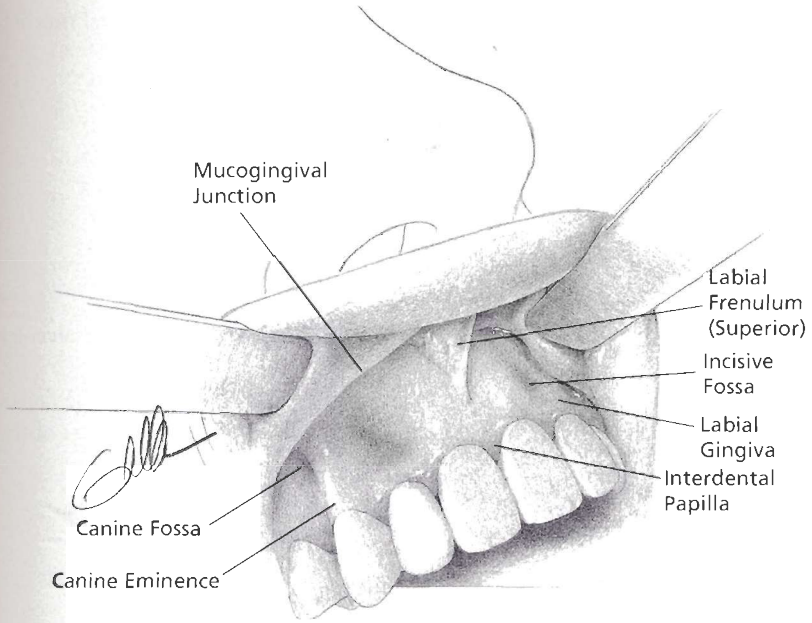


FIG. 6.2. Vestibule of the oral cavity.

tooth. Several minor salivary gland (buccal and labial glands) also open into the vestibule through small orifices.

- *Fordyce's spots* are yellow spots located in the buccal mucosa lateral to the corners of the lips. They are embryologic remnants of atrophied sebaceous glands and are usually bilateral.
- The *labial frenula* (Figs. 6.2 and 6.3) are mucosal folds located in the midline between the lips and the gingiva. The superior labial frenulum is more prominent. Additional frenula may be present in the buccal or labial vestibules.

> ***SURGICAL IMPLICATIONS***
>
> Occasionally, the superior labial frenulum is widely attached and may interfere with normal eruption of the central incisors, causing a diastema. Surgical removal of the frenulum between the central incisors may be necessary to allow return of the teeth to their normal position.

- The *gingiva* (gum) is covered by mucosa. Its free margin surrounds the inferior margin of the clinical crown of the teeth. The vestibular gingiva becomes continuous with the gingiva of the oral cavity proper. Interdental papillae are located between the teeth in the interdental spaces.
- The *retromolar trigone* (Fig. 6.3) is the special region of the gingiva distal to the last molars in both dental arches. The mucosa is attached to the underlying ascending ramus of the mandible from the posterior surface of the last molar tooth to its apex adjacent to the tuberosity of the maxilla.
- The alveolar mucosa covers the alveolar process of the maxillary and mandibular arches. The *mucogingival junction* is a sharp, scalloped line that separates the gingival mucosa from the alveolar mucosa.

THE ORAL CAVITY PROPER (FIG. 6.3)

- Is located internal to the dental arches.
- The oral cavity is bounded
  - Superiorly by the palate
  - Inferiorly by the tongue and floor of the mouth
  - Laterally by the lingual surfaces of the teeth, lingual gingivae, and lingual alveolar mucosa
  - Posteriorly by the vertical portion of the soft palate and anterior pillar of the fauces (palatoglossal arch), which extends from the soft palate to the sides of the base of the tongue

Oropharyngeal Isthmus (Fauces)

- Connects the oral cavity to the pharynx.
- Is bounded
  - Superiorly by the soft palate
  - Inferiorly by the posterior one-third of the tongue
  - Laterally by the palatoglossal arches
- The palatine tonsil is considered part of the pharynx.
- For the purpose of the tumor-node-metastasis classification system for neoplasms, the oral cavity extends from the skin and vermilion junction of the lips to the junction of the hard and soft palates superiorly and the line of the circumvallate papillae (sulcus terminalis) on the tongue inferiorly.

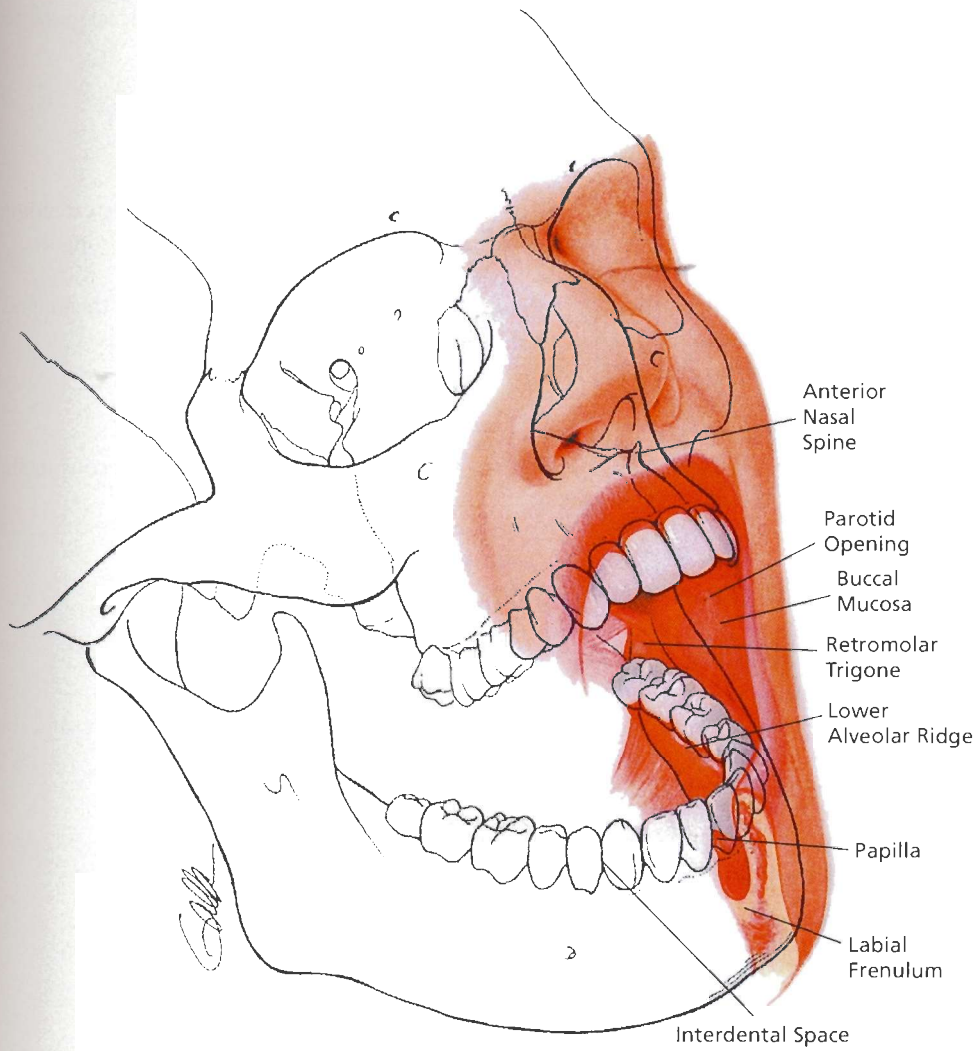


FIG. 6.3. Surface of the oral cavity, oblique view.

Buccal Mucosa

- Consists of all membranes covering the inner aspect of the cheeks and lips from the line of contact of the opposing lips to the line of insertion of the mucosa of the alveolar ridge (upper and lower) and pterygomandibular raphe.

Lower Alveolar Ridge

- Consists of the alveolar process of the mandible and its lining mucosa.
- Extends from the line of insertion of the mucosa in the buccal gutter to the line of the free mucosa of the floor of the mouth.
- Posteriorly, extends to the ascending ramus of the mandible.

Upper Alveolar Ridge

- Consists of the alveolar ridge of the maxilla and its lingual mucosa.

- Extends from the line of insertion of the mucosa in the upper gingival buccal gutter to the junction of the hard palate.
- Its posterior margin is the superior end of the pterygopalatine arch.

Floor of the Mouth

- Consists of the semilunar space of the mylohyoid and hyoglossus muscles extending from the inner aspect of the lower alveolar ridge to the undersurface of the tongue.
- Posteriorly, extends to the base of the anterior pillar.
- The anterior floor of the mouth is divided into two sides by the frenulum of the tongue. It contains the opening of the submandibular and sublingual salivary glands.

Hard Palate

- Consists of a semilunar area between the upper alveolar ridge and the mucous membranes lining the palatine process of the maxillary palatine bones.

THE TONGUE (FIGS. 6.4 TO 6.11)

- Is a highly specialized organ that facilitates taste, deglutition, and speech.
- Is located partly in the mouth and partly in the pharynx.
- Is attached to the hyoid bone, the mandible, the pharynx, the styloid process, and the soft palate.
- Is anatomically subdivided into root, dorsum, and tip.

Parts of the Tongue

Root

- Attaches to the hyoid bone and the mandible (Fig. 6.9).
- Inferiorly, contacts the geniohyoid and the mylohyoid muscles.

Dorsum

- Is the convex surface of the tongue.
- Is divided into anterior and posterior parts.
- The parts are separated by a V-shaped furrow called the *sulcus terminalis,* which extends from the foramen cecum to the palatoglossal arch.
- The sulcus terminalis is the junction of the anterior two-thirds (oral tongue) and the posterior one-third (pharyngeal tongue). These two parts differ in structure, covering mucous membrane, nerve supply, and development.

Oral Tongue (Fig. 6.4)

- Its apex and dorsum extend from the incisor teeth to the hard and soft palates.
- Its lateral margins are the gums and teeth.
- The superior surface mucosa has a median furrow and is adherent to the underlying muscles.
- Develops primarily from the mandibular arch.
- Sensation is mediated by CN V and taste by the chorda tympani nerve.
- On each tongue border are vertical folds called the foliate papillae, which are atrophied taste buds.

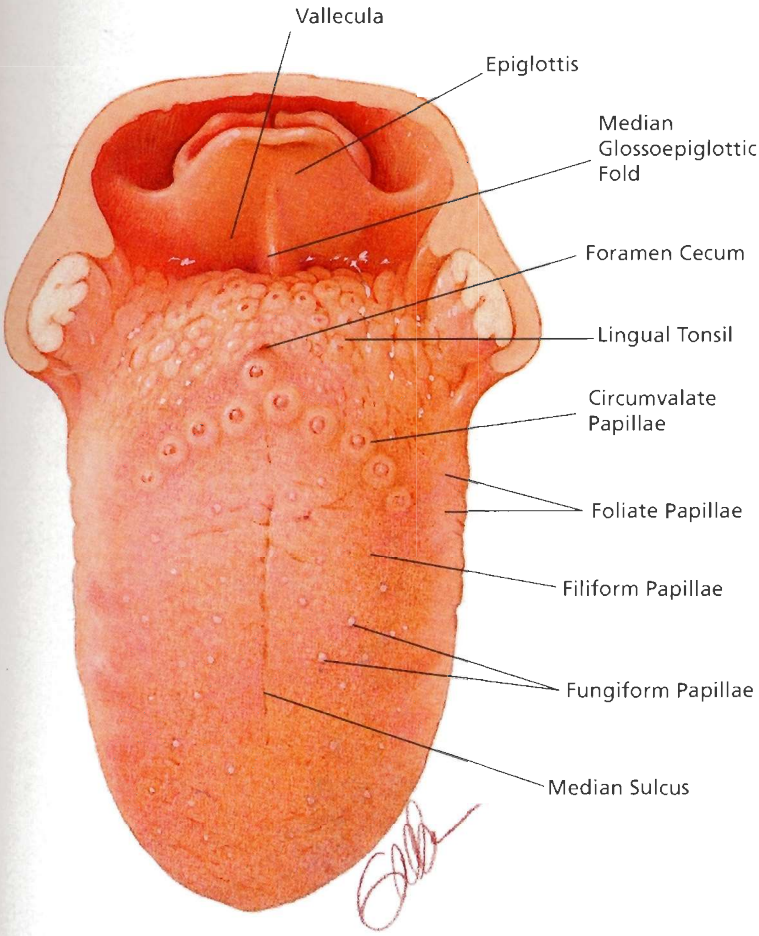


FIG. 6.4. Dorsum of the tongue.

Inferior Surface of the Tongue

- Is covered by mucous membrane.
- In its middle lies, the lingual frenulum that connects the floor to the tongue.
- Lateral to the frenulum is a deep lingual vein that is visible through the mucosa.
- Lateral to the vein is a fringed mucosal fold, the plica fimbriata, that runs forward toward the apex of the tongue.

Pharyngeal Tongue

- Is located behind the palatoglossal arches and the oropharyngeal isthmus.
- The base of the tongue forms the anterior wall of the oropharynx.
- The epiglottis is connected to the tongue by a median and two lateral glossoepiglottic folds. The depressions between these folds are called the epiglottic valleculae.
- Laterally, is devoid of papillae and has a prominent lymphoid structure called the lingual tonsil.
- Develops from the hypobranchial eminence of the third arch.
- Sensation is transmitted through CN IX.

Papillae of the Tongue (Fig. 6.5)

- Are formed by the projection of corneum.

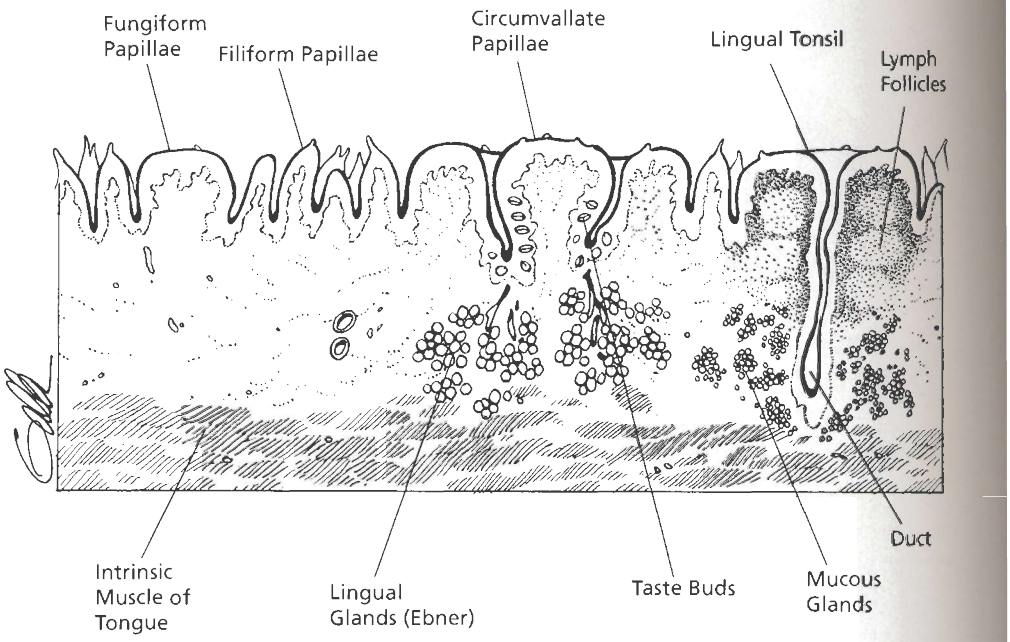


FIG. 6.5. Histology of the papillae of the tongue.

- Are limited to the anterior two-thirds of the tongue.
- The taste buds are distributed widely over the entire dorsum and side of the tongue, epiglottis, and undersurface of the soft palate.

Vallate (Circumvallate) Papillae

- Number 8 to 12.
- Form a V shape parallel, located anterior to the sulcus terminalis or foramen cecum.
- Each papilla is 1 to 2 mm in diameter.
- The entire papilla and the surrounding sulcus are covered with stratified squamous epithelium.

Fungiform Papillae

- Are distributed over the dorsum, the side, and the apex of the tongue.
- Are distinguished from the filiform papillae by their large size, round shape, and deep red color.
- Each has a secondary papilla beneath the epithelium.

Filiform Papillae

- Are minute, conical, or cylindrical in shape
- Lie parallel to the circumvallate papillae except at the apex, where they are transversely oriented.

Papillae Simplices

- Cover the entire mucous membrane of the tongue and the larger papillae.
- Each contains a capillary loop covered by epithelium.

Glands of the Tongue

- Mucous glands open on the posterior surface of the tongue and into the crypts of the lingual tonsils.
- The serous glands *(Ebner's glands)* open into the mucous glands and also into the sulci of the circumvallate papillae.
- Seromucinous glands open on the lower surface of the tongue through five or six ducts.

> ***SURGICAL IMPLICATIONS***
>
> Obstruction of a seromucinous gland causes a cystic enlargement called a ranula.

Muscles of the Tongue (Figs. 6.7 and 6.9)

- Are divided into right and left compartments by a medial fibrous septum fixed to the hyoid bone.
- Are divided into extrinsic and intrinsic groups.
- Except for the palatoglossus muscle, all muscles of the tongue are innervated by the hypoglossal nerve.

Extrinsic Muscles of the Tongue

Genioglossus (Geniohyoglossus) Muscle

- Is a triangular muscle lying parallel to the median plane.
- Spreads and forms a broad sheet in the sagittal plane.
- Origin: upper genial tubercle and internal aspect of the mandible just above the geniohyoid muscle.
- Anterior fibers radiate from their origin to the anterior fibers of the tongue. Posteriorly, the two muscles are separated by the septum of the tongue. Other fibers reach the back of the tongue, while the lowest insert into the hyoid bone.
- Action: protrudes the tongue. Acting in unison, both muscles draw the medial part of the tongue downward, causing a side-to-side concavity.

Hyoglossus Muscle

- Is a thin quadrilateral muscle arising from the whole length of the greater horn (cornu) and lateral part of the hyoid bone.
- Course:
  Travels vertically to the side of the tongue between the styloglossus laterally and the inferior longitudinal muscle medially.
  Passes lateral to the posterior part of the genioglossus and interlaces with the styloglossus and intrinsic muscles.
- CN XII and the lingual vein run across the lateral surface of the hyoglossus muscle in their course toward the tongue. The lingual artery lies between the hyoglossus and the genioglossus muscles.
- Located lateral to it and medial to the mandible are (in ascending order)
  Submandibular duct
  Deep portion of the submandibular gland
  Lingual nerve
  Sublingual gland
  Nerves and vessels of the tongue

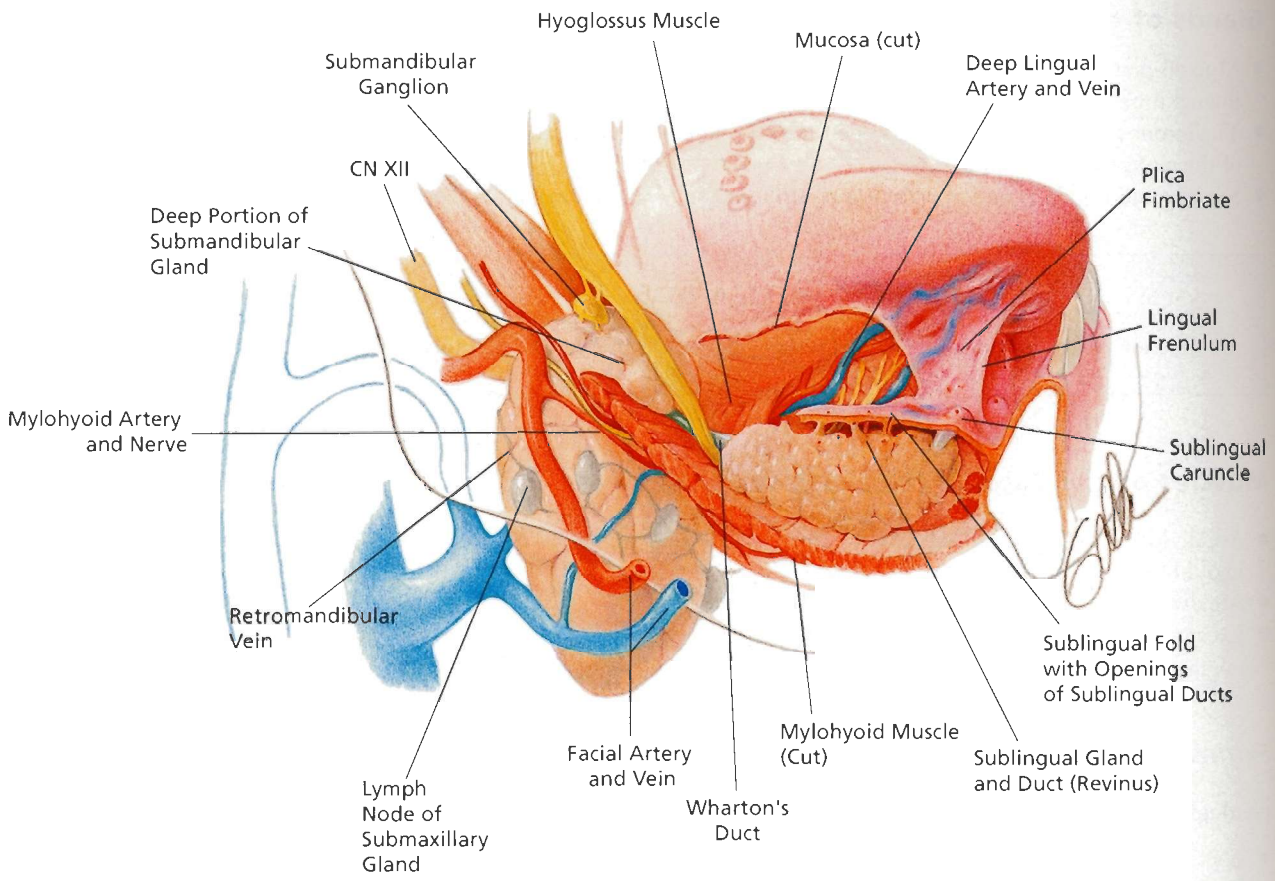


FIG. 6.6. Muscles, arterial supply, and innervation of the tongue.

- Its deep surface is adjacent to
  - Stylohyoid ligament
  - Genioglossus muscle
  - Inferior longitudinal muscle
  - Lingual artery
  - Glossopharyngeal nerve
- Its lower and posterior parts are separated from the lower and middle constrictor muscles by the lingual artery. This portion lies in the lateral wall of pharynx below the tonsil.
- Action: depresses the tongue.

Chondroglossus Muscle

- Is separated from the hyoglossus muscle by fibers of the genioglossus muscle.
- Origin: medial side and base of the lesser horn and body of the hyoid bone.
- Course: ascends and blends with intrinsic muscle of the tongue between the hyoglossus and genioglossus muscles.
- Action: assists the hyoglossus muscle in depressing the tongue.

Styloglossus Muscle

- Origin: anterior and lateral to the surface of the styloid process near the apex, forming the upper part of stylohyoid ligament.
- As it descends, becomes broader and runs deep to the medial pterygoid muscle.