Anatomy and Physiology of Nose and Paranasal Sinuses

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POINTS OF FOCUS

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- **PHYSIOLOGY OF NOSE**
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  - Olfaction
- **PHYSIOLOGY OF PARANASAL SINUSES**
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ANATOMY OF NOSE

ANATOMY OF NOSE

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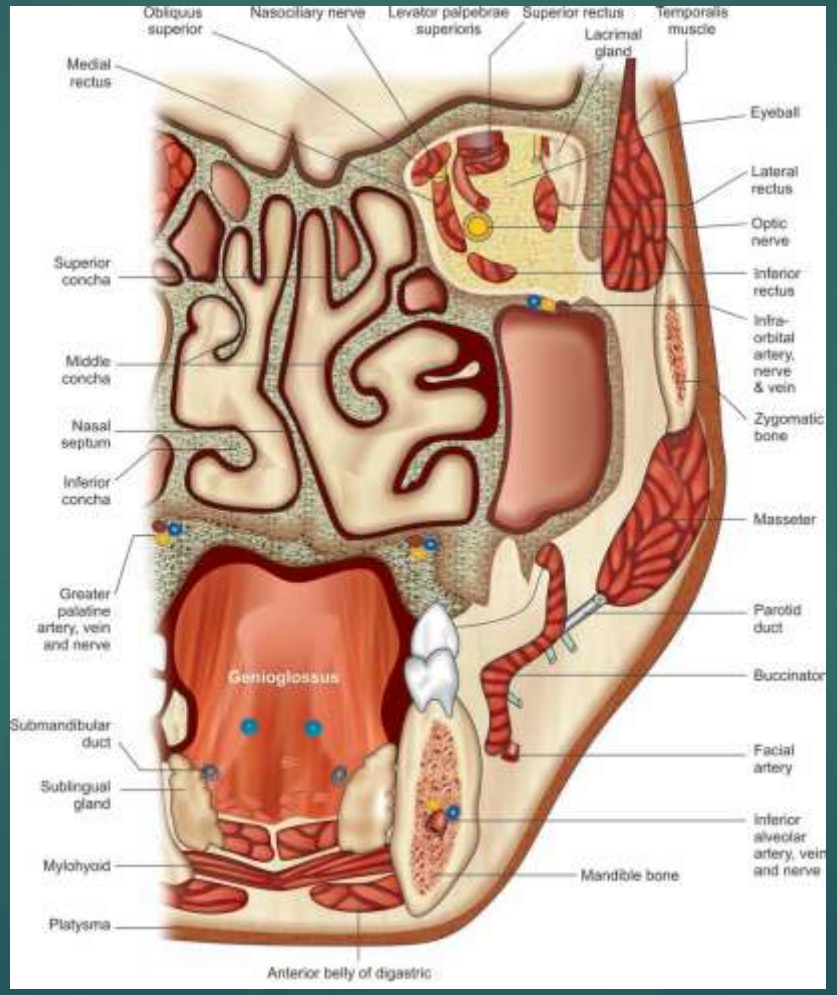
- Submucosal Vascular Plexus
- Nerve Supply of Nasal Cavity
- Lymphatic Drainage

Coronal section of head showing nose, sinuses, oral cavity and orbit



EXTERNAL NOSE

Osteocartilaginous Framework of Nose

- Upper one-third bony (nasal bones) and forms bridge (root) of nose
- Lower two-third cartilaginous and forms dorsum of nose
- **Bony Part**: Two nasal bones, nasal process of the frontal bone, frontal processes of the maxillae.
- **Cartilaginous Part:**
  - **Upper lateral cartilages**: Lower free margin seen intranasally, **limen vestibuli / nasal valve**.
  - **Lower lateral cartilages:** U-shaped alar cartilage, 2 crura lateral and medial.
  - **Lesser alar (or sesamoid) cartilages:** They may be two or more in number and lie above and lateral to alar cartilages.

External nose structure—lateral view

-**Septal**: The anterosuperior border of septal cartilage, which supports the dorsum of cartilaginous part of the nose, extends from undersurface of nasal bones to the nasal tip.

Supratip depression deformity of nose: It occurs due to loss of septal cartilage support such as in cases of septal abscess and excessive removal of septal cartilage during submucosal resection of septum.

Nasal Musculature

Facial muscles for movements of the nose: procerus, nasalis (transverse & alar parts), levator labii superioris alaeque nasi & depressor septi.

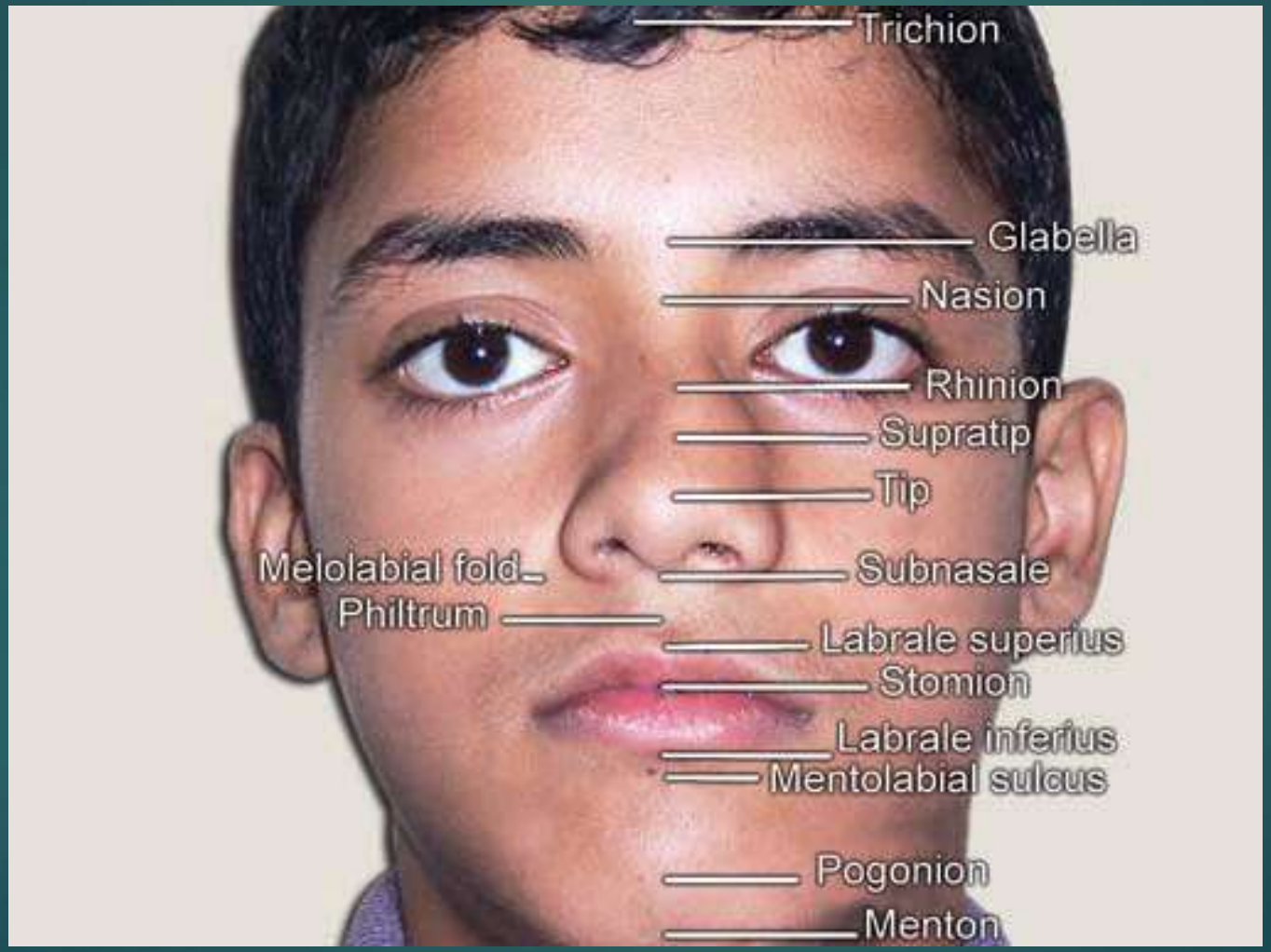
Nasal Skin

Thin and freely mobile. Skin of alar cartilages thick, adherent & have sebaceous glands.

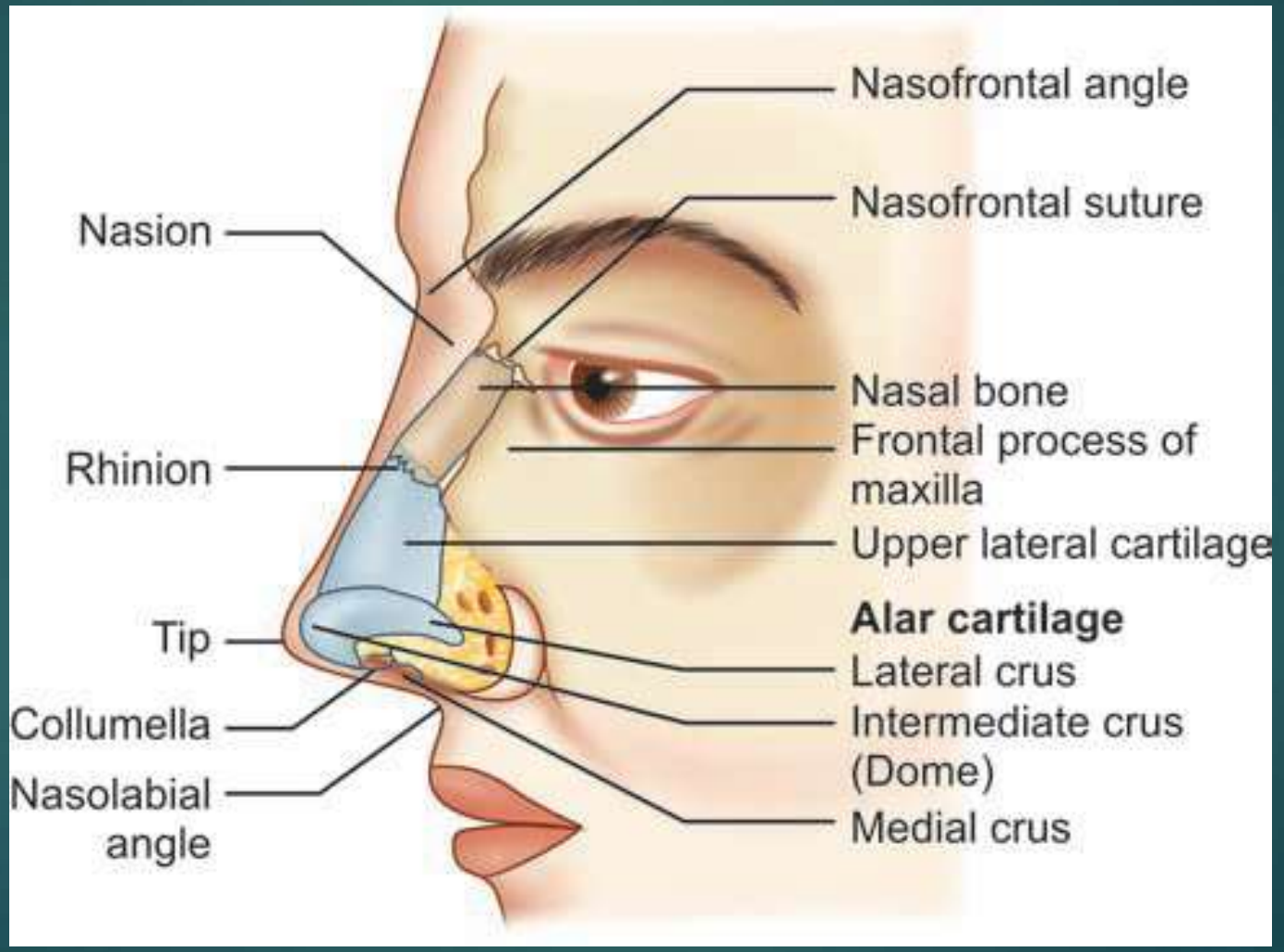
Rhinophyma:Hypertrophy of sebaceous glands of external nose skin result in a lobulated tumor called rhinophyma (see chapter diseases of external nose).

Dangerous Area of Face (Danger Triangle Area*):* Venous drainage goes intracranially. Triangular area from nasion to angles of mouth & includes external nose and upper lip. The inferior ophthalmic vein receive angular vein & drains into cavernous sinus. Infection of this area has potential to cause cavernous sinus thrombosis.

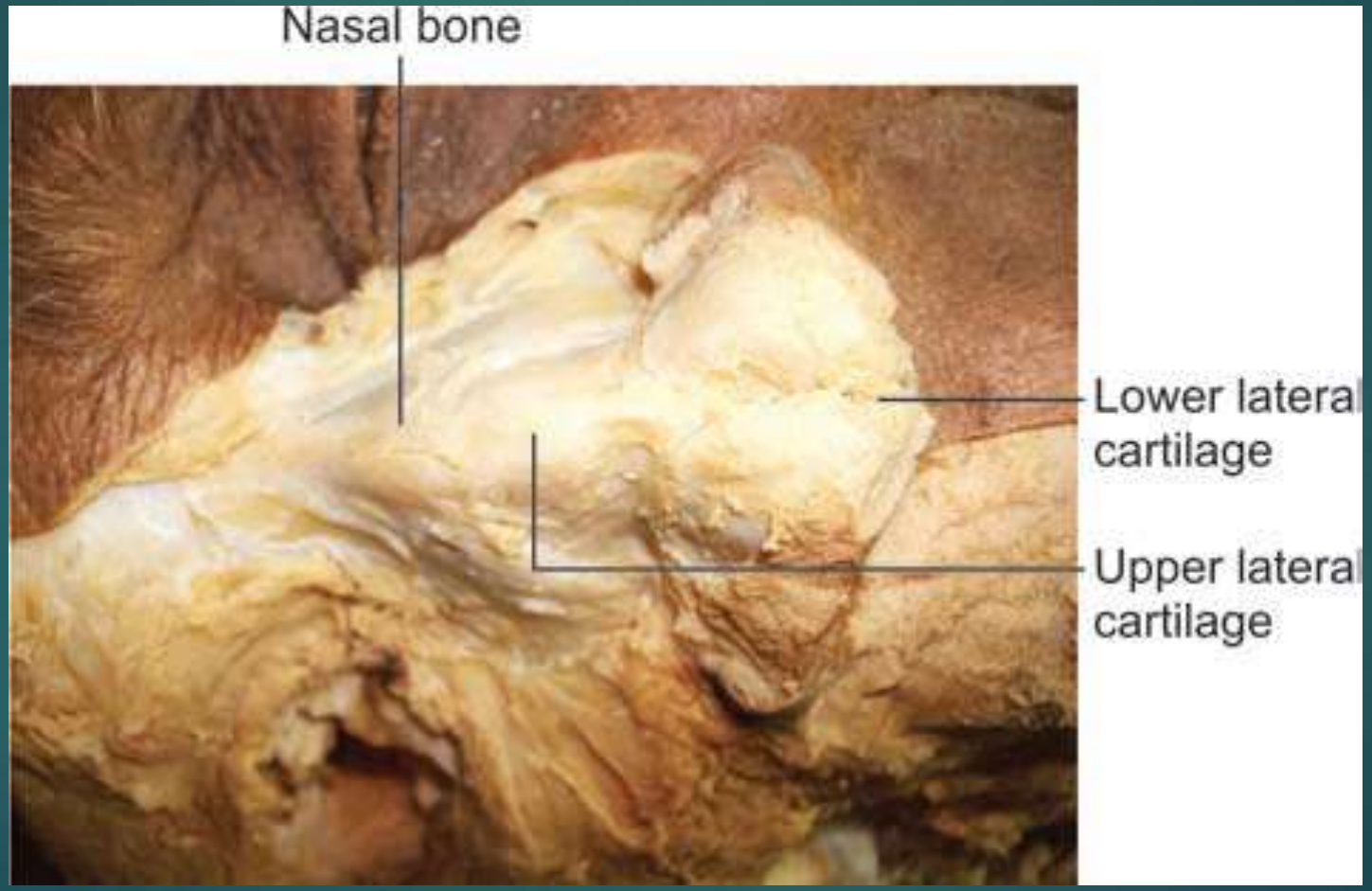
Crooked nose (“C” shaped) Note soft tissue anatomic landmarks (reference points)



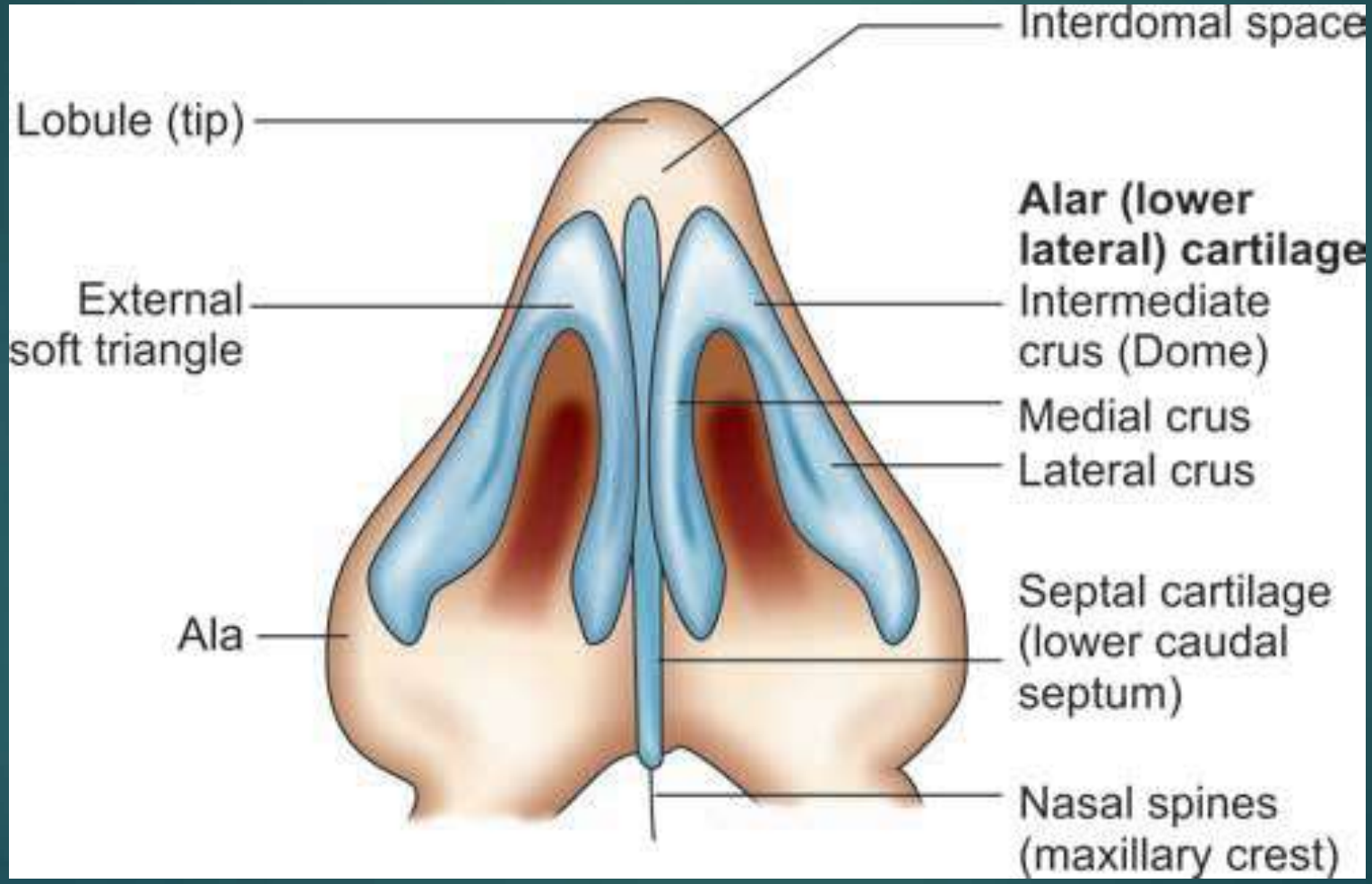
External nose structure—lateral view



Cadaveric dissection of external nose showing nasal bone and upper and lower lateral cartilages



External nose structure basal view



INTERNAL NOSE

The nasal septum divides the internal nose into two halves

right and left nasal cavities. The nasal cavities communicate

with the exterior through anterior nares (nostrils) and with the nasopharynx through posterior nasal choanae. The anterior and inferior skin-lined portion of internal nose is called vestibule and posterior mucosa-lined portion makes nasal cavity proper.

Each nasal cavity has four boundaries:

- Lateral wall
- Medial wall
- Roof of nasal cavity
- Floor of nasal cavity

Lateral Wall of Nasal Cavity

- Bones: The lateral wall is formed by following bones:
  - **Nasal bone**
  - Maxilla: Frontal process and medial surface of maxilla (medial wall of maxillary sinus)
  - **Lacrimal bone**
  - **Inferior turbinate**
  - **Ethmoid:** Lateral mass of ethmoidal bone
  - **Palatine bone**: Perpendicular plate
  - **Sphenoid**: Medial pterygoid plate

- **Turbinates**:
  - **Inferior turbinate:** largest turbinate & a separate bone.
  - **Middle turbinate:** part of ethmoidal bone
  - **Superior turbinate:** smallest turbinate & part of ethmoidal bone. one or more ethmoidal air cells. Posterior & superior to middle turbinate. Not seen on anterior rhinoscopy.
  - **Supreme turbinate:** may be seen lying above the superior turbinate in some cases.
- **Meatuses**:
  - **Inferior meatus**: Along whole length of lateral wall. Nasolacrimal duct opens in the anterior part & guarded by Hasner's mucosal valve.
  - **Middle meatus:** Lies below the middle turbinate.
  - **Superior meatus**: In posterior third of lateral wall. Posterior ethmoidal sinuses open

- **Sphenoethmoidal recess**: Above the superior turbinate. Sphenoid sinus opens medial to superior turbinate about 1 cm above the upper margin of posterior choana close to the posterior border of septum.
- **Atrium**: Shallow depression in front of middle meatus & above vestibule.

Medial Wall

It is formed by the nasal septum

Roof

It has three parts:

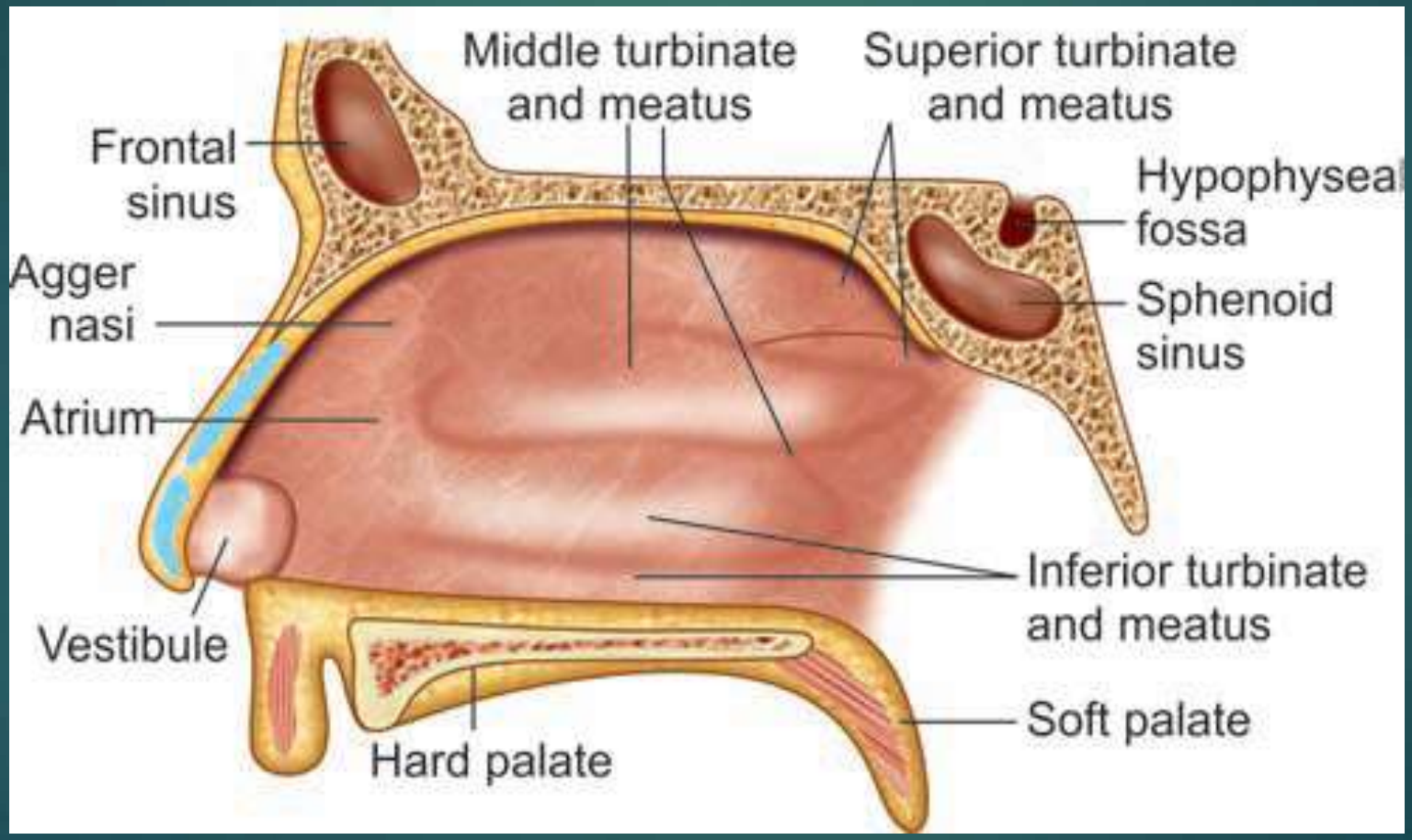
- Anterior sloping part (nasal bones)
- Middle horizontal part (cribriform plate of ethmoid through which olfactory nerves pass)
- Posterior sloping part (body of sphenoid bone).

Floor

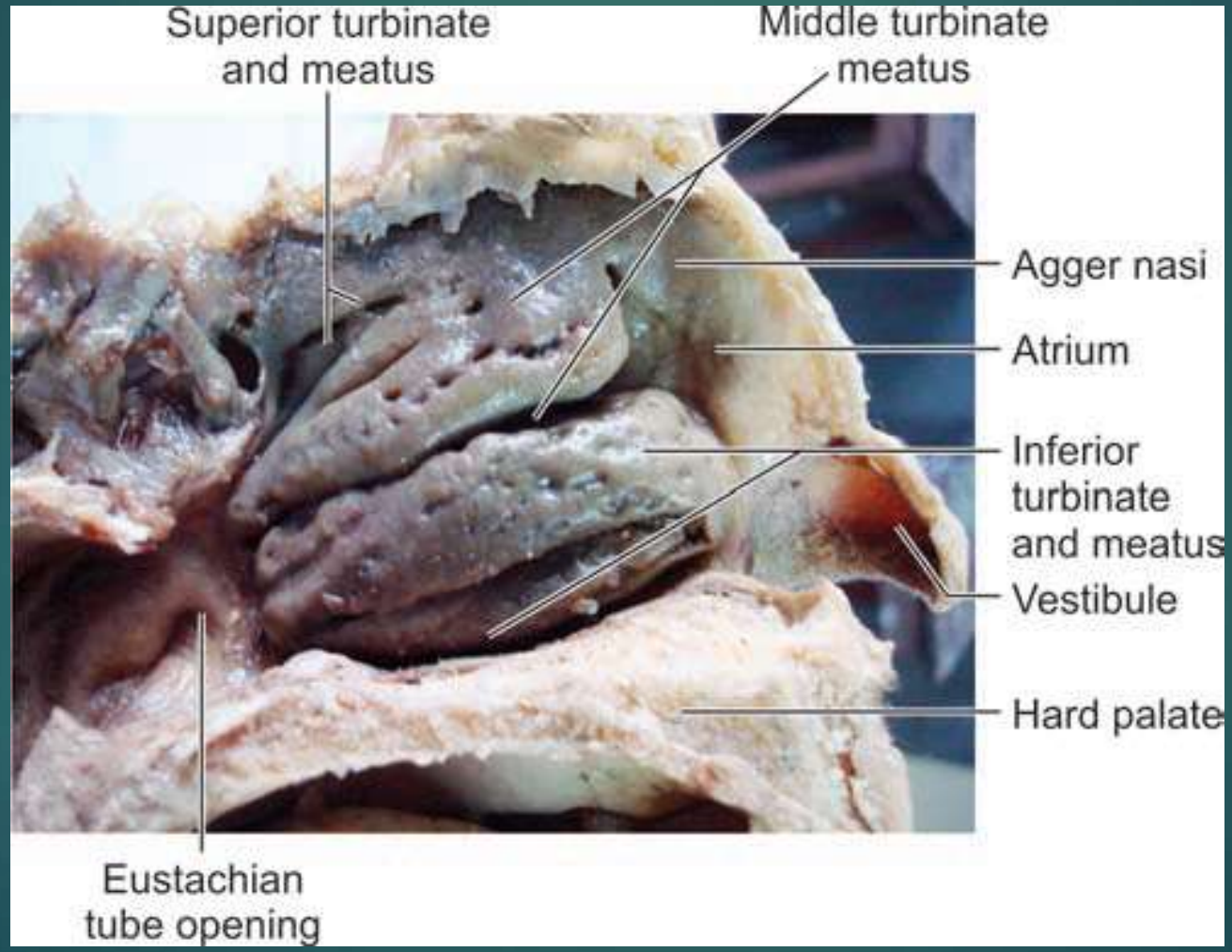
Floor of the nose makes roof (hard palate) of the oral cavity.

- It is made up of two bones: palatine process of the maxilla (anterior three-fourths)
- Horizontal plate of the palatine bone (posterior one-fourth).

Lateral wall of nasal cavity showing turbinates & meatuses



Lateral wall of nasal cavity of cadaver showing turbinates and meatuses



Vestibule of Nose

This anteroinferior portion of nasal cavity is lined by skin, which contains sebaceous glands, hair follicles and the hair (vibrissae).

Limen nasi (nasal valve): This area is the greatest constriction of respiratory tract. Its boundaries include:

Floor: Floor of the nose.

Superior and lateral: The caudal margin of upper lateral cartilage.

Medial: Columella and lower part of the nasal septum up to mucocutaneous junction

Complication of rhinoplasty: Injudicious resection of lateral nasal cartilage during rhinoplasty can produce collapse of nose which causes nasal obstruction during inspiration.

Nasal Septum

Nasal septum can be divided into three parts:

- **Columellar septum**
- **Membranous septum**
- **Septum proper**

The columellar and membranous parts can be moved from side to side.

1. **Columellar septum**: It is covered on either side by skin. The columella contains medial crura of lower lateral cartilages, which are joined together with fibrous tissue.
2. **Membranous septum:** It lies between the columella and the caudal border of septal cartilage and consists of only double layer of skin. There is no bony or cartilaginous support in membranous septum.
3. **Septum proper:** It is covered with mucous membrane and consists of osteocartilaginous framework. The principal constituent of septum proper is large quadrilateral septal cartilage.

Other major constituents are:

- The perpendicular plate of ethmoid
- The vomer

The large quadrilateral septal cartilage is wedged between vomer and perpendicular plate of ethmoid bone.

Middle Meatus and Osteomeatal Complex

Other bones, which make very small contributions, includes:

- Crest of nasal bones
- Nasal spine of frontal bone
- Rostrum of sphenoid
- Crests of palatine and maxilla
- The anterior nasal spine of maxilla

Septal cartilage: This large quadrilateral septal cartilage is wedged between vomer and ethmoid plate.

– *Inferior margin*: It lies in a groove of vomer and rests anteriorly on anterior nasal spine. It may get dislocated from anterior nasal spine (caudal septal deviation) or vomerine groove (septal spur).

Middle Meatus and Osteomeatal Complex

Superior margin: Septal cartilage fuses with the upper lateral cartilages of external nose. Therefore, septal deviation may be associated with deviation of cartilaginous part of external nose (dorsum of nose)

Caudal septal deviation: It occurs due to dislocation of inferior margin of septal cartilage from anterior nasal spine.

Septal spur: It is the result of dislocation of the inferior margin of septal cartilage from the vomerine groove.

Deficiency of septal cartilage: Septal cartilage provides support to the tip and dorsum of cartilaginous part of external nose. Septal cartilage destruction results in depression of dorsum of nose and drooping of the nasal

Middle Meatus and Osteomeatal Complex

- **Middle meatus space:** Below middle turbinate in the posterior half of lateral wall.
- **Osteomeatal complex** : Middle turbinate & middle meatus structures (uncinate process, bulla ethmoidalis, hiatus semilunaris and ethmoid infundibulum. Openings of frontal, maxillary and anterior ethmoidal sinuses.
- **Sinusitis**: Mucosal swelling & anomaly of osteomeatal unit cause obstruction, stasis and repeated infections of anterior ethmoidal, maxillary and frontal sinuses.
- **Functional endoscopic sinus surgery (FESS)**: Tries normal restoration to enhance sinus drainage.
- **Middle Turbinate**: Lower ethmoidal turbinate attached to lateral wall through the ground basal lamella. Anterior 1/3rd in sagittal plane attached to lateral edge of cribriform plate. Middle 1/3rd in frontal plane attached to lamina papyracea. Posterior 1/3rd horizontally attached to lamina papyracea & medial wall of maxillary sinus.

- **Fracture of middle turbinate**: Cause CSF rhinorrhoea and/or anosmia.
  - **Paradoxical middle turbinate**: Lateral surface of middle turbinate is convex. Cause narrowing of the middle meatus & affect ventilation and mucociliary clearance in osteomeatal unit.
- **Concha Bullosa**: Pneumatization of the middle turbinate. 30% of population. Asymptomatic. Air cells drain into frontal recess either directly or through agger nasi. Can affect ventilation and mucociliary clearance in osteomeatal unit. Symptoms require removal of medial wall of concha or entire concha bullosa.

Bulla ethmoidalis

- Middle ethmoidal air cells form this rounded bulge and they open on or above it. As the bulla ethmoidalis lies anterior to the ground lamella of middle turbinate, these air cells are considered part of anterior group of ethmoidal cells. It may extend superiorly to base of skull and posteriorly to ground lamella of middle turbinate. If not pneumatized bulla ethmoidalis may remain like a solid bony prominence.
  - **Lateral sinus of Grunwald**: Some time there are spaces above or behind the bulla ethmoidalis, which are called suprabullar or retrobullar recesses respectively and together form lateral sinus of Grunwald. It is bounded superiorly by the base of skull, laterally by lamina papyracea, inferiorly by the bulla, and medially opens (through hiatus semilunaris superior) in to the middle meatus bounded by the middle turbinate.

Ostiomeatal Complex

- **Hiatus semilunaris**: This 2-dimensional gap lies between the posterosuperior free border of uncinate process and front of bulla. This cleft opens laterally into a 3-dimensional funnel-shaped space called ethmoidal infundibulum and medially into the middle meatus.
- **Uncinate process:** This small thin lamina of ethmoid bone forms floor and medial wall of the ethmoidal infundibulum. This sickle shape structure runs from anterosuperior to posteroinferior direction.
  - **Two borders:**
    - **Free posterosuperior border**: It is sharp and runs parallel to anterior surface of bulla ethmoidalis.
    - **Attached anteroinferior border**: It is attached to the lateral wall of nose.

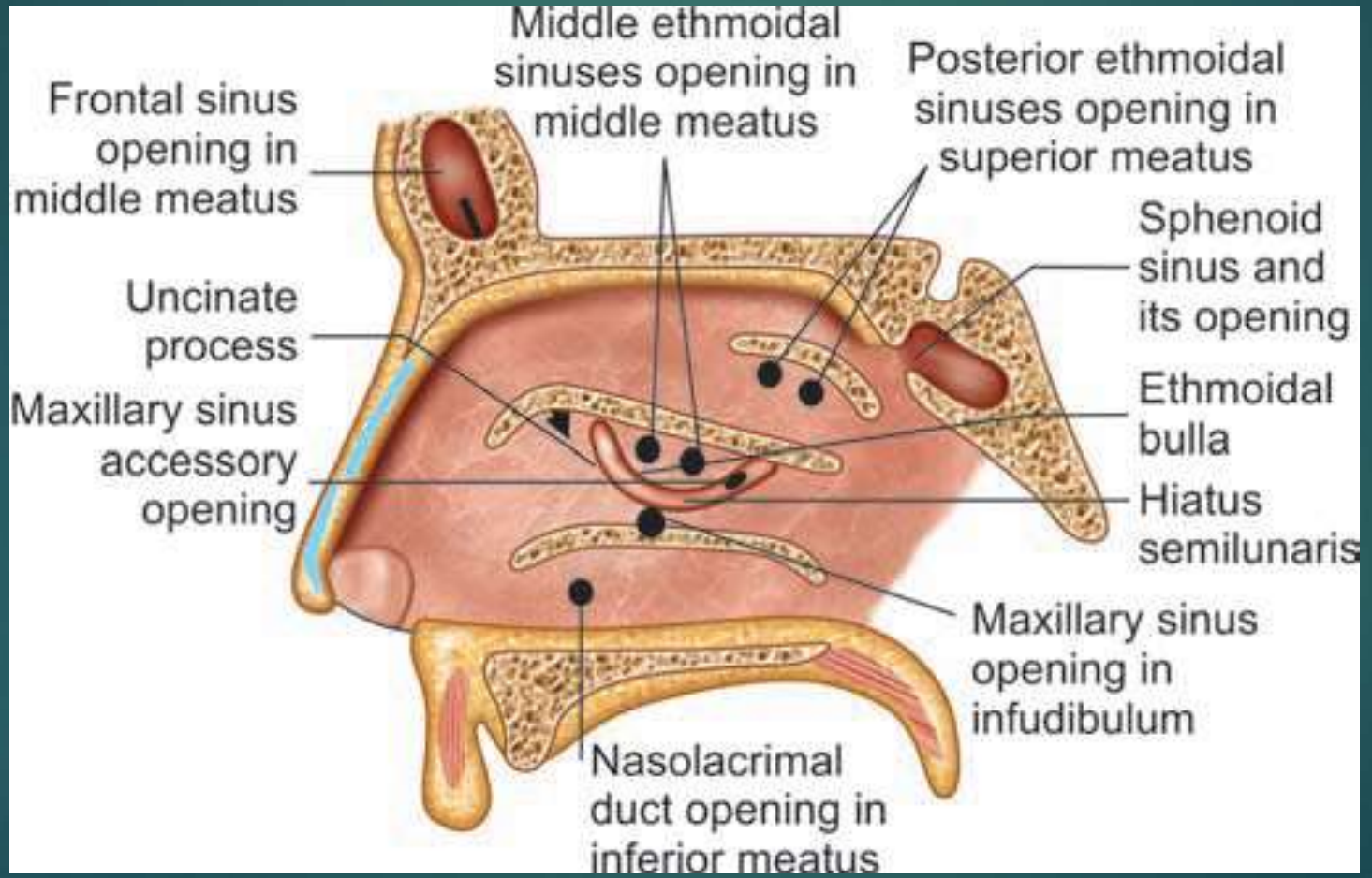
- **Two ends:**
  - **Posteroinferior end**: It is attached to inferior turbinate and divides the lower membranous part of middle meatus into anterior and posterior fontanelle, which are devoid of bone. If perforated this membranous apart opens into the maxillary sinus.
  - **Anterosuperior end**: It may be inserted laterally on the lamina papyracea, upwards into the base of skull or medially into the middle turbinate. These variable attachments account for the variations in the drainage of frontal sinus.

Osteomeatal Complex

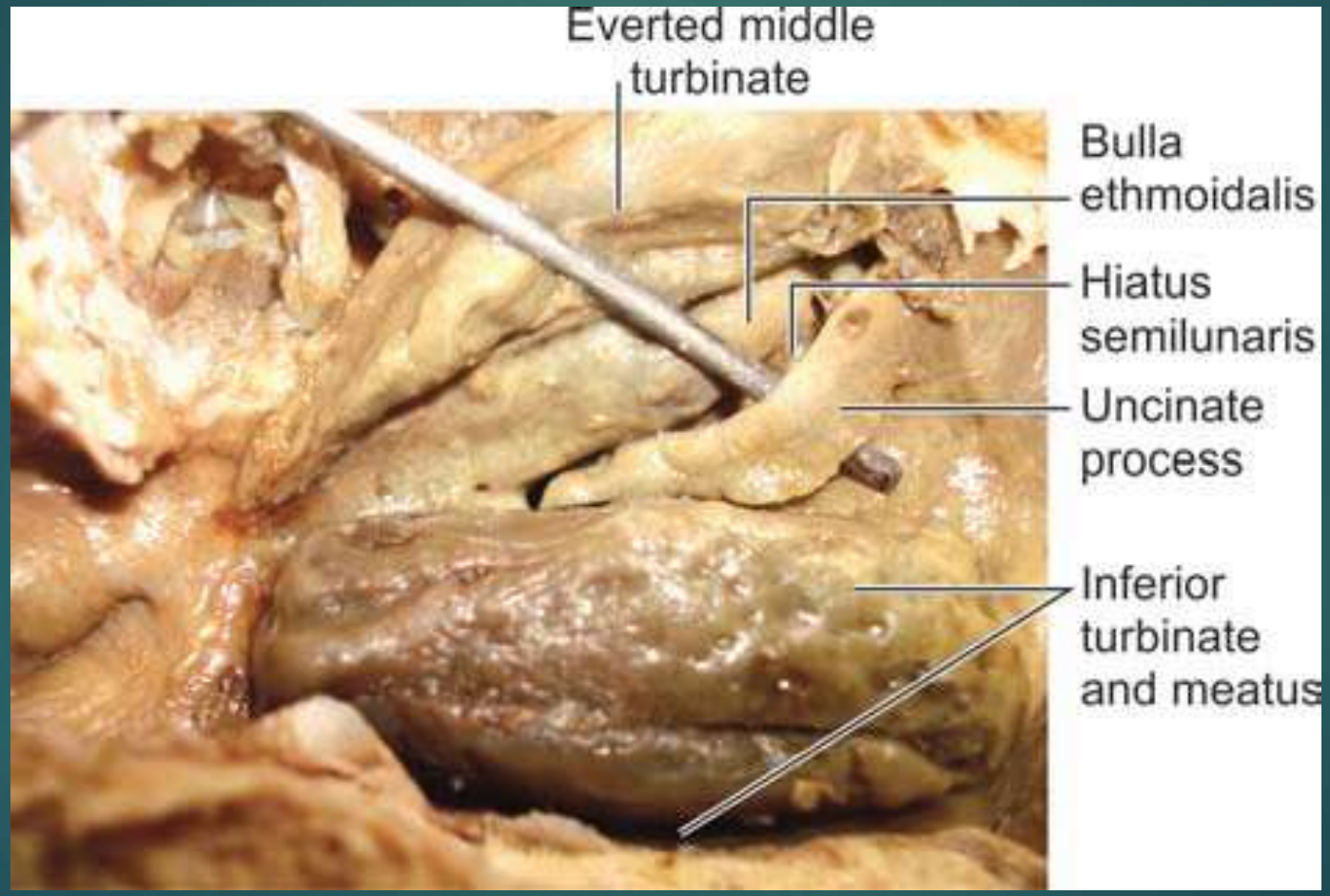
- **Ethmoidal infundibulum:** Anterior ethmoidal, frontal and maxillary sinuses open in this three-dimensional space.
  - **Boundaries:** This 3 dimensional space has following boundaries:
    - **Medial**: Uncinate process and frontal process of maxilla and some times lacrimal bone.
    - **Lateral**: Lamina papyracea.
  - **Sinus openings**:
    - **Frontal sinus**: It opens into the anterosuperior part of infundibulum just posterior to posterior wall (opening) of agger nasi cells.
    - **Anterior ethmoidal air cells**: They open into the infundibulum.
    - **Maxillary sinus**: It opens into posterior part of the infundibulum. In some patients maxillary sinus may have accessory openings,

- **Agger nasi**: It is an elevation that lies just anterior to the attachment of middle turbinate. This curved ridge runs downwards and forwards above the atrium. If pneumatized, it contains agger nasi cells, which communicate with frontal recess.
- **Large agger nasi cells:** They can constrict the frontal recess and can impair the frontal sinus drainage.

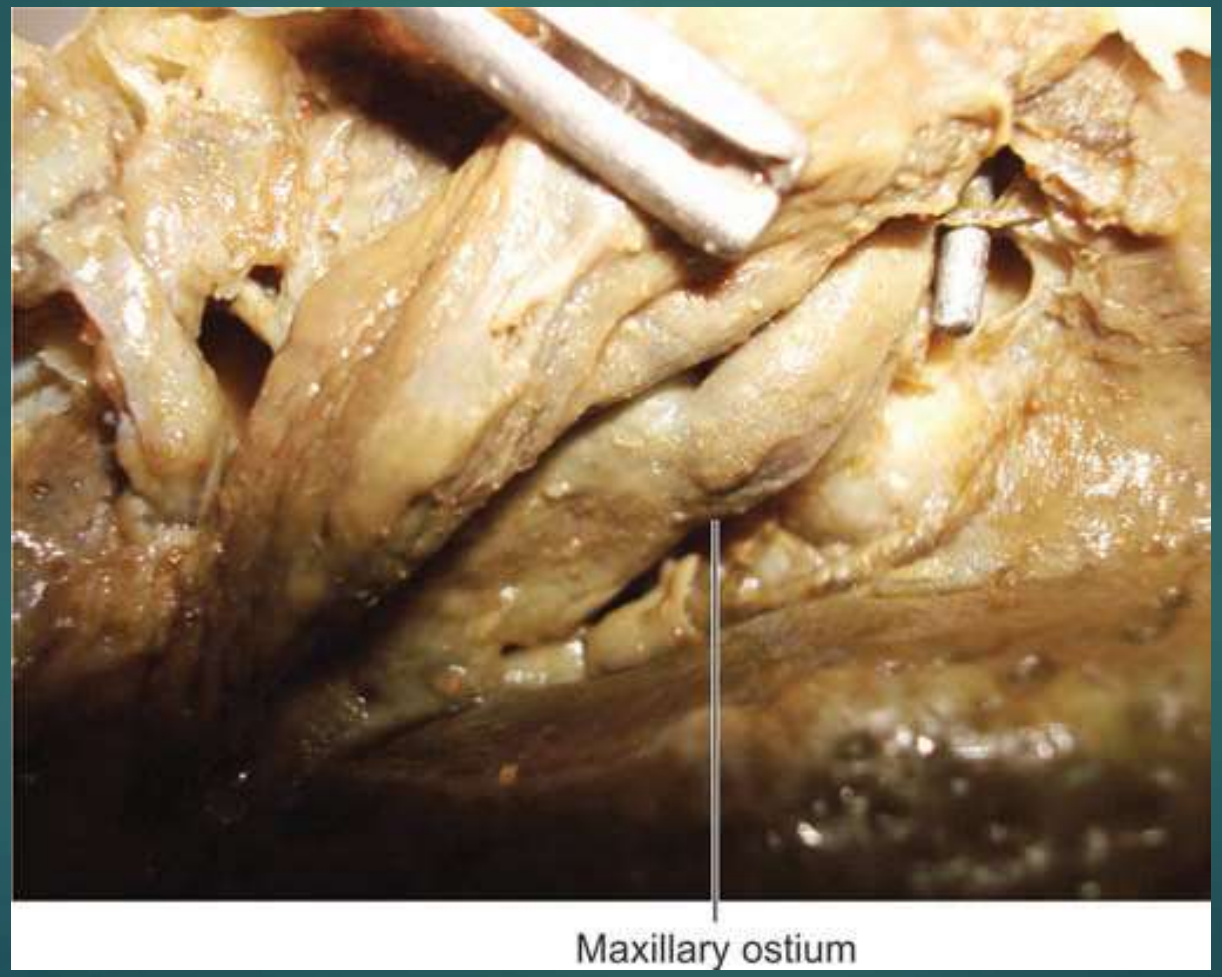
Openings of paranasal sinuses. Lateral wall of nose after removal of turbinates



Cadaveric dissection of osteomeatal complex. Middle turbinate is reflected upward. Probe lies in the ethmoidal infundibulum and is coming out through the lower attachment of uncinate



Cadaveric dissection of osteomeatal complex. Middle turbinate reflected upward. Uncinate process removed and ethmoidal infundibulum opened. Probe showing the frontal sinus opening. Note maxillary ostium



Nasal Septum

Three parts:

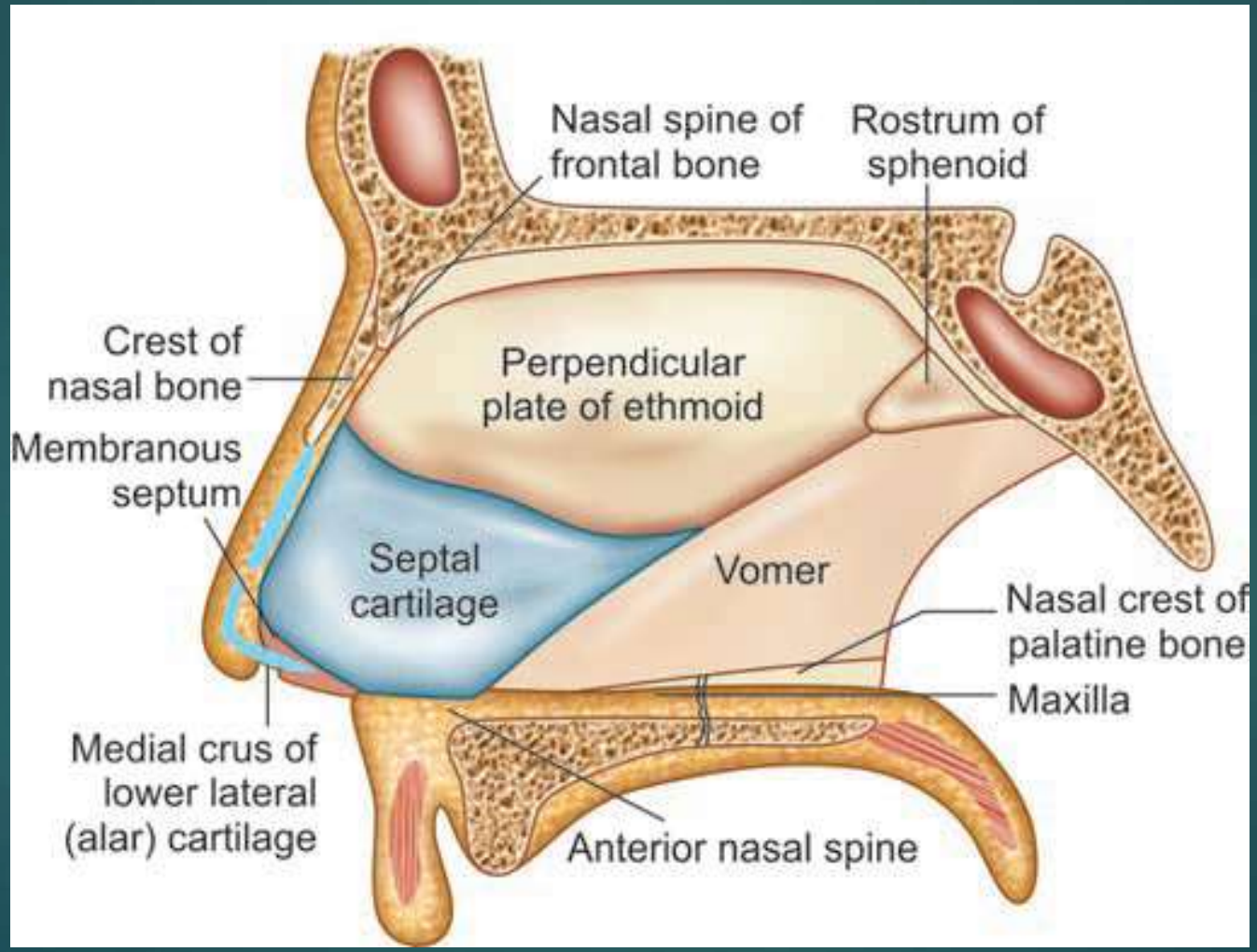
- **Columellar septum:** Covered by skin. Medial crura of lower lateral cartilages joined together with fibrous tissue.
- **Membranous septum:** Skin between columella & caudal border of septal cartilage
- **Septum proper**: Covered with mucous membrane and osteocartilaginous.
  - **Principal constituents:** Large quadrilateral septal cartilage (Major), Perpendicular plate of ethmoid & Vomer
  - **Small contributions**: Crest of nasal bones, Nasal spine of frontal bone, Rostrum of sphenoid, Crests of palatine and maxilla, Anterior nasal spine of maxilla.

Septal cartilage: Large quadrilateral septal cartilage wedged between vomer & ethmoid plate.

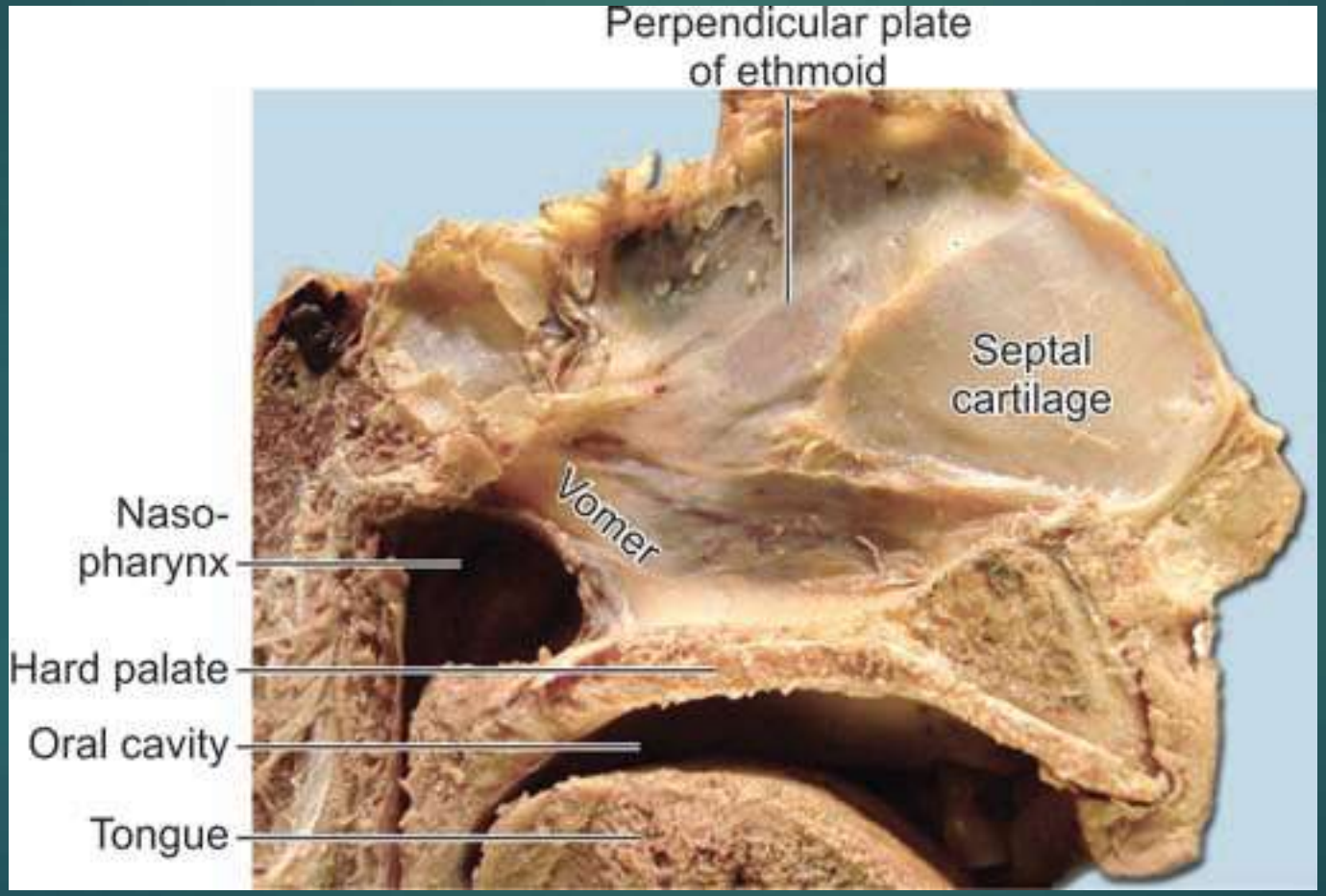
- **Inferior margin**: Lies in groove of vomer and rests anteriorly on anterior nasal spine.
  - **Caudal septal deviation: Inferior margin of septal cartilage gets dislocated from anterior nasal spine.**
  - **Septal spur: Inferior margin of septal cartilage gets dislocated from the vomerine groove.**
- **Superior margin**: Fuses with upper lateral cartilages. Septal deviation associated with deviation of cartilaginous external nose.

Septal cartilage destruction: Septal cartilage supports tip & dorsum of cartilaginous external nose. Septal cartilage destruction (septal abscess, injuries, tuberculosis or septal surgery) results in depression of lower part of dorsum of nose and drooping of the nasal tip.

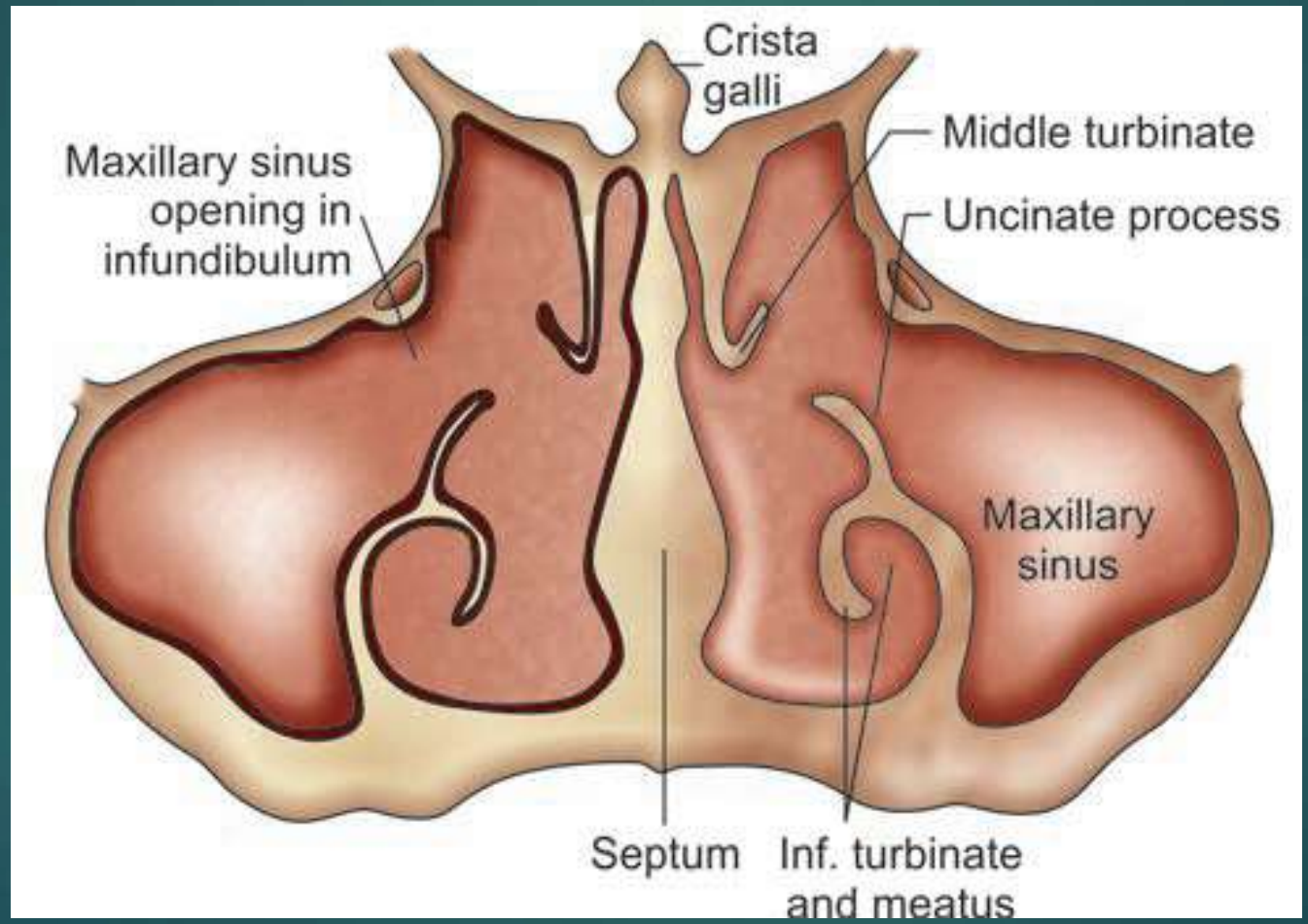
Structure of nasal septum lateral view. Bony & cartilaginous part seen after removing mucosa. Posterior triangular segment of cartilaginous septum generally overlaps bony septum



Nasal Septum of a cadaver



Osteomeatal complex. Coronal section of nose & paranasal sinuses at level of osteomeatal complex. Uncinate process is in sagittal plane bounding the infundibulum in which opens ostium of maxillary sinus



Linings of Internal Nose

- **Skin of nasal vestibule**: Vestibule is lined by skin (stratified squamous epithelium), which contains hair, hair follicles and sebaceous glands.
- **Olfactory epithelium**: The olfactory epithelium that is paler in color lines the olfactory region, which includes roof and upper 1/3 of nasal cavity (above the level of superior concha)
- **Respiratory mucosa**: The respiratory mucous membrane, which covers the lower 2/3 of the nasal cavity, shows variable thickness. It is thickest over nasal conchae especially at their ends. It is thick over the nasal septum and thin in the meatuses and floor of the nose. This respiratory mucous membrane is pseudostratified ciliated columnar epithelium and contains plenty of goblet cells. It is highly vascular and contains erectile tissue. The submucosal layer contains both racemose and tubular glands that secrete serous and mucous secretions for the surface mucous blanket. The deeper specialized vascular plexus (erectile tissue) consists of arterioles, capillaries, vascular sinusoids, venous plexuses, and venules.

Blood Supply of Nose

Internal Carotid System

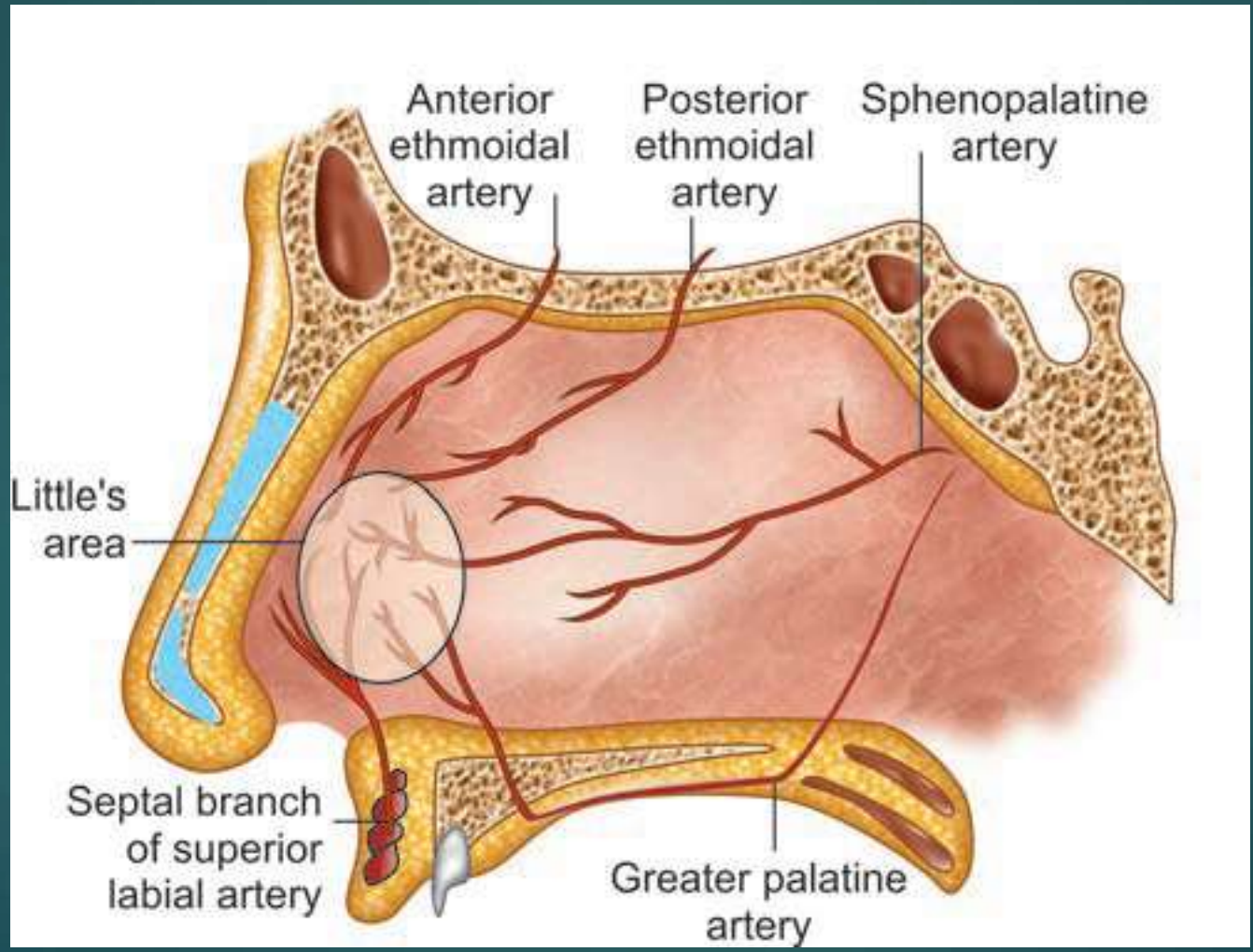
- Ophthalmic artery
- Anterior ethmoidal artery
- Posterior ethmoidal artery

External Carotid System

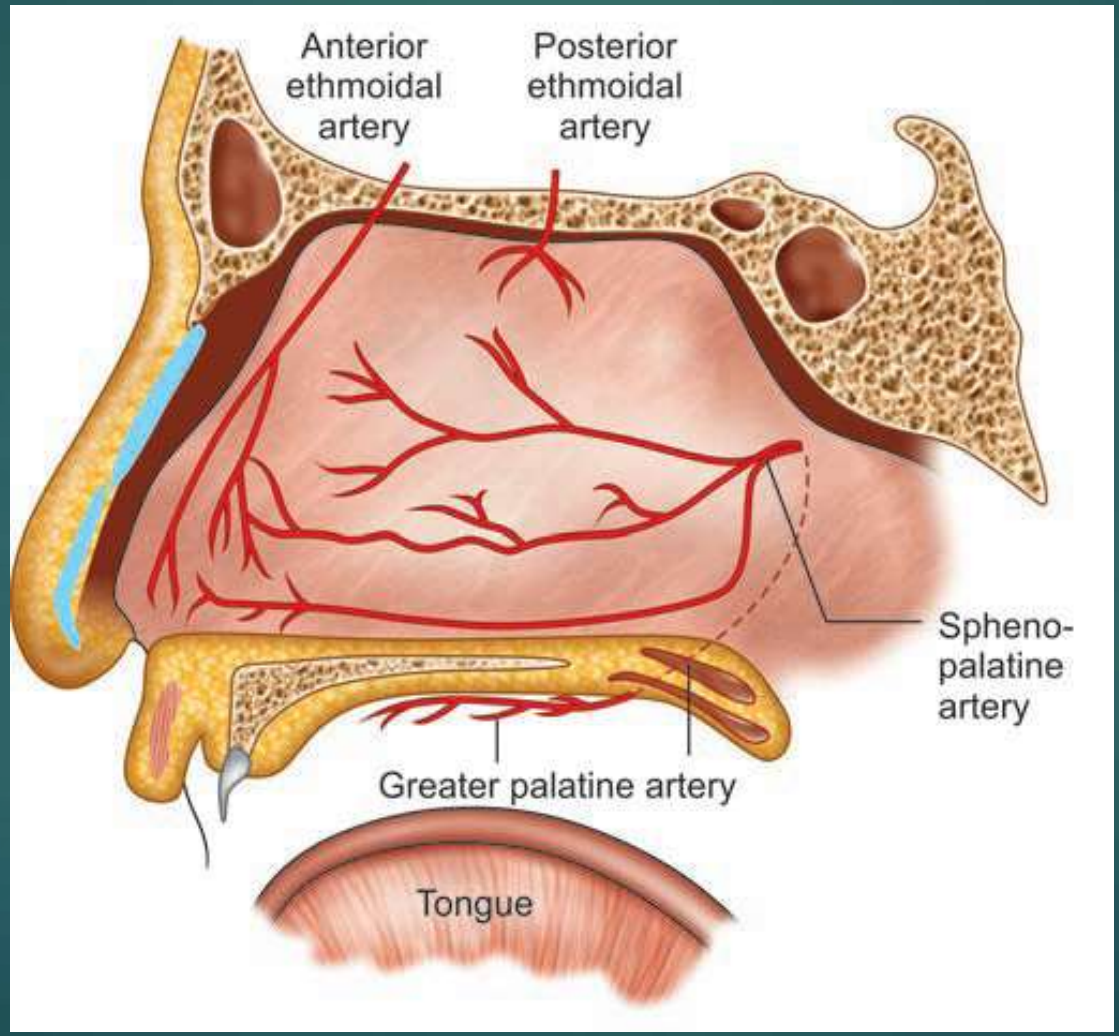
- **Maxillary artery**
  - Branches of sphenopalatine artery: Nasopalatine, posterior nasal septal branches and posterior lateral nasal branches.
  - Greater palatine artery
  - Nasal branch of anterior superior dental artery, which is a branch of infraorbital artery.
- **Facial Artery:** Superior labial artery

Little's area or Kiesselbach's plexus: This vascular area lies in the anteroinferior part of nasal septum just above the vestibule is the vascular area. Here anterior ethmoidal, sphenopalatine, greater palatine and septal branch of superior labial arteries and their corresponding veins form an anastomosis. This is the most common site for epistaxis and bleeding polyp (fibroangioma) of septum.

Blood supply of nasal septum



Blood supply of lateral wall of nose



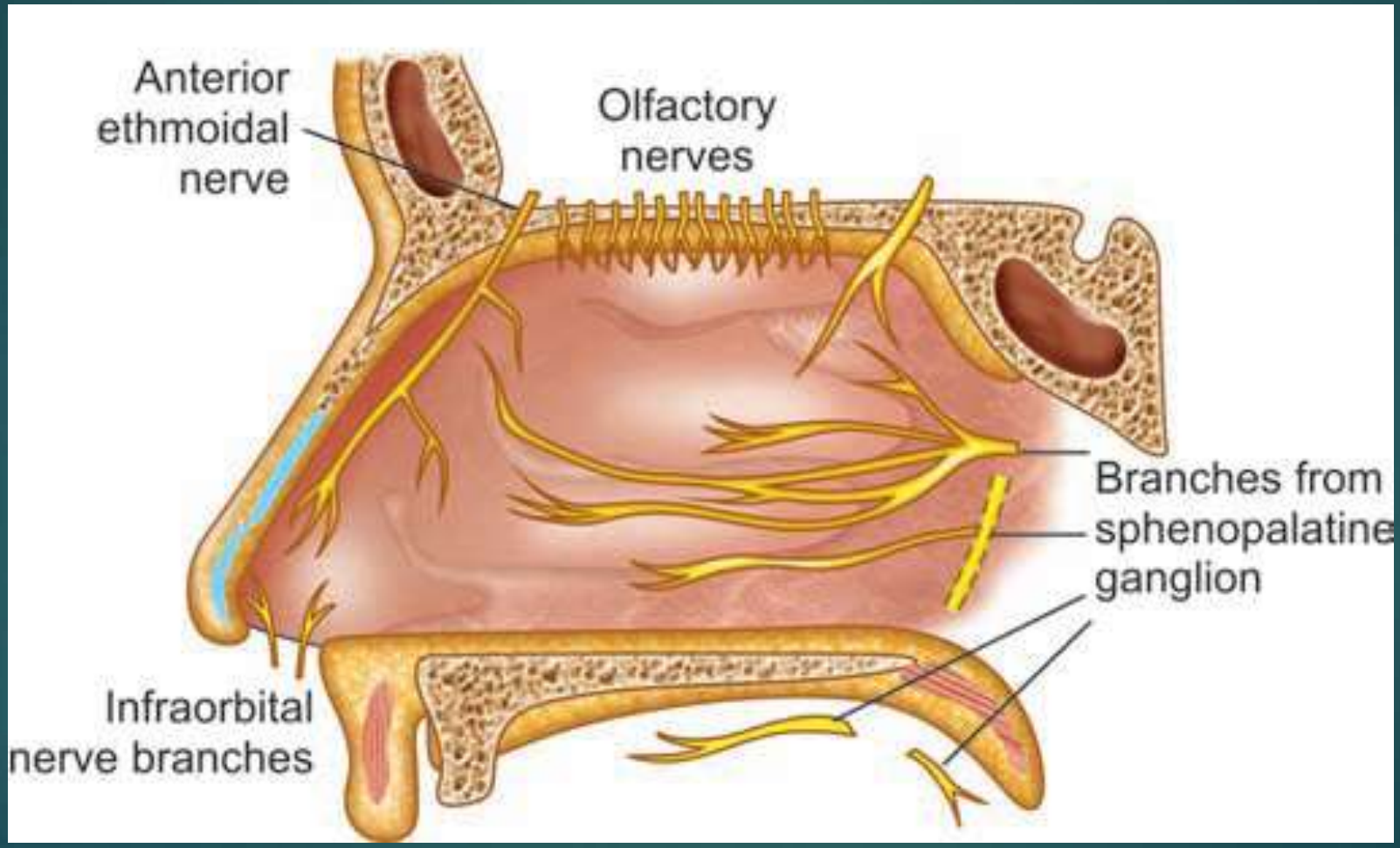
Nerve Supply of Nasal Cavity

- **Olfactory nerves:**
- **Olfactory nerves injuries**: Olfactory nerves carry meningeal sheaths of dura, arachnoid and pia mater and because of this injury to these nerves can result in CSF rhinorrhoea and meningitis.
- **Trigeminal Nerve**: Ophthalmic division (anterior ethmoidal branch) and maxillary division (sphenopalatine and infra-orbital branches)
  - **Vestibule of nose**: Branches of infraorbital nerve supply vestibule of nose.
  - **Posterior 2/3 of nasal cavity (septum and lateral wall)**: Sphenopalatine ganglion branches pass through the sphenopalatine foramen situated near the posterior end of middle turbinate.
    - **Sphenopalatine block**: Placing a pledget of cotton of 4% xylocaine posterosuperior to posterior end of middle turbinate.

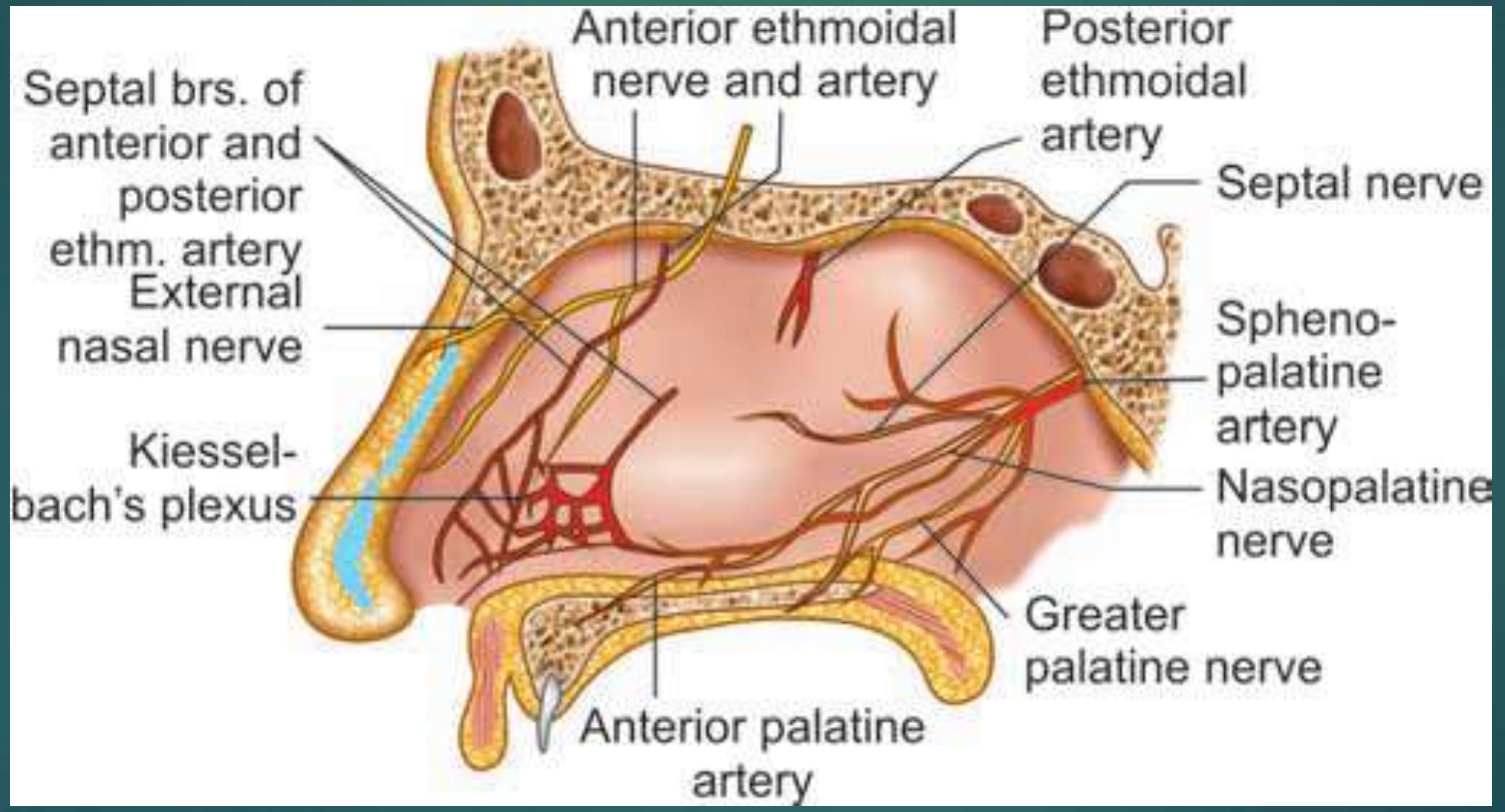
- **Anterosuperior part of the nasal cavity (lateral wall and septum)**: Anterior ethmoidal nerve.
    - **Anterior ethmoidal nerve block**: placing the cotton pledget ihigh up inside the anterior sloping part

- **Autonomic Nervous System:**
    - **Parasympathetic**:
    - **Sympathetic**:
- **Vidian neurectomy**: Excessive rhinorrhoea (vasomotor and allergic rhinitis) can be controlled by section of the vidian nerve.
- **Facial Nerve:** Muscles of the external nose.

Nerve supply of lateral wall of nose



Artery (red color) and nerve (yellow color) supply of nasal septum



Lymphatic Drainage of Nose

- **Submandibular lymph nodes**: The external nose and anterior part of nasal cavity drain into submandibular lymph nodes.
- **Retropharyngeal nodes**: Posterior part of nasal cavity drains into upper jugular nodes and retropharyngeal nodes, which drain to upper jugular nodes.
- **Perineural intracranial spread**: The perineural intracranial spread of cancer is possible through the lymphatics of the upper nasal cavity, which communicate with subarachnoid space along the olfactory nerves.

ANATOMY OF PARANASAL SINUSES

ANATOMY OF PARANASAL SINUSES

- Anterior and Posterior Group
- Maxillary Sinus (Antrum of Highmore)
- Frontal Sinus
- Ethmoidal Sinuses: Agger nasi cells, Grand (Basal) Lamella, Hellar cells, Onodi cells
- Sphenoid Sinus
- Mucous Membrane of Paranasal Sinuses
- Mucus Drainage of Sinuses
- Lymphatic Drainage
- Blood Supply
- Nerve Supply
- Development of Paranasal Sinuses

Maxillary Bone

Left maxilla; Anterolateral and medial view

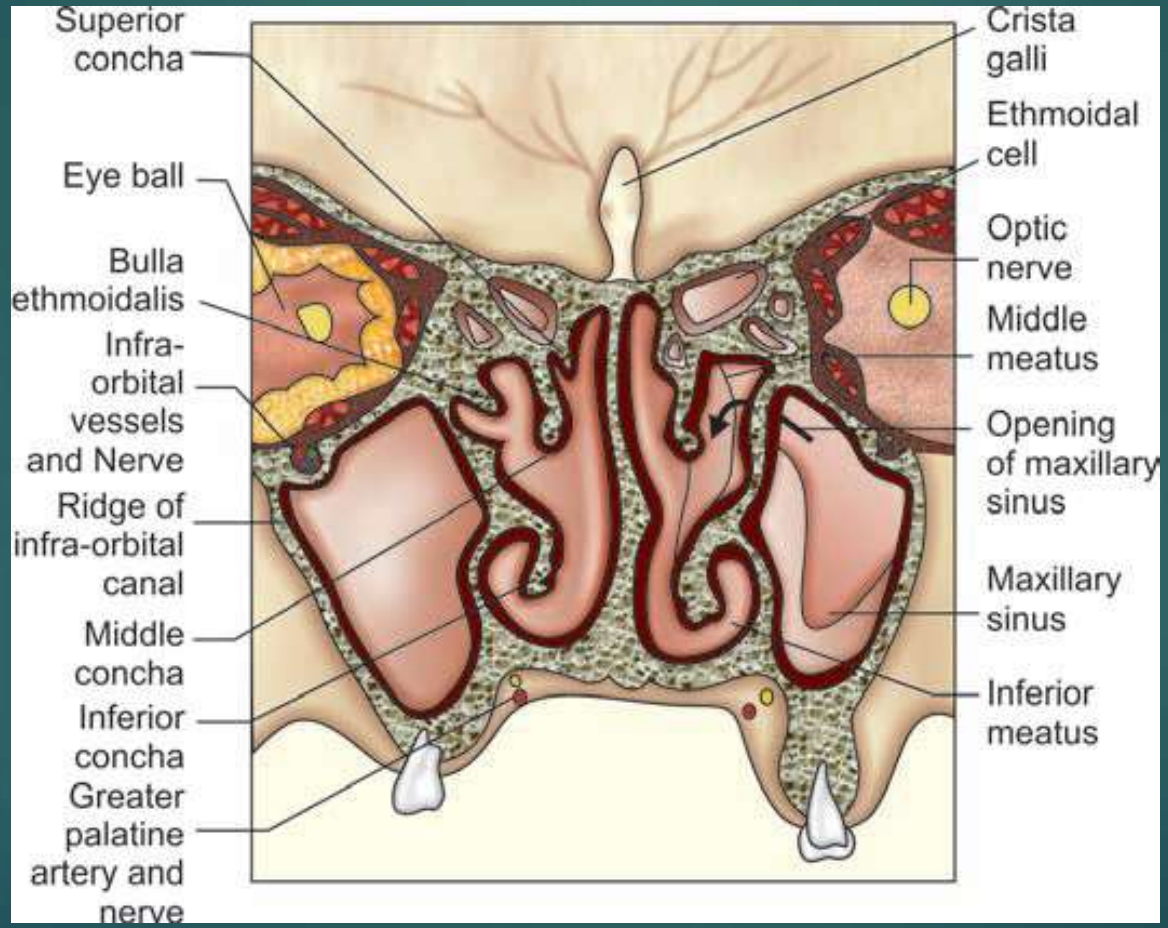
Maxillary Sinus (Antrum of Highmore)

- First to develop in human fetus. Largest paranasal sinus (15 ml capacity in adult). Pyramidal shape. Base towards lateral wall of nose and apex into zygomatic process.
- **Boundaries**
  - **Anterior wall**: Canine fossa related to cheek
  - **Posterior wall**: Infratemporal and pterygopalatine fosse.
  - **Medial wall**: Thin and membranous at places & faces middle and inferior meatuses.
  - **Floor**: Alveolar process of maxilla (roots of all the molars, second premolar separated by a thin lamina of bone, which may be dehiscent.
    - **Age variations**: Floor 1 cm below the floor of nose in adults. Until 3 years of age, floor is 4-5 mm above the nasal floor.

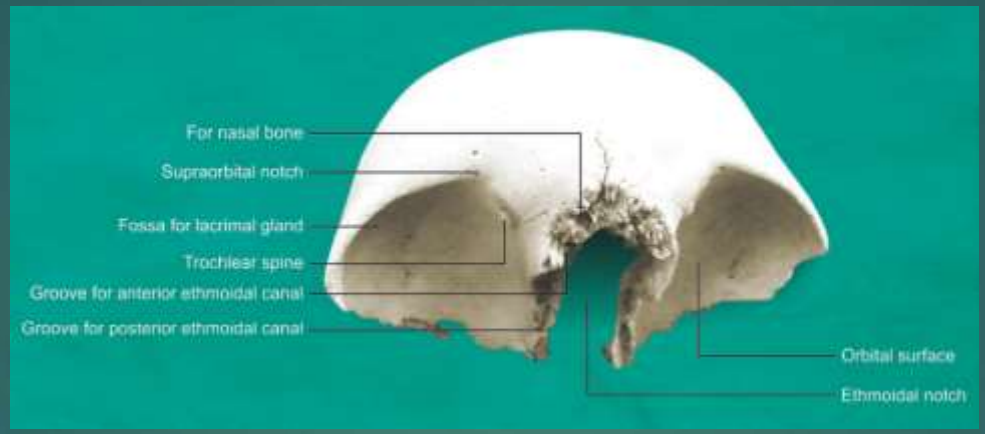
Maxillary Sinus (Antrum of Highmore)

- **Oroantral fistula**: Extraction of molar & second premolar. Infection maxillary sinusitis.
  - **Roof:** Roof is floor of orbit & traversed by infraorbital nerve and vessels.
- **Ostium of maxillary sinus**: Higher in medial wall in posterior part of ethmoidal infundibulum.
- **Accessory Ostium**: 30%. May be large. Behind / front of main ostium. Does not drain bypassed by the mucus blanket.
- **Recirculation of the mucopus**: In FESS accessory ostium is joined with main ostium to prevent recirculation of mucopus into maxillary sinus.

Coronal section of nose and paranasal sinuses seen from behind



Frontal Bone

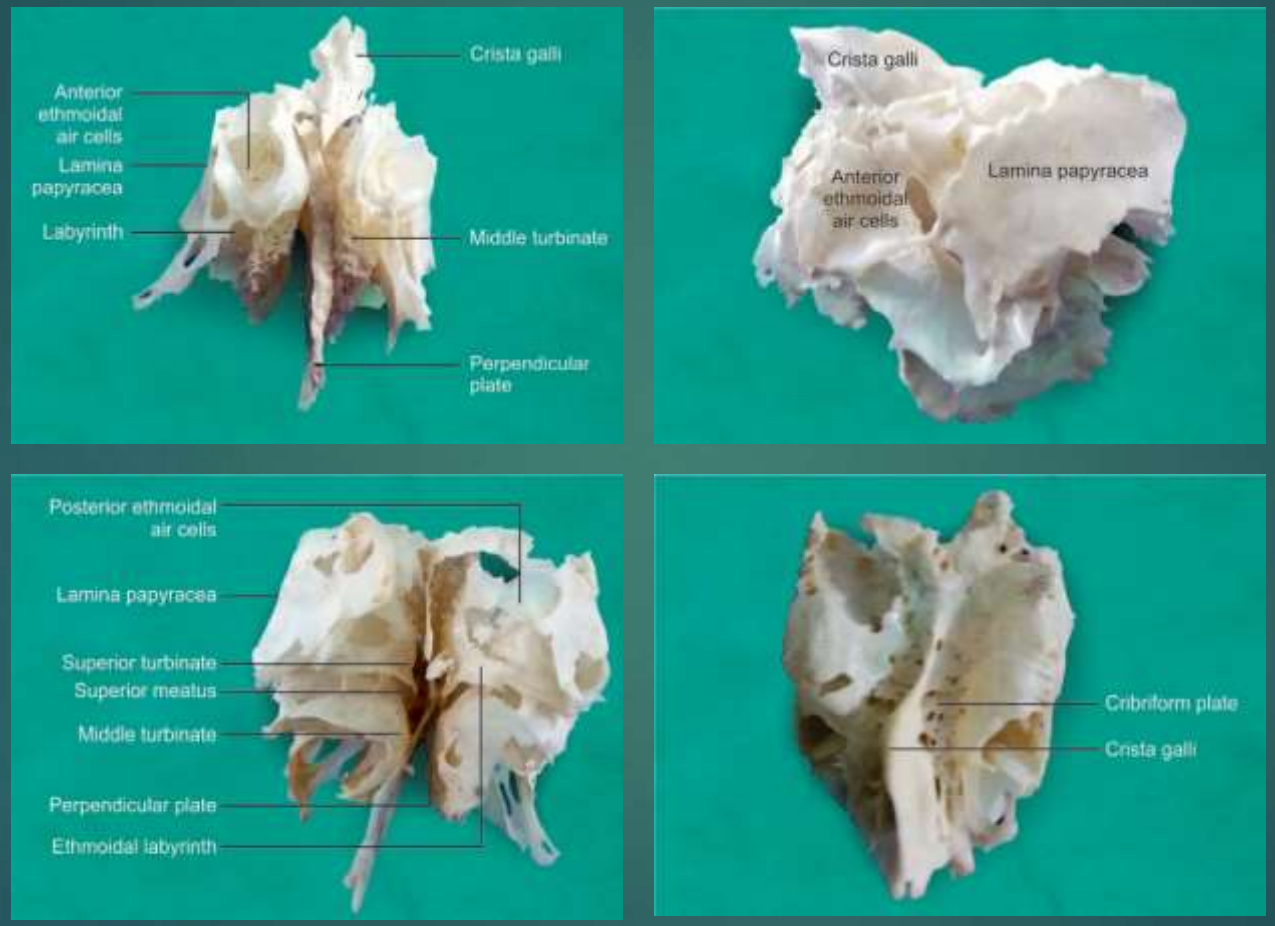


Frontal bone; Anteroinferior and Posterosuperior surface

Frontal Sinus

- Above and deep to the supraorbital margin. Loculated sinus
- Between inner and outer tables of the lower part of frontal bone.
- Shape & size: Vary (very large to absent). Bilateral asymmetric. A very large sinus may extend into the roof of the orbit.
- Intervening septum thin obliquely placed. May be deficient.
- **Relations**:
  - **Anterior wall:** Forehead skin.
  - **Floor:** Orbit.
  - **Posterior wall:** Meninges and frontal lobe of brain.
- **Ostium:** In floor and opens into the frontal recess. Depending upon the attachment of uncinate process, frontal recess opens either in the ethmoidal infundibulum or medial to the uncinate process into the middle meatus.

Ethmoidal Bone



Ethmoid bone;Anterior, Lateral view, Posterior view and Superior view

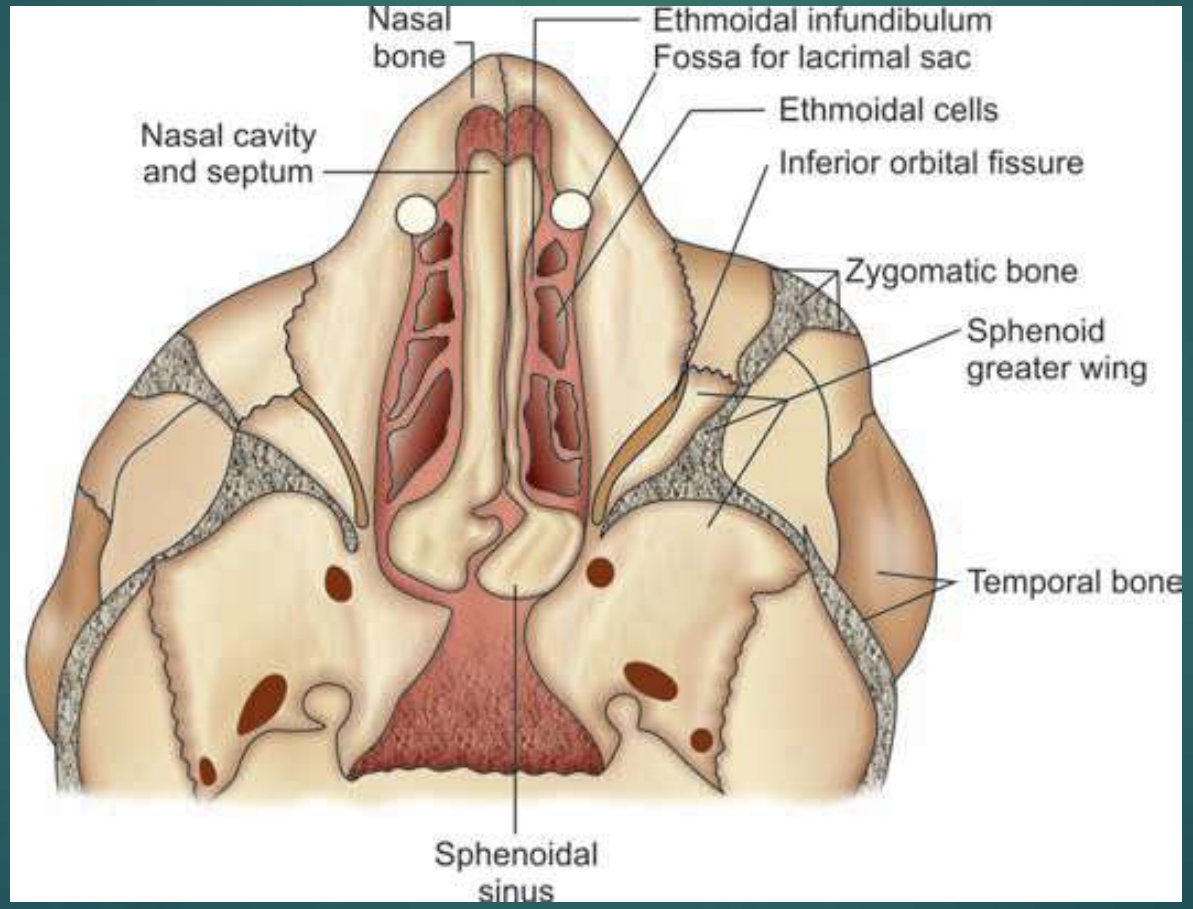
Ethmoidal Sinuses

- Thin walled air cavities in lateral masses of ethmoid bone.
- Vary in number (3 to 18)
- Between upper third of lateral nasal wall and medial wall of orbit.
- Anterior ethmoid group opens into the middle meatus.
- Posterior ethmoid group opens into the superior meatus and some in sphenoethmoidal recess.
- **Boundaries**
  - **Roof:** Frontal bone forms the floor of anterior cranial fossa.
  - **Lateral wall:** Lamina papyracea separates from the orbit.
- **Lamina papyracea**: Paper thin bone & can be easily damaged during intranasal surgery and destroyed by ethmoidal infections.
- **Optic nerve**: It is in close relationship with posterior group of ethmoidal air cells & at risk during surgery.

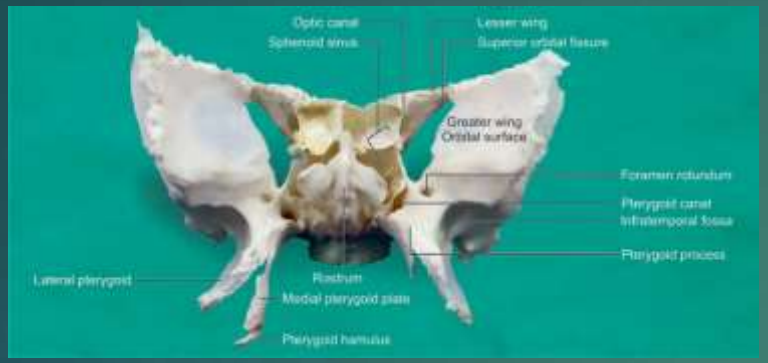
Ethmoidal Sinuses

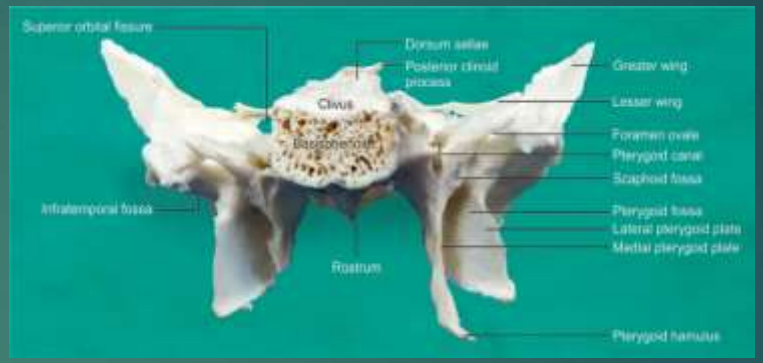
- **Agger nasi cells**: Most anterior of anterior ethmoid cells and lie in close proximity of frontal recess. Situated at the agger ridge just anterior to anterosuperior attachment of middle turbinate.
- **Big agar nasi cells**: Obstruct drainage of frontal sinus. Their removal provides better view of nasofrontal duct during endoscopic sinus surgery.
- **Grand (Basal) Lamella**: This bony insertion of middle turbinate into the skull base and lateral nasal wall separates anterior from posterior ethmoid cells. Grand lamella can be divided into 3 parts. Anterior 1/3 inserts into lamina cribrosa, middle 1/3 (oblique anterosuperior to posteroinferior course) into lamina papyracea and posterior1/3 horizontal part inserts into lateral nasal wall.
- **Hallar cells**: 10%. Roof of maxillary sinus near ostium. Asymptomatic. May affect maxillary sinus ventilation and drainage resulting in recurrent or chronic maxillary sinusitis.
- **Onodi cells**: Posterior ethmoid cells. Extend either laterally or superiorly along the sphenoid sinus. **The optic nerve can lie within them**.
- **Onodi cells must be recognized during the endoscopic sinus surgery on posterior ethmoid to avoid optic nerve injury.**

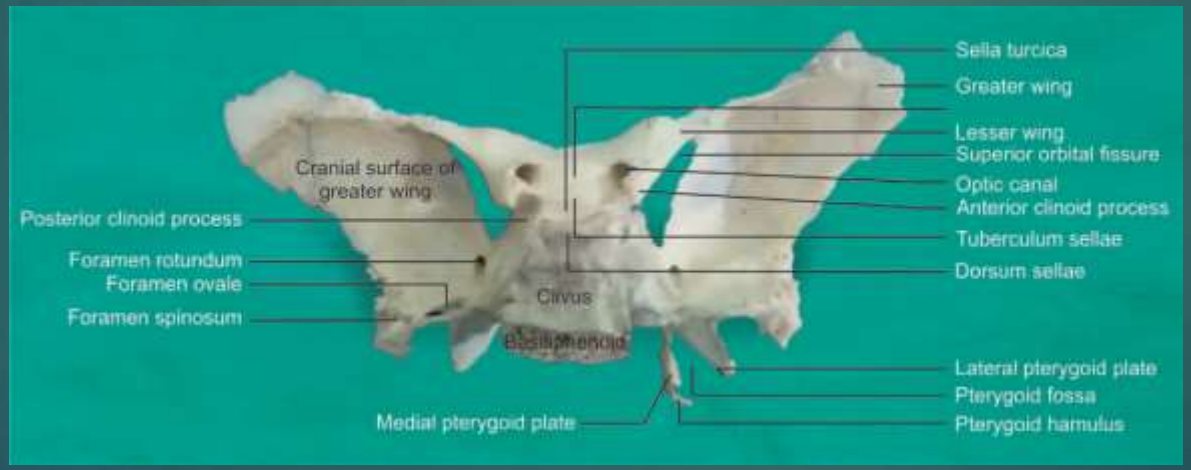
Axial section of nose and paranasal sinuses in the upper part showing ethmoidal and sphenoidal sinuses



Sphenoid Bone





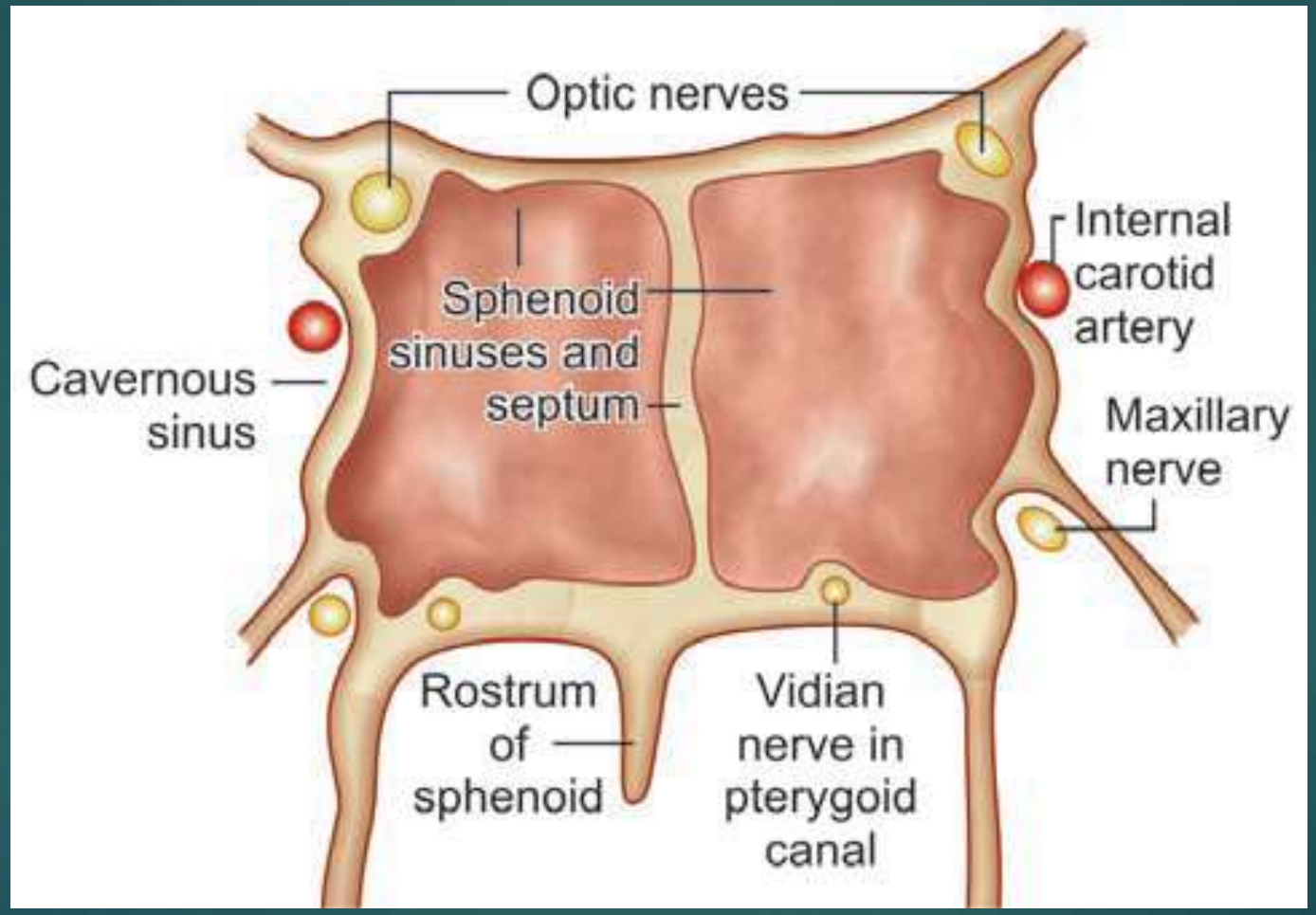


Sphenoid bone; Anterior, Posterior and Superior view

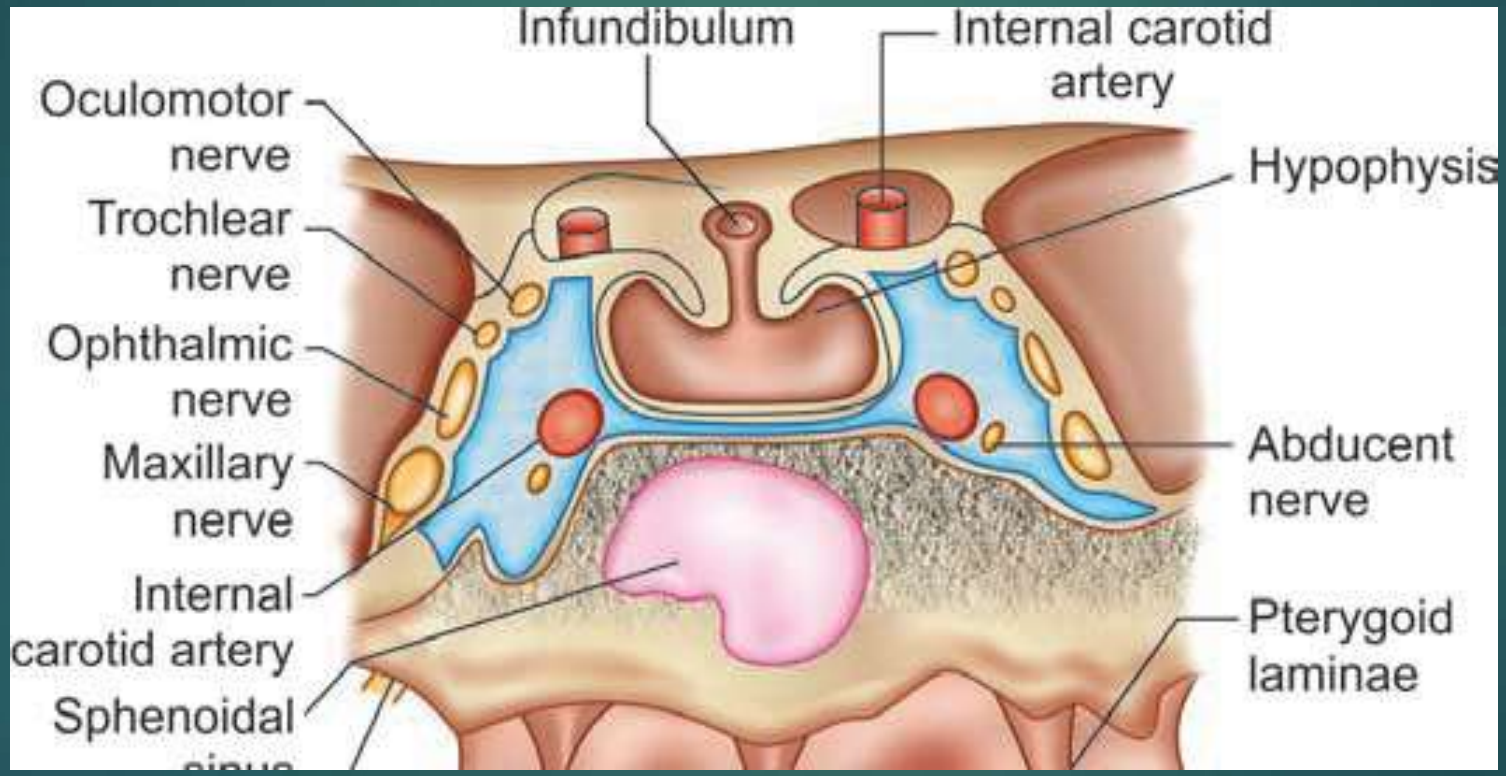
Sphenoid Sinus

- Two. One on each side. Rarely symmetrical. In body of sphenoid.
- Separated by a oblique thin bony septum. May be deficient.
- Ostium: Upper part of anterior wall, drains into sphenoethmoidal recess.
- Pneumatization: Varies. Wings of sphenoid, pterygoid plates & clivus
- **Anterior wall**: 7 cm away from nasal sill at 30^0angle.
- **Relations**:
  - **Anterior part**: **Superiorly** olfactory tract, optic chiasma and frontal lobe. **Laterally** optic nerve, internal carotid artery and maxillary nerve. Structures may be dehiscent.
  - **Posterior part**: **Roof** of sinus is floor of sella turcica (pituitary gland fossa). **Lateral wall** is related to cavernous sinus, which contains internal carotid artery and CN III, CN IV, CN VI and ophthalmic and maxillary divisions CN V (trigeminal).

Sphenoidal sinuses coronal section showing important structures situated in relation with sphenoid sinus walls



Relations of sphenoid sinus with cavernous sinus and pituitary fossa and gland



Mucous Membrane of Paranasal Sinuses

- Thinner and less vascular and continuous with that of the nasal cavity through the sinuses' openings.
- Ciliated pseudostratified columnar epithelium with numerous mucoserous glands and goblet cells (secrete mucus).
- **Cilia**: Help in drainage of mucus & more near ostia.
- **Nasal glands**: Produce **mucus blanket** (2 layers):
  - Inner thin serous layer or sol phase and
  - Outer viscous mucus layer or gel phase.

Mucus Drainage of Sinuses

- **Cilia**: Propel mucus in a spiral manner through ostium into meatus.
- **Anterior groups of sinuses**: Mucus passes along the lateral pharyngeal gutter. Infection causes hypertrophy of lateral pharyngeal lymphoid.
- **Posterior group of sinuses**: Mucus spreads over posterior pharyngeal wall.
- **Maxillary sinus**: Secretion transport stellate pattern. Begins from roof, floor & along all the four walls and converges at the ostium.
- **Frontal sinus**: Secretions flow in both directions along medial aspect of ostium. Flow out of sinus along floor and inferior parts of anterior and posterior walls. From the medial aspect of ostium, secretions flow superiorly and then laterally along the roof of frontal sinus.
- **Diagnostic imaging**: Plain CT scan first line of screening study.
- **PNS X-rays:** Do not offer adequate views of osteomeatal complex, sphenoid and ethmoid sinuses due to the overlapping of structures.

PNS

- **Lymphatic Drainage:** Upper deep cervical group of lymph nodes either directly or through lateral retropharyngeal lymph nodes.
- **Blood Supply:** Branches of external carotid artery (facial artery and sphenopalatine branch of maxillary artery) and internal carotid artery (anterior and posterior ethmoidal branches of ophthalmic artery).
  - **Sphenopalatine artery**: Enters nasal cavity through sphenopalatine foramen (posterior to middle turbinate) & divides into two main branches. **Septal branch** passes across inferior aspect of anterior surface of sphenoid sinus and can be damaged during ESS sphenoidectomy.

Nerve Supply: Paranasal sinuses

Mainly branches of trigeminal nerve

- **Ophthalmic nerve (CN V1)**: Supraorbital, supratrochlear and anterior and posterior ethmoidal nerves
- **Maxillary nerve (CN V2)**: Greater palatine, posterolateral nasal and superior nasal branches of the infraorbital nerve supply maxillary sinus.
- **Facial nerve:** Greater petrosal nerve (parasympathetic secretomotor) join deep petrosal nerve (sympathetic) & form Vidian nerve.
  - Secretomotor fibers relay in sphenopalatine ganglion. Postganglionic fibers carried by sphenopalatine nerve (branch of maxillary division of trigeminal nerve).

Blood and Nerve Supplies of Paranasal Sinuses

Sinuses	Arteries	Nerves
Frontal	Supraorbital, supratrochlear	Supraorbital, supratrochlear
Maxillary	Maxillary (main) and facial	Maxillary
Anterior ethmoidal	Anterior ethmoidal	Anterior ethmoidal
Posterior ethmoidal	Posterior ethmoid and sphenopalatine	Posterior ethmoid and sphenopalatine
Sphenoidal	Posterior ethmoid and sphenopalatine	Posterior ethmoid and sphenopalatine

Development and Growth of Paranasal Sinuses

Sinus	At Birth	Adult size	Growth	Radiological Appearance
Maxillary	Present	15 years	Biphasic growth: Birth-3 years, 7-12 year	4-5 months
Ethmoid	Present	12 years	Size increases up to 12 years	1 year
Frontal	Absent	13-18 year	Invades frontal bone (2-4 yrs), size increases until teens	6 years
Sphenoid	Absent	12-15 year	Reaches sella turcica (7yrs), dorsum sellae (late teens), basisphenoid (adult)	4 years

Pediatric sinusitis: At birth, both frontal as well as sphenoid sinuses are absent and therefore they are not clinically significant in young children.

PHYSIOLOGY OF NOSE

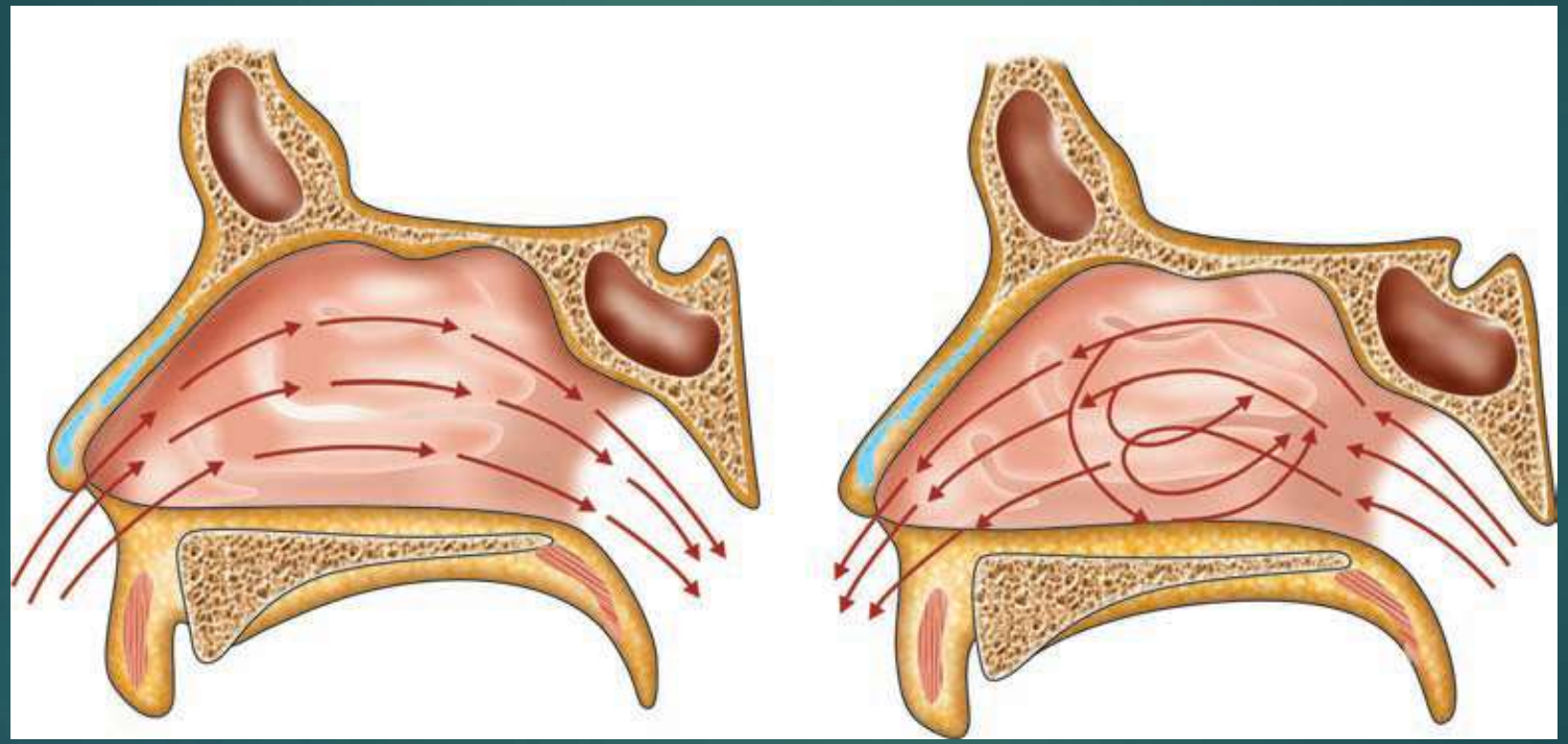
PHYSIOLOGY OF NOSE

- RESPIRATION: Nasal cycle
- AIR-CONDITIONING OF INSPIRED AIR
  - Filtration and purification
  - Temperature Control
  - Humidification
- PROTECTION OF AIRWAY
  - Mucociliary Mechanism
  - Factors Affecting Ciliary Beating
  - Kartagener’s syndrome
- VOCAL RESONANCE
- NASAL REFLEXES
- OLFACTION
  - Olfactory Pathways
  - Vomeronasal Organ (VNO) of Jacobson

RESPIRATION

- Humans are natural nose breathers. Mouth breathing is learned later on in life. The nose allows breathing during eating.
- **Bilateral choanal atresia**: Newborn can asphyxiate to death.
- **Air currents in nasal cavity**: During quite respiration pass between the turbinates and nasal septum. Little air passes through inferior meatus) and above superior turbinate. Anterior end of inferior turbinate increases and decreases in size & regulates inflow of air.
  - **Sniffing**: It helps weak odorous substances reaching olfactory area.
  - **Eddies**: During expiration, friction offered at nasal valve converts air currents into eddies under cover of inferior and middle turbinates and ventilates the sinuses through their openings in the nose.
- **Nasal cycle:** Normally one nasal airway opens up while the opposite airway closes down. This alternate opening and closing of each side of nose varies every few hours and is characteristic of an individual. 80% of normal subjects. Rhythmic cyclical congestion & decongestion of nasal mucosa control the nasal airflow. People are not conscious about this cycle as the total resistance of nasal airflow remains constant.

Nasal airflow. Inspiratory air flow. 50% of total airflow passes through middle part of nose. 35% air passes through inferior meatus & only 15% through olfactory region; Expiration. Limen nasi converts expiratory air current into eddies under cover of inferior & middle turbinates & ventilates sinuses



AIR-CONDITIONING OF INSPIRED AIR

- **Filtration and purification:** Nasal vibrissae filter coarse particles (up to 3 μm). Finer particles of 0.5-0.3 μm (such as dust, pollen and bacteria) adhere to the nasal mucus blanket (electrostatic attraction). But particles < 0.5 μm pass through nose into lower airways.
- **Temperature Control**: Turbinates double the surface area. Nasal mucosa (highly vascular with cavernous venous spaces or sinusoids) regulate temperature of the inspired air. Middle and inferior turbinates and adjacent part of the septum controls the blood flow that regulates the size of turbinates. “Radiator” mechanism warms up the inspired cold air (which may be < 0^0C) to near body temperature (37^0C). Hot air is cooled to the body temperature.

- **Humidification:** Serous glands regulate humidity (75% to 100%) in dry in winter. 1 liter of water evaporated from nose 24 hours. During expiration, nose removes water (for hydration) & heat (preventing hypothermia) from expired air.
  - **Moisture**: Facilitates ciliary epithelium. Dry air can stop ciliary function in 8-10 minutes, which predisposes respiratory tract to infections and affects gas exchange.
  - **Nasal obstruction**: It affects gaseous exchange in the lungs, which result in pO_2 fall and pCO_2 rise that causes apnea spells during sleep.

PROTECTION OF AIRWAY

- **Enzymes and immunoglobulins:** Muramidase (lysozyme) kills bacteria and viruses. Immunoglobulins (IgA and IgE) and interferon immunity against URTI
- **Sneezing**: Foreign particles expelled. Secretions wash noxious substance out.
- **Mucociliary Mechanism:** Mucous and serous glands. Mucus blanket has 2 layers 1) superficial mucus layer and 2) deep serous layer. Mucus blanket floats (5-10 mm/minute) on the cilia. Cilia beat constantly (10-20 times per second). Mucus into the pharynx in 10 to 20 minutes. Viscous mucus entraps bacteria, viruses and dust particles.
- **Ciliary Biphasic Beats**: 2 strokes: 1) **Rapid effective stroke** move mucus in one direction. 2) **Slow recovery stroke**: Cilia bend & travel slowly in reverse direction.

- **Factors Affecting Ciliary Beating:** Ideal pH 7. Alteration due to infections and certain nasal drops. Environmental pollution, Humidity, Drying, Drugs: such as adrenaline, Excessive heat and cold, Hypertonic and hypotonic solutions, Smoking (nicotine), Infections: viral and bacterial, Parasympathetic system, Airborne external irritants: SO_2 and CO_2.
- **Kartagener's syndrome (**Immotile cilia syndrome) Lead to stagnation of mucus. Absence of dynein arm on the peripheral ciliary microtubules.
  - **Triad of Chronic rhinosinusitis (mucus accumulation in nose), Bronchiectasis and Situs inversus**

VOCAL RESONANCE AND NASAL REFLEXES

VOCAL RESONANCE :

- Resonating chamber for phonating nasal consonants (M/N/NG), sound passes via nasopharynx and nose.
  - **Rhinolalia clausa**: Denasal speech. M/N/Ng pronounced as B/D/G.
  - **Rhinolalia aperta**: Reverse happens in Velopharyngeal insufficiency

NASAL REFLEXES:

- **Sneezing**: Finger pressure under columella may abort sneezing.
- **Cardiopulmonary responses**: Strong nasal stimuli result in breathing cessation and bradycardia. Important in sleep apnea syndrome.
- **Appetite**: Good smell of food > reflex secretion of saliva & gastric juice.
- **Nasobronchial and nasopulmonary reflexes**: Affect pulmonary functions.
- **Pulmonary resistance**: Nasal obstruction increases pulmonary

OLFACTION

- **Olfactory Pathways: Part of** Limbic system.
- **Olfactory receptor cells**: Olfactory epithelium in olfactory region receive odorous substances. **Primary olfactory receptor cells** are able to regenerate entirely.
- **Olfactory nerves**: Central processes of the olfactory cells make olfactory nerves.
- **Olfactory bulb**: Olfactory nerves end in the mitral cells of the olfactory bulb.
- **Olfactory tract**: Axons of mitral cells traverse in olfactory tract.
- **Higher centers in limbic lobe of cerebrum**: Olfactory tract carry smell to the prepiriform cortex and the amygdaloid nucleus.
  - **Anterior olfactory nucleus**: Sends impulses to opposite bulb and to ipsilateral limbic lobe through the anterior commissure.

  - **Primary olfactory cortex**: Olfactory tubercle, prepiriform and preamygdaloid areas. Projections to thalamus (for integration with taste fibers) and hypothalamus.

- **Vomeronasal Organ (VNO) of Jacobson:** Accessory olfactory tissue situated 1 cm behind the caudal end of septum and 3 mm above the nasal floor. Pale yellowish. Pit on the anteroinferior part of nasal septum. Function uncertain.
- **Ammonia: Vapors of ammonia cause irritation and stimulate fibers of the trigeminal nerve (not olfactory).**
- **Nose block: The olfaction is affected in patients of nose block and food tastes bland and unpalatable.**

PHYSIOLOGY OF PARANASAL SINUSES

FUNCTIONS AND VENTILATION OF SINUSES

FUNCTIONS: Not well proved, include:

- Air conditioning of the inspired air (humidification and warming)
- Keep the nasal chambers moist
- Resonance to voice.
- Protect the delicate structures in orbit (eye) & cranium (brain).
- Lighten the skull bones.
- Rapid growth of face
- Absorption of shock to the face and skull
- Increasing the area of olfactory membrane
- Regulation of intranasal pressure

VENTILATION OF SINUSES: Paradoxical and reverse to lungs. Get emptied during inspiration and filled during expiration. Expiration causes positive pressure in the nose and sets up eddies that ventilate the sinuses.

MUCOCILIARY CLEARANCE OF SINUSES

Maxillary sinus: Mucus from all the walls of maxillary sinus is transported through its natural ostium into ethmoidal infundibulum and then to middle meatus. Mucus does not go either to the accessory ostia present in the fontanelle or inferior meatal antrostomy made in Caldwell Luc operation.

Frontal sinus: Through its natural ostium mucus is transported into either direction means entry as well as exit. In the frontal sinus the direction of mucus flow is from medial to lateral.

From the lateral wall of ostium, mucus exits and from the medial wall, mucus enters into the frontal sinus.

Sphenoid sinus: Mucus is transported into the sphenoethmoidal recess through its natural ostium.

„Ethmoid sinuses:

Anterior group: Mucus from anterior group of paranasal sinuses travels towards nasopharynx and passes in front of the torus tubarius and then behind the posterior tonsillar pillar in the lateral wall of oropharynx.

Posterior group: Mucus from the posterior group of Paranasal sinuses is transported into the nasopharynx through the sphenoethmoidal recess and passes above and behind the torus tubarius and then spreads over the

posterior pharyngeal wall

THANK YOU