

Nostril, nasal cavity & post choanae:

Nose develops from precursor **neural crest cells**

3RD week: appear The nasal **placodes** (thickening of the **ectoderm** of the frontonasal prominence) – **failure of development leads to partial or complete absence of the nose**

Nasal cavity is recognizable in the 5.6mm crown-rump length embryo (4th intrauterine week)

5th week: placodes invaginate into **pits** that extend posteriorly to form the nasal cavity (**sac**)

Nasal pits (olfactory pits) divide each placode into medial and lateral nasal processes

Rounded lateral angles of the medial processes form the globular processes of His; the globular processes extend backwards as nasal laminae, which fuse in the midline to form the septum.

Medial processes fuse in the midline to form the philtrum and premaxilla.

Lateral processes form the alae of the nose.

The maxillary processes also form the lateral nasal wall.

Maxillary process of 1st branchial arch grows anteriomedially to fuse with the medial nasal folds and frontonasal process to form the primitive nasal cavity

The **nasal cavity is separated from the oral cavity by naso-buccal membrane** .

The nasobuccal membrane forms the floor of the nose

6th week: nasobuccal membrane ruptures to form the posterior choanae . (these are **more anterior than the definitive choanae** due to continuous posterior growth of plate) – **failure of rupture leads to choanal atresia (unilateral more common than bilateral)** Bilateral choanal atresia surgery ASAP, unilateral can be repaired at 2-3 years, Dx by inability to pass a nasal catheter through choana and CT scan, Tx Place stent for 6 weeks, M:F=1:2, most common is bony, unilateral 60%.

Note the primitive choana is located posterior to the primary palate then after the

development of secondary palate is located at the junction between the nose & the pharynx

The nostrils are occluded with an epithelial plug until about 24 weeks of gestation, when the plug resorbs

Lateral nasal folds form nasal bone, upper lateral cartilages and lateral crus.

Arrhinia is complete absence of the nose due to failure of olfactory placode to develop.

The nasal septum:

Formed from The medial component of the frontonasal process (down growth from internal parts of the merged medial nasal prominences), extends posteriorly to the opening of Rathke's pouch

Fusion between the palatal process and the septum is anterior to posterior – failure of fusion between maxillary and premaxillary (medial nasal process) leads to cleft lip –repair at 10 weeks, 10 pound, 10% Hb; failure of fusion between maxillary and lateral processes leads to facial cleft with and open nasolacrimal furrow; failure of fusion between palatine processes and nasal septum leads to cleft palate- most common cause of velopharyngeal incompetence, repaired at 1 year. More clefts occur on the left side than right. Most common type of cleft lip is combined with cleft palate.

Velopharyngeal incompetence causes: cleft palate, adenoidectomy, down synd., stroke, muscular dystrophy.

CHARGE (Coloboma, Heart abnormalities, Choanal atresia, Retarded growth, genitourinary, ear anomalies).

Bilateral choanal atresia is more commonly associated with craniofacial syndromes and skull base defects including encephalocele.

The epithelium around the forebrain thickens to become specialized olfactory sensory cells.

Nasal cartilage:

Nasal capsule which is the cartilage surrounding the developing nasal cavity becomes:

Upper lateral cartilage, Lower lateral cartilage, Septal cartilage

Septum/Septal cartilage: At early period entirely consists of a plate of cartilage, the ethmiovomerine cartilage.

1. perpendicular plate of the ethmoid: formed by ossification of the postero-superior part of this cartilage
2. septal cartilage: antero-inferior portion persists as the septal cartilage
3. vomer:

- o Ossified in the membrane covering its postero-inferior part.
- o 2 ossification centers, one on either side of the middle line, appear about the 8th wk of fetal life hence the vomer consists primarily of two lamellæ.
- o About the 3rd month these unite below, and thus a deep groove is formed in which the cartilage is lodged.
- o As growth proceeds, the union of the lamellæ extends upward and forward, and at the same time the intervening plate of cartilage undergoes absorption.
- o By the onset of puberty the lamellæ are almost completely united to form a median plate, but evidence of the bilaminar origin of the bone is seen in the everted alæ of its upper border and the groove on its anterior margin.

Note: Perpendicular plate **endochondrial** ossification Vs **vomer** is **membranous** ossification

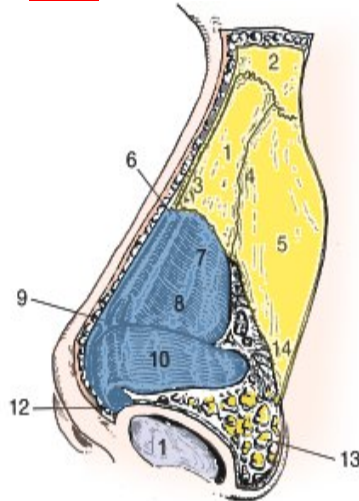
External features of the nose

Anatomy of the Nose

Note: over the dorsum and sides of the nose the skin is thin and loosely adherent where it becomes thicker and more adherent over the tip and alar cartilages.

The external nose is composed of two parts:

1- **Upper bony part** which is composed of :



Nasal bones which articulate together in the middle line. 1

Nasal process of frontal bone 2.

Nasal process of maxilla 5.

Lateral osteotomy is created in the ascending part of the maxilla

2- **Lower cartilagenous part** which is composed of: (hyaline cartilage which may be ossified)

Upper lateral cartilage 7+8.

Major alar cartilage (lower lateral cartilage) 10.

Minor alar cartilage at ala nasi 13.

1-4 minor sesamoid cartilages are found between upper and lower lateral cartilages.

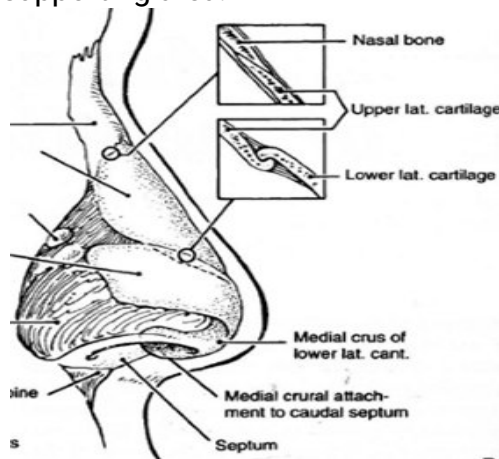
Limem Nasi: the groove between the upper and lower lateral cartilages (caudal margin of the upper lateral cartilage); which is the site of intercartilagenous incision

Sallion: Deepest part in the nasofrontal angle

Nasion: The anatomical midpoint of the nasofrontal suture

Supporting system:

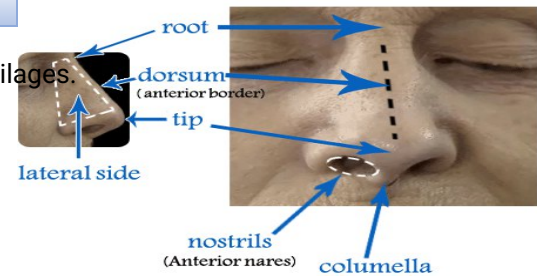
Major supporting area:



Key stone area (rhinion/osteocartilagenous junction): 6

The area where the upper lateral cartilage is attached to the undersurface of the nasal bone
This area should be preserved in rhinoplasty

Scroll area:



Where the superior lateral cartilage is attached to the undersurface of the inferior lateral cartilage

So the relation is interlocked scroll

Where the median crura of the lower lateral cartilages attached to the nasal septum

N.B: Major alar cartilage is composed of 2 crura lateral and medial.

The two medial crura form "columella".

So the columella is not part of the septum

The intermediate crus of the alar cartilage: represents the transitional segment between the lateral & medial crus

Nasal tip support:

Major support structures:

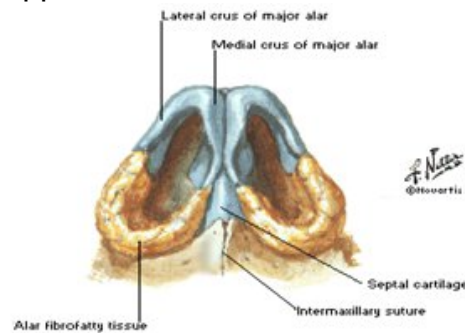
Attachment of the upper lateral cartilage to the lower lateral cartilage

The size & shape of the alar cartilage (lower lateral cartilage)

Medial crural foot plate attached to the caudal septum

Nasal spine

Minor support structures:



Interdomal soft tissue

Cartilaginous dorsum

Soft tissue-sesamoid complex attaching the lateral crus to the piriform wall

Alar cartilage attaching to the skin & soft tissue

Membranous nasal septum

Cottle's classification:

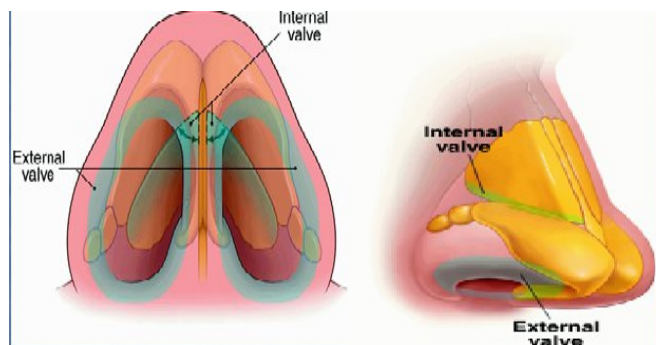
Area 1: Anterior caudal area

Area 2: Nasal valve area

Area 3: Superior mid area

Area 4: inferior mid area

Area 5: posterior choana area



Pyriform aperture:

The **anterior** most and **narrowest** area of the bony part of nose

Boundaries of pyriform aperture:

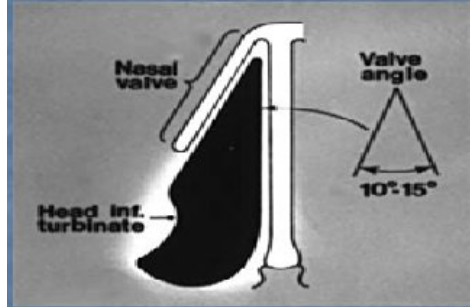
Superior: Nasal bone

Lateral : **nasal** process of maxilla

Inferior: **Alveolar** process of the maxilla

Anterior nasal spine:

lies in the **middle** Of **inferior** border of the pyriform aperture



Made by the junction of the **alveolar** processes at the midline

It can be up to **15mm** in length

Nasal Valve:

It is divided into:

1. External Nasal valve
 2. Internal Nasal Valve
- 1) External nasal valve (nasal vestibule) formed by:
- columella
 - Nasal rim (caudal border of the lower lateral cartilage).
 - nasal floor
- The nasalis muscle dilates this portion during inspiration. (So if denervated will lead to alar collapse even in quiet respiration).
- 1) Internal nasal valve formed by:
- Nasal septum
 - caudal border of the Upper lateral Cartilage
 - head of the inferior turbinate
 - pyriform aperture and the tissues that surround it.

Three components of nasal resistance:

- A. Nasal vestibule (external nasal valve): Collapses on inspiration
- B. Nasal valve (internal nasal valve): Narrowest point, Normal angle is 10° to 15°
- C. Nasal cavum: Located posterior to pyriform aperture, Minor component of resistance

Note: the nose is responsible for 50% of the total airway resistance. During expiration the positive pressure is transmitted to the alveoli. Removal of this resistance by tracheostomy reduces the dead space but results in a degree of alveolar collapse. Reduced alveolar ventilation gives a degree of right-left shunting.

Nasal Valve angle: angle between the caudal end of the upper lateral cartilage & nasal septum

It is located at the **posterior end** of the vestibule at **transition** between the skin and respiratory epithelium, **1.3cm** from the **Nares**.

The average valve area changes from **90 mm²** to a thin passage of **30 mm²** during normal respirations, the **extrinsic** and **intrinsic** muscles can change these relationships

This area is the **narrowest** part of the nose

Responsible for more than **2/3** of the **resistance** (producing a **major flow** resistant segment in the **nose**).

Air passing through this segment is moving at the **fastest** speed

The **anterior** tip of the **inferior** turbinates has the greatest influence on the nasal flow among the turbinates

1. Every **rhinoplasty** surgeon should know that excessive excision of the upper and lower lateral cartilages may cause valve collapse and depress nasal respiration.
2. **Air starved patient**, such as the asthmatic or chronic bronchitic, will frequently have nasal flaring in an attempt to minimize the effect of this area on total airflow.
3. **Breathe-Right device**, which is a small adhesive band with two parallel plastic strips applied across the middle third of the nasal dorsum, increase the cross-sectional area at the nasal valve by **21%**, and resulted in a **27%** decrease in nasal airway resistance.

Nasal obstruction symptoms occurs when **total nasal resistance** is greater than **3.0 cm H₂O/L/SEC**

The **greatest linear** velocities and **differential pressures** in the upper airways are found in the nasal valve space.

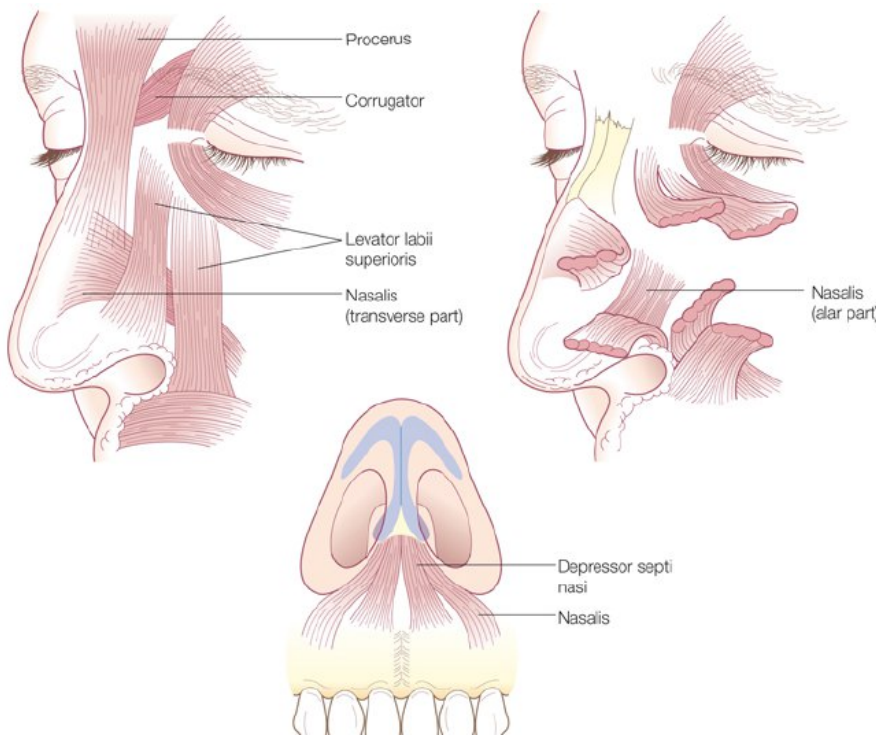
Once air passes through the nasal valve, the cross-sectional area greatly increases, and the velocity falls

rapidly.

The **significant decrease** in velocity coupled with the viscous retardation of air by the large surface area gives rise to **turbulent** flow.

There is a **small** amount of turbulent flow to the **roof** of the nose, which probably explains the physiology of the sniff and the route for smells to be perceived by the olfactory receptors at the roof of the nasal cavity.

The back of the nose connects with the nasopharynx, where the two passages combine into one where the normally **turbulent** airflow of the nose is transformed into a **linear** flow pattern.



External muscles of the nose:

- Depressor septi nasi: depresses septum and tip
- **Nasalis** (alar and transverse parts): contracts/**dilates** nasal aperture
- **Procerus** (depressor glabellae): shorten (**elevate**) nose and depress glabella
- Levator labii superioris

Major functions of the Nose

1. **Olfaction**

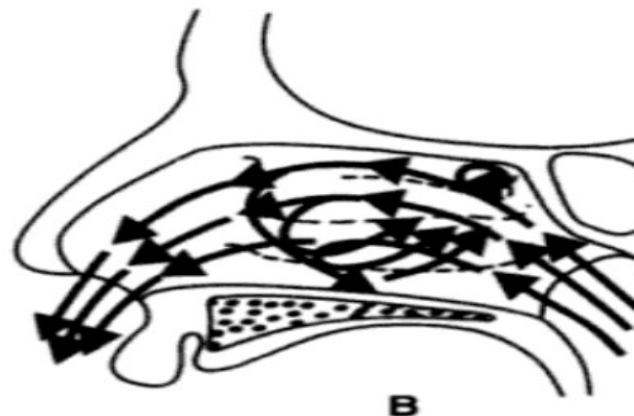
2. **Respiration:**

air conditioning unit :

- o Warming of inspired air:
 thermoreceptors are **limited** to nasal vestibule
 warming of inspired air up to **37** degree (10% of human body heat loss occurs through the nose)
 Averagely the posterior nasal space air is 31 degrees and is 95% saturated.
 This moisture comes from the **water content** of the mucus that is directly transudated from **nasal blood vessels** and supplied by **nasal glands**.
- o humidification of the inspired air
 Humidification is reduced by atropine acting on glands rather than the vasculature.



A



B

Regulate respiratory airflow by providing variable resistance to airflow

1. **Protection:**

Particles in inspired air:

Larger than 3 micrometer has a maximum deposition in the anterior part of the nose, at the **nasal valve area**.

3-0.5 micrometer are filtered by the nasal mucosa and transported by cilia propulsion to the **nasopharynx**.

The filtration of particles **smaller than 0.5 micrometer** is low; these particles seem to pass easily into the **lower airway**.

Note: Nose also adds Voice escape quality: if little escapes rhinolalia clausa; if too much escapes rhinolalia aperta (seen in cleft patients)

Note: sinuses have no effect on voice modification.

The nasal airflow:

During inspiration:

Air flow mainly passes through the middle part of the nasal cavity in a parabolic curve :

- 1) **Mainly**: Middle **meatus** & Olfactory cleft close to the medial surface of the middle turbinate
- 2) Lesser extent: above the middle turbinate the superior meatus & sphenoethmoidal recess
No air passes through the **inferior meatus** as Air tends to hit the **anterior** portion of the **inferior** and **middle** turbinates and is directed posteriorly between them.
Little air passes through the **Olfactory area** hence it requires one to sniff up for air current to reach the olfactory area to appreciate smell

The **medial** wall airflow pattern is **along the floor** or **adjacent to the medial turbinates** .

Velocity at the anterior valve is 12-18m/sec during quiet respiration

During expiration:

Air currents follow the same path (but longer duration and is more turbulent)

But forms **eddies** at the anterior end of the middle turbinate + limen nasi

Thus aerates the **middle meatus** + **paranasal sinuses**

Note: Turbulence is central to the nasal physiology & **increases contact** between **inspired** air and the nasal mucosa enhancing **not** only the **respiratory** functions but also **olfaction** and **protection**

Septal deflections may **significantly** change these relationships.

Air tends to hit the **anterior** portion of the **inferior** and **middle** turbinates and is directed posteriorly between them.

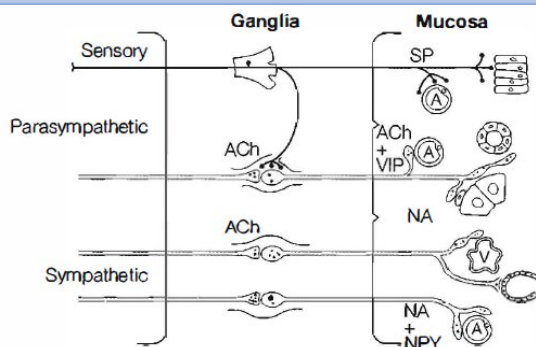


Figure 106.9 The autonomic nerve supply of the nose is mediated by substance P (SP), acetylcholine (ACh), vasoactive intestinal polypeptide (VIP), noradrenaline (NA) and neuropeptide Y (NPY). See text for details.

Factors affecting nasal flow:

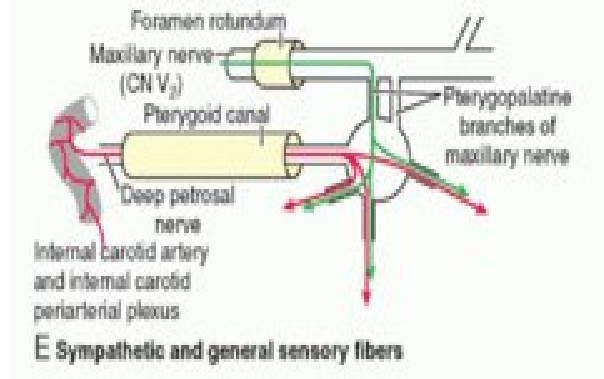
1. Autonomic regulation of nasal vasculature:

The vascular system of the mucosa is under constant sympathetic tone, when this tone decreases the vessels will get engorged

Sympathetic (originate from hypothalamus transmitted via the lateral horn of grey matter of the spinal cord at the level of the 1st and 2nd thoracic vertebrae; preganglionic axons relay/synapse in the superior cervical ganglion; **postganglionic sympathetic fibers form a plexus around internal carotid artery hitching along the carotid from which deep petrosal nerve arises that joins the preganglionic parasympathetic fibers of greater superficial petrosal nerve to form the nerve to pterygoid canal (vidian nerve)** ; These postganglionic sympathetic vasomotor fibers pass through the sphenopalatine ganglion (**without relaying**) to the nasal cavity, vasoconstrictor stimulation exerts the major control over venous sinusoid filling by decreasing the volume of blood held in the mucosa causing decongestion of nasal vessels (decongestion of nasal cavity).

It enters the **nose** by at least 4 routes:

Nerves around the blood vessels



Vidian nerve

Maxillary nerve Nasolacrimal nerve

TABLE 39-1 PHARMACOLOGY OF ENDOGENOUS
SUBSTANCES ON NASAL MUCOSA

Vasodilators	Vasoconstrictors
Histamine	Adrenaline
Vasoactive intestinal peptide	Noradrenaline
Substance P	
Prostaglandin E ₂	
Bradykinin	

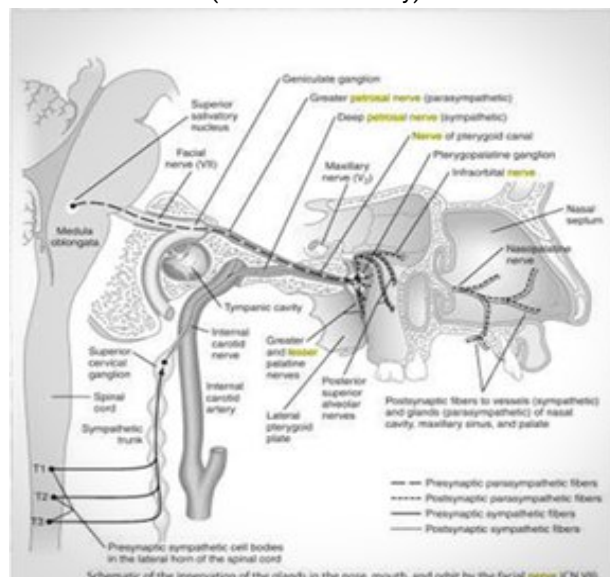
Noradrenaline is the main postsynaptic transmitter with Ach acting at the postganglionic synapses.

Cocaine blocks uptake of noradrenaline into the nerve endings.

Local anesthetics: Cocaine is both a local anaesthetic and a powerful vasoconstrictor.

Lignocaine dilates the precapillary sphincters and so a vasoconstrictor is often combined with it. Both groups at high concentrations have systemic effects on the heart and CNS.

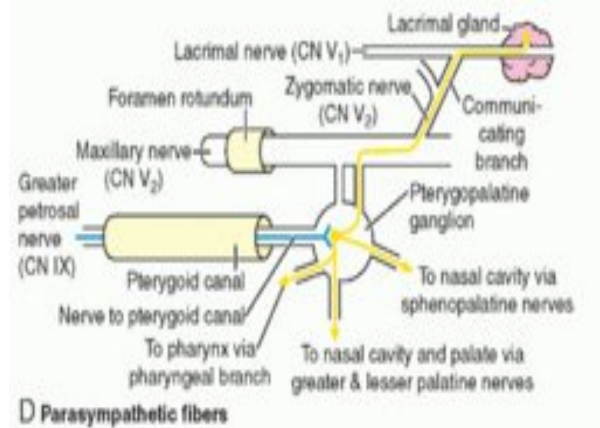
Note: Some surgeons are of opinion that excessive rhinorrhea (vasomotor and allergic rhinitis) can be controlled by section of the vidian nerve (vidian neurectomy).



Parasympathetic (superior secretory nucleus in pons / medulla oblongata proceed via the intermediate branch (nervus intermedius) of the facial nerve to the geniculate ganglion continuing along the greater superficial petrosal nerve, joins deep petrosal nerve forming nerve of the pterygoid canal (vidian nerve) which reaches to the sphenopalatine ganglion where only parasympathetic fibers relay/synapse, postganglionic fibers then pass through sphenopalatine foramen and supply the nasal mucosa. vasodilator fibers exert only minor control of nasal blood volume but cause more potent control of nasal secretions by stimulating a watery discharge.

Distributed along the **maxillary** division branches

At higher rates VIP causes atropine resistant vasodilation. Ach suppresses VIP release by negative feedback.



Pilocarpine and carbachol cause nasal congestion, vasodilation and watery secretions -blocked by atropine-
Histamine may cause vasodilation (In nasal mucosa receptors: H1 predominant, H2 present, H3 absent)

High-dose estrogen contraceptives are associated with rhinitis

Summary:

sympathetic innervation controls nasal airflow

parasympathetic innervation controls nasal secretions (via muscarinic receptors M1, M3)

Co2 = decongestion

Note that **terminal nasal trigeminal** efferent carries:

- o **All parasympathetic** nasal innervations
- o **Some of the sympathetic** nasal innervations

1. **Postural change/reflex**: alter nasal airflow through changes in relative venous pressure (Supine position/laying in lateral position congestion)
2. **Exercise**: results in epinephrine release causing nasal decongestion.
3. **Sex** hormones influence nasal airflow; thus, pregnancy, puberty, and menstruation can increase nasal obstruction
4. nasal cycle

Refers to **spontaneous** congestion and decongestion alternating between the two nasal passages.

The changes are produced by vascular activity, particularly the volume of blood on the venous sinusoids (capacitance vessels).

Cyclical changes occur between 4-12 hours; they are **constant** for each person.

This cycle occurs in approximately **80%** of the population

The nasal cycle results in airway resistance and nasal width changes that affect **airflow turbulence**.

In the **decongested** nasal passage:

1. airway resistance is decreased
2. increasing the nasal width
3. Causing turbulent airflow at **lower** flow velocities.

Although the resistance and airflow alternates between the two nasal cavities, the nasal cycle does **not** significantly change the **combined** nasal resistance and total airflow.

During the cycle secretions are lower in the more obstructed side

Factors affect the nasal cycle: Allergy; Infection; Exercise; Hormones (Pregnancy, puberty), fear

and emotions (including sexual activity); CO₂ in the inspired air produced by rebreathing may also reduce the nasal resistance; The autonomic nervous system controls the changes:

- a. **Vagal overactivity** may cause nasal congestion
- b. Drugs, which block the action of **noradrenaline**, cause nasal congestion.
- c. The **anticholinergic** effects of **antihistamines** can block the parasympathetic activity and produce an increase of sympathetic tone, hence an improved airway.

Studies suggest that the **sensation** of nasal patency may be related to the **temperature** of the nasal passages.

Inspired air cools the nasal lining on inspiration, and this may be detected by thermoreceptors in the mucosa.

Cold receptors sense airflow, and can be stimulated by menthol giving rise to an apparent increase in airflow.

sensation of nasal airflow is:

decreased by the injection of L.A

enhanced by the respiration of cooler air

REFLEXES FROM NASAL STIMULI

Chemical irritation, temperature change and physical stimuli may cause widespread cardiovascular and respiratory responses. Ranges from sneezing to cardiorespiratory arrest. Sensory stimulation can result in intense vasoconstriction of skin, muscles and visceral arteries. It is accompanied by lowered cardiac output. This is a modification of the submersion reflex, which diverts blood away from skin to the brain. When patients have an endotracheal tube passed through the nose, it may give rise to an unexplained bradycardia.

Hot or cold temperature reflex

sneezing upon sudden exposure of skin to dramatic temperature extremes

NASOPULMONARY REFLEXES

Increasing airflow through one side of the nose is associated with increased ventilation of the homolateral lung. Blowing air through the nose causes the bronchiole muscle to relax on the same side and increase respiratory activity.

REFLEXES ACTING ON THE NOSE

Nasal vasoconstriction occurs with increased arterial CO₂, and is mediated by chemoreceptors. Hypoxia has the same effect. Hyperventilation will cause nasal congestion.

CUTANEOUS STIMULATION

Heating the skin of the feet, arm or neck will produce an increase in nasal resistance. Cooling results in vasoconstriction.

Pressure to the axilla (Eccles' reflex) or lying on the dependent side will cause nasal blockage.

CENTRAL CONTROL

The hypothalamus controls cardiorespiratory responses. Stimulation causes marked nasal vasoconstriction.

Vagal overactivity causes prolonged congestion and nasal obstruction in some patients.

Nasal mucosa:

Respiratory epithelium: 20-30 nm

1. **Keratinized squamous epithelium:**

Located in the Nasal vestibule

Contain hair, **sweat** gland, sebaceous gland

1. **Squamous + transitional cell epithelium:**

Located in the **anterior 1/3** of the nasal cavity + **anterior** part of the inferior & middle turbinate

1. Pseudostratified columnar epithelium (respiratory epithelium):

Located in the **posterior 2/3** of the nasal cavity

Olfactory epithelium:

Cell types: Bipolar receptor, Sustentacular, Microvillar, Horizontal basal, Globose basal cells

Located in upper 1/3 of nasal cavity in the posteriodorsal recess (inferior surface of the cribriform fossa) + **superior** part of the nasal septum(10mm) & **superiomedial** part of superior turbinate

60-70 nm; lacks dynein arms

Covers an area of **5 cm² yellowish in color**

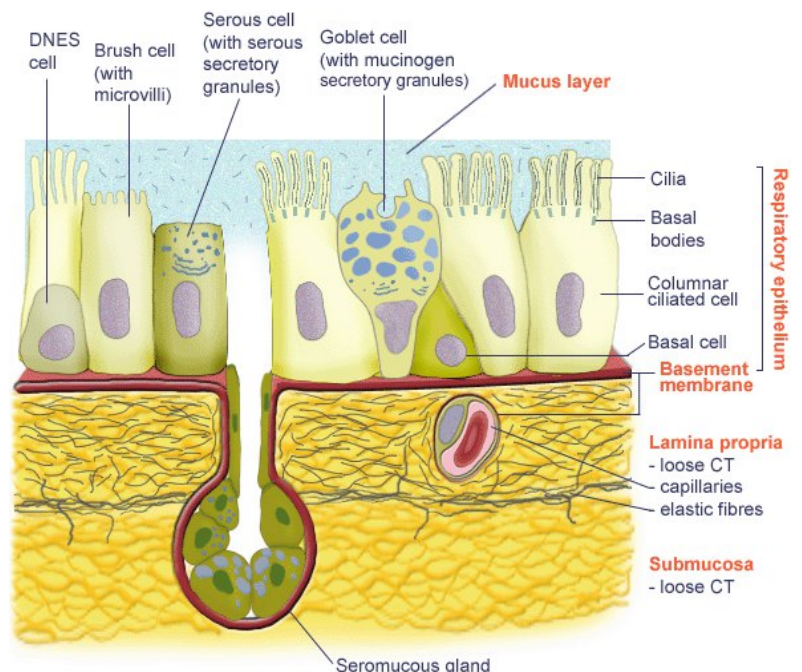
laminated, Pseudostratified epithelium composed of a limited number of cell types + goblet cells

	Olfactory epithelium	Respiratory epithelium
Types of cells	Bipolar neuron Supporting cells Basal cells Bowman's gland	Ciliated/nonciliated pseudostratified columnar epithelium Basal cells Mucin secreting Goblet cells
Cilia of bipolar neuron vs pseudotratiified columnar	Non-motile Radial Greater length Poor ultrastructure	Mobile

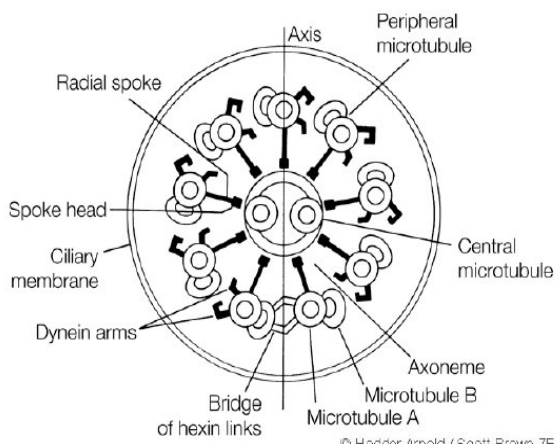
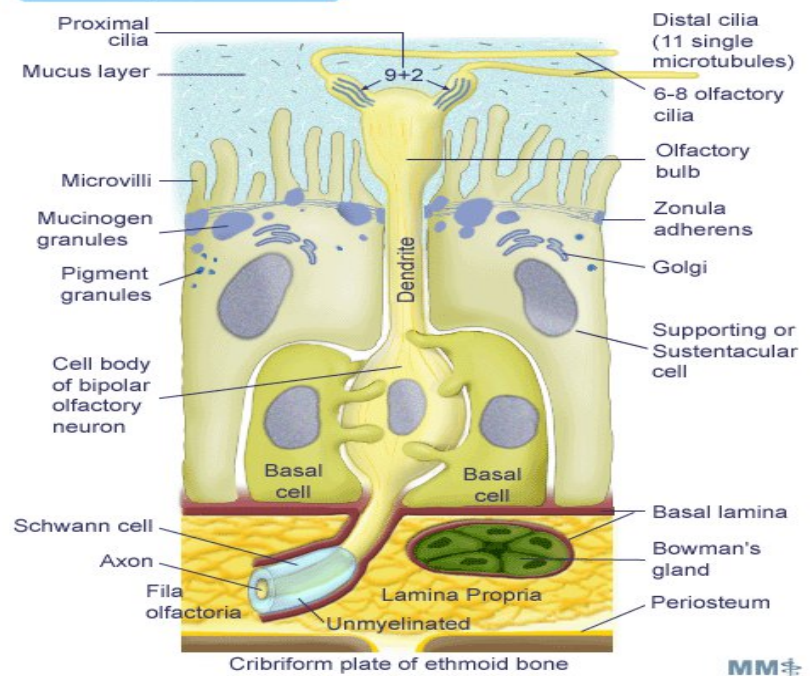
Olfactory bulb is highly organized with multiple layers (from outside in).

- Glomerular layer
- External plexiform layer
- Mitral cell layer
- Internal plexiform layer
- Granule cell layer

Note: The **mucoperichondrium** and **mucoperiosteum** of the **septum** are separate from that overlying the **maxillary crest**, reflecting their **embryological** development



Olfactory Epithelium



Lining of the nasal cavity (respiratory epithelium):

A. **Double Layered Mucous Blanket**

B. **Cell Components of respiratory epithelium:**

1. **Ciliated, Pseudostratified Columnar Epithelium:**

Anterior border begins at limen nasi

Each ciliated cell contains **50-200 cilia**

Ultrastructure of the cilia:

9 peripheral doublet + 2 central single organization of the microtubule

Each doublet has dynein arms extending outward between peripheral doublets

Dynein arms provide motion of the cilia

1. **brush cells with microvilli:**

Microvilli increase the surface area thus improving air humidification & warming

1. **basal cells: do not** extend to the **lumen**
2. **goblet cells (columnar: goblet cells 5:1)**

A. **basement membrane**

B. **lamina propria contains:**

1. Glandular structures:
 - Serous glands: responsible for humidification of air
 - Mucous glands: responsible for production of mucus along with goblet cells
1. Nervous structures which controls mucous secretions:
 - sympathetic**: for **thin** mucus secretions
 - parasympathetic**: for **thick** mucus secretions
1. vascular structures:
 - which helps in temperature modification of the inspired air
1. **Inflammatory cells**

Mucous Producing Glands:

Types:

- a. **goblet** cells (columnar cells, basal nucleus, secretory granules at lumen end)
- b. deep and superficial **seromucinous** glands (serous or mucous acini with cuboidal lined duct complexes)
- c. intraepithelial glands (20–50 mucous cells around a single duct)

Major Composition of Nasal Mucus:

1. 95% water: mainly from the **serous** glands; also **indirectly** from transudation from the **capillary network**.
2. 3% mucoglycoproteins(mucin); 2% salts
3. Immunoglobulins:
 - a) IgA: especially A₂ is a dimer, does not activate complement, on the surface, 70% of protein content
 - b) IgE?: on the surface, does not activate complement.
 - c) IgG: activates complement except G₄, if mucosa is breached.
 - d) IgM: if mucosa is breached
 - e) IgD
1. Interferon; inflammatory cells; complement; eosinophils, basophils, leukocytes.
2. **lysozymes**(bacteriolytic)produced from leukocytes and macrophages and works **only on bacteria without capsule**.
3. **lactoferrin** (bacteriostatic)by removing heavy metal ions it prevents growth of certain bacteria especially **staph and pseudomonas**.

But the mucus blanket does not contain IgE??

The mucous blanket is divided into **inner** and **outer** layers:

1. **Outer layer/gel phase:**

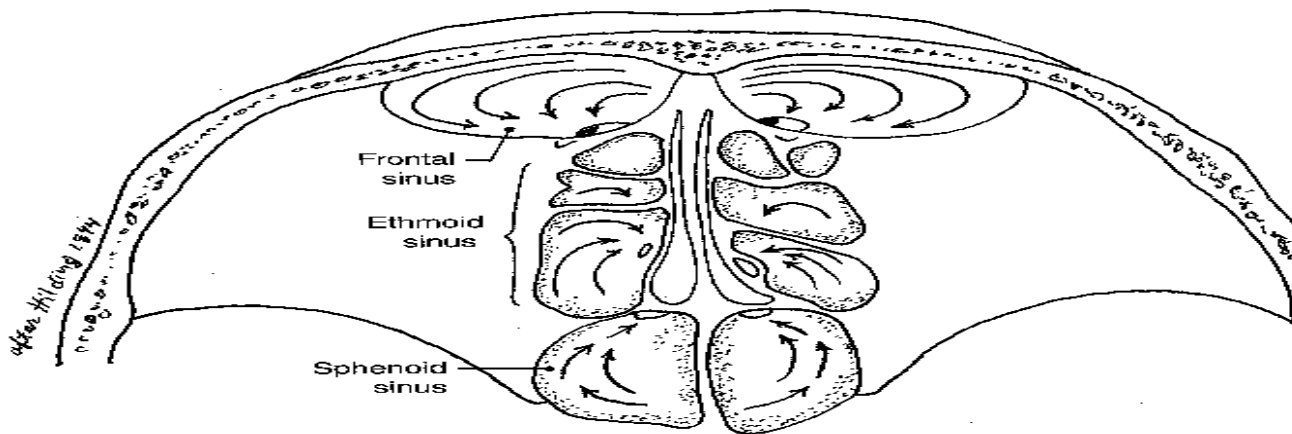
Produced by goblet cells + submucosal glands; lies on **top** of the nasal cilia

Glycoproteins give its **viscosity** & elasticity.

traps foreign particles matter

1. **Inner layer/sol phase:**

produced by **microvilli**; **surrounds** the cilia



less viscous & provides fluids that facilitates ciliary motility as well as the gel layer

The direction of mucus drainage from sinuses:

In all the sinuses, mucus moves toward the natural ostia.

a. **Maxillary sinus:**

mucociliary clearance (is spiral) begins at the **floor** and flows **against** gravity toward the **natural ostium** to empty into the ethmoidal infundibulum.

b. **Frontal sinus :**

Drains toward the ostium only from the **lateral** side.

Mucus **medial** to the ostium must course superiorly to join the lateral flow toward the ostium

c. **Sphenoid sinus:**

Flows in an **antigravitational** direction toward its ostium that drains into the sphenoethmoidal recess.

The direction of mucus drainage in relation to the Eustachian tube:

From **anterior** sinuses: Passes over the inferior turbinate and then anterior to the eustachian tube orifice

from **posterior** sinus secretions: Pass **posterior** to the eustachian tube

Oxygen tension

The PO₂ is lower in the maxillary sinuses than in the nose and it is lower still in the frontal sinuses.

If the ostium becomes blocked, the oxygen tension drops further.

Ciliary motion remains normal if the blood supply is adequate. If the blood supply is impaired, ciliary activity is reduced and stasis of secretions results.

Levels of nitrous oxide are higher in the sinuses than in the nasal cavity.

Pressure changes

Pressures in the maxillary sinus vary **with** respiration but lag behind by 0.2 sec.

There is little fluctuation when the nose is patent and the variation of pressure during quiet respiration is ± 4 pascals, which reaches 17-20 pascals on exercise.

If the nose is blocked, then pressure fluctuations are much more marked.

Barotrauma is five times less common than in the ear and is most frequently seen in the maxillary sinuses and in divers.

Cilia:

Beats **10-20** cycle/**second** (Hz)

Energy is produced by conversion of ATP to ADP by the ATPase of the dynein arms and the reaction is dependent on Mg^{2+} ions. Motion is produced by the pair of outer microtubules sliding with respect to each other.

With **fast forward** beat & **slower return** beat

Migration rate of mucus 1cm/min (baily 3-35mm/min, essential 3-25mm/min)

replaced by newly produced mucus **2 or 3 times each hour**

The mucus is directed from **anterior to posterior** (toward the **nasopharynx**)

May be functionally assessed by saccharin test and by nasal brush biopsy

Factors affecting the ciliary activity:

A. The cilia move in the following situation:

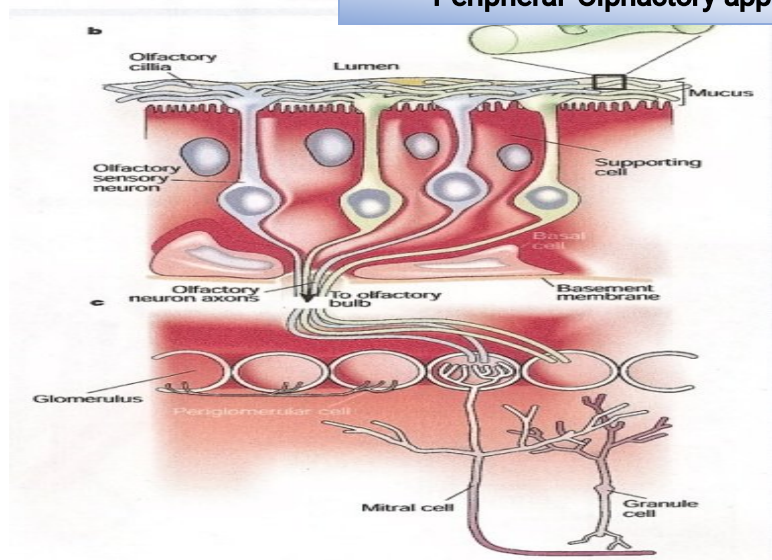
1. cilia will beat above pH 6.4 and will function in slightly alkaline fluids of pH 8.5 for long periods
2. Isotonic saline will preserve its activity
3. Acetylcholine increases the rate

A. The cilia activity decreases in the following situations:

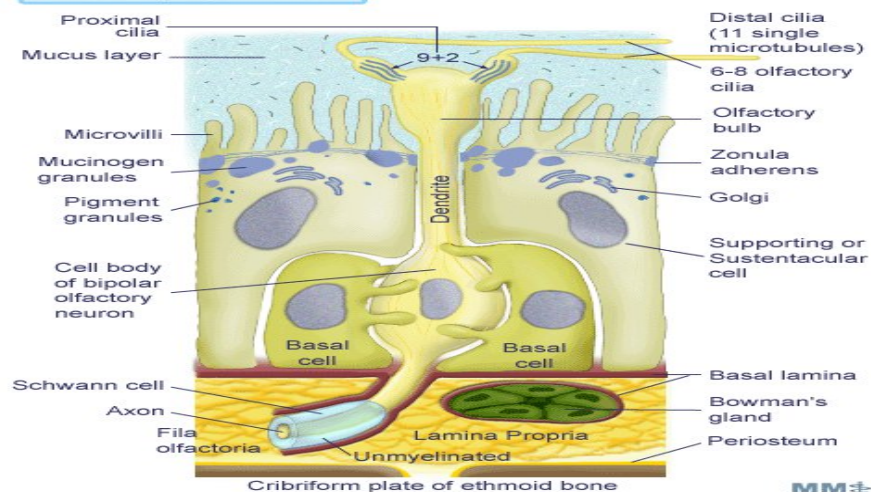
1. Drop in **humidity**
2. cease in **temperature** less than **10 C** or above **45 C**
3. **Adhesions** between the mucosal surfaces
4. URTI may damage the epithelium so that it sloughs away
5. **Ciliary** function may deteriorate with **age**
6. Saline solutions above 5% and below 0.2% will cause paralysis.
7. K^{+} ions do not affect ciliary function except at **non-physiological** levels.
8. Adrenaline decreases the rate
9. Cocaine hydrochloride in solutions above 10% cause immediate paralysis
10. Corticosteroids reduce the rate after 1 week of therapy.

Note: phenylephrine (α -1 agonist) at high concentrations decrease ciliary beat function but at lower concentrations increase the rate

Peripheral Olfactory apparatus



Olfactory Epithelium



a- Cells of Olfactory epithelium:

1. Supporting cells:

flask-shaped; their nuclei are the **most superficial** in the epithelium

1. primary olfactory neurons ; (olfactory receptor neurons)

bipolar in shape; non-motile cell has single odor receptor (not specialized as other senses)

their **nuclei** form a layer 2-8 cells thick in the **middle** zone of the **epithelium**

have **non**-motile cilia (Although these have the standard '9 + 2' fibril arrangement found in mobile cilia in other areas of the body)

the olfactory receptor neurons are derived from **ectoderm** & are unique in being replaced by **stem** cells every **30-50** days lifelong (from the basal cells)

1. Basal cells:

Situated deep in the epithelium in **juxtaposition** to the basal lamina.

Two types of cells can be distinguished morphologically:

1. Horizontal basal cells:

Resemble basal cells in other epithelia; they assemble keratin-containing intermediate filaments that attach to hemidesmosomes and mediate attachment to the basal lamina.

1. Globose basal cells:

Unique to the olfactory epithelium; they are relatively poorly characterized.

Proliferate at a much **higher** rate than any other cell type in the olfactory mucosa.

Ducts of Olfactory mucus gland: located in the **epithelium**

b-The lamina propria:

deep to the basal lamina (basement membrane); adherent to the underlying bone; contains:

- 1- **highly branched** specialized mucus-secreting cells of **Bowman's glands (seromucous gland)**:

Tubular acinar glands.

Consists of an **acinus** in the **lamina propria** and a secretory **duct** going out through the **olfactory epithelium**.

They are **more** important in mucus secretion in nasal cavity than **goblet** cells

the odorant dissolve in the mucus produced by bowman's gland

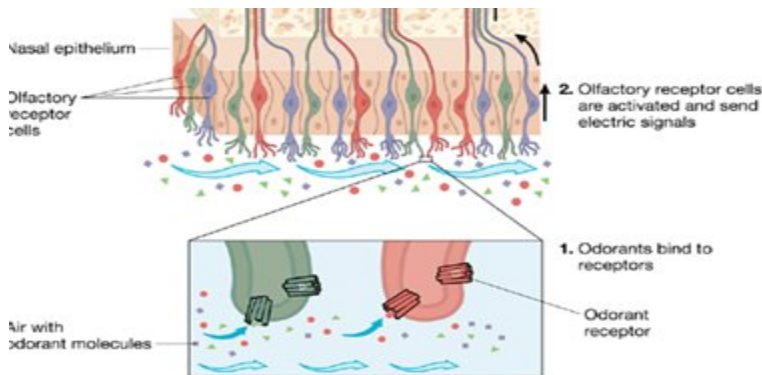
- 2- Blood vessels.

- 3- Fascicles of the olfactory nerve.

Note Olfactory **gland body** lies in the **submucosa** below the basement membrane while its duct lies in the Olfactory epithelium (netter p81)

	Goblet cell	Bowman's gland
Secret	Mucin	Seromucinous
Location	Epithelium	Subepithelium
More numerous	Sinuses	Nasal cavity
Distribution over the septum	Decrease from: anterior-posterior, superior-inferior	Vis versa

So secretory glands (bowman's gland) is not present in the sinuses



Transduction of odorant stimuli requires :

- 1) Dissolving of the stimuli into the **mucous** layer overlaying the Olfactory receptor (**1st** step in Odorant perception):

The mucosa is bathed in a **lipid**-rich secretion from the **Bowman's glands**, indicating that **lipid** solubility may be a critical factor in odor detection

- 2) **Diffusion** (possibly assisted by odorant-binding proteins) to the fine, tapering **immotile cilia** elaborated by the apical processes of the **sensory neurons**.

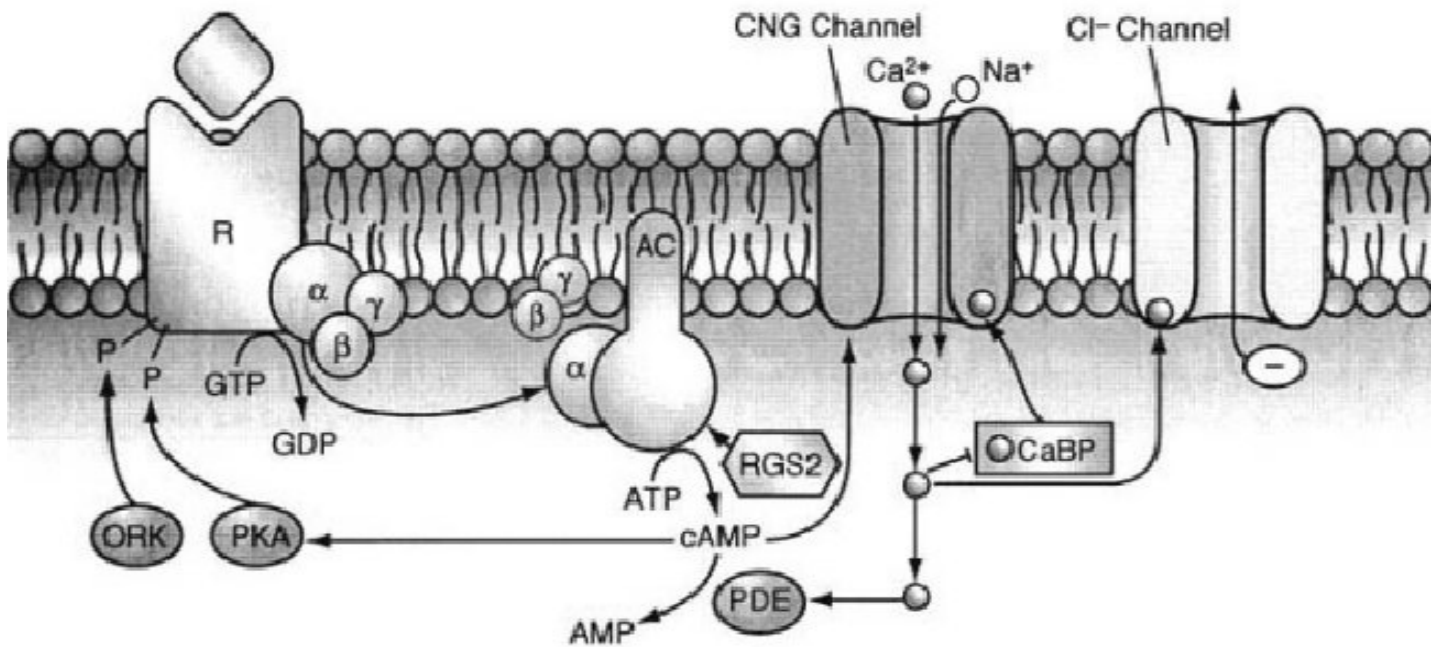
As this transduction process moves through the receptor cell membrane, several second messenger systems assist in depolarizing the cell and initiating the action potential.

Cyclic adenosine monophosphate (cAMP) and **inositol phosphate** (IP3) are the primary signaling pathways that can mediate olfactory transduction.

The **olfactory receptors** are members of **G-protein-coupled receptors (G_{olf})**, This G protein seems to be

exclusively localized to the olfactory **epithelium**.

With the binding of the receptor to an odorant, adenylate cyclase is activated by G_{olf} and converts ATP into cAMP

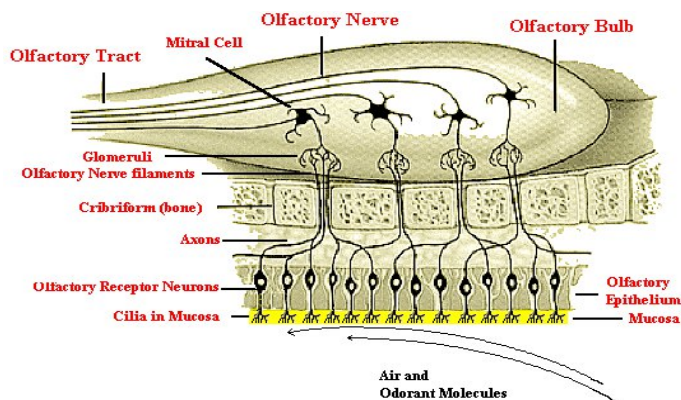


The cAMP then binds to a Na^+ , Ca^{2+} ion channel to allow influx of these ions, the cell depolarizes, and an action potential is produced.

Unlike the sensory epithelia of the auditory, vestibular, or gustatory systems, the receptor cell of the olfactory epithelium is a **bona fide** neuron

Each olfactory receptor cell has a **single slim unmyelinated** axon

Unmyelinated axon of olfactory receptor cell form **myelinated fascicles** (pass through lamina propria) which then form olfactory **fila (bundles)** that pass through the 15-20 foramina of cribriform plate into the **inferior** surface of the **Olfactory bulb** tract through trigone **hypothalamus, amygdale, hippocampus, piriform cortex**.



Each bundle carries tubular sheath of dura and pia which may be sheared in head injury leading to CSF leak and destruction of olfaction

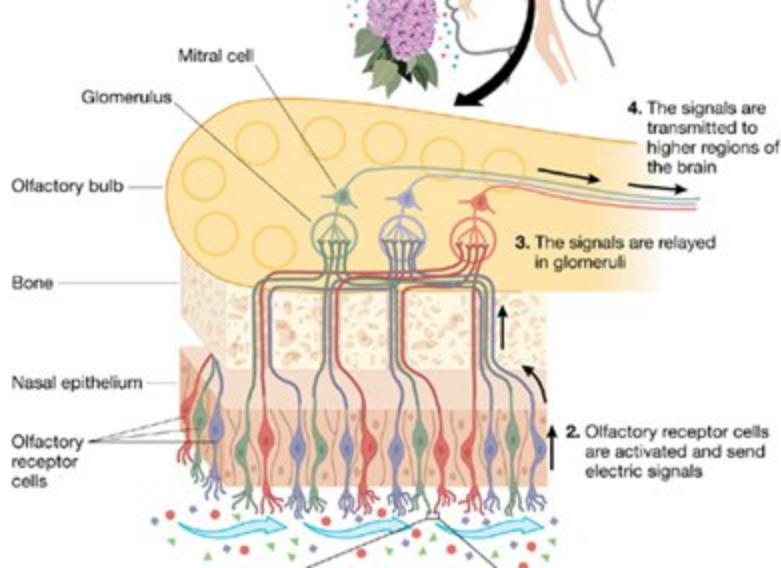
Note:

The Cell **body** of olfactory neuron is in the nasal mucosa

Axon goes through the cribriform plate

Anastomosis occurs in the Olfactory bulb

Central Olfactory apparatus



Fibers synapse in a structure called glomerus of the olfactory bulb with the dendrites of the mitral cells (2nd order neuron)

So the olfactory bulb is the 1st relay station for Olfactory input

Axon of **mitral** cells forms the olfactory Nerve

With increasing age the olfactory area is encroached upon by **respiratory** epithelium

Each zone contains a **group** of **different** olfactory **receptor** subtypes that seem to be confined within the **designated zone**.

Receptor cells of the same type are randomly distributed in the nasal mucosa but converge on the same glomerulus. In the glomerulus the receptor nerve endings excite mitral cells that forward the signal to higher regions of the brain with maintained specificity.

These zones are then **reproduced** by receptor projections to the olfactory bulb.

The axons from each identical olfactory receptor subtype converge and synapse with the mitral cells within **only** a few **glomeruli** of each olfactory bulb.

Therefore, a **specific odorant** may activate certain olfactory **receptor** types that then send signals to specific **glomeruli**, creating a pattern of activity much like other sensory systems in the brain.

Individuals with the **inability** to perceive particular odorants (**specific anosmia**) have been associated with **loss** of **specific genes** (receptor specificity for odorants)

General features of olfaction:

Ammonia is a strong stimulus of the trigeminal nerve

Adaptation to odor can occur within 1-5 min

If two odors were mixed the sum of the intensity will be less than the two individually perceived intensities and is dominated by the stronger component.

Cross adaptations are present between odors at high concentrations, whereas cross facilitations occur near threshold values

Odor association tend to stay longer in the memory than the associations from other senses
Olfaction helps two aspects of eating: the recognition of food types and the initiation of digestion. Initiation of digestion is mediated via the lateral and ventromedial hypothalamus, causes salivation and increases output of gastric acid and enzymes.

Gender issues:

Females are better in odor identification than men.

Female sense of odor is more acute at ovulation & less during menstruation.

A familial lack of perception to certain odors is more common in males.

Age issue:

Children

Children as young as 6 days of age are able to recognize their mother by smell.

Odor identification is **unreliable** in **young** children.

The ability to dislike unpleasant odors develops at the age of 4 years.

Elderly

Rapid **drop** in odor identification occurs in the **7th** decade

Notes:

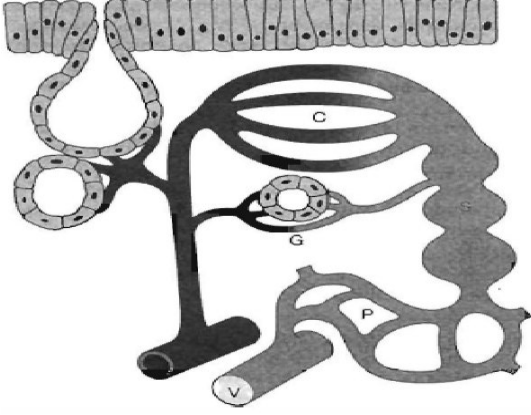
Most common cause of taste loss is olfactory dysfunction

Dysosmia is perception of unpleasant odors

Phantosmia is perception of and odor in the absence of a stimulus

Parosmia is distorted perception of odor

Cacosmia is perception of normal odors as bad smell by brain rather than by olfactory nerve



Nasal vasculature:

The nose is rigid box **without** constricting smooth muscle so changes in airway are produced by **alterations** in blood flow in **resistance** (arteries & arteriols) and pooling of blood in **capacitance** vessels (veins & venioles) .

Blood is shunted between the arteries and veins **in submucosa**

components of the Nasal vascular system :

1. precapillary resistance vessel (arteries & arteriols):

The maxillary artery is the main feeding vessel

Note: The maxillary artery can be found in the pterygopalatine fossa by a transantral or endoscopic approach.

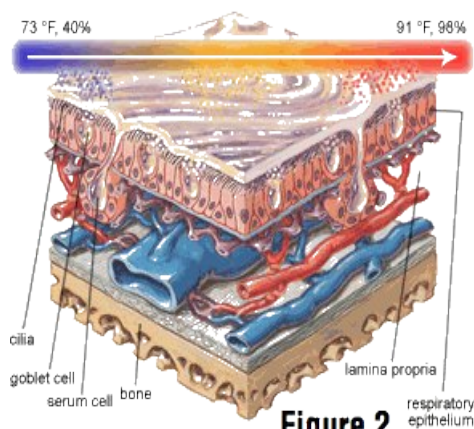


Figure 2

The flow is forward through the nose

1. capillaries (the most **superficial** component)
2. **sinusoids** (venous erectile tissue)
3. venous plexus
4. arteriovenous anastomoses
5. venules (the **deepest** component)

Towards the surface:

arteries branch into: arterioles (lack an elastic lamina) and end in capillaries

capillaries:

Run **parallel** and **just below** the surface epithelium.

They also run around **mucous glands**

Capillaries (in the turbinates) empties into: sinusoid: venous plexus: venules

Sinusoid system:

location:

- a- nasal **submucosa**;
- b- turbinate (especially the **inferior** turbinate)
- c- present on the septum adjacent to:
 - 1. the **inferior** turbinate
 - 2. On the **most anterior** septum.

Valveless; Receive **both** arterial and venous blood.

It's filling & emptying cause mucosal swelling & shrinkage resulting in changes in nasal **resistance** to airflow & control of airflow into the olfactory cleft.

The sinusoids themselves contain little or **no** muscles & thus **unresponsive** to **adrenaline**

The degree of the venous sinusoidal filling is controlled by cushion veins

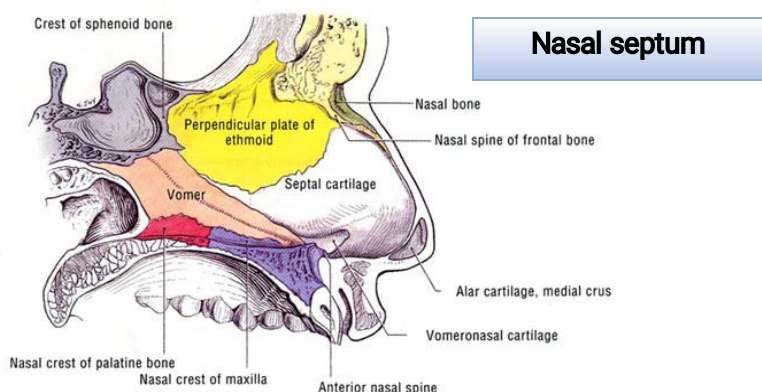
Cushion veins:

Located at the **distant** end of the sinusoid; Have very thick **longitudinal** muscular wall

Under the influence of both sympathetic & parasympathetic innervations

Upon reduction of **sympathetic** stimulation or increase in **parasympathetic** stimulation the veins punch up (but they do not close the lumen completely) , allowing proximal venous sinusoid to distend, **increasing nasal** resistance

Produce **histological** appearance similar to **cavernous hemangioma**



Surface area of the septum in adults $30-35 \text{ cm}^2$

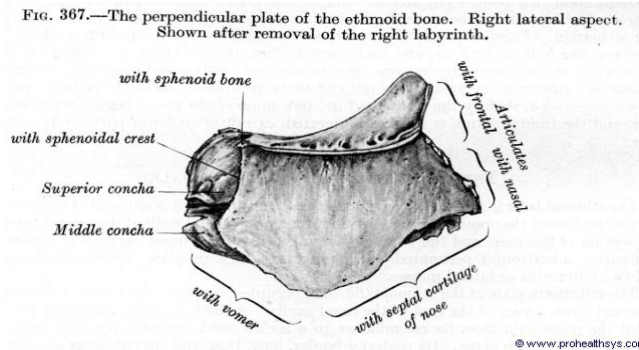
Mucosal surface area in adults 1700 mm^2 , infants 450 mm^2

Septum develops from the frontonasal process

Cleft lip and palate are the most congenital conditions with septal involvement (missing basal support of the septum and due to surgical closure leading to scar formation)

It is made of 4 bones & 1 cartilage:

- 1. Quadrilateral cartilage



Thickness:

- o 3-4 mm centrally
- o 4-8 mm anteroinferiorly

1. Perpendicular plate of the ethmoid
2. Vomer
3. Crest of Palatine bone
4. Crest of maxilla and Anterior nasal spine of the maxilla

Septal cartilage-**ethmoid** articulation is **End to End**

Septal cartilage-**maxillary crest** articulation is **tongue-groove**

Caudal part of the septum (quadrilateral cartilage) extends **beyond nasal** spine

Histology:

ciliated and non ciliated pseudostratified columnar cells with each cell bearing 300-400 microvilli (to increase surface area to prevent dryness)

basal pluripotential stem cells

Septal hematoma

Internal nasal bleeding that cannot escape through the mucous membranes or skin.

These haematomas can be found in the septum or around the triangular cartilages.

A septal haematoma should be drained to avoid an abscess development.

If an incision in the mucosa is made to drain a haematoma, it should be a horizontal incision to avoid disruption of the mucociliary transport.

Septal abscess

The most common cause of a septal abscess is a septal haematoma.

Three to five days after the trauma that caused the haematoma, a fever and nasal blockage may occur which, at that time, will not be associated with the trauma and frequently is interpreted as flu.

The treatment consists of drainage of the abscess and antibiotics

Septal fractures

Frontal trauma will frequently result in vertical fractures, whereas lateral trauma can give horizontal fractures

In vertical fractures in particular, the consequent scar can impede mucociliary transport.

Incomplete fractures can lead to bending of the cartilage

In vertical fractures, there may be a luxation or subluxation of the caudal part of the quadrilateral cartilage.

In case of a luxation, the caudal rim of the cartilage can be seen to the left or to the right of the columella.

In case of a subluxation, this is only seen after the tip of the nose is lifted.

Mucosal trauma

Surgery is probably the most common cause

Can lead to severe atrophy of the mucosa which may result in atrophic rhinitis with symptoms such as fetor, crusting, congestion, epistaxis and headache.

Too vigorous surgery of the inferior turbinate can change the aerodynamics of the nose in such a way that serious trauma of the mucosa may result.

Septal perforation

Septal perforations are either the result of trauma or systemic disease.

When there is no skeleton to prevent drying of the back of the mucosa opposite to the mucosal laceration, the mucosa on both sides of the septum will disappear and this leads to a perforation.

Examples are cautery for nose bleeding, nose picking and cocaine abuse.

In submucosal skeleton resections, such as the Killian procedure, a septum perforation is a common complication,

Although septal perforations can be asymptomatic, they may present to the surgeon with debilitating symptoms such as nasal blockage, atrophy of the mucosa, dryness, crusting, nose bleeding, whistling and headache.

The nose blockage and whistling are related to abnormal aerodynamics.

The other symptoms are the result of the poor condition of the mucosa, which is worse around the perforation. Perforations in the anterior part of the septum present more symptoms than perforations in the posterior part.

Small perforations have a stronger tendency to produce sounds than larger ones.

In large perforations, the patient's complaints can be mild.

Closure of a septal perforation is difficult due to lack of material to reconstruct the skeleton and the mucosa.

Vital tissues are brought into the perforation to reconstruct the skeleton and the lining of the septum and to replace the atrophic tissues around the perforation. For the mucosa, pedicled flaps are used.

When closure of a perforation is difficult, conservative treatment might be an alternative. Crusting and infection can be reduced by douching the nose with saline. A silastic button may have a positive effect by improving the aerodynamics and protecting the edges of the perforation, although the button itself can be the cause of crusting.

Septal disease in systemic disorders

Hereditary haemorrhagic telangiectasia or Osler Weber-Rendu disease is an autosomal dominant condition: There is a deficiency of the muscle or elastic tissue in the wall of the blood vessels.

Therefore, they cannot contract when severed. This can lead to telangiectasia in the skin, the lips, nail beds, the mouth tongue and the nose. The gastrointestinal tract and the lungs can also be involved.

In arteriosclerosis, Osler-Weber-Rendu disease and juvenile angiofibroma, nasal bleeding can be difficult to control.

Infectious diseases : Syphilis, Tuberculosis, Leprosy, Diphtheria

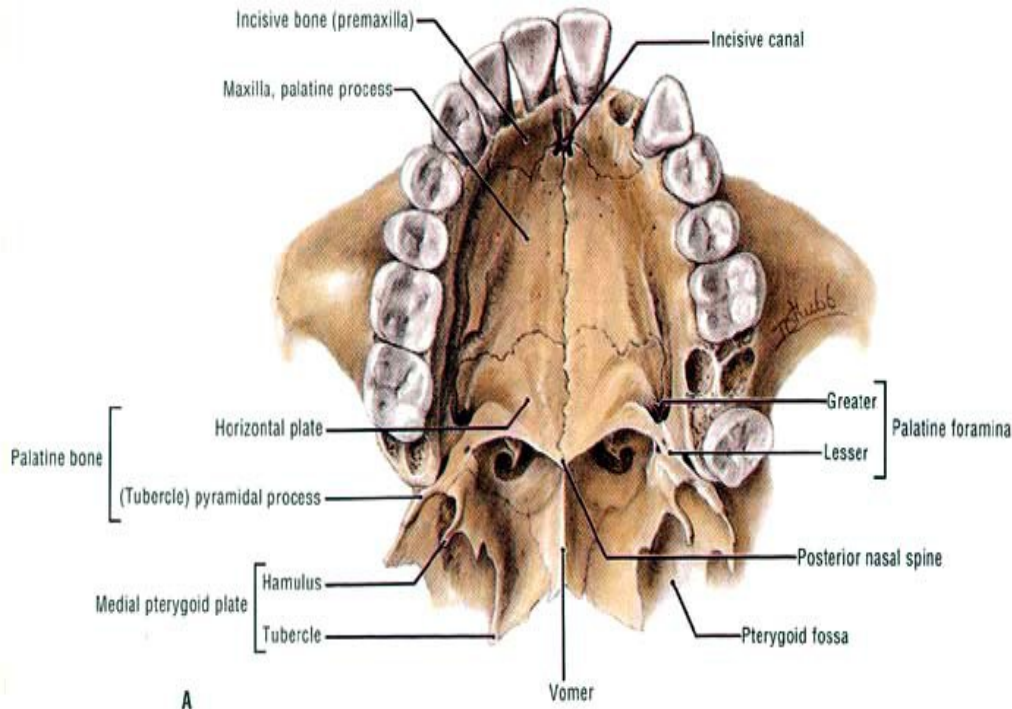
Auto-immune: Sarcoidosis, Lupus erythematosus, Takayasu disease, Wegener's granulomatosis

Developmental disturbances:

As a rule of thumb, the length of the nose should be approximately a third of the distance between the hairline above the forehead and the lower border of the chin.

Indications for septoplasty

Nasal obstruction, crusting, rhinorrhoea, post-nasal discharge, recurrent sinus pressure or pain, epistaxis, headache, snoring and sleep apnoea.



The indications for corrections for aesthetic reasons are in general more straight forward than those for functional reason

Bony lateral nasal wall:

- 1) Maxilla: antero-inferior
- 2) Perpendicular palate of the palatine bone: posterior
- 3) Inferior turbinate: overlaying inferior over 1+2
- 4) Ethmoid (superior and middle turbinate): superior

Note the medial pterygoid plate is not part of the nasal lateral wall

Floor of the nasal cavity:

- 1) Palatine process of the maxilla
- 2) Horizontal process of the palatine bone

Nasal choana

- 1) Superiorly: body of sphenoid with overlapping alae of the vomer & vaginal process of the medial pterygoid plate
- 2) Lateral wall: medial pterygoid plate
- 3) Medial wall: posterior part of the septum (vomer)
- 4) Floor: horizontal plate of the palatine bone

Blood & nerve supply of the nose

External Nose: see netter p 288

A. (mainly): Facial artery branches :

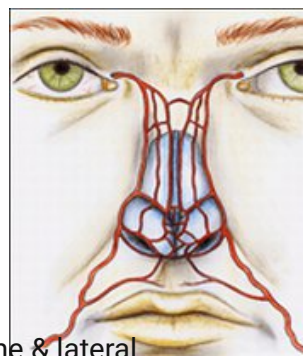
Superior labial artery : columella and lateral nasal wall

Angular artery : nasal side wall, nasal tip, and nasal dorsum

A. Maxillary artery: Infra-orbital artery (lateral side of the nose)

B. Ophthalmic artery:

1. Dorsal branch (nasal bridge (Dorsum))
2. External branch of the anterior ethmoid artery (junction between the nasal bone & lateral cartilage)



There are significant anastomoses between these vessels on each side and between the right and left sides

Nerve Supply

The skin of the external nose receives its sensory supply from the two upper divisions of the trigeminal Nerve

Part of the nose	Nerve supply
lateral surface of the root of the nose	infratrochlear branch of ophthalmic
skin over the root and dorsum as far as the tip of the nose	external nasal branch of ophthalmic
anterior lateral wall	pes anserinus minor & anterior superior alveolar branch

nasal alae	external nasal branches of infraorbital branch of maxillary
nasal vestibule	internal nasal branches of infraorbital branch of maxillary

pes anserinus minor: made of anastomosis between inferior palpebral and superior labial branches of the maxillary division of trigeminal nerve with superior buccal branches of the facial nerve **see page 849 essential**

Nasal cavity

External carotid artery system

Internal maxillary artery: (supplies 90% of nasal mucosa)

Sphenopalatine artery via sphenopalatine foramen: (main blood supply)

- o lateral nasal artery, supplying lateral nasal wall;
- o posterior septal artery, supplying posterior aspect of septum

Descending palatine artery: forms the greater and lesser palatine arteries; supplies lower portion of the nasal cavity

Greater palatine artery: passes inferiorly through greater palatine canal and foramen, travels within hard palate mucosa; bilateral arteries meet in midline and travel through single incisive foramen back into nasal cavity

Internal carotid artery system : ophthalmic artery enters orbit and gives off anterior and posterior ethmoid arteries; courses via anterior and posterior ethmoidal canal, takes an intracranial course and then turns inferiorly over the cribriform plate

Anterior ethmoid artery: supplies lateral and anterior one-third of nasal cavity; anastomoses with sphenopalatine artery (also known as nasopalatine artery; most common artery injured in septoplasty surgery, causing hematomas)

Posterior ethmoid artery: supplies small portion of superior turbinate and posterior septum

Innervation

Nasociliary nerve

Branch of ophthalmic division of cranial nerve (CN) V (CNV1)

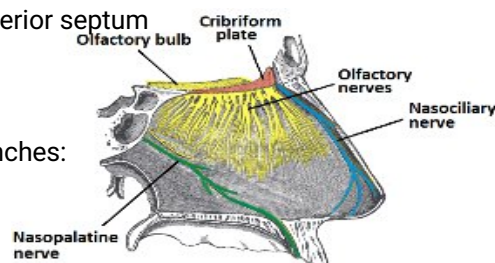
Arises in the lateral wall of cavernous sinus and enters orbit and gives off two branches:

1. Infratrochlear nerve: Supplies skin at the medial angle of eyelid
2. Anterior ethmoidal nerve:

Leaves orbit with anterior ethmoidal artery

Supplies anterior superior nasal cavity, anterior ends of middle and inferior turbinate and corresponding septum; also region anterior to the superior turbinate

Leaves nasal cavity and supplies skin on dorsum of the tip of nose



Maxillary nerve (CN V2)

- Exits middle cranial fossa via foramen rotundum

1. Pterygopalatine (sphenopalatine) ganglion: contains parasympathetic, sympathetic, and sensory nerves
 - Lateral posterior superior nasal branch: Supplies posterior portion of superior and middle turbinates, posterior ethmoid cells
 - Medial posterior superior nasal branch: Cross anterior surface of sphenoid; roof of nasal cavity; posterior septum
 - Nasopalatine nerve: Supplies anterior hard palate
 - Greater palatine nerve: Supplies mucous membrane over posterior portion of inferior turbinate and middle and inferior meatus

- Infraorbital branch

Supplies portion of vestibule of the nose; anterior portion of inferior meatus; part of the floor of nasal cavity

Nasal septum

The external and internal carotid arteries are responsible for the rich blood supply to the nose.

Arterial Branch	Main blood artery	foramen	Supplied area
Anterior & posterior Ethmoidal artery	Ophthalmic artery	Cribriform plate foramen	Superior part of the septum
Septal branch of Sphenopalatine artery	3 rd part of the maxillary artery	Sphenopalatine foramen	Posterior inferior part
Greater palatine artery	3 rd part of the maxillary artery (Descending palatine artery)	Greater palatine canal then Incisive canal	Anterior inferior part Floor of the nose
Labial branch	Facial artery		Anterior part

Note the **blood** supply of the **cartilaginous** nasal septum is **directly** via overlaying **mucoperichondrium**



Anterior & posterior ethmoidal arteries are the **terminal** branches of the **internal** carotid artery
Sphenoplatine artery is the **main** blood supply of the septum

Little's area (kiesselbach's plexus) is an anastomosis of the:

1. **Anterior** ethmoid artery
2. Septal branch of the greater palatine artery
3. Septal branch of **superior** labial artery
4. Septal branch of sphenoplatine artery

So **all** blood vessels supplying the septum participate in the formation of kiesselbach plexus **except** the posterior ethmoidal artery

Woodruff plexus (nasopharyngeal plexus):

Anastomosis of posterior nasal, posterior ethmoid, sphenopalatine, and ascending pharyngeal arteries along posterior lateral nasal wall inferior to the inferior turbinate

Located at the posterior 1cm of the nasal floor + inferior meatus + inferior turbinates + middle meatus

Responsible for posterior bleeds, associated with high blood pressure

Note: maxillary ostia is the dividing line between anterior and posterior bleeding

Septal Nerve Supply

See p 88-92 netter

The **maxillary** division of the trigeminal nerve provides the sensory supply to the **majority** of the nasal septum

1. **Nasopalatine nerve (long sphenoplatine nerve):**

Medial to branch of the sphenopalatine artery

One branch of the [pterygopalatine ganglion](#)

supplies the **bulk** of the **bony** septum

entering the nasal cavity via the sphenopalatine foramen

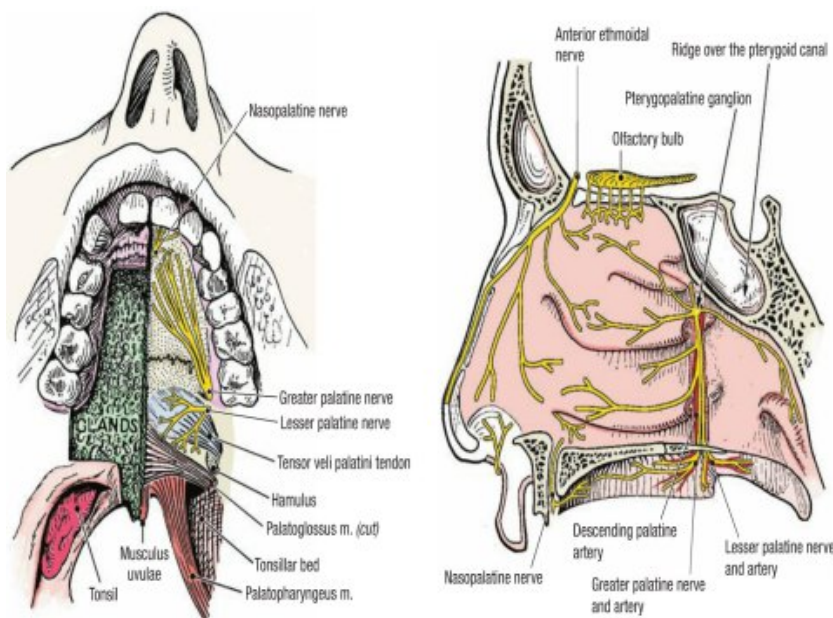
passing medially across the roof of the upper septum

Running down and forwards to the incisive canal to reach the hard palate.

1. **Anterior ethmoidal branch of the Nasociliary nerve :**

Supply the anterosuperior part of the septum

2.



anterior superior alveolar nerve :

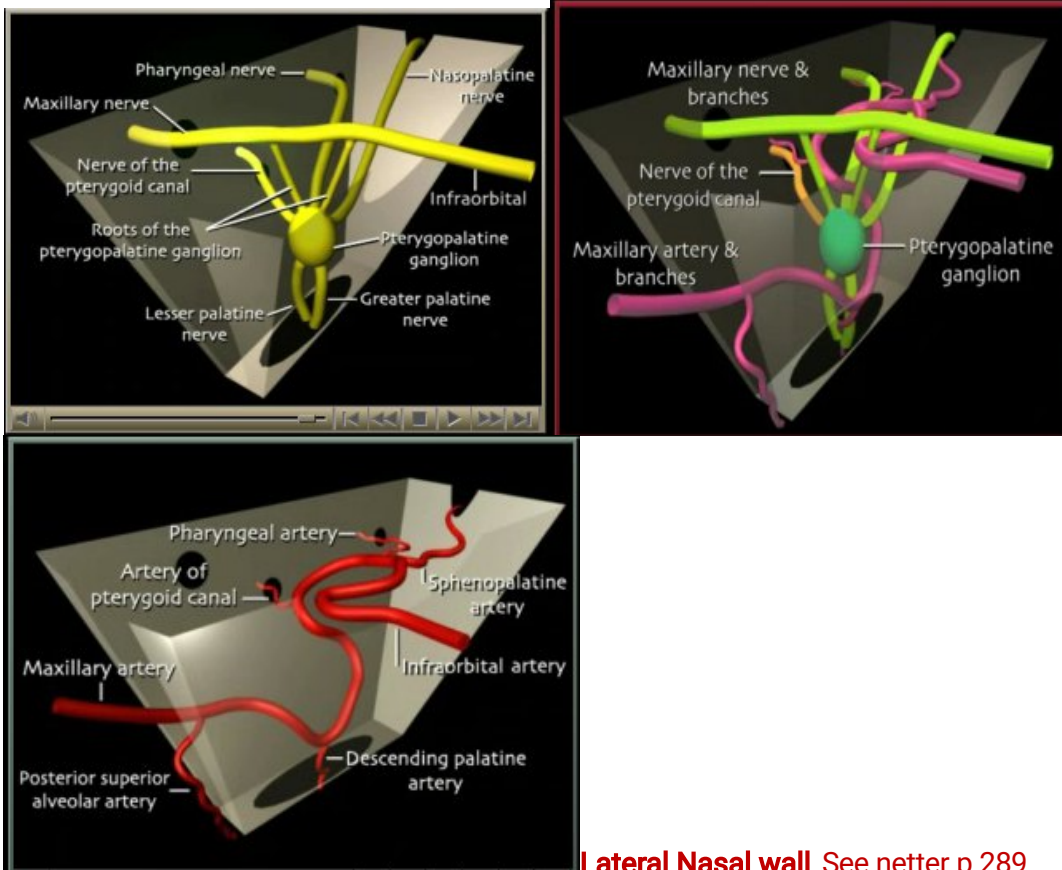
supply the smaller anteroinferior portion

3. **nerve to pterygoid canal and posterior inferior branch of the anterior palatine nerve:**

supply a small portion posterior inferior

4. olfactory nerve:

The olfactory epithelium covers the **inferior** surface of the **cribriform plate** spreading down to cover a variable area on the **upper** septum and **adjacent** lateral wall (over the medial surface of the superior concha)



Lateral Nasal wall See netter p 289

Branches:

Lateral nasal branches of the anterior & posterior ethmoid arteries: Superior part of the lateral nasal wall

Lateral nasal branches of the sphenopalatine artery:

Posterior $\frac{1}{2}$ of **inferior** and **middle** turbinates.

Enters through the sphenopalatine foramen which lies just **inferior** to the **horizontal** attachment of **middle** turbinate

May be damaged in excessive enlargement of a middle meatal antrostomy.

Its branches to the respective turbinates and meatus enter **posteriorly**

On the conchae, the vessels are **partially embedded** in deep grooves.

In the **inferior meatus**, the sphenopalatine branch dips **below the level of the palate** to re-emerge **anteriorly**, leaving the **central** portion of the meatus relatively **avascular**

Facial artery: Anterior part

Greater palatine: Part of the lateral wall adjacent to the palate

Note: the main blood supply of the lateral nasal wall is through the sphenopalatine artery

There is considerable overlap between the internal and external carotid arterial systems on each side and between the right and left sides which may complicate attempts at arterial ligation in the management of epistaxis.

The vascular supply to the nose is well-developed and this is enhanced by cavernous plexus found in the lamina propria, in particular on the inferior and middle turbinates, which is controlled autonomically.

The veins of the plexus are between 0.1 and 0.5 mm wide and anastomose with each other.

In addition, numerous arteriovenous anastomoses are found in the deep mucosa and around the glands.

Venous drainage is to the **sphenopalatine veins** via **facial and ophthalmic vessels**, **intracranially** via the **ethmoidal veins** to veins on the **dura** and to the **superior sagittal sinus** via the **foramen caecum**

Lateral wall nerve supply

Superior concha : olfactory supply

Anterosuperior : anterior ethmoidal nerve

Posterior:

posterior superior lateral nasal branch (branches of the pterygopalatine ganglion)

Posterior inferior lateral nasal branch (greater palatine nerve)

Anterior: internal nasal branch of infraorbital nerve

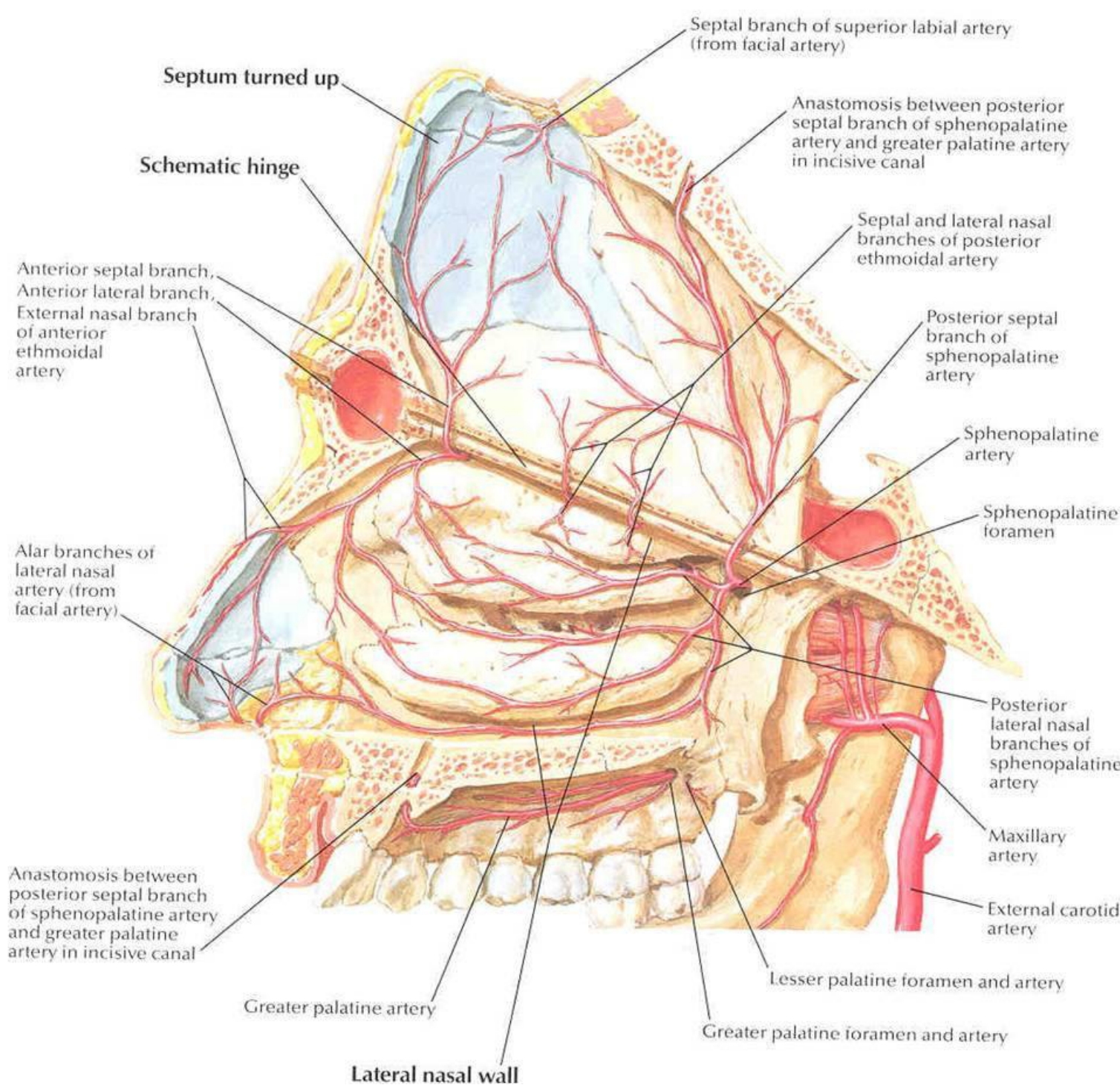
Anterior inferior meatus : The anterior superior alveolar nerve

may be damaged in inferior meatal surgery

Inferior turbinate:

mainly greater palatine and the rest

by anterior ethmoidal nerve



Ethmoid sinus:

1. Anterior ethmoid artery
2. Posterior ethmoid artery
3. Sphenopalatine artery

Sphenoid sinus:

1. Posterior ethmoid artery
2. Sphenopalatine artery : antero-inferior face of the sphenoid sinus

Frontal sinus:

1. Supra-orbital artery
2. Anterior ethmoid artery

Maxillary sinus:

1. Branches from facial artery
2. Branches from maxillary artery
 - a. Infra-orbital branch of maxillary artery
 - b. Greater palatine branch of maxillary artery

In summary:

Ophthalmic branches:

1. posterior ethmoid artery
2. anterior ethmoid artery + external branch
3. Dorsal branch
4. supra-orbital branch

Maxillary:

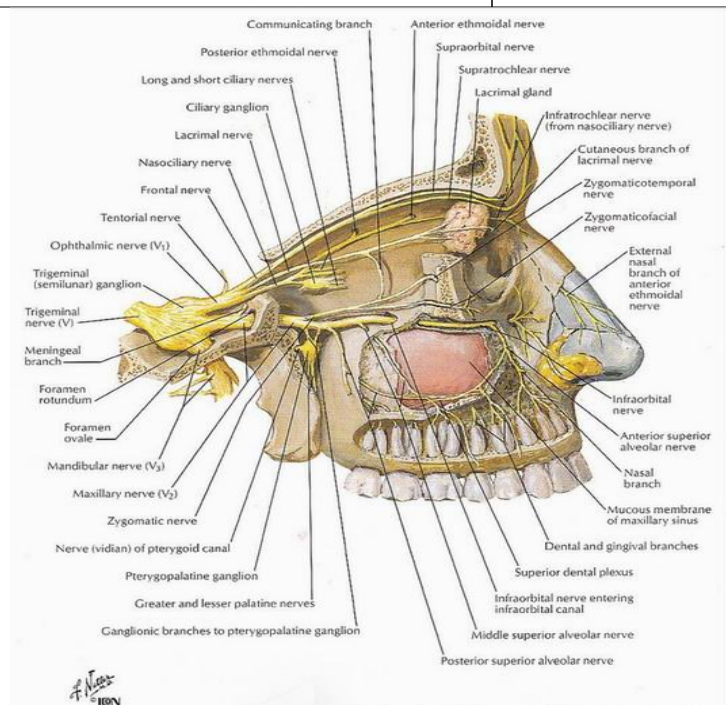
1. infra-orbital artery
2. sphenoplatine artery
3. greater palatine artery

Facial:

1. alar branch of superior labial artery
2. lateral nasal branch of angular artery

Sinuses nerve supply:

Name of sinus	Nerve supply
Frontal	Supraorbital branch Frontal Nerve (branch of ophthalmic)
Anterior & posterior ethmoid & sphenoid	Anterior & posterior ethmoid Nerves & orbital branches of Pterygopalatine ganglion
Maxillary	
Anterior surface	Anterior superior alveolar nerve
Lateral surface	Middle superior alveolar nerve
Posteriomedial	Greater palatine nerve
Roof	Perforating branches from the infra-orbital Nerve



Floor (hard & soft palate) innervation:

Nasopalatine	Central incisor to the canine
--------------	-------------------------------

Greater palatine	Premolar – end of hard palate
Lesser palatine	Soft palate

Venous drainage of the nose

Venous system is valveless.

Veins arise from dense venous net work (**cavernous sinus** in the **submucosa**) Accompany arteries & drain into the following:

1. **ethmoidal veins communicate with :**

veins of the orbital surface of the frontal lobe of the brain

superior sagittal sinus: direct intracranial connections through the foramen caecum

ophthalmic plexus drain via:

- a) **Superior** ophthalmic plexus into the **cavernous** sinus
- b) **Inferior** ophthalmic plexus into the **pterygoid** plexus

1. **Sphenopalatine vein (via facial and ophthalmic vessels)** drains via sphenopalatine foramen into pterygoid plexus.

2. **facial veins**

a) **Anterior** facial vein:

Drain via the **common** facial vein into the **internal** jugular vein

Communicates with cavernous sinus via ophthalmic veins, infraorbital and deep facial veins, and the pterygoid plexus

a) **Angular** facial vein: drains external nose via ophthalmic vein to cavernous sinus

Lymphatic drainage of the nose

	Area	arteries	Nerves
Outer nasal surface	Root of the nose	Dorsal artery	Infra-trochlear Nerve
	Dorsum	External branch of anterior ethmoid	External branch of anterior ethmoid
	Lateral side	Infra-orbital artery	pes anserinus minor & anterior superior alveolar branch
	Alar area	Alar branch of superior labial Lateral nasal branch of angular branch of facial	External nasal branch of the infraorbital branch

Septum	Superior-anterior	Anterior ethmoidal artery	Anterior ethmoid nerve
	Superior-posterior	Posterior ethmoidal artery	Olphactory nerve
	Posterior-inferior	Sphenopalatine artery	Nasopalatine nerve (short+ long sphenopalatine nerve)
	Anterior-inferior	Superior labial artery	Superior anterior alveolar nerve
Lateral wall	Superior-anterior	Lateral superior nasal branches of Anterior ethmoid artery	Anterior ethmoid nerve
	Superior-posterior	Lateral superior nasal branches of posterior ethmoid artery	Olphactory nerve
	Posterior-inferior	Lateral inferior nasal branches of sphenopalatine artery	posterior superior lateral nasal branch (branches of the pterygopalatine ganglion) Posterior inferior lateral nasal branch (greater palatine nerve)
	Anterior inferior	Superior labial artery	Internal nasal branch of infraorbital Anterior superior alveolar nerve
	Lateral wall adjacent to the palate	Greater palatine artery	

Anterior 1/3: submental +submandibular LNs

Posterior 2/3: retropharyngeal +superior deep cervical LNs

The major differences are:

- Alar area: supplied by facial artery and maxillary branch of trigeminal nerve
- Sphenopalatine artery supply posterior part of the nose (both the lateral + septum)
- Nerve equivalent to sphenopalatine: nasopalatine, posterior superior lateral nasal branches of the ganglion & posterior lateral branch of greater palatine

Note that there is very **wide** range of possible anatomical variation between different people & even between the 2 sides of the **same** individual's nose

All three turbinates and all the paranasal sinuses arise from the cartilaginous nasal capsule.

Embryology:

THE TURBINATE BONES

A series of elevations arise from the lateral aspect of the nasal capsule (the lateral wall of the nose) from the 6th foetal week which will ultimately form the turbinates.

The most inferior or **maxilloturbinal** forms the inferior turbinate.

The middle, superior and supreme turbinates result from reduction of the complex **ethmoturbinal** system.

Primitive **nasoturbinal** is represented by the agger nasi region and uncinate process of the ethmoid.

Ethmoturbinal:

series of lateral wall ridges, appear during the **8th wk** (5-6 in number)

ultimately form 3-4 ridges through the process of fusion & regression

Name of ethmoturbinal	Derivative
1 st ethmoturbinal	Ascending part: agger Nasi (nasoturbinal); Decending part: uncinate process
2 nd	Middle turbinate
3 rd	Superior turbinate
4 th +5 th fuse	Supreme turbinate (Note: 60% of population has supereme nasal concha)

Maxilloturbinal	Inferior turbinate (Note: the inferior turbinate is not ethmoid derivative)
-----------------	---

The **inferior** turbinate is a **separate** bone, while the superior and middle turbinates are parts of **ethmoid** bone

The **middle** turbinate forms an important **landmark** from the point of view of FESS and should be preserved.

Concha Bullosa: an **aerated** middle/superior turbinate, may result in nasal obstruction

Furrows form between the ethmoturbinals & ultimately establish the primodal meati & recesses:

1st furrow (between the 1st & 2nd ethmoturbinals):

a. **Descending** aspect forms:

- 1) Ethmoidal infundibulum
- 2) Hiatus semilunaris
- 3) Middle meatus

a. **Ascending** aspect forms: Frontal recess

2nd furrow (between the 2nd & 3rd ethmoturbinals): Superior meatus

3rd furrow (between the 3rd & 4th ethmoturbinals): Supreme meatus

5 basal/ground lamellae of the paranasal sinus:

These lamellae are obliquely oriented and lie parallel to each other. They are helpful in maintaining orientation in ethmoid procedures.

- 1) Uncinate process
- 2) Bulla lamella: (usually results in the largest and most constant cell of anterior ethmoid complex)
 - If pneumonized it is called bulla ethmoidalis
 - If not pneumonized it is called: torus ethmoidalis/lateralis)
- 1) Basal lamella of the middle turbinate- divides anterior and posterior ethmoid complexes.
- 2) Lamella of superior turbinate
- 3) Lamella of supreme turbinate (if present)

Note: The ethmoid sinus is commonly referred to as "the labyrinth" due to its complexity and intersubject variability

The ethmoid bone:

The ethmoid bone ossifies in the cartilaginous nasal capsule from 3 centers:

One for each labyrinth; one for the perpendicular plate.

a) Labyrinth:

Labyrinth centers are present from 4th/5th intrauterine month; and are partially ossified at birth.

a) Perpendicular plate and crista galli:

Develop from 1 centre during the 1st Yr of birth; **Fuse** with the labyrinths at the beginning of the 2nd year.

a) Cribriform plate:

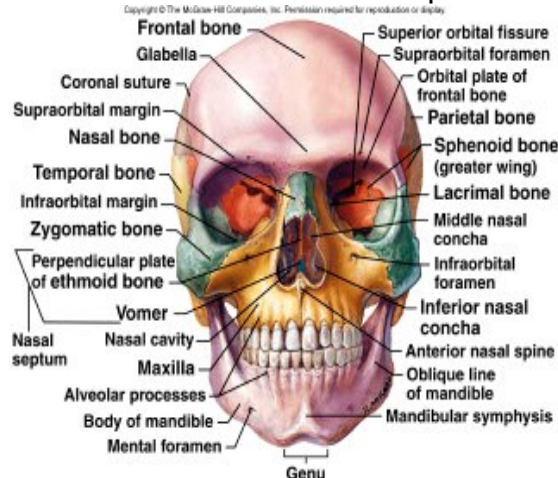
Both perpendicular plate centre and those for the labyrinth contribute to the cribriform plate.

Cribriform plate ossification occurs at the age of 3 years

Ossification of the cribriform plate stabilizes the whole **ethmoid complex**

Note: The nasal cavity grows rapidly in the 1st 6 years; the external nasal dimensions are generally mature at the age of 13 in females, 15 in males

Note: Normal nasal flora: Strep. Pneumonia, H.influenza, Moraxella catarrhalis, Staph



Nasolacrimal duct:

Each maxillary process is separated from the lateral nasal processes by the nasolacrimal groove.

This groove invaginates, and the epithelium within it is reabsorbed to form the nasolacrimal duct.

Frontal bone:

Ossifies in 2 centers one in each superciliary ridge appearing in 8th intrauterine week

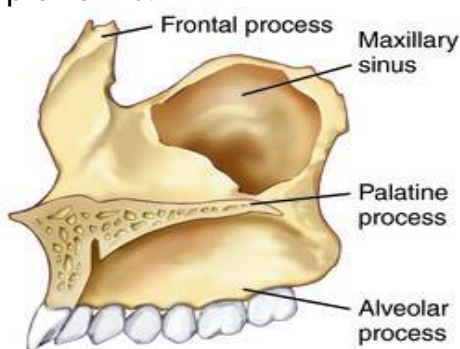
At birth the bone has 2 halves begin to fuse in 2nd year of life

The maxilla

Arise from 5 ossification centers these fuse to form:

Alveolar, palatine, zygomatic, frontal processes and the floor of the orbit.

The premaxilla:



Forms the anterior nasal spine

Maxillary bone is the 2nd largest Facial bone

The body is described as a quadrilateral pyramid & contains the maxillary sinus

Forming:

The majority of the roof of the mouth

Lateral wall and the floor of the nose

Floor of the orbit

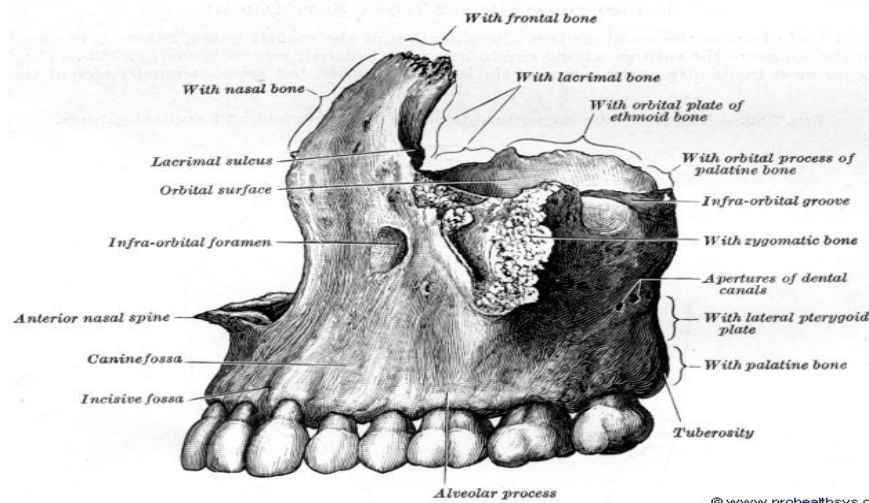
Contributing in the formation of:

Infratemporal fossa

Pterygopalatine fossa

Inferior orbital Fissure

FIG. 383.—The left maxilla. Lateral aspect.



© www.prohealthsys.com Pterygomaxillary fissures.

Maxillary Bone processes:

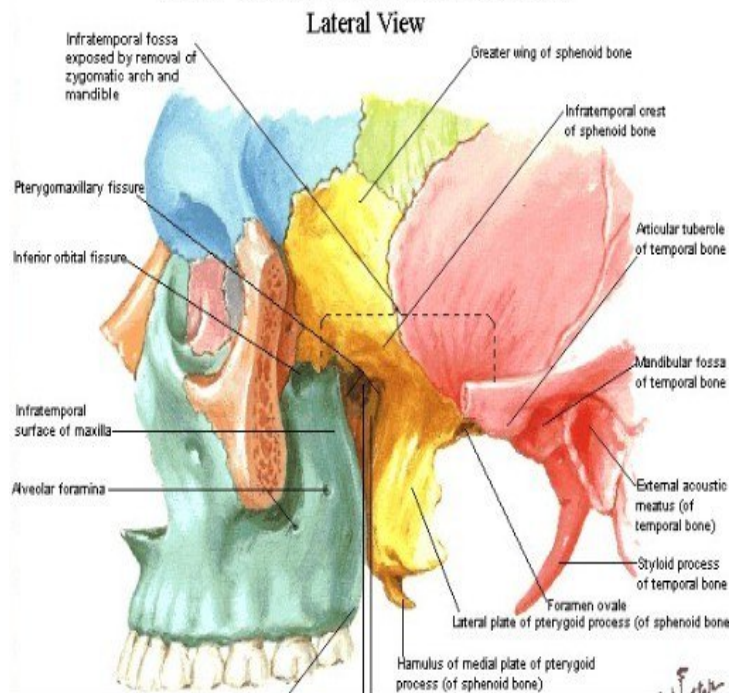
1. frontal process
2. zygomatic process
3. palatine process
4. alveolar process

The zygomatic process divides the lateral surface of the maxillary bone into anterior & posterior parts

It articulates with 8 bones:

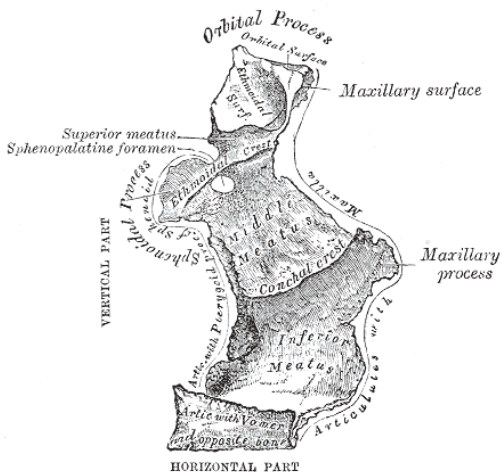
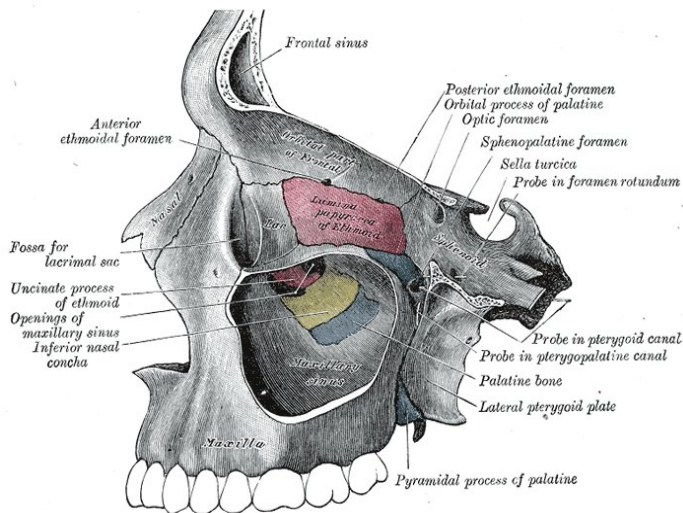
- 1) The opposite maxillary bone
- 2) Palatine bone
- 3) Zygomatic bone
- 4) Nasal Bone
- 5)

Skull - Infratemporal Fossa Exposed



Frontal Bone

- 6) Lacrimal Bone
- 7) Ethmoid Bone (lamina papyracea)
- 8) Inferior concha



The anterior surface:

Has the infraorbital foramen transmitting the infraorbital artery and nerve

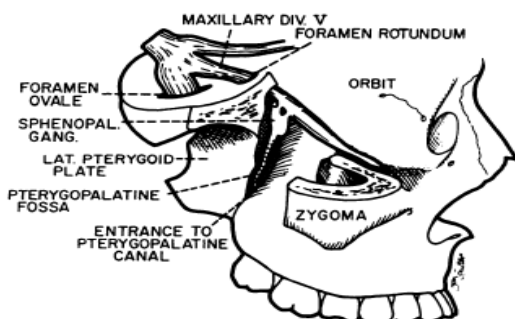
Nasolacrimal canal:

Nasolacrimal canal is created by indentation in the following bones:

- 1- Frontal process of maxilla (Nasolacrimal notch)
- 2- lacrimal Bone
- 3- Anterior part of Inferior turbinate

Conchal Crest:

Anterior to the Nasolacrimal groove



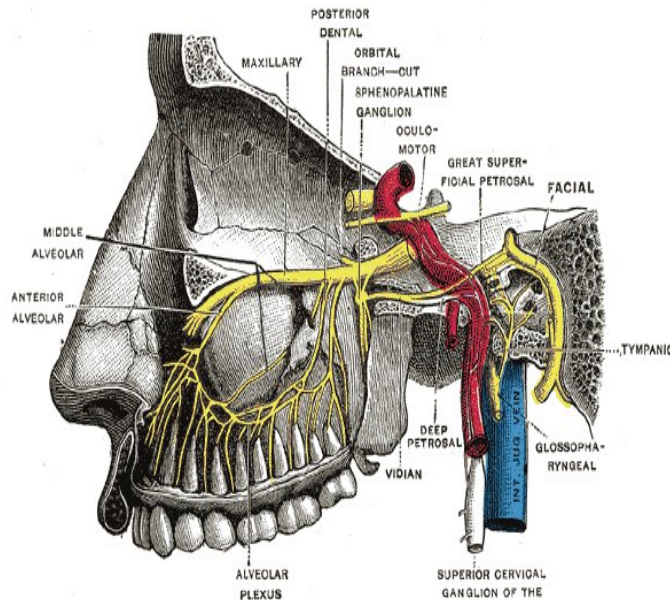
The posterior surface (Infratemporal surface)

attachment site for the inferior turbinate

Convex

At the center:

- 1- The surface is pierced and grooved near its centre by the alveolar canals which transmit the posterior superior alveolar vessels and nerves.
- 2- At the lower part of this surface:
There is a maxillary tuberosity which is rough for articulation with:
 - The tubercle (pyramidal process) of the palatine bone.
 - It gives origin to a few fibers of the medial pterygoid muscle
 -



articulates with the lateral pterygoid plate of

the sphenoid bone (in some cases)

- 3- The Anterior boundary of the pterygopalatine fossa:

Above the maxillary tuberosity.
grooved for the maxillary nerve

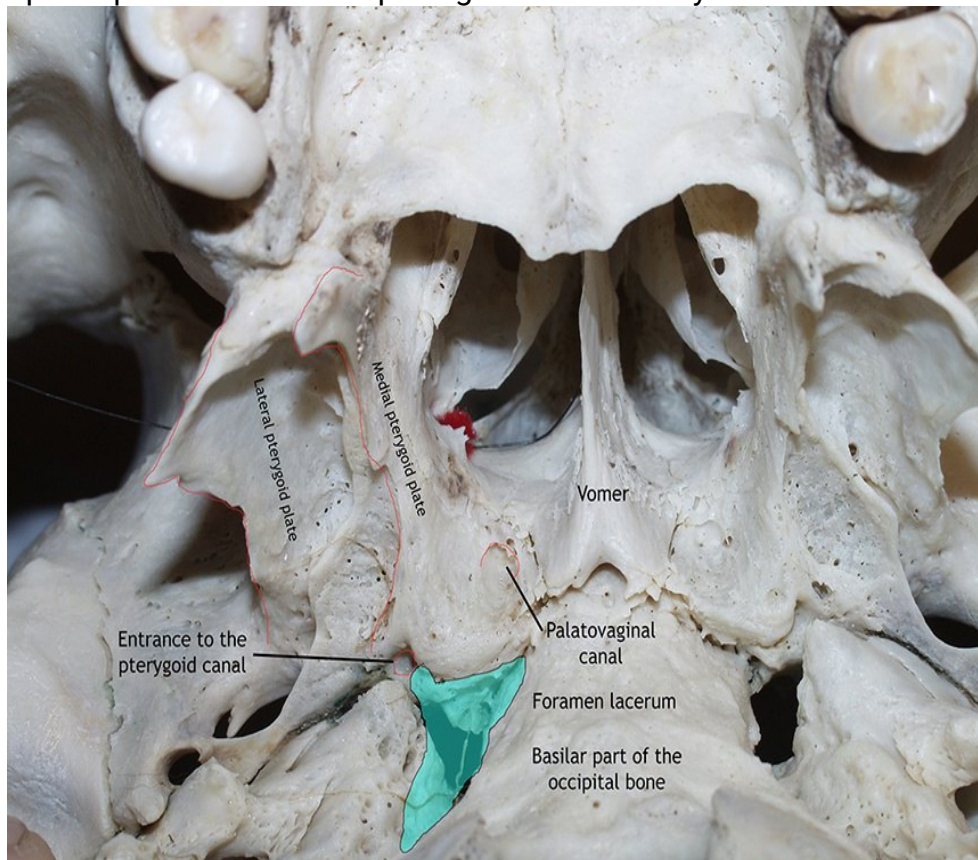
Pterygopalatine canal (Greater palatine canal):

Transmits:

- 1- descending palatine vessels
- 2- anterior palatine nerve: branch of the maxillary Nerve

Pterygoid canal reaching into the foramen lacerum

Sphenopalatine foramen opening into nasal cavity



Pharyngeal nerve going

through the palatovaginal canal (palatovaginal canal) - canal between the [sphenoid bone](#) and the [palatine bone](#) that connects the [nasopharynx](#) with the [pterygopalatine fossa](#)

Ethmoid Crest:

attachment site for:

- 1- middle turbinate
- 2- agger nasi

Inferior aspect of the Maxilla:

2 articulated maxillae = alveolar arch

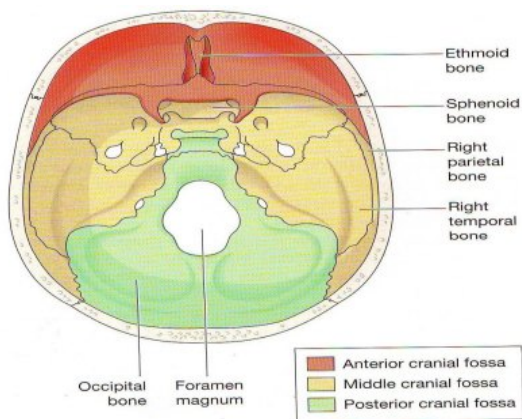
Forms the incisive foramen just posterior to the incisors

This foramen transmits (in separate canals to each side of the nose):

- 1- Nasopalatine Nerve from above
- 2- Greater palatine Artery from below

Palatine process of maxilla + horizontal plate of the palatine bone = hard palate

The inferior surface of the palatine process is pitted by Sharpey's fibers from the palatine periosteum, by vascular foramina and indentations from small salivary gland



The bones forming the base of the skull and the cranial fossae - viewed from above.

Sphenoid bone:

Embryology:

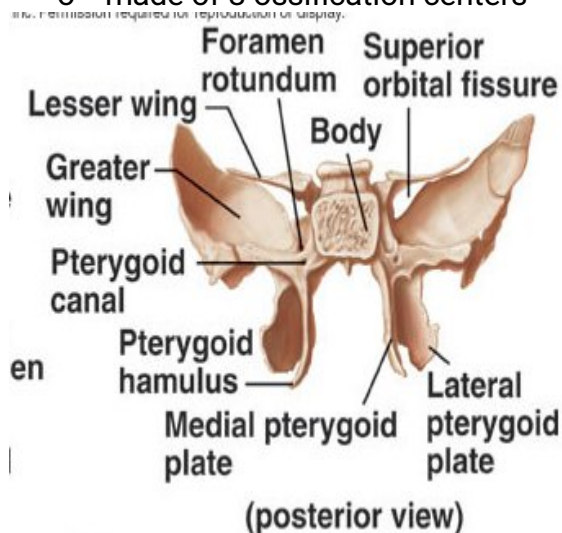
Divided into:

presphenoidal:

- o anterior to tuberculum sellae
- o made of 6 ossification centers
- o **Its anomalous fusion results in hypertelorism.**

postsphenoidal:

- o composed of sella turcica and dorsum sellae
- o made of 8 ossification centers



Pre and post fuse around 8th week intrauterine

(premature ossification can produce depression in nasal bridge (seen achondroplasia))

Anatomy:

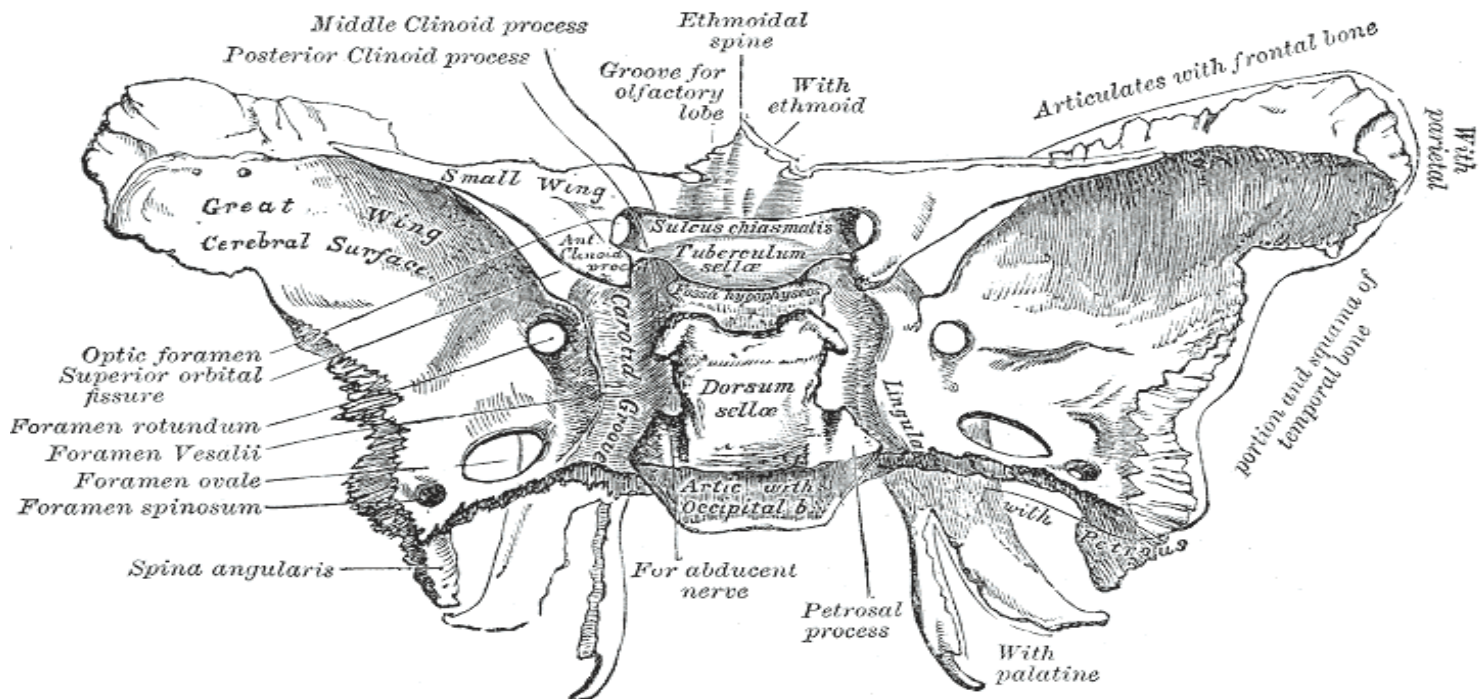
- The largest bone in the skull base
- Divides the Anterior & Posterior Cranial fossa By its lesser wings
- Greater wings contributes into the middle cranial fossa
- Lies anterior to the temporal & occipital bone

Sphenoid bone components:

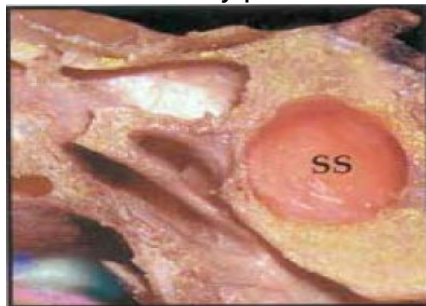
- Body: pneumatized to a variable degree
- 2 wings: lesser and greater wings
- 2 pterygoid processes: lateral and medial

Forms of pneumatization:

- Conchal 2-3% (rudimentary sinus)
- Presellar 11% (as far as the anterior bony wall of pituitary fossa)
- Sellar 59% (extends beneath pituitary fossa)
- Mixed 27%



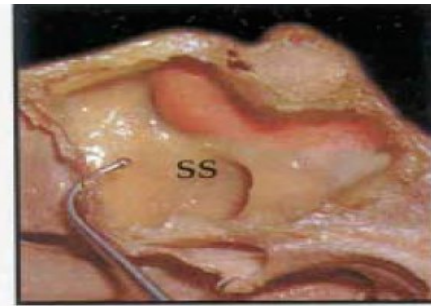
Sinus Divided by paramedian septum, absent in 1%



Conchal



Presellar



Sellar (including "postsellar")

Surfaces of the body:

A- The superior surface of the body:

1. The ethmoidal spine: articulates with the cribriform plate.
2. Groove for olfactory lobe: smooth surface slightly raised in the middle line and grooved on either side for the olfactory lobes of the brain.
3. The chiasmatic groove (optic groove):
 - the anterior border bound the posterior aspect of the olfactory groove
 - above and behind which lies the optic chiasm
 - Ends on either side in the optic foramen (which transmits the optic Nerve and ophthalmic Artery into the orbital cavity). (optic foramen distance from posterior ethmoid artery is 5-10mm)
1. The tuberculum sellae; elevation behind the chiasmatic groove.
2. The sella turcica:

deep depression posterior to the tuberculum sellae

The fossa hypophyseos: The deepest part of sella turcica of which lodges the hypophysis cerebri.

The anterior boundary: is completed by 2 small eminences called the middle clinoid processes.

the posterior boundary: is formed by a square-shaped plate of bone, the dorsum sellae

1. The dorsum sellae:

ends at its superior angles in 2 tubercles, the posterior clinoid processes

The size and form of which vary considerably in different individuals.

The posterior clinoid processes:

1- Deepen the sella turcica.

2- Give attachment to the tentorium cerebelli.

On either side of the dorsum sellae is a notch for the passage of the abducent nerve.

Petrous process: sharp process below the notch, Articulates with the apex of the petrous portion of the temporal bone, Forms the medial boundary of the foramen lacerum.

1. clivus:

Posterior portion of the sphenoid (basisphenoid) articulates with basilar part of the occipital bone (basocciput) to form the clivus

Basisphenoid + basocciput = clivus

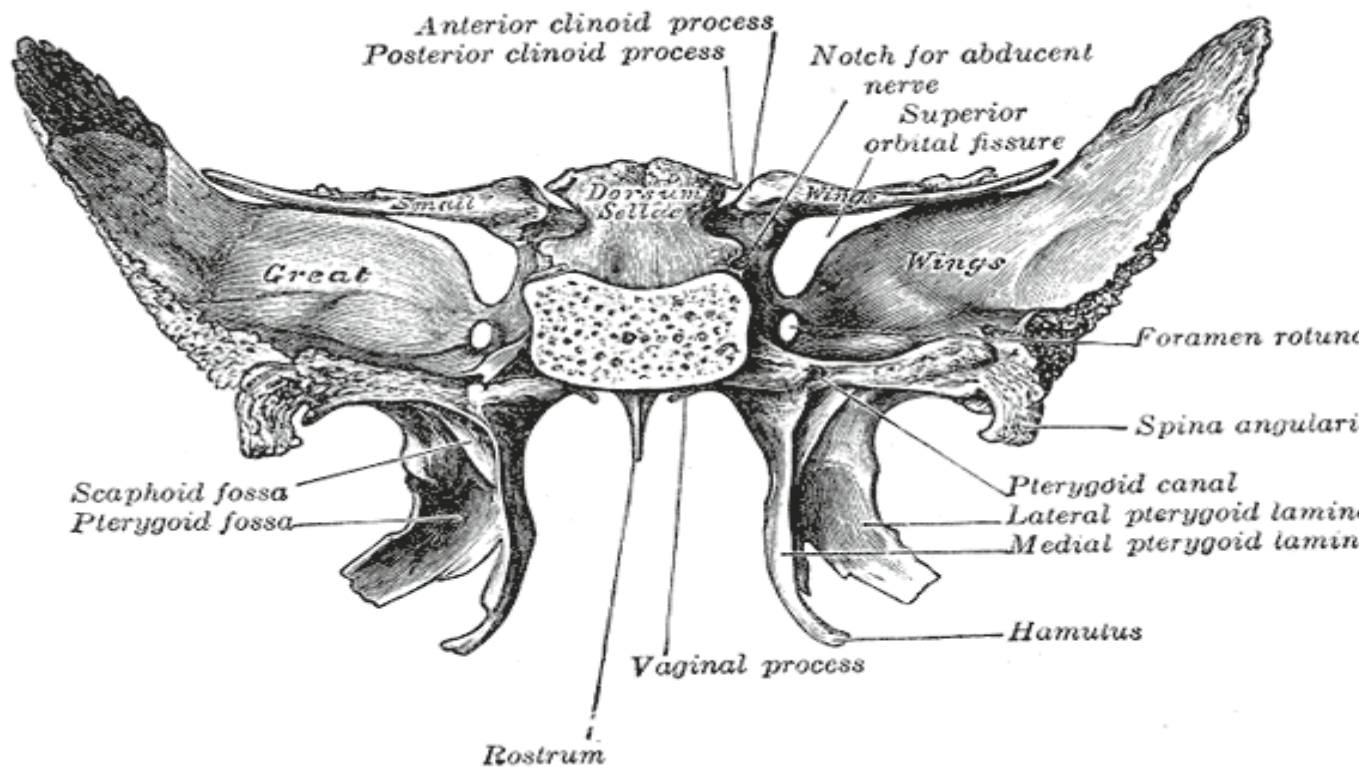
Shallow depression posterior to dorsum sellae

Slopes obliquely backward

Continuous with the groove on the basilar portion of the occipital bone

It supports the upper part of the pons.

Note: the bone slopes away posterior to dorsum sellae toward the clivus



Carotid sulcus: groove on the lateral surface of the body made by the internal carotid artery as it transverses the cavernous sinus (dehiscent in 25%)

A- Anterior surface of the body:

1- crest: articulates with the perpendicular plate of the ethmoid

2- ostia of the sinuses:

On either side

Half way up the face

Large (5-8mm) on macerated skull, but are partially overlapped & closed by sphenoid concha & mucus membrane

The sinuses open into the sphenoethmoidal recess superior and medial to the superior turbinate

A- Inferior surface of the body:

Bears the rostrum which articulates with the vomer

Greater wings:

Contributes to:

Intra cranially:

- 1- The middle cranial fossa
- 2- foramen lacerum

Orbit:

- 1- The posterior-lateral orbital wall
- 2- Lower part of the superior orbital fissure
- 3- upper part of the inferior orbital fissure

Lateral aspect of the skull:

- 1- Medial wall of the Infratemporal fossa: Lateral surface of the greater wings
- 2- posterior wall of pterygopalatine fossa: anterior surface of pterygoid process

Note: the greater wings and lateral pterygoid plates forms the lateral aspect of the infratemporal fossa

Pterygoid processes

Perpendicular process

Arise from the junction of the body & greater wings

Each pterygoid process is formed of medial & lateral inferior pterygoid plate

Medial pterygoid plate has inferiorly the pterygoid hamulus around which the tensor palat tendon hooks

At the base of Medial pterygoid plate is lacerum foramen:

- o Bounded by medial pterygoid plate, petrous part of temporal bone and basilar part of occipital bone
- o Internal Carotid artery runs along the cranial aspect of the foramen
- o Lateral to the foramen lies the internal auditory meatus

Between the Lateral pterygoid plate and the posterior aspect of maxilla lies the pterygomaxillary fissure which leads to the pterygopalatine fossa

At the base of the lateral pterygoid plate is the foramen ovale & spinosum

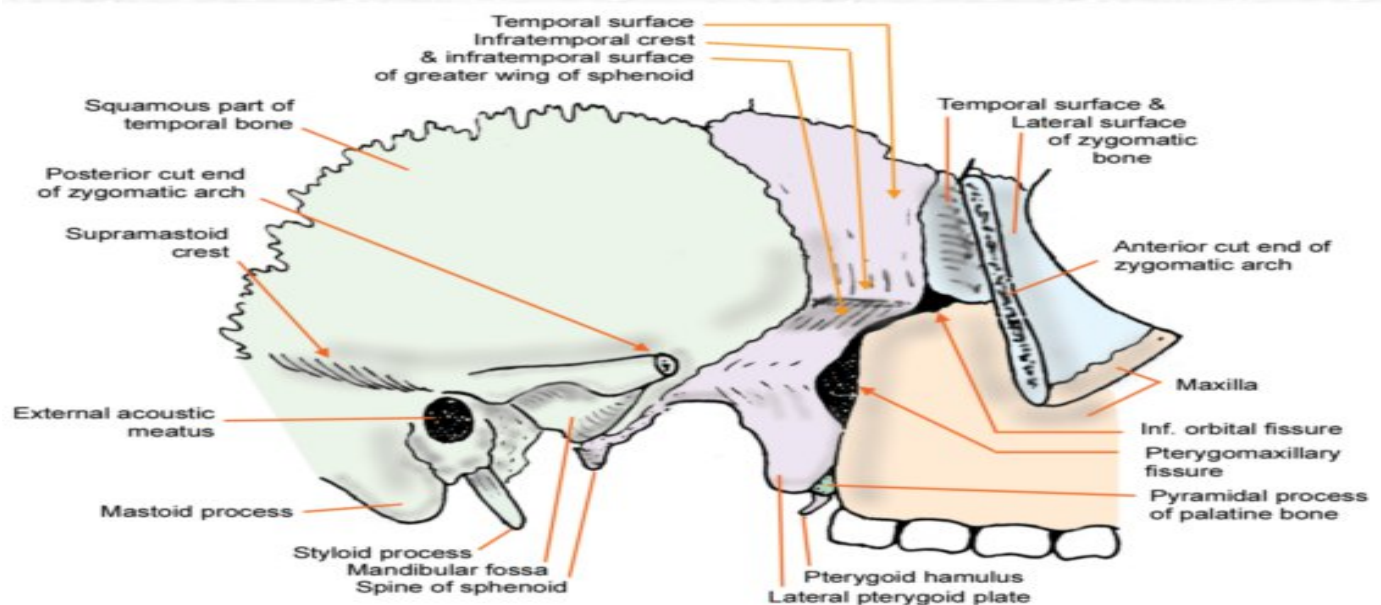
The medial pterygoid plate articulates with vertical plate of the palatine bone

lateral and medial plate which diverge around the pterygoid canal which transmits the pterygoid nerve and artery and which may invaginate the floor of the sphenoid sinus

Anterior and posterior pterygoid plates are fused anteriorly creating pterygoid fossa

Cranial to the pterygoid fossa is the sphenoid fossa

Note: between the Greater wings and superior aspect of maxilla lies the inferior orbital fissure



Inferior meatus & turbinate

Inferior meatus:

Part of the lateral wall of the nose **lateral** to the **inferior** turbinate.

It is the **largest** meatus, extending almost the **entire** length of the nasal cavity.

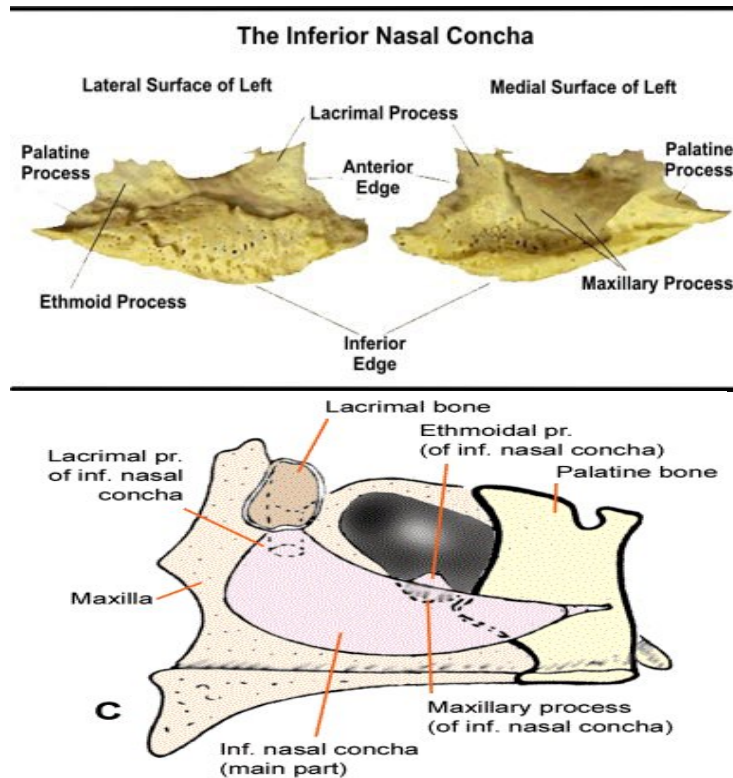
The meatus is **highest** at the junction of the **anterior** and **middle** third (this ranges from 1.6 to 2.3 cm (mean 1.9 cm) at 1.6 cm along the bony lateral wall)

The **nasolacrimal duct** opens into the inferior meatus usually just **anterior** to its **highest** point (Anterior 1/3)

There is **no** true **valve**, the opening being covered by small folds of mucosa.

Endoscopically can be identified by gentle massage of lacrimal sac at the medial canthus.

Inferior turbinate:



composed of a **separate** bone

60mm in anterior to posterior direction

The inferior concha has its own ossification centre which appears around the 5th intrauterine month.

The inferior concha has an **irregular** surface, **perforated** and grooved by vascular channels to which the mucoperiosteum is firmly attached.

articulates with:

- 1) **Inferior** margin of the **maxillary** hiatus via maxillary process.
- 2) lacrimal bones, completing the **medial** wall of the nasolacrimal duct
- 3) ethmoid bone
- 4) palatine bone

Possess an impressive submucosal cavernous plexus with large sinusoids under autonomic control which provides the major contribution to nasal resistance.

The turbinate is covered by respiratory epithelium, with a high number of goblet cells (approximately 8/mm²) which decrease in density towards the posterior end.

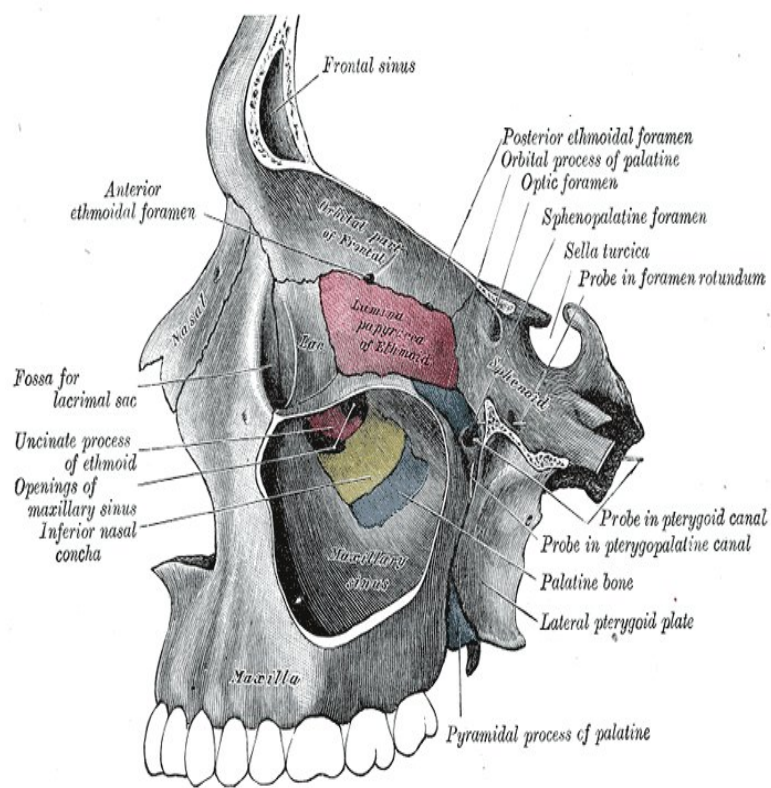
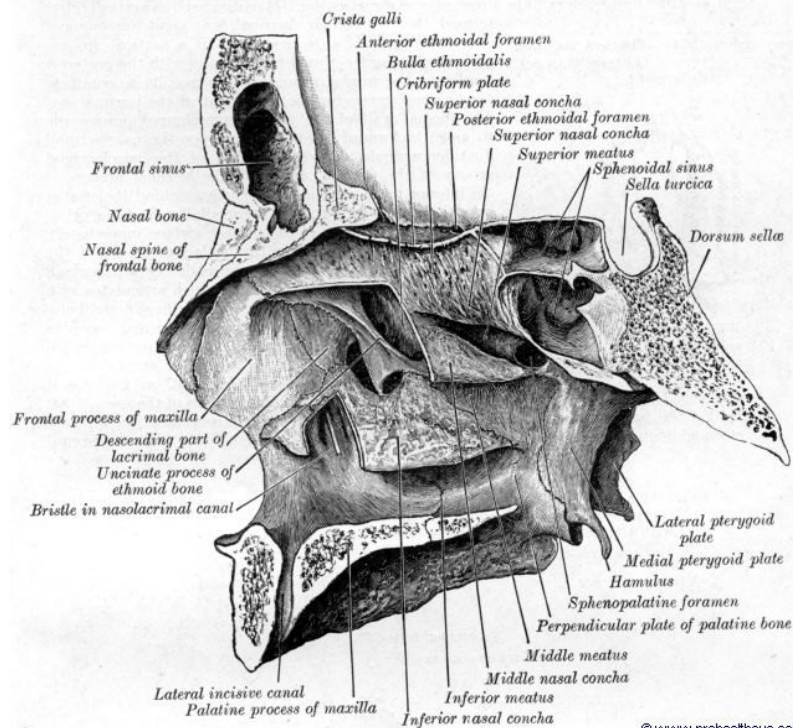
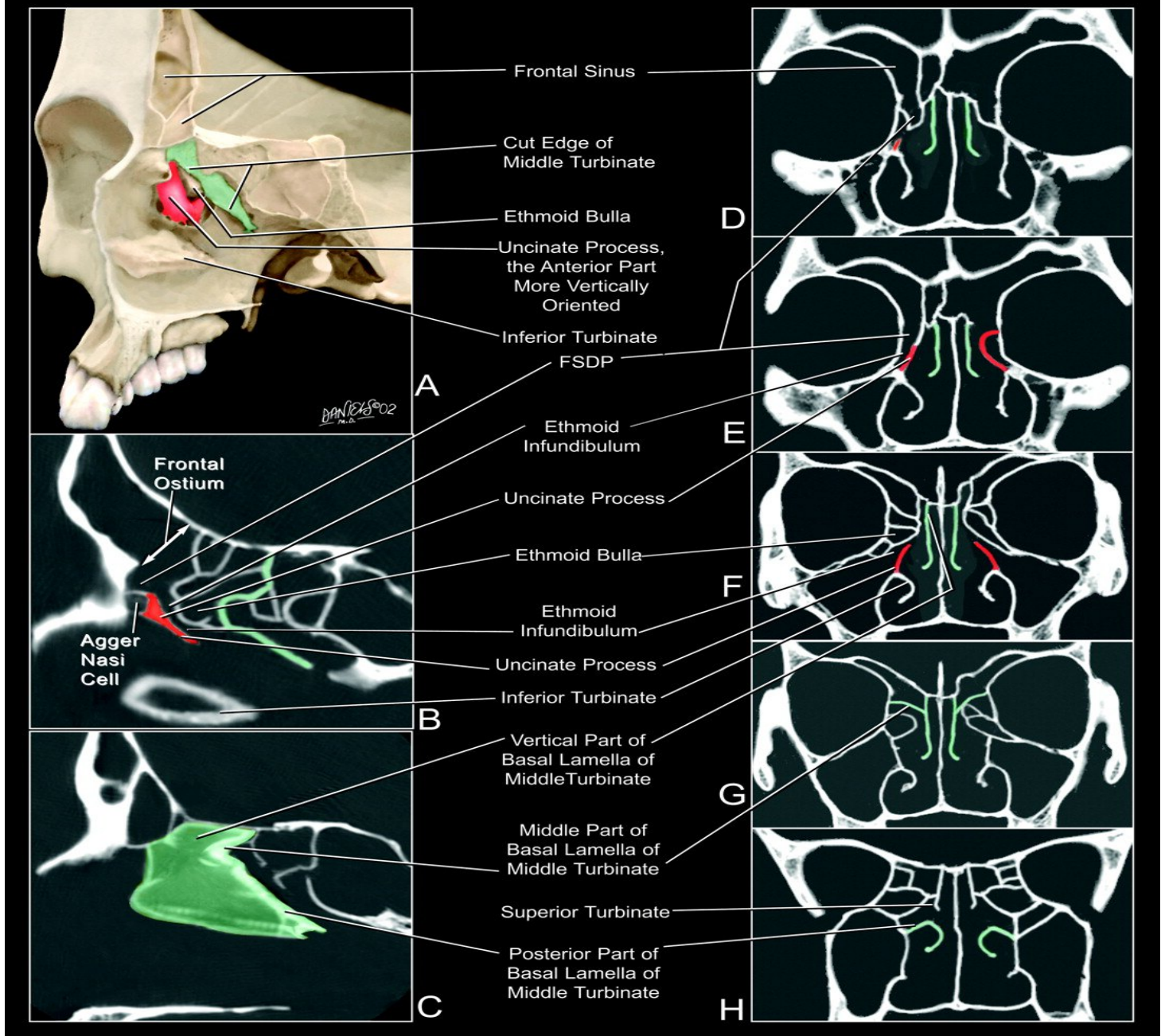


FIG. 371.—The lateral wall of the right nasal cavity, after removal of parts of the middle and inferior nasal conchæ.



© www.proheathsys.com **Nerve supply : greater palatine nerve**

(major) + anterior ethmoid nerve



The configuration of the structures of the **middle meatus** is complex and variable

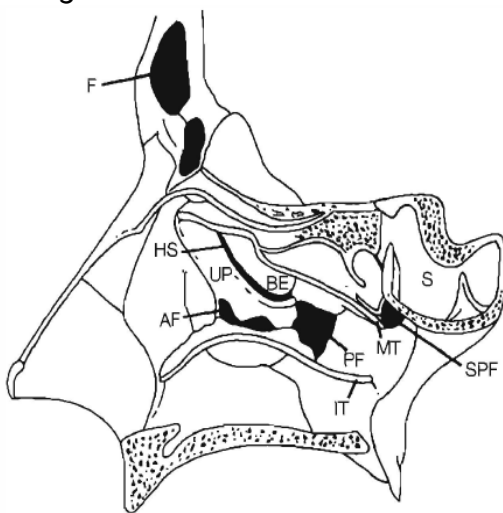


Figure 104.29 Bony structures of lateral nasal wall. AF, anterior fontanelle; BE, bulla ethmoidalis; F, frontal sinus; HS, hiatus semilunaris; IT, inferior turbinate: attachment; MT, middle turbinate: attachment; PF, posterior fontanelle; S, sphenoid sinus; SPF, sphenopalatine foramen; UP, uncinate process.

bone

posterior: the perpendicular plate of the palatine bone;

anterosuperior: a small portion of the lacrimal bone;

Superior: the uncinate process and bulla of the ethmoid.

inferior: the maxillary process of the inferior turbinate

A portion of the maxillary hiatus is nevertheless left open by these osseous attachments, which in life are filled by the mucous membrane of the middle meatus, the mucous membrane of the maxillary sinus and the intervening connective tissue -the membranous portion of the lateral wall.

This membranous area can be defined as lying anterior or posterior to the uncinate process, constituting the anterior and posterior fontanelles, respectively.

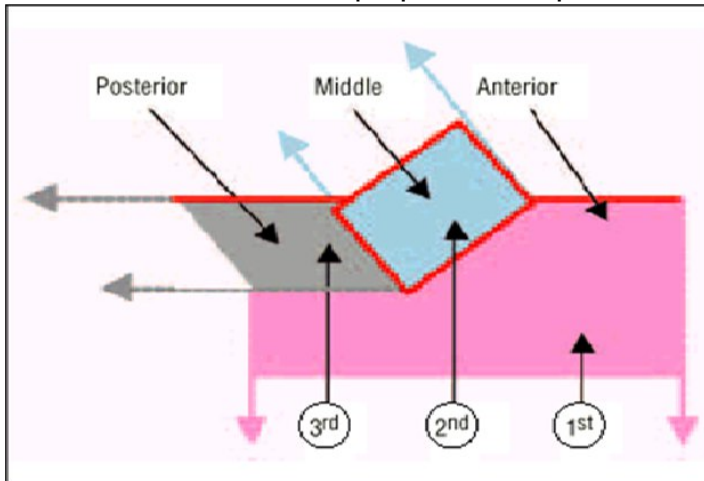
It is in the fontanelles that accessory ostia are found, their formation probably arising as a consequence of infection and, consequently, they have been compared to perforations in the tympanic membrane.

It is difficult to ascertain a 'natural' incidence for accessory ostia but it is probably of the order of 4-5 percent in the general adult population, increasing to 25 percent in patients with chronic rhinosinusitis.

Accessory **Middle turbinate** frequently in the posterior fontanelle which is generally larger than its anterior counterpart.

In the **anterior and superior** aspect of the middle turbinate, it attaches **laterally** at the agger nasi **area** specifically at the **crista ethmoidalis** of the **maxilla**

The posterior end is attached to the crista ethmoidalis of the perpendicular process of the palatine bone (lamina perpendicularis)



Then moves superiorly medially at follow:

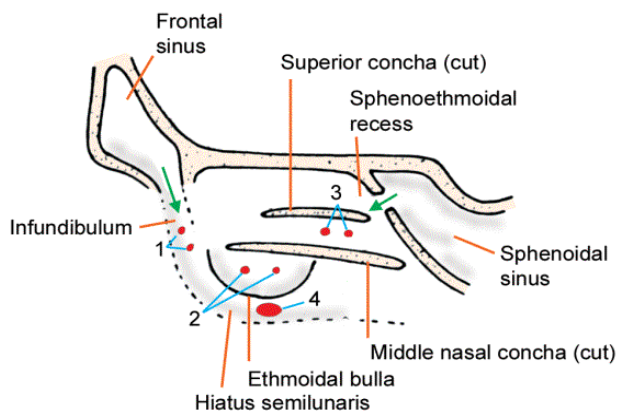
Part	Location	Plane	Attachment
1 st	Anterior=medial	Sagittal (vertical)	Skull base (between the cribriform plate & lateral lamella/ lateral aspect of lamina cribrosa "cribriform fossa")
2 nd (basal lamella)	Middle	Coronal (obliquely)	Lamina papyracea and/or medial wall of the maxillary sinus
3 rd	Posterior-lateral	Horizontal	Crista ethmoidalis of Perpendicular plate of the palatine bone

As we move from the 1st part to the 3rd part we moves from medial to lateral

1st part:

The anterior cranial fossa may invaginate into this attachment with olfactory filae

Danger area is above + medial+ lateral to The superior /vertical attachment of middle turbinate



- 1 = Openings of anterior ethmoidal sinuses
- 2 = Openings of middle ethmoidal sinuses
- 3 = Openings of posterior ethmoidal sinuses
- 4 = Opening of maxillary sinus

2nd part (basal lamella):

An **important** land mark in FESS

Separates the anterior from the posterior ethmoid air cells

- o The **boundaries**:
- o Superiorly: skull base (fovea ethmoidalis)
- o Inferiorly: 3rd part of middle turbinate
- o Medially: 1st part of the middle turbinate
- o Laterally: lamina papyracea

3rd part:

The attachment of the middle turbinate into the perpendicular plate is just **anterior** to **sphenoplatine artery**

Notes:

The shape of the middle turbinate is highly variable as it can be paradoxically curved (medially concave) or pneumatized.

If the vertical portion or lamella of the middle turbinate is pneumatized, the cell that is formed is referred to as the intralamellar cell.

Pneumatization of the head of the middle turbinate is referred to as a concha bullosa.

Length of 40mm, height anteriorly 14.5mm posteriorly 7mm

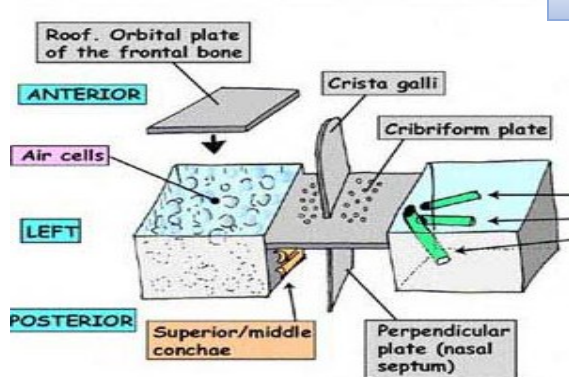
Middle turbinate is an important landmark:

It separates the **cribriform plate** from the **fovea ethmoidalis**

its **anterior** tip marks the limits of **anterior** dissection of **maxillary antrostomy** so you won't injure the nasolacrimal duct

the **basal lamella** identifies the entrance into the **posterior ethmoidal** sinuses

the **lower** half of the middle turbinate and its insertion into the choana help to identify the entrance into the **sphenoidal** sinus



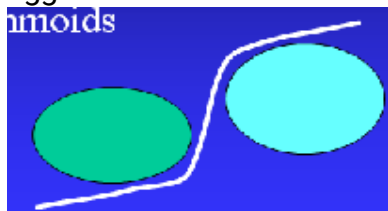
Embryology:

arise as multiple separate **evaginations** from the lateral wall of the nasal **capsule** around the 5th month of gestation

3–4 cells at birth (**most developed paranasal sinus at birth**)

formed from 5 ethmoid turbinals:

- 1) agger nasi
- 2) **ethmoids**

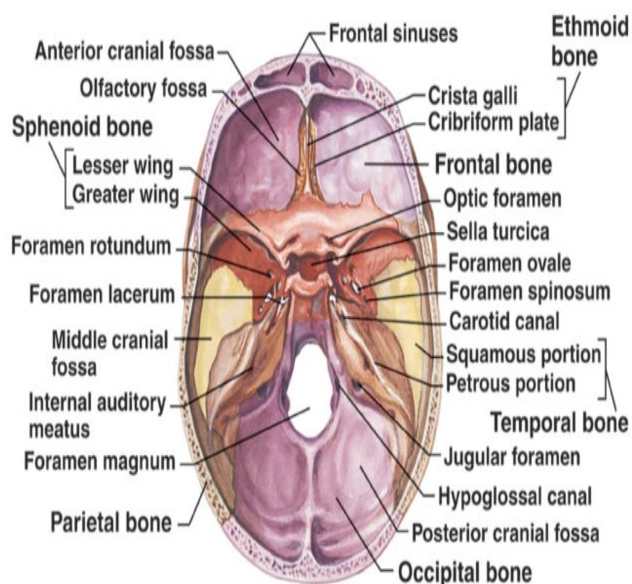


- 3) ethmoid bulla
- 4) ground lamella
- 5) posterior wall of the most posterior ethmoid cell

Volume at Adult:

10–15 aerated cells, total volume of 2–3 ml (adult size at 12–15 years old)

they are divided into anterior and posterior ethmoid sinus by basal lamella of the middle turbinates



anterior ethmoid cells: 2-8

posterior ethmoid cells: 1-5 (fewer # and larger in size)

Posterior ethmoid air cells relations:

Anteriorly: basal lamella of the middle turbinate

Posteriorly: sphenoid sinus

Superiorly: fovea ethmoidalis

Inferiorly: the **posterior** part of the middle turbinate

Medially: superior meatus & superior turbinate

Laterally: lamina papyracea

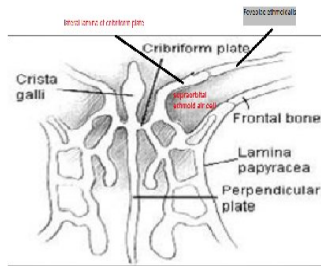
The posterior ethmoid cells are often found to be the cause of potential **complications** during FESS because:

- 1) **Optic** nerve is too close to the **posterior** ethmoid air cells
- 2) The **medial rectus** is closer to the posterior ethmoid than to the anterior ethmoid because of the

thinner orbital fat

- 3) The **posterior** ethmoid artery lies in the **roof** of the posterior ethmoid just anterior to the anterior wall of the sphenoid sinus

Cribriform plate:



Perforated by the Olfactory nerve fibers

Attached to:

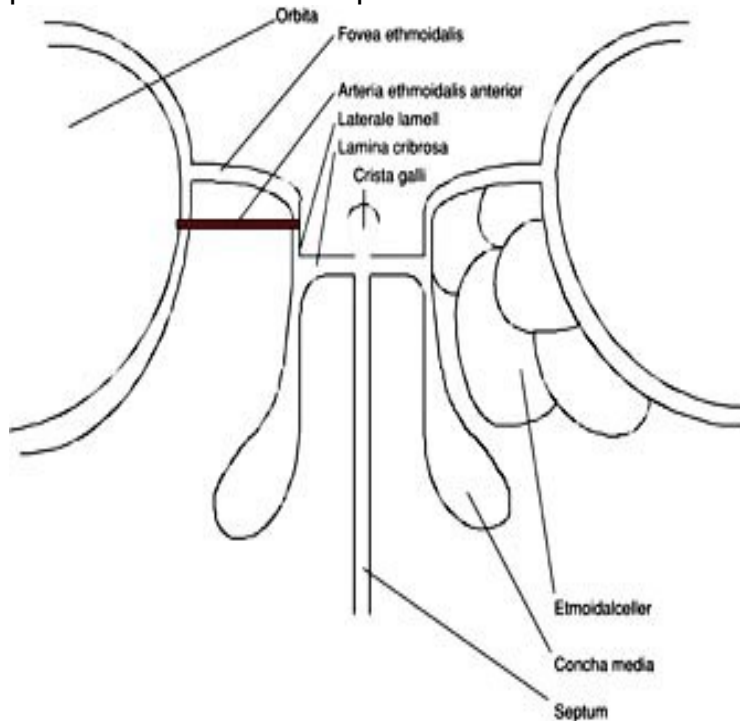
medially: crista galli + perpendicular plate of the ethmoid bone (both at same level)

laterally: lateral lamella + superior attachment of middle turbinate (both at same level)

superior attachment of the middle turbinate is the **land mark** of cribriform plate

meningitis post intranasal surgery occurs due to:

- 1) penetration of cribriform plate
- 2)



Olfactory nerve

spread via perineural lymphatic of

Ethmoid roof:

In a disarticulated skull, the ethmoid bone is open superiorly (at least the anterior 2/3) lateral to the lateral lamella of cribriform plate & insertion of middle turbinate

The bony coverage of these open ethmoidal cells is provided by the frontal bone with its foveolae ethmoidalis = Osis frontalis

so the roof of the ethmoid bone is made by:

- 1) **most** medially: lateral lamella of cribriform plate
- 2) laterally: **frontal bone**

the part of the roof which is made of the frontal bone has different configurations:

- a) anterior ethmoid roof: step ladder
- b) posterior ethmoid roof: flat

Foveolae ethmoidalis:

part of the frontal bone

joins the lateral lamella of cribriform plate medially

thicker and denser than the adjacent bony lateral lamella of cribriform plate

This difference is **greatest medially** (in the transition from the thicker bony lamellae of the frontal bone to the much thinner lateral lamella of the cribriform plate)

The lateral lamella of the cribriform plate, where the anterior ethmoid artery crosses from the medial orbital wall into the cribriform, is the thinnest bone in the entire anterior skull base

Foveolae ethmoidalis 0.5mm thickness

Lateral lamella of the cribriform : 0.2mm thickness

ethmoidal sulcus:

the **thickness of the wall may be reduced to 0.05 mm**, and is therefore by a factor 10x thinner than the roof of the ethmoid, The length of the ethmoidal sulcus can vary between 3 and 16 mm. The height of the lateral lamella of the cribriform plate is also variable (1-17 mm) and the ethmoid roofs themselves are often asymmetric 10% with the right more often lower than the left.

At the calvarium:

the dura of the **anterior** cranial fossa is **relatively** thin & **adherent** to the **skull base, particularly** where **anterior ethmoidal artery** and the **olfactory filaments** pass through the cribriform plate. In the majority of cases, the anterior ethmoidal artery is intradural on its way through the olfactory fossa.

Trauma in this region, therefore, may easily lead to dural tears with subsequent CSF leakage and, possibly, even intracranial bleeding from branches of the anterior ethmoidal artery.

The Olfactory fossa:

The space between midline (**crista gali**) and the **lateral lamella** of cribriform plate

floor of olfactory fossa: The cribriform plate (lamina cribrosa)

lateral wall of the olfactory fossa: The lateral lamella of cribriform plate

It contains the **Olfactory bulb**

Lateral lamella of cribriform plate connections:

Superior end connects to: The foveolae ethmoidalis (roof of the ethmoid)

Inferior end connects to: The cribriform plate (floor of the olfactory fossa)

So the length of the lateral lamella of the cribriform plate is:

- The depth of the olfactory fossa
- Determines the relationship between the olfactory fossa and the ethmoid roof
- Configuration of the ethmoid roof

Note: lateral lamella of the cribriform plate is the medial wall of the ethmoid dome

Keros classification of the ethmoid roof configuration

This classification is based on the **length** of the **lateral lamella** of the cribriform plate=Depth of the olfactory fossa.

Note: the **lateral lamella** of the cribriform plate is on the **same** plane of **middle turbinate**

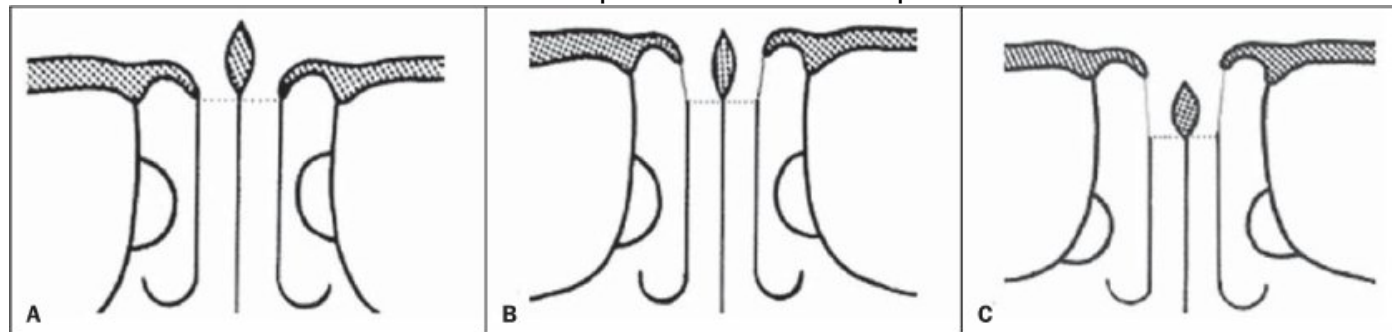
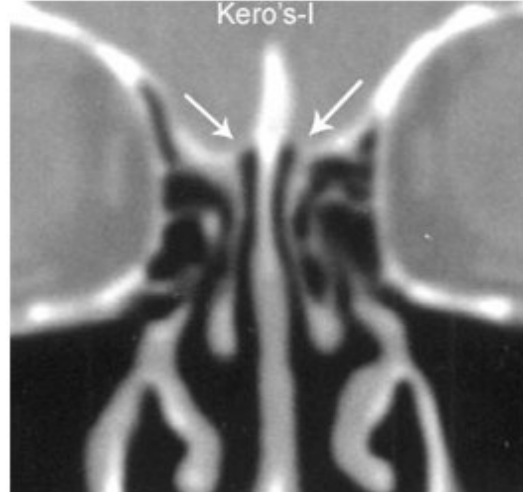
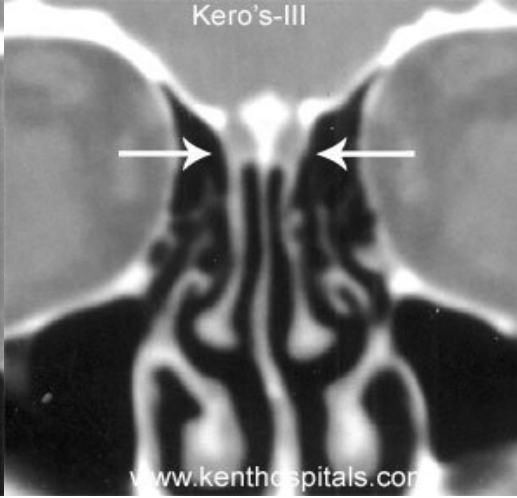
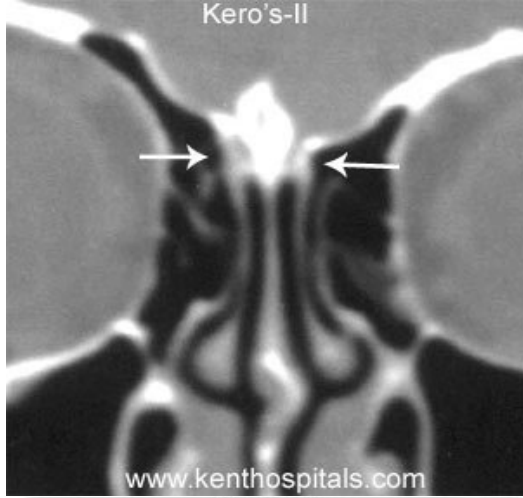


Figure 1. Schematic representation of the three types of olfactory fossae according to the Keros classification: A, type I; B, type II; C, type III. (Modified from Stammberger⁽⁹⁾).

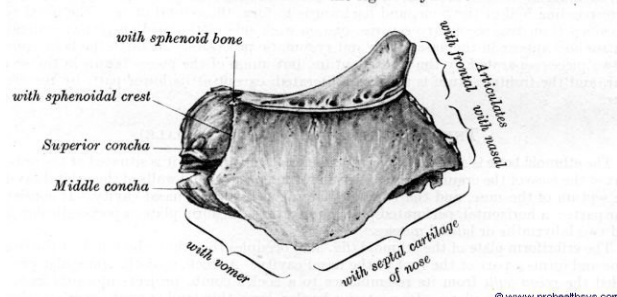
Type of Kero's	Lateral lamella length/ depth of Olfactory fossa	Description of lateral lamellalength	Relation between the ethmoid roof and cribriform plate
Type I	1-3mm	short (almost nonexistent)	The roof and plate are almost in the same plane
Type II	4-7mm	Longer	The roof lies higher than the cribriform plate
Type III	8-17mm	Very long	The roof lies significantly above the plate



The clinical significance of the Keros classification:
Keros type III with a long, thin, lateral lamella forming a significant part of the medial part of the ethmoid sinus. Which means 14-16mm of **anterior cranial fossa** is **medial** to where **instrumentation** may be used. So **greatest concern** for the surgeon **for inadvertent intracranial injury**

Note: The Keros classification does not evaluate the skull base height in the posterior ethmoid. This should be evaluated by comparing the ratio of the ethmoid height to that of the height of the maxillary sinus.

FIG. 367.—The perpendicular plate of the ethmoid bone. Right lateral aspect. Shown after removal of the right labyrinth.



Lateral wall of ethmoid labyrinth:

It is made of lamina papyracea which is paper thin Perpendicular plate of the ethmoid bone

Nerve supply of the ethmoid sinus:

- 1) Anterior + posterior ethmoid nerves
- 2) Supra-orbital nerve
- 3) Posterior superior lateral nasal branch

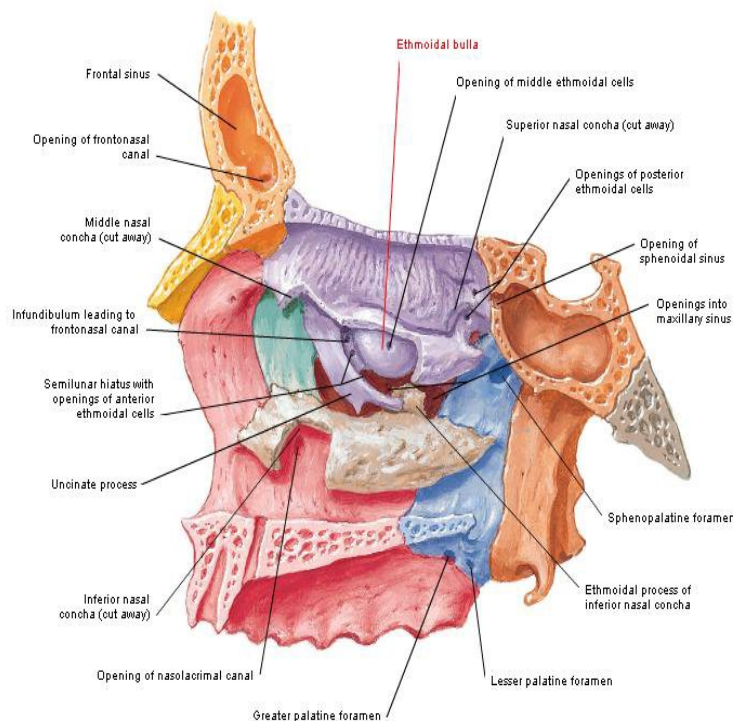
Ethmoid Bulla:

A hollow bony prominence based on **lamina papyracea**

The **largest anterior** ethmoid air cell

The most **constant** ethmoid air cell + **constant** features of the middle **meatus**

May be completely unpneumatized (**8%**): alternatively called **torus lateralis/ethmoidalis (lateral bulge)**



Relations of the ethmoid bulla:

Anteriorly & inferiorly

The **ethmoid infundibulum** separates the bulla from the **uncinate** process

So Anterior surface of the bulla forms the posterior margin of the ethmoid infundibulum + hiatus semilunaris

Superiorly

Suprabullar recess (anterior & superior portion of the lateral sinus) separates the bulla from **fovea ethmoidalis**

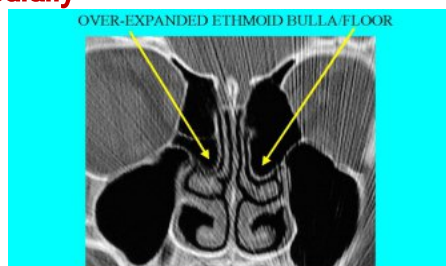
may reach the ethmoidal roof, forming the posterior wall of **frontal recess**

Posteriorly

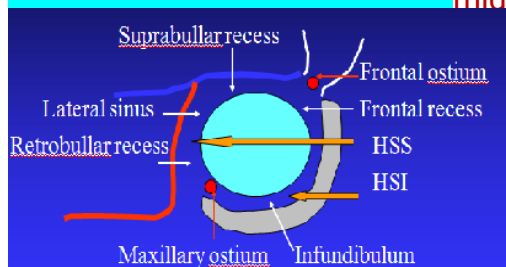
may fuse with the basal lamella of the middle turbinate

the **retrobullar** recess Separates the posterior wall of the bulla and **basal lamella of the middle turbinate**

Medially



middle meatus separates the bulla from the **middle turbinate**

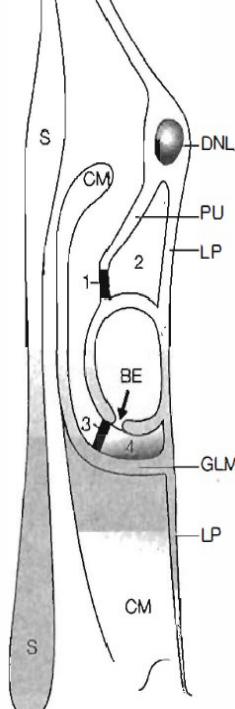


the lumen between the middle turbinate & bulla is called **concha sinus**

Laterally: based on lamina papyracea (lamina orbitalis)

Drainage: bulla ethmoidalis drain Posteriorly into the retrobullar recess

black triangle indicates the tip of the nose. 1, inferior hiatus semilunaris; 2, ethmoidal infundibulum; 3, superior hiatus semilunaris; 4, retrobullar recess; BE, bulla ethmoidalis; CM, concha media; DNL, nasolacrimal duct; GLM, ground lamella of middle turbinate, middle (frontal) portion; LP, lamina papyracea; PU, uncinate process; S, nasal septum.



Lateral sinus

Divided into:

- 1) suprabullar space:
 - located superiorly and anteriorly
 - borders:
 - superiorly: skull base (fovea ethmoidalis)
 - inferiorly: bulla
 - laterally: lamina papyracea
 - Posteriorly: basal lamella of middle turbinate
 - It is separated from the frontal recess by suprabullbar lamella.
 - o In the absence of this lamella the suprabullbar recess of the lateral sinus is contiguous with the frontal recess of the infundibulum
 - o if the bulla directly adheres to fovea ethmoidalis there will be no suprabullbar space
- 1) retrobullar recess:
 - the most posterior aspect of anterior ethmoid, located inferior posterior
 - borders:
 - o anteriorly: ethmoid bulla
 - o posteriorly: basal lamella
 - if the bulla directly adheres to the basal lamella there will be **no** retrobullar recess
 - in case the bulla did **not** adhere to the basal lamella the suprabullar recess will extend into the retrobullar recess

Suprabullar and retrobullar space may be contiguous or separated by complete/incomplete bony septation

both **Suprabullar and retrobullar space** drain into hiatus semilunaris **superior**, so these recesses can be approached **medially & inferiorly** through hiatus semilunaris **superior**

Uncinate Process:

hook/sickle/crescentic-shaped thin bone located in sagittal plane
 covered by mucoperiosteum
 part of the ethmoid bone, medial to the ethmoid infundibulum
 forms the anterior border of the hiatus semilunaris
 lateral to the middle turbinate (derived from the second ethmoidal turbinal)
 forms the 1st layer of the middle meatus

Dimensions: 2 cm in **length**, 3-4 mm in **width**, **sagittally oriented**

Attachment:

1. Anterior-superior: ethmoidal crest of the maxilla
 - Immediately below this it attach to the posterior edge of the lacrimal bone
 - This is why in maxillary antrostomy we remove bone anterior as far as the anterior attachment of the uncinate process so to avoid injury to lacrimal duct**
1. Anterio-inferior: no attachment
2. Posterior: free margin with no bony attachment

3. **Posterior-inferior:** the superior edge of the inferior turbinate.
4. **Laterally:** lamina papyracea
5. **Superior attachment:** is highly variable, may be attached to
 - 1) The lamina papyracea
 - 2) The roof of the ethmoidal sinus
 - 3) Middle turbinate

The superior, middle, inferior part of the uncinate process is related to 3 sinuses:

1) **Superior segment of the uncinate process :**

Superior attachment of the uncinate process determines:

- The configuration of the ethmoidal infundibulum
- infundibulum relationship to the frontal recess

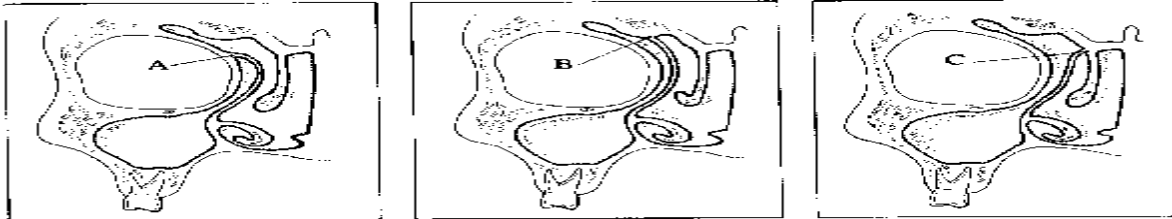
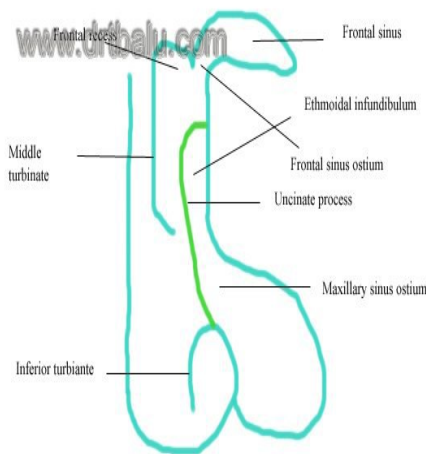


Fig 4. Variants of uncinate process. Most often, superior attachment of uncinate process is laterally onto lamina papyracea (A), but it may attach to skull base centrally (B) or medially (C).



Classification of the uncinate process based on its superior attachment

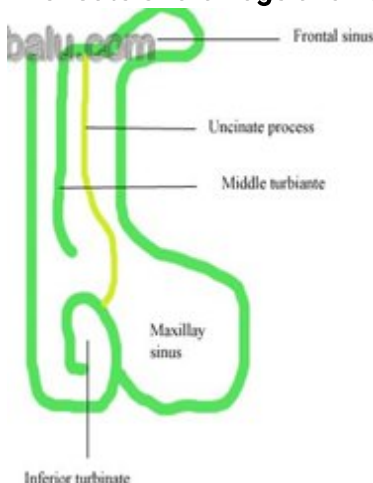
Type I uncinate (most common type):

The uncinate process bends laterally in its upper most portion and inserts into the lamina papyracea. So the ethmoidal infundibulum is closed superiorly by a blind pouch called the recessus terminalis (terminal recess).

So below the uncinate process lies the recess terminalis of the infundibulum superior & medial to this attachment lies the frontal recess

In this case the ethmoidal infundibulum and the frontal recess are separated from each other

The route of drainage and ventilation of the frontal sinus run medial to the ethmoidal infundibulum.



So that the frontal recess opens into the middle meatus directly medial to

the ethmoidal infundibulum, between the uncinate process and the middle turbinate

Type II uncinate:

The uncinate process extends superiorly to the roof of the ethmoid (base of skull).

The frontal sinus opens directly into the ethmoidal infundibulum.

In these cases a disease in the frontal recess may spread to involve the ethmoidal infundibulum and the maxillary sinus secondarily.

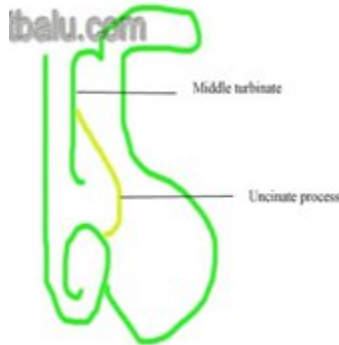
Sometimes the superior end of the uncinate process may get divided into three branches one getting attached to the roof of the ethmoid, one getting attached to the lamina papyracea, and the last getting attached to the middle turbinate

Type III uncinate process:

The superior end of the uncinate process turns medially to get attached to the middle turbinate.

Here also the frontal sinus drains directly into the ethmoidal infundibulum.

1)



Mid aspect of the uncinate:

Parallels the ethmoid bulla

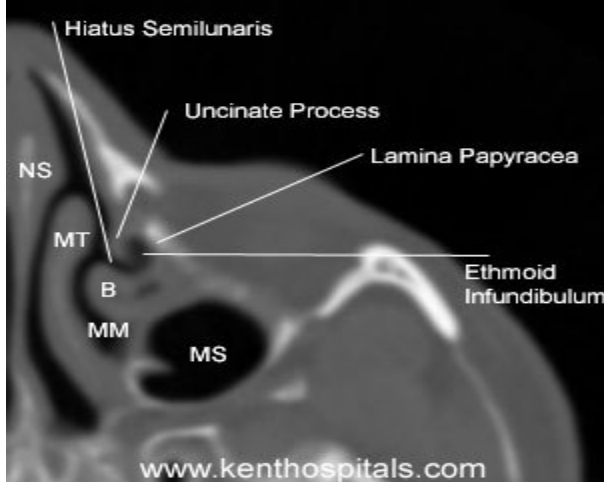
So removal of the uncinate process is one of the 1st steps in Fess to allow surgical access to the ethmoid bulla

1) **Inferior aspect:**

Forms part of the medial wall of the maxillary sinus

The maxillary sinus ostium lies lateral & superior to it

This part should be removed to widen the natural ostium



Ethmoid Infundibulum:

funnel-shaped/hooke like 3D pyramidal space

In the lateral wall of the nose

Belongs to the anterior ethmoid.

houses opening to:

1. the maxillary sinus: at the floor & lateral wall between its middle & posterior 1/3
2. anterior ethmoid sinuses

Borders:

- o **Medial wall:** the uncinate process
- o **Lateral wall:** the lamina papyracea (orbitalis)
- o **Floor:** is made by the union of the lamina papyracea & uncinate process
- o **Anterior & superior wall:** frontal process of maxilla
- o **superior & lateral:** lacrimal bone
- o **Posterior wall:** ethmoidal bulla

The superior attachment of the uncinate process determines the spatial relationship of frontal sinus drainage (**80%** attach to the lamina papyracea resulting in frontal sinus drainage medial to the uncinate, 20% attach to the skull base or middle turbinate resulting in frontal sinus drainage lateral to the uncinate and into the infundibulum)

The location of the opening of the sinuses into the infundibulum:

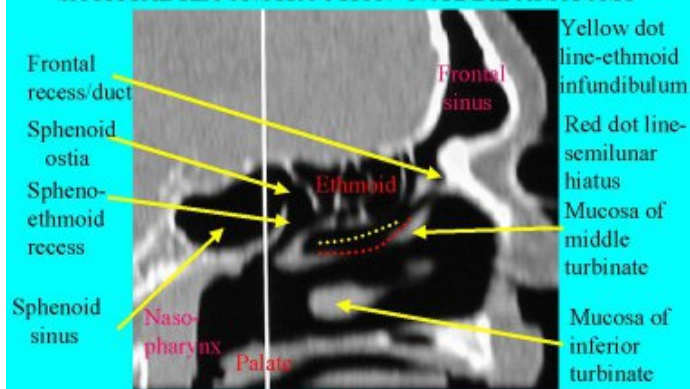
1. The frontal sinus opens into the superior most aspect of the ethmoidal infundibulum into the fronto-nasal recess
2. The anterior ethmoidal cells open anteriorly into the infundibulum.
3. The ostium of the maxillary sinus opens postero-inferiorly into the infundibulum and can be located just above the inferior turbinate.

Anterior and posterior fontanelles: Defects in the medial wall of the infundibulum covered with dense connective tissue and periosteum.

The mucosal membrane may produce partial or complete septations and form additional blind bulges near the skull base or the middle turbinate. These can expand anteriorly in varying numbers and sizes and evolve into so-called infundibular cells. If such a cell develops anteriorly and superiorly, it can extend as far as the lacrimal bone and may be called an ethmolacrimal cells.

Depending on the form of the uncinate process, the anterior length of the ethmoidal infundibulum may reach 4-5 cm. Its greatest depth (measured from the free posterior margin of the uncinate process) may be as much as 12 mm, and its greatest width from the free margin of the uncinate process to lamina papyracea 5-6 mm.

SAGITTAL RECONSTRUCTION--NORMAL ANATOMY



FIGURE



	From	To
Hiatus semilunaris inferior	Middle meatus	Infundibulum
Hiatus semilunaris Superior	Middle meatus	Lateral sinus

Semilunar Hiatus:

1-Hiatus semilunaris inferior:

2D crescent shape cleft and depression

Seen from a **median** view

Borders:

- o **Anteriorly:** **concave** posterior free margin of the uncinat process
- o **Posteriorly:** **convex** anterior surface of ethmoid bulla

Clinical significance

From the middle meatus through this 2D cleft (Hiatus semilunaris) a 3D space of the infundibulum can be reached (hiatus semilunaris is the doorway from the middle meatus into the infundibulum)

So the hiatus semilunaris is the **door** through which we enter the ethmoidal infundibulum **room/ passage way**

2-Hiatus semilunaris superior:

2D crescent shape cleft and depression

Seen from a **median** view

Borders:

- o **Superiorly:** skull base
- o **Posteriorly:** basal lamella of middle turbinate
- o **Inferio-anterior:** ethmoid bulla

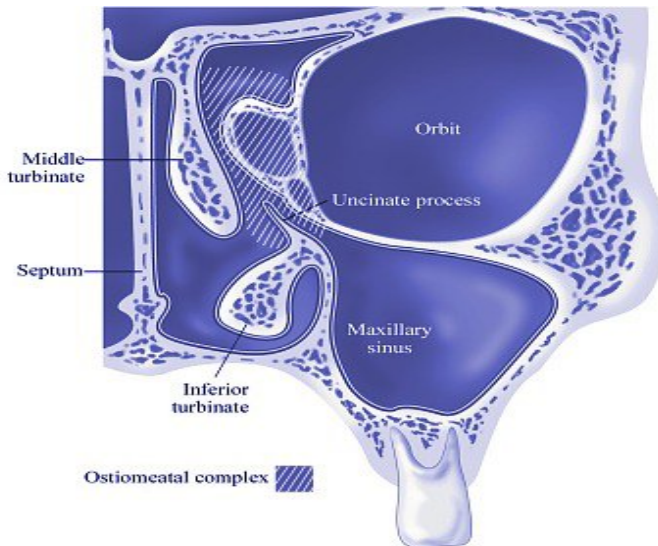
From the middle meatus through this 2D cleft (Hiatus semilunaris superior) a 3D space of the lateral sinus can be reached (hiatus semilunaris is the doorway from the middle meatus into the lateral sinus)

lateral sinus)

Osteomeatal Complex:

The common final way of drainage & ventilation for the, maxillary & anterior ethmoid sinuses +/- frontal sinus

Functional designation (not anatomical structure) that refers to the middle meatal structures which include:



middle turbinate

middle meatus

uncinate process

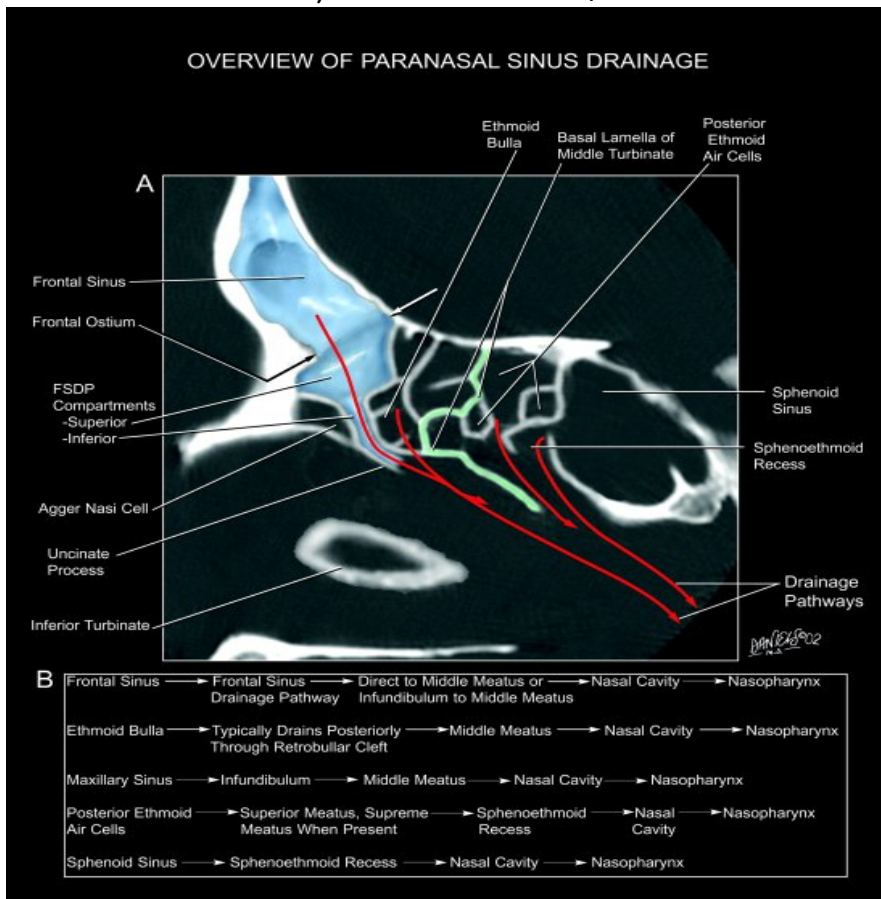
ethmoid bulla

anterior ethmoid air cells

semilunar hiatus

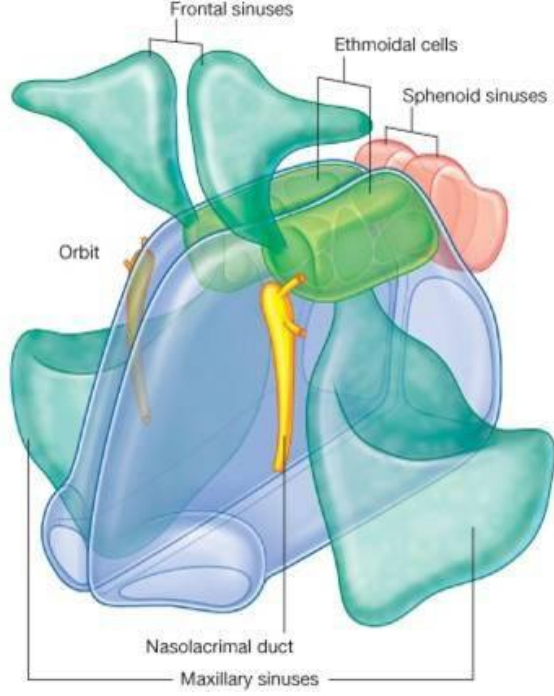
ethmoid infundibulum.

Ostium of : maxilla, anterior ethmoid +/- frontal air cells

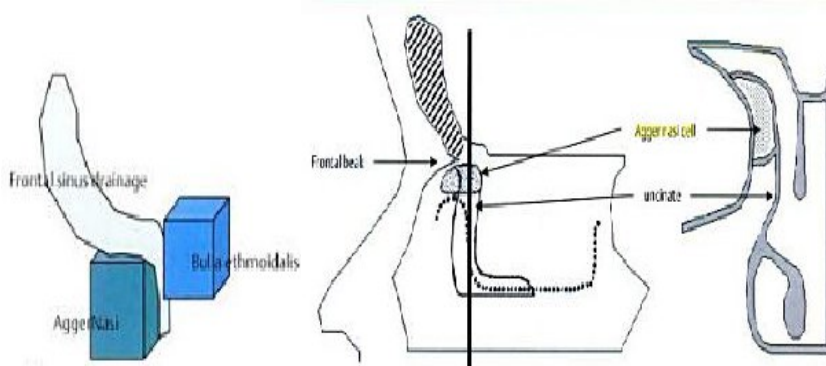


resulting in the pathological disease in these sinuses

So it is the critical area of obstruction



1-

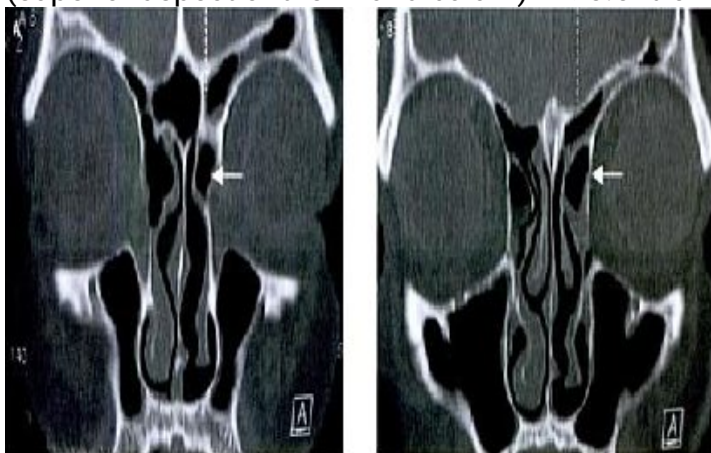


Agger Nasi cell:

the most anterior ethmoid air cells

the most constant frontal recess cell

intranasal prominence which is pneumonization in 90% of patients by anterior ethmoid air cells (superior aspect of the infundibulum) in 98.5 % of the time

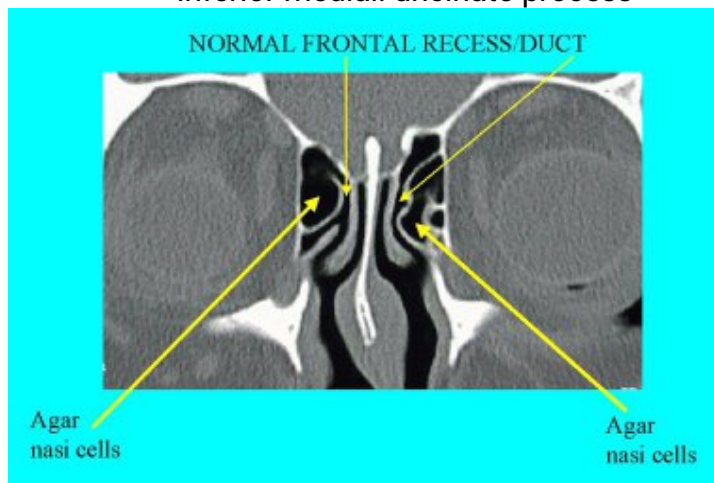


Drain into semilunar hiatus inferior

Relations: mound/prominence on the lateral wall just anterior & superior to the insertion of the middle turbinate

Borders:

- o **Anteriorly** : frontal process of the maxillary bone
- o **Anteriolaterally** : nasal bone
- o **Superiorly** : frontal sinus
- o **Posteriorly** : frontal recess
- o **inferiorly** :
 - inferior-lateral : lacrimal bone
 - inferior medial: uncinate process



may cause structural blockage of frontal recess.

When the agger nasi is aerated, its increased size

It composes:

Anterior wall of the frontal recess: The superior posterior wall of the agger nasi cell.

floor of the frontal sinus : The roof of the agger nasi cell is an important landmark for frontal sinus surgery

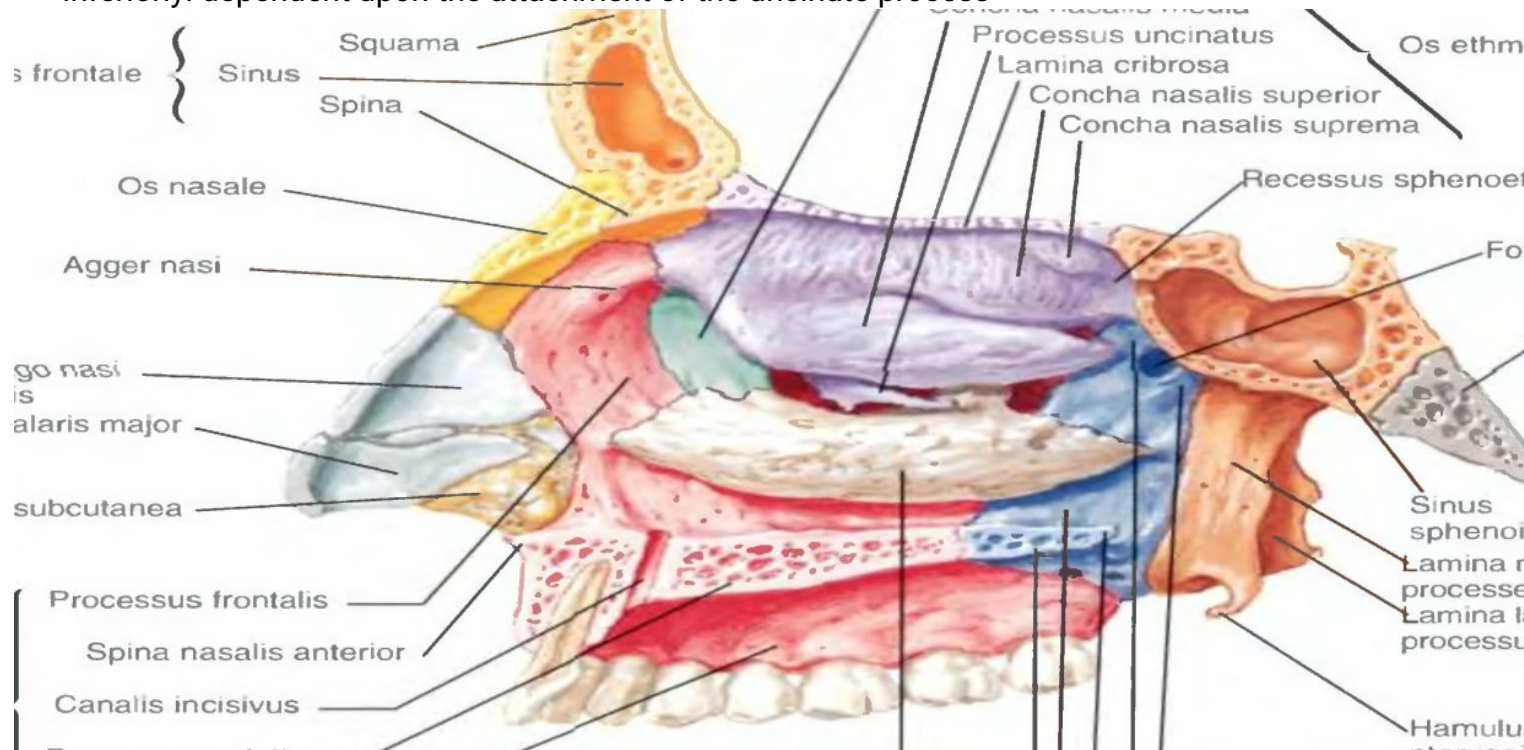
The frontal recess may be defined as follows:

Medially: middle turbinate

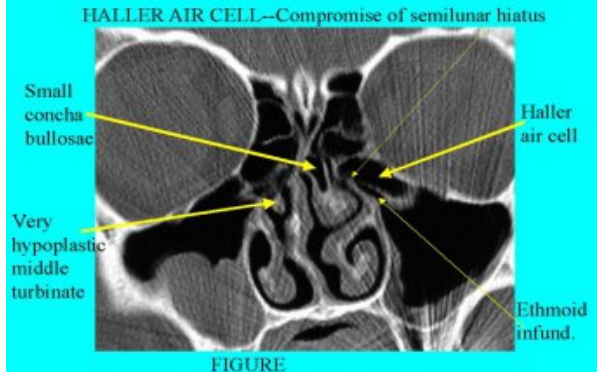
Laterally: lamina papyracea, lacrimal bone

Superiorly: skull base

Inferiorly: dependent upon the attachment of the uncinat process



1-



Haller cells:

ethmoid air cells that extend into maxillary sinus above the ostium, pneumatize the medial and inferior orbital walls

Origin:

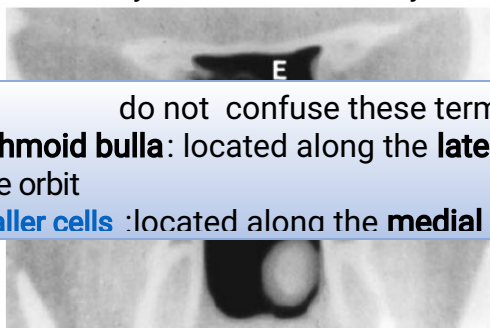
- o anterior ethmoid air cells 88%
- o posterior ethmoid air cells 12%

Location

- o below the orbit
- o in the medial part of the maxillary sinus roof.(i.e., in the orbital floor)

It occurs in 10% of people.

As it is closely related to maxillary ostium/ ethmoidal infundibulum:



do not confuse these terms:

Ethmoid bulla: located along the **lateral** wall of the orbit

Haller cells: located along the **medial** floor of the

Coronal CT cut through the sphenoid sinus reveals a "horizontal septum" (arrows). The cell above the septum (E) represents a sphenothmoidal cell (Onodi cell) that has pneumatized above the sphenoid sinus (S), bringing the ethmoid sinus into close proximity to the optic nerve and carotid artery. (Reproduced with permission from

Enlarged Haller cells may contribute to narrowing of the maxillary ostium/ ethmoidal infundibulum and variation of the infundibulum & recurrent sinus disease.

1- Onodi cells/sphenothmoidal cell

Definition:

Lateral and posterior pneumatization of the most posterior superior ethmoid cells along the lamina papyracea over the superolateral sphenoid sinus.

12% of the patients have Onodi cells

Note:

- o Sphenoid sinus is located inferior & medial to the most posterior ethmoid air cell
- o Carotid artery & optic nerve are located at the lateral aspect of the sphenoid sinus

Clinical significance:

- o commonly mistaken as a sphenoid cell
- o radiographically, it appears as a septate sphenoid sinus with the superior compartment being onodi cells
- o Because the Onodi cells are posterior ethmoid cells that are positioned superolateral to the sphenoid sinus, the optic nerve & carotid artery may often course through the lateral aspect of onodi cell instead of sphenoid sinus proper.
- o Optic nerve relation is more important than internal carotid artery
- o Optic nerve may indent into the lateral wall

So the presence of Onodi cells increases the chance that the optic nerve and/or carotid artery would be exposed (or nearly exposed) in the pneumatized cell.

The optic nerve, and more rarely, the internal carotid artery, may be exposed within or lie immediately adjacent to such an air cell

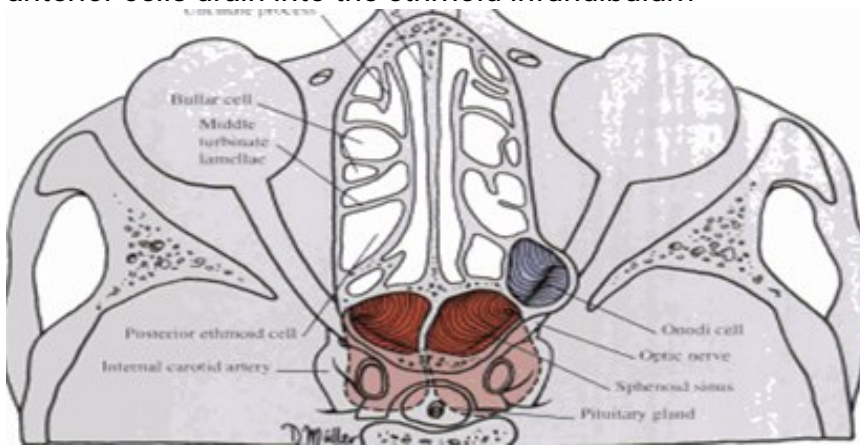
So the sphenoid sinus is entered through the most inferior and medial portion of the posterior ethmoid sinus

Summary:

During endoscopic sinus surgery attempts to localize the sphenoidal sinus via instrumentation through the posterior most ethmoidal air cells can lead to optic nerve, and even, internal carotid artery, injury

Drainage:

- o anterior cells drain into the ethmoid infundibulum
- o

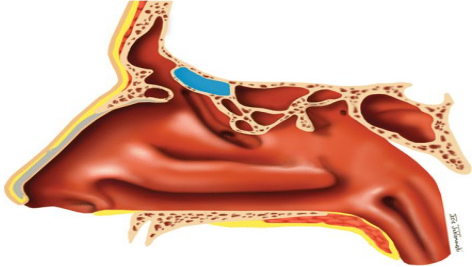


ethmoid recess (superior meatus) posterior cells drain into the sphenoidal sinus

So:

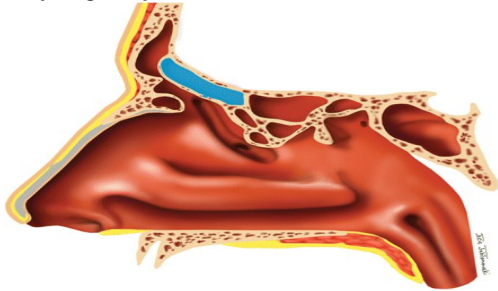
- o the Onodi cell are the most posterior part of the ethmoid air cells
- o the agger nasi are the most anterior part of the ethmoid air cells

1-



Frontal cells: (frontoethmoidal cells)

rare anatomical variant of the anterior ethmoid cells
impinge upon the frontal recess



extends within the lumen of the frontal ostium

above the agger nasi

they become clinically evident if:

- o if they become primarily infected
- o cause obstruction of the frontal sinus drainage system

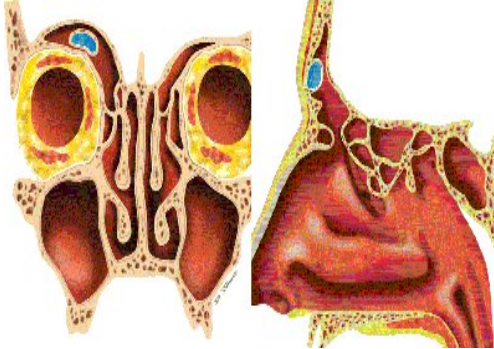
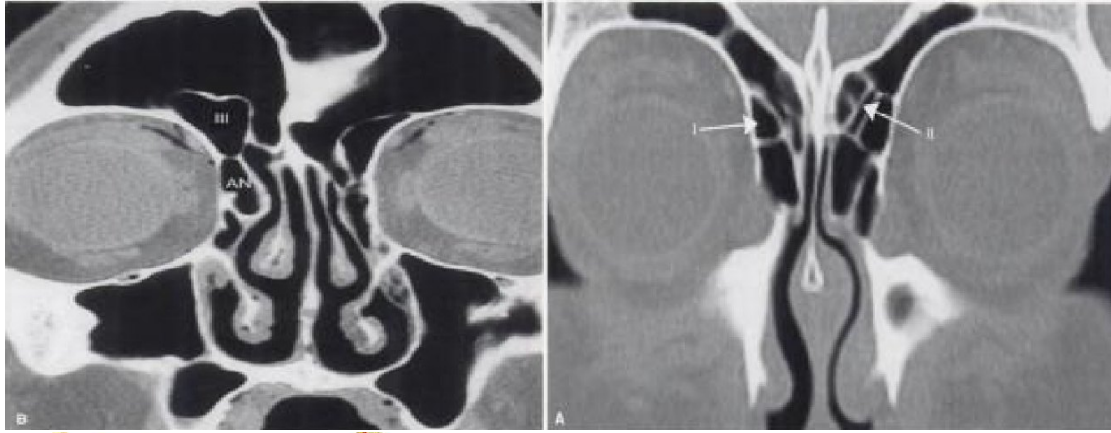
Types of frontal cells: (Kuhn classification)

1. **type 1: single** frontal **recess** cell above the agger nasi cell
2. **type 2: tier** of frontal cells within the frontal **recess** above the agger nasi
3. **type 3: single** massive cell, arising above the agger nasi

pneumatize **cephaled** extending into the frontal **sinus**, but not >50% of the sinus height

1. **type 4: single isolated** frontal cell **entirely in** the frontal **sinus** (sinus within sinus), away from agger nasi cell





bordered by the **anterior** wall of the frontal sinus



Note: difference between type III frontal cell and frontal bulla is that frontal cell is along the agar nasi while the frontal bulla is along the skull base, and these can be distinguished on CT using the sagittal and axial cuts, not coronal.

1- **supraorbital vs frontal bulbar ethmoid cells:**

Both frontal bulbar cell & supraorbital cell are:

- o ethmoid air cells that reside above the frontal bulla
- o can cause significant compromise from the posterior portion of the frontal recess
- o pneumatizes along the skull base in the posterior frontal recess

Difference:

- o frontal bulbar cells: pneumatization extends into the frontal sinus

suprorbital ethmoid air



suprabullbar cells: does not pneumatize into the frontal cells

Further details on the suprabullbar recess:

- o Extends out over the orbit by pneumatizing the orbital plate of the frontal bone
- o **Septate** frontal sinus is the hallmark of extensive pneumatized suprabullbar cell
- o Its **ostium** is **posteriolateral** to the frontal sinus
- o its opening is closely related to the canal for the **anterior ethmoid artery**
- o This cell is commonly **mistaken** for frontal sinus

septation in the frontal

Missed supra-orbital cell is a common cause for iatrogenic frontal sinusitis.

Vasculature of ethmoid air cells:

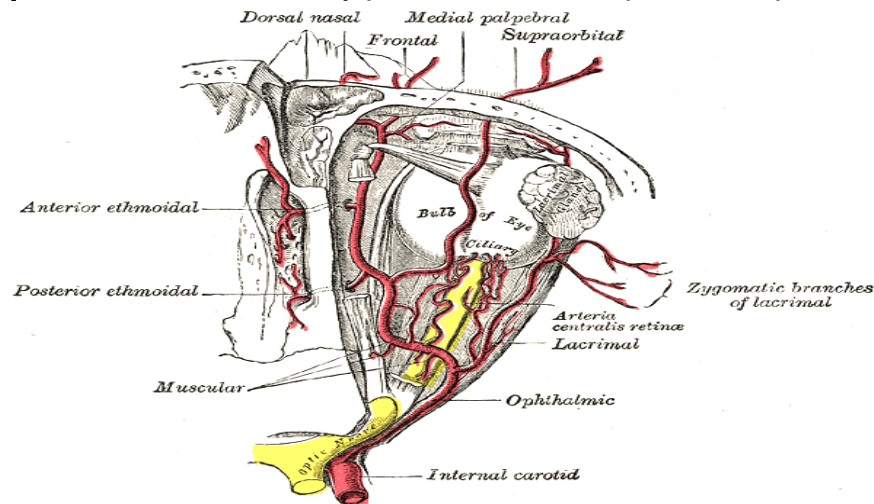
Artery: Netter p323+ 327 + tutorial p25, 27

A. Anterior and posterior ethmoid arteries (from ophthalmic artery)

originate from the **ophthalmic artery** in the orbit

anterior ethmoid artery Pass between **superior oblique** and **medial rectus muscle**

posterior ethmoid artery pass **above** the superior oblique muscle



Through the anterior and posterior ethmoid **foramen** at the **fronto-ethmoidal** suture into the **anterior** ethmoid **complex**. It crosses the **anterior** ethmoid either **at the level** of the ethmoidal roof or as much as **5mm below** this level, running in a mucous membrane fold or a thin **bony** mesentery in the roof of the anterior ethmoidal sinuses.

The artery may be surrounded by only a thin-walled bony channel, which can be **dehiscent** in over **20- 40 % inferiorly**.

After this passage through the anterior ethmoid, the artery enters the olfactory fossa (intracranially) through either the lateral lamella of the lamina cribrosa or where this attaches to the frontal bone of the ethmoidal roof.

The **longer** the lateral lamella of the cribriform plate, i.e. the **deeper** the olfactory fossa -the **higher** the ethmoidal roof above the level of the cribriform plate- the **more** likely the ethmoidal artery is to be found travelling **freely** through the ethmoid cavity and penetrating through the **lateral** lamella of the cribriform plate.

- o The **posterior** ethmoid artery lies in the **roof** of the **posterior** ethmoid just anterior to the anterior wall of the sphenoid sinus
- o After intracranial entry, the artery turns **anteriorly** forming a groove in the lateral lamella, the called **ethmoidal sulcus**. Here, it gives off anterior meningeal branches and finally reaches the nasal cavity again through the **cribroethmoidal foramen** and the **cribriform plate**.
- o Here it divides into the anterior nasal artery with superior, lateral and medial nasal branches, as well as a posterior branch. This division may take place before or after its passage through the lamina cribrosa.
- o **Intranasal** location is:
 - Below:** skull base
 - Posterior to:** frontal recess & ethmoid bulla
 - anterior** to: vertical attachment of the middle turbinate

Note:

The anterior & posterior ethmoid foramen are situated in the frontal bone between the lower margin of the foveolae ethmoidalis & upper edge of the lamina papyrea

Cranial cavityorbital cavitycranial cavitynasal cavity

The artery can be the source of significant intraoperative bleeding when injured

The anterior ethmoidal artery has been estimated to be unilaterally absent in 14 %, bilaterally

absent in 2 % and multiple in 30 %.

If the anterior ethmoidal artery is absent, it is replaced by a branch of the posterior ethmoidal artery.

The ethmoidal foraminae (situated at the frontoethmoidal suture) that transmit the anterior and posterior ethmoidal arteries mark the **roof** of the ethmoidal sinuses, above which lie the

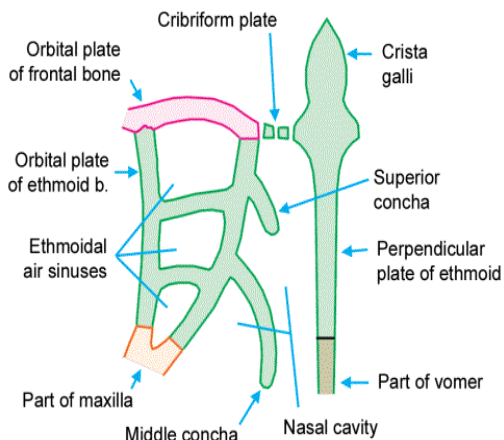
A. Posterior lateral nasal artery (sphenopalatine artery)

Vein:

- o Maxillary and ethmoid veins (cavernous sinus)
- o Unique feature of the venous supply of the ethmoidal sinuses is the **intracranial** pathways

Innervation: netter 324

- o Anterior ethmoid air cell: nasociliary branch of V1
- o Posterior ethmoid air cell: posteriolateral orbital branches of pterygopalatine ganglion



General notes about the ethmoid bone:

Lamina papyracea is Part of the **lateral** wall of the ethmoid

Lateral lamella is in the **medial wall of the ethmoid sinus**

Middle and **superior** turbinate are part of the ethmoid

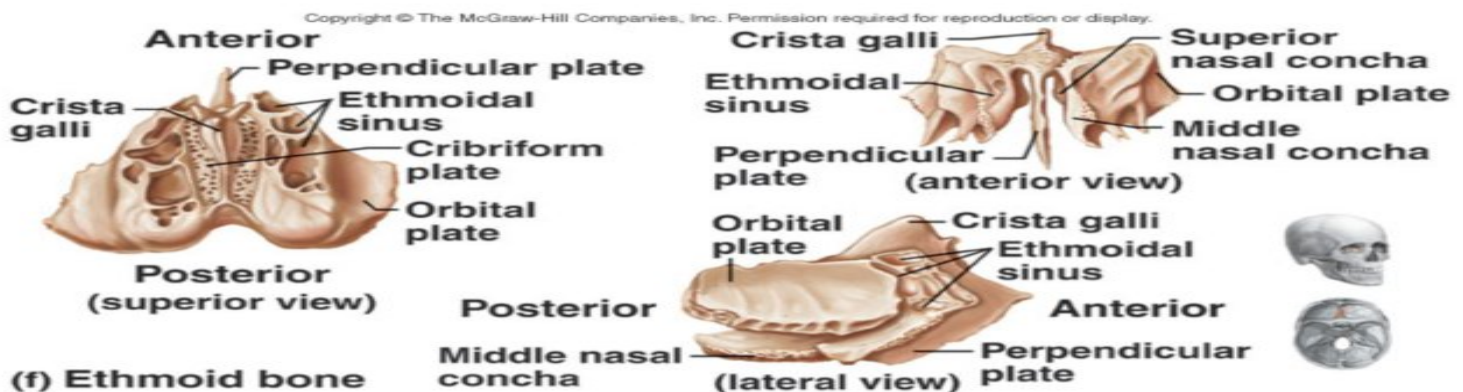
Uncinate process is part of the ethmoid, **lateral** of the middle turbinate

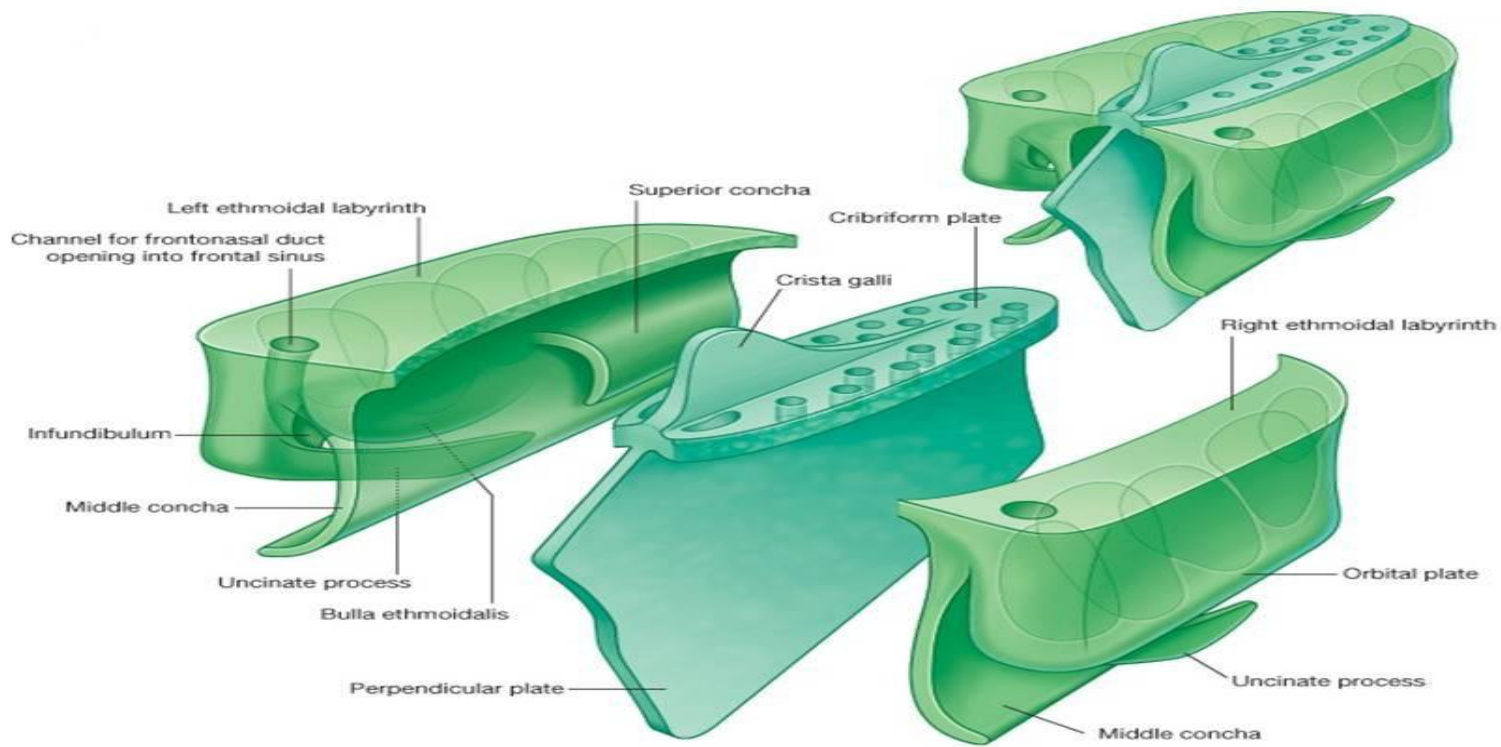
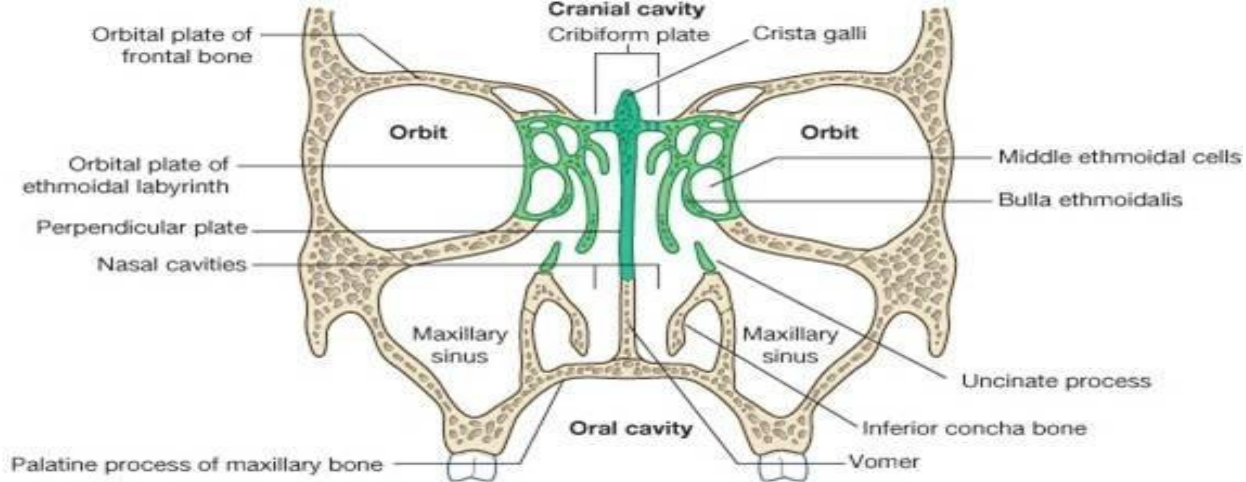
crista galli and **perpendicular plate** are on the same level

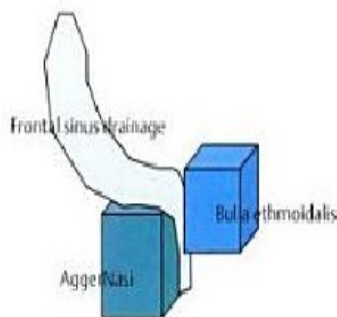
lateral lamella of the cribriform plate and insertion of **middle turbinate** are on the same level

Layers from medially to laterally: Middle turbinate, uncinate process, fundibulum, bulla, lamina papyracea

H. *Ethmoid bone*







Embryology:

- o **not** present at **birth**, starts to develop after the **4th** years
- o Adult Volume: 4–7 ml by 18 years old
- o **Dimensions**: **28** mm length, **24** mm width, **20** mm depth
- o **Intersinus septum is usually present but dehiscent in 9%**
- o % of agenesis: Unilateral: 4% ; bilateral: 5%; Underdeveloped: 5-10%
- o The frontal sinus is **pyramid** in shape, originates from **pneumatization** of the frontal recess in an **antero-superior** direction, into the **vertical** part of the frontal **bone**.

Natural Ostium: postero-inferio-medial

Drainage into Frontal recess: middle meatus directly/infundibulum then into the middle meatus

- o In a sagittal section through the transition of the floor of the frontal sinus (frontal sinus infundibulum) to the frontal recess, an hourglass-shaped structure is present.
- o The natural ostium of the frontal sinus is somewhat variable in its configuration but most frequently it presents as an hourglass narrowing opening (rather than a duct).
- o Its narrowest part is at the level of the frontal ostium

Funnel (superior part of the hour glass)	Frontal sinus
Narrowed part of the hour glass	Frontal sinus ostium
Inverted funnel (inferior part of the hour glass)	Frontal recess

- o In **10 %** of patients, **multiple** ostia are found, though these openings should **not** be confused with a more laterally placed **suprabullar** (superior anterior ethmoidal) **cell** running into the orbital roof
- o Pott's puffy tumour is a frontal infection which can lead to meningitis, brain abscess, orbital cellulitis, or osteomyelitis of the frontal bone.

Frontal recess:

- o 3D Cavity; the term 'frontonasal duct' has been generally abandoned as: no true duct exists, either histologically or topographically, in most people.
- o It is not an independent bony tubular structure but simply the potential space which other independent bony structures leave between them
- o found in the most anterosuperior portion of the middle meatus/anterior ethmoid complex

The frontal recess may be defined as follows:

medial: middle turbinate

lateral: lamina papyracea, lacrimal bone

superior: skull base

inferior: dependent upon the attachment of the uncinate process

Anterior: superior posterior surface of agger nasi cell (when present) + frontal cells

Posterior: anterior wall of ethmoid bulla/skull base (depends on the presence of **suprabulbar recess**)

The **agger nasi** cell is the **most constant** frontal recess cell

The frontal recess tapers as it approaches the superiorly located internal os of the frontal sinus

frontal recess in anterior middle meatus either medial (more frequent) or lateral to the uncinate (posterior and medial to agger nasi cells)

The entrance to frontal recess is just **above** the superior border of the bulla. If the bulla is entered first, one should preserve its superior border as a landmark for entrance to the frontal recess.

Best landmark of frontal sinus ostium is to follow the **uncinate** process remnant up to its **superior** attachment

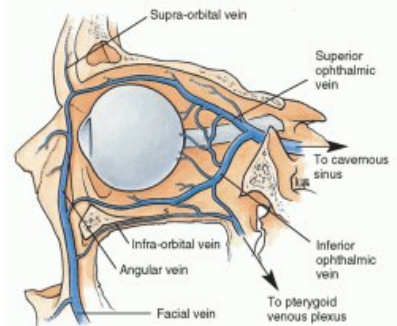
The limits, shape and **width** of the frontal recess are largely determined by its neighboring structures (these structure can narrow the frontal recess):

1. The shape of the **ethmoidal bulla**: if it extends far forward in the case of a well-developed

bulia, the frontal recess will be narrowed from posteriorly.

2. Significant pneumatization of the **agger nasi** may cause Narrowing.

Note that frontal recess is pneumatized by variety of anterior ethmoid cells



Anterior ethmoid artery is identified in the posterior part of the frontal recess, anterior to the vertical part of the basal lamella, immediately below skull base

Vasculature:

supraorbital and supratrochlear arteries

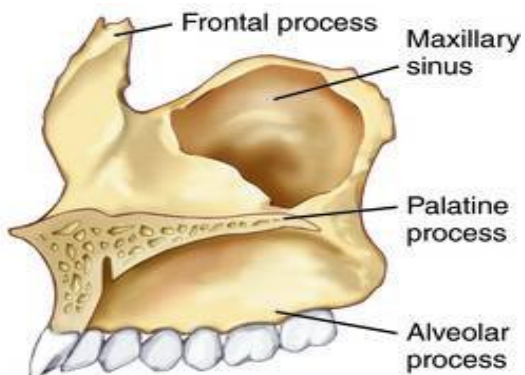
ophthalmic (cavernous sinus) and supraorbital (anterior facial) veins

Innervation:

supraorbital and supratrochlear nerves

Maxillary Sinus

Foramina of Breschet: small venous foramina that drain the sinus mucosa into the dural veins



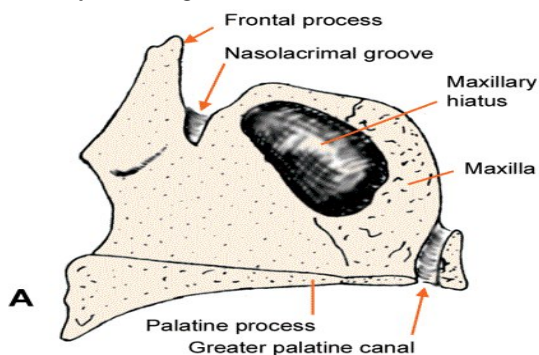
Embryology:

1st to develop in utero (7-10 weeks)

Arise from the inferior aspect of the ethmoid infundibulum

Formed as a lateral evagination between the middle & inferior turbinates at 3 months gestation

Has biphasic growth, coincides with teeth growth at 3 and 7–12 years



Size at birth 7*4*4 mm³, can be seen on CT at age of

4-5 months

Adult size (18 years) 15 cm³ (largest paranasal sinus)

Has a **Triangular**/pyramidal shape with the base being the **lateral** nasal wall and the apex towards the zygomatic process

Dimensions: AnteriorPosterior: 3.5cm, Transverse: 2.5cm, Height: 3.3 cm

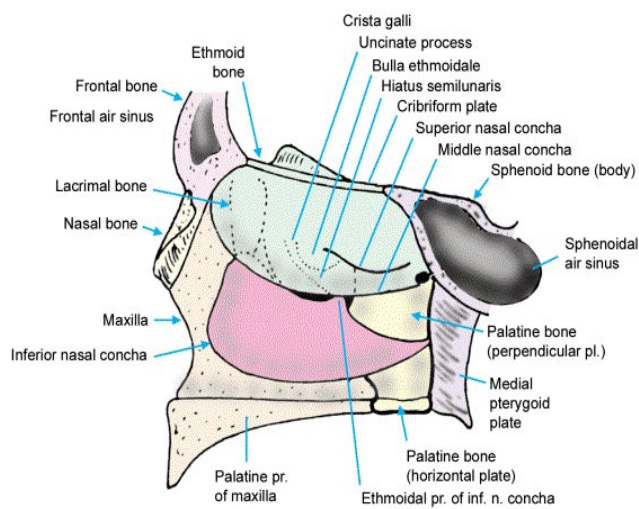
Floor of the maxillary sinus:

At birth: superior to the nasal floor

8-9 yr: at the same level as the nasal floor

Adult hood: below the level of the nasal floor

Average: 0.5cm, Max: 1.25cm



relatively **symmetrical**; rarely absent

Borders:

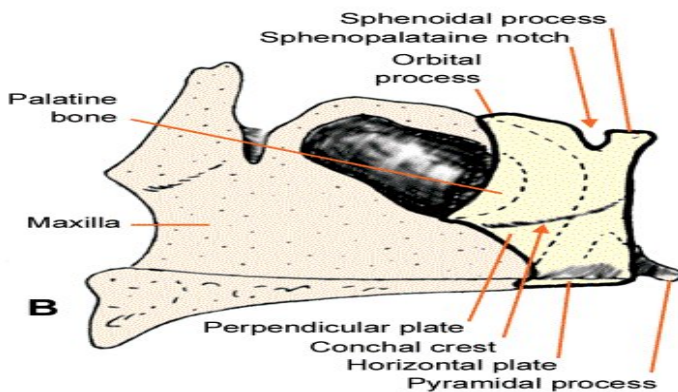
Anteriorly: facial surface of the maxilla

Posteriorly: infratemporal surface of the maxilla

- o contains **pterygopalatine fossa** housing the: maxillary artery, pterygopalatine ganglion, and branches of the trigeminal nerve)

roof: orbital floor

inferior: alveolar process of maxilla (contains second bicuspid and 1st & 2nd molars)



Drainage:

- o At the floor and lateral aspect of the infundibulum between its middle & posterior 1/3
- o 10–30% have accessory ostium located anterior/posterior to the uncinates
- o Infra-orbital Haller cells can be in close proximity to the infundibulum and Maxillary ostium
- o the exact site, size & orientation of the maxillary sinus ostium is subjected to great variation

General features:

- o Indented antero-medially by the lacrimal notch which is related to the lacrimal sac
- o posterior edge contributes to the inferior orbital fissure
- o **traversed by the infra-orbital canal which may be dehiscant**
- o inferiorly the floor of the sinus is thicker but can encroach around the roots of the teeth
- o the majority of the maxillary sinus is in the body of the maxillary bone but not entirely
- o Its medial wall is made by the ethmoid, inferior turbinates. vertical plate of palatine bone

maxillary hiatus

In a disarticulated skull, the maxillary bone has a large opening in its medial wall (the maxillary hiatus) whose size is reduced by the overlapping bones

The posterior aspect is overlapped by the Perpendicular Plate of palatine bone

The Inferior is overlapped with maxillary process of the inferior concha

anterosuperior: a small portion of the lacrimal bone

The Superior aspect is overlapped with the ethmoid (mainly the bulla + uncinates process)

A portion of the maxillary hiatus is nevertheless left open by these osseous attachments, which in life is filled by the mucous membrane of the middle meatus, the mucous membrane of the maxillary sinus and the intervening connective tissue - the membranous portion of the lateral wall. This will leave the maxillary **ostium** at the **base (posterior inferior part)** of ethmoid **infundibulum**

Nasolacrimal duct:

**The orifice lies 3-3.5 mm behind the posterior margin of the nostril
Maxillary sinus ostium is 3-6 mm away from the posterior end of
the Nasolacrimal duct, nasolacrimal duct is around 12 mm long**

So it can be injured during maxillary antrostomy

The anterior lateral part of the uncinate is attached to the posterior part of the Nasolacrimal Duct

This is why in maxillary antrostomy , remove bone as far at the anterior attachment of the uncinate process to avoid injury to lacrimal duct

Nasolacrimal duct is contained within the Nasolacrimal canal (Canal > Duct)

Nasolacrimal duct passes into the anterior part of the inferior turbinate

Antral wash out should be done through incision in the posterior part of the inferior meatus where the bone is thinner and to avoid injury to nasolacrimal duct, it is hazardous in children with

um of
illary sinus

Fontanelle area:

Bony dehiscence of the lateral nasal wall usually above the insertion of the inferior turbinate where the nasal mucosa approximate the mucoperiosteum of the maxillary sinus area (membranous-mucosal components)

The inferior aspect of the uncinate process separate the fontanelle area into anterior & posterior fontanelles

Posterior fontanelle is larger & more distinct

The natural maxillary sinus is located in the posterior fontanelle

The fontanelles (especially the posterior) may be perforated creating an accessory ostium into the maxillary sinus (20-25%)

Accessory ostium may be an indicator of chronic infection

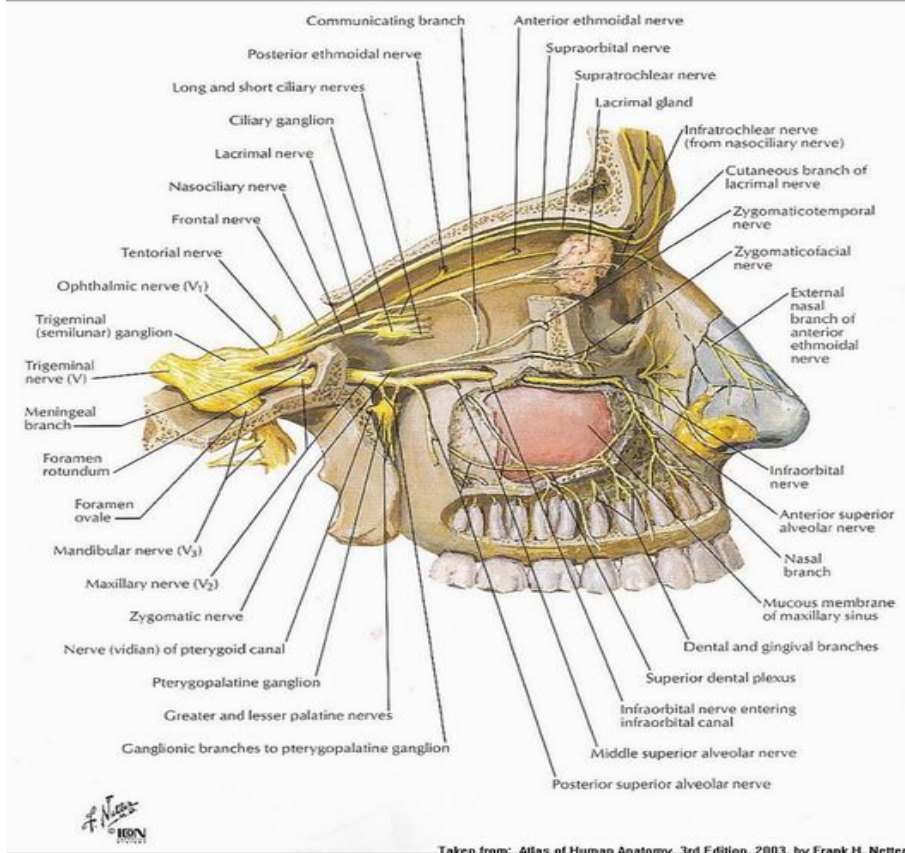
Note: that both the anterior + posterior fontanelle areas are located in the middle meatus above the inferior turbinates

Innervation :

- infraorbital nerve (V2) with middle + anterior superior alveolar+ Posterior superior alveolar
- greater palatine nerve
- posterior inferior lateral nasal branch

Vasculature:

- Branches from facial artery; branches from maxillary artery (Infra-orbital branch, Greater palatine branch)



Sphenoid sinus

Embryology:

Recognizable at around the 4th intrauterine month as an evagination from the posterior aspect of nasal capsule (sphenothmoidal recess)/(cartilaginous cupular recess ossified to become ossiculum Bertini then becomes part of the sphenoid body)

Minimal in size at birth

Pneumonization occurs at the middle childhood (6 year) completed by 9-12 years

Adult Volume: 0.5–8 ml (adult size at 12–18 years old), asymmetry is the rule rather than the exception

Located:

anterior & lateral to the sphenoid bone

superiorly: anterior cranial fossa (**frontal** lobe) + pituitary gland

laterally: cavernous sinus+ middle cranial fossa

medially: sphenoid septum which differ in location, direction, #, thickness

anteriorly: superior turbinate + sphenothmoidal recess + posterior ethmoid (anterior + inferior to sphenoid sinus)

posteriorly: posterior cranial fossa (**pons**) + basillary artery + basi-sphenoid/**clivus**

inferiorly: nasopharynx



So in transtethmoidal approach we enter the sphenoid sinus via the most **inferior & medial** part of ethmoid (to avoid injury to the posterior ethmoid artery superiorly, optic nerve laterally)

Septum of the sphenoid sinus:

The sinuses are divided by a septum

Asymmetry is the **rule** rather than the exception

Often **paramedian**

There may be diverticula and incomplete septa.

It is completely absent in approximately **1 %** of the population

The septum may attach **laterally** to one side in the region of **internal carotid artery/optic nerve**, an important consideration if the septum is being removed

sphenoid sinus pneumonization:

- o The sinus cavities are variable in size and shape.

- o Pneumatization can extend:

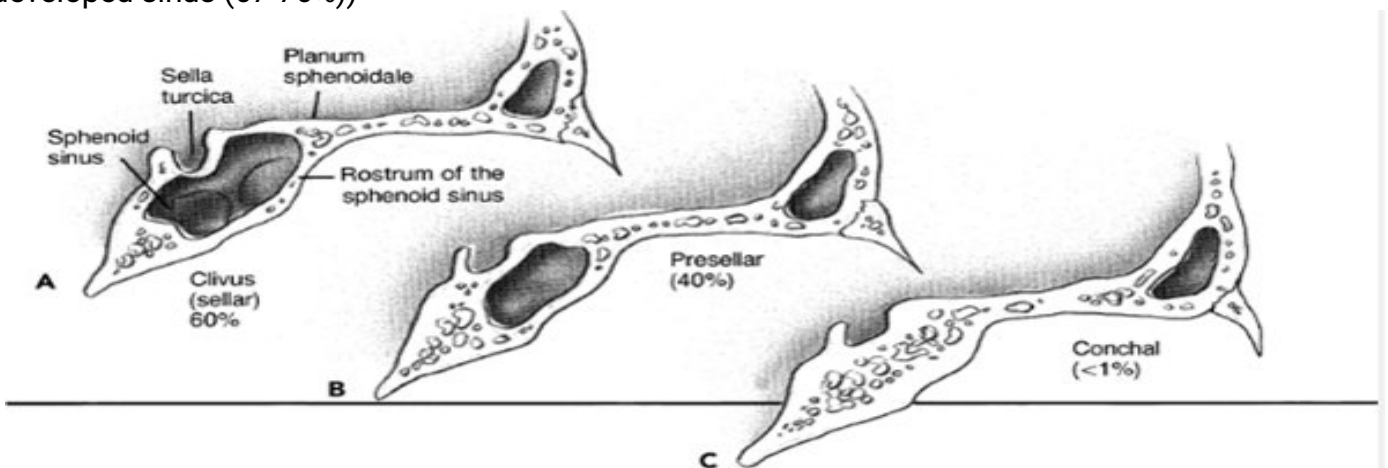
- laterally**: into the greater wing forming lateral recess

- inferiorly**: into pterygoid processes and rostrum

- Posteriorly**: may extend for variable distance inferior to sella tursica

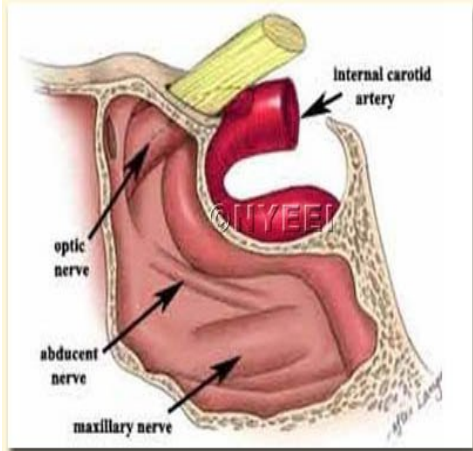
Hamberger sphenoid sinus classified based on pneuminization:

1. **Conchal** pneumatization: The sinus is entirely filled with cancellous bone (rudimentary sinus) (0-5 %)
2. **Presellar** pneumatization: extends to anterior bony wall of the pituitary fossa (cancellous bone extends under the sella to the anterior aspect of the floor (23-25 %).
3. **Sellar** pneumatization: extends back beneath the pituitary fossa (sella bulges into well developed sinus (67-76%))
- 4.



Mixed (27%)

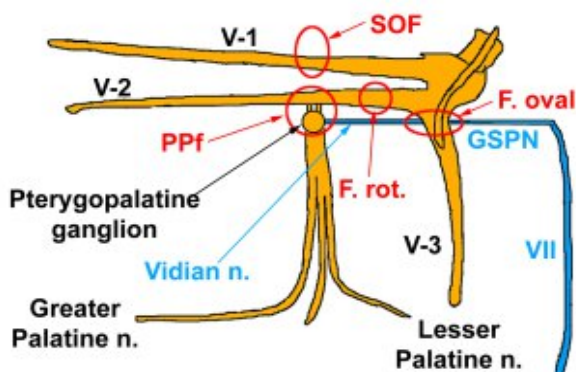
Note: **conchal sphenoid** is **not** an **absolute** contraindication for **transsphenoidal hypophysectomy** because the bone can be drilled out to permit access



Key structures associated with the sphenoid sinus:

1. Optic Nerve inside optic canal (6% dehiscence) especially in case of fungal sinusitis, tumor, mucocele
2. ICA in cavernous sinus (**22%** dehiscence)
3. Vidian nerve in pterygoid canal
4. Sella
5. **Maxillary** division of the trigeminal nerve (V2) In Foramen rotundum

Note that **both V1 +V2** go through the **lateral** wall of cavernous sinus but only V2 indents on the **inferiolateral wall** of **sphenoid**



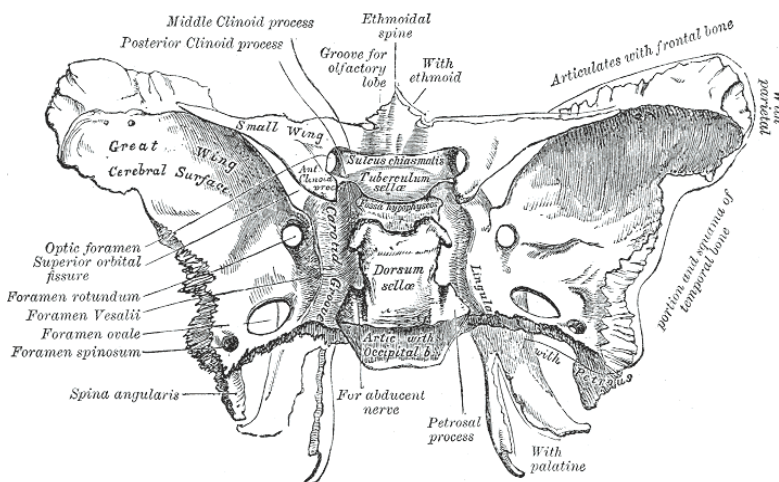
Structures that **intend** over the sphenoid sinus wall:

1. **Optic nerve**: superior part of the lateral +posterior wall
2. **Internal carotid artery**: inferior part of the lateral + posterior wall
3. **Vidian nerve**: floor of the sphenoid sinus

Opticocarotid recess/Infra-optic recess:

Pneumatization of the posterior-superior lateral wall of the sphenoid sinus between the ICA & optic nerve

Its size & depth depends on the degree of **anterior** clinoid process



Optic nerve canal lies antero-lateral

aspect of the sphenoid roof
May be absent in **4 %** of people

Location of the ostium:

The ostium is **2*3mm**, slit, oval or round in shape

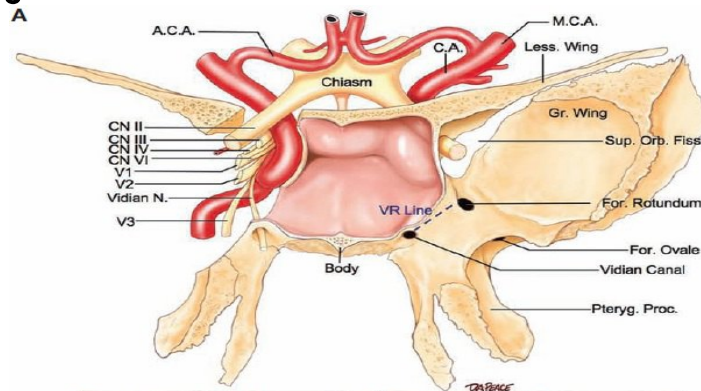
Located in the sphenoethmoidal recess

7 cm from the **nostril** rim at a **30** degree angle from the **anterior nasal spine**

1 cm above the **roof of choana** (or $\frac{1}{3}$ of the distance from choana to skull base) & **1-2 mm** medial to the nasal septum

Medial to the superior turbinate within millimeters from the its **posterior-inferior** edge

Drainage:



Sphenoid ostium drain into

sphenoethmoid recess in the superior meatus

sphenoethmoid recess:

Formed by the space between the superior turbinate + septum + nasal roof

Borders:

Laterally : superior (& supreme, if present) turbinate

Medially : Septum

Superiorly : skull base

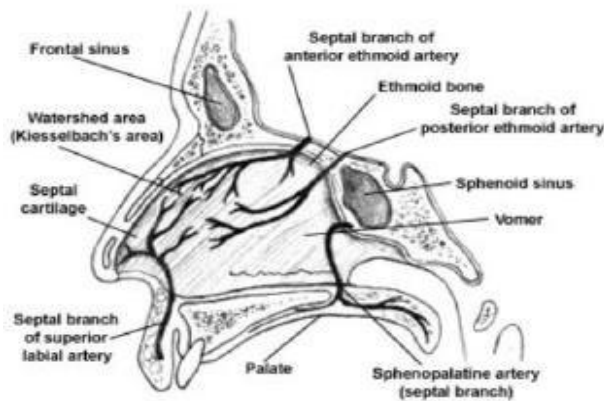
Posteriorly : anterior surface of the sphenoid sinus

Inferiolaterally : inferior margin of the superior turbinate

blood + nerve supply:

posterior ethmoid Nerve + Artery: roof

sphenopalatine: floor



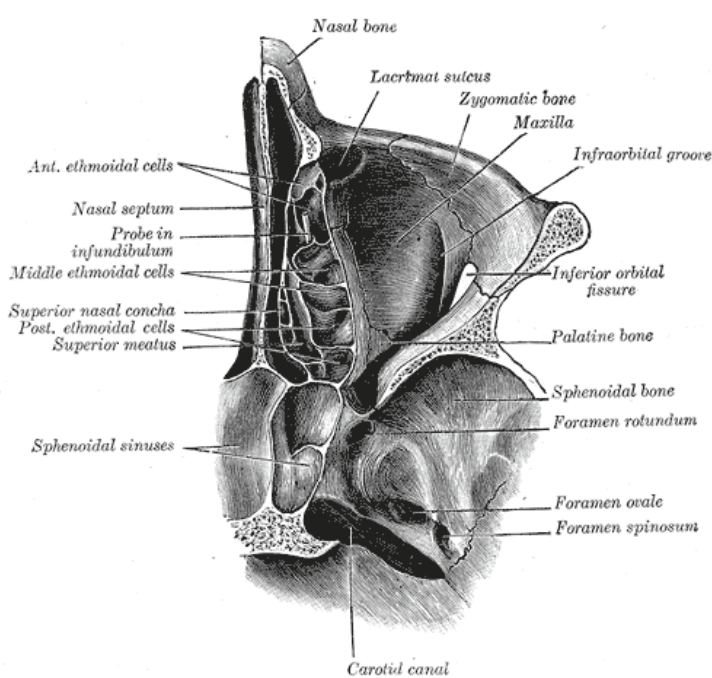
retropharyngeal lymph node

lymphatic drainage:

Relationship between the sphenoid & ethmoid sinus

Although the most posterior ethmoidal cell is closed by the sphenoid concha, the sphenoid sinus does not simply lie behind it; that portion of the sphenoid is usually quite small with the most posterior ethmoid cell often running lateral to the sphenoid sinus

Clinical application: the sphenoid sinus is entered through the most inferior and medial portion of the posterior ethmoid sinus



Sphenopalatine Foramen:

posterior to **inferior** attachment of the **middle** turbinate
formed by:

1. **superior**: sphenoid sinus
2. **Inferior**: palatine bone
3. **anterior**: ethmoid process of the palatine bone
4. **posterior**: sphenoid process of the palatine bone

Leads from pterygopalatine fossa into nasal cavity

Contains:

1. **sphenopalatine** artery and vein supply:
inferior posterior part of the septum
inferior anterior part of the sphenoid sinus
posterior part of inferior + middle turbinate
1. **Nasopalatine** nerve: sensory nerve fibers, and secretomotor fibers (parasympathetic fibers from **vidian** nerve to **pterygopalatine** ganglion)

Important points

Summary of para-nasal sinus drainage (netter p 321)	
Frontal sinus	Middle meatus directly Or infundibulum then middle meatus (depending on the position of the uncinate)
Maxillary sinus	Posterior inferior part of the infundibulum: middle meatus
Anterior ethmoid	Infundibulum: middle meatus
Bulla	Retrobullbar recess: middle meatus
Posterior ethmoid	Superior meatus
Sphenoid	Sphenoethmoidal recess

Frontal ostium located **anterior superior** to the angle made between the bulla & uncinate (infundibulum)

Maxillary ostium located **posterior inferior** to the angle between the bulla & uncinate (infundibulum)

Note (netter page 321):

The drainage from the sphenoethmoidal recess + superior meatus: **above** the eustachian tube

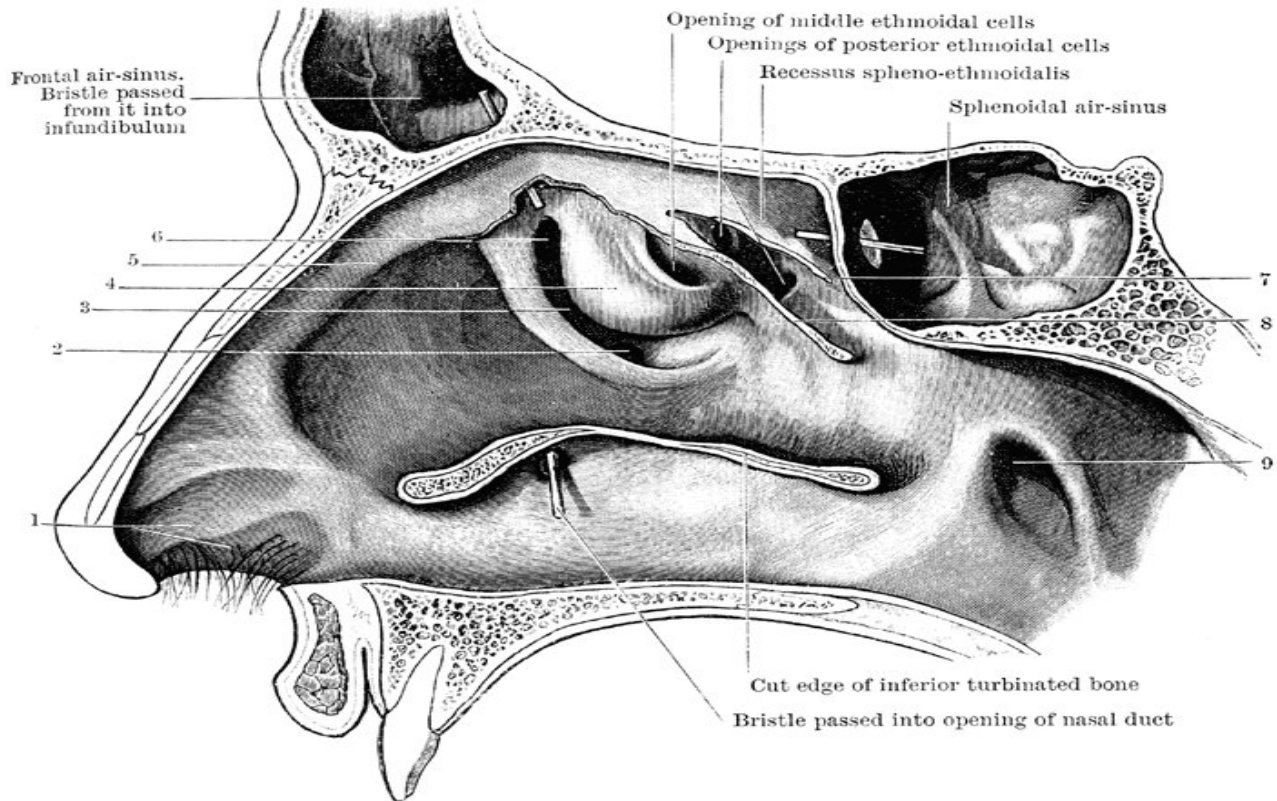
The drainage from the middle meatus: **Below** the Eustachian tube

The area **above** and **lateral & medial** to the **vertical** attachment of the middle turbinates is considered the dangerous area in the FESS

Sources of **meningitis** following FESS:

1. via roof of the ethmoid
2. perineural lymphatic of the Olfactory nerve filaments

It does not mean penetration of the cribriform plate



Summary about paranasal sinus development:

- 1st paranasal sinus to develop: maxillary
- Last one to develop: frontal
- The most well developed at birth: ethmoid
- The 1st one to reach full development: ethmoid
- Last one to reach full development: frontal

	Maxillary sinus	Ethmoid sinus	Frontal	sphenoid
Onset of development	3 rd month of gestation	5 th month	4 years	4 th month of gestation
Age of full development	18 yr	15 yr	20 yr	18 yr
Adult size	15ml	2ml	4ml	.5ml-8ml
Specific features	1 st one to develop	The most well	Last one to full develop,	Minimal in size at birth Pneumonization occurs at the

Summary of sinuses innervations:

Frontal sinus:

Ophthalmic: supratrochlear & supraorbital nerve

Maxillary sinus:

Maxillary Nerve : Roof: infra-orbital nerve; Inferior & posterior: greater palatine; Medial: posterior lateral nasal nerve
Lateral: anterior & middle superior alveolar

Sphenoid sinus:

Ophthalmic: posterior ethmoid

Maxillary : sphenoplatine

Important measurements in the sphenoid sinus

Bulla ethmoidalis-5 cm
Basal lamella-6cm

Anterior wall sphenoid-7 cm

Nasopharynx $\cong$ within 1 cm
posterior sphenoid wall

Posterior ethmoid-7 cm
and skull base

Nasofrontal ostia 6-6½ cm

11 cm 9 cm 7 cm

Ethmoid sinus:

Ophthalmic: anterior & posterior ethmoid

Maxillary : orbital branch of pterygoid ganglion

Distance from nasal spine:

5 cm: bulla ethmoidalis

6 cm: frontal recess, basal lamella of middle turbinate.

6-6.5 cm: nasofrontal duct ostia

7 cm: anterior ethmoidal artery, posterior ethmoid base of skull, sphenoidal sinus anterior wall, choanal bridge

nasopharyngeal wall approximates **posterior** sphenoid wall to within **1 cm**

ostium of sphenoidal sinus:

adjacent to septum ~**1.5 cm** above **choanal bridge**

1/3 up from **choana** to base of skull

2/3 distance from the **vaginal process** to the **top of the anterior sphenoid sinus**

The 4 lamella of ethmoid used in Fess: (constant landmarks that used as guide lines in FESS)

1st lamella: uncinat process

2nd lamella: ethmoid bulla

3rd lamella: basal lamella of the middle turbinate

4th lamella: superior turbinate