1. (Dara) Discuss the multiple nasal functions.

- **Warming**: Through heat exchange, the nasal mucosa maintains the nasal cavity at a range of 31–37°C Celsius. One theory regarding the efficiency of heat exchange relates to the location of the sphenopalatine artery. The sphenopalatine artery courses anteriorly in the nasal cavity over the turbinates, whereas air flows in a posterior direction forming an efficient countercurrent exchange.
- **Humidification**: Vascular mucosa increases relative humidity to 95% before air reaches the nasopharynx.
- **Filtration**: The largest particles are filtered by vibrissae.
- **Voice modification**: Nasal aerodynamics may have a role in modifying high-frequency sounds and consonants.
- **Smell**: It is the active process of sniffing that allows environmental particles to reach the olfactory system.
- **Sinonasal function**: Nasal ciliary flow is a vital component of normal sinonasal function.

2. (Deya) Describe the sympathetic and parasympathetic supply to the nose. How do they affect nasal submucosal vascular and glandular function?

- **Parasympathetic Supply** - responsible for mucous secretion, and to a lesser degree, vasodilatation.
  - Input to the nose and sinuses originates in the superior salivary nucleus and is distributed by the nervus intermedius to the greater superficial petrosal nerve.
  - Greater superficial petrosal nerve unites with the deep petrosal nerve to form the nerve of the pterygoid canal (vidian nerve), through which the parasympathetic nerve fibers enter the sphenopalatine ganglion, where synapse occurs.
  - Postsynaptic fibers then travel with all branches of the sphenopalatine ganglion to reach the glandular epithelium
  - Neurotransmitters a/w parasympathetic innervation include acetylcholine, vasoactive intestinal peptide (VIP), nitric oxide (NO), enkephalin, and somatostatin.
    - Acetylcholine acts primarily on the M3 receptors resulting in increased glandular secretion from the mucous/serous glands.
    - NO serves as an endothelial-derived relaxing factor, a free radical for bacteriostasis, an activator of ciliary beat frequency.
    - VIP functions primarily as a potent vasodilator.

- **Sympathetic Supply** - responsible for vasoconstriction but has little effect on mucous secretion.
  - Input to the nose arises in the intermediolateral column of T1 to T3
  - Preganglionic fibers travel through anterior thoracic roots through the stellate ganglion to the superior cervical ganglion, where they synapse.
  - Postsynaptic fibers then travel through the carotid plexus, where the deep petrosal nerve originates.
  - Deep petrosal nerve unites with the greater superficial petrosal nerve to form the vidian nerve.
  - Fibers then pass through sphenopalatine ganglion w/o synapsing, to reach nose & paranasal sinus mucosa.
  - Neurotransmitters: NE and neuropeptide Y (NPY), both of which are potent vasoconstrictors.
  - Sympathetic receptors: α agonists act on the resistance and capacitance blood vessels to decrease blood flow and nasal airway resistance. β2 agonists are vasodilators. Because there is a marked α predominance in nasal blood vessels, vasoconstriction generally prevails.
3. (Amy) Give histologic details of the three types of epithelium in the nose.
Give histologic details of the three types of epithelium in the nose.

1) **Nasal Vestibule:** Found in nasal vestibule on the anterior tip of the inferior turbinate. Consists of stratified squamous epithelium that is a continuation of the skin of the face. Contains hairs that help to filter out large particles before they are carried into the nasal cavity with incoming air. Secretions from sebaceous glands also aid in entrapping particles.

2) **Respiratory Segment:** The remainder of the turbinates and most other surfaces are lined with pseudostratified ciliated columnar epithelium with a basement membrane. It is composed primarily of ciliated cells which extend through the full thickness of the epithelium. Goblet cells secrete mucus and are interspersed amongst the ciliated cells. Brush cells are columnar cells with microvilli; their basal surface is in synaptic contact with the trigeminal nerve. Basal cells are stem cells from which the other cell types differentiate. Small granule cells contain secretory granules. The lamina propria (which includes the basement membrane) is attached to the periosteum of the underlying bone. It contains a rich network of capillary loops that warm inhaled air; these vessels become engorged during allergic reactions and upper respiratory infections.

3) **Olfactory Segment:** Located in the dome of the nasal cavity and the adjacent lateral and medial nasal walls. The total surface area is a few square centimeters. Olfactory epithelium is pseudostratified epithelium. It contains olfactory cells, which are bipolar neurons that span the thickness of the epithelium and give rise to the olfactory nerve. Sustentacular cells are columnar and provide mechanical support. Basal cells and brush cells are also present and are similar to those in the respiratory segment. The lamina propria contains olfactory glands that secrete proteinaceous material.

4. (Kathy) Describe normal ciliary function. What factors interfere with their normal activity?

In mammals, cilia beat 10-20 times per second at room temperature. This beat has a characteristic biphasic motion, with a rapid effective stroke and a slower recovery stroke. During the effective stroke, the extended cilium reaches a superficial, viscous mucous layer. During the recovery stroke, the cilium bends to travel in the other direction through the thinner periciliary layer. Thus the mucus layer is conveyed in the direction of the effective stroke. Drying (possibly produced by localized deflections or turbulence within the nasal cavity), drugs (e.g., cocaine, adrenaline), excessive heat or cold, hypertonic or hypotonic solutions, smoking (nicotine), infections (viral or bacterial), and noxious fumes (e.g., sulfur, carbon monoxide) all inhibit the normal ciliary beat.

Clearance of benign and pathological substances in the mucus is governed by the propulsive force of the beating cilia and the physical characteristics of the overlying mucus. The respiratory cilia continually beat in a coordinated fashion, and in times of stress (e.g., exercise, infection, or fever) ciliary beat frequency increases to accelerate mucus clearance. Thus, upper airway ciliary motility is under dynamic modulation. Multiple investigations incontrovertibly demonstrate a marked decrease in sinonasal mucociliary clearance in patients with chronic rhinosinusitis. Possible explanations for this finding are 1) a reduced basal ciliary beat frequency, 2) an alteration of the viscoelastic properties of airway secretions, and/or 3) a blunted dynamic response of sinonasal cilia to environmental stimuli. Studies of the first two explanations yield conflicting results, and to date, the third possibility remains uninvestigated.

5. (Rosow) What is Kargagener’s syndrome?

**Who it’s Named For:** Manes Kartagener (1897-1975), Swiss internist

**Intro:** Primary ciliary dyskinesia (PCD, also called the immotile-cilia syndrome) is characterized by chronic cough, chronic rhinitis, and chronic sinusitis. Otitis is common in childhood, as are nasal polyposis normally (ciliary dyskinesia), or to be missing altogether (ciliary aplasia). Kartagener's Syndrome is a subgroup of primary ciliary dyskinesia featuring the clinical triad of chronic sinusitis, bronchiectasis, and situs inversus. Of note, bronchiectasis develops during childhood and is not present at birth; therefore, no child is born with Kartagener's triad. Other clinical findings include infertility in men due to living but immotile spermatozoa; women similarly have decreased fertility, with fewer than 50% successfully taking pregnancy to term. Also can be associated with hydrocephalus, transposition of great vessels, pyloric stenosis, and epispadias.

**Incidence:** Approx. 1 in 20-40,000

**Inheritance:** Autosomal recessive

**Defect:** Heterogeneous set of mutations to axonemal dynein heavy chain protein

**Diagnosis:** Brush biopsies can be taken from inferior turbinate, cells transferred to isotonic saline solution, and microscopically examined for normal beat pattern and frequency. Alternatively, can put biopsy in glutaraldehyde and perform electron microscopy.
Less commonly, can test mucociliary transport by administering aerosol of 99Tc-tagged Teflon particles, then measuring radioactivity in lungs over 2 hours (patient must not cough during test). Can also deposit saccharin on the inferior turbinate and measure time until tasted.

**Management:** Daily chest PT, treatment with mucolytics (recombinant DNase, Mucomyst). Antibiotics may be necessary for treatment of frequent pneumonia, sinusitis. Some patients may need PE tubes, sinus surgery, or nasal polypectomy as warranted.

6. (Rosow) Discuss the normal nasal cycle

The nasal cycle is the normal, irregularly timed pattern of physiologic change seen in a healthy nose. Roughly every 1-4 hours, the venous sinusoids he mucosa receive autonomic input to either become engorged or diminish in size, while the opposite occurs on the contralateral side. The amplitude of each cycle is increased by nasal infection or by gravity (greater congestion in supine position). The nasal cycle can contribute to a sensation of nasal obstruction, especially in the setting of infection or deviated septum. The role of the nasal cycle is unclear, although it has been postulated that the increased hydrostatic pressure contributes to defense against inhaled microorganisms by stimulating production of plasma exudate.

7. (Josh) What is the Cottle sign?
8. (Josh) Nasal valves—where are they and how does one assess dysfunction?

The **internal nasal valve** (b) is the narrowest portion of the nasal cavity and therefore any compromise of its components creates symptoms of nasal obstruction. The angle is bound medially by the septum and laterally by the inferior edge of the upper lateral cartilages and the anterior aspect of the inferior turbinate. This angle narrows and widens with nasal muscular contraction and relaxation on inspiration and expiration. The internal valve is normally 10 to 15 degrees in Caucasians and wider in Asians and others. Deformities of the adjacent septum or loss of anatomic support structures can predispose the valve to collapse or narrow causing nasal obstruction. The upper lateral cartilage at its junction with the septum may be thickened, twisted, or concave as a result of weakness, trauma, or even absent in the case of prior surgery. Webs of scarred mucosa may form between the septal mucosa and the lateral nasal wall or turbinates and may narrow the valve through scar contracture. Adhesions causing valve narrowing create a fixed obstruction with false-negative cottle maneuver. The **external nasal valve** (a) is a laterally based space boxed by the pyriform aperture, the ULC and LLC attachments, and the caudal septum. Obstruction as a result of external valve compromise may be a post-rhinoplasty phenomenon, as a result of the aging process, or a result of caudal septal dislocation or trauma.

The Cottle Maneuver is manual lateral distraction of the nasal valve. This maneuver may improve the sensation of nasal obstruction in cases of nasal valve collapse or anterior septal deviation. A positive sign may suggest nasal valve compromise, but is not always a reliable indicator with many false positives seen.

9. (Tali) Discuss objective measures of nasal obstruction.

No perfect objective test of nasal obstruction. Most commonly used objective measurements are rhinomanometry and acoustic rhinometry. Both give information about site of obstruction. There are many factors that may cause variability in these measures by changing the nasal resistance. They include: variability in nasal cycle, secretions, exercise, hyperventilation, breathing CO2, posture, medications (e.g. decongestant spray decreases nasal resistance), smoking, age, height, and time of the day.

**Rhinomanometry:** Simultaneous recording of transnasal pressure and airflow. By recording pressure and flow over given time period, mean pressure and volume of each nasal breath can be measured. From these measurement, can calculate other parameters such as resistance (pressure/flow).

Assesses nasal patency representative of how hard it is for pt to breath.

**Acoustic Rhinometry:** Presentation of a shock wave to the nasal airway → measuring reflected sound to obtain profile of cross-sectional area of different sites in the nose. May give more precise anatomic information for nasal surgeon and better for study of rapidly changing microvascular conditions and nasal volume changes.
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**Manometric Rhinometry:** Volume of air in nose measured by closing off nose, removing a volume of air, and then recording the resulting pressure change.

**CT/MRI:** Can assess cross-sectional area

**Peak expiratory flow meter:** Has been used to assess nasal airway and may correlate with nasal resistance.

10. (Scott) Discuss the role of objective testing in nasal airway.

Objective measurements of nasal airway:
- Methods used to objectively measure nasal patency and resistance include rhinomanometry and acoustic rhinometry.
- Rhinomanometry provides information about nasal airway flow and resistance, while acoustic rhinometry tells us about the anatomic cross-sectional area of the nasal cavity.
- Nasal airway resistance accounts for more than 50% of total airway resistance.

Resistance is pressure divided by flow. Based on laminar flow equations, decreases in r, or the nasal airway radius, cause 4-fold decreases in flow, or Q (where L is length, r is radius, P is pressure, h is viscosity, and r is density) (Bailey, 1998).

\[
Q = \left(\frac{DPr^4}{8hL}\right)
\]

Reynolds number greater than 2000 is equated with turbulent flow. Inspiratory flow is generally considered as laminar flow. Turbulent flow requires more energy expenditure but results in better mixing, which contributes to nasal function. Turbulent flow can prevent clearance of air, which can cause a sensation of obstruction regardless of nasal passage patency.

**Rhinomanometry:**
The nasal resistance is calculated from the measurement of the nasal airflow at a fixed transnasal pressure point. Three types of rhinomanometry: active anterior rhinomanometry (AAR), active posterior rhinomanometry (APR), and passive anterior rhinomanometry (PAR). Active involved flow from the respiratory cycle, while passive involved a flow pump.

AAR uses a face-mask and one nostril is sealed off with adhesive tape. A hard plastic tube is passed through this tape to measure the nasopharyngeal pressure. It is a dynamic test that studies nasal ventilation, showing the nature of the air stream and a difference in the shape of the inspiratory and expiratory limbs of the nasal cavity.

Rhinomanometry relates to degree of obstruction. The two major types of obstruction are mucosal hypertrophy and structural deformity. Rhinomanometry is performed with and without decongestion and total resistance is calculated. Resistance above 0.3 Pa/mL/s is usually symptomatic. The one caveat of rhinomanometry is that no resistance can be measured when the nasal passage is completely obstructed or with a septal perforation.

**Acoustic rhinometry:**
AR does not measure airflow parameters but explores the geometry of the nasal cavity. The principle of acoustic rhinometry is that an audible sound (150 - 10,000 Hz), propagated in a tube, is reflected by local changes in acoustic impedance. This method provides estimates of cross-sectional endonasal areas and the endonasal volume. It defines objectively the structural and mucosal components of the nasal passage. Due to the rapid acquisition of data that can be completed in a minute, patient tolerance is excellent, even in children.

Why use it:
- It can be used to differentiate if the nasal obstruction is structural or mucosal in nature by conducting the test before and after topical decongestion.
- Objective testing is useful in the quantitative assessment of the benefit of therapy (septoplasty/turbs).
- It provides quantitative information on the response of the nasal mucosa to intranasal challenges with allergens and other types of physical and chemical stimuli.

Conventional rhinomanometry determines nasal patency, or an individual's ability to breathe. Acoustic rhinomanometry may be used for states of changing musculovascular conditions or changes in nasal valve dimensions.

11. (CY) What are some physiologic and pathologic conditions that lead to nasal obstruction?

Physiologic: Hyperventilation, supine posture, alcohol, aspirin, and cold air, nasal cycle (involves swelling and then shrinkage of the linings of each side of the nose, has a periodicity varying from 1 to 4 hours and is found in 80% of the population

Pathologic: Septal deviation, Turbinate hypertrophy, Rhinoplasty, Septal perforation, Valvular collapse, Choanal atresia, Neoplasm, Polyposis, Allergic rhinitis, Septal hematoma, Septal perforation, Rhinitis medicamentosa, Vasomotor rhinitis, Sinusitis