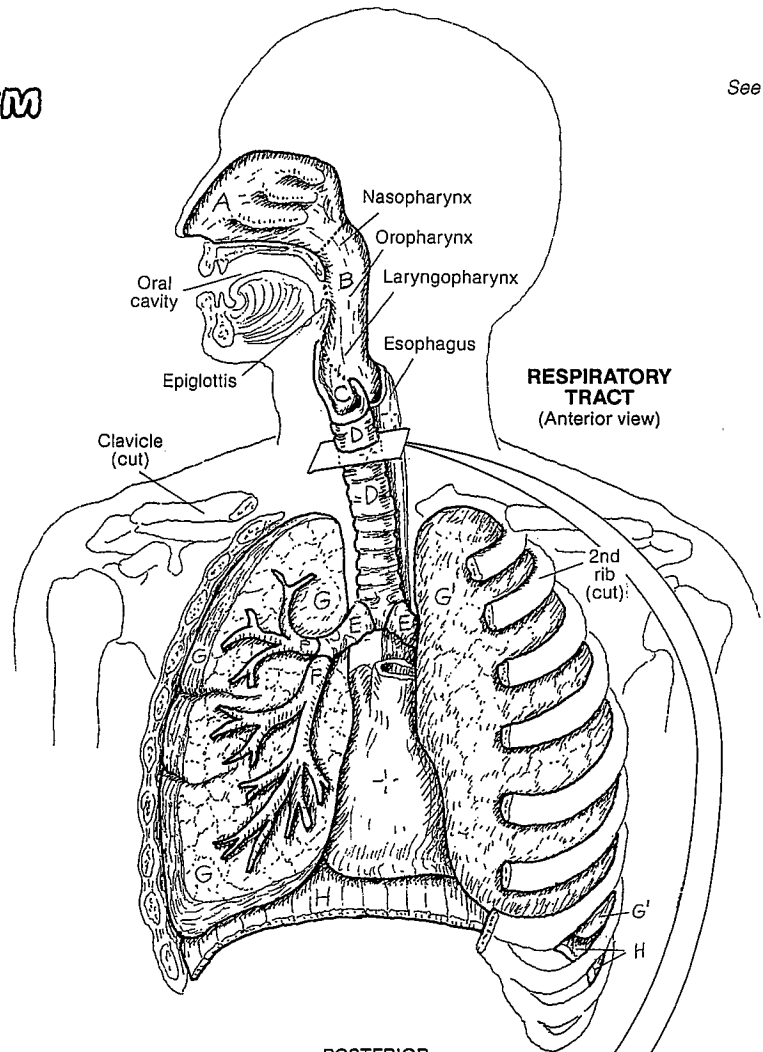


OVERVIEW OF THE SYSTEM

CN: Use red for L and light colors throughout. (1) Begin with the structures of the respiratory system. (2) Color the cross section of the trachea (D), including the respiratory mucosa (I). (3) Color the magnified section of the mucosa in the lowest view.

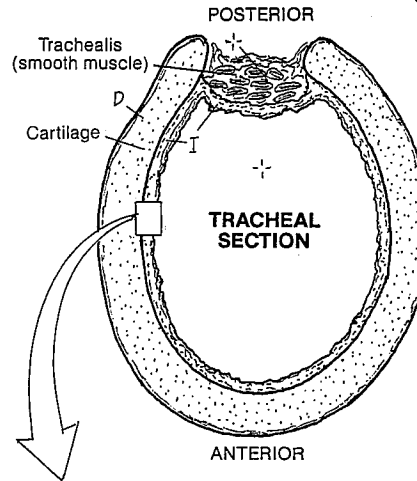
- NASAL CAVITY_A
- PHARYNX_B
- LARYNX_C
- TRACHEA_D
- PRIMARY BRONCHI_E
- BRONCHIAL TREE_F
- R. LUNG_G, L. LUNG_{G'}
- DIAPHRAGM_H



The respiratory tract conducts air to the respiratory units of the lungs where it can readily be absorbed by the blood, and it removes carbon dioxide-laden air from the air cells and exhausts it to the external atmosphere. It develops and refines sounds into potentially intelligible vocalization, and it helps maintain the acid-base balance of the blood by blowing off excess acid in the form of carbon dioxide. Nowhere in the body does the outside world, with all its creatures of microscopic dimension, have such easy access to the protected interior cavities of the body as it does at the air/blood interfaces of the lung. The respiratory tract has both air-conducting and respiratory (gas exchange) parts.

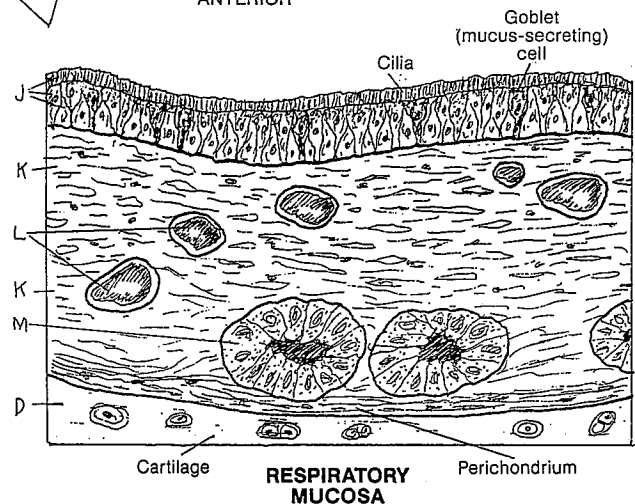
The air conduction tract includes an upper (*nasal cavity, pharynx, larynx*) and a lower tract (*trachea, primary bronchi and bronchial tree*). The upper tract is lined with respiratory mucosa, except in the lower pharynx where it has a stratified squamous epithelial surface. Except for the nose and pharynx, the skeleton of the respiratory tract is cartilaginous down to the smallest airways (bronchioles), where the cartilage is replaced by smooth muscle. The parts associated with gaseous exchange are the smallest bronchioles and alveoli (respiratory units), which take up much of the *lung's* volume.

The muscular diaphragm provides much of the force necessary for inspiration and expiration of air. One-quarter of that force is generated by the intercostal muscles moving the ribs.



- RESPIRATORY MUCOSA_I
- PSEUDOSTRATIFIED COLUMNAR EPITHELIUM_J
- LAMINA PROPRIA_K
- BLOOD VESSEL_L
- GLAND_M

The mucosa of the respiratory tract is largely *pseudostratified columnar* and (in the bronchioles) cuboidal *epithelia* with mucus-secreting *goblet* (unicellular gland) *cells* and *cilia*. Here excreted mucus traps foreign particulate matter, inhaled air is hydrated (mixed with water), putting oxygen in solution, and the air is heated from underlying vessels. The epithelial cells are supported by a loose fibrous, *glandular, vascular lamina propria*, replete with fibroblasts and cells of the lymphoid system. Deep to this connective tissue layer is the supporting tissue (bone in the nasal cavity, muscle in the pharynx, hyaline cartilage in the trachea, larynx, and bronchi, smooth muscle in the bronchioles, and thin fibers supporting the air cells).

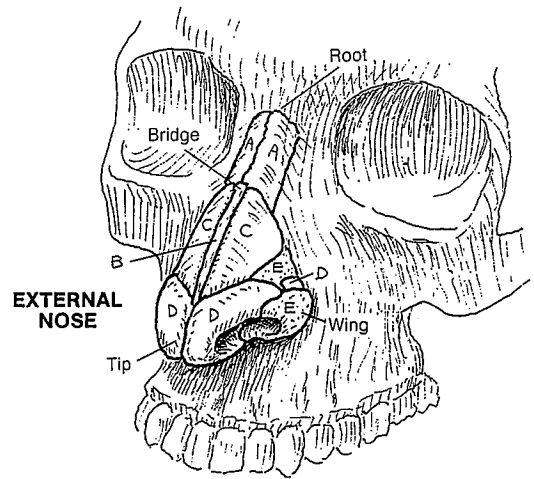


EXTERNAL NOSE, NASAL SEPTUM & NASAL CAVITY

CN: Use very light colors for H and I. (1) Begin with the upper illustration. (2) Color the nasal septum and its structure in the nasal cavities diagram. (3) Color the elements of the lateral wall of the nasal cavity and relations in the lowest illustration.

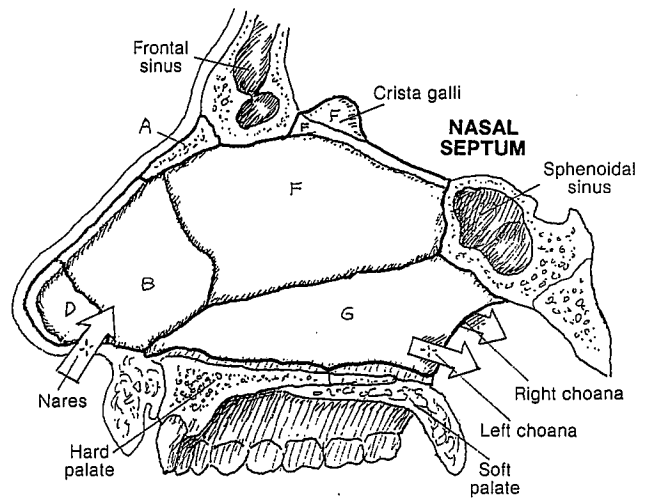
EXTERNAL NOSE :-

- NASAL BONE _A
- CARTILAGE OF NASAL SEPTUM _B
- LATERAL NASAL CARTILAGE _C
- ALAR CARTILAGE _D
- FIBRO-FATTY TISSUE _E



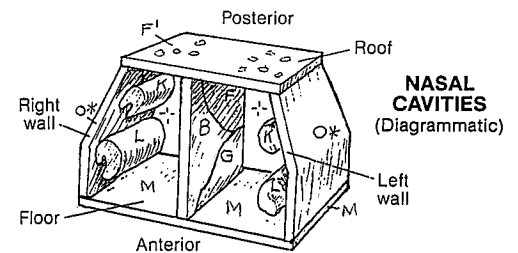
NASAL SEPTUM :-

- CARTILAGE OF NASAL SEPTUM _B
- ALAR CARTILAGE _D
- PERPENDICULAR PLATE OF ETHMOID BONE _F
- VOMER BONE _G

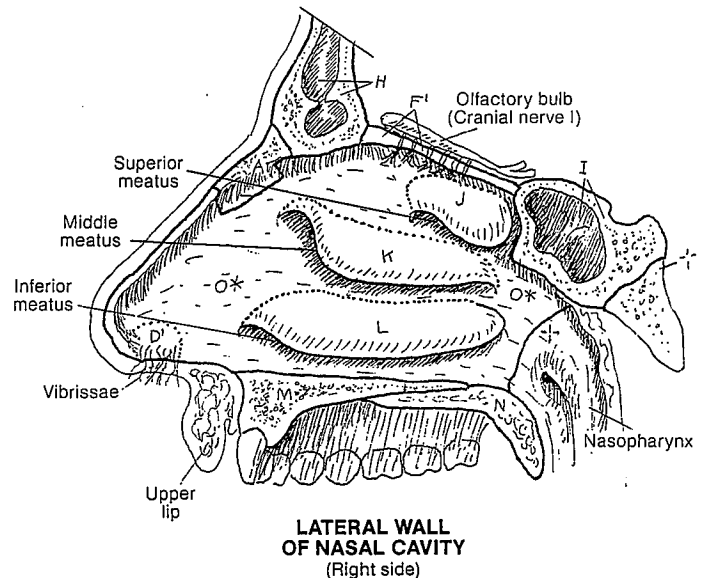


NASAL CAVITY & RELATIONS :-

- NASAL BONE _A
- FRONTAL BONE _H
- SPHENOID BONE _I
- CRIBRIFORM PLATE OF ETHMOID _F
- VESTIBULE OF NOSE _{D'}
- SUPERIOR CONCHA _J
- MIDDLE CONCHA _K
- INFERIOR CONCHA _L
- HARD PALATE _M
- SOFT PALATE _N
- LATERAL WALL _{O*}

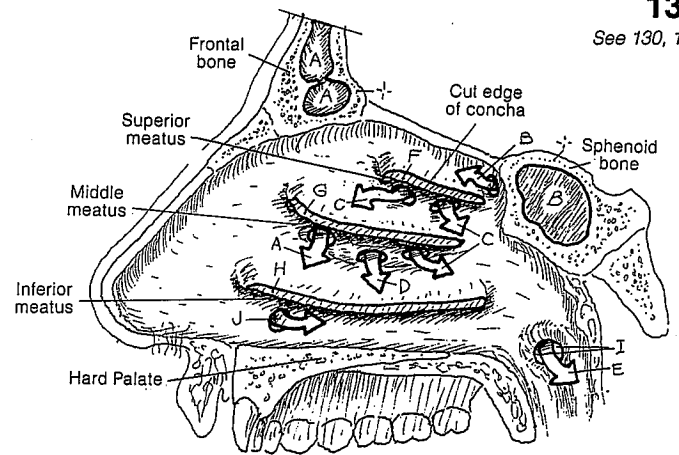


The nose is a largely cartilaginous affair external to the skull proper. Its orifices (nares, or nostrils) open into the nasal cavity of the skull, which is a bony tunnel divided by a partly cartilaginous *nasal septum*. The nasal cavity opens into the muscular pharynx through two bony-walled posterior apertures called choanae. The nose, situated as it is in front of the face, often receives the brunt of a facial impact. In such an event, it is not unusual for the *cartilage of the nasal septum* (septal cartilage) to break off from the *perpendicular plate of the ethmoid*. This "deviated septum" may obstruct air flow through the narrowed half of the cavity. The skin-lined *vestibule* of the nose has long hairs (vibrissae) that serve to discourage entrance of foreign bodies. The nasal cavity is carpeted with a mucosal lining characterized by ciliated epithelial cells that secrete mucus and whose cilia sweep small particulate matter down into the nasopharynx. The bony *conchae* (so called because of their resemblance, in frontal section, to the conch shell) increase the surface area of the nasal cavity, significantly boosting the local temperature and moisture content. The *inferior concha* on each side is attached to the ethmoid bone by an immovable joint (suture); the *superior and middle conchae* are part of the ethmoid bone. The spaces under the conchae (meatuses) are open to paranasal sinuses (air-filled cavities), the subject of the next plate. Note that the roof of the nasal cavity (*cribriform plate*) transmits the olfactory nerve fibers; resting on or near this plate are the frontal lobes of the brain. Note that the floor of the nasal cavity is the *palate*, which is also the roof of the oral cavity. The *soft palate* is a muscular extension of the bony palate and plays a role in swallowing.



PARANASAL AIR SINUSES

CN: Use the same colors for the bones A and B, and conchae F, G, and H, that were used for those structures on Plate 130. (1) Color the sinus drainage sites in the lateral wall of the nasal cavity. Include the edges of the conchae which have been cut away to reveal the meatuses and related drainage sites. (2) Color the coronal section. Note that it is a composite view, showing openings into the nasal cavity that do not appear in any one single coronal plane. Even so, this view cannot show the relations of the sphenoid sinus and opening, nor the mastoid air cells and the auditory tube. (3) Color the lower drawings. Note that nasolacrimal duct and the duct of the frontal sinus are shown on one side only.



SINUS DRAINAGE SITES
(Right lateral wall of nasal cavity, nasal conchae removed)

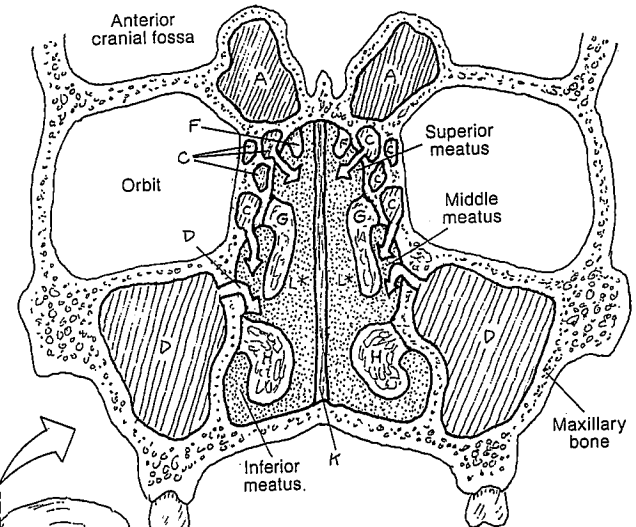
AIR SINUSES:

- FRONTAL ^A
- SPHENOID ^B
- ETHMOID ^C
- MAXILLARY ^D
- MASTOID ^E

NASAL CONCHAE:

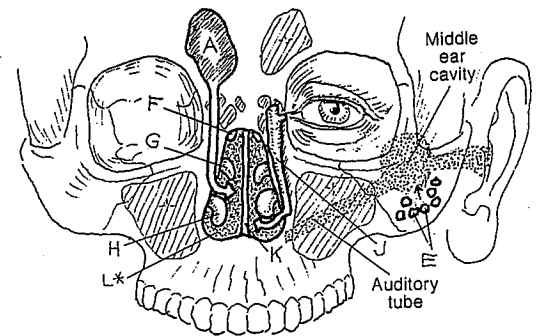
- SUPERIOR ^F
- MIDDLE ^G
- INFERIOR ^H

- OPENING OF AUDITORY TUBE ^I
- NASOLACRIMAL DUCT ^J
- NASAL SEPTUM ^K
- NASAL CAVITY ^{L*}

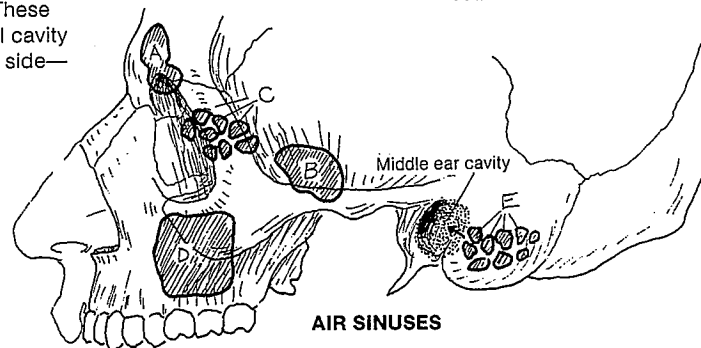


PARANASAL SINUSES
(Diagrammatic, composite, coronal section)

The skull has a number of cavities in it. You are familiar with some of them (mouth, nose, external ear, orbits), but perhaps not so familiar with others. The frontal, sphenoid, maxillary, ethmoid, and temporal bones have variably sized cavities, all of which directly or indirectly communicate with the nasal cavity. These are the *paranasal air sinuses*, to be distinguished from the venous sinuses of the dura mater. These air sinuses serve to lighten the skull and they add timbre to the voice. They are lined with respiratory-type epithelium, which is continuous with the epithelium of the nasal cavity. The mucus secretions from these epithelial linings pass down canals and enter the nasal cavity just under the conchae (meatuses). Their specific drainage sites are indicated by the arrows. Should these passageways become blocked by inflammation and swelling, pressure builds within the sinuses to a point where considerable pain can be experienced (sinusitis, sinus headache). Agents that constrict the blood vessels (decongestants) help to reduce the swelling and reestablish proper drainage. The *mastoid air cells*, in the mastoid process of the temporal bone, drain into the middle ear (tympenic) cavity, communicating by way of the auditory (pharyngotympanic) tube with the nasopharynx just posterior to the nasal cavity. The *nasolacrimal duct* receives secretions from the lacrimal gland, which functions to keep the covering (conjunctiva) of the eye globe moist. Tears drain into slits at the medial aspect of the eyelids, which open into sacs that narrow into the nasolacrimal ducts. These ducts pass downward along the lateral walls of the nasal cavity and open into the meatus of the inferior concha on each side—and that is why one blows one's nose after crying.



PARANASAL SINUS AND DUCTS



AIR SINUSES

PHARYNX & LARYNX

CN: Use dark or bright colors for N, O, and Q. (1) Begin with the over-view diagram in the upper right corner. (2) Complete the large composite sagittal section (do not color the arrows representing air flow). Take note of the surrounding structure as a frame of reference (not to be colored). (3) Color all six laryngeal views simultaneously.

PHARYNX ^A

NASOPHARYNX ^B

PHARYNGEAL TONSIL ^C

OROPHARYNX ^D

PALATINE TONSIL ^E

LARYNGOPHARYNX ^F

The pharynx is an incomplete tube of mostly skeletal (constrictor) muscle and fibrous tissue, appearing to hang from the edges of the choanae (posterior nasal apertures) at the base of the skull. Posteriorly, it is supported by fascia in front of the sphenoid bone and the upper six cervical vertebrae. It is the posterior and inferior continuation of the *nasal cavity*; it is open to the *oral cavity* anteriorly. Inferiorly, it continues as the *esophagus* behind and the *larynx* in front. Most of pharynx is lined with stratified squamous epithelium, except the nasopharynx (respiratory lining). Coordinated muscular activity in the pharynx underlies the mechanism of swallowing (deglutition).

Masses of partially encapsulated lymphoid tissue incompletely encircle the nasal and oral openings into the pharynx (Waldeyer's ring)—i.e., at the opening of the auditory tube (tubal tonsils), at the roof of the nasopharynx (adenoids), between the palatoglossal and palatopharyngeal pillars (palatine tonsils; see Plate 137), and at the posterior tongue (lingual tonsils). See tonsil function in Plate 127.

HYOID BONE

LARYNX ^H

LARYNGEAL CAVITY ^{H'}

EPIGLOTTIS ^I

THYROID CARTILAGE ^J

THYROHYOID MEMBRANE ^K

CRICOID CARTILAGE ^L

CRICOTHYROID LIGAMENT ^M

ARYTENOID CARTILAGE ^N

CORNICULATE CARTILAGE ^O

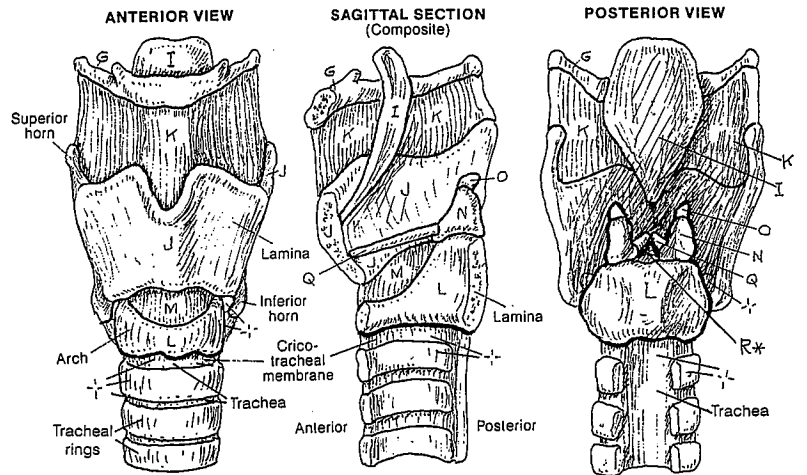
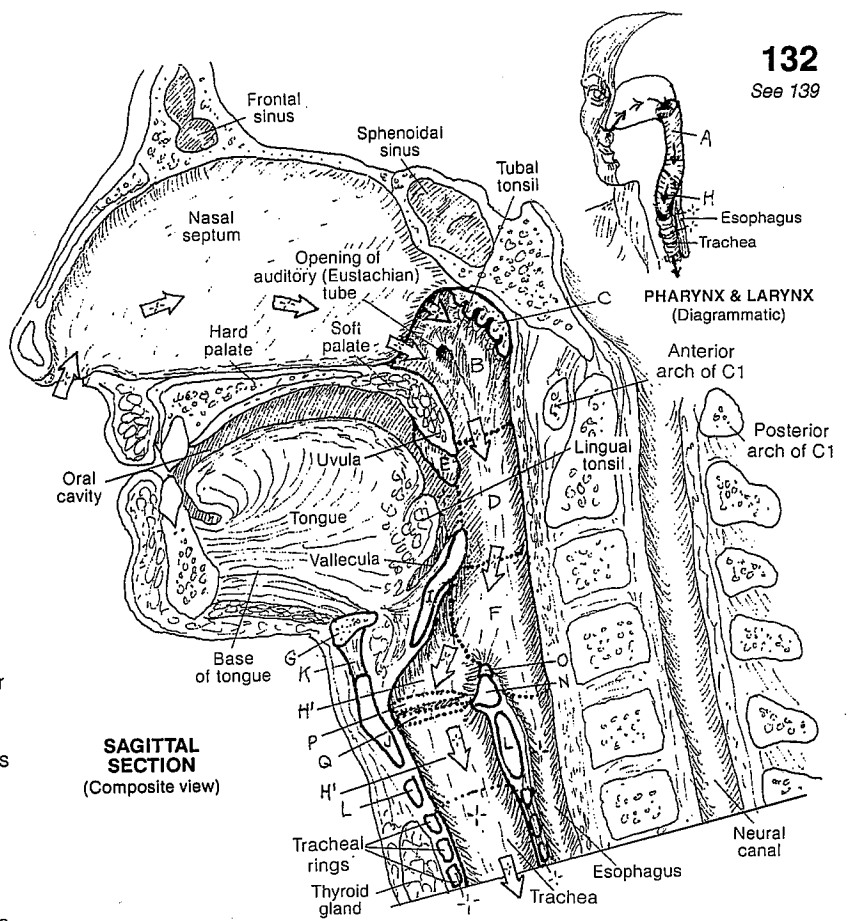
VESTIBULAR FOLD ^P

VOCAL FOLD ^Q

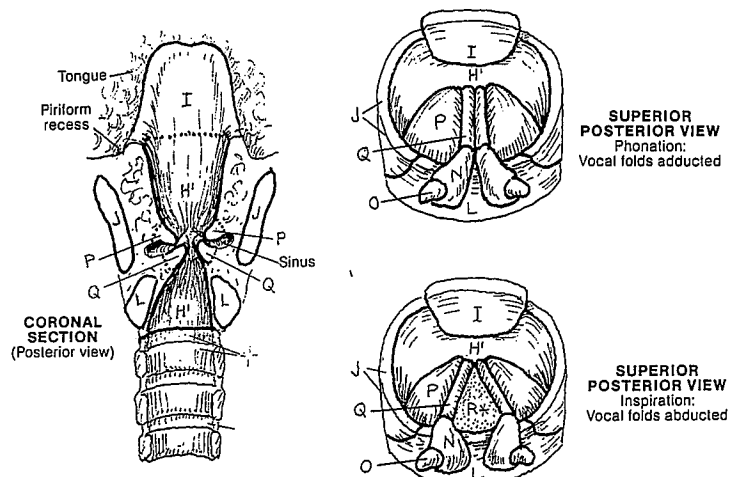
RIMA GLOTTIS ^{R*}

The larynx provides a mechanism for sound production, manipulation of sound waves, and protection from inadvertent aspiration (inhaling) of solid matter. The larynx is supported by a framework of hyaline cartilage connected by ligaments. Although associated with the larynx, the hyoid bone is not a laryngeal structure.

The thyroid cartilage is composed of two laminae that together are V-shaped when seen from above. The *arytenoid cartilages* articulate with the top of the cricoid, pivoting on it. The *vocal folds* are mucosa-lined ligaments stretching between thyroid and arytenoid cartilages. They are abducted/adducted by the movement of the arytenoid cartilages. In breathing they are abducted; in coughing, they are momentarily fully adducted (closing the *rima*), permitting intrathoracic pressure to build; opened rapidly by abduction of the folds, the rima experiences hurricane-force winds from the depths of the respiratory airway (explosive cough). During phonation, the vocal folds are generally adducted, varying somewhat with pitch and volume. The *vestibular folds* (false vocal folds) are fibrous and move only passively.



VIEWS OF THE LARYNX



LOBES & PLEURAE OF THE LUNGS

CN: Use bright colors for A-E, very light colors for F and G, and a reddish-brown color for H. In all of the illustrations the thickness of the pleurae (F and G) has been enlarged for coloring purposes. (1) Begin with the anterior view. Note that the ribs and intercostal muscles have been removed (see Plate 50). Sections of the pleurae have been stripped away and separated. The potential pleural space is between these layers; in the coronal and cross sections, this space is drawn as a dark line and not as a structure to be colored. Similarly, the title is left uncolored. A small section of the parietal pleura has been cut and pulled away to reveal the underlying visceral pleura and a portion of the costodiaphragmatic recess below the lung superficial to the diaphragm. (2) Color the coronal view, noting the left crus of the diaphragm and the cardiac notch of the left lung. (3) Color the cross section of the lung lobes and pleurae (as seen from above), noting the vertebral level and the roots of the lungs.

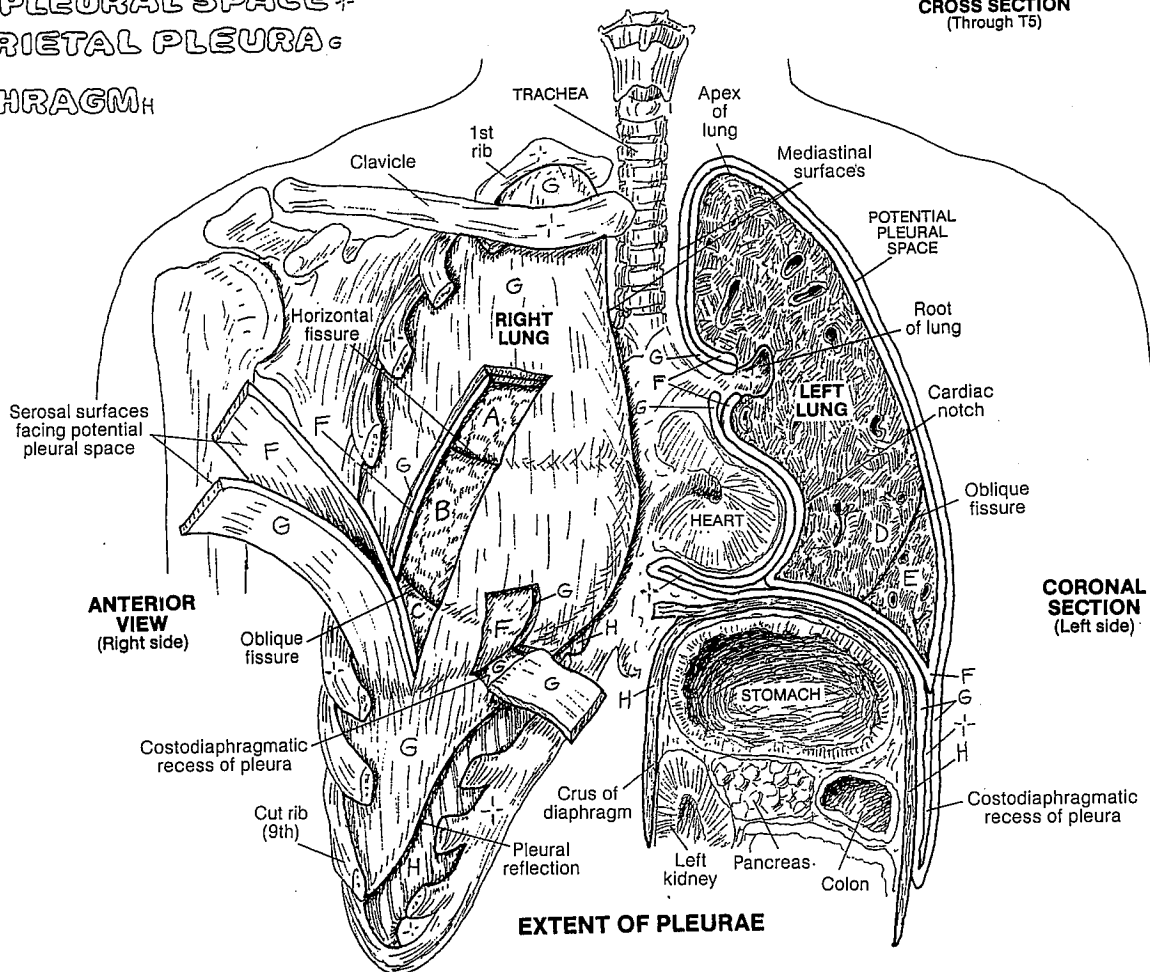
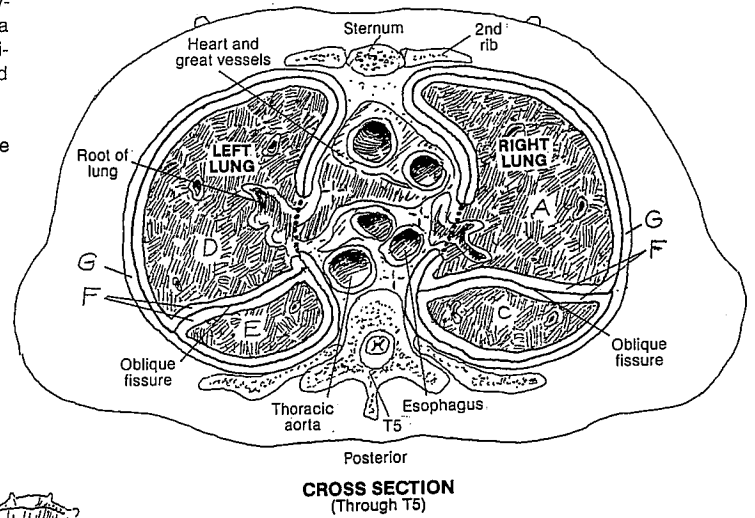
LOBES

- R. UPPER_A L. UPPER_D
- R. MIDDLE_B L. LOWER_E
- R. LOWER_C

PLEURAE

- VISCERAL PLEURA_F
- PLEURAL SPACE₊
- PARIETAL PLEURA_G

DIAPHRAGM_H



The lobes of the lungs are largely enveloped in *visceral pleura*, a thin serosal membrane that turns (reflects) off the lungs at their roots to become the *parietal pleura*, which lines the inner surface of the chest wall, the lateral mediastinum, and much of the diaphragm. These serous membranes are in contact with each other, separated by a thin layer of serous (watery, glycoprotein) fluid. The interface of these membranes is potentially a cavity or space (*pleural space/cavity*). With certain diseases, the space is capable of expanding to accommodate increasing amounts of fluid (pleural effusion) at the expense of the lung, resulting in a

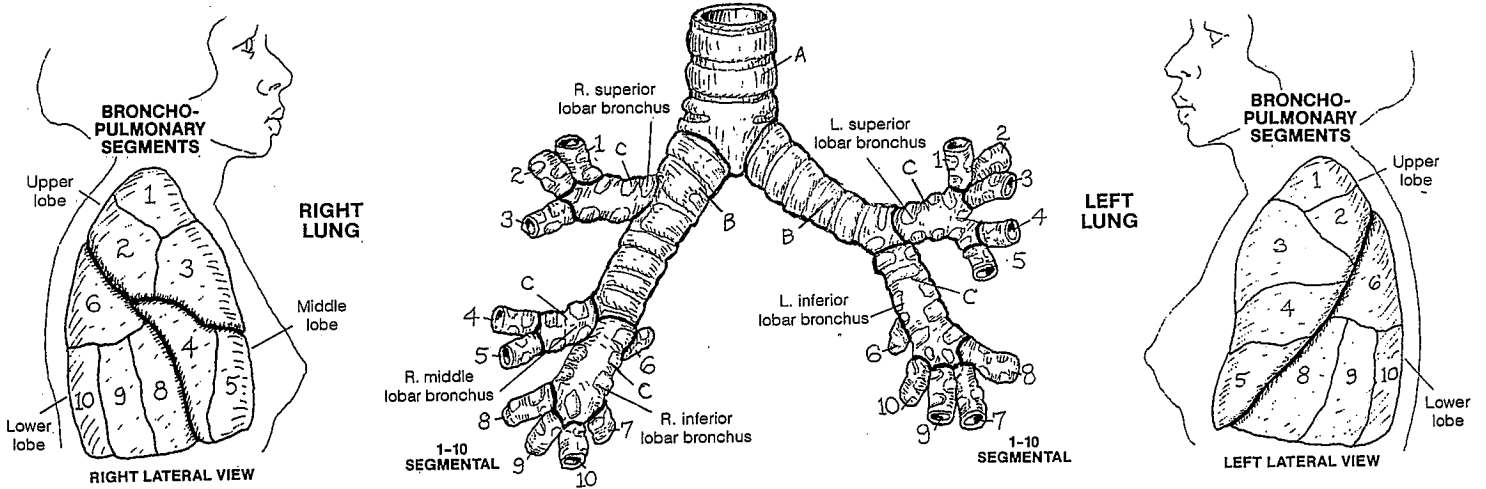
reduction of total lung capacity. The serous fluid maintains surface tension between the pleural surfaces (resisting separation of visceral and parietal layers in contact with one another) and prevents frictional irritation between moving pleural membranes. During quiet inhalation, the inferior and anterior margins of the visceral pleura-lined lungs do not quite reach the parietal pleura, leaving a narrow space or recess—i.e., the costomediastinal recess between the rib cage and the mediastinum (not shown), and the costodiaphragmatic recess between rib cage and diaphragm (see coronal section at lower right).

LOWER RESPIRATORY TRACT

TRACHEA, MAIN (PRIMARY) BRONCHUS, LOBAR (SEC.) BRONCHUS.

SEGMENTAL (TERTIARY) BRONCHI / BRONCHOPULMONARY SEGMENTS:

- 1 APICAL 2 POST. 3 ANT. 4 LAT. (R.L.) 4 SUP. (L.L)
- 5 MED. (R.L.) 5 INF. (L.L) 6 SUP. 7 MED. BASAL
- 8 ANT. BASAL 9 LAT. BASAL 10 POST. BASAL



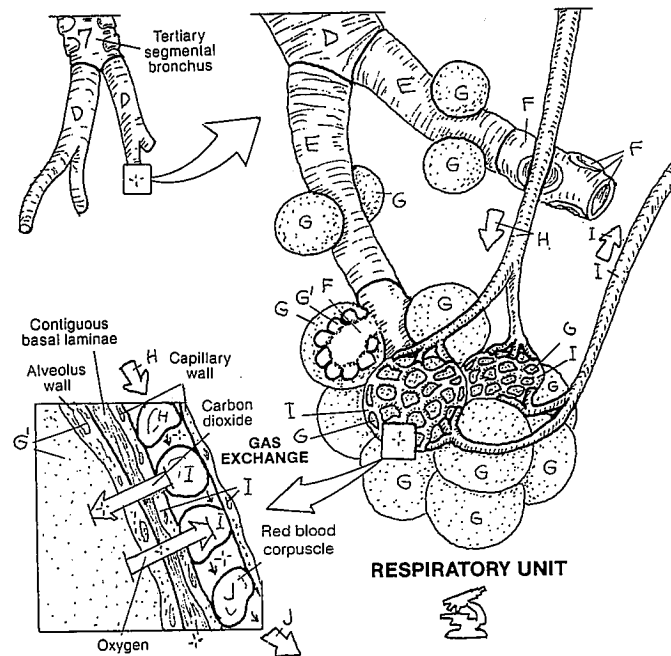
CN: Save blue for H, purple for I, and red for J (in the respiratory unit below). (1) Use ten different colors for both lungs, and key those colors to the ten segmental bronchi of each lung. (2) Below, use the same color as above for the 7th segmental bronchus. Use one light color for the alveoli (G¹) and the alveolar sacs (G). Note in the gas exchange diagram that red blood cells in the purple capillary (F) receive three different colors according to their stage of oxygenation.

The lower respiratory tract consists of the *trachea* and the *bronchial tree*, including the respiratory units that are engaged in gaseous exchange. The lungs are divided by connective tissue septa into triangular-shaped, surgically resectable anatomical and functional units called *bronchopulmonary segments*, each served by a segmental bronchus, supplied by a segmental artery, and drained by segmental veins and lymphatics. Segments are of special significance to those interpreting lung sounds by stethoscope (auscultation) or listening to the sounds coming from the lungs when the chest wall is tapped (percussion). By such methods, sites of alveolar dysfunction/disease and levels of abnormal accumulations often can be determined.

BRONCHIOLE

- RESPIRATORY BRONCHIOLE =
- ALVEOLAR DUCT =
- ALVEOLAR SAC, & ALVEOLUS =
- PULMONARY ARTERIOLE =
- CAPILLARY NETWORK =
- PULMONARY VENULE =

Within each bronchopulmonary segment, a segmental bronchus branches into several *bronchioles* (less than 1 mm in diameter, supported by smooth muscle instead of cartilage). These bronchioles give off smaller terminal bronchioles, characterized by ciliated cuboidal cells without glands. The terminal bronchioles represent the end of the air-conducting pathway. Each terminal bronchiole divides into two or more *respiratory bronchioles*, characterized by occasional alveolar sacs on their walls. Each respiratory bronchiole supplies a respiratory unit, which is a discrete group of air cells (*alveoli*), arranged in *alveolar sacs*, fed by *alveolar ducts*. Extending from its source bronchiole, each respiratory bronchiole has more and more alveolar sacs, terminating as an alveolar duct opening into alveolar sacs. The walls of the air cells, composed of simple squamous epithelia supported by thin interwoven layers of elastic and reticular fibers, are surrounded by capillaries that arise from pulmonary arterioles and become the tributaries of pulmonary venules. The walls of these capillaries are fused to and structurally similar to those of the alveoli. Oxygen and carbon dioxide rapidly diffuse, on the basis of pressure gradients, through these walls.



MECHANISM OF RESPIRATION

CN: Use light colors throughout, except for a bright or dark color for E. (1) Begin with the illustration at far left (inspiration); note that the thoracic wall (A) is shown only in the far right

diagram. Color the diaphragm, its location represented by broken lines. (2) Color the expiration illustration and the bucket handle analogy. (3) Finish with the illustration at far right.

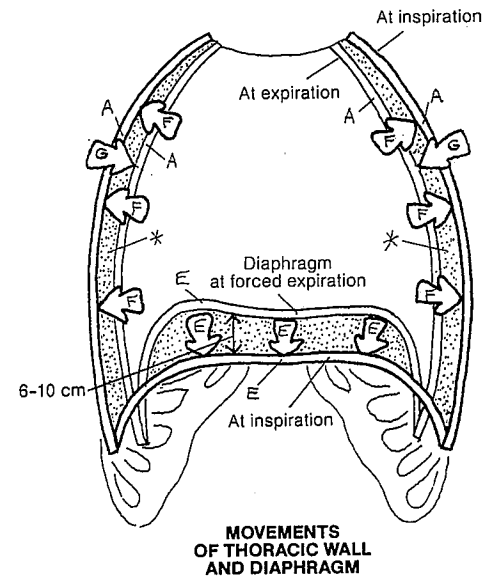
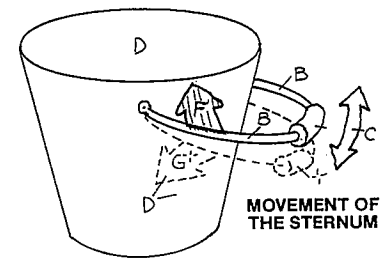
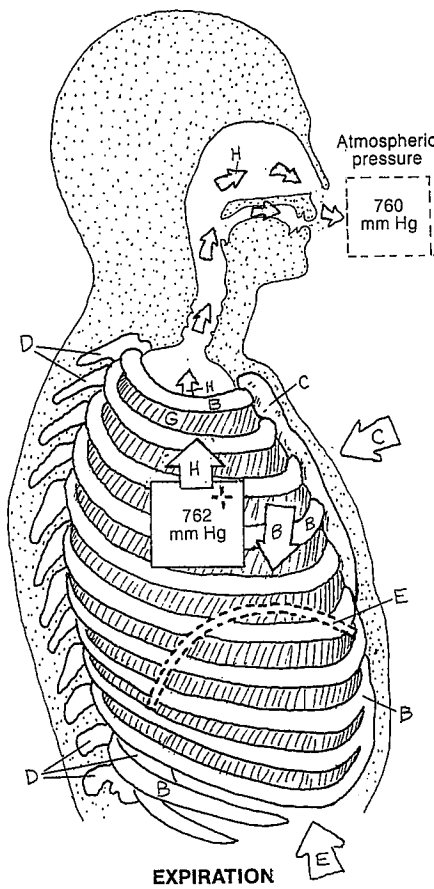
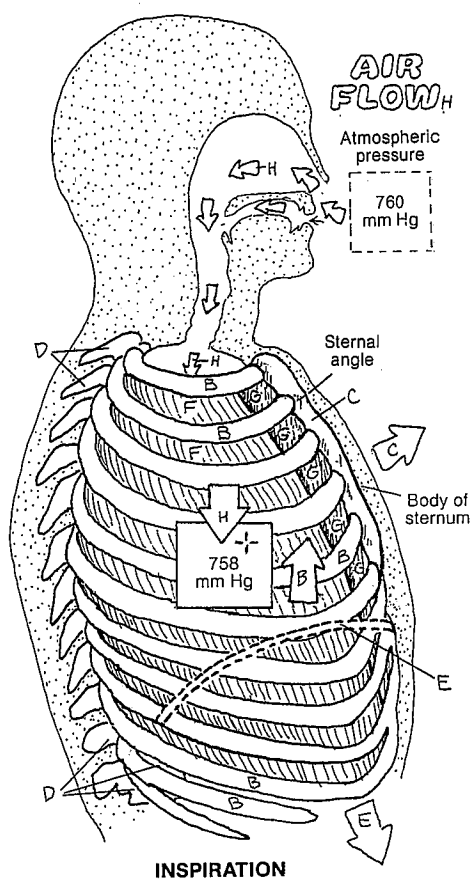
- THORACIC WALL ^A
- RIB & COSTAL CARTILAGE ^B
- STERNUM ^C
- THORACIC VERTEBRAE ^D

MUSCLES OF INSPIRATION ⁺

- DIAPHRAGM ^E
- EXTERNAL INTERCOSTAL ^F

MUSCLE OF EXPIRATION ⁻

- INTERNAL INTERCOSTAL ^G



The mechanism of respiration makes possible breathing, which consists of inhalation (inspiration) and exhalation (expiration) phases. The physical principle underlying air movement in/out of the thorax is the inverse relationship of pressure and volume (as one goes up, the other goes down). Volume changes within the thorax alter the intrathoracic pressure 1-2 mm Hg above/below atmospheric pressure (outside the body) in quiet breathing—enough of a change to move about 500 ml of air with each breath. The thoracic diaphragm accomplishes about 75% of the inspiratory effort, the external intercostals 25%. Expiration is largely diaphragm and external intercostal relaxation/stretch, and lung elasticity, with some help from the internal intercostals. In inspiration, contraction of the diaphragm flattens the muscle and lowers the floor of the thorax, increasing the vertical dimension of the thoracic cavity. Contraction of the external intercostals

elevates the ribs, swinging the sternal body slightly outward at the sternal angle. This increases the transverse and anteroposterior dimensions of the thoracic cavity. These actions collectively increase the intrathoracic volume, momentarily lowering the pressure within. Given the relatively higher atmospheric pressure outside the head, air is induced to enter the respiratory tract to find lower pressure. The action of the bucket handle demonstrates the hinge action at the sternal angle and related rib elevation. In expiration, the relaxed diaphragm forms "domes" over the underlying liver and stomach, decreasing the vertical dimension of the thorax. Recoil/descent of the ribs decreases the transverse and anteroposterior dimensions. The thoracic volume is thus decreased, momentarily increasing the intrathoracic pressure above atmospheric. Air escapes to the outside, aided by the natural elastic recoil of the lungs.