IX. RESPIRATORY SYSTEM
OVERVIEW

ON: 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 (J). (3) Color the
enlargement of the mucosa in the lowest view.

NASAL CAVITY
PHARYNX
LARYNX
TRACHEA
PRIMARY BRONCHI
BRONCHIAL TREE
H. LUNG
L. LUNG
DIAPHRAGM

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 exhaus-
ta it to the external atmosphere. It develops and refines
sounds into potentially intelligible vocalization, and helps main-
tain acid-base balance of the blood by blowing off excess acid
in the form of carbon dioxide. Nowhere in the body does the out-
side 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 respira-
tory tract has both air-conducting and respiratory (gas ex-
change) parts.

The air conduction tract includes an upper (nasal cavity,
pharynx, larynx) and 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 air-
ways (bronchioles) where the cartilage is replaced by smooth
muscle. Those parts associated with gaseous exchange are the
smallest bronchioles and alveoli (respiratory units) and 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:
PSEUDOSTRATIFIED COLUMNAR EPITHELIUM
LAMINA PROPIA
BLOOD VESSEL
GLAND

The mucosa of the respiratory tract is largely pseudostrati-
fied columnar and (in the bronchioles) cuboidal epithelium 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. These 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
nasal cavity, muscle in the pharynx, hyaline cartilage in the tra-
chea, larynx, and bronchi, smooth muscle in the bronchioles, and
thin fibers supporting the air cells).
The external nose is a largely cartilaginous affair external to the skull proper. Its orifices (nostrils or nares) 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 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 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.
IX. RESPIRATORY SYSTEM
PARANASAL AIR SINUSES

ON: Use the same colors for the bones A and B, and conchae F, G, and H, that were used for those structures on Plate 92. (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 ducts of the frontal sinus are shown on one side only.

AIRC SINUSES:
FRONTAL A
SPHENOID B
ETHMOID C
MAXILLARY D
MASTOID E

NASAL CONCHAE:
SUPERIOR F
MIDDLE G
INFERIOR H

OPENING OF AUDITORY TUBE
NASOLACRIMAL DUCT
NASAL SEPTUM
NASAL CAVITY

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, the 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 ( tympanic) 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. These 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 explains how it is that one blows one’s nose after one cries.
IX. RESPIRATORY SYSTEM
PHARYNX & LARYNX

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. Food and air share this common tube. Most of the pharynx is lined with stratified squamous epithelium except the nasopharynx. Should air pass into the esophagus it will usually leave passively where it came in (bulging), should food attempt passage through the larynx, a more dynamic event ensues (coughing). This potentially serious possibility is made slight by the complex swallowing mechanism (deglution).

LARYNX: H
EPICLOTTIS I
THYROID CARTILAGE J
THYROHYOID MEMBRANE K
CRICOID CARTILAGE L
CRICOHYOID LIGAMENT M
ARYTENOID CARTILAGE N
CORNICULATE CARTILAGE O
VESTIBULAR FOLD P
VOCAL FOLD Q
RIMA GLOTTIS R
TRACHEA S
CARTILAGE S

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 which together are V-shaped when looking at them 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.
IX. RESPIRATORY SYSTEM
LOBES & PLEURA OF THE LUNGS

LOBES:
R. UPPER, R. MIDDLE, R. LOWER, L. UPPER, L. LOWER

BRONCHI:
MAIN (PRIMARY BRONCHUS), F
LOBAR (SECONDARY) BRONCHUS, C

PLEURAE:
VISCERAL PLEURA, H
PARIETAL PLEURA, I
PLEURAL CAVITY, *

CN: Use your lightest colors for A-E. (1) Begin with the large illustration. You may color over the segmental bronchi when coloring the lobes of the lung. When coloring the cut pleural edges (in both this view and the cross section), note that the visceral pleura (H) turns to become the parietal pleura (I) at the roots of the lungs. (2) Complete the posterior and cross sectional views.

The illustration largely speaks for itself, and during coloring it should be studied intently to appreciate relationships and form. Note carefully how the thin serous membrane lining the lung (visceral pleura) turns (reflects) outward at the root of the lung to line the inner surface of the chest wall (parietal pleura). The space between these membranes is the pleural cavity; it is empty of structure. The thin watery (serous) fluid on the facing pleural surfaces maintains capillary attraction between the pleural surfaces (resisting pneumothorax), and prevents frictional irritation between moving pleural membranes.

During expiration, the diaphragm is relaxed, forming paired domes over the upper abdominal viscera. As a result, crevices (recesses) of the pleural cavity are created between the ribs and the diaphragm, and the ribs and the mediastinum. Devoid of lung, they may fill with fluid in diseases of and trauma to the lungs or chest (pleural effusion). Increased fluid volume may replace lung space, inducing shortness of breath, necessitating removal of the fluid by syringe (thoracentesis) at the costodiaphragmatic recess(es). In doing this, thought must be given to the sites of the liver, spleen, lung, and intercostal vessels/nerve.
IX. RESPIRATORY SYSTEM
LOWER RESPIRATORY TRACT

SEGMENTAL TERTIARY BRONCHI:
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

BRONCHIOLE A
RESPIRATORY BRONCHIOLE B
ALVEOLAR DUCT C
ALVEOLAR SAC & ALVEOLUS D
PULMONARY ARTERIOLE E
CAPILLARY NETWORK F
PULMONARY VENULE G

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 which 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.

CN: Save blue for E, purple for F, and red for G (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 (D), and the alveolar sacs (D). Note in the gas exchange diagram, that red blood cells in the purple capillary (F) receive three different colors based on their stage of oxygenation.

The lower respiratory tract consists of the trachea and the bronchial tree, including the respiratory units which are engaged in gaseous exchange. The lungs are divided by connective tissue septa into triangular-shaped, surgically-reatachable 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 can often be determined.
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 after 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 buckst 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.