Respiratory System

- Consists of the respiratory and conducting zones
- Respiratory zone:
  - Site of gas exchange
  - Consists of bronchioles, alveolar ducts, and alveoli

Respiratory System

- Conducting zone:
  - Conduits for air to reach the sites of gas exchange
  - Includes all other respiratory structures (e.g., nose, nasal cavity, pharynx, trachea)
- Respiratory muscles – diaphragm and other muscles that promote ventilation

Respiratory System

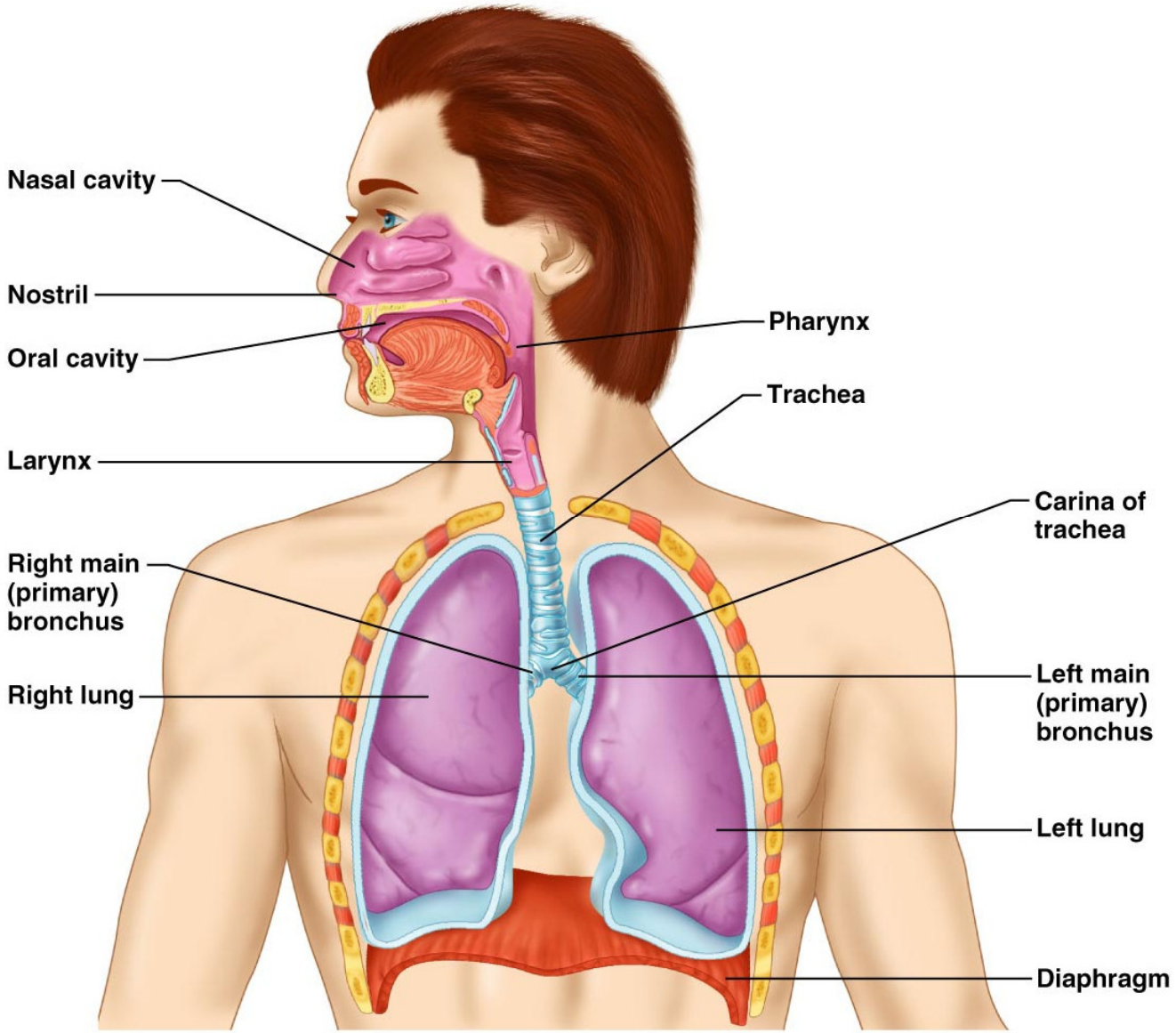


Figure 22.1

Major Functions of the Respiratory System

- Major function is to supply the body with oxygen and dispose of carbon dioxide
- Respiration – four distinct processes must happen
  - Pulmonary ventilation – moving air into and out of the lungs
  - External respiration – gas exchange between the lungs and the blood
  - Transport – transport of oxygen and carbon dioxide between the lungs and tissues
  - Internal respiration – gas exchange between systemic blood vessels and tissues

Functional Anatomy of the Respiratory System

- Includes nose, nasal cavity, pharynx, larynx, trachea, bronchi, lungs
- Consists of two zones:
  - Respiratory zone: site of gas exchange (bronchioles, alveolar ducts, alveoli)
  - Conductiong zones: all other respiratory passageways

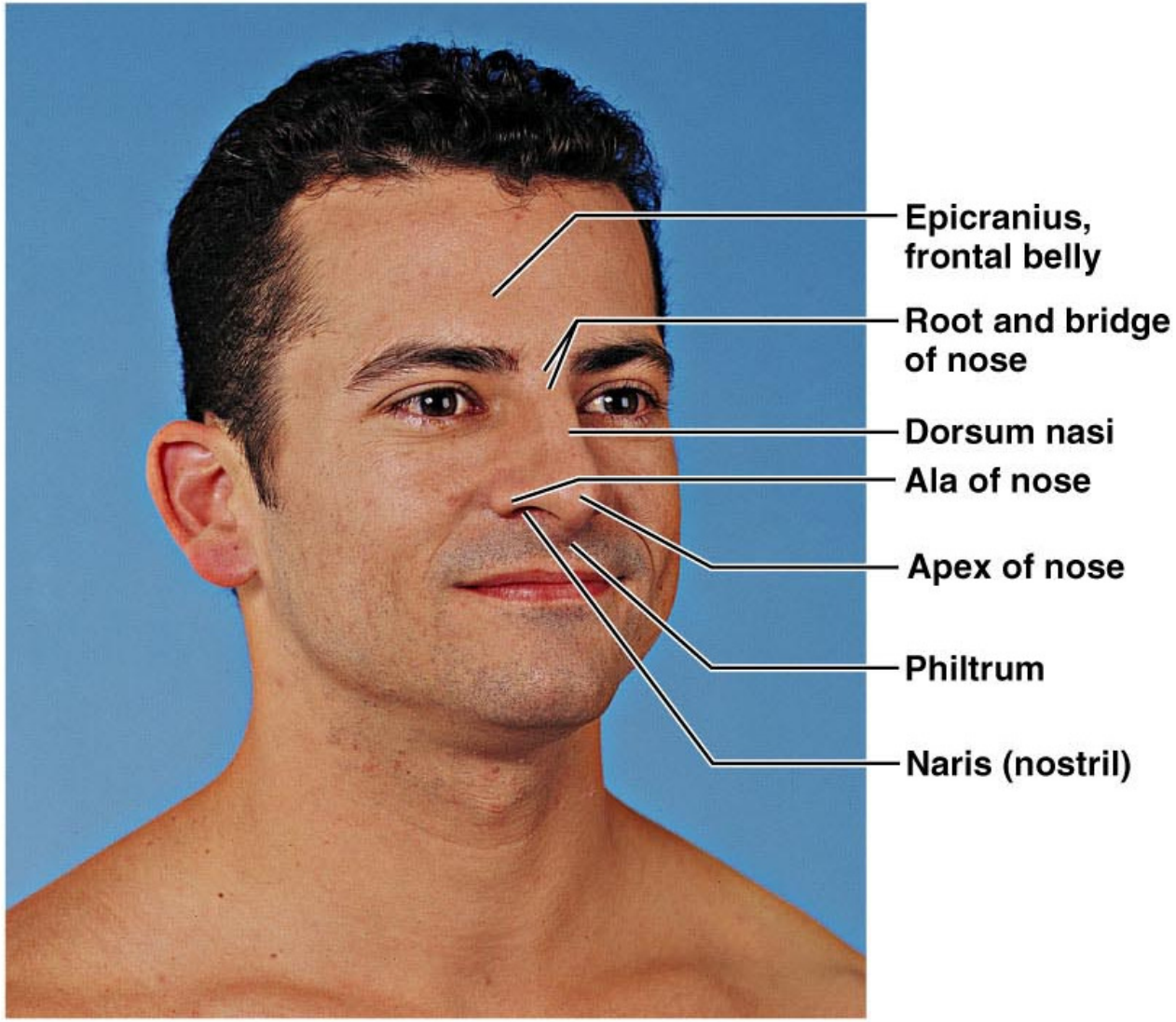
The Nose

- The only externally visible part of the respiratory system that functions by:
  - Providing an airway for respiration
  - Moistening and warming the entering air
  - Filtering inspired air and cleaning it of foreign matter
  - Serving as a resonating chamber for speech
  - Housing the olfactory receptors

Structure of the Nose

- Nose is divided into two regions:
  - External nose, including the root, bridge, dorsum nasi, apex, philtrum, nares, alae
  - Internal nasal cavity
- Philtrum – a shallow vertical groove inferior to the apex
- The external nares (nostrils) are bounded laterally by the alae

Structure of the Nose



(a)

Figure 22.2a

Structure of the Nose

Fashioned by the nasal and frontal bones (superiorly), maxillary bones, and hyaline cartilage.

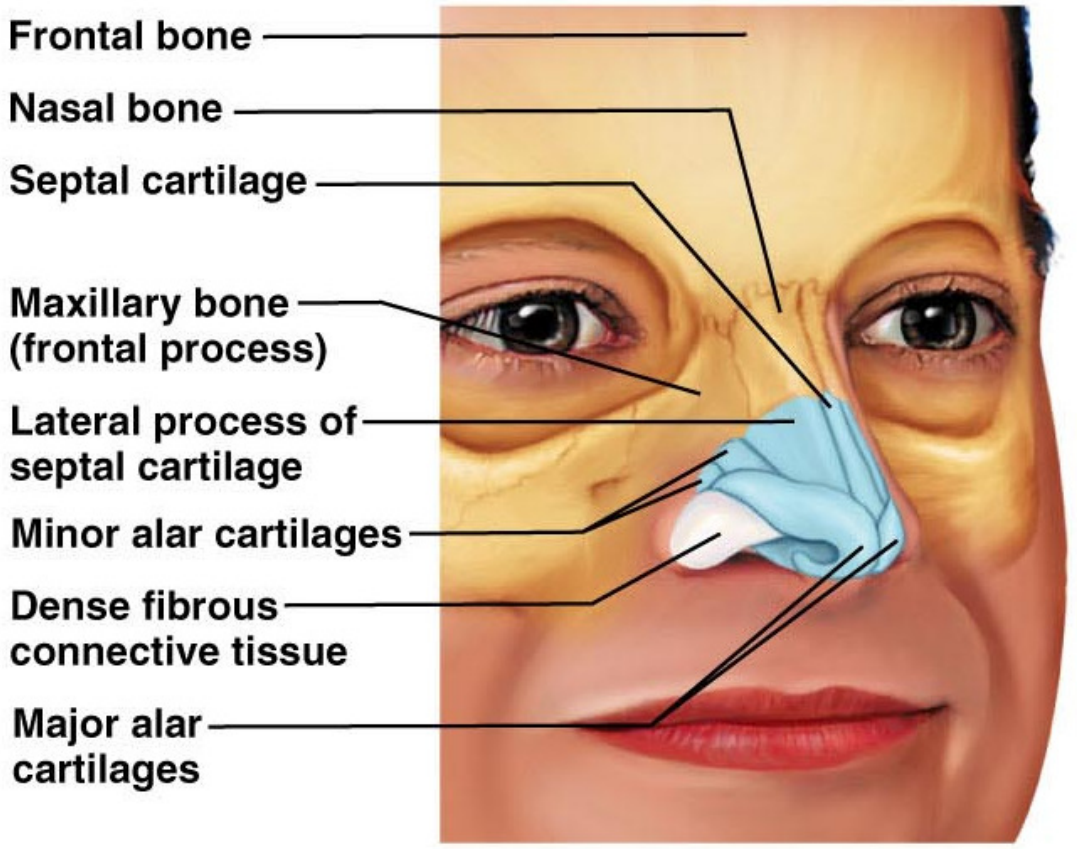


Figure 22.2b

Nasal Cavity

- Lies in and posterior to the external nose
- Is divided by a midline nasal septum
- Opens posteriorly into the nasal pharynx via internal nares
- The ethmoid and sphenoid bones form the roof
- The floor is formed by the hard and soft palates

Nasal Cavity

- Vestibule – nasal cavity superior to the nares
  - Lined with skin containing subaceous and sweat glands and vibrissae
  - Vibrissae – hairs that filter coarse particles from inspired air
- Olfactory mucosa
  - Lines the superior nasal cavity
  - Contains smell receptors

Nasal Cavity

- Respiratory mucosa:
  - pseudostratified ciliated columnar epithelium
  - Lines the balance of the nasal cavity
  - Glands secrete mucus containing lysozyme and defensins to help destroy bacteria
  - Superior, middle, inferior conchae: increase mucosal surface area
- Paranasal sinuses: in frontal, sphenoid, ethmoid, maxillary bones
  - Lighten the skull and warm & moisten air

Nasal Cavity

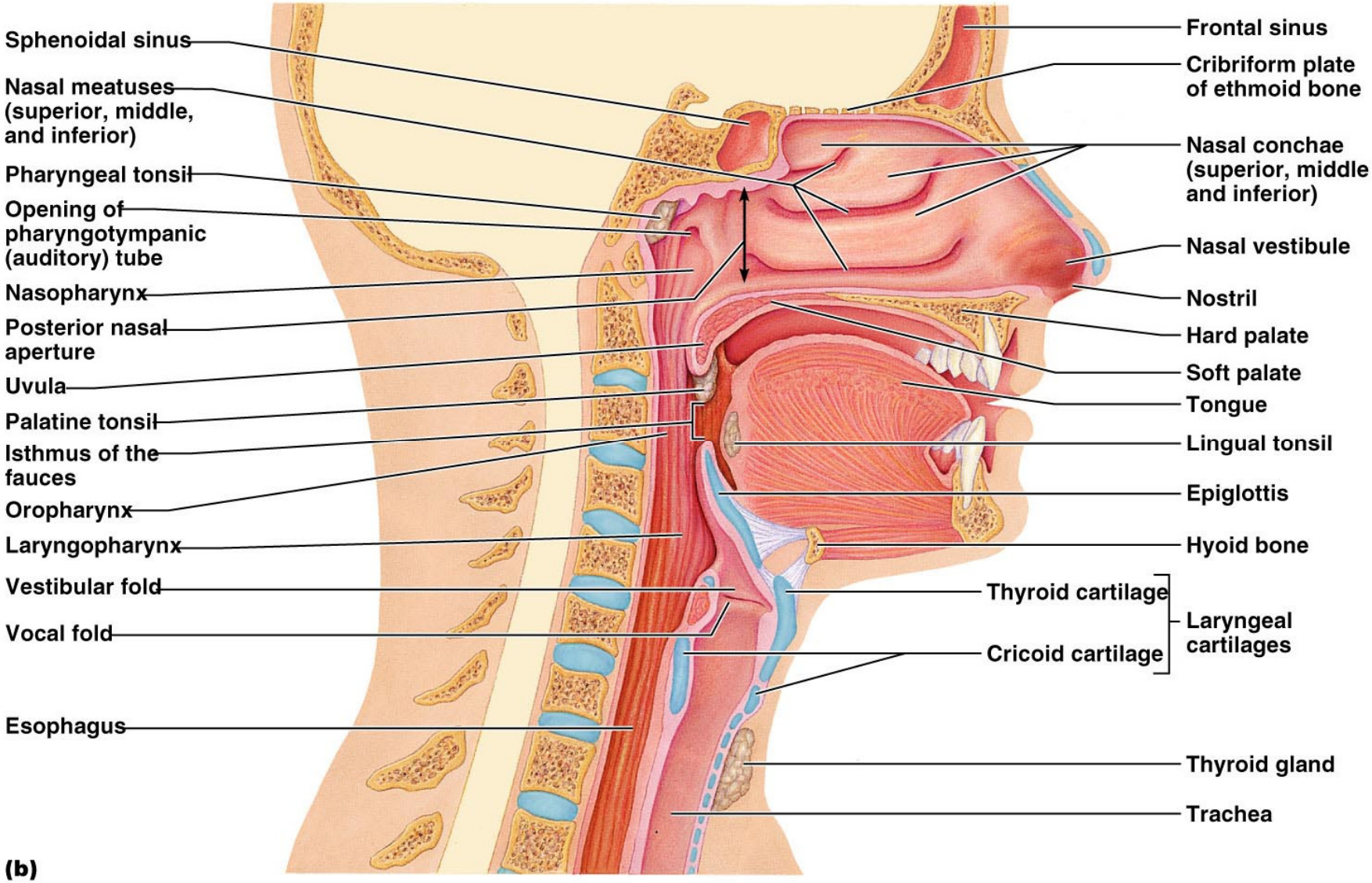


Figure 22.3b

Functions of the Nasal Mucosa and Conchae

- During inhalation the conchae and nasal mucosa:
  - Filter, heat, and moisten air
- During exhalation these structures:
  - Reclaim heat and moisture
  - Minimize heat and moisture loss

Paranasal Sinuses

- Sinuses in bones that surround the nasal cavity
- Sinuses lighten the skull and help to warm and moisten the air

Pharynx

- Funnel-shaped tube of skeletal muscle that connects to the:
  - Nasal cavity and mouth superiorly
  - Larynx and esophagus inferiorly
- Extends from the base of the skull to the level of the sixth cervical vertebra
- It is divided into three regions
  - Nasopharynx
  - Oropharynx
  - Laryngopharynx

Nasopharynx

- Lies posterior to the nasal cavity, inferior to the sphenoid, and superior to the level of the soft palate
- Strictly an air passageway
- Lined with pseudostratified columnar epithelium
- Uvula closes during swallowing to prevent food from entering the nasal cavity
- The pharyngeal tonsil (adenoid) destroys pathogens entering the nasopharynx
- Pharyngotympanic (auditory) tubes open into the lateral walls

Oropharynx

- Posterior to the oral cavity
- Serves as a common passageway for food and air
- The epithelial lining changes to (protective) stratified squamous epithelium
- Palatine tonsils lie in the lateral walls of the fauces
- Lingual tonsil covers the base of the tongue

Hypopharynx (Laryngopharynx)

- Serves as a common passageway for food and air
- Lies posterior to the upright epiglottis where respiratory and digestive pathways diverge
- Continuous with the esophogus posteriorly
- Food always has the “right of way” and the air passage is closed when swallowing

Larynx (Voice Box)

- Attaches to the hyoid bone and opens into the hypopharynx superiorly
- Continuous with the trachea posteriorly
- The three functions of the larynx are:
  - To provide an open airway
  - To act as a switching mechanism to route air and food into the proper channels
  - To function in voice production

Framework of the Larynx

- There are 9 different cartilages of the larynx
  - Thyroid cartilage with a midline laryngeal prominence (Adam's apple)
  - Signet ring–shaped anteroinferior cricoid cartilage
  - Three pairs of small arytenoid, cuneiform, and corniculate cartilages
- Epiglottis – elastic cartilage that covers the laryngeal inlet during swallowing

Framework of the Larynx

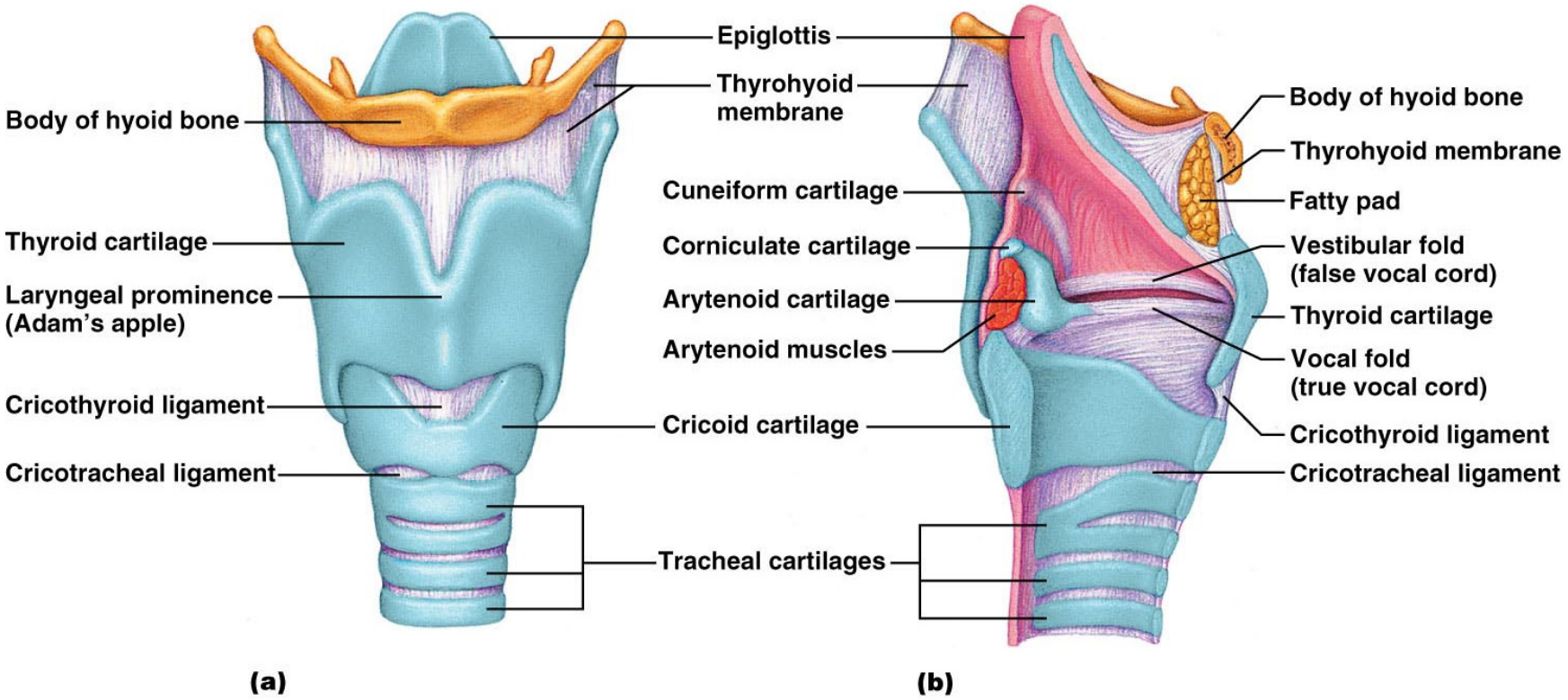


Figure 22.4a, b

Vocal Ligaments

- Attach the arytenoid cartilages to the thyroid cartilage
- Composed of elastic fibers that form mucosal folds called true vocal cords
  - The medial opening between them is the glottis
  - They vibrate to produce sound as air rushes up from the lungs
- False vocal cords (vestibular folds)
  - Mucosal folds superior to the true vocal cords
  - Have no part in sound production
  - Help close the glottis when swallowing

Vocal Production

- Speech – intermittent release of expired air while opening and closing the glottis
- Pitch – determined by the length and tension of the vocal cords
    - Wide glottis: deep tones
    - Narrow glottis: high pitched tones
- Loudness – depends upon the force at which the air rushes across the vocal cords
- Vocal cords do not move when we whisper
- The pharynx resonates, amplifies, and enhances sound quality
- Sound is “shaped” into language by action of the pharynx, tongue, soft palate, and lips

Movements of Vocal Cords

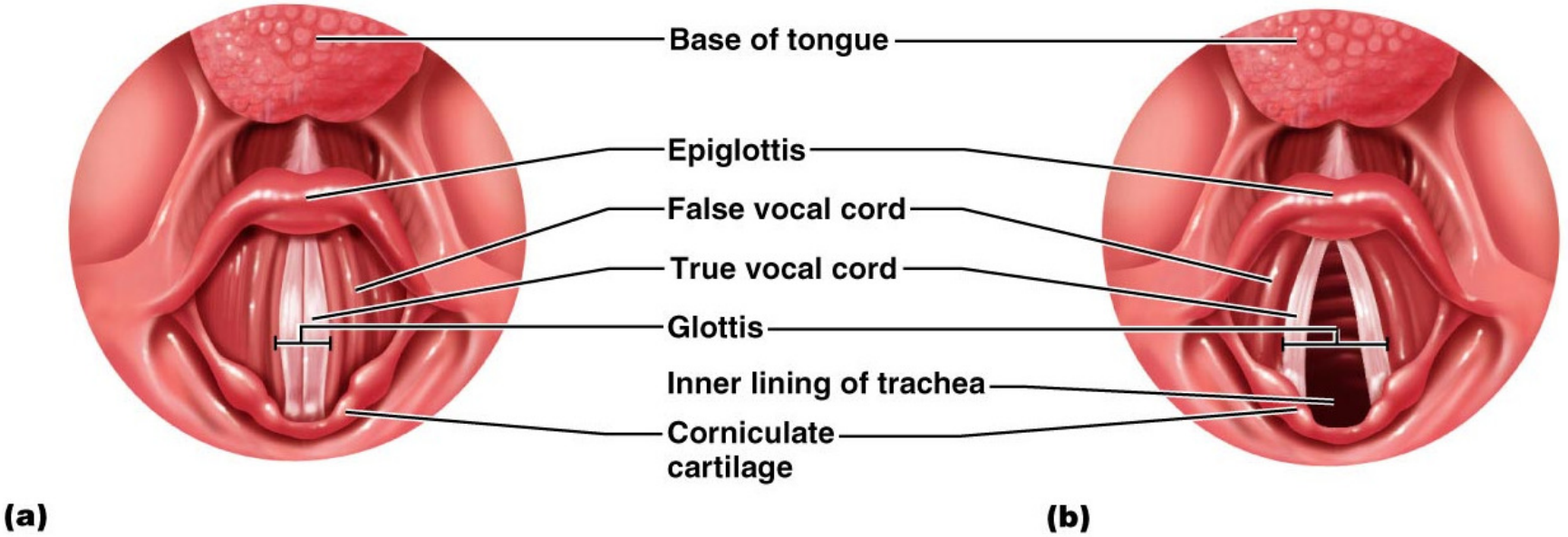


Figure 22.5

Sphincter Functions of the Larynx

- The larynx is closed during coughing, sneezing, and Valsalva's maneuver
- Valsalva's maneuver
  - Air is temporarily held in the lower respiratory tract by closing the glottis
  - Causes intra-abdominal pressure to rise when abdominal muscles contract
  - Helps to empty the rectum
  - Stabalizes the trunk when lifting heavy loads

Trachea

- Flexible and mobile tube extending from the larynx into the mediastinum
- Composed of three layers
  - Mucosa – made up of goblet cells and ciliated epithelium
  - Submucosa – connective tissue deep to the mucosa
  - Adventitia – outermost layer made of C-shaped rings of hyaline cartilage

Trachea

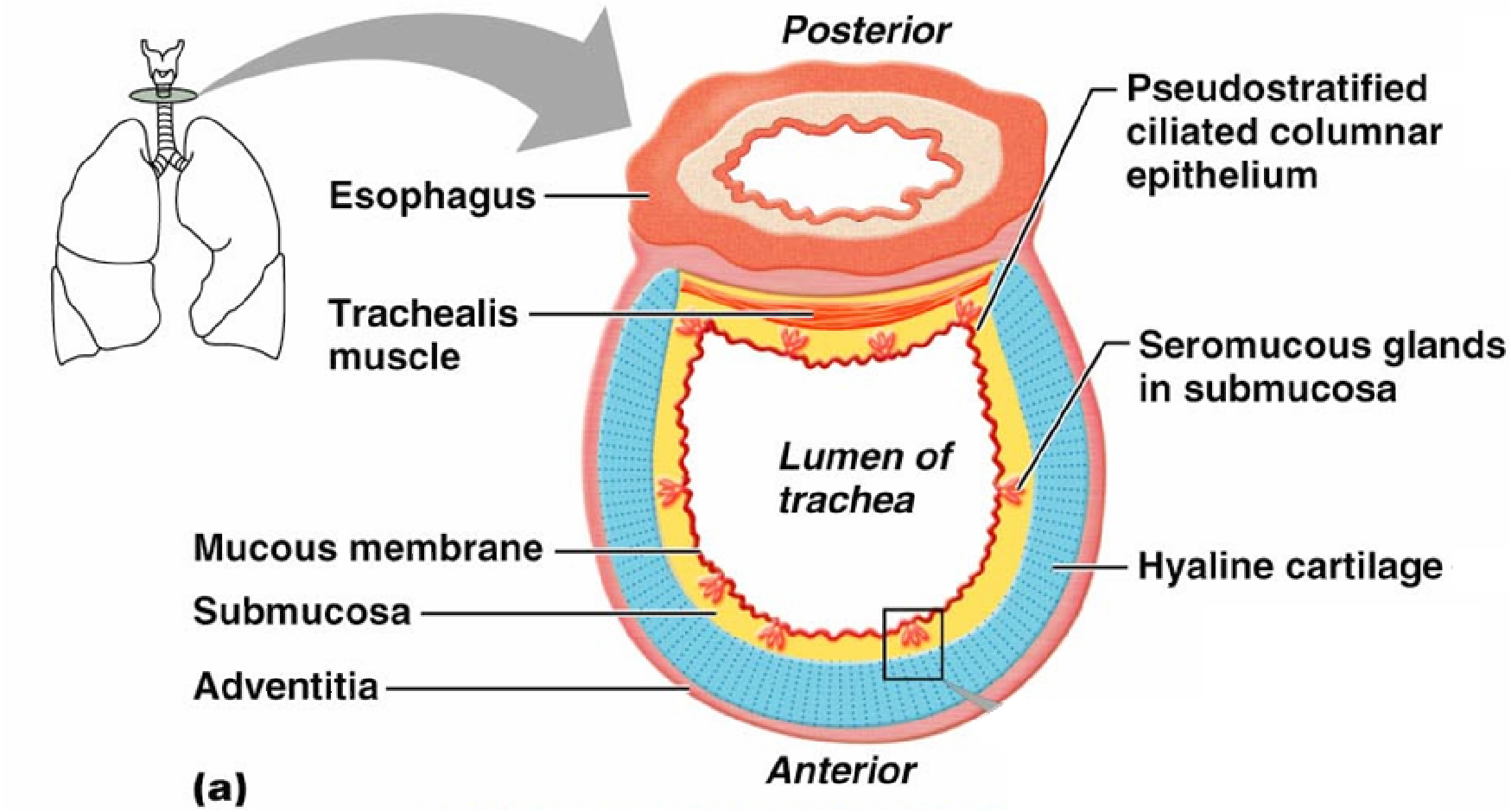
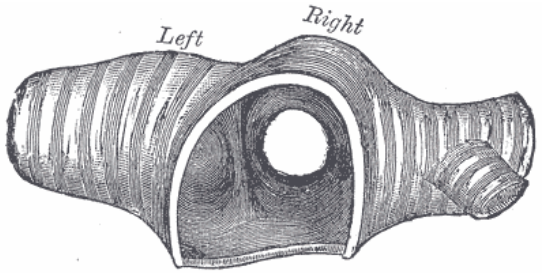


Figure 22.6a

Conducting Zone: Bronchi

- Carina of the last tracheal cartilage marks the end of the trachea and the beginning of the bronchi
- Air reaching the bronchi is:
  - Warm and cleansed of impurities
  - Saturated with water vapor



- Bronchi subdivide into secondary bronchi, each supplying a lobe of the lungs
- Air passages undergo 23 orders of branching

Conducting Zone: Bronchial Tree

- Site where conducting zone structures give rise to respiratory zone structures
- Conducting zone structures: right & left main (primary) bronchi
- Subdivides into secondary bronchi (3 on right, 2 on left)
- Secondary bronchi subdivide into tertiary bronchi
- As conducting tubes become smaller, structural changes occur
  - Cartilage support structures change
  - Epithelium types change
  - Amount of smooth muscle increases

Conducting Zones

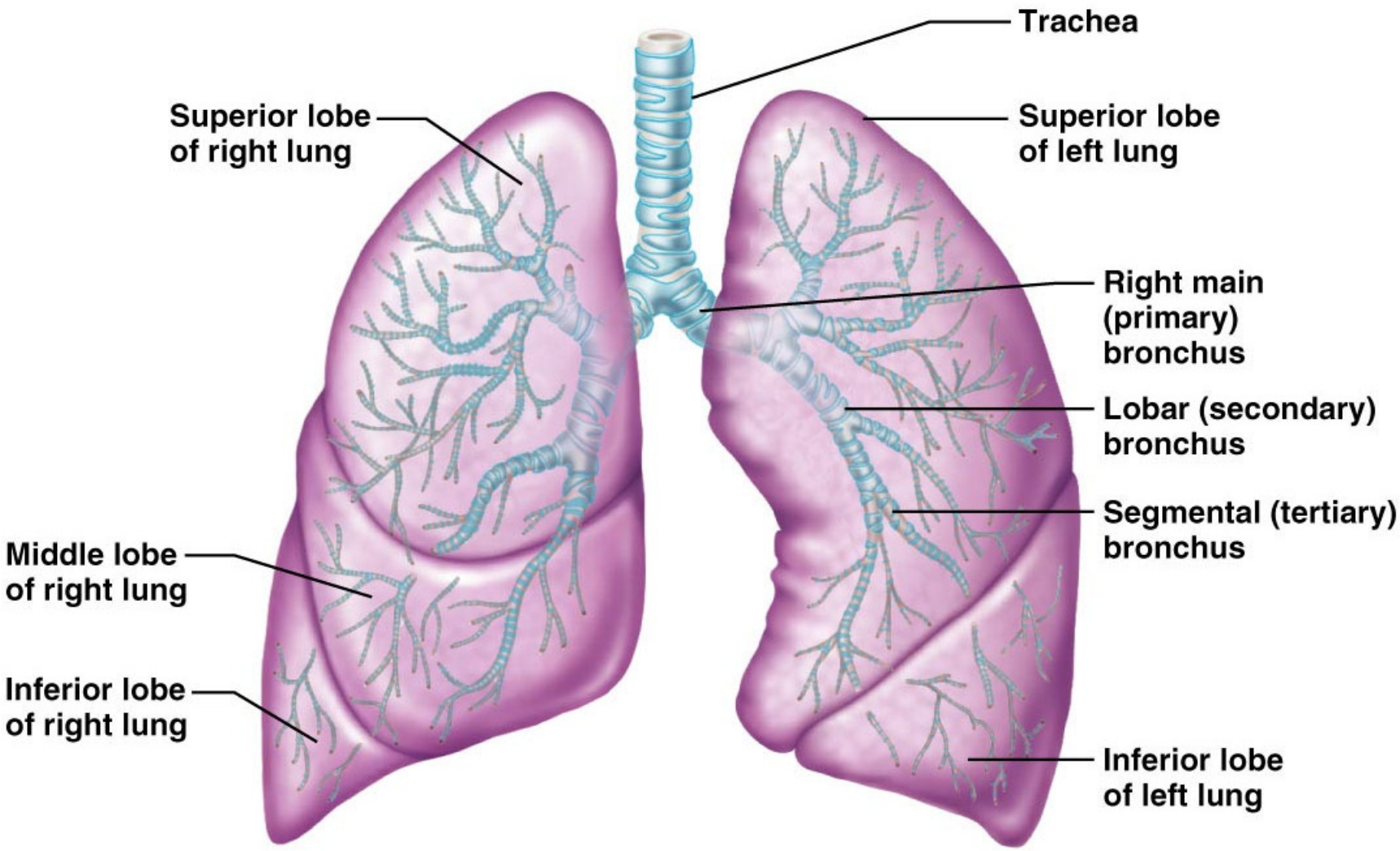


Figure 22.7

Conducting Zone: Bronchial Tree

- Bronchioles
  - Consist of cuboidal epithelium
  - Have a complete layer of circular smooth muscle
  - Lack cartilage support and mucus-producing cells

Respiratory Zone

- Defined by the presence of alveoli; begins as terminal bronchioles feed into respiratory bronchioles
- Respiratory bronchioles lead to alveolar ducts, then to terminal clusters of alveolar sacs composed of alveoli
- Approximately 300 million alveoli:
  - Account for most of the lungs' volume
  - Provide tremendous surface area for gas exchange

Respiratory Zone

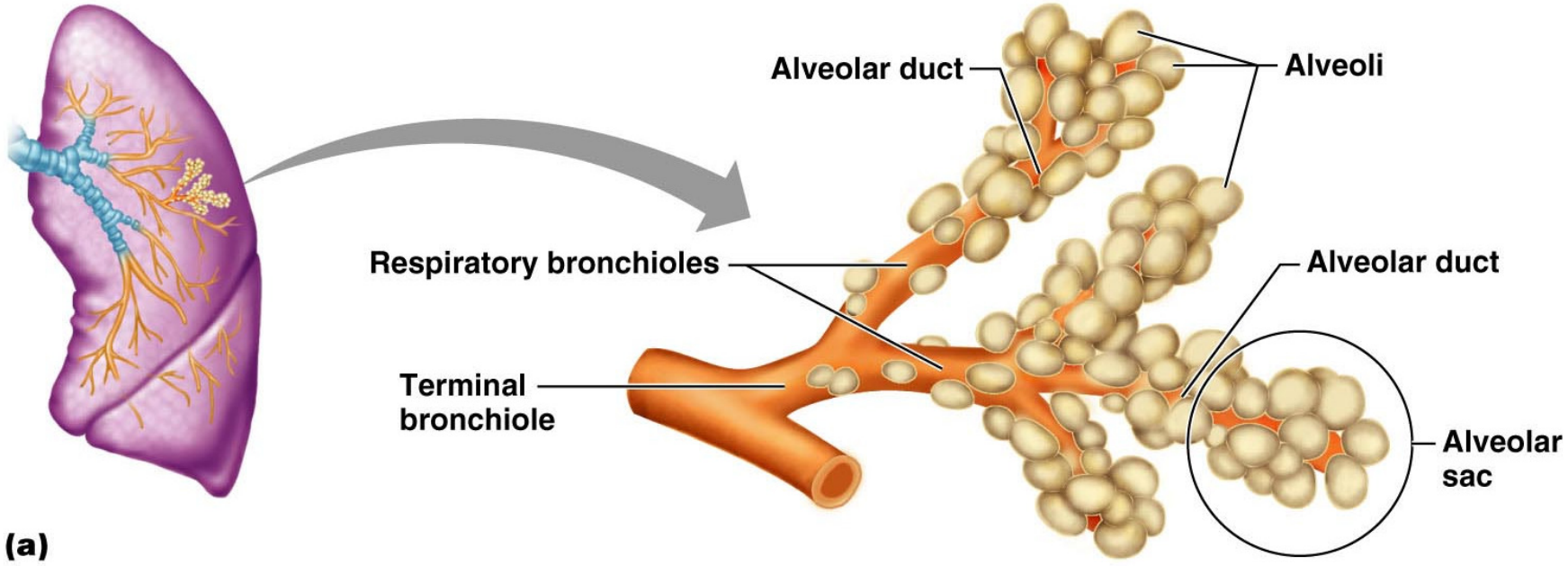


Figure 22.8a

Respiratory Zone

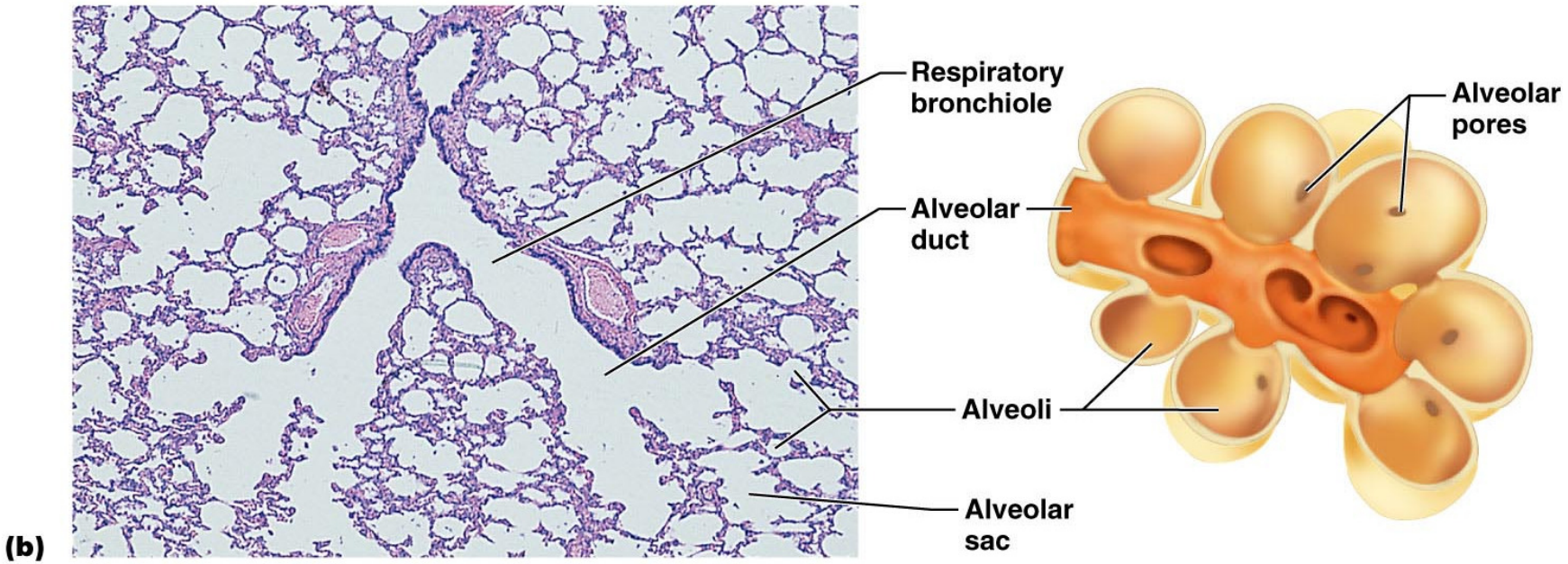


Figure 22.8b

Respiratory Membrane

- This air-blood barrier is composed of:
  - Alveolar and capillary walls
  - Their fused basal laminas
- Alveolar walls:
  - Are a single layer of type I squamous epithelial cells surrounded by a basement membrane
  - External surface covered with pulmonary capillaries
  - Respiratory membrane: alveoli + capillary walls & basement membrane
    - Permit gas exchange by simple diffusion
- Type II cells secrete surfactant that coats the gas exposed alveolar surfaces

Alveoli

- Surrounded by fine elastic fibers
- Contain open pores that:
  - Connect adjacent alveoli
  - Allow air pressure throughout the lung to be equalized
- House macrophages that keep alveolar surfaces sterile

Respiratory Membrane

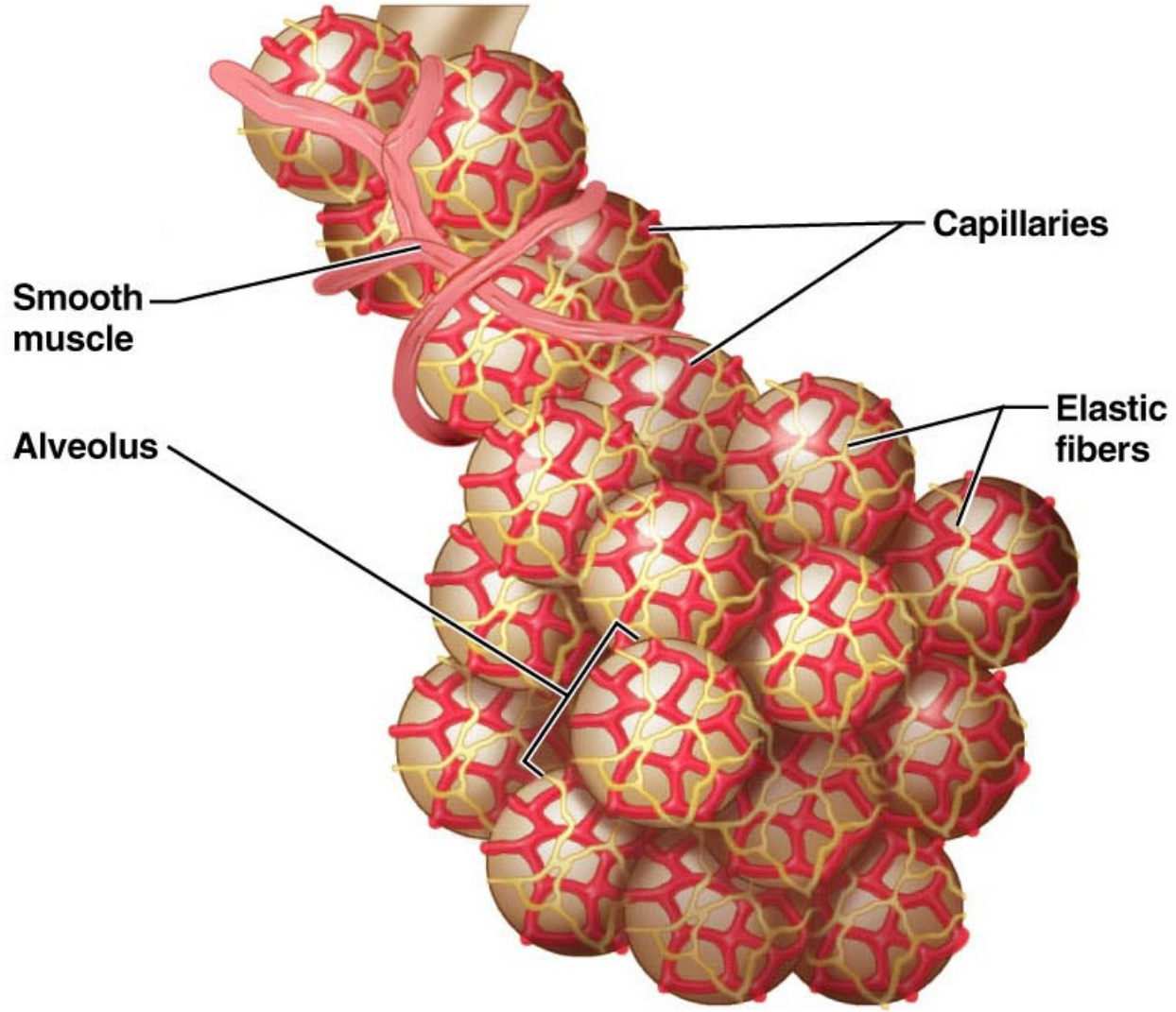


Figure 22.9b

Respiratory Membrane

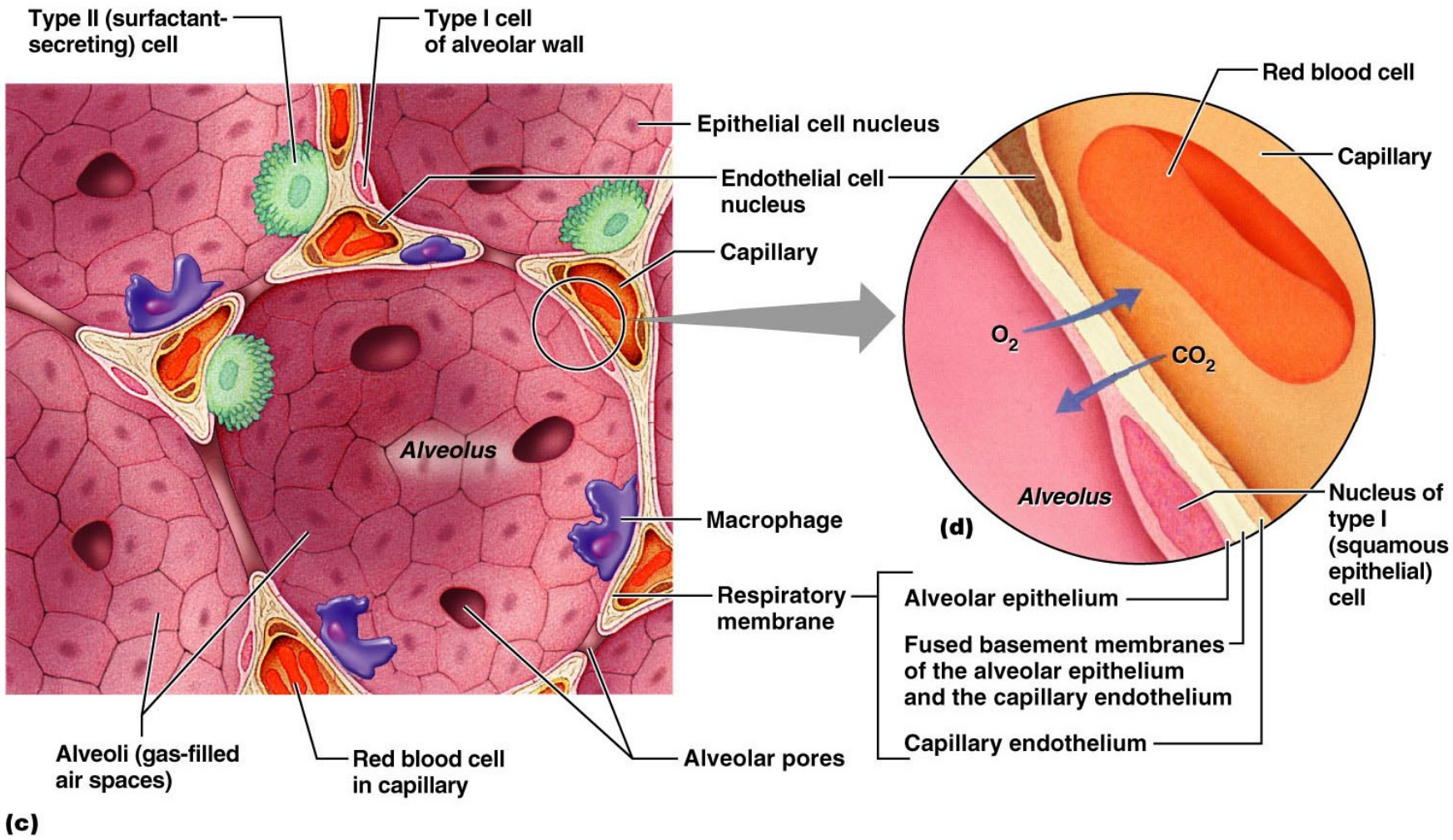


Figure 22.9c ,d

Gross Anatomy of the Lungs

- Lungs occupy all of the thoracic cavity except the mediastinum
  - Root – site of vascular and bronchial attachments
  - Costal surface – anterior, lateral, and posterior surfaces in contact with the ribs
  - Apex – narrow superior tip
  - Base – inferior surface that rests on the diaphragm
  - Hilus – indentation that contains pulmonary and systemic blood vessels

Organs in the Thoracic Cavity

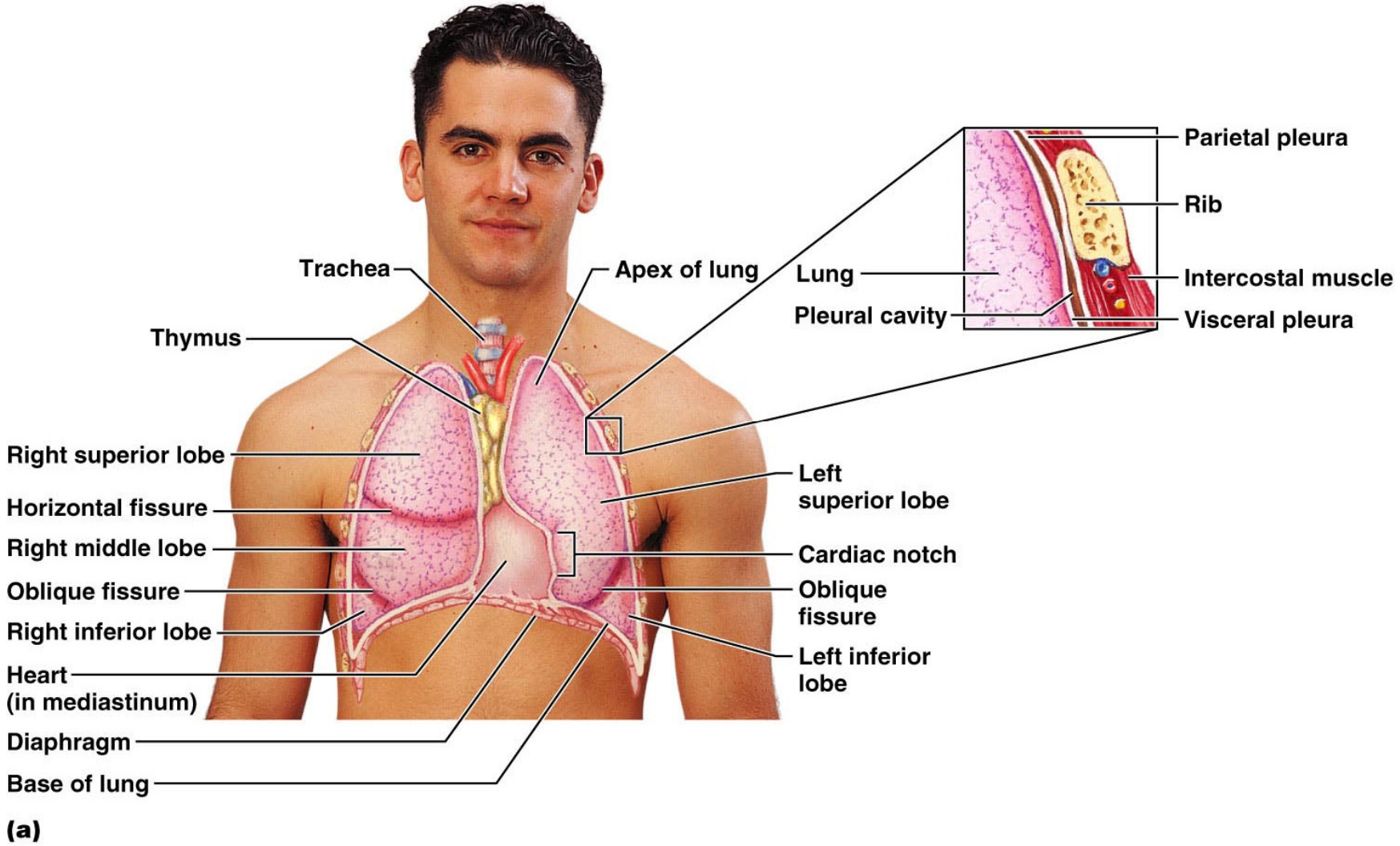


Figure 22.10a

Transverse Thoracic Section

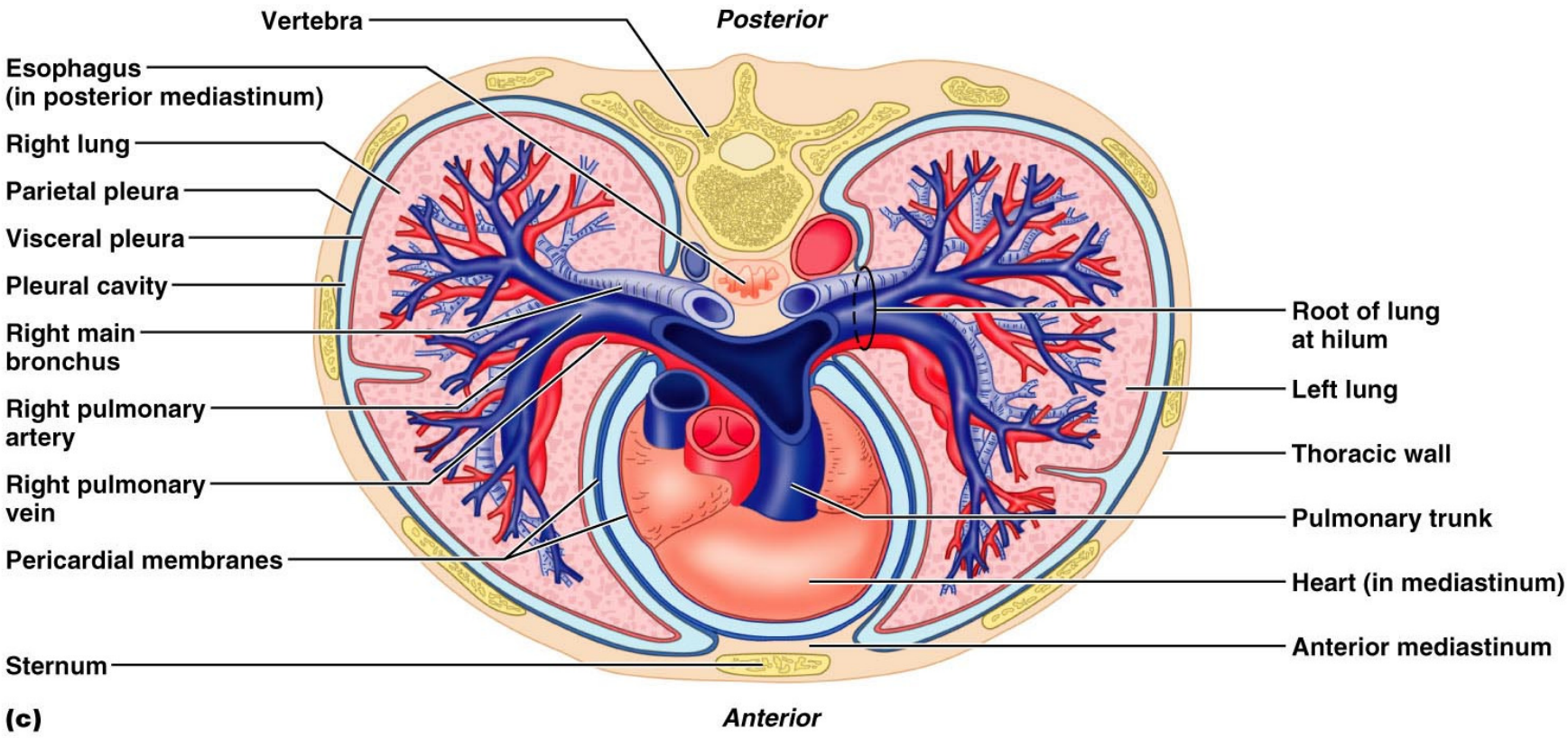


Figure 22.10c

Lungs

- Cardiac notch (impression) – cavity that accommodates the heart
- Left lung – smaller and is separated into upper and lower lobes by the oblique fissure
- Right lung – larger and is separated into three lobes by the oblique and horizontal fissures

Blood Supply to Lungs

- Lungs are perfused by two circulations: pulmonary and bronchial
- Pulmonary arteries – supply systemic venous blood to be oxygenated
  - Branch profusely, along with bronchi
  - Ultimately feed into the pulmonary capillary network surrounding the alveoli
- Pulmonary veins – carry oxygenated blood from respiratory zones to the heart

Blood Supply to Lungs

- Bronchial arteries – provide systemic blood to the lung tissue
  - Arise from aorta and enter the lungs at the hilus
  - Supply all lung tissue except the alveoli
- Bronchial veins anastomose with pulmonary veins
- Pulmonary veins carry most venous blood back to the heart
- Innervated by sympathetic and parasympathetic motor fibers and visceral sensory fibers
    - Sympathetic fibers: dilate air tubes
    - Parasympathetic fibers: constrict air tubes

Pleurae

- Forms a thin, double-layered serosa
- Parietal pleura
  - Covers the thoracic wall and superior face of the diaphragm
  - Continues around heart and between lungs
    - Thus, the lungs cling tightly to the thoracic wall
  - Produces pleural fluid that fills the pleural cavity
- Visceral, or pulmonary, pleura
  - Covers the external lung surface
  - Divides the thoracic cavity into three chambers
    - The central mediastinum
    - Two lateral compartments, each containing a lung

Breathing

- Breathing, or pulmonary ventilation, consists of two phases
  - Inspiration – air flows into the lungs
  - Expiration – gases exit the lungs

Pressure Relationships in the Thoracic Cavity

- Respiratory pressure is always described relative to atmospheric pressure
- Atmospheric pressure (P_{atm})
  - Pressure exerted by the air surrounding the body
  - Negative respiratory pressure is less than P_{atm}
  - Positive respiratory pressure is greater than P_{atm}

Pressure Relationships in the Thoracic Cavity

- Intrapulmonary pressure (P_{pul}) – pressure within the alveoli
- Intrapleural pressure (P_{ip}) – pressure within the pleural cavity

Pressure Relationships

- Intrapulmonary pressure and intrapleural pressure fluctuate with the phases of breathing
- Intrapulmonary pressure always eventually equalizes itself with atmospheric pressure
- Intrapleural pressure is always less than intrapulmonary pressure and atmospheric pressure

Pressure Relationships

- Two forces act to pull the lungs away from the thoracic wall, promoting lung collapse
  - Elasticity of lungs causes them to assume smallest possible size
  - Surface tension of alveolar fluid draws alveoli to their smallest possible size
- Opposing force – elasticity of the chest wall pulls the thorax outward to enlarge the lungs
  - Strong adhesion force between parietal and visceral pleura

Pressure Relationships

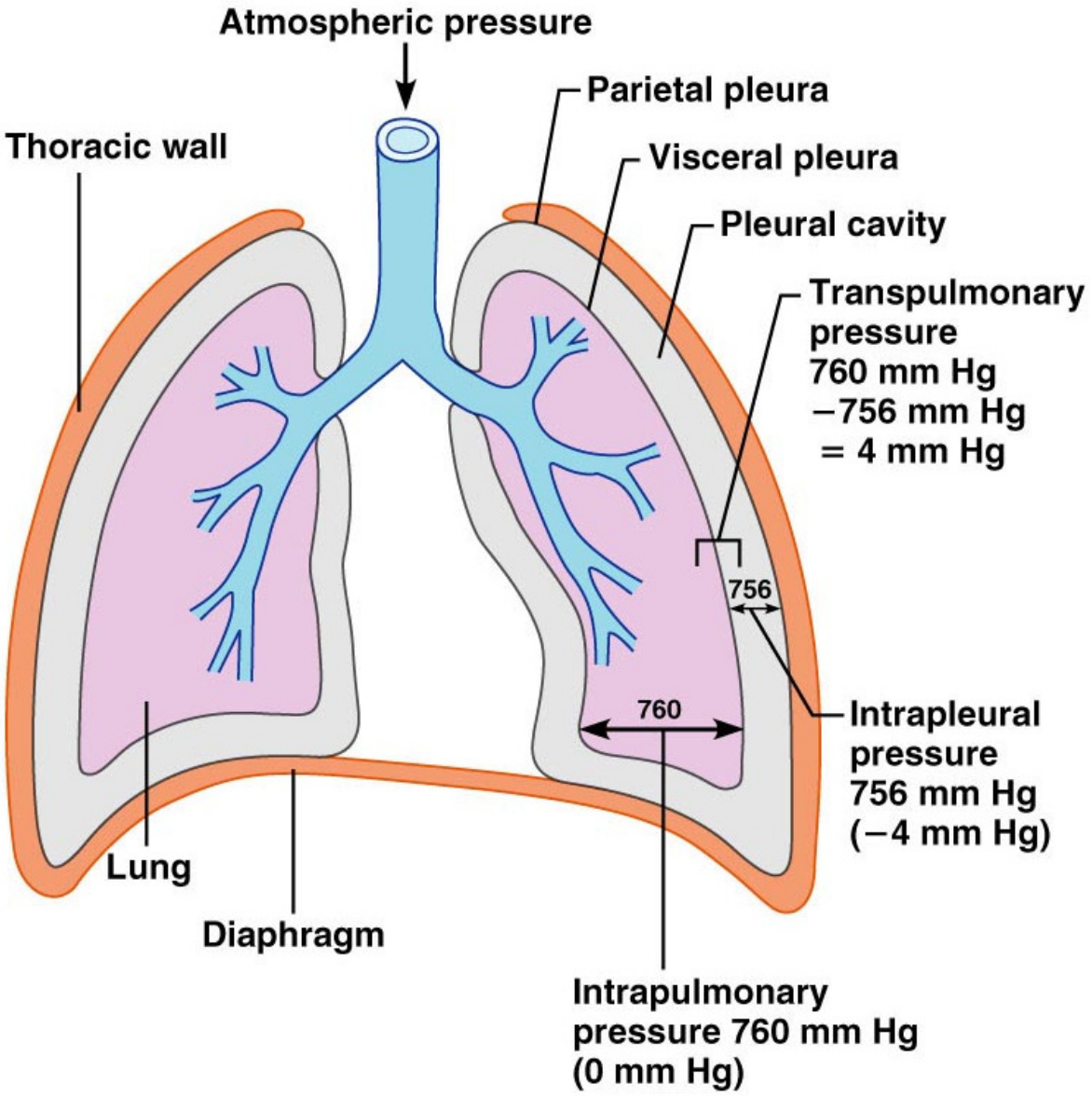


Figure 22.12

Lung Collapse

- Caused by equalization of the intrapleural pressure with the intrapulmonary pressure
- Transpulmonary pressure keeps the airways open
  - Transpulmonary pressure – difference between the intrapulmonary and intrapleural pressures ($P_{pul} - P_{ip}$)
  - The greater the transpulmonary pressure, the larger the lungs

Pulmonary Ventilation

- A mechanical process that depends on volume changes in the thoracic cavity
- Volume changes lead to pressure changes, which lead to the flow of gases to equalize pressure

Boyle's Law

- Boyle's law – the relationship between the pressure and volume of gases

$$P_1V_1 = P_2V_2$$

  - P = pressure of a gas in mm Hg
  - V = volume of a gas in cubic millimeters
  - Subscripts 1 and 2 represent the initial and resulting conditions, respectively

Inspiration

- The diaphragm and external intercostal muscles (inspiratory muscles) contract and the rib cage rises
- The lungs are stretched and intrapulmonary volume increases
- Intrapulmonary pressure drops below atmospheric pressure (–1 mm Hg)
- Air flows into the lungs, down its pressure gradient, until intrapleural pressure = atmospheric pressure

Inspiration

Box of air model: if we increase the size of the box, more air rushes in.

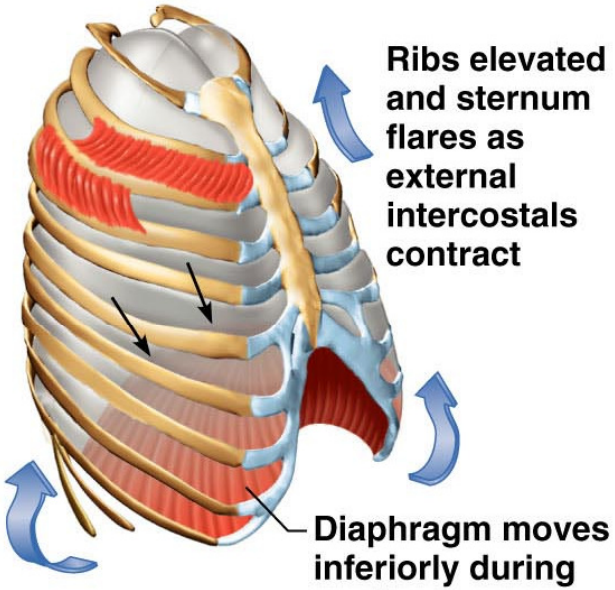
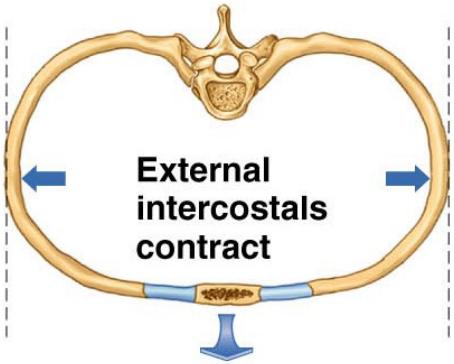
	Sequence of events	Changes in anterior-posterior and superior-inferior dimensions	Changes in lateral dimensions
Inspiration	① Inspiratory muscles contract (diaphragm descends; rib cage rises) ↓ ② Thoracic cavity volume increases ↓ ③ Lungs stretched; intrapulmonary volume increases ↓ ④ Intrapulmonary pressure drops (to –1 mm Hg) ↓ ⑤ Air (gases) flows into lungs down its pressure gradient until intrapulmonary pressure is 0 (equal to atmospheric pressure)		

Figure 22.13.1

Deep (forced) Inspiration

- As in exercise
- Accessory muscles like the scalenes, sternocleidomastoid, and pectoralis minor contract and raise the ribs more

Expiration

- Inspiratory muscles relax and the rib cage descends due to gravity
- Thoracic cavity volume decreases
- Elastic lungs recoil passively and intrapulmonary volume decreases
- Intrapulmonary pressure is greater than atmospheric pressure (+1 mm Hg)
- Gases flow out of the lungs down the pressure gradient until intrapulmonary pressure is 0

Expiration

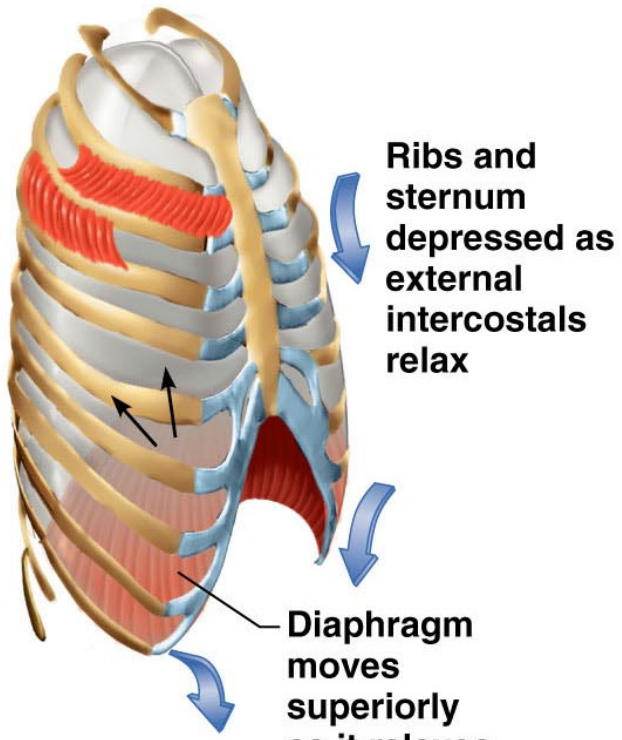
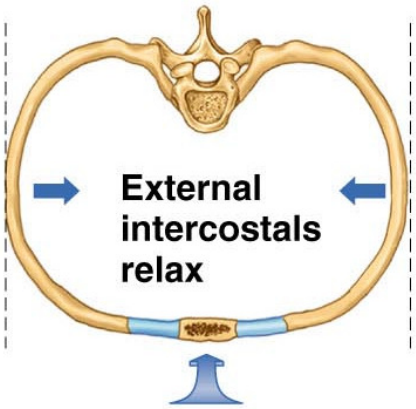
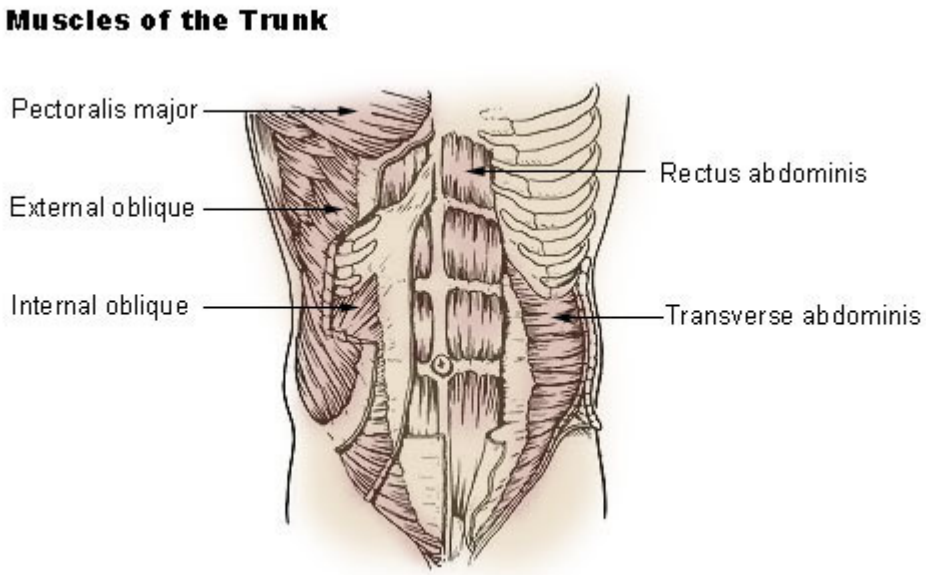
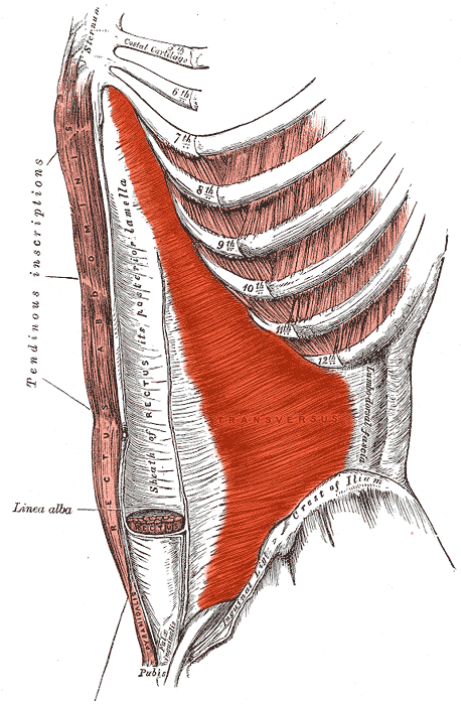
	Sequence of events	Changes in anterior-posterior and superior-inferior dimensions	Changes in lateral dimensions
Expiration	① Inspiratory muscles relax (diaphragm rises; rib cage descends due to recoil of costal cartilages) ↓ ② Thoracic cavity volume decreases ↓ ③ Elastic lungs recoil passively; intrapulmonary volume decreases ↓ ④ Intrapulmonary pressure rises (to +1 mm Hg) ↓ ⑤ Air (gases) flows out of lungs down its pressure gradient until intrapulmonary pressure is 0		

Figure 22.13.2

Deep (forced) Expiration

- Involves the contraction of the abdominal wall muscles (e.g. oblique and transverse muscles)
- These muscles increase intraabdominal pressure and the abdominal organs move superiorly against the diaphram
- Transverse abdominus lowers the ribcage





Pulmonary Pressures

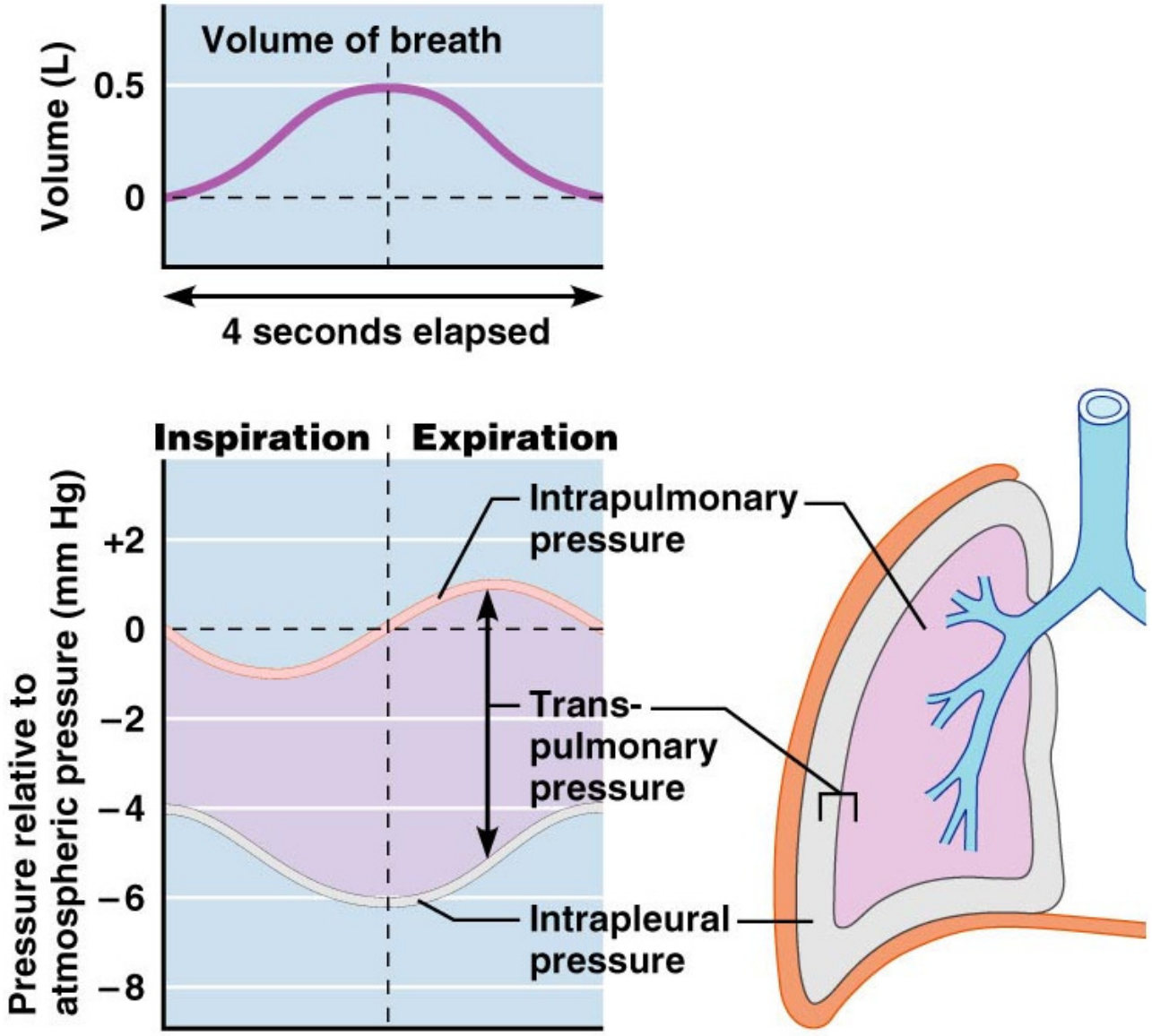


Figure 22.14

Physical Factors Influencing Ventilation: Airway Resistance

- Friction encountered in the respiratory passageways is the major nonelastic source of resistance to airflow
- The relationship between flow (F), pressure (P), and resistance (R) is:

$$F = \frac{\Delta P}{R}$$

Physical Factors Influencing Ventilation: Airway Resistance

- The amount of gas flowing into and out of the alveoli is directly proportional to ΔP, the pressure gradient between the atmosphere and the alveoli
- Gas flow is inversely proportional to resistance with the greatest resistance being in the medium-sized bronchi

Airway Resistance

- As airway resistance rises, breathing movements become more strenuous
- Severely constricted or obstructed bronchioles:
  - Can prevent life-sustaining ventilation
  - Can occur during acute asthma attacks which stops ventilation
- Epinephrine release via the sympathetic nervous system dilates bronchioles and reduces air resistance

Resistance in Repiratory Passageways

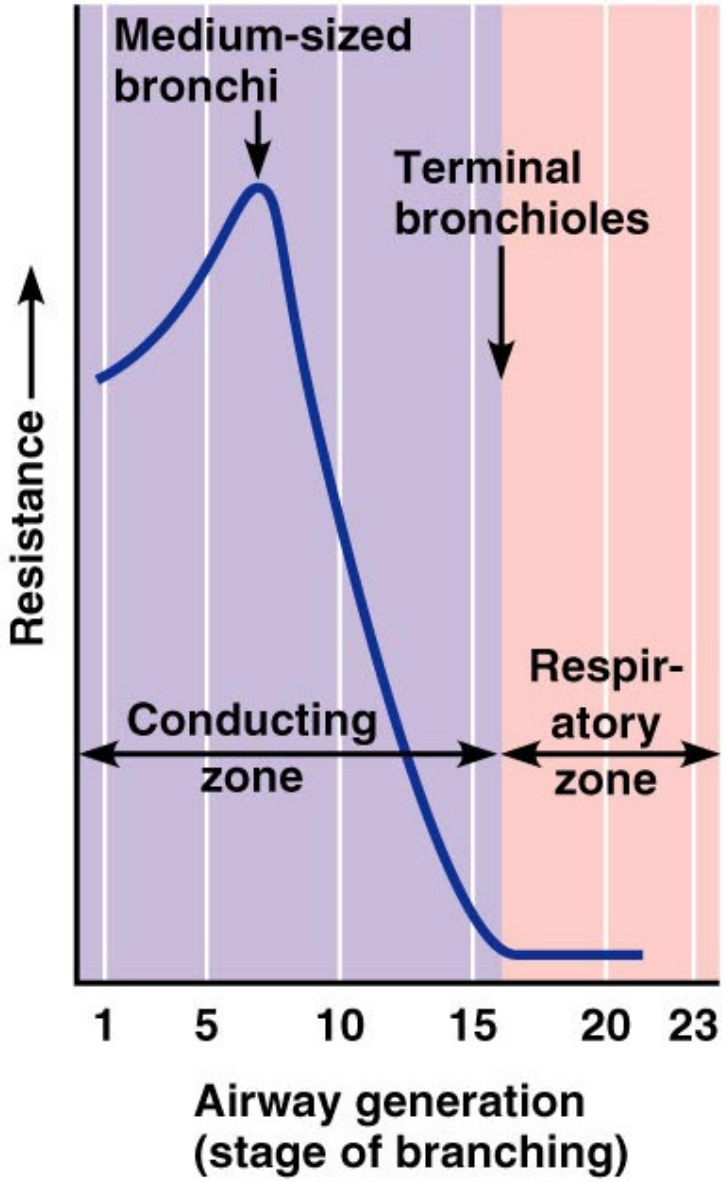


Figure 22.15

Alveolar Surface Tension

- Surface tension – the attraction of liquid molecules to one another at a liquid-gas interface (liquid attracts liquid stronger than air attracts air)
- Surface tension:
    - Draws the liquid molecules closer together
    - Resists any force that tends to increase the surface area of the liquid
- The liquid coating the alveolar surface is always acting to reduce the alveoli to the smallest possible size
- Surfactant, a detergent-like complex, reduces surface tension and helps keep the alveoli from collapsing between breathes
- Premature babies face difficulty breathing due to low levels of surfactants

Lung Compliance

- The ease with which lungs can be expanded
- Specifically, the measure of the change in lung volume that occurs with a given change in transpulmonary pressure
    - The more a lung expands for a given rise in transpulmonary pressure, the greater its compliance
- Lung compliance is determined by two main factors
    - Distensibility of the lung tissue and surrounding thoracic cage
    - Surface tension of the alveoli

Factors That Diminish Lung Compliance

- Scar tissue or fibrosis that reduces the natural resilience of the lungs
- Blockage of the smaller respiratory passages with mucus or fluid
- Reduced production of surfactant
- Decreased flexibility of the thoracic cage or its decreased ability to expand

Factors That Diminish Lung Compliance

- Examples include:
  - Deformities of thorax
  - Ossification of the costal cartilage
  - Paralysis of intercostal muscles