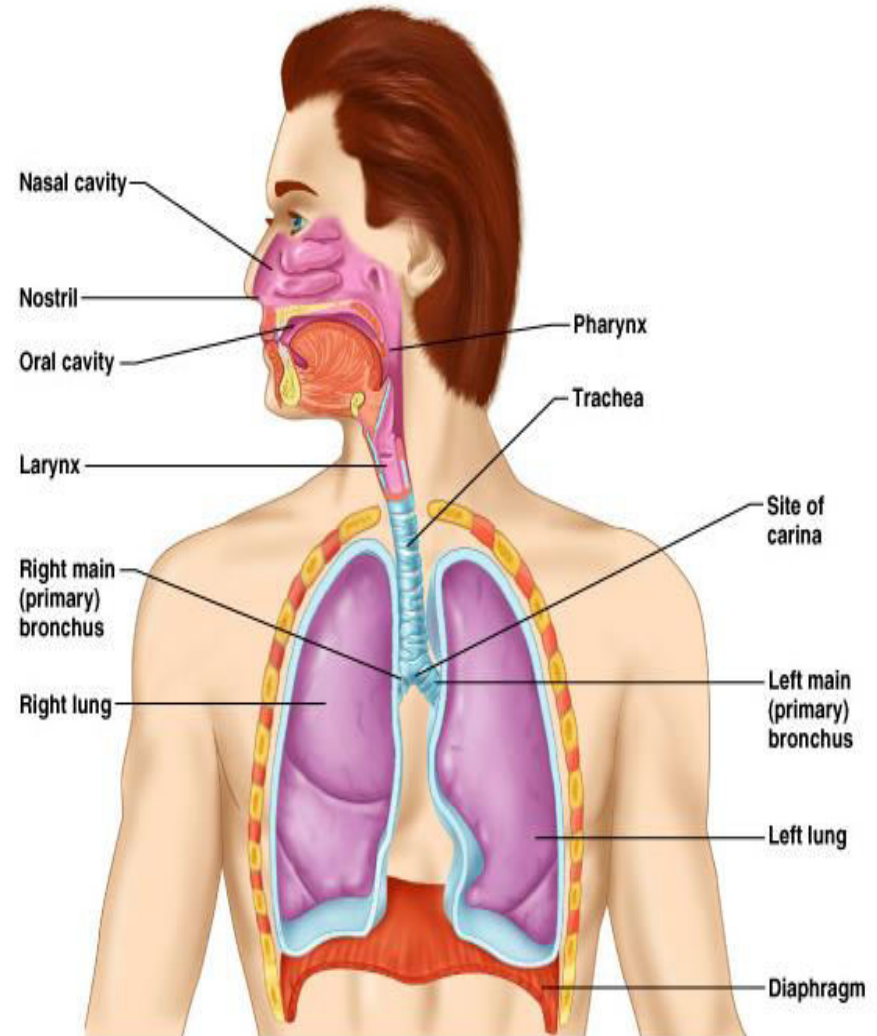


The Respiratory System



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Respiration Includes

- Pulmonary ventilation
 - Air moves in and out of lungs
 - Continuous replacement of gases in alveoli (air sacs)
- External respiration
 - Gas exchange between blood and air at alveoli
 - O₂ (oxygen) in air diffuses into blood
 - CO₂ (carbon dioxide) in blood diffuses into air
- Transport of respiratory gases
 - Between the lungs and the cells of the body
 - Performed by the cardiovascular system
 - Blood is the transporting fluid
- Internal respiration
 - Gas exchange in capillaries between blood and tissue cells
 - O₂ in blood diffuses into tissues
 - CO₂ waste in tissues diffuses into blood

Cellular Respiration

- Oxygen (O_2) is used by the cells
- O_2 needed in conversion of glucose to cellular energy (ATP)
- All body cells
- Carbon dioxide (CO_2) is produced as a waste product
- The body's cells die if either the respiratory or cardiovascular system fails

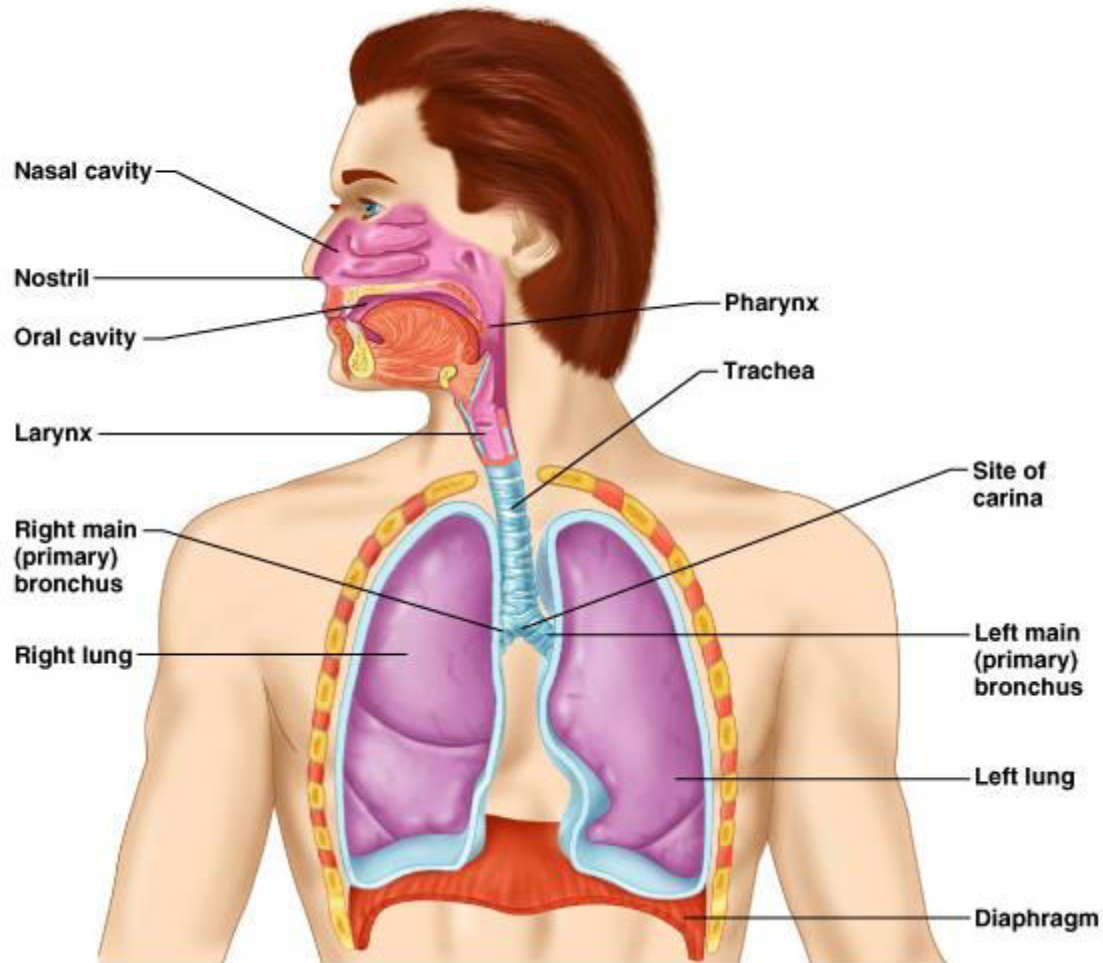
The Respiratory Organs

Conducting zone

- Respiratory passages that carry air to the site of gas exchange
- Filters, humidifies and warms air

Respiratory zone

- Site of gas exchange
- Composed of
 - Respiratory bronchioles
 - Alveolar ducts
 - Alveolar sacs



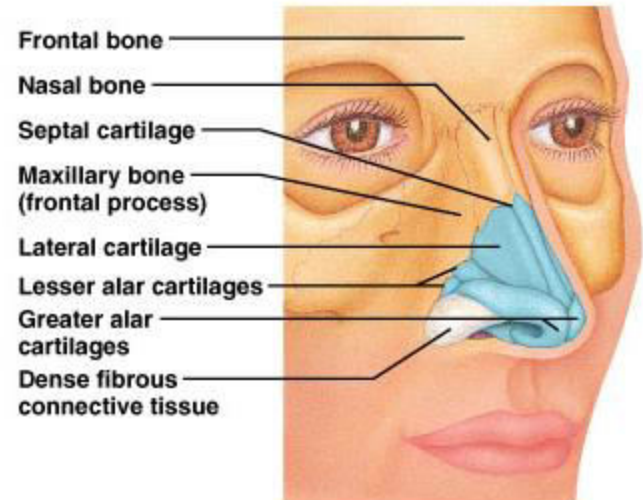
Conducting zone labeled

Conducting zone will be covered first

Nose

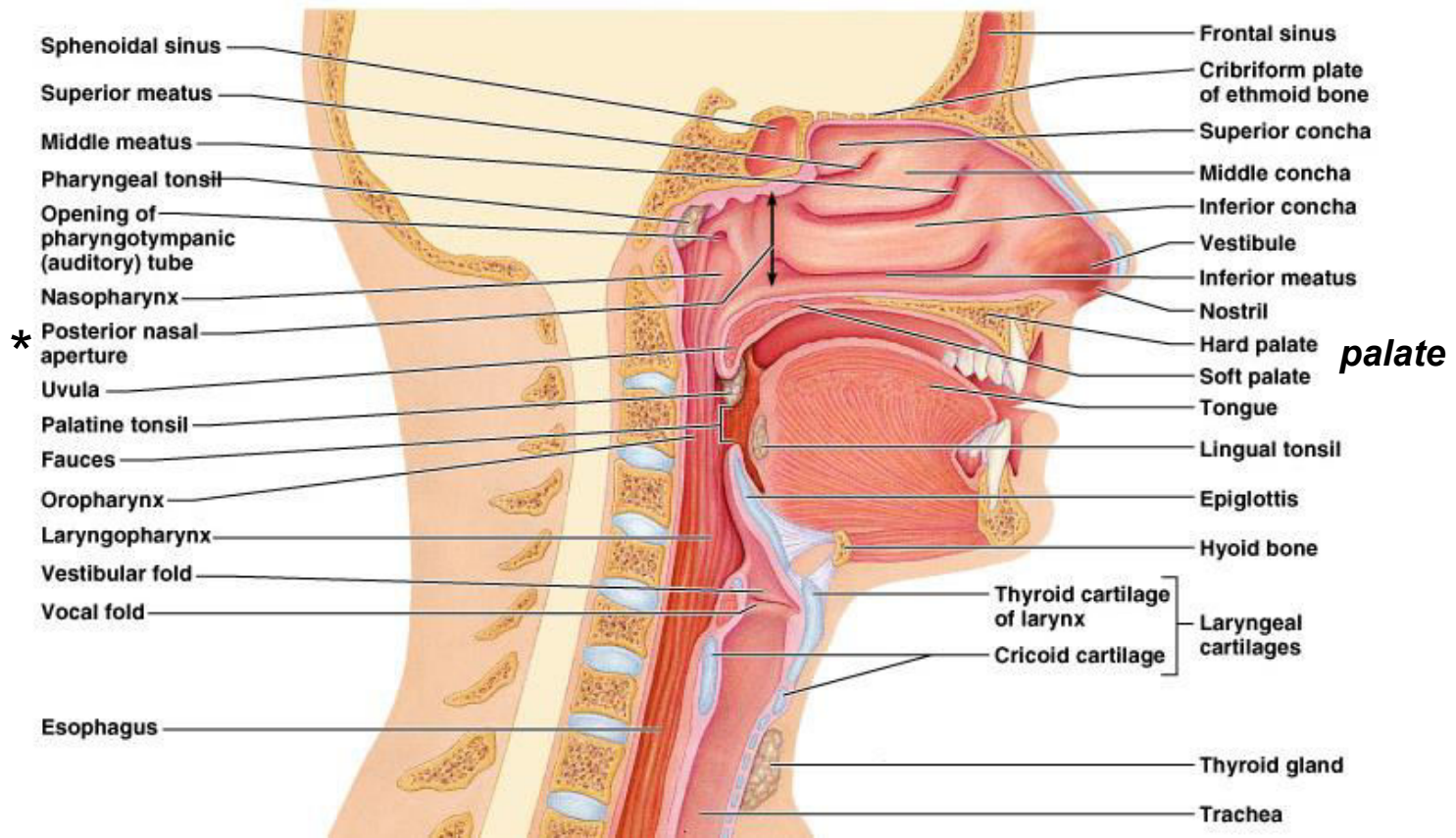
- Provides airway
- Moistens and warms air
- Filters air
- Resonating chamber for speech
- Olfactory receptors

External nose



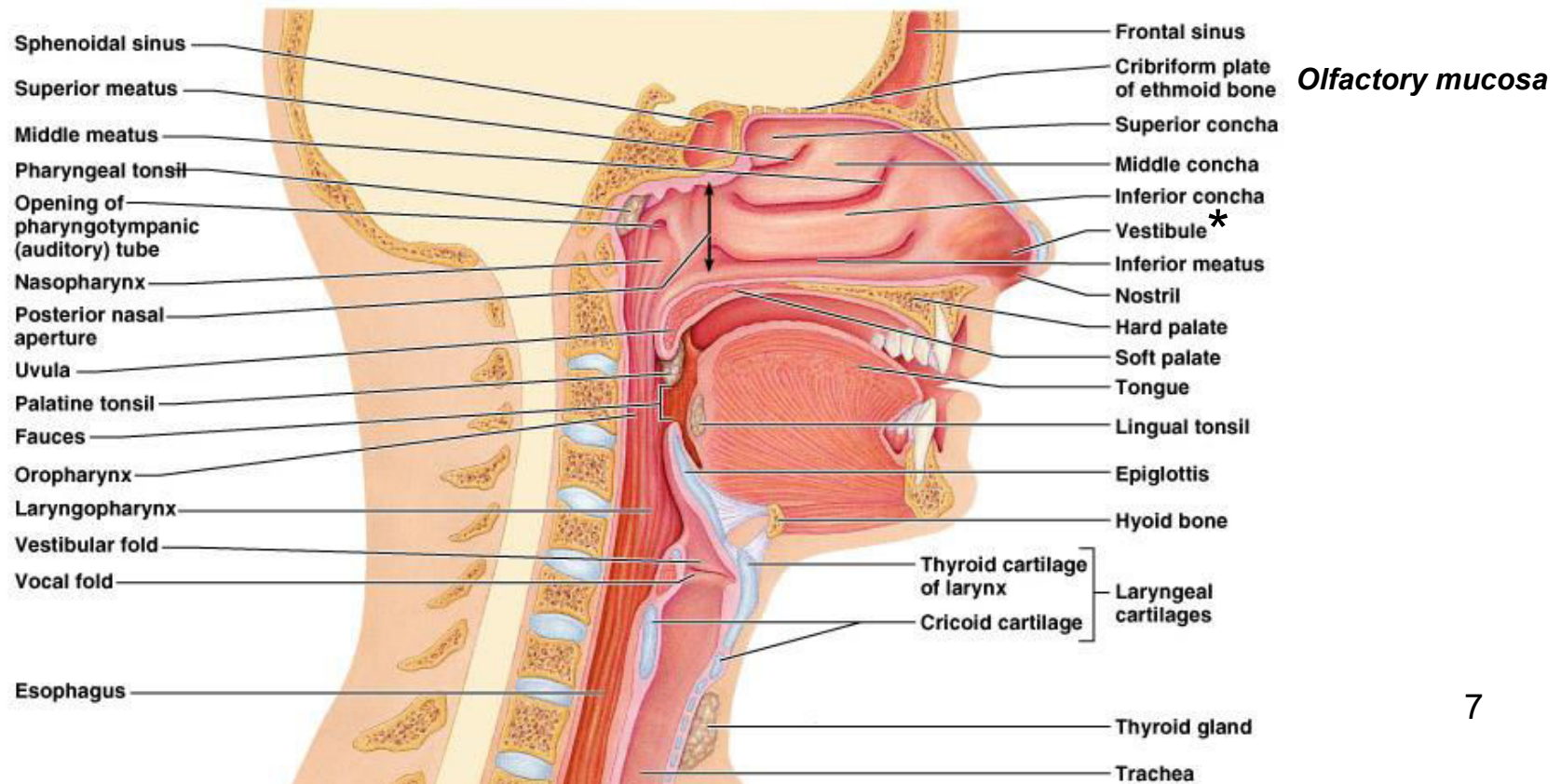
Nasal cavity

- Air passes through nares (nostrils)
- Nasal septum divides nasal cavity in midline (to right & left halves)
 - Perpendicular plate of ethmoid bone, vomer and septal cartilage
- Connects with pharynx posteriorly through *choanae* (posterior nasal apertures*)
- Floor is formed by palate (roof of the mouth)
 - Anterior hard palate and posterior soft palate

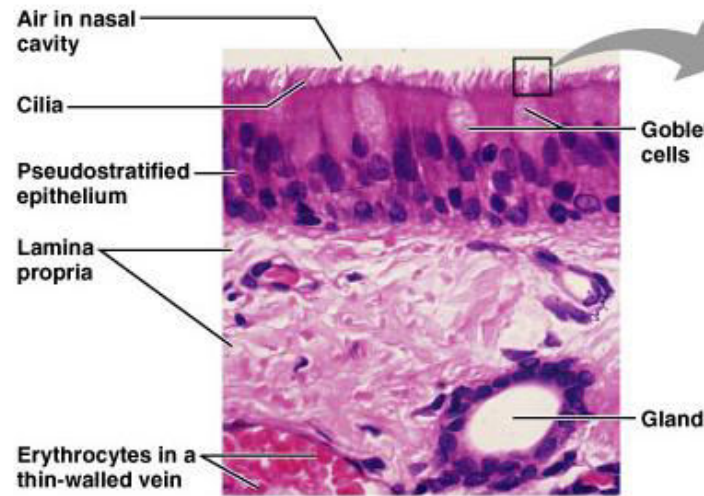


Linings of nasal cavity

- Vestibule* (just above nostrils)
 - Lined with skin containing sebaceous and sweat glands and nose hairs
 - Filters large particulars (insects, lint, etc.)
- The remainder of nasal cavity: 2 types of mucous membrane
 - Small patch of olfactory mucosa near roof (cribriform plate)
 - Respiratory mucosa: lines most of the cavity



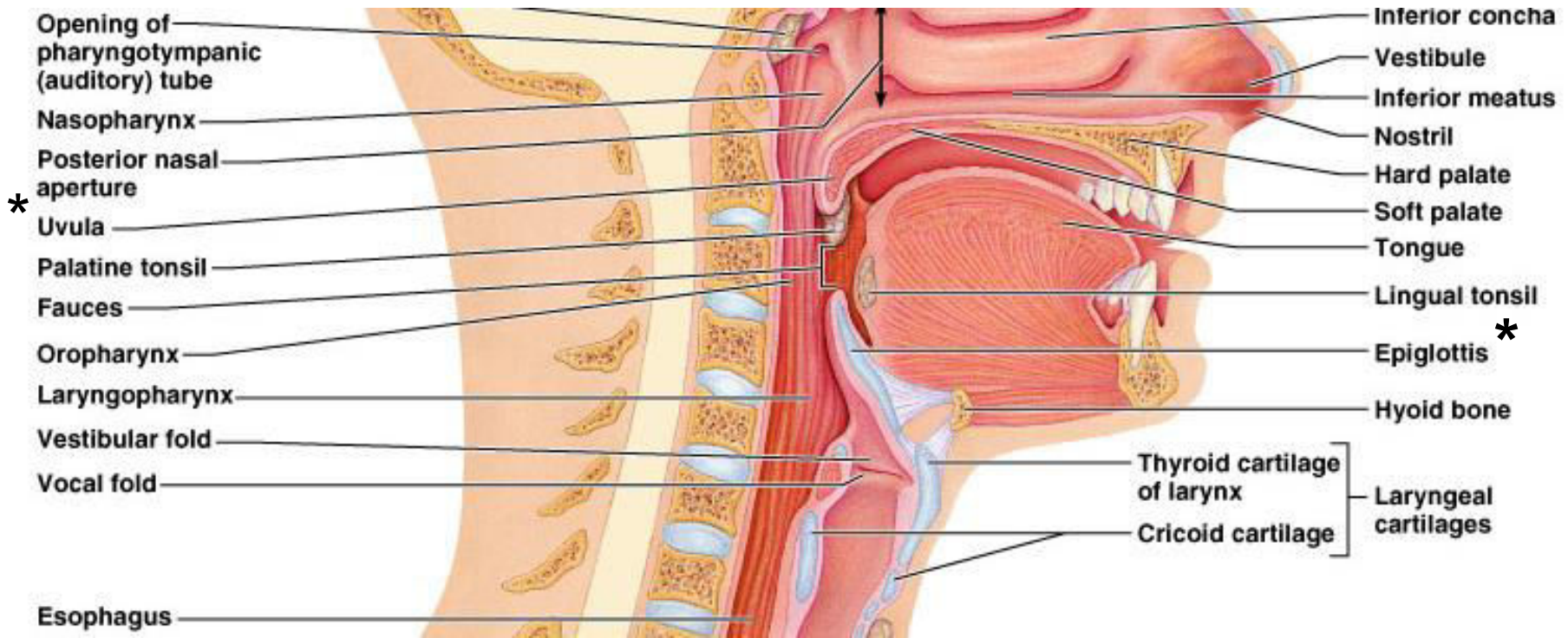
Respiratory Mucosa



- Pseudostratified ciliated columnar epithelium
- Scattered goblet cells
- Underlying connective tissue lamina propria
 - Mucous cells – secrete mucous
 - Serous cells – secrete watery fluid with digestive enzymes, e.g. lysozyme
- Together all these produce a quart/day
 - Dead junk is swallowed

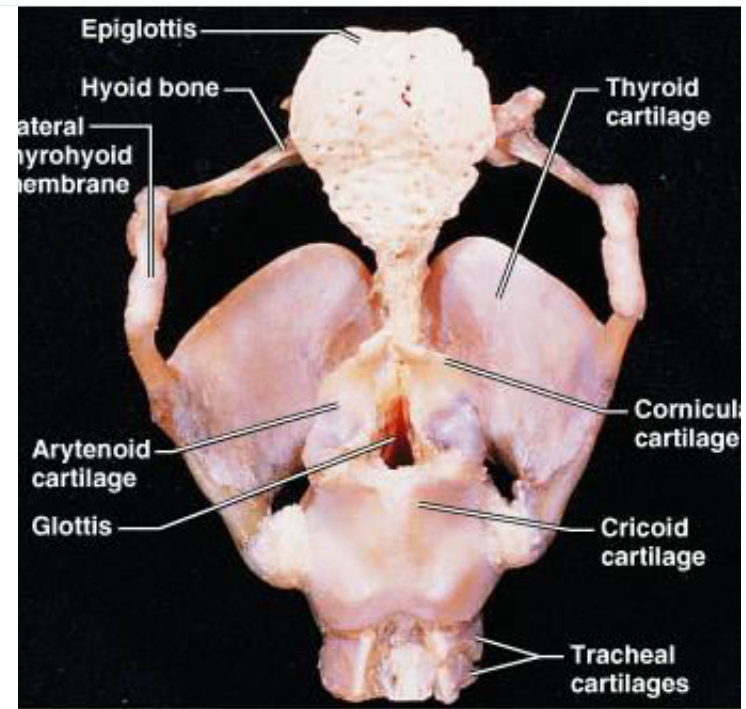
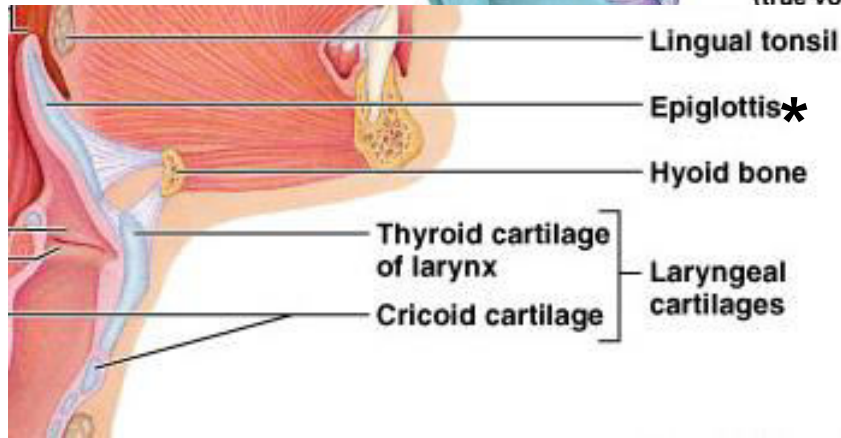
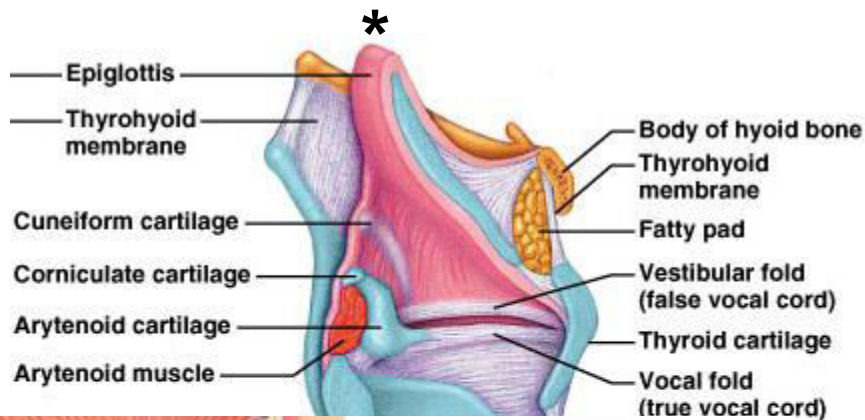
The Pharynx (throat)

- 3 parts: **naso-**, **oro-** and **laryngopharynx**
- Houses tonsils (they respond to inhaled antigens)
- Uvula closes off nasopharynx during swallowing so food doesn't go into nose
- Epiglottis posterior to the tongue: keeps food out of airway
- Oropharynx and laryngopharynx serve as common ***passageway for food and air***
 - Lined with stratified squamous epithelium for protection



The Larynx (voicebox)

- Extends from the level of the 4th to the 6th cervical vertebrae
- Attaches to hyoid bone superiorly
- Inferiorly is continuous with trachea (windpipe)
- Three functions:
 1. Produces vocalizations (speech)
 2. Provides an open airway (breathing)
 3. Switching mechanism to route air and food into proper channels
 - Closed during swallowing
 - Open during breathing



Posterior views

Epiglottis* (the 9th cartilage)

Elastic cartilage covered by mucosa

On a stalk attached to thyroid cartilage

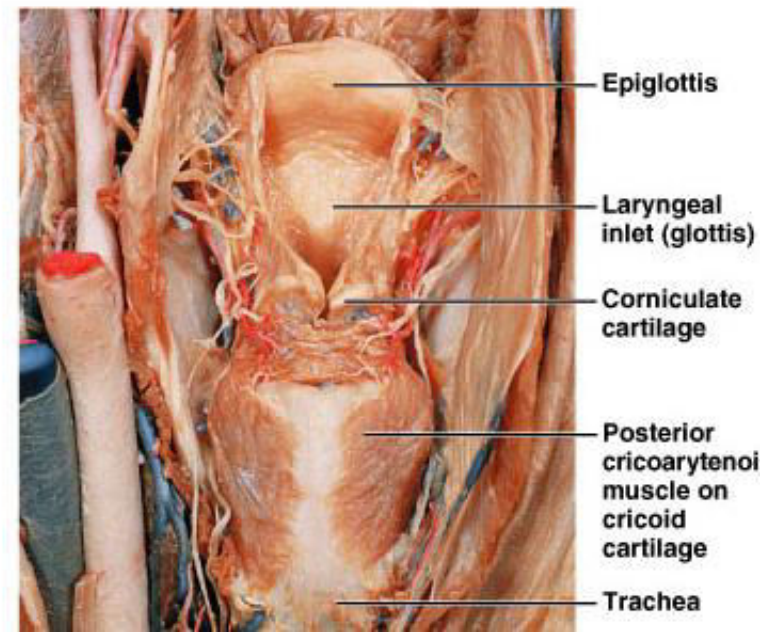
Attaches to back of tongue

During swallowing, larynx is pulled superiorly

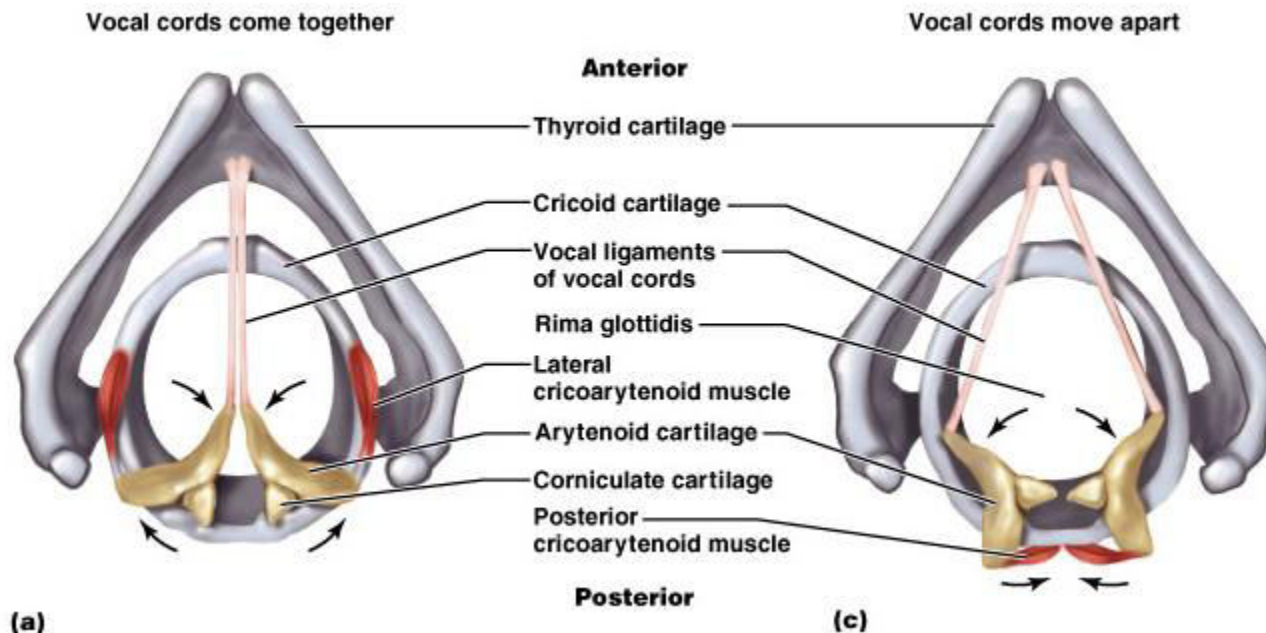
Epiglottis tips inferiorly to cover and seal

laryngeal inlet

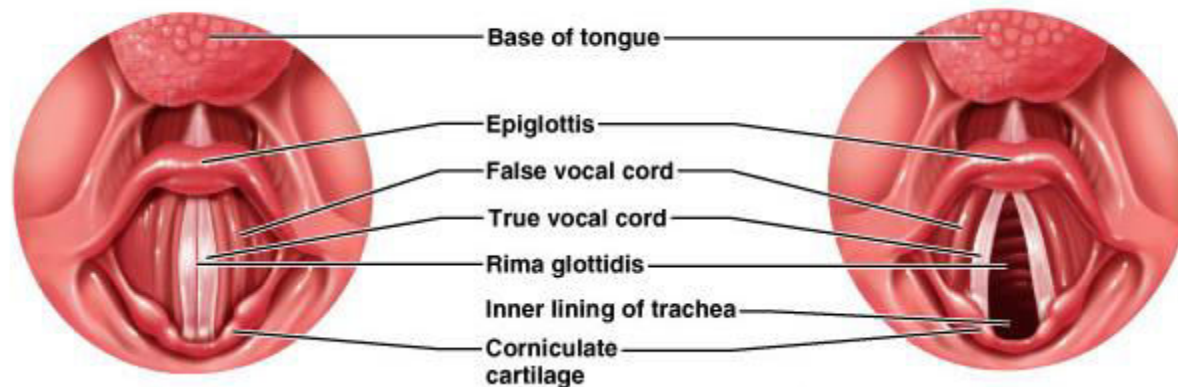
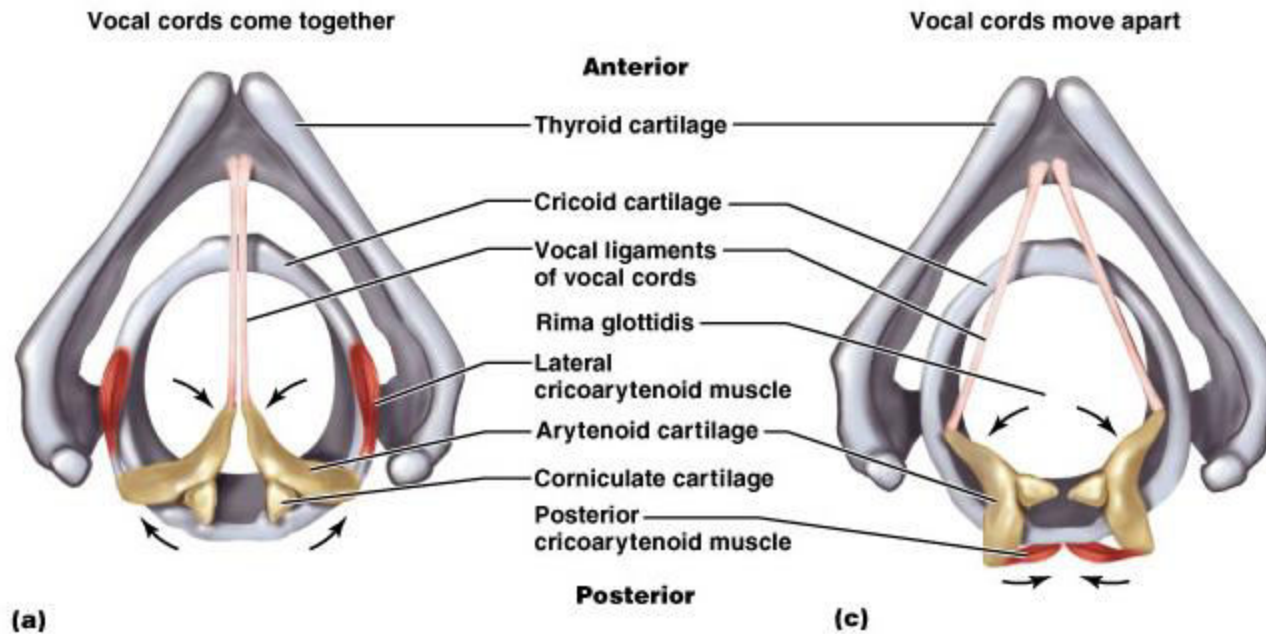
Keeps food out of lower respiratory tract



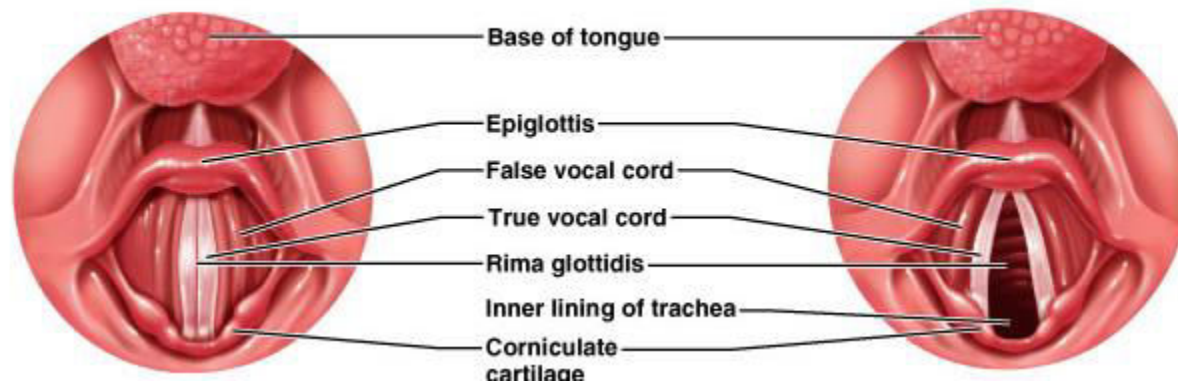
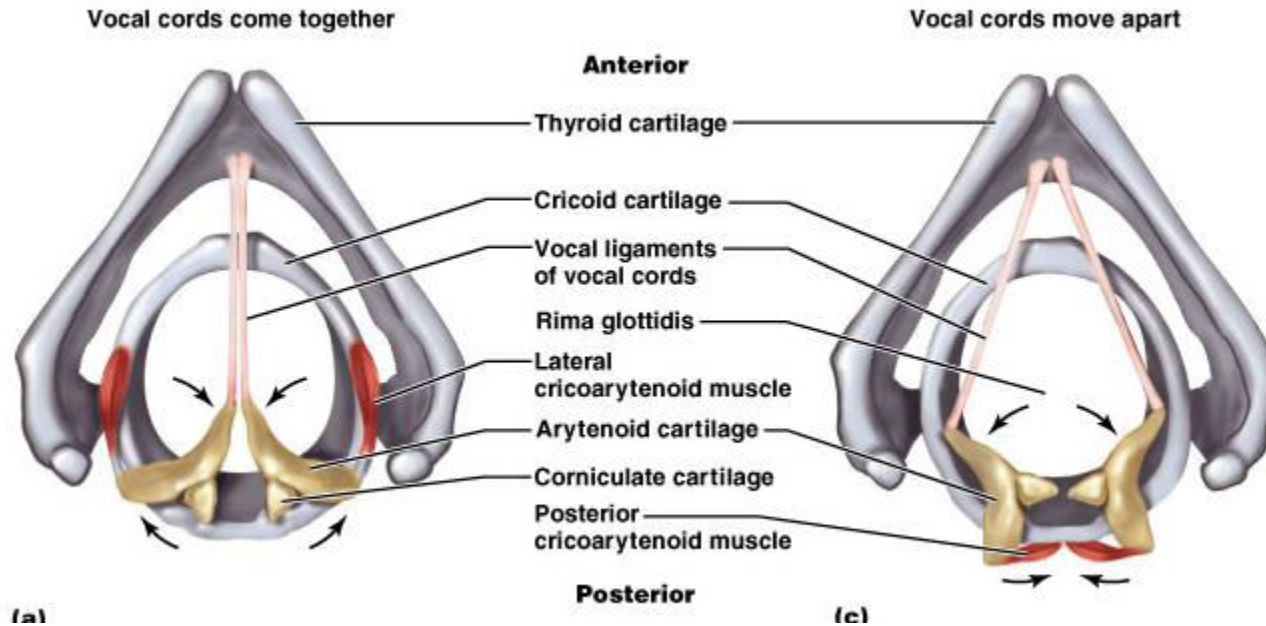
- Cough reflex: keeps all but air out of airways
- Low position of larynx is required for speech (although makes choking easier)
- Paired vocal ligaments: elastic fibers, the core of the true vocal cords



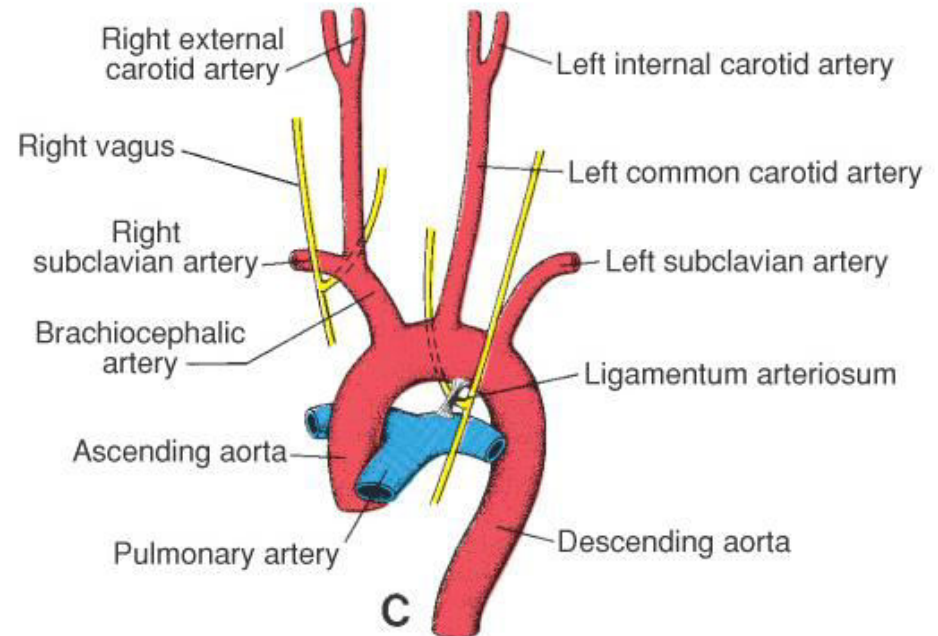
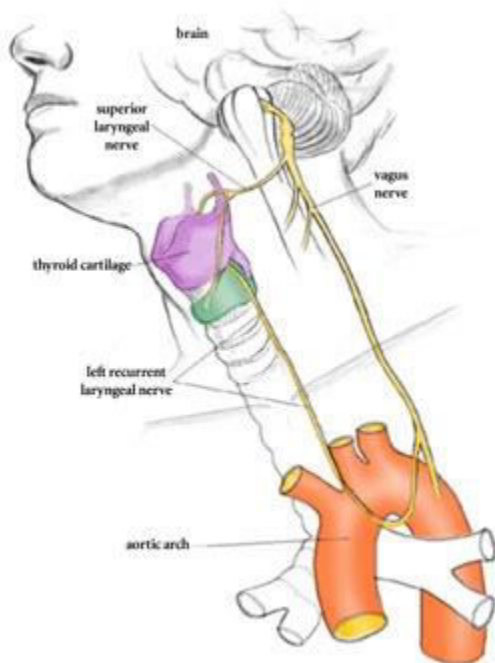
- Pair of mucosal vocal folds (true vocal cords) over the ligaments: white because avascular



- Glottis is the space between the vocal cords
- Laryngeal muscles control length and size of opening by moving arytenoid cartilages
- **Sound is produced by the vibration of vocal cords as air is exhaled**

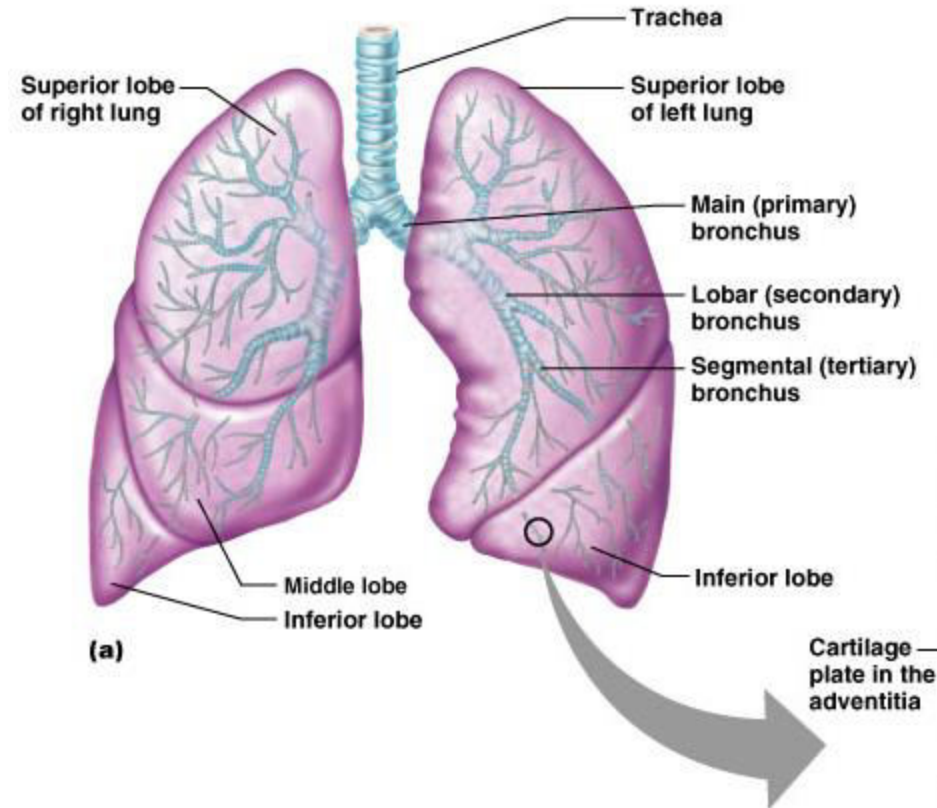


- **Innervation of larynx (makes surgery at neck risky)**
 - Recurrent laryngeal nerves of Vagus
 - These branch off the Vagus and make a big downward loop under vessels, then up to larynx in neck
 - Left loops under aortic arch
 - Right loops under right subclavian artery
 - Damage to one: hoarseness
 - Damage to both: can only whisper

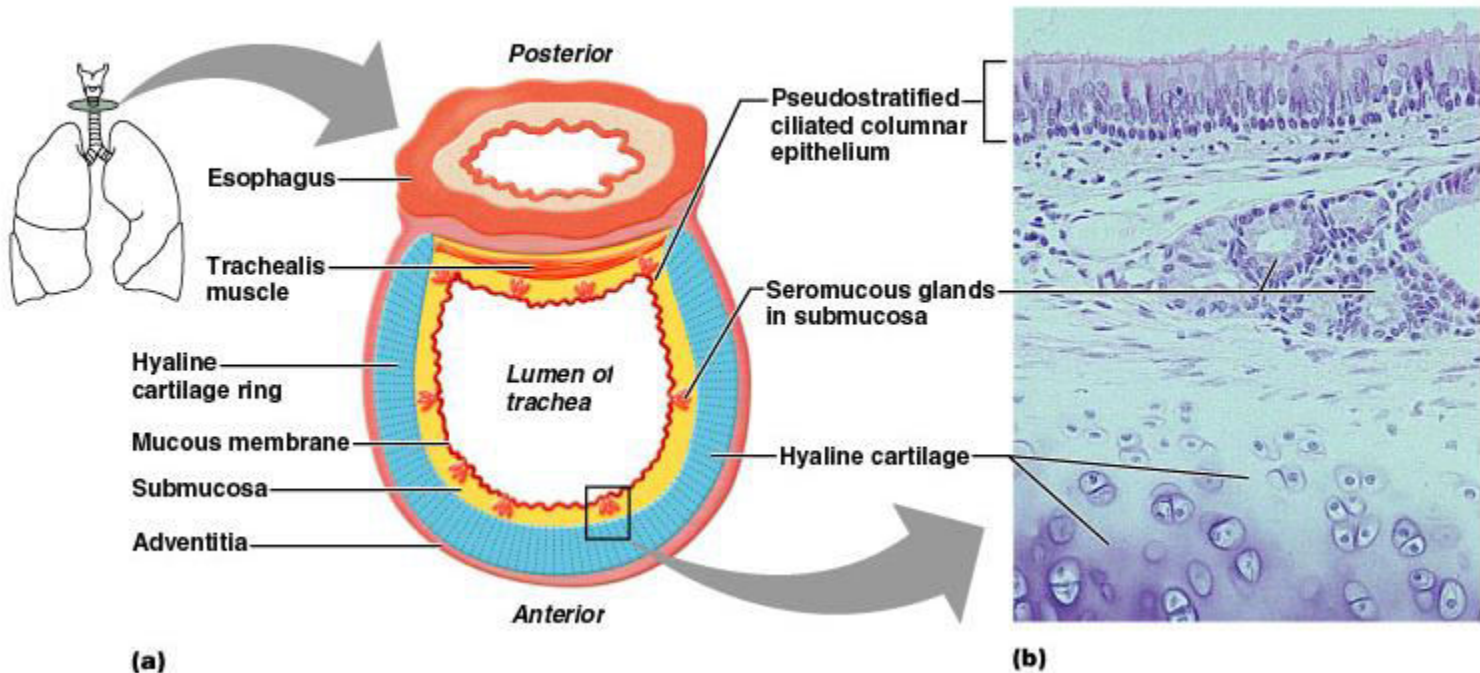


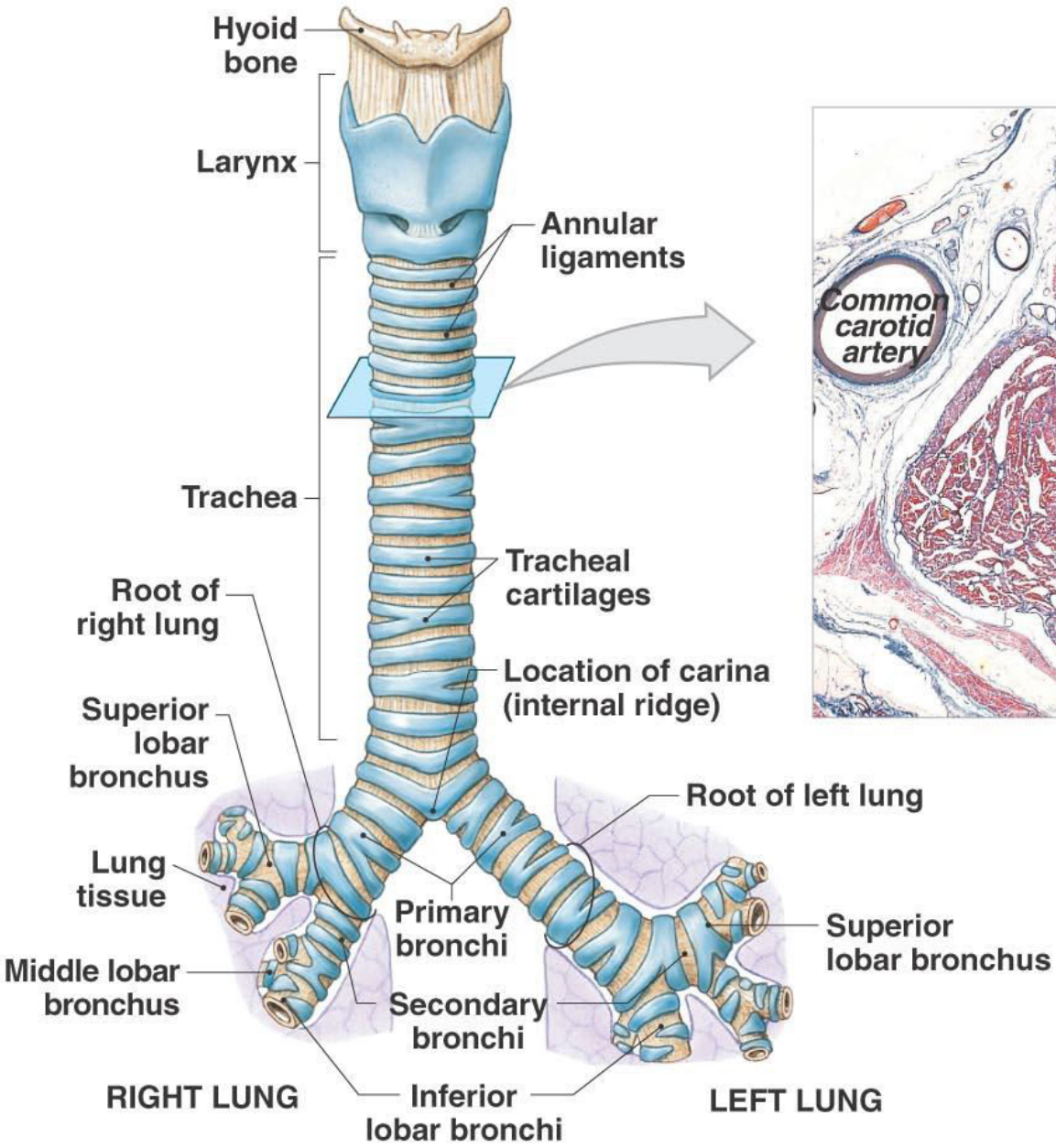
Trachea (the windpipe)

- Descends: larynx through neck into mediastinum
- Divides in thorax into two main (primary) bronchi
- 16-20 **C**-shaped rings of hyaline cartilage joined by fibroelastic connective tissue
- Flexible for bending but stays open despite pressure changes during breathing

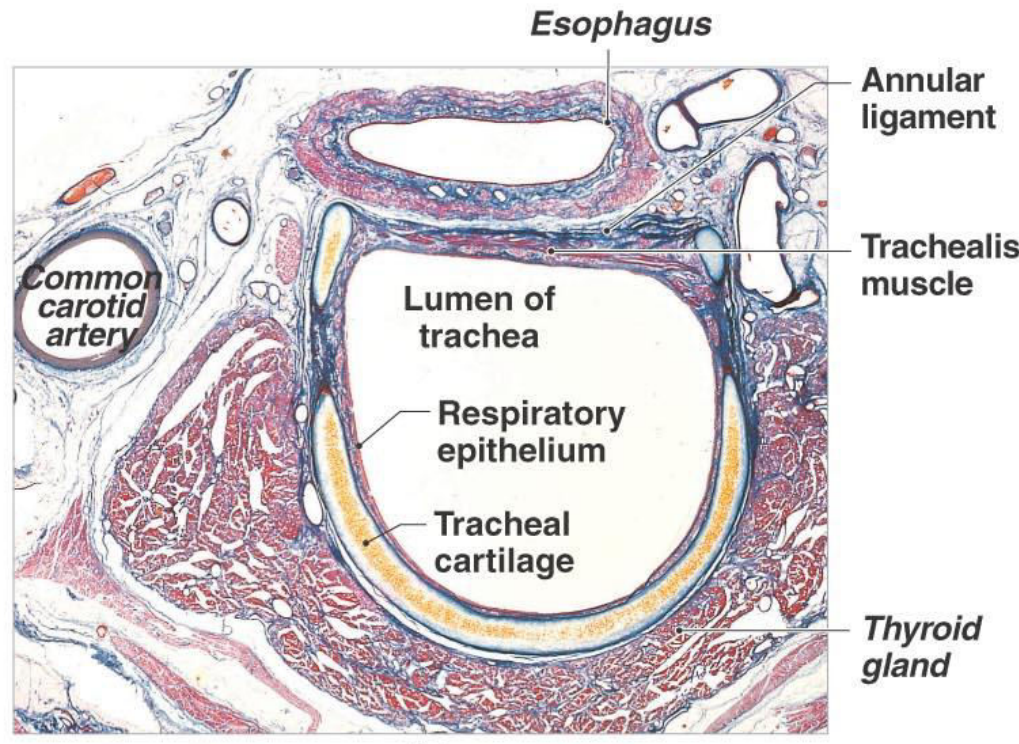


- Posterior open parts of tracheal cartilage abut esophagus
- *Trachealis* muscle can decrease diameter of trachea
 - Esophagus can expand when food swallowed
 - Food can be forcibly expelled
- Wall of trachea has layers common to many tubular organs – filters, warms and moistens incoming air
 - *Mucous membrane* (pseudostratified epithelium with cilia and lamina propria with sheet of elastin)
 - *Submucosa* (with seromucous glands)
 - *Adventitia* - connective tissue which contains the tracheal cartilages)





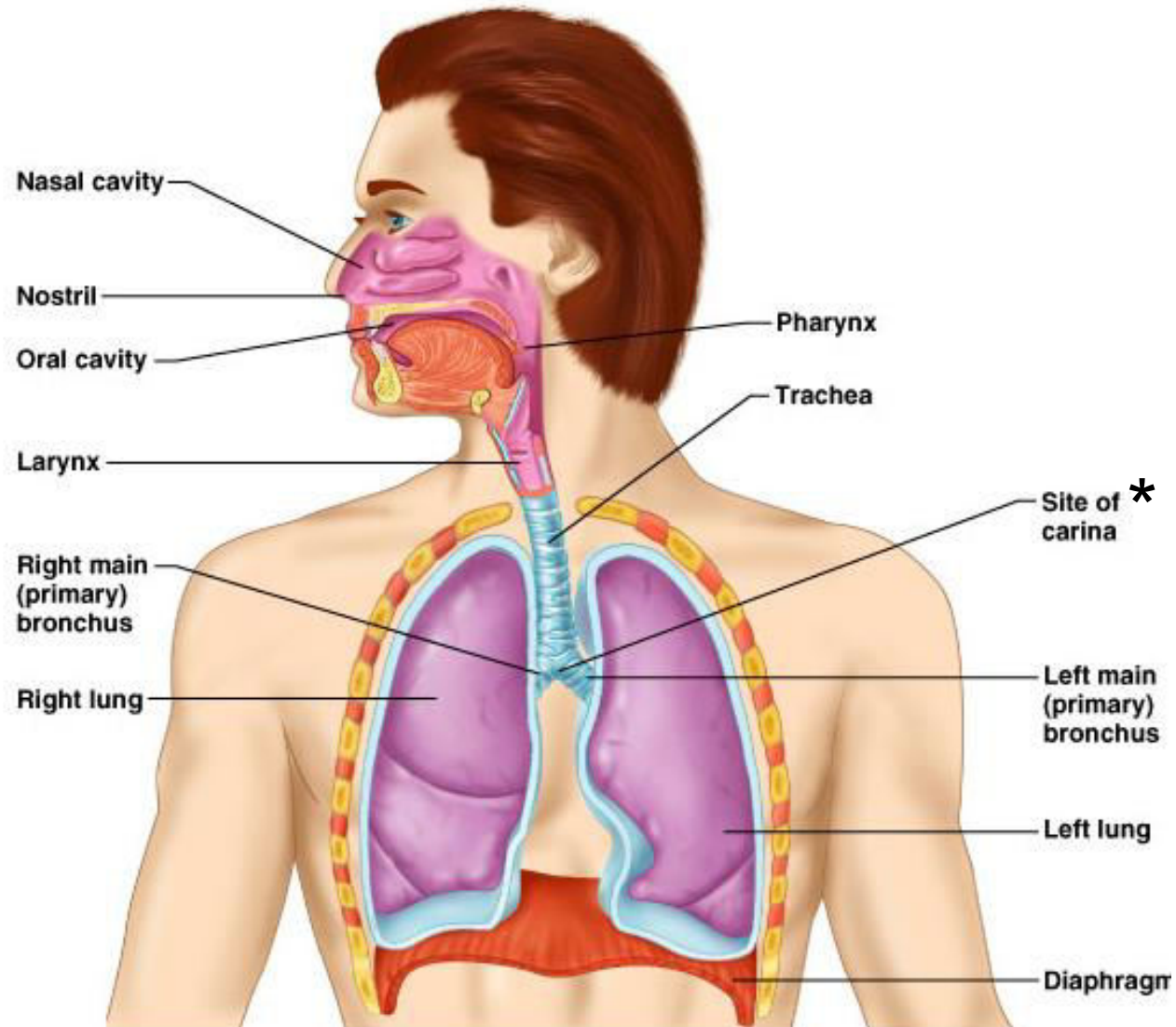
(a)



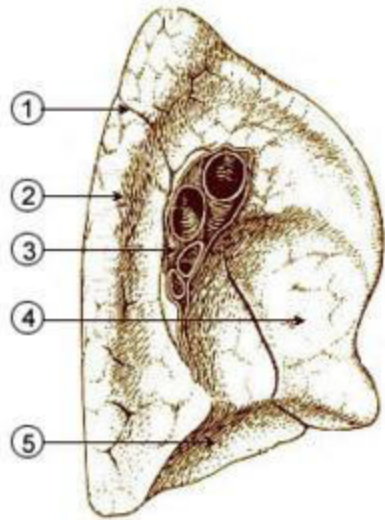
(b)

Carina*

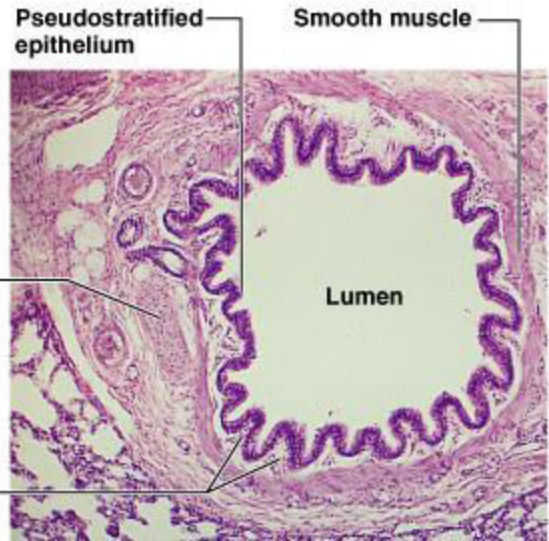
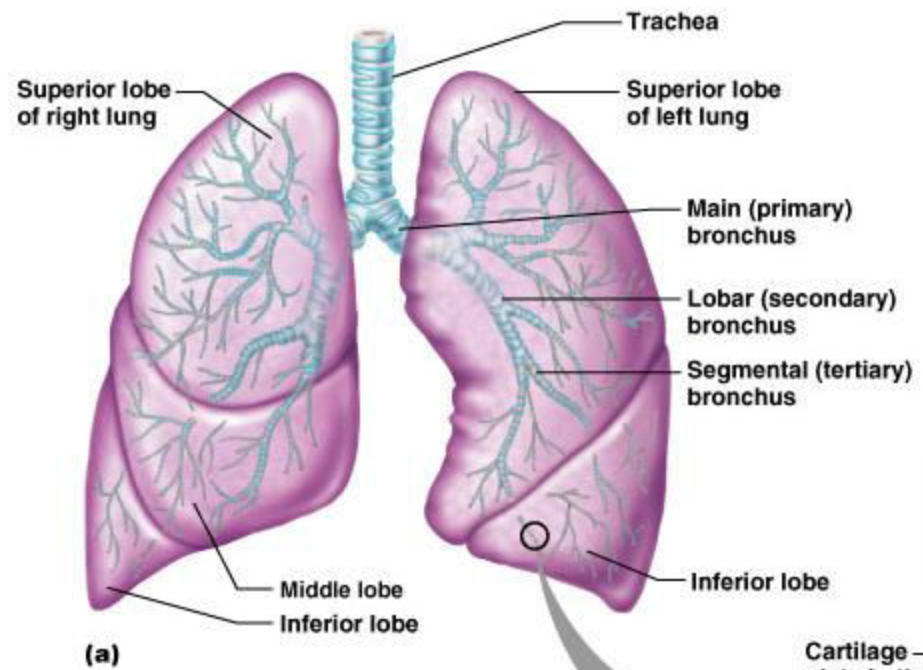
- Ridge on internal aspect of last tracheal cartilage
- Point where trachea branches (when alive and standing is at T7)
- Mucosa highly sensitive to irritants: cough reflex



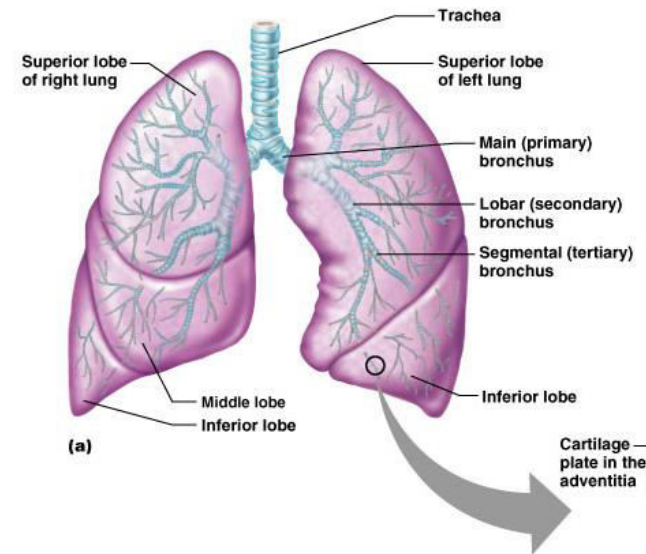
- Bronchial tree bifurcation
 - Right main bronchus (*more susceptible to aspiration*)
 - Left main bronchus
- Each main or primary bronchus runs into hilus of lung posterior to pulmonary vessels



1. [Oblique fissure](#)
 2. Vertebral part
 3. Hilum of lung
 4. [Cardiac impression](#)
 5. [Diaphragmatic surface](#)
- (Wikipedia)

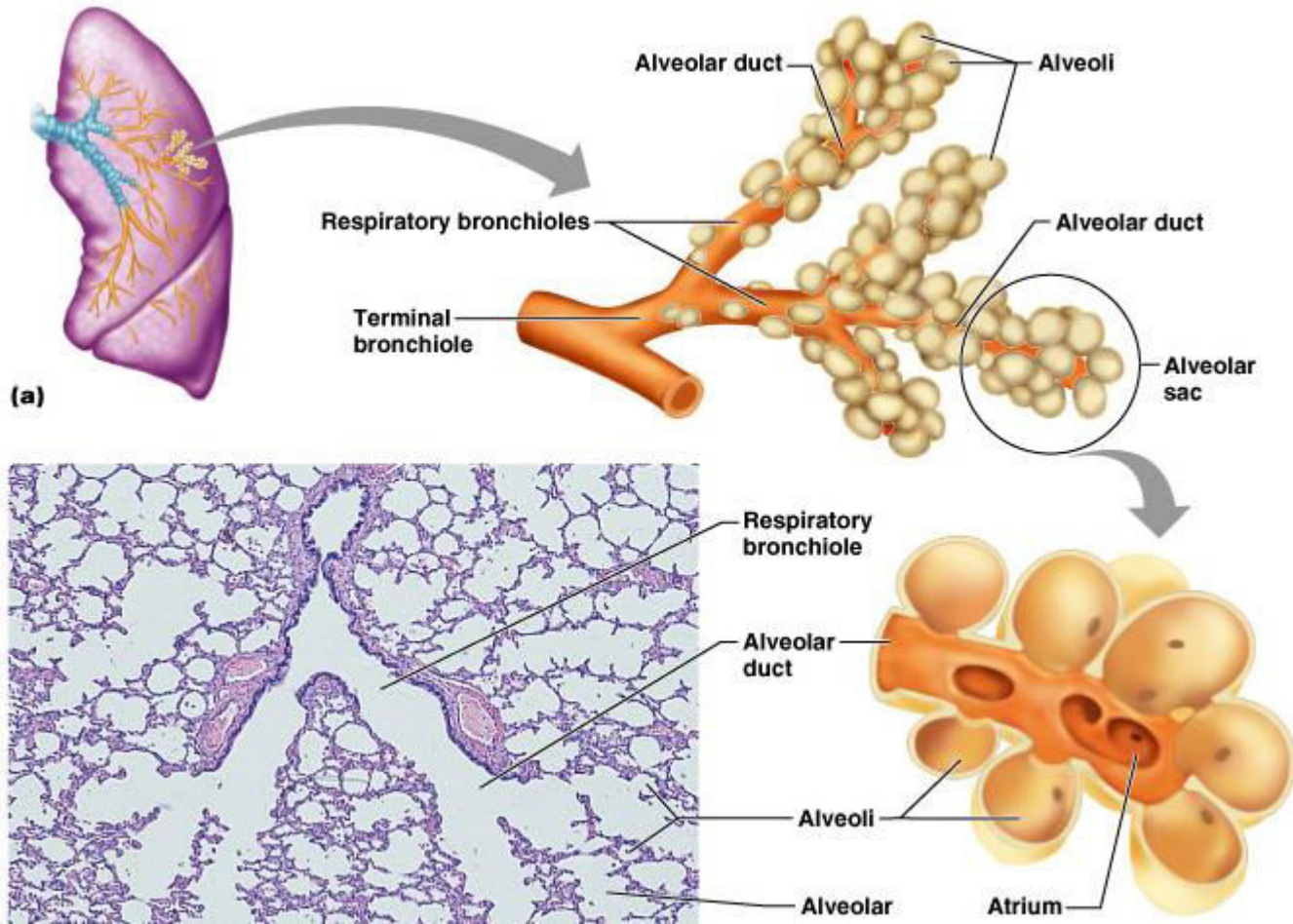


- Main=primary bronchi divide into secondary=lobar bronchi, each supplies one lobe
 - **3 on the right**
 - **2 on the left**
- Lobar bronchi branch into tertiary = segmental bronchi
- Continues dividing: about 23 times
- Tubes smaller than 1 mm called bronchioles
- Smallest, terminal bronchioles, are less the 0.5 mm diameter
- Tissue changes as becomes smaller
 - **Cartilage plates, not rings, then disappears**
 - **Pseudostratified columnar to simple columnar to simple cuboidal without mucus or cilia**
 - **Smooth muscle important: sympathetic relaxation (“bronchodilation”), parasympathetic constriction (“bronchoconstriction”)**



Respiratory Zone

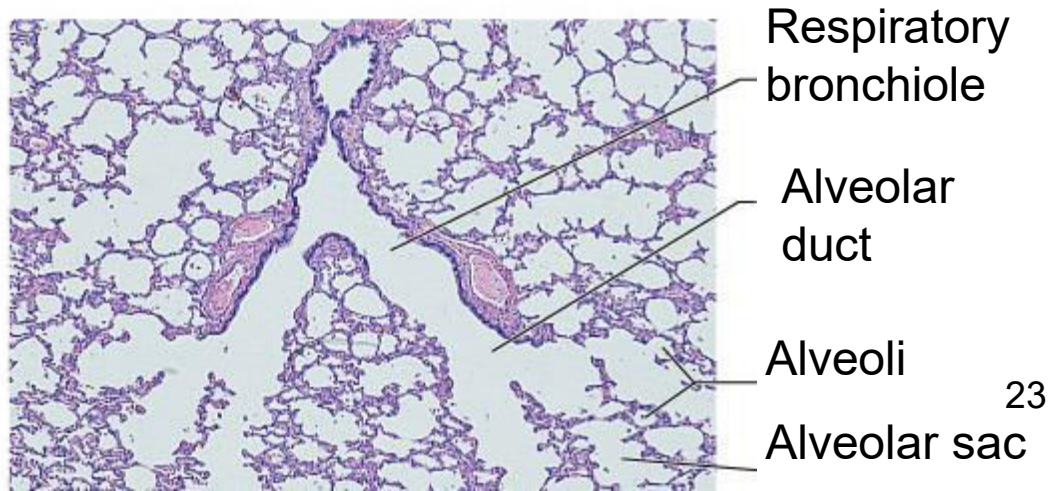
- End-point of respiratory tree
- Structures that contain air-exchange chambers are called alveoli
- Respiratory bronchioles lead into alveolar ducts: walls consist of alveoli
- Ducts lead into terminal clusters called alveolar sacs – are microscopic chambers
- There are 3 million alveoli!



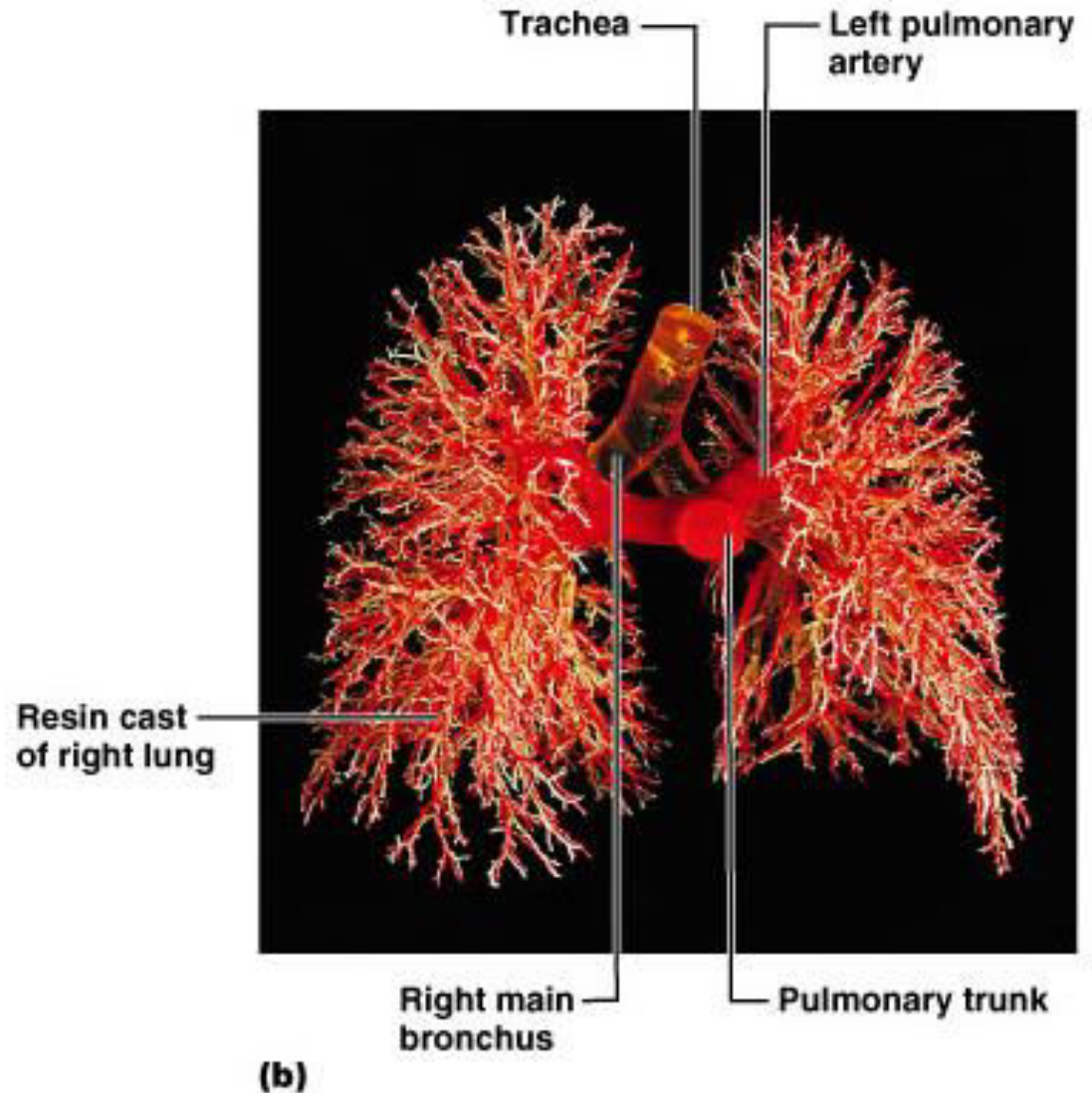
Gas Exchange

- Air filled alveoli account for most of the lung volume
- Very great area for gas exchange (1500 sq ft)
- Alveolar wall
 - Single layer of squamous epithelial cells (type 1 cells) surrounded by basal lamina
 - 0.5um (15 X thinner than tissue paper)
 - External wall covered by cobweb of capillaries
- ***Respiratory membrane***: fusion of the basal laminas of
 - Alveolar wall
 - Capillary wall

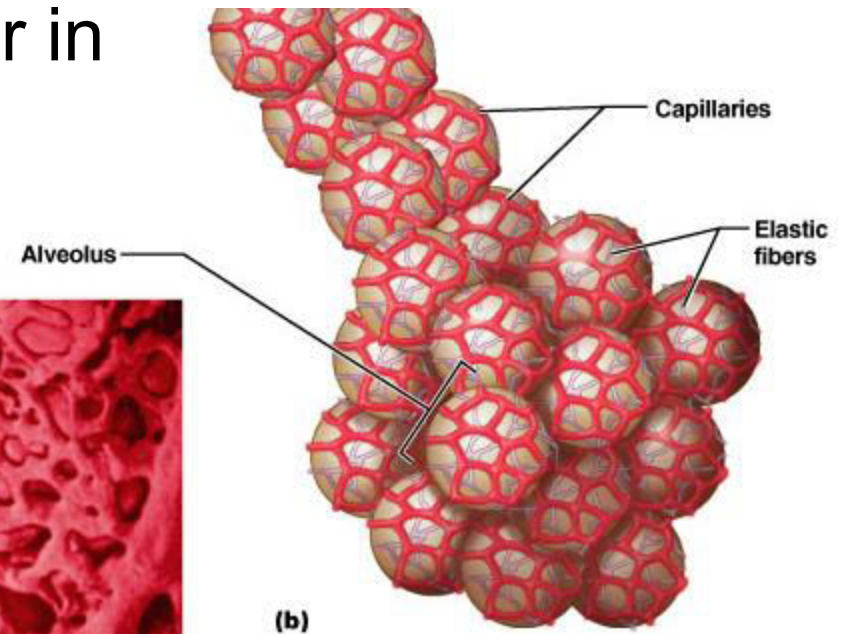
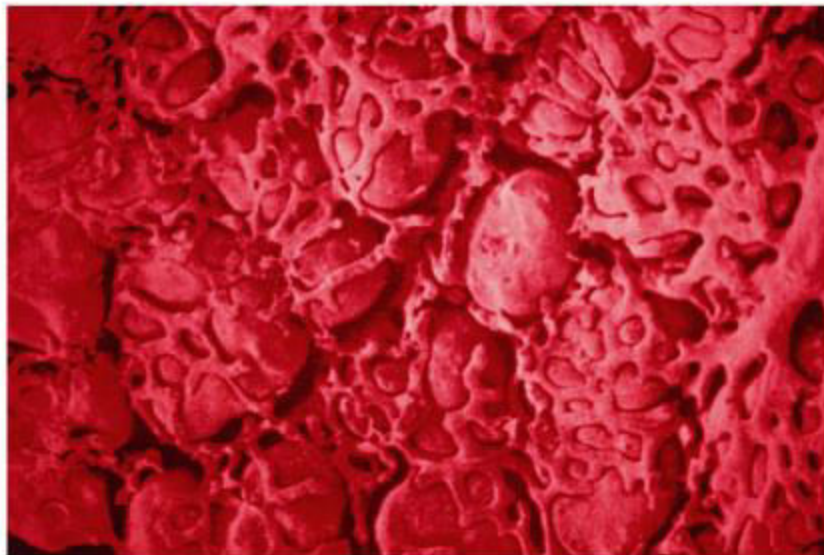
(air on one side;
blood on the other)



Bronchial “tree” and associated Pulmonary arteries

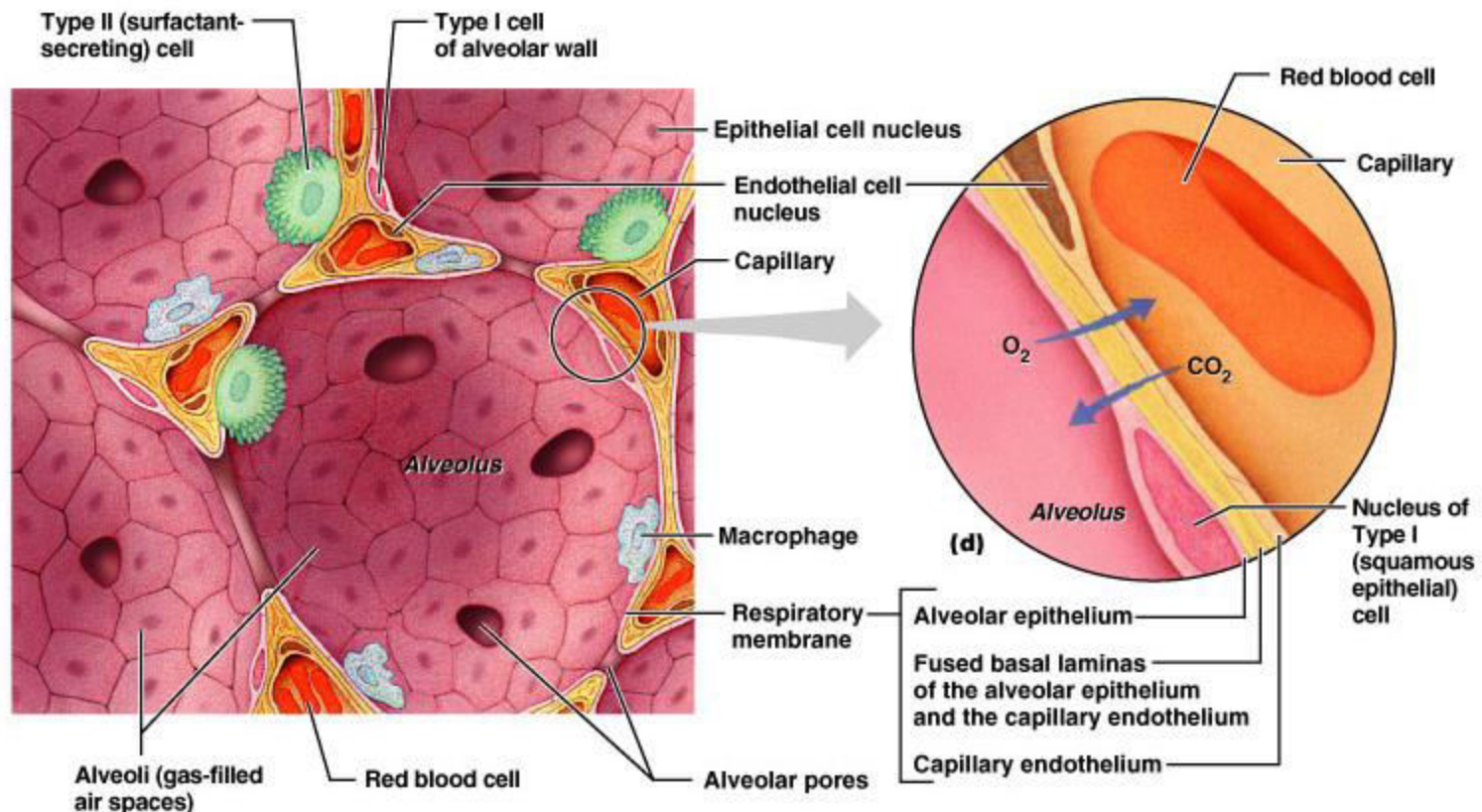


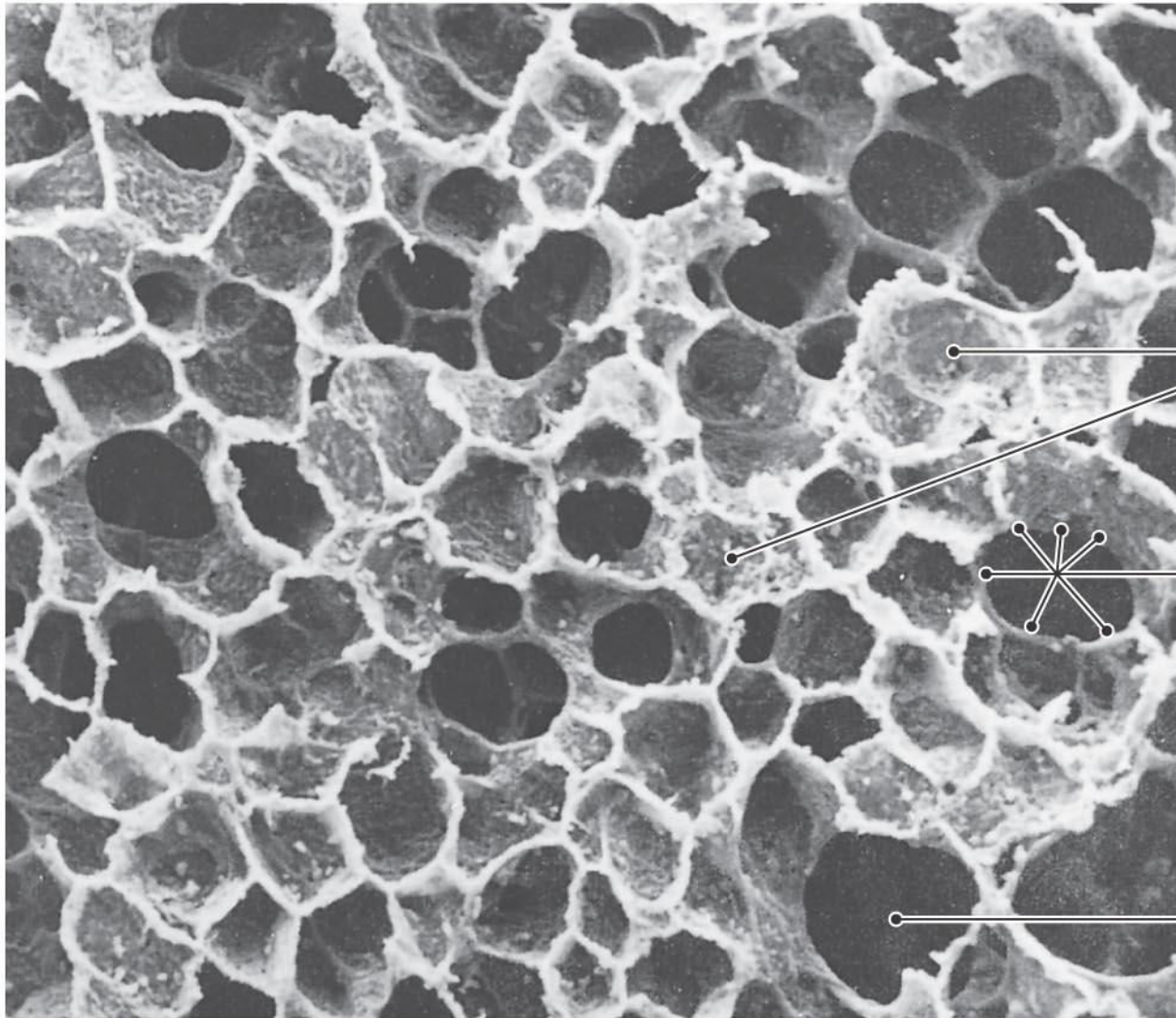
- This “air-blood barrier” (the respiratory membrane) is where gas exchange occurs
 - Oxygen diffuses from air in alveolus (singular of alveoli) to blood in capillary
 - Carbon dioxide diffuses from the blood in the capillary into the air in the alveolus



Microscopic detail of alveoli

- Alveoli surrounded by fine elastic fibers
- Alveoli interconnect via alveolar pores
- Alveolar macrophages – free floating “dust cells”
- Note type I and type II cells and joint membrane





Alveoli

Alveolar sac

Alveolar duct

(b) SEM of lung alveoli

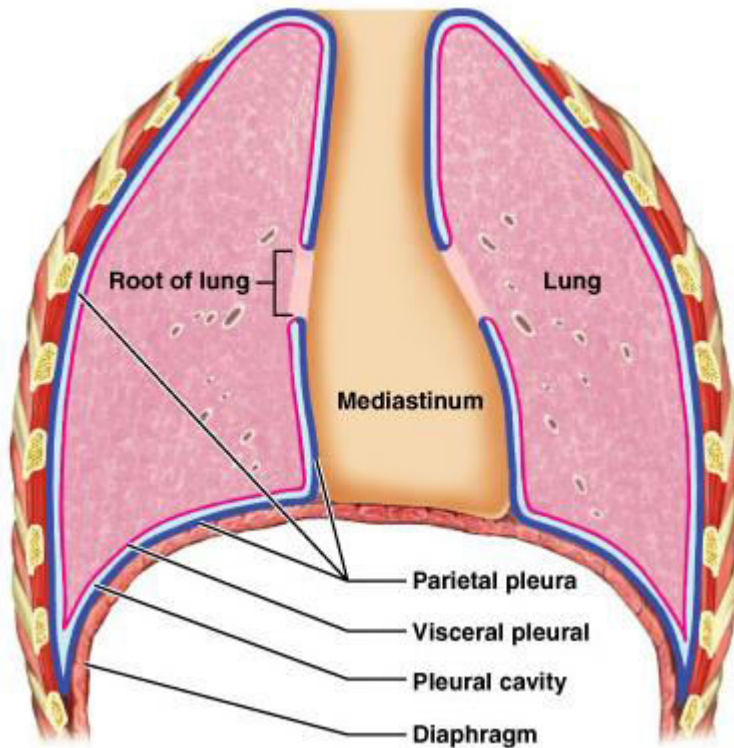
Lungs and Pleura

Around each lung is a flattened sac of serous membrane called ***pleura***

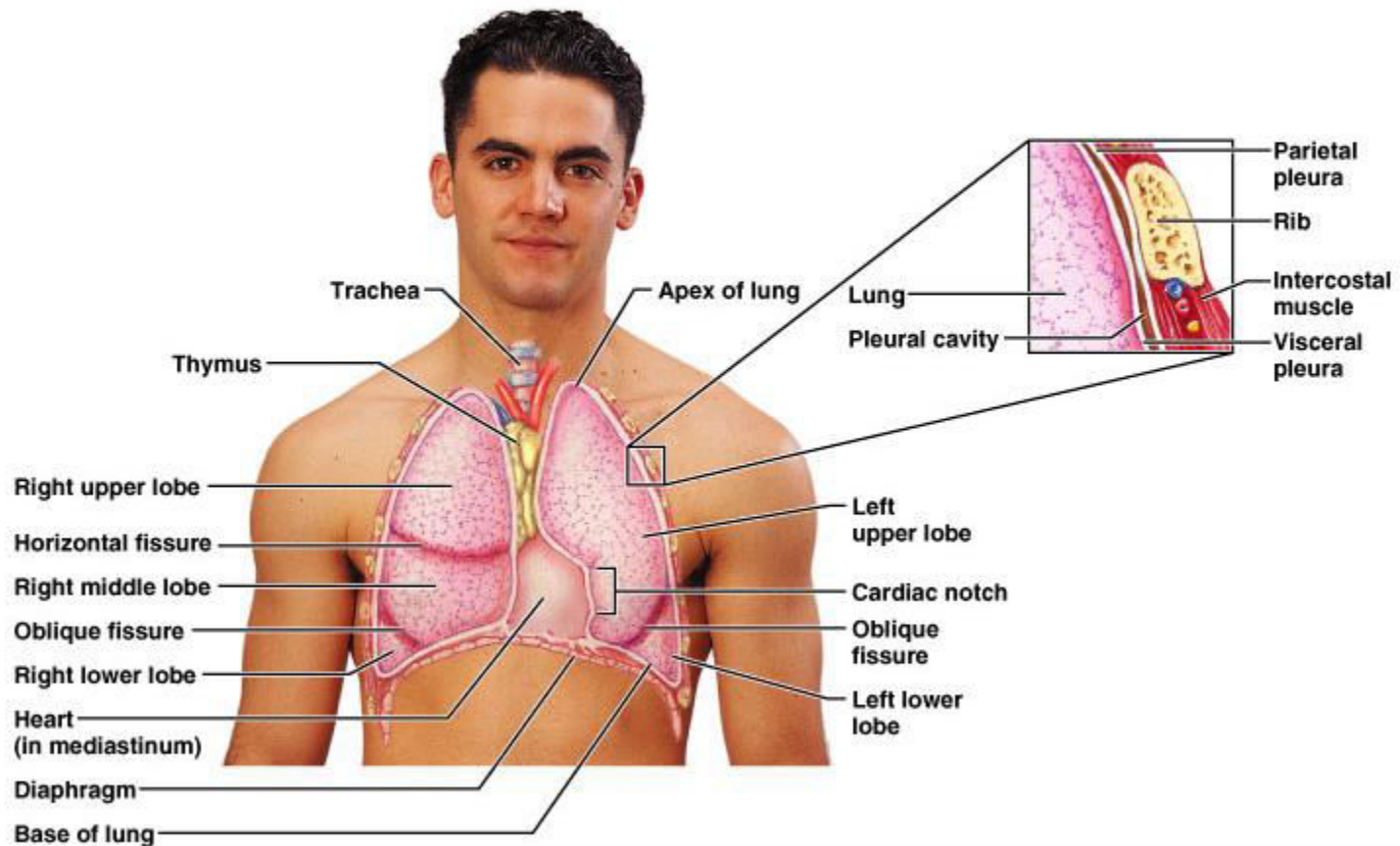
Parietal pleura – outer layer
Visceral pleura – directly on lung

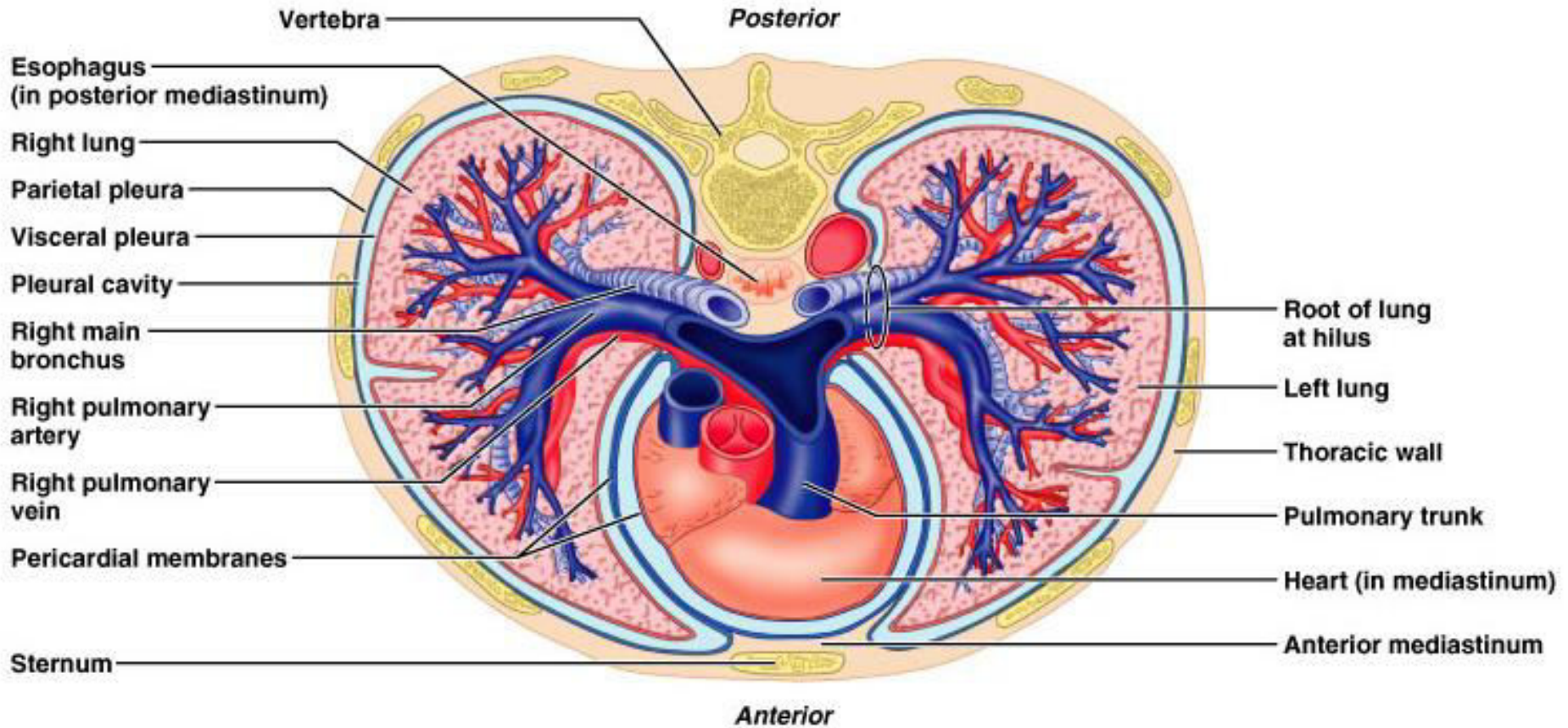
Pleural cavity – slit-like potential space filled with pleural fluid

- Lungs can slide but separation from pleura is resisted (like film between 2 plates of glass)
- Lungs cling to thoracic wall and are forced to expand and recoil as volume of thoracic cavity changes during breathing



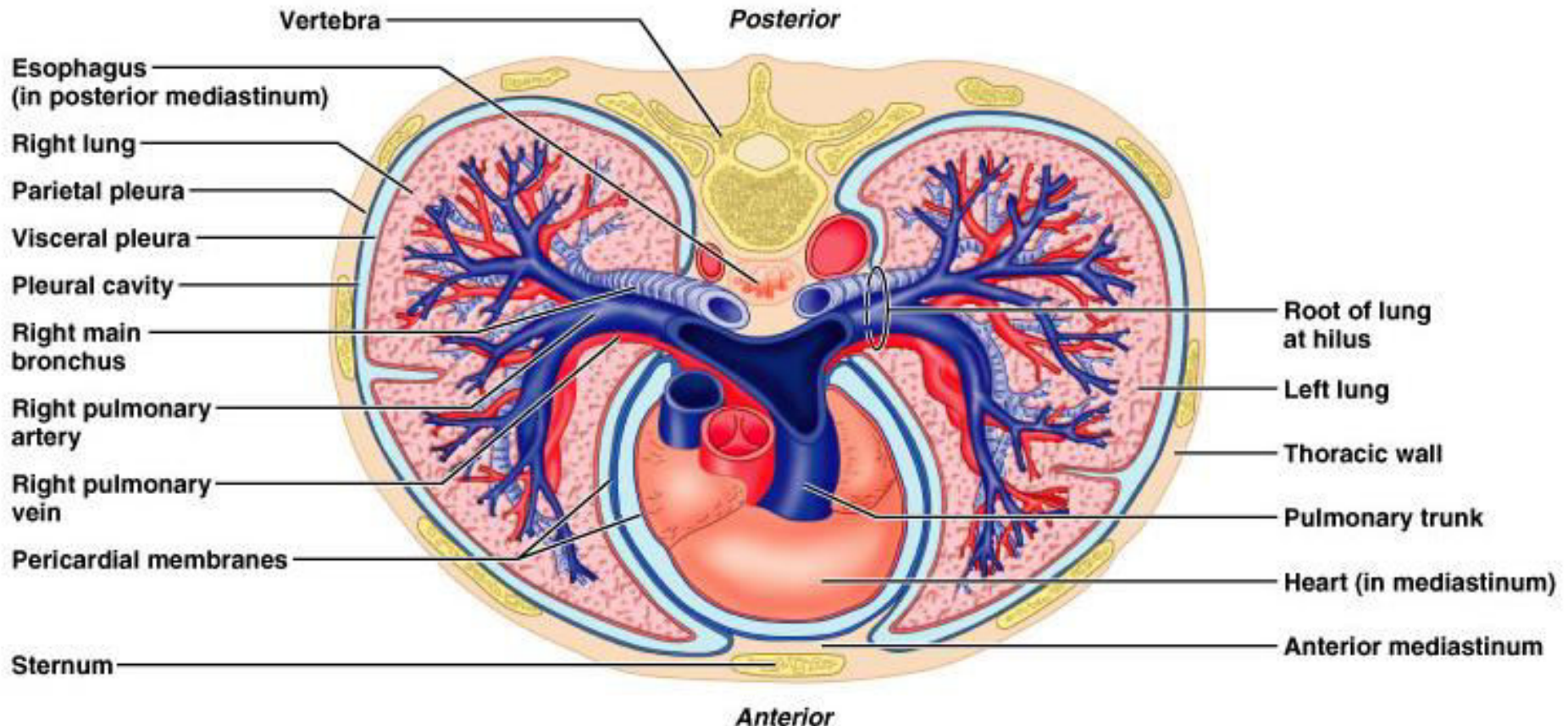
- Pleura also divides thoracic cavity in three
 - 2 pleural, 1 mediastinal
- Pathology
 - Pleuritis
 - Pleural effusion





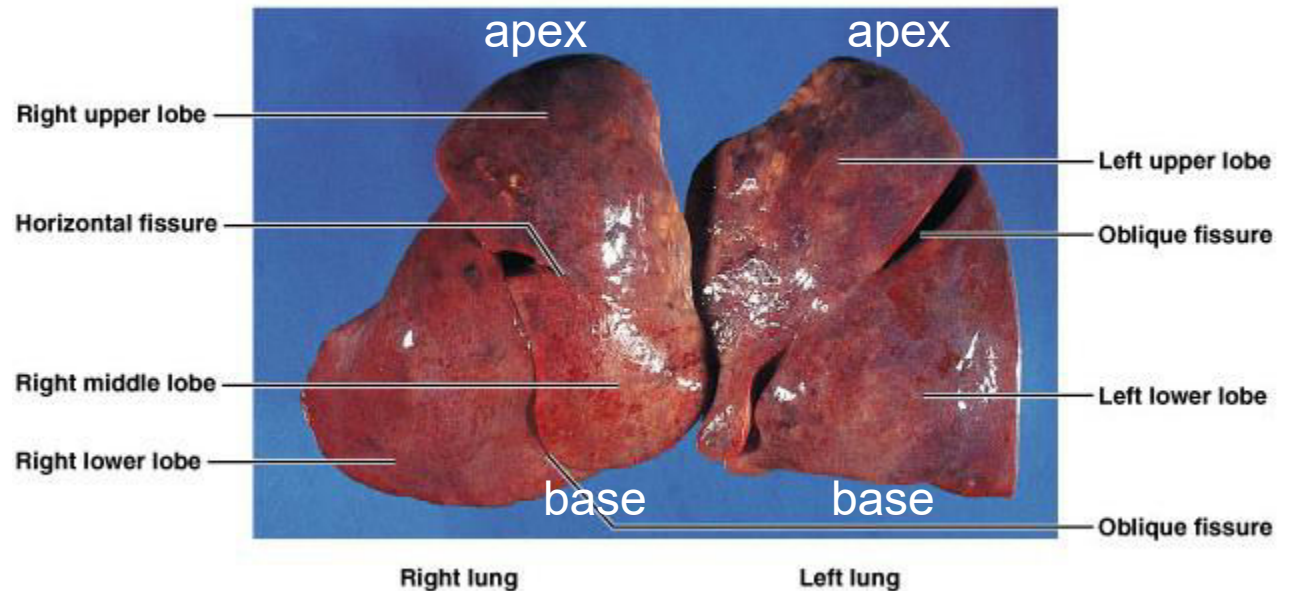
Relationship of organs in thoracic cavity

- Paired lungs occupy all thoracic cavity lateral to the mediastinum
- Mediastinum contains (mainly): heart, great blood vessels, trachea, main bronchi, esophagus



Lungs

- Each is cone-shaped with anterior, lateral and posterior surfaces contacting ribs
- Superior tip is apex, just deep to clavicle
- Concave inferior surface resting on diaphragm is the base



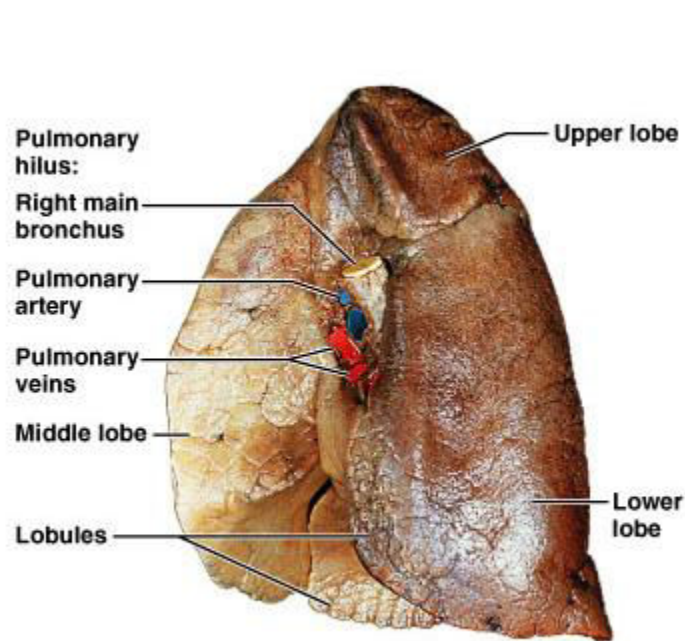
(a)

- ***Hilus or (hilum)***

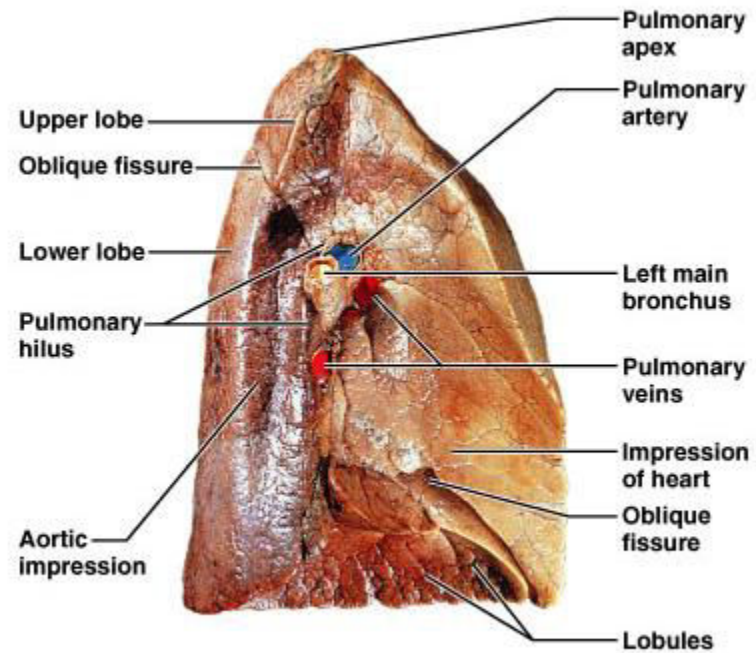
- Indentation on mediastinal (medial) surface
 - Place where blood vessels, bronchi, lymph vessel, and nerves enter and exit the lung

- ***“Root”*** of the lung

- Above structures attaching lung to mediastinum
 - Main ones: pulmonary artery and veins and main bronchus



(b) Medial view R lung



(c) Medial view of L lung

- Right lung: 3 lobes

- Upper lobe

Horizontal fissure

- Middle lobe

Oblique fissure

- Lower lobe

- Left lung: 2 lobes

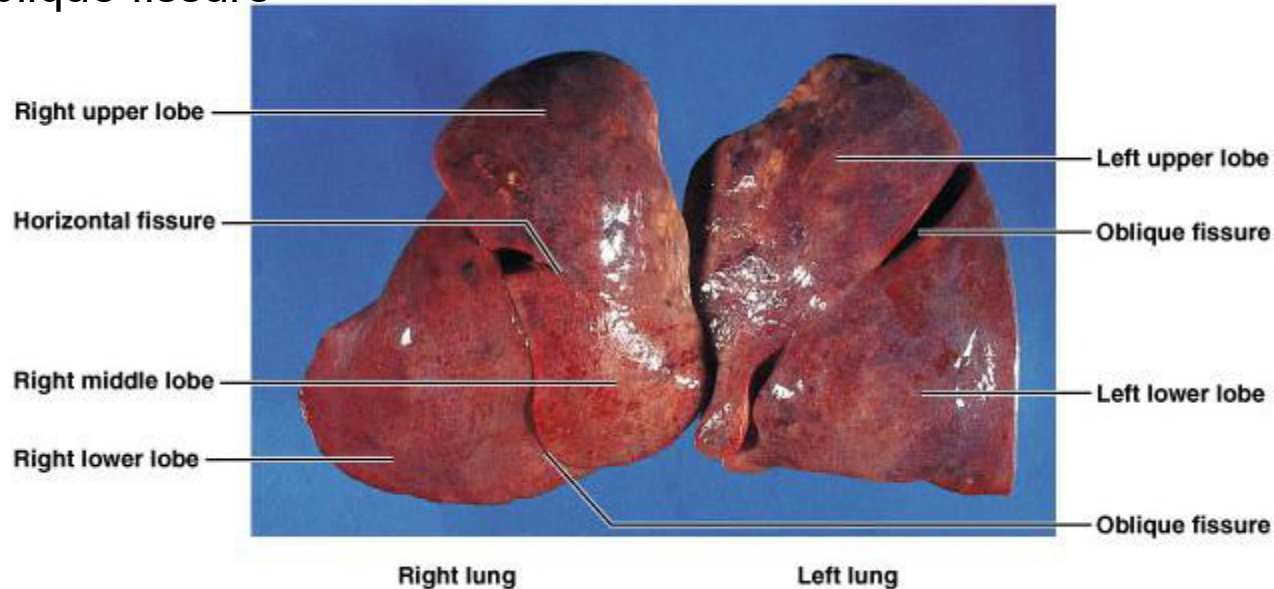
- Upper lobe

Oblique fissure

- Lower lobe

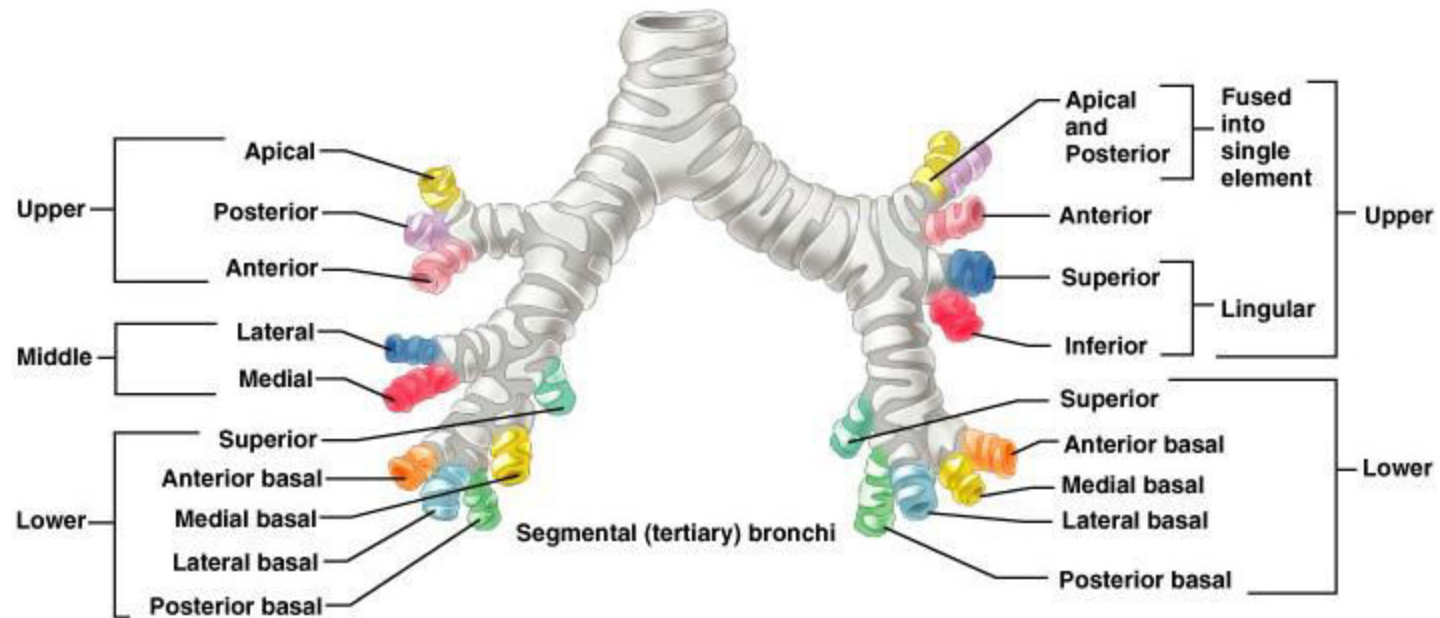
Abbreviations in medicine:
e.g. " RLL pneumonia"

Each lobe is served by
a lobar (secondary)
bronchus



(a)

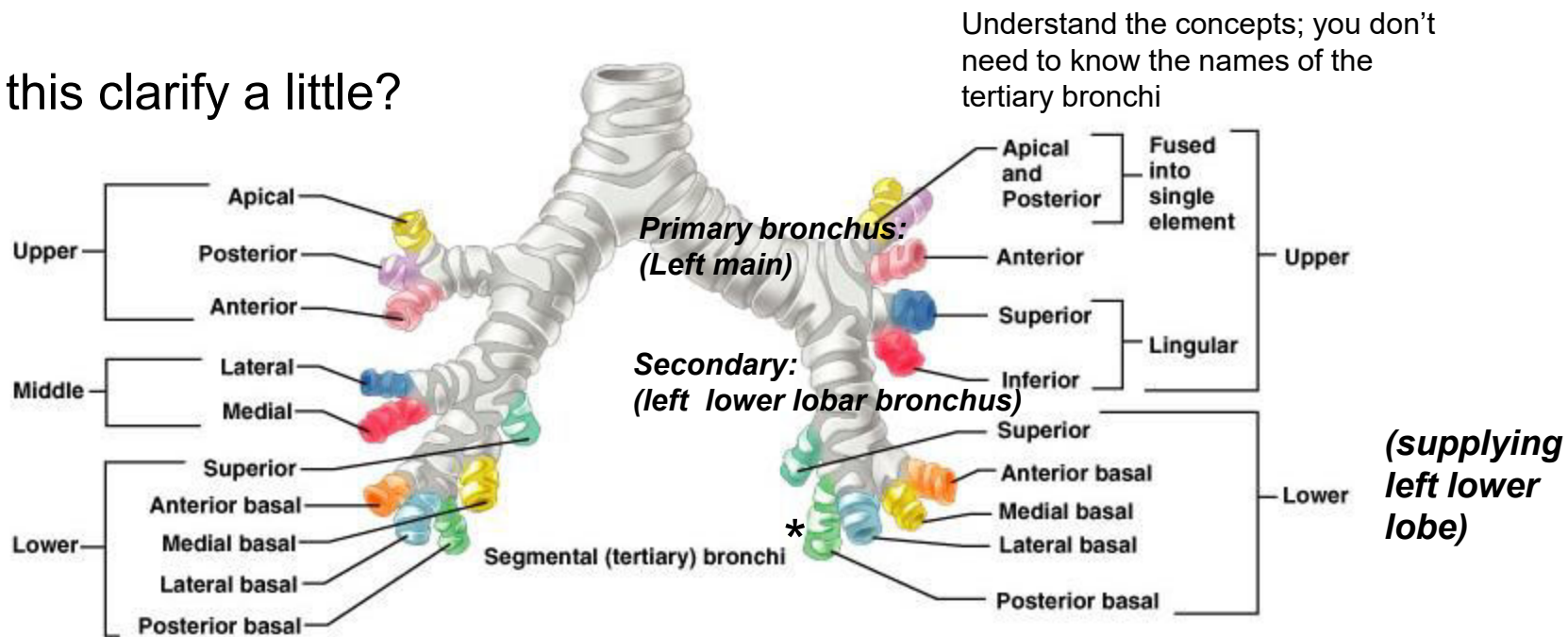
- Each lobe is made up of **bronchopulmonary segments** separated by dense connective tissue
 - Each segment receives air from an individual **segmental (tertiary) bronchus**
 - Approximately 10 bronchopulmonary segments in each lung
 - Limit spread of infection
 - Can be removed more easily because only small vessels span segments
- Smallest subdivision seen with the naked eye is the **lobule**
 - Hexagonal on surface, size of pencil eraser
 - Served by large bronchiole and its branches
 - Black carbon is visible on connective tissue separating individual lobules in smokers and city dwellers



- Pulmonary arteries bring oxygen-poor blood to the lungs for oxygenation
 - They branch along with the bronchial tree
 - The smallest feed into the pulmonary capillary network around the alveoli
- Pulmonary veins carry oxygenated blood from the alveoli of the lungs to the heart

- Stroma – framework of connective tissue holding the air tubes and spaces
 - Many elastic fibers
 - Lungs light, spongy and elastic
 - Elasticity reduces the effort of breathing
- Blood supply
 - Lungs get their own blood supply from ***bronchial arteries and veins***
- Innervation: ***pulmonary plexus*** on lung root contains sympathetic, parasympathetic and visceral sensory fibers to each lung
 - From there, they lie on bronchial tubes and blood vessels within the lungs

Does this clarify a little?



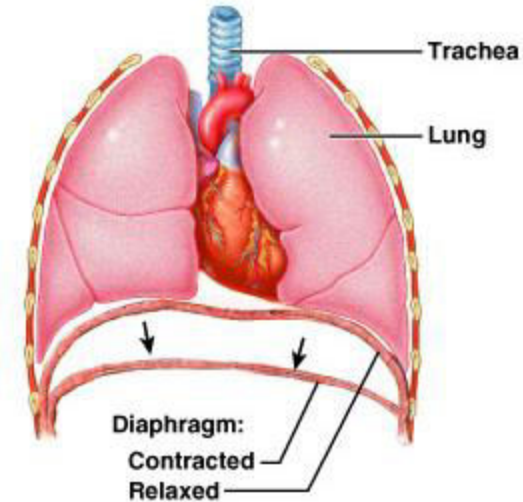
- Bronchopulmonary – means both bronchial tubes and lung alveoli together
 - Bronchopulmonary segment – chunk receiving air from a segmental (tertiary) bronchus*: tertiary means it's the third order in size; also, the trachea has divided three times now
- “Anatomical dead space”
 - The conducting zone which doesn't participate in gas exchange

Ventilation

- Breathing = “pulmonary ventilation”
 - Pulmonary means related to the lungs
- Two phases
 - Inspiration (inhalation) – air in
 - Expiration (exhalation) – air out
- Mechanical forces cause the movement of air
 - Gases always flow from higher pressure to lower
 - For air to enter the thorax, the pressure of the air in it has to be lower than atmospheric pressure
 - Making the volume of the thorax larger means the air inside it is under less pressure
(the air has more space for as many gas particles, therefore it is under less pressure)
 - The diaphragm and intercostal muscles accomplish this

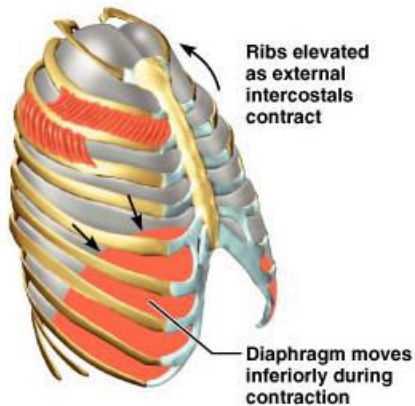
Muscles of Inspiration

- During inspiration, the dome shaped **diaphragm** flattens as it contracts
 - This increases the height of the thoracic cavity



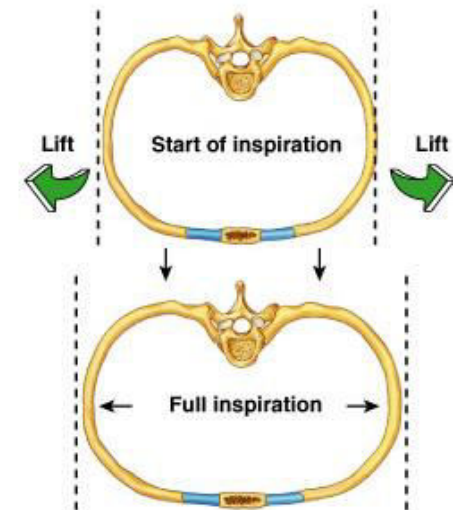
(a) Superoinferior expansion

Together:



(d) Inspiration

- The **external intercostal muscles** contract to raise the ribs
 - This increases the circumference of the thoracic cavity



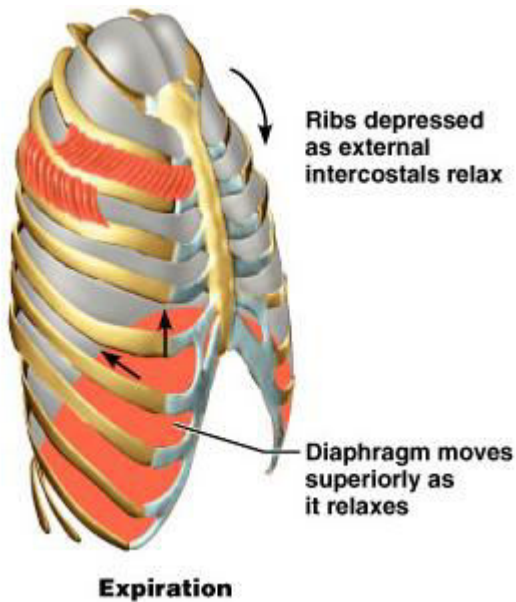
(b) Lateral expansion

Inspiration continued

- Intercostals keep the thorax stiff so sides don't collapse in with change of diaphragm
- During deep or forced inspiration, additional muscles are recruited:
 - Scalenes
 - Sternocleidomastoid
 - Pectoralis minor
 - Quadratus lumborum on 12th rib
 - Erector spinae

(some of these “accessory muscles” of ventilation are visible to an observer; it usually tells you that there is respiratory distress – working hard to breathe)

Expiration



- Quiet expiration in healthy people is chiefly passive
 - Inspiratory muscles relax
 - Rib cage drops under force of gravity
 - Relaxing diaphragm moves superiorly (up)
 - Elastic fibers in lung recoil
 - Volumes of thorax and lungs decrease simultaneously, increasing the pressure
 - Air is forced out

Expiration continued

- Forced expiration is active
 - Contraction of abdominal wall muscles
 - Oblique and transversus predominantly
 - Increases intra-abdominal pressure forcing the diaphragm superiorly
 - Depressing the rib cage, decreases thoracic volume
 - Some help from internal intercostals and latissimus dorsi

(try this on yourself to feel the different muscles acting)

Pneumothorax (collapsed lung)

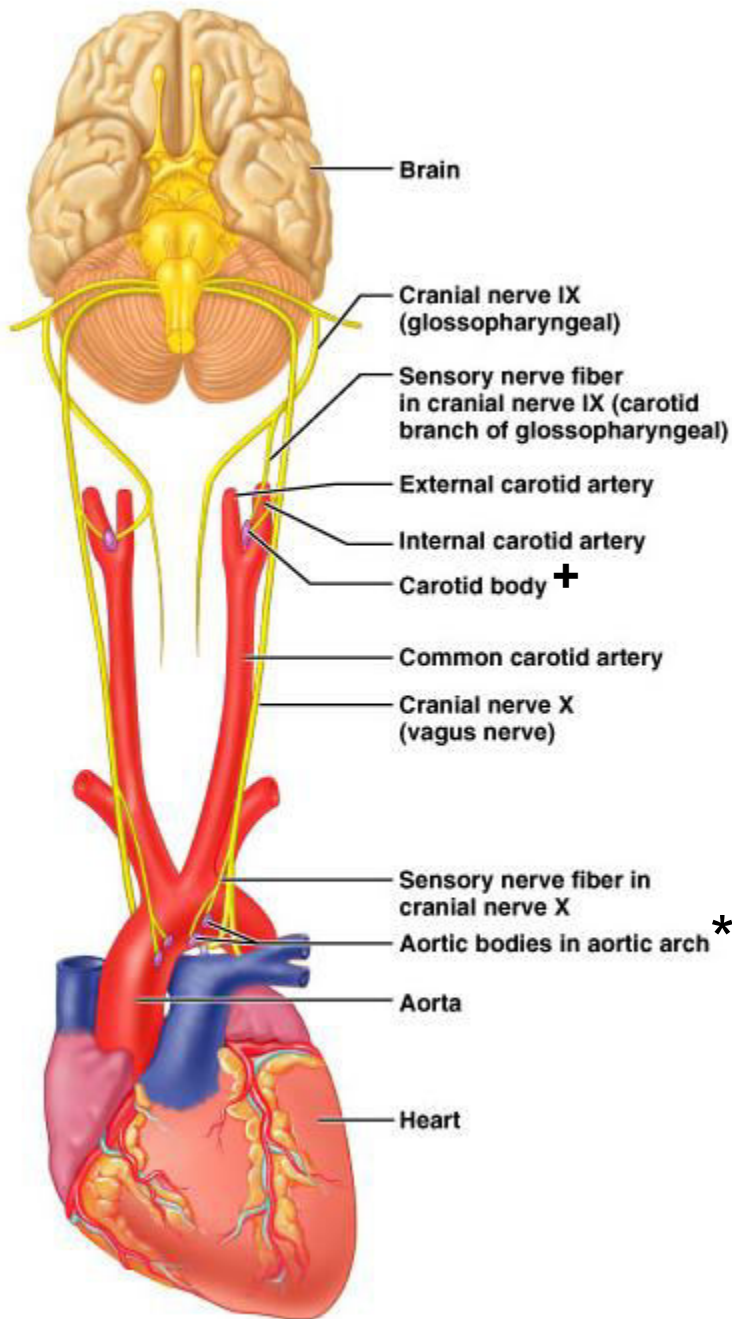
- Think about the processes involved and then try and imagine the various scenarios
 1. Trauma causing the thoracic wall to be pierced so air gets into the pleura
 2. Broken rib can do (1); always do a CXR if there's a broken rib
 3. Visceral pleura breaks, letting alveolar air into pleural space

Neural Control of Ventilation

- Reticular formation in medulla
 - Responsible for basic rate and rhythm
 - Can be modified by higher centers
 - Limbic system and hypothalamus, e.g. gasp with certain emotions
 - Cerebral cortex – conscious control
- Chemoreceptors
 - Central – in the medulla
 - Peripheral: see next slide
 - Aortic bodies on the aortic arch
 - **Carotid bodies** at the fork of the carotid artery: monitor O₂ and CO₂ tension in the blood and help regulate respiratory rate and depth

The carotid sinus (dilated area near fork) helps regulate blood pressure and can affect the rate (stimulation during carotid massage can slow an abnormally fast heart rate)

Peripheral chemoreceptors regulating respiration

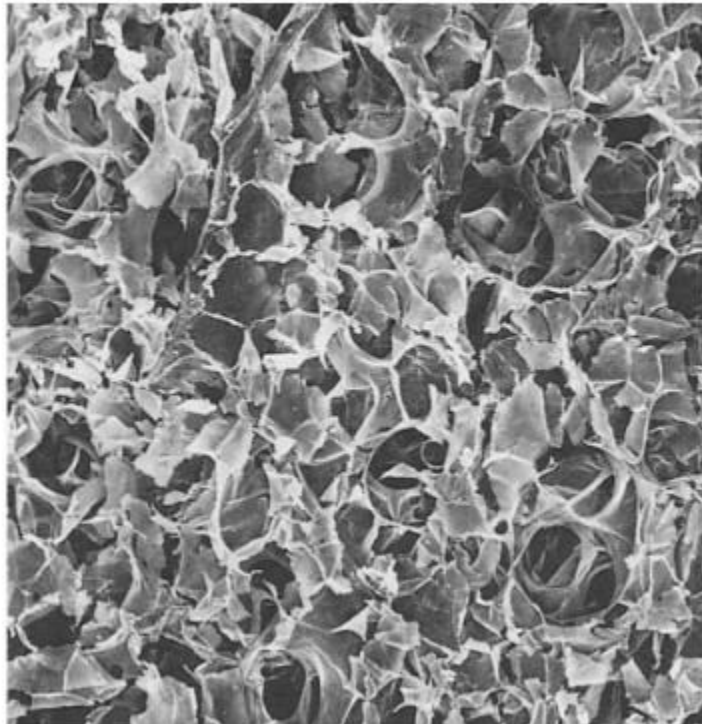


- Aortic bodies*
 - On aorta
 - Send sensory info to medulla through X (vagus n)
- Carotid bodies+
 - At fork of common carotid artery
 - Send info mainly through IX (glossopharyngeal n)

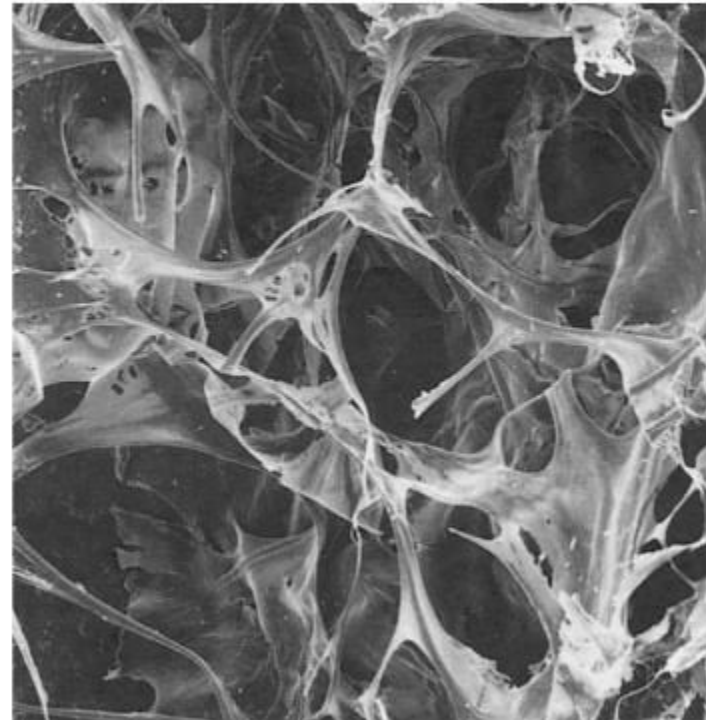
- There are many diseases of the respiratory system, including asthma, cystic fibrosis, COPD (chronic obstructive pulmonary disease – with chronic bronchitis and/or emphysema) and epiglottitis

example:

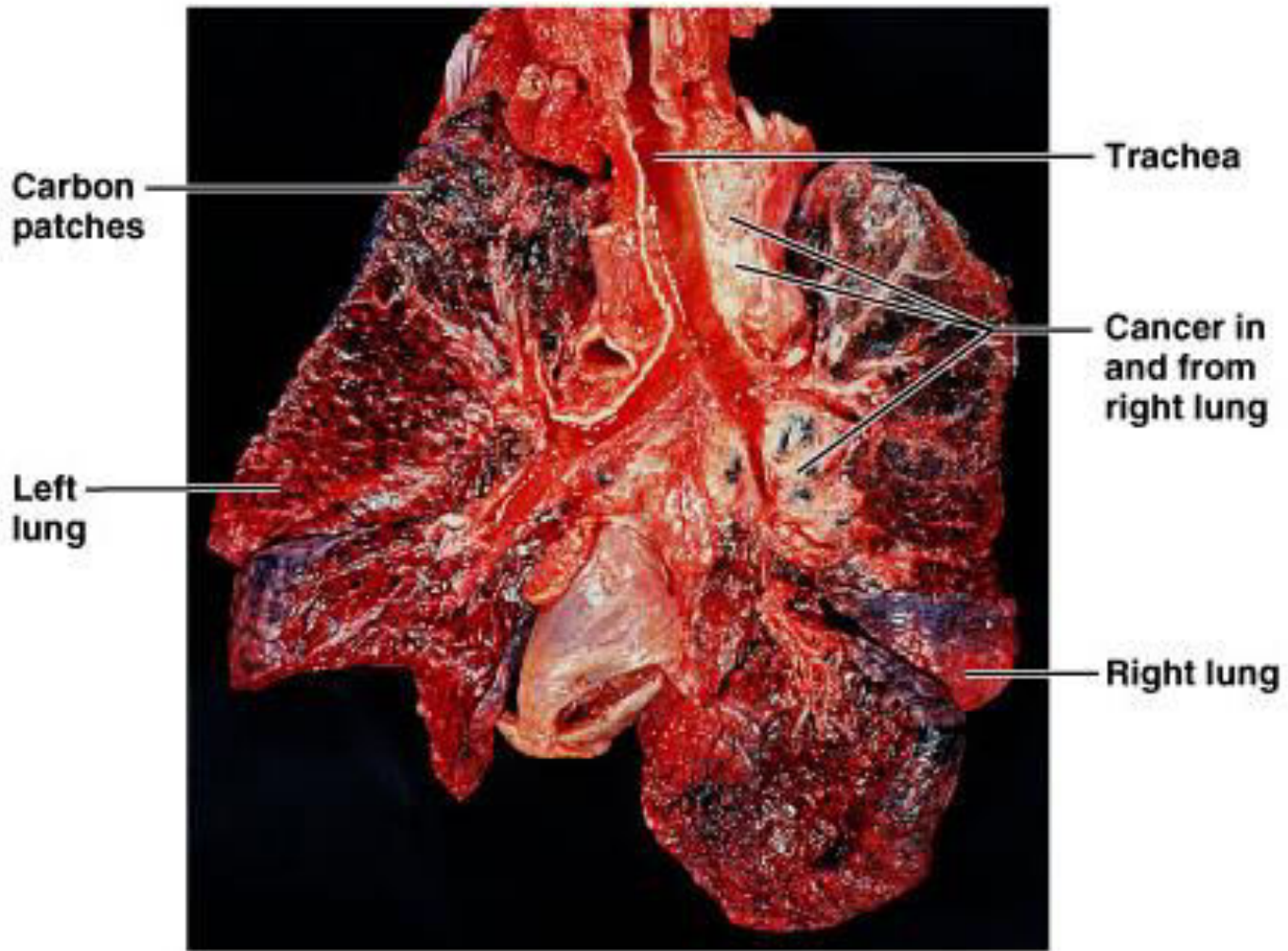
normal



emphysema



you might want to think twice about smoking....



general CXR site:

- <http://www.radiologyinfo.org/en/info.cfm?pg=chestrاد&bhcp=1>

CXR atlas:

- http://www.meddean.luc.edu/lumen/MedEd/medicine/pulmonar/cxr/atlas/cxratlas_f.htm
(penuemothorax)