

# Respiratory system

## Contents

- Anatomy
- Gases & ventilation
- Gas exchange & transport
- Ventilation/perfusion
- Control of respiration

## Anatomy

### Rib cage

#### Boundaries of thorax:

- Suprasternal notch/thoracic inlet
  - [1<sup>st</sup> rib impalpable]
- Diaphragm

#### 1 Ribs

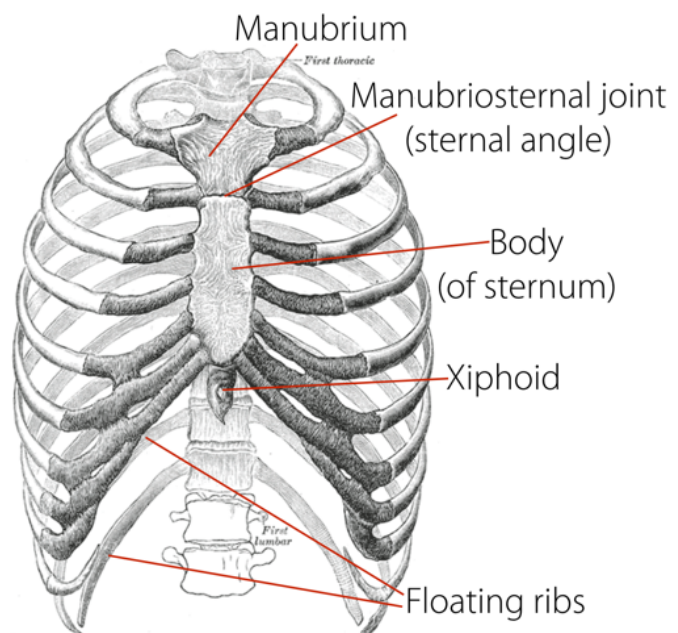
- 1-7 = *true*
- 8-12 = *false*
  - 11 & 12 = *floating*

#### Sternal attachments

- Manubrium: clavicle and ribs 1 & 2
- Body: ribs 2-7
- Xiphoid: muscles

#### Accessory muscles

- Sternocleidomastoid - inspiration
- Scalenus - inspiration
- Trapezius - inspiration
- Rectus abdominis - expiration



A **flail chest** occurs when several ribs are fractured in more than one place. This generates a segment of the rib cage that is not effectively attached to the rest. This region demonstrates **paradoxical movement**: it is drawn in during inspiration and pushed out during expiration. There is underlying partial lung collapse and a respiratory failure is common.

#### 2 Rib cage movements

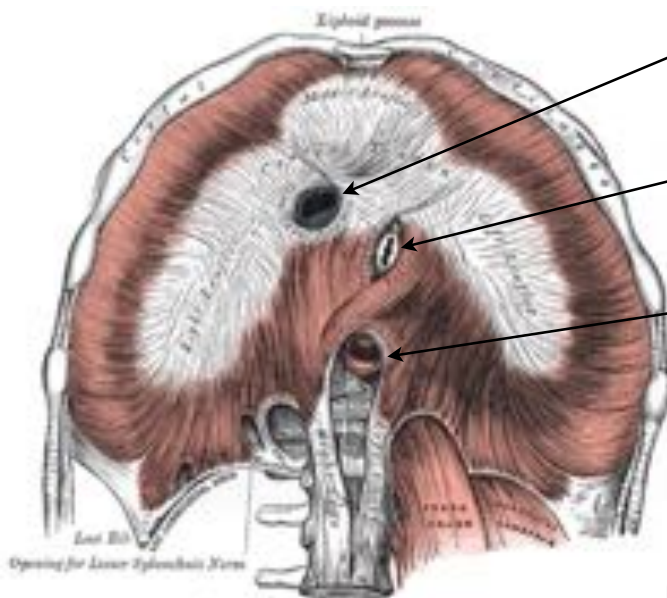
On **inspiration**: ribs move up and out ("bucket handles") & diaphragm contracts  
[Increase in antero-posterior, latero-lateral and supero-inferior dimensions]

#### Diaphragm

- Dome-shaped formed of peripheral muscle with central aponeurosis
- Attachments:

- Lower 6 costal cartilages
- Xiphisternum
- **Right & left crus** attach to lumbar vertebrae
- More **inferior posteriorly**
- Innervated by R & L **phrenic nerves (C3-5)**

#### Diaphragmatic orifices



**T8:**

- IVC
- Right phrenic nerve

**T10:**

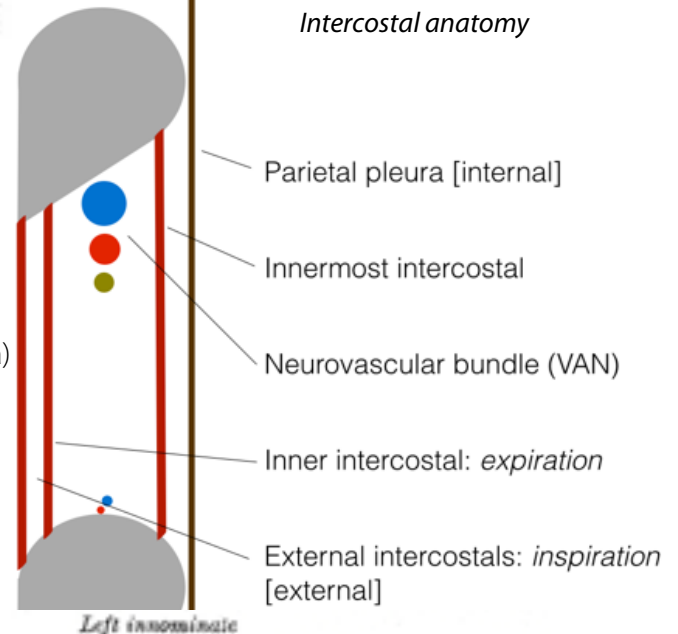
- Oesophagus
- Left & right vagus

**T12:**

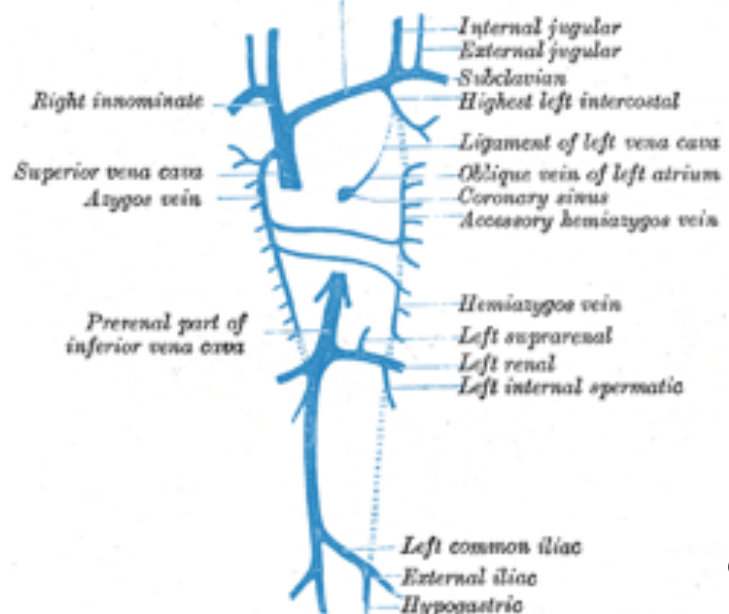
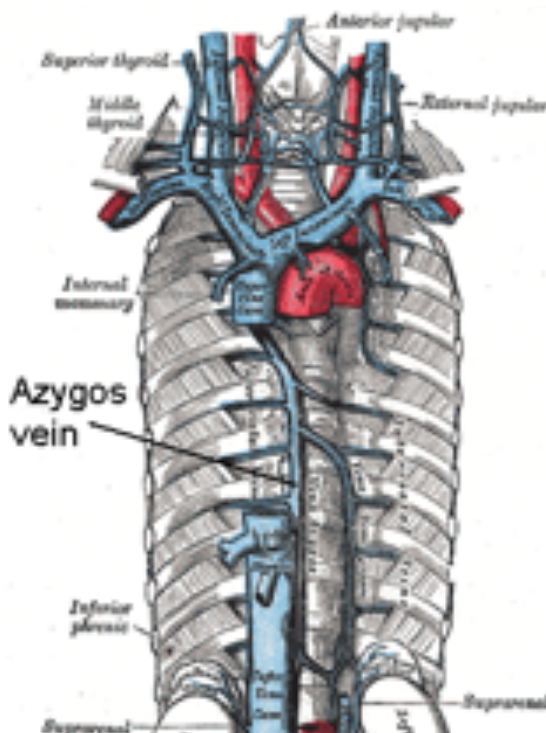
- Aorta
- Azygous vein
- Thoracic duct

- Sympathetic chain

#### *Intercostal anatomy*



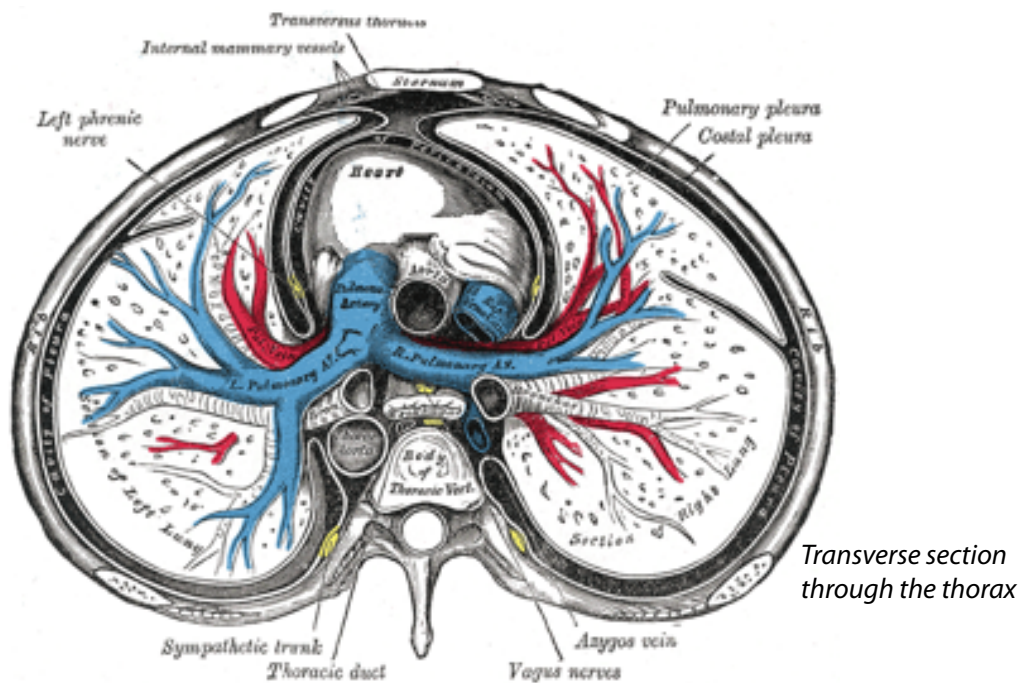
*Left innominate*



3

#### Neurovascular supply:

- Intercostal nerves (T1-11) [and subcostal nerve (T12)] from anterior root
- **Anterior intercostal arteries** (← internal thoracic ← subclavian)
- **Posterior intercostal arteries** (← thoracic aorta)
  - $\frac{2}{3}$ <sup>rd</sup> of chest
  - Drain to azygous & internal thoracic veins



#### Pleura

4

- **Parietal & visceral**; continuous at *hila*
- Double-layer forms **pulmonary ligament**
- *Costo-diaphragmatic recess* is where costal & diaphragmatic parietal pleura are in contact
  - Forms **costo-phrenic angle** on chest X-ray

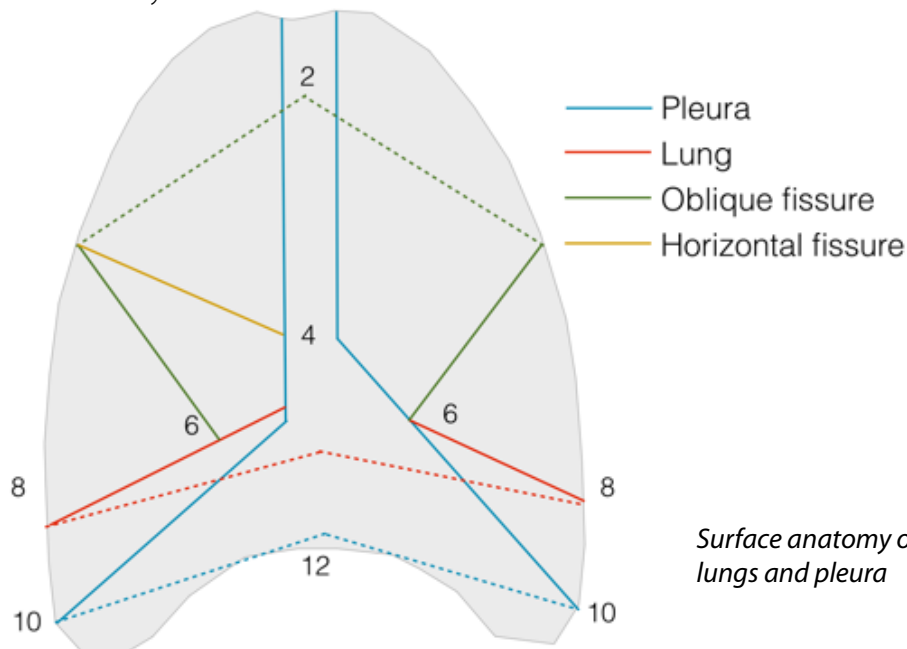
#### 5 Surface anatomy

##### Lungs:

- T10 posteriorly in mid-line
- 8<sup>th</sup> intercostal space in mid-axillary line
- 6<sup>th</sup> costal cartilage in mid-clavicular line
- Diverge at 6<sup>th</sup> costal cartilage anteriorly
- **Oblique fissure**
  - T2 posteriorly to 6<sup>th</sup> CC anteriorly
- **Horizontal fissure (right only)**
  - Where 4<sup>th</sup> rib crosses oblique fissure to 4<sup>th</sup> CC anteriorly

##### Pleura:

- T12 posteriorly in mid-line
- 10<sup>th</sup> intercostal space in mid-axillary line
- 8<sup>th</sup> costal cartilage in mid-clavicular line
- 6<sup>th</sup> costal cartilage anteriorly
- + notch on left

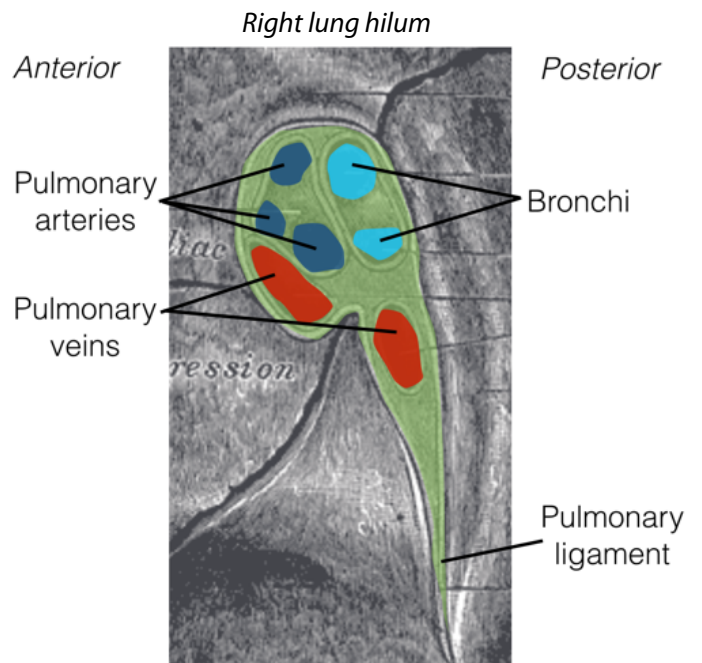


## 6 Neurovascular supply to lungs & pleura

- **Pulmonary arteries** - to gas exchange areas
  - From pulmonary artery [right side heart]
- **Bronchial arteries** - to conducting airways
  - From aorta
- Nerve plexi in lung hila
- Lymph drains from pleura (peripherally) to hila (centrally)
  - Plus to axillary, subclavicular and suprasternal lymph nodes

## 7 Lung hila

- Pulmonary veins (anterior)
- Pulmonary artery
- Lymphatics
- Bronchi (posterior)

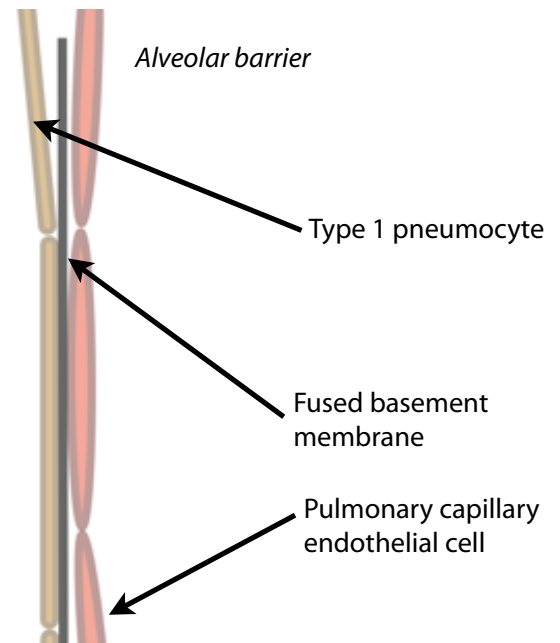


## 8 Respiratory epithelium

- All *conducting airways*
- **Pseudostratified ciliated columnar epithelium**
- Mucous glands & goblet cells
- Squamous metaplasia with smoke

### Alveolar ultrastructure

- **Type 1 pneumocytes**: thin epithelial cells on BM
- **Type 2 pneumocytes**: on surface of alveoli & secrete surfactant
- Alveolar **macrophages**: phagocytose debris inside alveoli
- Diffusion barrier:
  - Cytoplasm (thin) of type 1 pneumocyte
  - *Fused basement membrane* of type 1 pneumocyte and vascular endothelial cell
  - Cytoplasm (thin) of pulmonary capillary endothelial cell



- **Neurovascular bundle** lies immediately inferior to the rib
- Diaphragm has **three hiatuses**, most *superiorly anteriorly*
- **Conducting airways**, up to terminal bronchioles, have pseudostratified ciliated epithelium



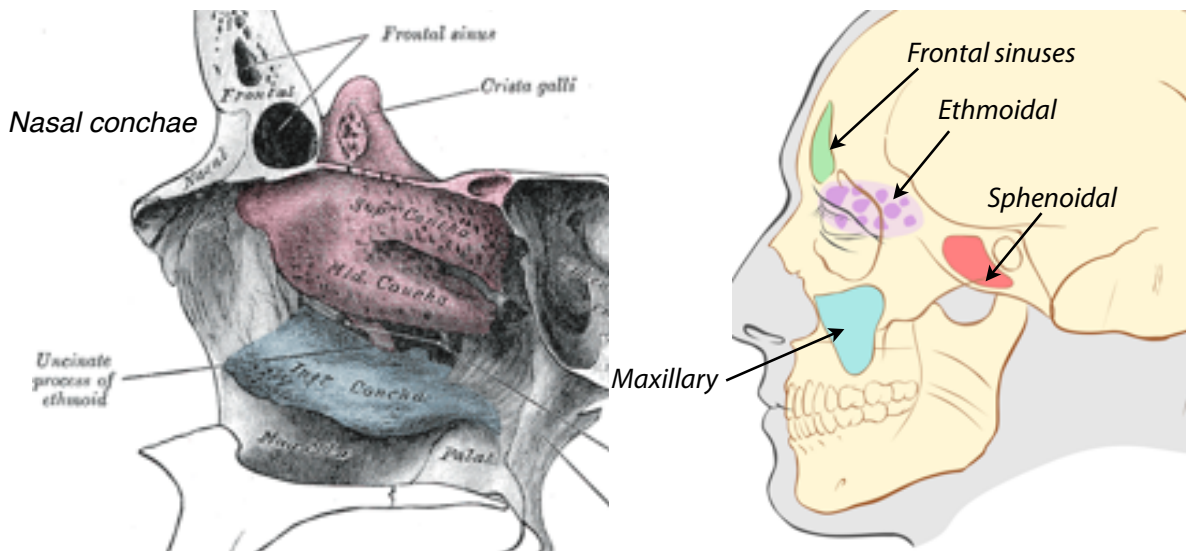
## 9 Upper airways

(= all above the trachea)

### Air sinuses

- Frontal, ethmoidal, maxillary, sphenoidal (paired)
  - Drain below conchae via ostia
  - Conchae are bone swirls on lateral wall: superior, middle, inferior
- **Drainage of air sinuses**
  - *Spheno-ethmoidal recess* ← sphenoidal sinus
  - *Superior meatus* ← ethmoidal sinus
  - *Middle meatus* ← ethmoidal, frontal & maxillary sinus
  - *Inferior meatus* ← nasolacrimal duct

**Sinusitis** may be a mild condition caused by upper respiratory tract viruses (e.g. adenovirus). However it can be bacterial in origin and then may spread through skull (including the cribriform plate) to cause meningitis, dural empyemas, and intracerebral abscesses.

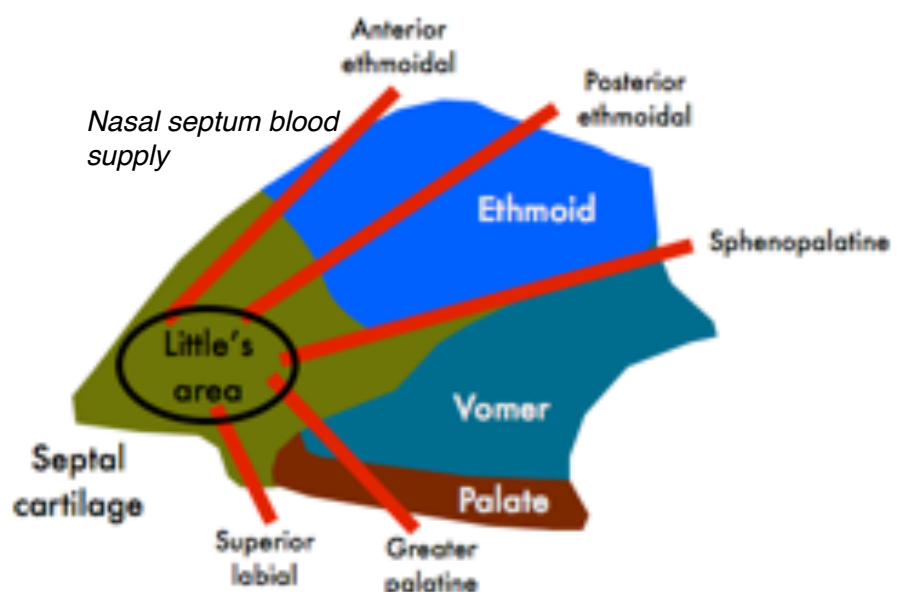


### - Nasal septum blood supply

- Anastomosis at **Little's area** = *Kiesselbach's plexus*
- Anterior & posterior ethmoidal arteries
- Sphenopalatine artery
- Superior labial artery
- Greater palatine artery

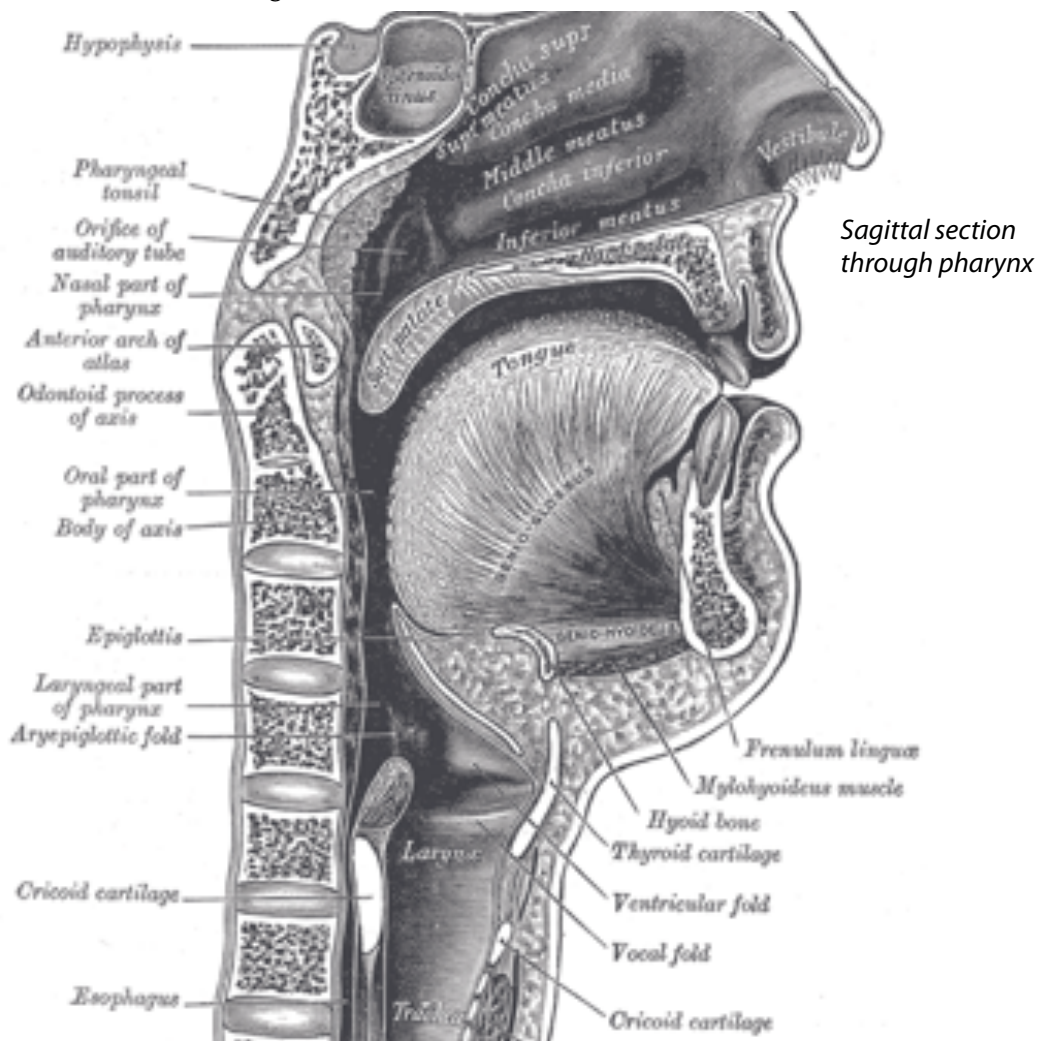
Most nose bleeds (epistaxis) are anterior, when the point of bleeding can be easily seen.

**Posterior epistaxis** comes from the sphenopalatine or posterior ethmoidal arteries. It can cause severe haemorrhage and present with haematemesis of swallowed blood.



## 10 Pharynx

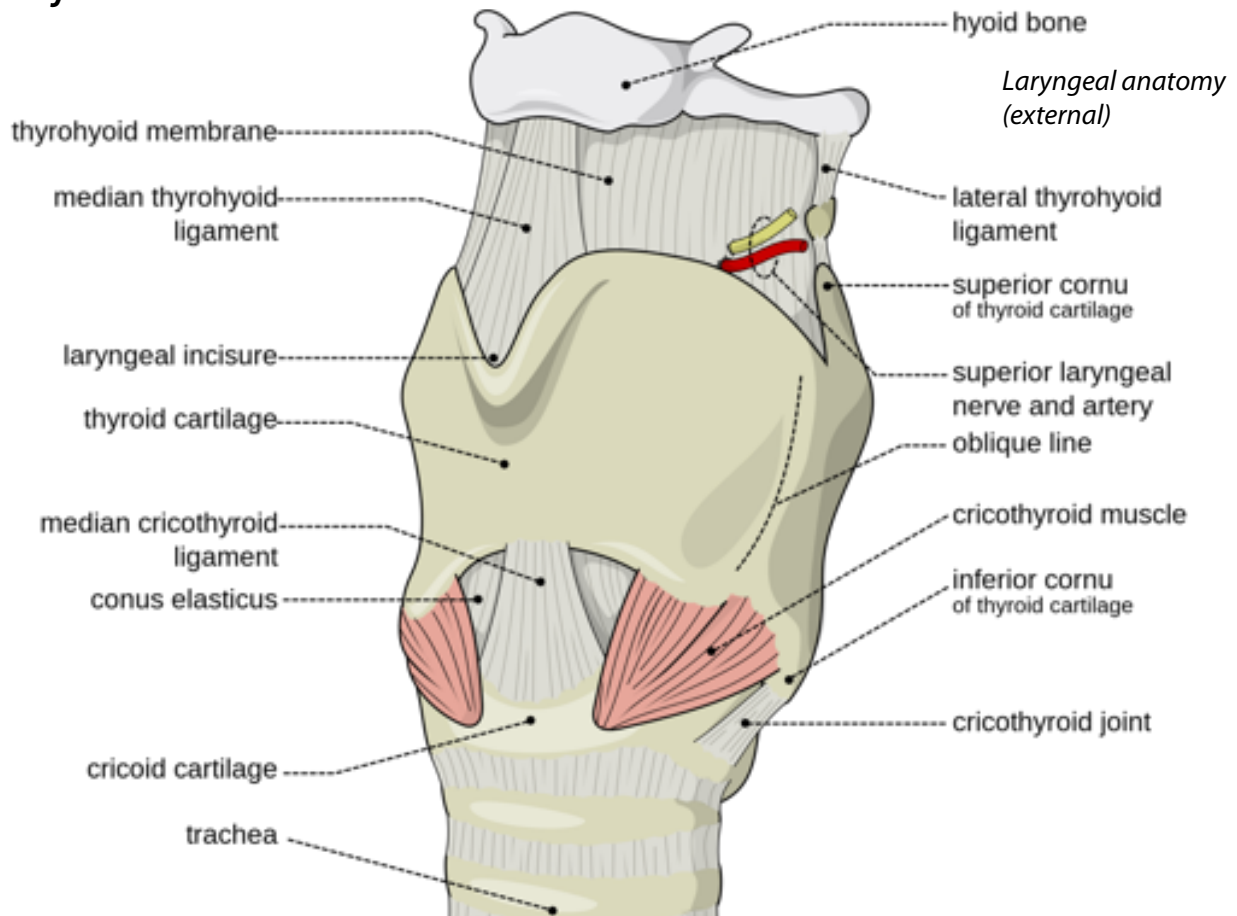
- Muscular tube from base of skull to oesophagus of **constrictor muscles** attached to *median raphe* (= a fibrous insertion on the posterior midline of the pharynx)
- **Nasopharynx** = all above soft palate
  - Nasopharyngeal contraction closes soft palate on swallowing
  - **Eustachian tube** (*pharyngotympanic tube*) connects to middle ear
- **Oropharynx** = soft palate to hyoid bone
- **Laryngopharynx** = behind larynx from epiglottis to C5 (oesophagus)
- Waldeyer's ring
  - **Adenoids** = tonsils (posterior nasopharynx), plus
  - **Palatine tonsils** (between palatoglossal and palatopharyngeal arches), plus
  - Posterior tongue



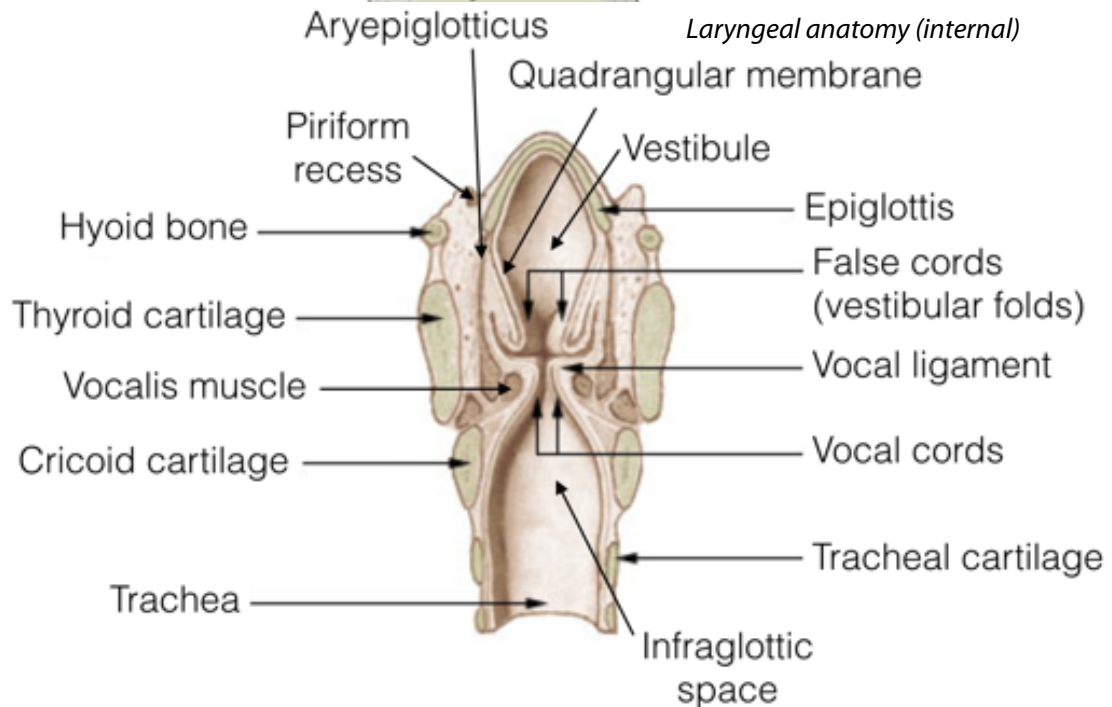
## 11

- Gag reflex
  - Activated by stimulation of mechanoreceptors on the posterior wall of the oropharynx
  - Afferent: **IX** (*glossopharyngeal*)
  - Efferent: **X** (*vagus*) - with bilateral response

## 12 Larynx



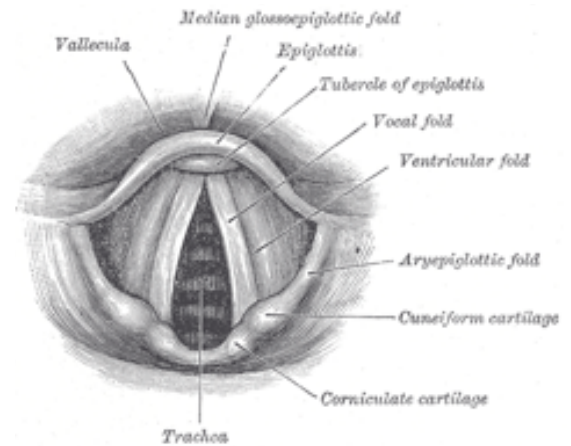
## 13



## 14 - Epiglottis

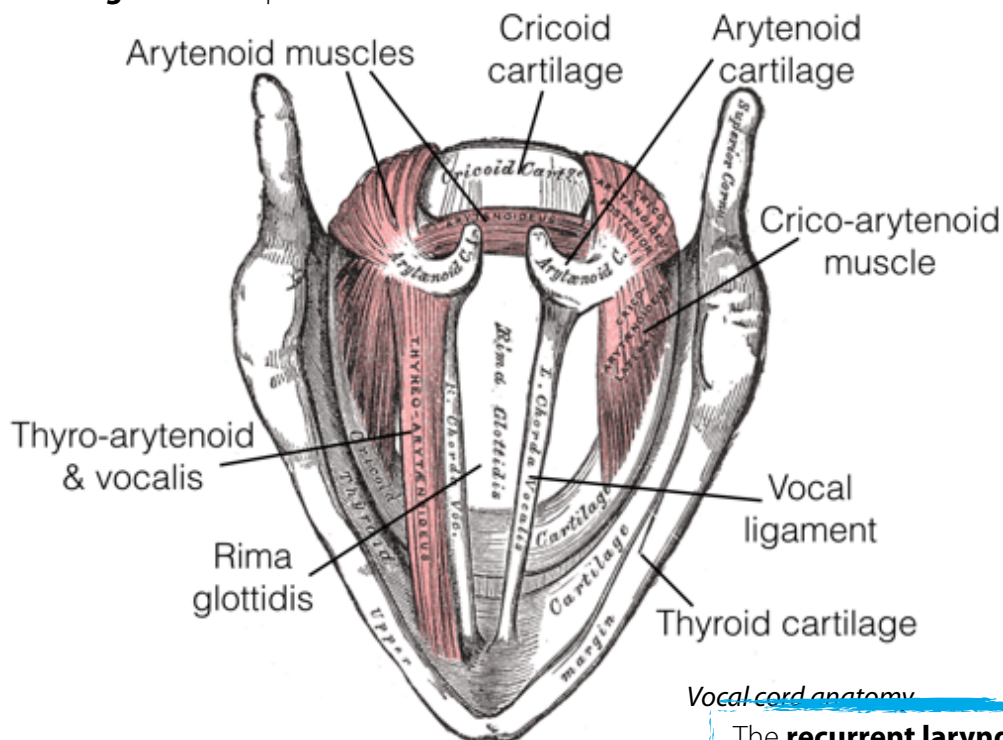
- Open when breathing/speaking
- **Quadrangular membrane** runs from arytenoids to epiglottis
  - Superior edge = *aryepiglotticus*
  - Inferior edge = *false cords*

- Closed for swallowing, by:
  - **Laryngeal elevation** (suprahyoid muscles)
  - Aryepiglotticus contraction
- *Piriform recess* - lateral to opening of larynx



- Internal structure

- **True vocal cords:** from arytenoid cartilages to thyroid cartilage
- Movement of arytenoid and crico-arytenoid muscles alter angle
- *Vocalis* and *thyro-arytenoid* muscles loosen/tighten
- **Rima glottidis** = space between true cords



- Supply

- **Superior laryngeal artery** (superior thyroid artery)
- **Inferior laryngeal artery** (inferior thyroid artery)
- Motor:
  - **Recurrent laryngeal nerve**
    - Except cricothyroid (external superior laryngeal)
- Sensory:
  - Above cords → *internal superior laryngeal*
  - Below cords → *recurrent laryngeal*

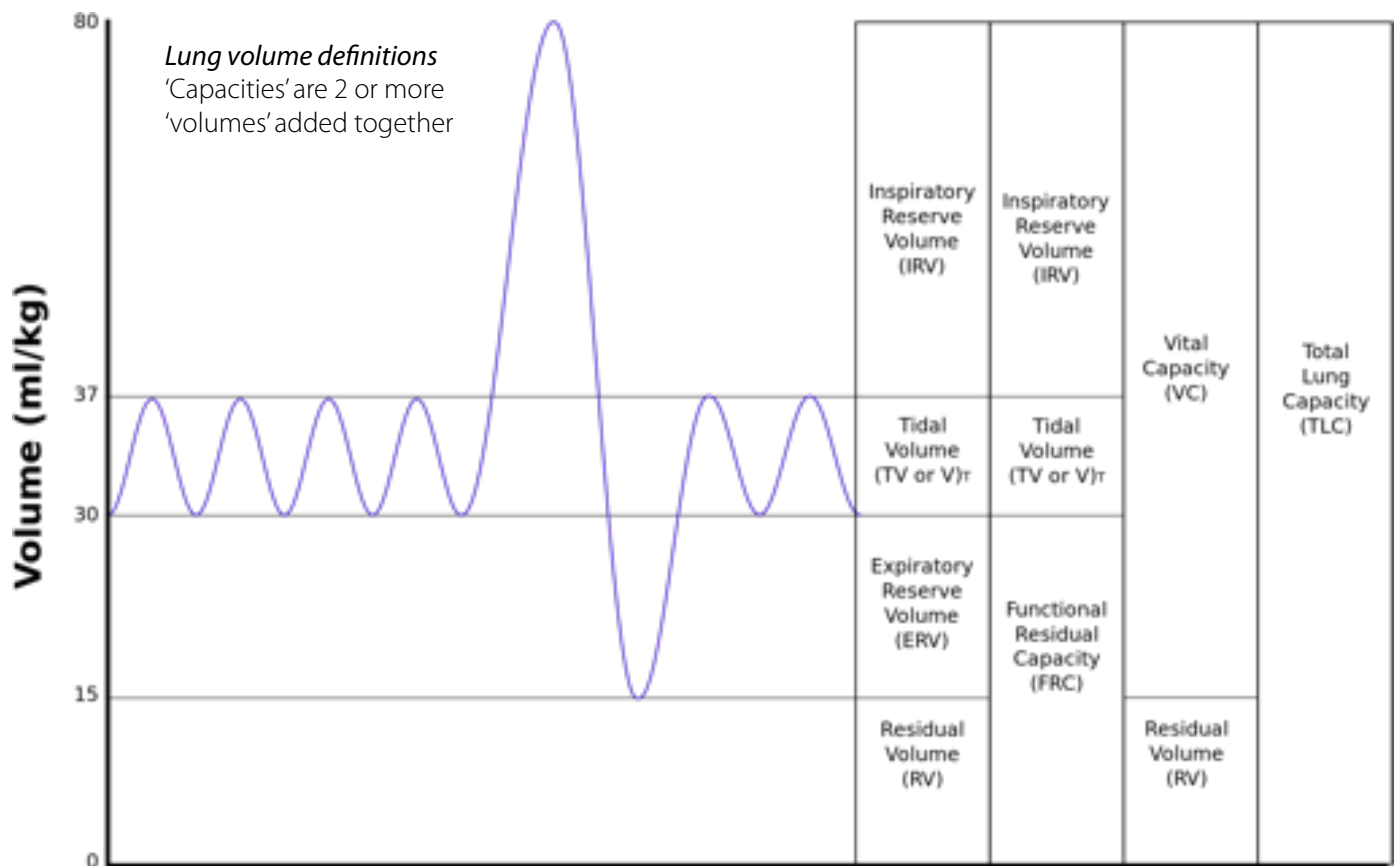
## Vocal cord anatomy

The **recurrent laryngeal nerve** may be damaged during thyroid or aortic surgery. **Semon's law** states that complete transection causes partially abducted cords with an inability to speak. However partial damage to both RLN causes weakness of posterior crico-arytenoids only, resulting in full adduction of the cords and complete obstruction.

- 5x arteries anastomose at **Little's area** on nasal septum
- **Gag reflex:** glossopharyngeal afferents, vagal efferents
- **Epiglottis** closes the laryngeal inlet from *aryepiglotticus contraction* and *laryngeal elevation*



# Gases & ventilation



## 16 Ventilation and dead space

- Ventilation ( $V$ ) = Tidal volume ( $V_T$ ) x frequency ( $f$ )
- **Physiological dead space** = anatomical + alveolar
  - **Anatomical** = conducting airways (these areas have high velocity & partial pressure gradients)
  - **Alveolar** = below respiratory bronchioles (normally zero)
  - Dead space ventilation ( $V_D$ ) does not contribute to gas exchange
- $V_A = (V_T - V_D) \times f$

## 17 Pressures and lung volumes

- Lung: elastic *inward* recoil
- Chest: elastic *outward* recoil
- **Pleural fluid** keeps pleura opposed
  - Recoil generates *negative*  $P_{pl}$
  - **Therefore the lungs move with the chest wall**
- **Pleural pressure** 'always' negative
  - Even at functional residual capacity (FRC)
  - Connects chest wall & lungs
  - $P_{pl}$  &  $P_A$  rise with expiration
  - Changes increase with  $\uparrow V_T$