

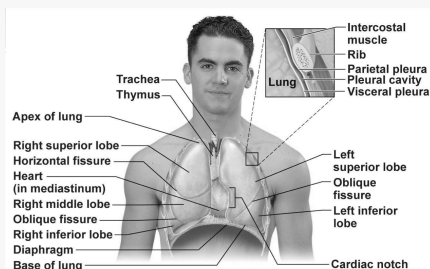
Lung Anatomy

Occupy all of the thoracic cavity *except* mediastinum

Root site of vascular, bronchial attachments

Costal surface anterior, lateral, posterior surfaces

Structures of the Lungs



Upper Respiratory Tract

conduction, filtration, humidification and warming of inhaled air

Nasal Nasal conchae, nasal vestibule, nostril

Cavity

Paranasal Sinuses Maxillary, frontal, sphenoidal and ethmoidal sinuses

Pharynx Nasopharynx, oropharynx, laryngopharynx

Larynx (superior) Vocal cords, epiglottis, vestibular fold, thyroid cartilage, vocal fold, cricoid cartilage, thyroid gland

Lower Respiratory Tract

conduction, gas exchange

Trachea cervical, thoracic

Bronchi left primary bronchus, right primary bronchus

Bronchioles respiratory bronchiole, terminally bronchiole, alveoli

Lungs left lung, right lung (larger)

Functional Anatomy

Respiratory zone: Microscopic structures: respiratory bronchioles, alveolar, ducts, alveoli

site of gas exchange

Alveoli ~300 million alveoli account for most of the lungs' volume, *main site for gas exchange*

Surrounded by fine elastic fibres

Functional Anatomy (cont)

Contain open pores that connect adjacent alveoli, allow air pressure throughout lung to be equalised

House alveolar macrophages that keep alveolar surfaces sterile

Conducting zone Conduits to gas exchange sites

Includes all other respiratory structures

Trachea Windpipe: from larynx into mediastinum

Wall composed of 3 layers: mucosa, submucosa, adventitia

Carina: Last tracheal cartilage, point where trachea branches into two bronchi

Conducting zone structures Trachea → right and left primary bronchi

Primary bronchus → secondary bronchi → 3rd, 4th etc.

Bronchioles: < 1mm diameter

Terminal bronchioles: < 0.5mm diameter

Respiratory muscles Diaphragm and other muscles that promote ventilation

Respiratory Volumes

Adult Male average	Adult Female average
Tidal volume (TV)	
500mL	500mL
<i>amount of air inhaled/exhaled each breath at rest</i>	
Inspiratory reserve volume (IRV)	
3100mL	1900mL
<i>amount of air during forceful inhalation after normal TV</i>	
Expiratory reserve volume (ERV)	
1200mL	700mL
<i>amount of air during forceful exhalation after normal TV exhalation</i>	
Residual volume (RV)	
1200mL	1100mL
<i>amount of air remaining in lungs after forced exhalation</i>	



Respiratory Capacities

Adult Male average	Adult Female average
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Total lung capacity (TLC)

6000mL	4200mL
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max amount of air contained in lungs after max inspiratory effort:
 $TLC = TV + IRV + ERV + RV$

Vital capacity (VC)

4800mL	3100mL
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max amount of air that can be expired after max inspiratory effort: $VC = TV + IRV + ERV$

Inspiratory capacity (IC)

3600mL	2400mL
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max amount of air that can be inspired after normal expiration: $IC = TV + IRV$

Functional residual capacity (FRC)

2400mL	1800mL
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volume of air remaining in lungs after normal TV expiration: $FRC = ERV + RV$

Pulmonary Function Tests

Spirometer

instrument used to measure respiratory volumes/capacities

Can distinguish between	Obstructive pulmonary disease: increased airway resistance e.g. bronchitis, asthma
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	Restrictive disorders: reduction in TLC due to structural/functional lung changes e.g. fibrosis, tuberculosis (TB)
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Minute ventilation	Total amount of gas flow into/out of respiratory tract in 1 minute
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Forced vital capacity (FVC)	Gas forcibly expelled after taking a deep breath
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Forced expiratory volume (FEV)	Amount of gas expelled during specific time intervals of FVC
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Partial Pressure Gradient

Dalton's Law of Partial Pressures	Total pressure exerted by mixture of gases is the sum of pressures exerted by each
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Partial pressure of each gas is directly proportional to its percentage in the mixture

Partial Pressure Gradient (cont)

Example: Atmospheric pressure is 760mmHg at sea level

Oxygen constitutes ~21% of the atmosphere

$$21\% \times 760 = 159\text{mmHg}$$

Mechanisms of Breathing: Pulmonary Ventilation

Inspiration and expiration	Inspiration: gases flow into lungs Expiration: gases exit the lungs
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Mechanical processes dependant on volume changes in thoracic cavity	Volume changes → pressure changes Pressure changes → gases flow to equalise pressure
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Boyle's Law	Relationship between pressure and volume of a gas
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Mechanics of Breathing: Inspiration

Inspiration	Expiration
<i>Sequence of events</i>	
1. Inspiratory muscles contract → diaphragm descends, rib cage rises	1. Inspiratory muscles relax → diaphragm rises, rib cage descends due to costal cartilage recoil
2. Thoracic cavity volume increases	2. Thoracic cavity volume decreases
3. Lungs are stretched → intrapulmonary volume increases	3. Elastic lungs recoil passively → intrapulmonary volume decreases
4. Intrapulmonary pressure drops → -1mmHg	4. Intrapulmonary pressure rises → +1mmHg
5. Air flows into lungs down its pressure gradient until intrapulmonary volume = 0 (equal to atmospheric pressure)	5. Air flows out of lungs down its pressure gradient until intrapulmonary pressure is 0

Internal Respiration

Capillary gas exchange in body tissues

<i>Partial pressures and diffusion gradients are reversed compared to external respiration</i>	pO ₂ in tissue is always lower than in systemic arterial blood
	pO ₂ of venous blood in 40mmHg
	pCO ₂ is 45mmHg

External Respiration

Exchange of O₂ and CO₂ across the respiratory membrane

<i>Influenced by:</i>	Partial pressure gradients
	Gas solubilities
	Ventilation-perfusion (V/Q) coupling
	Structural characteristics of the respiratory membrane

Control of Respiration

Medullary Respiratory Centres	Pontine Respiratory Centres	Chemical Factors
<i>Involves neurons in the reticular formation of the medulla and pons</i>	Influence and modify activity of the VRG	Influence of pO₂
1. Dorsal respiratory group (DRG)	Smooth out transition between inspiration/expiration and vice versa	<ul style="list-style-type: none"> Peripheral chemoreceptors in the aortic and carotid bodies are O₂ sensors (when excited, they cause respiratory centres to increase ventilation) Substantial drops in arterial pO₂ (to 60mmHg) must occur in order to stimulate increased ventilation
<ul style="list-style-type: none"> Near the root of cranial nerve IX Integrates input from peripheral stretch and chemoreceptors 		
2. Ventral respiratory group (VRG)		Influence of arterial pH

Control of Respiration (cont)

<ul style="list-style-type: none"> Rhythm-generating and integrative centre Sets eupnea (12-15 breaths/min) Inspiratory neurone excite the inspiratory muscles via the phrenic and intercostal nerves Expiratory neurone inhibit the inspiratory neurone 	<ul style="list-style-type: none"> Can modify respiratory rate/rhythm even if CO₂ and O₂ levels are normal Decreased pH may reflect CO₂ retention, accumulation of lactic acids, excess ketone bodies in diabetic Pts Respiratory system controls will attempt to raise the pH by increasing respiratory rate and depth
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Oxygen Transport

Molecular O₂ is carried in the blood	1.5% dissolved in plasma
	98.5% loosely bound to each Fe of haemoglobin (Hb) in RBCs
	4x bound O ₂ per Hb
O₂ and Hemoglobin	Oxyhemoglobin (HbO ₂): hemoglobin-O ₂ combination
	Reduced hemoglobin (HSB): haemoglobin that has released O ₂
Influence of pO₂ on Hemoglobin Saturation	Oxygen-hemoglobin dissociation curve
	Shows how binding and release of O ₂ is influenced by the pO ₂
Hemoglobin Saturation Influencing Factors	
Increases in temperature, H ⁺ , pCO ₂ , and 2,3-bisphosphoglycerate (BPG)	Modify Hb structure decreasing affinity for O ₂
	Occur in systemic capillaries



Oxygen Transport (cont)

Increases O₂ unloading

Shifts HbO₂ dissociation curve to the right

Decreases in these factors shift the curve to the left by decreasing O₂ unloading

Carbon Dioxide Transport

CO ₂ is transported in the blood in three forms	7-10% dissolved in plasma
	20% bound to globin of Hb (<i>carbamino</i> hemoglobin)
	70% transported as bicarbonate ions (HCO_3^-) in plasma
CO ₂ combines with water to form carbonic acid (H_2CO_3), which quickly dissociates	$\text{CO}_2 + \text{H}_2\text{O} \leftrightarrow \text{H}_2\text{CO}_3 \leftrightarrow \text{H}^+ + \text{HCO}_3^-$
In systemic capillaries	<p>HCO_3^- quickly diffuses from RBCs into plasma</p> <p>Chloride shift occurs when outrush of HCO_3^- from the RBCs is balanced as Cl^- moves in from plasma</p>
In pulmonary capillaries	<p>HCO_3^- moves into RBCs, binds with H^+ to form H_2CO_3</p> <p>H_2CO_3 is split by carbonic anhydrase into CO₂ and H₂O</p> <p>CO₂ diffuses into the alveoli</p>

