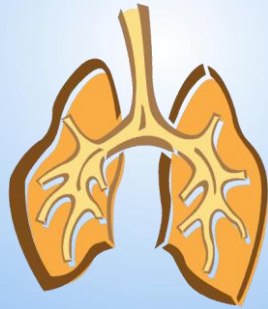


Anatomy and Function of the Respiratory System in Domestic Animals



Respiration

- Respiration is the mechanism by which oxygen is delivered to the tissues and carbon dioxide is removed.
- It is essential for cell metabolism and for the maintenance of life as a whole.
- Oxygen is required to liberate energy from food.
- In brief, respiration involves the exchange of gases between cells, tissues, fluid, and blood, and then between blood and the external environment (in the lungs).

Definitions

- * **Respiration** - sequence of events that result in the exchange of oxygen and carbon dioxide between the external environment and the mitochondria
- * **External respiration** - gas exchange at the respiratory surface
- * **Internal respiration** - gas exchange at the tissues
- * **Mitochondrial respiration** - production of ATP via oxidation of carbohydrates, amino acids, or fatty acids. Oxygen is consumed and carbon dioxide is produced
- * **Gas molecules move down concentration gradients**

Functions of respiratory system

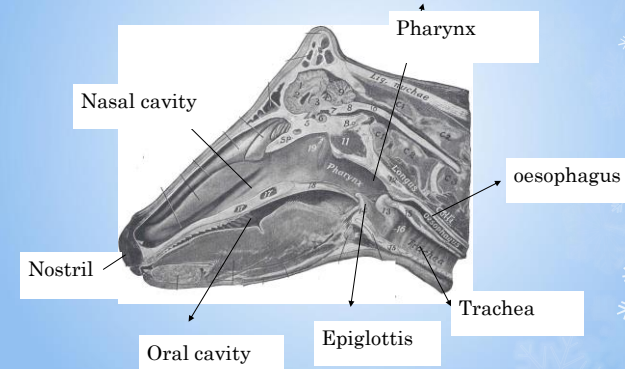
- Ventilation- process of movement of air in and out of the lungs
- Assists in regulation of pH of blood and other body fluids by removing appropriate level of carbon dioxide.
- Assists in temperature control.
- Phonation-production of sounds.

Anatomy of the Respiratory System

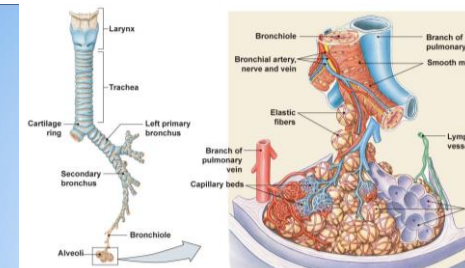
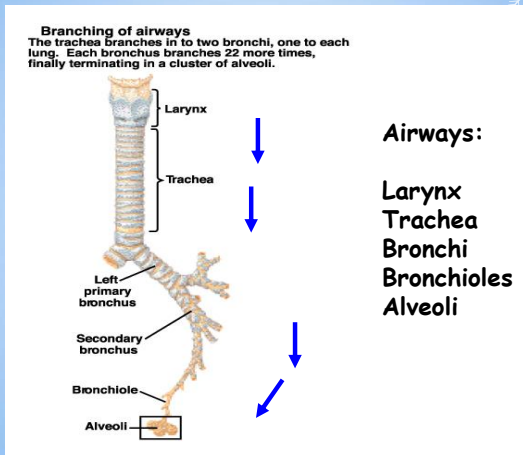
Organs of respiratory system

1. Nostrils
2. Nasal cavity
3. Pharynx
4. Larynx
5. Trachea
6. Primary /principal bronchi
7. Secondary bronchi
8. Bronchioles
9. Alveolus

Organs of the respiratory System (tract)



Mammalian lungs



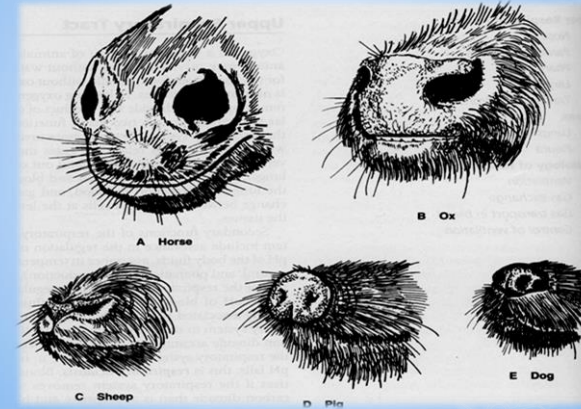
	Name	Division	Diameter (mm)	How many?	Cross-sectional area (cm ²)
Conducting system	Trachea	0	15-22	1	2.5
	Primary bronchi	1	10-15	2	↓
		2	1-10	4	
		3			
		4			
Bronchioles	5	0.5-1		1 × 10 ⁴	↓
	6-11		2 × 10 ⁴		
Exchange surface	Alveoli	12-23	0.3	8 × 10 ⁷	5 × 10 ³
		24		3-6 × 10 ⁸	>1 × 10 ⁶

External Nares

Nose/Nares:

- External nares-the opening
- Nasal cartilage-gives shape
- Sweat glands on the hairless rostral end-moist.
- Rostral bone in pigs-rooting habits
- Nasal cavity separated into halves by median plane-nasal septum.
- Separated from mouth by palates.
- The epithelium contains vascular mucous membrane (moist) and olfactory epithelium (olfactory sensation)

External Nares



Pharynx:

- Common soft tissue passage for feed and air.
- Caudal to oral and nasal cavities.
- Walls supported by striated muscles-deglutination
- Opening into the pharynx-2 caudal nares, 2 auditory tubes, oral cavity, larynx and oesophagus.

Larynx

- Box like gatekeeper to the entrance of trachea.
- Regulates the size of the airway.
- Prevent entry of other substance other than air.
- Organ of phonation-Voice box.
- Syrinx-birds

Trachea and Bronchi

- Trachea extends from caudal end of larynx to bronchi.
- Formed with C shaped tracheal cartilage connected by annular ligaments.
- Trachea passes caudad as far as the base of the heart - divides into 2 principal (primary) bronchi.
- Ruminants and pigs-an additional tracheal bronchi arising cranial to principal bronchi.
- The principal bronchi divides into secondary (lobar) then tertiary bronchi.

Bronchi

- Divide to the extent that they are less than 1mm in diameter- cartilages disappear-level now called bronchioles.
- Then these divide to form alveolar ducts and alveoli.

Trachea and Bronchi

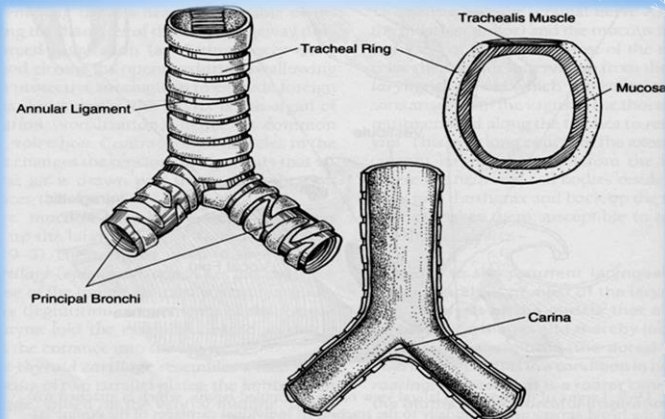


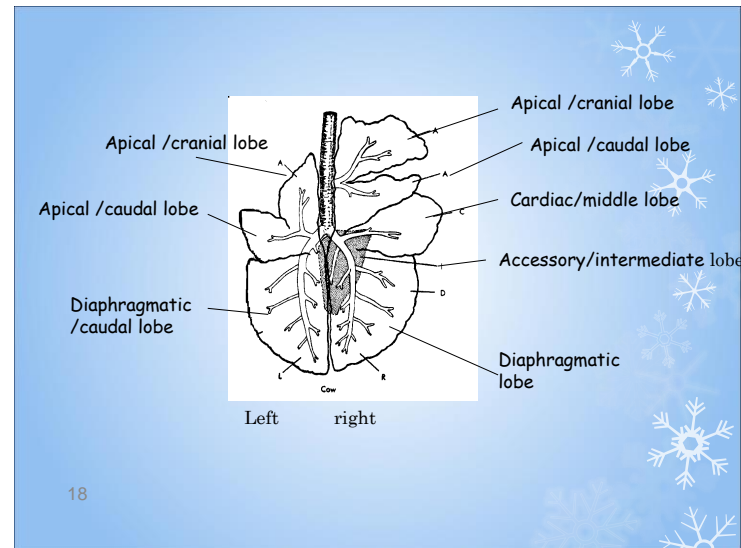
Figure 19-6. Anatomy of the trachea and principle bronchi. A) Ventral view. B) Transverse section.

Lungs

- Each lung is enclosed in a cage bounded below by the diaphragm and at the sides by the chest wall and the sternum.
- Each lung is surrounded by a serosa-pleura.
- The pleura, has two layers, separated by a thin layer of fluid.
- Two layers-parietal (lining thoracic cavity), visceral (lining the lungs)
- The junction of the two pleural sacs at the midline of the thoracic cavity is a double layered fold called mediastinum.
- Mediastinum of cattle- is solid and thick. Horse-is thin often with opening. !!!

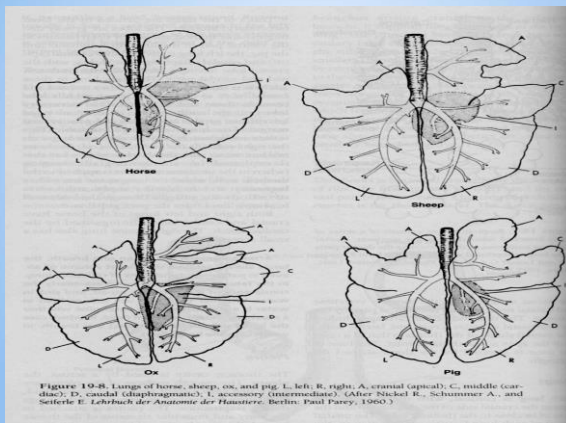
Lungs

- The lungs are divided first into right and left, the left being smaller to allow for positioning of the heart.
- Then into lobes (three on the right, two on the left) supplied by lobar bronchi.
- In pigs and ruminants the left apical lobe has further cranial and caudal lobed.
- The left and right lungs have an indentation on the median border - Hilus.
- Principal bronchus, pulmonary vessels, lymphatics and nerves enters the lungs from the hilus.



18

Anatomy of Lungs in livestock



Lung adaptations

- Environmental air vary in temperature
- Contain dust, microbes
- These should not reach alveolus
- Therefore Inspires air is filtered and cleaned

Lung adaptations

1. Mucus

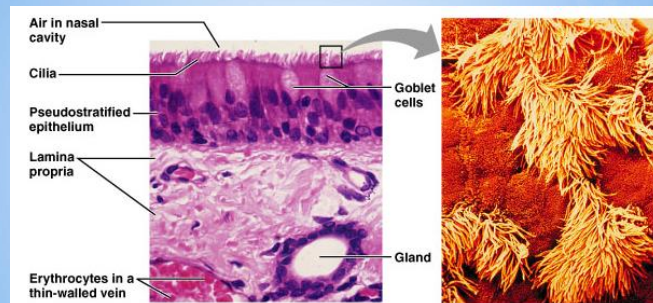
- - thin sticky mucus secreted by epithelial cells
- - Covering whole respiratory tract
 - Traps particles in air when in contact
 - Facilitated by change in direction of air
 - Random movement of particles

Lung adaptations

2. Cilia

- Hair cells of epithelial cells remove particles trapped
- Cilia in nose move down wards
- Cilia in trachea and below move up
- Particles are brought into mouth - swallowed

Cells of the Respiratory System



Lung adaptations

3. Length

- Length of respiratory tract-warm air.
- Maintain humidity to right level.

4. Protection

- Entry of food and water into trachea is prevented by epiglottis

Mechanism of breathing

- Inspiration & expiration.
- Potential space between the two pleural surfaces-filled with minimum fluid .
- The pressure inside the pleural cavity is always slightly negative to the atmospheric pressure.
- Negative pressure exerts pulling force- keeps lungs expanded.

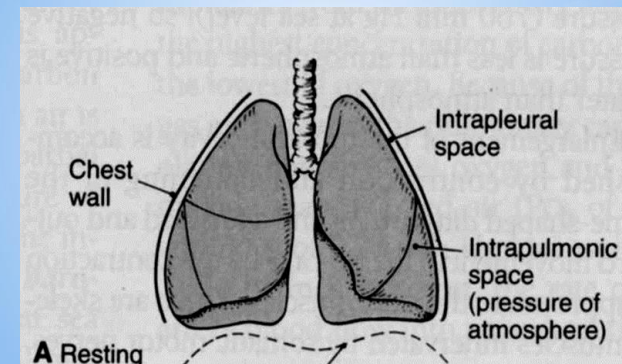
Mechanism of Breathing

- Expiration and inspiration brought out by Boyle's law.
- Change in pressure and volume of gas.
- Change in volume of thoracic cavity by intercostal muscles and diaphragm.
- Increased volume-contraction of muscles and diaphragm.
- Inspiration-decrease in intrapulmonic pressure.
- Expiration-increase in intrapulmonic pressure.

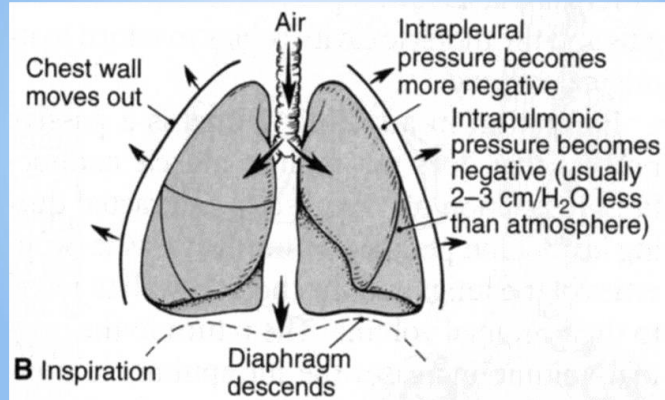
Boyle's Law

- **The pressure of a gas decreases if the volume of the container increases**, and vice versa.
- When the volume of the thoracic cavity increases even slightly during inhalation, the intrapulmonary pressure decreases slightly, and **air flows into the lungs** through the conducting airways. Air flows into the lungs from a region of higher pressure (the atmosphere) into a region of lower pressure (the intrapulmonary region).
- When the volume of the thoracic cavity decreases during exhalation, the intrapulmonary pressure increases and **forces air out of the lungs** into the atmosphere.

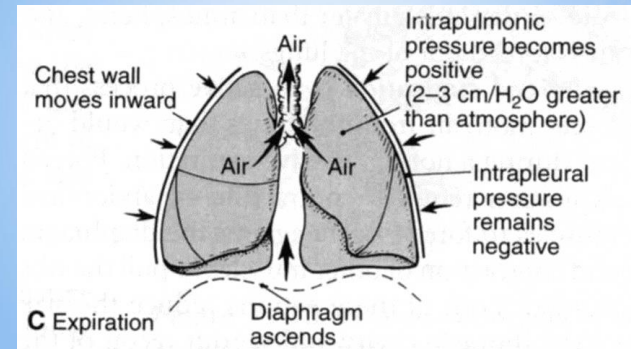
Mechanism of Breathing



Mechanism of Breathing



Mechanism of Breathing



Gaseous exchange

- Relies on simple diffusion.
- Diffusion gradients are maintained by ventilation (breathing), which renews alveolar air, maintaining oxygen concentration near that of atmospheric air and *preventing* the accumulation of carbon dioxide
- The flow of blood in alveolar capillaries which continually brings blood with low oxygen concentration and high carbon dioxide concentration.
- Haemoglobin in blood continually removes dissolved oxygen from the blood and binds with it.!!!

Mechanism of Breathing

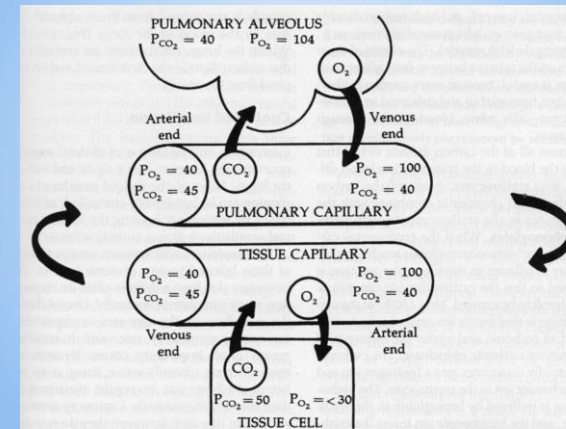
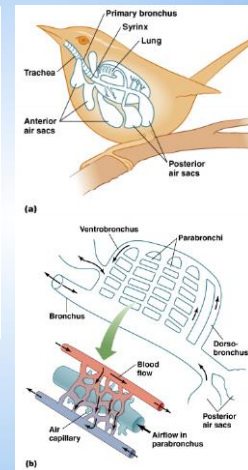


FIGURE 19-11 Direction of diffusion of oxygen (O₂) and carbon dioxide (CO₂) as shown by ar-

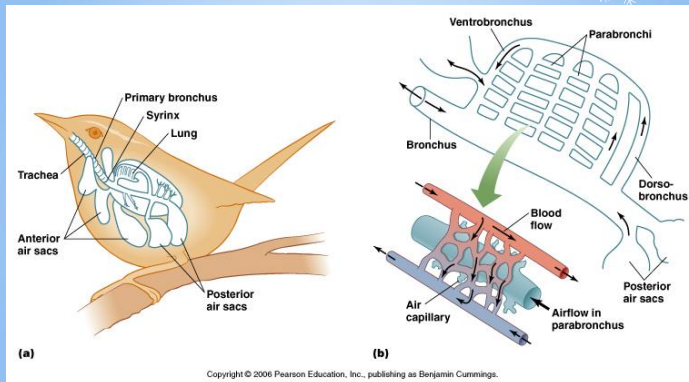
Types of breathing

- 1. *Costal/Thoracic respiration*: In this type of respiration thoracic muscles are mainly involved and the movement of the rib cage is more prominent. It is seen in dogs and cats.
- 2. *Abdominal respiration*: This type of respiration is seen in ruminants viz cattle, goat, sheep and yak. Here the abdominal muscles are involved and movement of the abdominal wall is noticed
- 3. *Costo- abdominal respiration*: In this type of respiration muscles of both thorax and abdomen are involved so the movement of the ribs and the abdominal wall are noticed.

- Lung is stiff and changes little in volume
- Rely on a series of flexible air sacs
- Gas exchange occurs at parabronchi



Bird lungs - crosscurrent flow



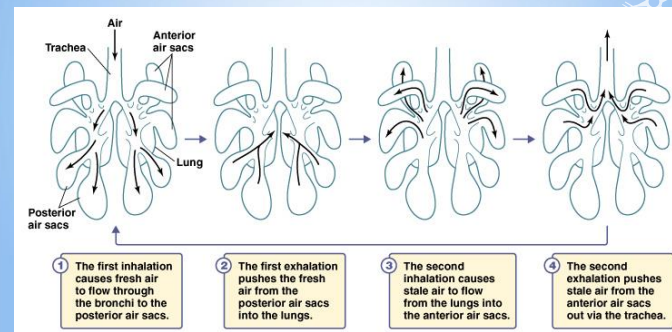
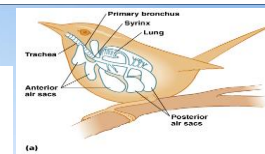
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Oxygen extraction efficiency high (up to 90%)

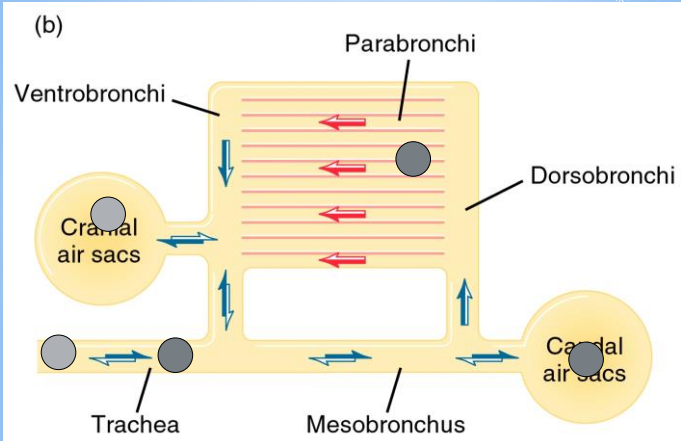
Bird Ventilation

Requires two cycles of inhalation and exhalation

Air flow across the respiratory surfaces is unidirectional



Bird Ventilation

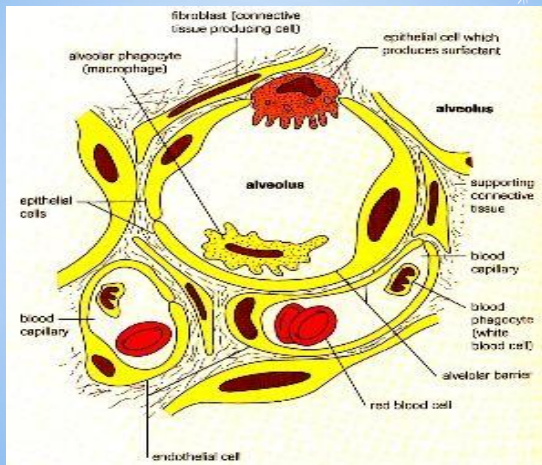
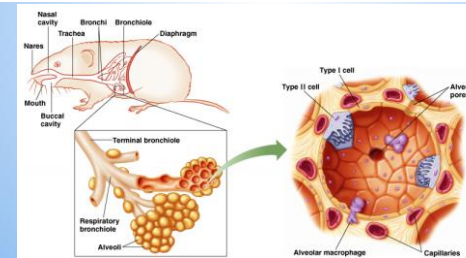


Two main parts

- Upper respiratory tract: mouth, nasal cavity, pharynx, trachea
- Lower respiratory tract: bronchi and lungs

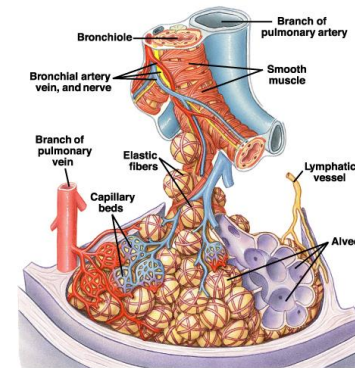
Alveoli are the site of gas exchange

Both lungs are surrounded by a pleural membrane



Mammalian lungs

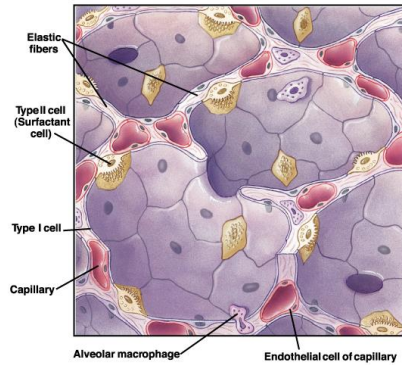
Structure of lung lobule
Each cluster of alveoli surrounded by elastic fibres and a network of capillaries.



Mammalian lungs - alveoli

Alveolar structure

The alveoli are composed of type I cells for gas exchange and type II cells that synthesize surfactant. Alveolar macrophages ingest foreign material that reaches the alveoli.

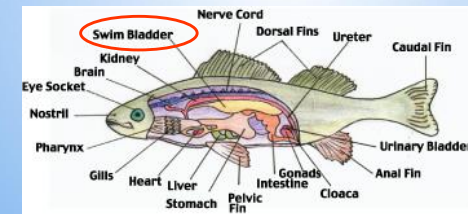


Type I cells
gas exchange

Type II cells
surfactant
secretion

Swim bladder

- Fish
- Many bony fish have a swim bladder that helps to maintain neutral buoyancy
- Gas-filled sac
- Fill with gas to increase buoyancy
- Remove gas to reduce buoyancy
- In most species this gas is oxygen



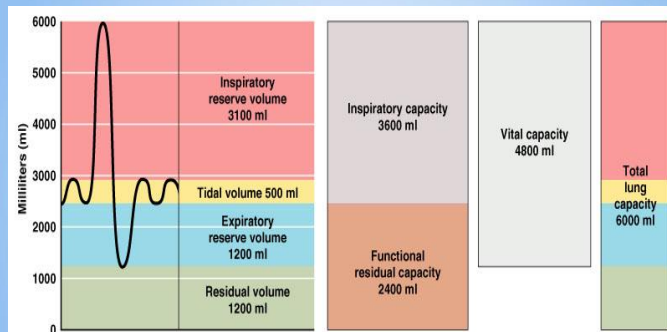
LUNG VOLUMES

- **TIDAL VOLUME (TV):** Volume inspired or expired with each normal breath. = **500 ml**
- **INSPIRATORY RESERVE VOLUME (IRV):** Maximum volume that can be inspired over and above the inspiration of a tidal volume/normal breath. Used during exercise/exertion. = **3100 ml**
- **EXPIRATORY RESERVE VOLUME (ERV):** Maximal volume that can be expired after the expiration of a tidal volume/normal breath. = **1200 ml**
- **RESIDUAL VOLUME (RV):** Volume that remains in the lungs after a maximal expiration. CANNOT be measured by spirometry. = **1200 ml**

LUNG CAPACITIES

- **INSPIRATORY CAPACITY (IC):** Volume of maximal inspiration: $IRV + TV = 3600 \text{ ml}$
- **FUNCTIONAL RESIDUAL CAPACITY (FRC):** Volume of gas remaining in lung after normal expiration, cannot be measured by spirometry because it includes residual volume: $ERV + RV = 2400 \text{ ml}$
- **VITAL CAPACITY (VC):** Volume of maximal inspiration and expiration: $IRV + TV + ERV = IC + ERV = 4800 \text{ ml}$
- **TOTAL LUNG CAPACITY (TLC):** The volume of the lung after maximal inspiration. The sum of all four lung volumes, cannot be measured by spirometry because it includes residual volume: $IRV + TV + ERV + RV = IC + FRC = 6000 \text{ ml}$

Respiratory Volumes



(a) Spirographic record for a male

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Respiratory Frequency in Number of Respiratory Cycles Per Minute

- Varies by species
 - Horse - 12
 - Cow - 29
 - Pig - 40
 - Sheep - 25
- Obviously body size has a lot to do with respiration rates!



Ventilation Control by Respiratory Centres of the Brain

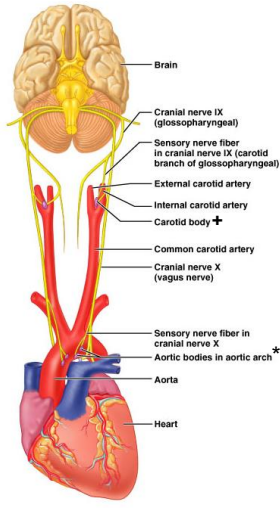
- The trachea, bronchial tree, and lungs are innervated by the **autonomic nervous system**.
- The autonomic nerve fibers that innervate the heart also send branches to the respiratory structures.
- The involuntary, rhythmic activities that deliver and remove respiratory gases are regulated in the **brainstem** within the reticular formation through **both the medulla oblongata and pons**.

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

48

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).

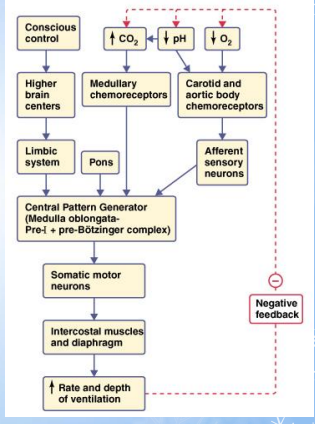
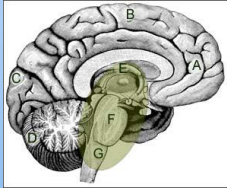


Peripheral chemoreceptors regulating respiration

- 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)

Regulation of Ventilation

- Chemosensory input helps modulate the output of the central pattern generators
- Chemoreceptors detect changes in CO_2 , H^+ , and O_2
- Oxygen is the primary regulator in water-breathers while CO_2 is the primary regulator in air-breathers

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
 - O_2 (oxygen) in air diffuses into blood
 - CO_2 (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
 - O_2 in blood diffuses into tissues
 - CO_2 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

Clinical terms

- **Eupnea** - normal quiet respiration
- **Dyspnea** - difficult/laboured breathing
- **Apnea** - Absence of breathing
- **Hyperpnea** - increased depth of breathing.
- **Panting**-Increased rate of breathing/ventilation-mechanism to dissipate heat-reduced tidal volume-not much change in gaseous exchange.
- **Polypnea** - rapid shallow breathing
- **Anoxia/Hypoxia**-Absence or deficiency of oxygen in the tissues.
- **Atelectasis**-collapse or airless state of lungs.
- **Bronchoscopy**-Visual examination of the bronchi using an endoscope

Clinical Terms Conti

- **Epistaxis**-bleeding from the nose/nares.
- **Hydrothorax**- Accumulation of fluid in the pleural cavity.
- **Pleuritis/Pleurisy**-Inflammation of pleura.
- **Pneumonia/pneumonitis**-Inflammation of lungs

Clinical importance

- **Respiratory acidosis**- When CO_2 accumulates in the blood as a result of insufficient removal of CO_2 -pH of blood and other tissue fluid falls.
- **Respiratory alkalosis**- More CO_2 is removed than appropriate-pH rises.
- **Residual volume**-The volume of air that remains in the lungs after expiration-keeps the lungs in expanded form-important to verify whether a foetus was born live or dead. Also in legal cases-whether an animal was dead before drowning or died from drowning.

Clinical Terms

- **Tracheotomy** - cutting open trachea to facilitate ventilation. Done in cases of difficult breathing-bronchitis, anaesthesia, artificial respiration.
- **Faulty drenching** - aspiratory pneumonia, sudden death.
- **Gape worm**- *Syngamus trachea* worm in birds.
- **Asphyxiation** - Strangulation to death - tethering
- **Hypoxic vasoconstriction**-unique mechanism to balance blood and air flow within the lungs. When alveolar O_2 concentration is low, vasoconstriction of that area occurs and diverts blood to other areas of lungs.

Clinical terms

- Heaves- Condition in horses. Characterized by laboured/forceful breathing with enlarged abdominal muscles. Caused by chronic exposure to allergens that causes release of histamines and constriction of airway smooth muscles and increase in airways resistance.
- **Sinusitis**- Inflammation of mucous membranes lining the sinus of the cranial bones. Sinuses are air filled cavities between the two plates of cranial bones. Many of these sinuses communicate with nasal cavity.

Clinical terms

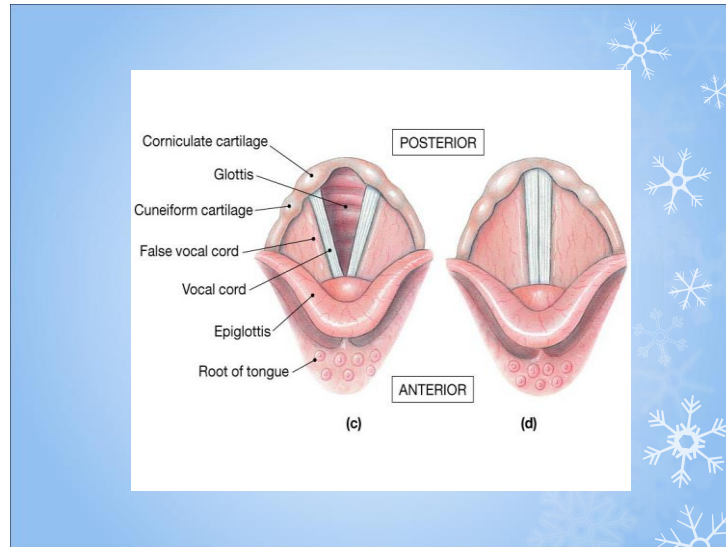
- Maxillary sinusitis- Inflammation of mucous membranes of maxillary sinus. Upper cheek teeth projects into maxillary sinus. Disease of this type of teeth can cause sinusitis.
- Frontal sinusitis- Inflammation of mucous membrane of frontal sinus. Frontal bone projects into cornual process (horn). Improper dehorning can cause sinusitis in animals. Fracture of horn has to be treated with care as the cornual sinus communicates with frontal sinus and nasal cavity- **Butox** to treat maggot wound in horn.

Sound Production

- Inferior ligaments are called the **vocal folds**.
 - are **true vocal cords** because they produce sound when air passes between them
- Superior ligaments are called the **vestibular folds**.
 - are **false vocal cords** because they have no function in sound production, but protect the vocal folds.
- The tension, length, and position of the vocal folds determine the quality of the sound.

Sound production

- Intermittent release of exhaled air through the vocal folds
- Loudness – depends on the force with which air is exhaled through the cords
- Pharynx, oral cavity, nasal cavity, paranasal sinuses act as **resonating chambers** that add quality to the sound
- Muscles of the face, tongue, and lips help with **enunciation of words**



Transport of O₂ in the Blood

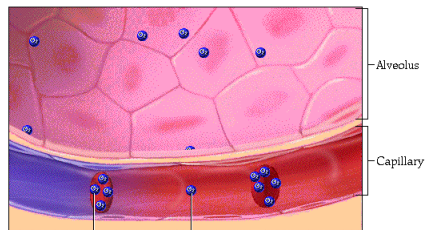
- Two mechanisms exist for O₂ transport
 - Dissolved in plasma
 - Combined with hemoglobin

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Oxygen Transport

Of the O₂ that diffuses from the alveoli:



98.5% combines with hemoglobin 1.5% dissolves in plasma

- O₂ is transported by the blood either,
 - Combined with haemoglobin (Hb) in the red blood cells (>98%) or,
 - Dissolved in the blood plasma (<2%).

Oxygen in Physical Solution

- For each 1 mm Hg increase, 0.003 mL O₂ dissolves into plasma.
- This results in ~ 3 mL of O₂/liter blood.
- With 5 L total blood volume = 15 mL dissolved O₂
- Dissolved O₂ establishes the P_{O₂} of the blood.
 - Regulates breathing
 - Determines loading of hemoglobin

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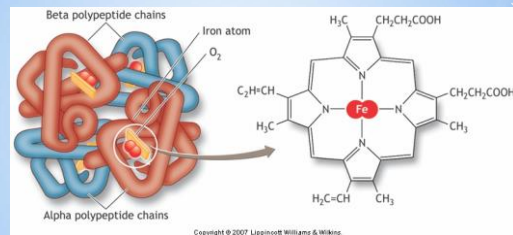
Oxygen Transport

- The resting body requires 250ml of O₂ per minute.
- We have four to six billion haemoglobin containing red blood cells.
- The haemoglobin allows nearly 70 times more O₂ than dissolved in plasma.

Oxygen Combined with Hemoglobin

- Each of four iron atoms associated with hemoglobin combines with one O₂ molecule.

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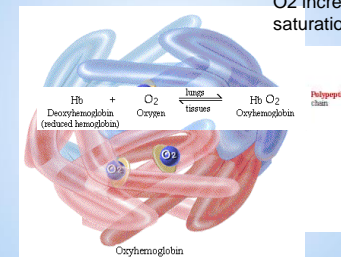
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Haemoglobin

Haemoglobin molecules can transport up to four O₂'s

Co-operative binding: haemoglobin's affinity for O₂ increases as its saturation increases.



When 4 O₂'s are bound to haemoglobin, it is 100% saturated, with fewer O₂'s it is partially saturated.

Oxygen binding occurs in response to the high PO₂ in the lungs

Carbon Dioxide Transport

- Carbon dioxide also relies on the blood for transportation. Once carbon dioxide is released from the cells, it is carried in the blood primarily in three ways...
- Dissolved in plasma,
- As bicarbonate ions resulting from the dissociation of carbonic acid,
- Bound to haemoglobin.

Dissolved Carbon Dioxide

- Part of the carbon dioxide released from the tissues is dissolved in plasma. But only a small amount, typically just 7 - 10%, is transported this way.
- This dissolved carbon dioxide comes out of solution where the PCO_2 is low, such as in the lungs.
- There it diffuses out of the capillaries into the alveoli to be exhaled.

Solubility

- CO_2 is about 25 times more soluble than O_2 .
- CO_2 and O_2 are both more soluble than N_2 .

CO_2 Transport

- Three mechanisms
 - Bound to Hb
 - Dissolved in plasma
 - Plasma bicarbonate

CO₂ in Physical Solution

- ~ 5% CO₂ is transported as dissolved CO₂.
- The dissolved CO₂ establishes the pCO₂ of the blood.

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CO₂ Transport as Bicarbonate

- CO₂ in solution combines with water to form carbonic acid.
- Carbonic anhydrase
 - Zinc-containing enzyme within red blood cell
- Carbonic acid ionizes into hydrogen ions and bicarbonate ions.

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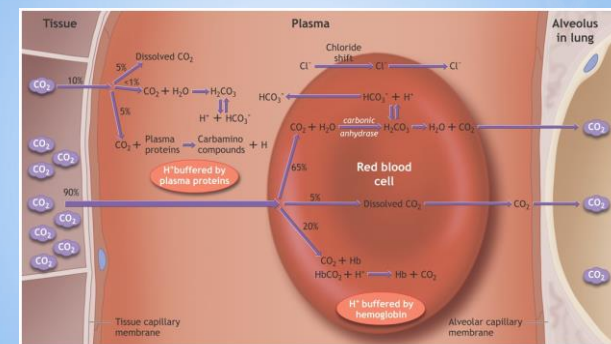
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CO₂ Transport as Carbamino Compounds

- CO₂ reacts directly with amino acid groups to form carbamino compounds.
- Haldane Effect: Hb interaction with O₂ reduces its ability to combine with CO₂.
- This aids in releasing CO₂ in the lungs.

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Conduction vs. Respiratory zones

- Most of the tubing in the lungs makes up **conduction zone**
 - Consists of nasal cavity to terminal bronchioles
- The **respiratory zone** is where gas is exchanged
 - Consists of alveoli, alveolar sacs, alveolar ducts and respiratory bronchioles

Respiratory Bronchioles, Alveolar Ducts, and Alveoli

- Lungs contain small saccular outpocketings called **alveoli**.
- They have a thin wall specialized to promote diffusion of gases between the alveolus and the blood in the pulmonary capillaries.
- Gas exchange can take place in the **respiratory bronchioles and alveolar ducts** as well as in the **alveoli**, each lung contains approximately 300 to 400 million alveoli.
- The spongy nature of the lung is due to the packing of millions of alveoli together.

Respiratory Membrane

- squamous cells of alveoli .
- basement membrane of alveoli.
- basement membrane of capillaries
- simple squamous cells of capillaries
- about .5 μ in thickness**

Pleura and Pleural Cavities

- The outer surface of each lung and the adjacent internal thoracic wall are lined by a serous membrane called **pleura**.
- The outer surface of each lung is tightly covered by the **visceral pleura**.
- while the internal thoracic walls, the lateral surfaces of the mediastinum, and the superior surface of the diaphragm are lined by the **parietal pleura**.
- The parietal and visceral pleural layers are continuous at the **hilus** of each lung.

Pleural Cavities

The potential space between the serous membrane layers is a **pleural cavity**.

- The pleural membranes produce a thin, serous **pleural fluid** that circulates in the pleural cavity and acts as a lubricant, ensuring minimal friction during breathing.
- **Pleural effusion** – pleuritis with too much fluid

Blood supply of Lungs

- **pulmonary circulation** -
- **bronchial circulation** – bronchial arteries supply oxygenated blood to lungs, bronchial veins carry away deoxygenated blood from lung tissue → superior vena cava
- **Response of two systems to hypoxia** – pulmonary vessels undergo **vasoconstriction**
bronchial vessels like all other systemic vessels undergo **vasodilation**

Gas Exchange in Lungs & Tissues

- Exchange of gases between lungs and blood and gas movement at the tissue level progress passively by diffusion, depending on their pressure gradients.

4. Effect of Carbon Monoxide (CO)

CO combines Hb at the same point as does O₂, and can displace O₂ from hemoglobin.

CO binds with about 250 times as much tenacity as O₂.

P_{CO} greater than 0.4 mmHg can be lethal.

In the presence of CO (low concentration), the affinity of hemoglobin for O₂ is enhanced

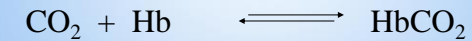
II Carbon Dioxide Transport

<u>Method</u>	<u>Percentage</u>
• Dissolved in Plasma	7 - 10 %
• Chemically Bound to Hemoglobin in RBC's	20 - 30 %
• As Bicarbonate Ion in Plasma	60 -70 %

85

Carbaminohemoglobin Formation

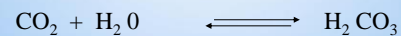
- Carbon dioxide molecule reversibly attaches to an amino portion of hemoglobin.



86

Carbonic Acid Formation

- The **carbonic anhydrase** stimulates water to combine quickly with carbon dioxide.



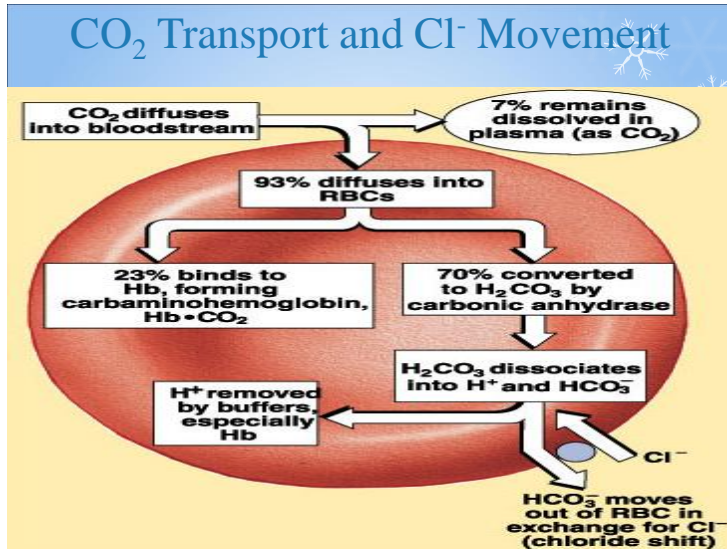
87

Bicarbonate Ion Formation

- Carbonic acid breaks down to release a hydrogen ion and bicarbonate.



88



Oxygen Transport

<u>Method</u>	<u>Percentage</u>
Dissolved in Plasma	1.5 %
Combined with Hemoglobin	98.5 %

90

