Respiratory System

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Respiratory System

- major function
  - supply body with O_2 & dispose of CO_2
- four distinct processes
  - collectively termed respiration
    - pulmonary ventilation
    - external respiration
    - transport of respiratory gases
    - internal respiration

Respiration

- 1) pulmonary ventilation
  - movement of air into & out of lungs
    - ventilation
      - AKA breathing
        - » refreshing of gases in alveoli (air sacs)

Respiration

- 2) external respiration
  - gas exchange between the blood & lungs
    - O_2 loading & CO_2 unloading
- 3) transport of respiratory gases
  - transport of O_2 & CO_2 between the lungs & tissue cells of body
    - via cardiovascular system
      - via blood

Respiration

- 4) internal respiration
  - gas exchange between systemic blood & tissue cells
    - O_2 unloading & CO_2 loading

Respiration

- respiratory & circulatory systems' activities are coupled
- processes 1 & 2 are responsibility of respiratory system
  - pulmonary ventilation
  - external respiration

Cellular Respiration

- actual use of oxygen and production of carbon dioxide by tissue cells

Functional Anatomy of Respiratory System

- organs (anatomy)
  - nose
  - nasal cavity
  - pharynx
  - larynx
  - trachea
  - bronchi & smaller branches
  - lungs
    - contain terminal air sacs (alveoli)

Functional Anatomy of Respiratory System

- functionally
  - respiratory zone
    - actual site of gas exchange
  - conducting zone
    - includes all other respiratory passageways

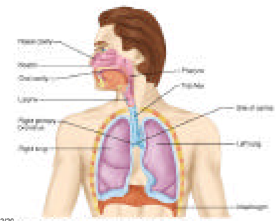
Functional Anatomy of Respiratory System

- respiratory zone
  - actual site of gas exchange
  - begins as terminal bronchioles feed into respiratory bronchioles
    - w/in lungs
  - consists of
    - respiratory bronchioles
    - alveolar ducts
    - alveoli

Functional Anatomy of Respiratory System

- conducting zone
  - includes all other respiratory passageways
  - provide rigid conduits for air to reach the sites of gas exchange
  - cleanses, humidifies & warms incoming air

Major Respiratory Organs (fig 23.1)



Nose

- only external visible part
- produces mucus
- provides an airway for respiration
- moistens and warms incoming air
- filters inspired air & cleanses it of foreign matter
- serves as a resonating chamber for speech
- houses the olfactory receptors

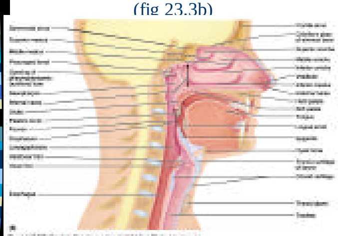
Nose

- consists of
  - external nose
  - internal nasal cavity

Nose

- internal nasal cavity
  - located in and posterior to external nose
  - divided in midline
    - **nasal septum**
  - continuous posteriorly w/ nasal portion of pharynx through **internal nares** (posterior nares)
  - three scroll-like mucosa-covered projections known as **nasal conchae**
    - project medially from each lateral wall of nasal cavity

Anatomy of Upper Respiratory Tract (fig 23.3b)



Nasal Cavity

- lined w/ two types of mucous membranes
  - olfactory mucosa
    - contains receptors for smell
  - respiratory mucosa

Mucous Membranes

- respiratory mucosa
  - pseudostratified columnar epithelium
  - contains scattered goblet cells
  - rests on a lamina propria
    - richly supplied w/ mucous & serous gland
      - » mucous glands secrete mucous
      - » serous glands secrete a watery fluid containing enzymes
      - » glands secrete ~ quart of mucus-containing lysozyme (anti-bacterial enzyme)

Functions of Mucus, Lysozome, Cilia

- sticky mucus
  - traps inspired dust, bacteria & other debris
- lysozome
  - attacks & destroys bacteria chemically
- ciliated cells
  - create a gentle current that moves the sheet of contaminated mucus posteriorly toward the throat (pharynx)
    - swallowed & digested by stomach juices

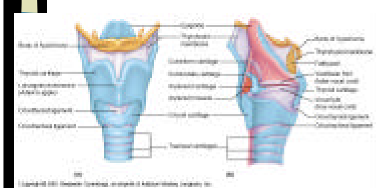
Larynx

- AKA voicebox
- extends for 2 inches
  - level of fourth to sixth cervical vertebra
- attaches superiorly to hyoid bone
- opens into laryngopharynx
- continuous w/ trachea inferiorly

Larynx

- consists of 9 cartilages connected by ligaments & membranes
- ninth cartilage
  - spoon-shaped epiglottis
    - extends from posterior aspect of tongue to its anchoring point on the thyroid cartilage

Larynx (fig 23.4b)



Larynx

- functions
  - 1) provide an open airway
  - 2) act as a switching mechanism to route air & food into the proper channels
  - 3) voice production

Action of the Epiglottis

- known as the guardian of the airways
- breathing
  - when only air is flowing into the larynx
    - inlet is wide open
    - free edge projects upward
- swallowing
  - larynx is pulled superiorly
    - epiglottis tips to cover the laryngeal inlet
      - keeps food out of lower respiratory passages

Cough Reflex

- initiated if anything other then air enters the larynx
- acts to expel substances entering the larynx
- does not work when we are unconscious

Cough Mechanism

- closes the glottis
- forces air superiorly from lungs against the glottis
- glottis opens suddenly
- a blast of air rushes upward
- dislodges foreign particles
- propels substances superiorly

Vocal Ligaments

- composed largely of elastic fibers
- form the core of mucosal folds
- known as the vocal folds ~true vocal cords
- appear pearly white
  - lack blood vessels

Vocal Cord Action

- vibrate
- produce sound
  - – as air rushes up from the lungs
- loudness of voice
  - – dependent on force of airstream rushing across the vocal cords
    - > the F, the stronger the vibration, the louder the sound

Vocal Cord Action

- length of vocal cords & size of glottis changes
  - – w/ action of the laryngeal muscles
    - length of folds & pitch of sound varies
      - – tenser the vocal folds
        - » faster they vibrate
        - » higher the pitch
      - – glottis wide when deep tones are produced
      - – glottis narrows to a slit for high pitched sounds

Vocal Cord Action

- do not move at all
  - – when we whisper
- vibrate vigorously
  - – when we yell
- power source for creating airstream
  - – muscles of chest, abdomen & back

Vocal Cord Action

- vocal folds
  - – actually produce buzzing sounds
- the quality of voice depends on
  - – pharynx (resonating chamber)
  - – oral, nasal & sinus cavities
  - – muscles of pharynx, tongue, soft palate & lips

Laryngitis

- inflammation of vocal folds
- causes the vocal folds to swell
  - – interferes w/ their vibration
- produces a change in the voice tone
  - – hoarseness
- severe cases
  - – inability to speak

Laryngitis

- other causes
  - – overuse of voice
  - – very dry air
  - – bacterial infections
  - – tumors on the vocal folds
  - – inhalation of irritating chemicals

Sphincter Functions of the Larynx

- larynx closed at two points by muscle action
  - – 1) via epiglottis during swallowing & speaking
  - – 2) during coughing, sneezing, straining to have a bowel movement
    - vocal folds act as a sphincter

Abdominal Straining

- associated w/ defecation or urination
- inhaled air is held temporarily
  - – in the lower respiratory tract
    - by closing the glottis
- abdominal muscles contract
  - – intra-abdominal P rises
    - events are known as *Valsalva's manuever*
      - – help to empty rectum or bladder
      - – stabilize the body trunk when lifting a heavy load

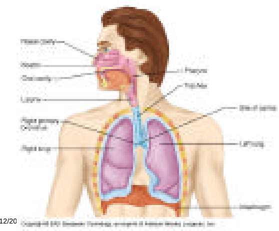
Trachea

- AKA windpipe
- descends from larynx through the neck into mediastinum
- ends by dividing into two primary bronchi at midthorax
- very flexible
- mobile

Trachea

- air passageway
- cleans, warms & moistens incoming air

Major Respiratory Organs (fig 23.1)



Trachea Mucosa

- AKA mucociliary escalator
- contains cilia & mucus producing cells
- dust is trapped on mucus
- cilia moves the mucus to pharynx
  - where it is swallowed

Effects of Smoking

- inhibits & ultimately destroys the cilia
- when the function is lost
  - coughing is the only means of preventing mucus from accumulating in the lungs
- smokers w/ respiratory congestion should avoid medications that inhibit the cough reflex

Tracheal Wall

- consists of three layers
  - mucosa
    - innermost
  - submucosa
    - middle
  - *adventitia
    - outermost layer

Adventitia

- connective tissue
- reinforced internally by 16-20 C shaped rings
  - hyaline cartilage
    - incomplete posteriorly where connected to trachealis muscle
  - function of C rings
    - prevent the trachea from collapsing
    - keeps airway patent despite P changes during breathing

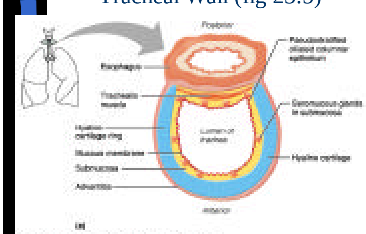
Adventitia

- open posterior parts of C rings
  - not rigid
  - abut the esophagus
  - connected by smooth muscle fibers of trachealis muscle

Adventitia

- open posterior parts of C rings
  - function
    - allow esophagus to expand anteriorly
      - as swallowed food passes through it
    - contraction of trachealis muscle
      - decreases the trachea diameter
        - » expired air rushing upward from lungs w/ > F
        - » helps expel mucus from trachea during coughing

Tracheal Wall (fig 23.5)



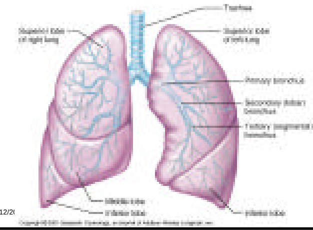
Heimlich Manuever

- procedure
- air in a person's lungs is used to expel an obstructing piece of food
  - due to tracheal obstruction
    - result in suffocation
      - because of a closed trachea or glottis of larynx

The Bronchial Tree

- bronchi and subdivisions
- consists of right & left primary bronchi
  - subdivide w/in lungs
    - form secondary & tertiary bronchi & bronchioles
- function
  - air passageways connecting trachea w/ alveoli
  - cleans, warms & moistens incoming air

The Bronchial Tree (fig 23.7)



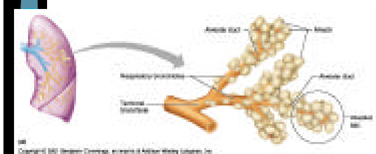
Respiratory Zone

- actual site of gas exchange
- begins as terminal bronchioles feed into respiratory bronchioles
  - w/in lungs
- consists of
  - respiratory bronchioles
  - alveolar ducts
  - alveoli

Alveoli

- microscopic chambers at end of bronchial tree
- main sites of gas exchange
  - thin structures
  - large surface area
    - sufficient to allow gas diffusion to sustain life

Respiratory Zone (fig 23.8)



Respiratory Membrane

- AKA alveolar-capillary membrane
  - air/blood barrier
    - gas flows on one side
    - blood flows on other side
- consist of
  - alveolar and capillary walls
  - fused basal laminas

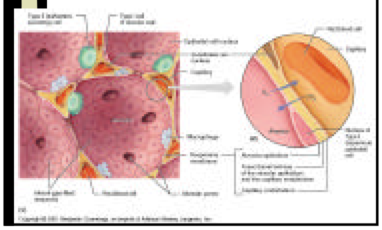
Respiratory Membrane

- walls of alveoli
  - single layer of squamous epithelial cells
    - type 1 cells
  - surrounded by a flimsy basal lamina
- external surfaces of alveoli
  - densely covered w/ a cobweb of pulmonary capillaries

Respiratory Membrane

- function
  - allow gas exchange by diffusion
    - oxygen passes from alveolus to blood
    - carbon dioxide leaves the blood to enter the gas filled alveolus

Respiratory Membrane (fig 23.9)



Alveolar Macrophages

- AKA dust cells
- crawl freely along the internal alveolar surfaces
- destroy infectious microorganisms present in alveoli

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Aged or Dead Macrophages

- do not accumulate in alveoli
- swept up by ciliary current of superior regions
  - carried passively to the pharynx
- ~2 million dust cells are cleared & swallowed/hr

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Lungs

- paired organs
  - left (smaller)
    - consists of two lobes (upper & lower)
  - right
    - consists of three lobes (upper, middle, lower)
- located w/in pleural cavities of thorax
- composed primarily of alveoli and respiratory passageways

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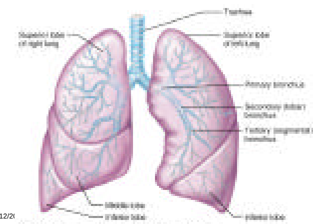
The Lungs (fig 23.7)



The Pleurae

- form a thin, double-layered serosa
- help divide the thoracic cavity
  - three separate chambers
    - the central mediastinum
    - two lateral pleural compartments
      - each containing a lung

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The Pleurae

- compartmentalization
  - helps prevent one mobile organ (heart or lung) from interfering w/ another
  - helps limit the spread of local infections

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The Pleurae

- produce pleural fluid
  - fills the pleural cavity
    - lubricating secretion
      - allows lungs to glide easily over the thorax wall
        - » during breathing

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Pleurisy

- inflammation of the pleurae
- decreased production of pleural fluid
- dry & rough pleural surfaces
- can result in pneumonia

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Pulmonary Ventilation

- AKA breathing
- consists of two phases
  - inspiration
    - period when air flows into the lung
  - expiration
    - period when gases exits the lungs

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Pressure Relationships in Thoracic Cavity

- mechanical factors that promote gas flow
  - atmospheric pressure
  - respiratory pressure
  - intrapulmonary pressure
  - intrapleural pressure
  - transpulmonary pressure

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Atmospheric Pressure (P_{atm})

- P exerted by air (gases) surrounding the body
- 760 mm Hg

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Respiratory Pressure

- always described relative to P_{atm}
- example
  - negative respiratory pressure of 4 mm Hg
    - P is 4 mm Hg lower than P_{atm}
    - 760 mm Hg - 4 mm Hg = 756 mm Hg
  - positive respiratory pressure
    - higher than P_{atm}
  - respiratory pressure of 0= P_{atm}

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Intrapulmonary Pressure (P_{alv})

- AKA intra-alveolar pressure
- pressure w/in alveoli of lungs
- increases and decreases w/ phases of breathing
- always eventually equalizes itself w/ P_{atm}

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Intrapleural Pressure (P_{ip})

- pressure w/in pleural cavity
- always fluctuates w/ breathing phases
- always 4 mm Hg less than P_{alv}
- negative relative to P_{alv} and P_{atm}
  - due to opposing forces that exist in thorax

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Intrapleural Pressure (P_{ip})

- opposing forces
  - two forces act to pull lungs (visceral pleura) away from the thorax wall (parietal pleura)
    - cause lung collapse

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Intrapleural Pressure (P_{ip})

- opposing forces
  - force 1
    - natural tendency of lungs to recoil
      - elasticity
        - » lungs assume a small size
  - force 2
    - suface tension of alveolar fluid
      - acts to draw alveoli to their smallest dimension

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Intrapleural Pressure (P_{ip})

- forces
  - opposed by
    - elasticity of chest wall
    - pulls the thorax outward & enlarges the lungs
  - create a negative intrapleural pressure

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Intrapleural Pressure (P_{ip})

- pleural fluid
  - secures pleurae together
    - slide from side to side but remain closely opposed
      - separating them requires extreme force
  - amt of fluid in cavity
    - must remain low for the negative P_{ip} to be maintained
      - pleural fluid is continously pumped actively into lymphatics
        - » excessive fluid accumulating in intrapleural space w ould create a positive pressure in cavity

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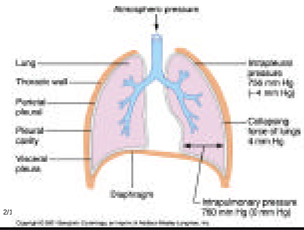
Pressure Relationships (fig 23.12)



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Transpulmonary Pressure

- AKA transpulmonic pressure
- difference between intrapulmonary pressure and intrapleural pressure
  - P_{alv} - P_{ip}
- keeps the airspaces of the lungs open
- keeps the lungs from collapsing
  - any condition that equalizes the P_{alv} & P_{ip} causes the lungs to collapse

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Atelectasis

- ~ lung collapse
- occurs
  - when air enters the pleural cavity through a chest wound OR
  - rupture of visceral pleura
    - allow air to enter pleural cavity from the respiratory tract
- associated w/ pneumonia

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Atelectasis

- ~ lung collapse
- lungs are separate cavities
- one lung can collapse w /out interfering w/ other

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A Pneumothorax

- presence of air in intrapleural space
- reversed by closing the hole & drawing air out of intrapleural space w/ chest tube
- allow s the lungs to reinflate & resume its normal function

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Volume Changes in Thoracic Cavity

- volume changes lead to pressure changes
  - lead to flow of gases to equalize the pressure
    - delta V — delta P — F (flow of gases)

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Boyle's Law

- AKA Ideal Gas Law
- relationship between P & V
- when T is constant
  - P of gas varies inversely w/ volume
    - $P_1V_1 = P_2V_2$

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Boyle's Law

- gases conform to the shape of their container
- gases always fill their container
- example
  - large volume
    - gas molecules are far apart
    - P is low
  - small volume
    - gas molecules become compressed
    - P is high

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Muscles

- inspiratory muscles
  - diaphragm
  - external intercostals

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Muscles

- inspiratory muscles
  - diaphragm
    - prime mover of inspiration
    - flattens on contraction
    - increases the vertical dimensions (height) of thorax
    - increases intra-abdominal P

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Muscles

- inspiratory muscles
  - external intercostals
    - synergists of the diaphragm
    - 11 pairs that lie between the ribs
    - contraction lifts the rib cage & pulls the sternum forward
      - change the lateral dimensions

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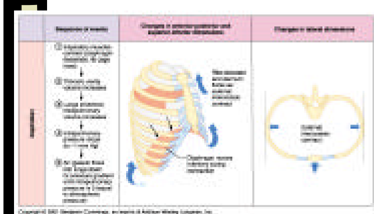
Inspiration (fig 23.13)



Inspiration

- dependent on muscle contraction
- occurs when $P_{alv} < P_{atm}$
  - air rushes into lungs
    - along the P gradient
- inspiration ends
  - $P_{alv} = P_{atm}$

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Deep (Forced) Inspiration

- occurs during vigorous exercise or COPD
- thoracic volume is further increased by accessory muscles
  - scalenes
  - sternocleidomastoid
  - pectoralis minor

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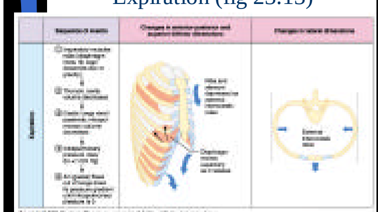
Expiration (fig 23.13)



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Expiration

- passive process
- depends more on natural elasticity of lungs than on muscle contraction
- relaxation of inspiratory muscles
  - resume their initial resting length
-

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Expiration

- | thoracic & intrapulmonary volume — compression of alveoli — | P
- when $P_{alv} = P_{atm}$

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Forced Expiration

- active process
- produced by contraction of abdominal wall muscles
  - 1) increase intra-abdominal P
    - forces organs superiorly
  - 2) depression of rib cage
  - 3) decrease in thoracic volume

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Alveolar Film

- liquid film that coats alveolar w alls
  - acts to reduce the alveoli to their smallest possible size
- water
  - major component
- surfactant
  - another component
  - produced by type II alveolar cells
  - contains a detergent like complex of lipids & proteins

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Surfactant

- functions
  - reduce surface tension of water molecules
    - interferes w / cohesiveness of molecules
  - prevent the collapse of alveoli after each expiration

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Infant Respiratory Distress Syndrome (IRDS)

- condition affects premature babies
- inadequate production of pulmonary surfactant
- premature babies are unable to keep their alveoli inflated between breaths
  - surfactant produced during last two months of fetal development

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Hiccups

- sudden inspirations
- result from spasms of diaphragm
- believed to be initiated by irritation of diaphragm or nerves
- sound
  - result of inspired air hitting the vocal folds of closed glottis

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Gas Exchange

- occurs by bulk flow
  - gases
  - solutions of gases
- occurs by diffusion
  - gases
    - through tissues

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Dalton's Law

- law of partial pressures
- total P exerted by a mixture of gases
  - sum of P's exerted independently by each gas in the mixture
- P exerted by each gas
  - its partial pressure
    - directly proportional to its % in the total gas mixture

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Comparison of Gas Partial Pressures (Table 23.4)

Atmosphere

Gas	%	PP (mm Hg)
Nitrogen	78.6	597
Oxygen	20.9	159
Carbon Dioxide	0.04	0.3
Water	0.46	3.7
Total	100%	760 mm Hg

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Comparison of Gas Partial Pressures (Table 23.4)

Alveoli

Gas	%	PP (mm Hg)
Nitrogen	74.6	569
Oxygen	13.7	104
Carbon Dioxide	5.2	40
Water	6.2	47
Total	100%	760 mm Hg

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Calculation of Partial Pressures

- atmospheric pressure
  - N makes up ~79% of air
  - P_{N2} = 78.6% x 760 mm Hg = 597 mm Hg (PP of nitrogen)
  - P_{O2} = 21% x 760 mm Hg = 159 mm Hg (PP of oxygen)

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Henry's Law

- each gas will dissolve in proportion to its PP
  - when a mixture of gases is in contact w/ a liquid
- the > the [ ] of gas in the gas phase
  - the more & the faster the gas will into solution in the liquid

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Henry's Law

- each gas will also dissolve in proportion to its solubility
  - gases have different solubilities in water or plasma
    - carbon dioxide is most soluble
    - oxygen is only 1/20th as soluble
    - nitrogen is nearly insoluble
- at any given PP
  - carbon dioxide is more soluble and almost no nitrogen will go into solution

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Henry's Law

- solubility of any gas in water decreases w/ increasing temp

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Gaseous Composition

- gaseous makeup of atmosphere
  - different from alveoli
- atmosphere
  - almost entirely oxygen & nitrogen
- alveoli
  - more carbon dioxide & water vapor
  - less oxygen

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Composition of Alveolar Gas

- due to
  - 1) gas exchange occuring in lungs
    - O_2 diffuses from alveoli into pulmonary blood
    - CO_2 diffuses in opposite direction
  - 2) humidification of air by conducting passages
  - 3) mixing of alveolar gas w/ each breath
    - mixture of newly inspired air w/ gases remaining in passages between breaths

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Gas Exchange

- external respiration
  - gas exchange between blood, lungs & tissues
  - oxygen enters
  - carbon dixiode leaves blood in the lungs

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Gas Exchange

- internal respiration
  - gas exchange at the body tissues
  - carbon dioxide enters
  - oxygen leaves

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Factors Influencing Gas Movement Across Respiratory Membrane

- 1) PP gradients and gas solubilities
- 2) alveolar ventilation & pulmonary blood perfusion matching
- 3) thickness & surface area of respiratory membrane

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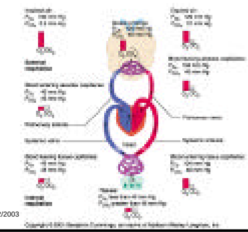
Partial Pressure Gradients

- gas composition of alveolar air & expired air are different
  - due to mixing of dead space air w/ expired air
- fig 23.17
  - external respiration (top of figure)
    - lung exchange
  - internal respiration (bottom of figure)
    - capillary exchange

Partial Pressure Gradients & Gas Exchange (fig 23.17)



Summary of Gas Exchange

- gas exchange
  - occurs by simple diffusion
  - driven by PP gradients
    - oxygen & carbon dioxide
      - on opposite sides of respiratory membrane

Alveolar Ventilation & Pulmonary Perfusion

- alveolar ventilation
  - amt of gas reaching the alveoli
- perfusion
  - blood flow in pulmonary capillaries
- these two events must be coupled for efficient gas exchange
  - occurs via autoregulation mechanism

Ventilation

- Inadequate ventilation
  - low P_{O2}
    - constriction of the terminal arterioles
    - redirection of blood to respiratory areas where P_{O2} is high
      - O_2 loading
  - maximal ventilation (high P_{O2})
    - pulmonary arterioles dilate
      - | blood flow into associated capillaries

Ventilation

- high P_{CO2}
  - dilation of the passageways (bronchioles)
  - rapid elimination of CO_2 from body
- low P_{CO2}
  - constriction of passageways

Transport of Oxygen in Blood

- 1) bound to hemoglobin
  - w/in RBC's
  - 98.5% of oxygen
- 2) dissolved in plasma
  - 1.5% of oxygen
    - poorly soluble in water

Hypoxia

- inadequate oxygen delivery to body tissues
- anemic
  - due to decrease in RBCs or abnormal Hb production
- ischemic
  - blood circulation is impaired or blocked
- histotoxic
  - inability of body cells to use oxygen
    - in when adequate amts are available
- hypoxemic
  - | arterial P_{O2}

Transport of Carbon Dioxide in Blood

- 1) as a gas dissolved in plasma
  - 7-10 %
- 2) chemically bound to Hb
  - 20%
- 3) in plasma as the bicarbonate ion (HCO_3^-)
  - 70%

Transport of Carbon Dioxide as HCO_3^-

- CO_2 diffuses into RBCs
  - CO_2 + H_2O — H_2CO_3 (carbonic acid)
- H_2CO_3 is unstable
  - quickly dissociates into H^+ + HCO_3^-

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Carbonic Acid-Bicarbonate Buffer System

- important in resisting shifts in blood pH
  - H^+ released during dissociation
    - buffered by Hb or other proteins
      - found in RBCs or plasma
  - HCO_3^- generated in RBCs during dissociation
    - diffuses into plasma
      - act as alkaline reserve part of buffer system

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Carbonic Acid-Bicarbonate Buffer System

- | H^+
  - | pH
- | H^+
  - | pH

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Carbonic Acid-Bicarbonate Buffer System

- CO_2 + H_2O ═ H_2CO_3 ═ H^+ + HCO_3^-
- | [H^+] in blood
  - removal of H^+
    - by combining w / HCO_3^- — H_2CO_3
      - | pH
- | [H^+] in blood
  - dissociation of H_2CO_3
    - release of H^+
      - | pH

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Respiratory Rate or Depth Changes

- result in dramatic changes in blood pH
  - alters the amt of H_2CO_3 in blood
- slow, shallow breathing
  - CO2 accumulation in blood
    - | H_2CO_3
    - | blood pH
- rapid, deep breathing
  - removal of CO2 from blood
    - | H_2CO_3
    - | blood pH

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Respiratory Ventilation

- provides a fast-acting means to adjust blood pH and P_{CO2}

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Neural Mechanisms

- involve activity of neurons in the
  - medulla
    - medullary respiratory center
      - dorsal respiratory group
      - ventral respiratory group
  - pons
    - pons respiratory center
      - pneumotaxic center
      - apneustic center

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Medullary Respiratory Centers

- clustered neurons in two areas of medulla oblongata
  - dorsal respiratory group
  - ventral respiratory group

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Dorsal Respiratory Group (DRG)

- pacesetting respiratory center
  ~inspiratory center
- responsible for rhythmicity of breathing
- located dorsally near root of cranial nerve IX

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Dorsal Respiratory Group (DRG)

- functions
  - inspiration
    - nerve impulses excite diaphragm & external intercostal muscle
      - expansion of thorax
      - entrance of air into lungs
  - becomes dormant
    - expiration occurs passively
    - inspiratory muscles relax
    - lung recoil
  - cycle continues off/on
    - respiratory rate of 12-15 breaths/min

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Ventral Respiratory Group (VRG)

- a network of neurons that extend w/in ventral brain stem
  - from spinal cord to pons-medulla junction

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Ventral Respiratory Group (VRG)

- functions
  - inspiration & expiration
  - ~effect the activity of respiratory muscles
  - mainly in forced breathing
    - primarily forced expiration
      - when more strenous breathing movements are needed

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Pons Respiratory Centers

- influence & modify the activity of the medullary neurons
- smooth out transition
  - from inspiration to expiration
  - from expiration to inspiration

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Pneumotaxic Center

- more superior pons center
- transmits inhibitory impulses to the inspiratory center
- fine-tunes the breathing rhythm
- prevents lung over inflation

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Apneustic Center

- provides drive for inspiration
- continuously stimulates inspiratory center
- prolongs inspiration
- causes breath holding

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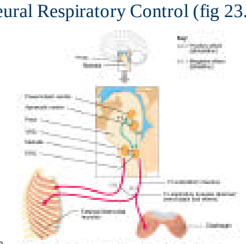
Neural Respiratory Control (fig 23.24)



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Factors Influence Respiratory Centers

- pulmonary irritants
- strong emotions & pain
- voluntary control
  - cerebral cortex

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Pulmonary Irritants

- lungs contain receptors
  - become stimulated to constrict air passages
    - activated
      - accumulated mucus
      - inhaled debris
        - dust
        - lint
        - cigarette smoke
        - fumes

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Pulmonary Irritants

- receptors communicate w / respiratory ctrs
  - – via vagal nerve afferents
    - stimulate a cough
      - – when irritant is in trachea or bronchi
    - stimulate a sneeze
      - – when irritant is in nasal cavity

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Strong Emotions & Pain

- activate the sympathetic centers of hypothalamus
  - – modification of respiratory rate & depth
- example
  - – breath holding when angry
    - excitation
      - – increase in respiratory rate

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Voluntary Control

- cerebral motor cortex sends direct signals to motor neurons
  - – stimulate the respiratory muscles
    - bypass the medullary centers
- example
  - – voluntarily holding one's breath
    - hold only temporarily
    - respiratory centers automatically reinitiates breathing
      - – when CO_2 reaches critical levels

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Chemical Factors Affecting Respiratory Centers

- most important regulators
  - – carbon dioxide
  - – oxygen
  - – hydrogen ions

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Influence of P_{CO2}

- carbon dioxide
  - – most potent & most closely controlled chemical
- normal conditions
  - – arterial P_{CO2} ~ 40 mm Hg
    - maintained w /in 3 mm Hg (+ or -)
      - – by rising & falling levels of CO_2

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Influence of P_{CO2}

- chemoreceptors
  - – sensors that respond to chemical fluctuations
    - located in 2 major body areas
      - – medulla (central chemoreceptors)
        - » influenced by CO_2
      - – vessels of neck (peripheral chemoreceptors)
        - » influenced by O_2

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Influence of P_{CO2}

- CO_2 levels
  - – act as an initial stimulus
    - ↑ H+ levels → stimulating the chemoreceptors ↑ ventilation (more CO_2 exhalation) → regulation of $[H^+]$
- * *primary goal of breathing during rest is to regulate $[H^+]$ in the brain*

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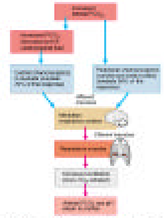
P_{CO2} & H^+ Regulation of Ventilation (fig 23.26)



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Influence of P_{O2}

- slight
- mostly limited to enhancing the sensitivity of central receptors to P_{CO2}
- arterial P_{O2} must drop substantially
  - – 60 mm Hg
    - oxygen levels to become a major stimulus
      - – increased ventilation

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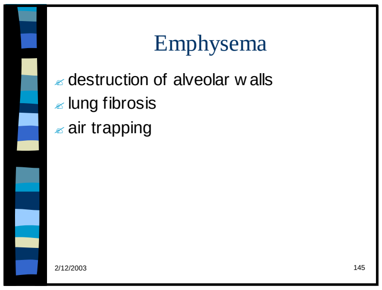
Emphysema
destruction of alveolar w alls
lung fibrosis
air trapping
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