Chapter 22: The Respiratory System

Four processes = pulmonary ventilation; external respiration; gas transport; internal respiration.

I. Functional Anatomy

Conduction zones lead into respiratory zones.

(A) Nose and Paranasal Sinuses

Air warmed, filtered and moistened.
Involved in speech and taste.

Nostrils = external nares, divided by septum.
Hard and soft palates.

Olfactory epithelium surrounded by respiratory mucosa.
Many goblet cells.
Mucous with lysozyme.

Air slowed by nasal conchae.

Sinuses in frontal, sphenoid, ethmoid and maxillary bones.
Lighten skull, moisten air.

(B) Pharynx  Regions: naso-, oro-, laryngo-

-1- Uvula blocks nasopharynx during swallow.
Contains pharyngeal tonsil (adenoids).
Connected to middle ears by pharyngotympanic (Eustachian) tubes.

-2- Oropharynx contains palatine tonsils.

-3- Laryngopharynx shared by respiratory and digestive systems.

(C) Larynx

Contains vocal cords.
Prominent thyroid cartilage = Adam’s apple.
Nine cartilages include epiglottis.

Glottis closes during Valsalva Maneuver, increases abdominal pressure.
(D) **Trachea** = windpipe.

Mucosa with pseudostratified epithelium.
Smoking destroys cilia.
Held open by cartilage rings.
Blockages expelled by **Heimlich Maneuver**.

(E) **Bronchi**

-1- **Conducting Zone** = primary, secondary and tertiary, terminal bronchioles. Cartilage, mucous and cilia become less prevalent, more smooth muscle.

-2- **Respiratory Zone** = respiratory bronchioles, alveolar ducts, alveolar sacs, each with many alveoli.

Respiratory membrane = two layers of simple squamous epithelium with basement membrane between.

Alveolar wall with Type I (squamous) and Type II (surfactant) cells. Macrophages are **dust cells**.

(F) **Lungs**

Left with two lobes, right with three.
Each with apex, base, attached at root.
Costal surfaces border ribs.

Divided into bronchopulmonary segments, each with own artery, vein and terminary bronchus. 8-10/ lung.
Can be surgically removed separately.

Visible subdivisions ~2cm in diameter = lobules, each with large bronchiole.

Provided by pulmonary and systemic blood.

Capillary endothelium contains ACE and other enzymes.

Sympathetic and parasympathetic innervation.

Pleurae with visceral and parietal layers, fluid between.

Inflammation is **pleurisy**. Associated with pneumonia.
II. Breathing Mechanics

(A) Pressure Relationships in thoracic cavity.

Comparison to Atmospheric $P = 760$ mm Hg.  
Intrapulmonary $P$ in alveoli, $= \text{Atm } P$.  
Intrapleural $P$ in pleural cavity, always lower than Atm $P$,  
keeps alveoli open.

Atelectasis = lung collapse, associated with pneumothorax (air in pleural cavity).

(B) Pulmonary Ventilation

Based on volume changes, lead to pressure changes.  

Inspiration: diaphragm and external intercostals contract.  
Thoracic cavity expands, decreases its pressure.  
Air moves in.  
Can be exaggerated with accessory muscles.

Expiration: when passive, quiet breathing, elastic recoil.  
Inspiratory muscles relax.  
Pressure higher in thoracic cavity,  
Air moves out.  
Forced with abdominal and internal intercostals muscles.

(C) Physical Factors

-1- airway resistance: Flow is the difference in pressure/ resistance.  
Impacted by tube diameter, compensated for by branching.  
Bronchoconstriction with asthma, dilation is sympathetic.

-2- alveolar surface tension  
Compresses alveoli, alleviated by surfactant.

Respiratory Distress Syndrome without surfactant. Common in premature babies.

-3- lung compliance = ability to stretch.  
Reduced with restrictive conditions.  
Fibrosis, skeletal or muscular impairment.
(D) **Respiratory Volumes**

Tidal Volume (TV): in and out during quiet breathing.

Inspiratory and Expiratory Reserve Volumes (IRV & ERV).

Residual Volume.

Combined in capacities,

\[ \text{e.g. Vital Capacity = TV + IRV + ERV} \]

Dead space contains useless volumes.

Measured with spirometers.

Forced Vital Capacity (FVC) can distinguish obstructive from restrictive conditions.

(E) **Nonrespiratory Movements**

Coughing, sneezing, crying, laughing, hiccups, yawns.

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**III. Gas Exchange**

Among blood, lungs and tissues.

(A) **Gas Properties**

**Dalton’s Law**: partial pressure of a gas reflects its percentage in air.

\[ \sim 80\% \text{ N}_2, \ 20\% \text{ O}_2, \ \text{very little} \ 	ext{H}_2\text{O} \text{ and CO}_2 \text{ in atmosphere.} \]

Atm P effected inversely by altitude.

**Henry’s Law**: gas moves into liquid based on its PP.

Influenced by solubility and temperature.

Hyperbaric chambers force O2 into blood.

(B) **Alveolar Gas**

Less O2, more CO2, reflects body’s use.

(C) **External Respiration**

Influenced by:
-1- PP gradients and solubilities.
-2- Matching pulmonary perfusion with alveolar ventilation.
-3- Structure of the respiratory membrane.
(D) **Internal Respiration**

Between capillaries and body tissues. Reverse from lungs.

**IV. Gas Transport**

(A) **Oxygen**

Most carried by hemoglobin.

Dissociation curves are “S” shaped to reflect that O2 binding is self-promoting.

Fully saturated at PO2 70 mmHg- adaptive.

Influenced by temperature, pH, and BPG (increases with anaerobic activity). Binding enhanced with lower temperature, increased pH and decreased CO2.

**Hypoxia** may lead to **cyanosis**.

Causes: anemic; ischemic; histotoxic (poisons like cyanide); hypoxemic. CO competes with O2, with no cyanosis.

(B) **CO2**

~10% dissolved in plasma, 20% on Hb (CarbaminoHb), binds to globin, not heme. ~7% as bicarbonate.

Carbonic anhydrase in RBCs creates carbonic acid from H2O and CO2. Carbonic acid $\rightarrow$ H+ and HCO3- (bicarbonate). HCO3- exchanged for Cl- when released from RBCs. All this reverses in lungs.

Carbonic acid a common buffer system.

**V. Control of Respiration**

(A) **Neural**

Dorsal and ventral respiratory groups (DRG & VRG) of medulla.

Normal rate and rhythm = **eupnea**.

Input from stretch and chemoreceptors.
Pontine respiratory group in pons influences medulla.
Still being studied.

(B) Influencing Factors

-1- chemicals: CO2, O2, H+.
Central (brainstem) and peripheral chemoreceptors.

Hypercapnia \(\rightarrow\) lowers pH \(\rightarrow\) increases breathing rate and depth.
Hyperventilation \(\rightarrow\) hypocapnia.

Some sensitivity to O2 in aortic & carotid bodies.
Less influential than CO2, pH.

-2- higher brain centers: hypothalamus and limbic system (emotions).
Cortical control is voluntary.

Irritant reflexes from lungs \(\rightarrow\) vagal afferents.

Hering-Breuer Reflex: stretched lungs inhibit respiration.

VI. Respiratory Adjustments

(A) Exercise:
increases ventilation due to psychological stimuli,
stimulation of skeletal muscles and respiratory centers,
and input from proprioceptors.

(B) High Altitude:
AMS: Acute Mountain Sickness.
Headaches, shortness of breath, dizziness.
Acclimatization involves increased hematocrit.
VII. Homeostatic Imbalances

(A) COPD: Chronic Obstructive Pulmonary Disease

Chronic bronchitis, emphysema, some asthma.
Associated with smoking.
Dyspnea (difficulty breathing), coughing, infections, leads to hypoventilation.

Emphysema = alveolar destruction.
“Barrel Chest” a compensation by strengthening thoracic muscles.

(B) Asthma = airway inflammation, leads to bronchoconstriction.
Triggered by allergens.

(C) Tuberculosis = bacterial. Usually contained within tubercles.
Symptoms when immunity low. Effects 1/3 the world’s population.

(D) Lung Cancer

Causes most deaths from cancer, men and women. ~90% associated with smoking.

VIII. Development

Cystic Fibrosis the most common lethal genetic disease in North America.
Viscous, hypertonic mucous.