Respiratory System
(Chapter 23)
Lecture Materials
for
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Primary Sources for figures and content:
Marieb, E. N. Human Anatomy & Physiology 6th ed. San Francisco: Pearson Benjamin

Anatomy of Respiratory System:
1. Upper respiratory system:
   -functions to warm and humidify air
   -nose, nasal cavity, sinuses, pharynx
2. Lower respiratory system:
   A. Conducting portion:
      -bring air to respiratory surfaces
      -larynx, trachea, bronchi, bronchioles
   B. Respiratory portion:
      -gas exchange
      -alveoli

Respiratory Mucosa (mucus membrane)
-lines conduction portions
-pseudostratified columnar epithelium
-usually ciliated
-scattered goblet cells (mucin production)

- lamina propria = areolar CT with
  -mucus glands (mucin) and
  -serous glands (lysozyme)
Glands produce ~1 quart mucus fluid /day
-cilia move mucus to pharynx to be swallowed
  (cilia beat slow in cold)
Respiratory Defense Systems:
1. Mucus: from goblet cells and glands in lamina propria, traps foreign objects
2. Cilia: “mucus escalator”: move carpet of mucus with trapped debris out of respiratory tract
3. Alveolar macrophages: phagocytose particles that reach alveoli

Cystic fibrosis = failure of mucus escalator:
produce thick mucus which blocks airways and encourages bacteria growth

Smoking → destroys cilia

Inhalation of irritants → chronic inflammation → cancer e.g. squamous cell carcinoma

The Upper Respiratory System

1. Nose: only external feature
Functions:
   1. Opening to airway for respiration
   2. Moisten and warm entering air
   3. Filter and clean inspired air
   4. Resonating chamber for speech
   5. Houses olfactory receptors
Features:
   -external nares conduct air into vestibule
   -vestibule = space in flexible part, lined with hairs to filter particles, leads to nasal cavity

2. Nasal Cavity
   -divided into right and left by nasal septum
   -superior portion has olfactory epithelium
   -nasal conchae (superior, middle, inferior) project into cavity on both sides

   -nasal conchae cause air to swirl:
     1. Increase likelihood of trapping foreign material in mucus
     2. Provide time for smell detection
     3. Provide time and contact to warm and humidify air
   -hard and soft palate form floor

   -internal nares open to nasopharynx
   -mucosa has large superficial blood supply (warm, moisten air) Epistaxis = nose bleed
   -paranasal sinuses in frontal, sphenoid, ethmoid and maxillary bones; lined with respiratory mucosa, connected to nasal cavity, aid in warming/moistening air
Rhinitis = inflammation of nasal mucosa → ↑ mucus production.
Infection → blockage of sinuses: headache from negative pressure

3. Pharynx:
- chamber between internal nares and entrances to larynx and esophagus
- Three parts

A. Nasopharynx: air only
  - posterior to nasal cavity
  - pseudostratified columnar epithelium
  - closed off by soft palate and uvula during swallowing
  - pharyngeal tonsil located on posterior wall (inflammation can block airway)
  - auditory tubes open here

B. Oropharynx: food and air
  - posterior to oral cavity
  - stratified squamous epithelium
  - palatine and lingual tonsils in mucosa

C. Laryngopharynx: food and air
  - lower portion
  - stratified squamous epithelium
  - continuous with esophagus

Lower Respiratory System
4. Larynx (voice box)
- hyaline cartilages around glottis = opening from laryngopharynx to trachea

Functions of larynx:
1. Provide continuous airway
2. Act as switch to route food and air properly
3. Voice production

- contains epiglottis = elastic cartilage flap, covers glottis during swallowing

- folds of epithelium over ligaments of elastic fibers create vocal folds/cords.

- vocal cords project into glottis
- air passing through glottis vibrates folds producing sound

Pitch controlled by tensing/relaxing cords:
  tense & narrow = high pitch

Volume controlled by amount of air

Sound production = phonation

Speech = formation of sound using mouth and tongue with resonance in pharynx, mouth, sinuses and nose

Laryngitis = inflammation of vocal folds due to infection or overuse, can inhibit phonation
As bronchi get smaller, structure changes:
1. less cartilage in adventitia
2. more smooth muscle in lamina propria
3. epithelium thinner, less cilia, less mucus

7. Terminal bronchiole
- smallest bronchi of respiratory tree
- no cartilage
- last part of conducting portion

Trachea, Bronchi and Bronchioles innervated by ANS to control airflow to lungs:

Sympathetic = bronchodilation
Parasympathetic = bronchoconstriction

Asthma = strong bronchoconstriction activated by inflammatory chemicals (histamine), reduces airflow. Epinephrine inhaler mimics sympathetic (bronchodilate)

- each terminal bronchiole delivers air to one pulmonary lobule (separated by CT)
- inside lobule, terminal bronchiole branches into respiratory bronchioles: no cilia or mucus
- each respiratory bronchiole connects to alveolar sac made up of many alveoli
8. Alveoli
- wrapped in capillaries
- held in place by elastic fibers

- three cell types:
  1. Type I cells: simple squamous epithelium, lines inside, gas exchange
  2. Type II cells: cuboidal epithelial cells, produce surfactant (phospholipids + proteins), prevent alveolar collapse
  3. Alveolar macrophages: phagocytosis of particles

-alveoli connected to neighbors by alveolar pores (equalize pressure)
-Gas exchange occurs across the respiratory membrane (0.5μm thick):
  1. Type I cells of alveolus
  2. Thin basal lamina (fusion)
  3. Endothelial cells of capillary

Pneumonia = inflammation of lungs from infection or injury, fluid in alveoli prevents gas exchange
Pulmonary embolism = block in branch of pulmonary artery, reduced blood flow causes alveolar collapse

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**Respiratory Physiology**

3 steps of respiration:
1. Pulmonary ventilation
2. Gas Diffusion/Exchange
3. Gas Transport to/from tissues

1. Pulmonary Ventilation
   = movement of air into/out of alveoli
   - visceral pleura adheres to parietal pleura via surface tension: altering size of pleural cavity will alter size of lungs
   Pneumothorax = injury of thoracic cavity, air breaks surface tension, lungs recoil = atelectasis (collapsed lung)

Mechanics of breathing:
- Boyle’s Law: gas pressure is inversely proportional to volume
- Air flows from area of high pressure to low

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**Gross Anatomy of Lungs**

- concave base, rests on diaphragm
- right: 3 lobes
- left: 2 lobes (accommodates heart)
- housed in pleural cavity
- cavity lined with parietal pleura
- lungs covered by visceral pleura
- both pleura produce serous pleural fluid to reduce friction during expansion

Pleurisy = inflammation of pleura, can restrict movement of lungs causing breathing difficulty
Factors influencing pulmonary ventilation:
1. Airway resistance
   -diameter of bronchi
   -obstructions
2. Alveolar surface tension
   -surfactant (Type II cells) reduces alveoli surface tension to allow inflation
   Respiratory distress syndrome = too little surfactant, requires great force to open alveoli to inhale
3. Compliance
   = effort required to expand lungs and chest
   High compliance = expand easily (normal)
   Low compliance = resist expansion
   Compliance affected by:
   A. CT structure: loss of elastin/replacement by fibrous tissue = ↓ compliance
   Emphysema = respiratory surface replaced by scars, ↓ elasticity ↓ compliance, and have loss of surface for gas exchange

B. Alveolar expandability (vs. collapse)
   - ↑ surface tension(↓ surfact.) = ↓ compliance
   - fluid (edema) = ↓ compliance
C. Mobility of thoracic cage
   - less mobility = ↓ compliance

Inspiration
- inhalation involves contraction of muscles to increase thoracic volume
A. Quiet breathing = eupnea
   - diaphragm: moves 75% of air
   - external intercostals: elevate ribs, 25% more
B. Forced breathing = hyperpnea
   - maximum rib elevation increases respiratory volume 6X: serratus anterior, pectoralis minor, scalenes, sternocleidomastoid

Expiration
A. Eupnea: passive, muscles relax, thoracic volume decrease
B. Hyperpnea: abdominal muscles (obliques, transversus, rectus) contract forcing diaphragm up, thoracic volume further decreases

Respiratory Volumes and Capacities:
-a breath = one respiratory cycle
(go to handout)

Respiratory rate = breaths/min ~18-20 at rest
Respiratory Minute Volume (RMV/MRV) = respiratory rate X tidal volume ~ 6 L
Not all reaches alveoli, some air remains in conducting portions = anatomic dead space (~1ml / lb body weight)
Alveolar ventilation = air reaching alveoli / min at rest ~ 4.2 L
Both tidal volume and respiratory rate are adjusted to meet oxygen demands of body

2. Gas Exchange
-Air = 79% N₂, 21% O₂, 0.5% H₂O, 0.04% CO₂, trace inert gases
-Partial pressure of gas = concentration in air
-Gasses follow diffusion gradients to diffuse into liquid: rate depends on partial pressure and temperature

High Altitude Sickness = ↓PP O₂ at high altitude causes ↓ diffusion into blood

Decompression Sickness = PP of air gasses high underwater, high amounts of N₂ diffuse into blood. If pressure suddenly decreases, N₂ leaves blood as gas causing bubbles (damage, pain), Hyperbaric chambers used to treat

Diffusion at respiratory membrane efficient:
1. Substantial differences in PP across the membrane
2. Distance is small
3. Gasses are lipid soluble
4. Large surface area for diffusion
5. Coordination of blood and air flow: ↑ blood to alveoli with ↑ O₂

In Lung:
-PP O₂ ↑ in alveoli, ↓ in capillary:
  diffuse into capillary
-PP CO₂ ↓ in alveoli, ↑ in capillary:
  diffuse into alveoli

In Tissues:
Pressures and flow reversed:
O₂ into tissues
CO₂ into capillary

3. Gas Transport
A. Transport of Oxygen
-1.5% dissolved in plasma
-most bound to iron ions on heme of hemoglobin in erythrocytes: 4 O₂/Hb,
~280 million Hb/RBC = 1 billion O₂/RBC

Hemoglobin saturation = %hemes bound to O₂
~ 97.5% at alveoli
@ ↑PP O₂ hemoglobin binds O₂
@ ↓PP O₂ hemoglobin drops O₂

Carbon Monoxide Poisoning: CO outcompetes O₂ for binding to Hb, even at low PP CO₂, causes suffocation (no O₂)

Other factors that affect Hb saturation:
1. Bohr effect: Hb releases O₂ in acidic pH (high CO₂ creates carbonic acid)
2. Temperature: Hb releases O₂ in ↑ temp
3. BPG (2,3bisphosphoglycerate): produced by healthy RBC during glycolysis, ↑ BPG = ↑ O₂ release
4. Pregnancy: fetal Hb = ↑ O₂ binding

Hypoxia = inadequate O₂ delivery to tissues

B. Transport of Carbon Dioxide
1. ~ 70% as Carbonic acid
   -in RBCs and plasma
   -carbonic anhydrase in RBCs catalyze reaction with water:
   \[ \text{CO}_2 + \text{H}_2\text{O} \leftrightarrow \text{H}_2\text{CO}_3 \leftrightarrow \text{H}^+ + \text{HCO}_3^- \]
   -reaction reversed at lungs
2. ~ 23% as carbaminohemoglobin
3. CO₂ bound to amino groups of Hb
4. ~7% dissolved in plasma as CO₂

Regulation of Respiration
(handout)
Age Related Changes
1. Elastic tissue deteriorates:
   ↓ compliance, ↓ VC
2. Arthritic changes in rib cage:
   ↓ mobility, ↓ RMV
3. Emphysema, some degree
   ↓ gas exchange
   Higher risk for smokers, dusty job, etc.