Chapter 23
The Respiratory System

- Cells continually use $O_2$ & release $CO_2$
- Respiratory System designed for gas exchange
- Cardiovascular system transports gases in blood
- Failure of either system
  - rapid cell death from $O_2$ starvation
The Respiratory System in General

Structural Zones:

Upper Respiratory System:
- Nose
- Pharynx = Nasopharynx / Oropharynx / Laryngopharynx

Lower Respiratory System
- Larynx = voice-box
- Trachea = windpipe
- Bronchi = airways
- Lungs
Functional Zones

• Conducting Zone - filters, warms & moistens air
  – Nose
  – Nasal Cavity
  – Pharynx
  – Larynx
  – Trachea
  – Bronchi
  – Bronchioles
  – Terminal Bronchioles

• Respiratory Zone – site of gas exchange
  – Respiratory bronchioles
  – Alveolar ducts
  – Alveolar sacs
  – Alveoli
Functional Zones

Number of branches:

1. Trachea
2. Primary bronchus

Terminal bronchioles (60,000)

Bronchial tree

Respiratory bronchioles (500,000)

Air flow

Terminal bronchiole

Respiratory zone

Alveolar sacs (8 million)

Alveolar

Alveolus
Skin, nasal bones, & cartilage lined with mucous membrane
Openings called external nares or nostrils
Nose - Internal Structures

- Warming, moistening and filtering incoming air
- Detecting olfactory stimuli
- Modifying speech vibrations as they pass through the large, hollow resonating chambers
Path of Air

- Nostrils
- Vestibule – has course hairs that filter dust
- Over three shelves lined formed by projections of conchae and lined with mucous membranes
- Groove like passages called meatuses formed by shelves
- Capillaries warm air as it whirls around conchae and meatuses. Goblet cells produce mucous moistens and traps dust. Drainage from nasolacrimal ducts also moistens air. Cilia move mucus and trapped dust toward the pharynx for swallowing or to be spit out.
Ciliated pseudostratified columnar epithelium with goblet cells produce a moving mass of mucus / smoking destroys cilia
Pharynx

- Muscular tube (5 inch long) hanging from skull
  - skeletal muscle & mucous membrane
- Extends from internal nares to larynx
  - passageway for food and air
  - resonating chamber for speech production
  - tonsil (lymphatic tissue) in the walls protects entry-way into body
- 3 anatomical regions –
  - Nasopharynx – passage for air only
  - Oropharynx – air and food passageway
  - Laryngopharynx (also called hypopharynx)– air and food and ends at esophagus and larynx
Epiglottis

- A leaf-shaped flap of cartilage at the root of the tongue, which is depressed during swallowing to cover the opening of the trachea.
- Part of the larynx
Anatomy of the Pharynx

- Nasopharynx
- Oropharynx
- Hypopharynx
- Nasal cavity
- Oral cavity
- Larynx
- Esophagus
- Trachea
The Anatomy of the Larynx

(a) Anterior view
- Epiglottis
- Hyoid bone
- Laryngeal prominence
- Thyroid cartilage
- Cricoid cartilage
- Tracheal cartilages

(b) Posterior view
- Epiglottis
- Cuneiform cartilage
- Vestibular ligament
- Vocal ligament
- Arytenoid cartilages
- Tracheal cartilages

(c) Sagittal section
- Hyoid bone
- Thyroid cartilage
- Corniculate cartilage
- Arytenoid cartilage
- Cricoid cartilage

Figure 23.4
Cartilages of the Larynx / Voice Box

- Thyroid cartilage forms “Adam’s Apple”

- Epiglottis-leaf-shaped piece of elastic cartilage
  - during swallowing, larynx moves upward
  - epiglottis folds down to cover glottis when swallowing to divert food into esophagus and keep food out of trachea (wind pipe)
Movement of Vocal Cords

- Opening and closing of the vocal folds occurs during breathing and speech. Site of sound production.
Speech

• Speech is modified sound made by the larynx.
• Speech requires pharynx, mouth, nasal cavity & sinuses to resonate that sound

• Tongue & lips form words

• Pitch is controlled by tension on vocal folds
  – pulled tight produces higher pitch
  – male vocal folds are thicker & longer from effect of testosterone so vibrate more slowly producing a lower pitch
Trachea

- Size is 5 in. long & 1 inch in diameter
- Extends from larynx and splits into left and right bronchi
- Layers
  - mucosa = pseudostratified columnar with cilia
  - submucosa = loose connective tissue & seromucous glands
  - hyaline cartilage of 16 to 20 incomplete “C” rings
  - open side facing esophagus to accommodate swallowing
  - opening of “C” ring to the posterior
Bronchi and Bronchioles

- Primary bronchi supply each lung / branch forming secondary bronchioles
- Secondary bronchi supply each lobe of the lungs (3 right + 2 left)
- Tertiary bronchi supply each bronchopulmonary segment
- Repeated branching called bronchioles form a bronchial tree
Histology of Bronchial Tree

- Epithelium changes from pseudostratified ciliated columnar to non-ciliated simple cuboidal as pass deeper into lungs / smoking destroys cilia
- Incomplete rings of cartilage replaced by rings of smooth muscle & then connective tissue
Clara cells

- Also called Club cells
- Columnar, nonciliated cells among epithelial cells of bronchi
- May protect against harmful effects of inhaled toxins and carcinogens
- Produce surfactants
- Function as stem cells
Clara cells are found in terminal and respiratory bronchioles. The domed profile of the membrane on the lumenal surface and lack of cilia distinguish the Clara cells.
Lungs

- Paired cone-shaped organs in the thoracic cavity.
- Separated from each other by the heart and other structures of the mediastinum.
Membranes of the Lungs

- Pleural membrane – double layer serous membrane that encloses each lung.
  - Parietal pleura- superficial layer
  - Visceral pleura – deep layer which covers the lungs themselves.

- In between the two layers is the pleural cavity that contains a small amount of lubricating fluid secreted by the membranes.
Pleural Membranes & Pleural Cavity

- Visceral pleura covers lungs --- parietal pleura lines ribcage & covers upper surface of diaphragm
- Pleural cavity is potential space between ribs & lungs
Fissures divide lungs into lobes.
Lobule of the Lung

Lymphatic vessel
Arteriole
Venule
Branch from Terminal Bronchi

All wrapped in elastic tissue

(a) Diagram of a portion of a lobule of the lung

(b) Lung lobule
Alveoli

- 700 million in a typical set of lungs
- 70% of area is covered with capillaries
- Average diameter is 200 micrometers
Cells Types of the Alveoli

• Type I alveolar cells
  – simple squamous cells where gas exchange occurs

• Type II alveolar cells (septal cells)
  – secretes alveolar fluid containing surfactant
  – surfactant reduces the surface tension of the alveoli allowing them to open and receive air for gas exchange

• Alveolar macrophages – remove fine dust particles and other debris from alveolar spaces
Respiratory Membrane

- A layer of type I and II alveolar cells and macrophages form alveolar wall
- Epithelial basement membrane under the alveolar wall
- Capillary basement membrane often fused to basement membrane
- Capillary endothelium
Details of Respiratory Membrane

Capillary

Monocyte (“fixed” in CT)

Type II alveolar (septal) cell

Respiratory membrane

Type I alveolar cell

Alveolar macrophage

Red blood cell

Air Space

Diffusion of O₂

Diffusion of CO₂

Alveolus

Capillary endothelium

Capillary basement membrane

Epithelial basement membrane

Type I alveolar cell

Interstitial space

Alveolar fluid with surfactant
1. Pulmonary Ventilation / Breathing

- Inspiration / Air moves into lungs when pressure inside lungs is less than atmospheric pressure

- Expiration / Air moves out of the lungs when pressure inside lungs is greater than atmospheric pressure

- Movement of gases from changes of pressure & concentration of oxygen & carbon dioxide
Boyle’s Law

- As the size of a closed container decreases, the pressure inside is increased, size & volume of lungs change.
- The molecules have less wall area to strike so the pressure on each inch of area increases.
• When alveolar pressure decreases, air “rushes in.”
• When alveolar pressure increases, air “rushes out.”
Inspiration

Expiration

atmospheric pressure: 760

intrapleural pressure: 756

intrapulmonary pressure: 760

Rest

Inspiration

Expire

Fig. 41.12b, p. 716
External Respiration

- Exchange of gas ($O_2$ & $CO_2$) between air & blood

- Gases diffuse from areas of high partial pressure to areas of lower partial pressure

- Deoxygenated blood becomes saturated

- Compare gas movements in pulmonary capillaries to tissue capillaries
Internal Respiration

- Exchange of gases between blood & tissues

- Conversion of oxygenated blood into deoxygenated blood

- Note: diffusion of $O_2$ inward
  - at rest 25% of available $O_2$ enters cells
  - during exercise more $O_2$ is absorbed

- Note: diffusion of $CO_2$ outward
Gas Transport

- Oxyhemoglobin contains 98.5% chemically combined oxygen and hemoglobin
  - inside red blood cells
  - $\text{Hgb} + \text{O}_2 = \text{oxyhemoglobin}$ is “bright red”
  - Deoxyhemoglobin is “blue”
  - only 1.5% of oxygen transported dissolved in blood

- There are several factors affecting dissociation of $\text{O}_2$ from hemoglobin: pH, $\text{CO}_2$ levels, temperature

- Remember - the Hbg has a lot of $\text{O}_2$ to dissociate from and it must dissociate at the right time and place in body
Carbon Dioxide Transport

• Is carried by the blood in 3 ways
  1. 7% dissolved in plasma
  2. 23% combined with the Globin part of Hb molecule forming Carbamino-hemoglobin
  3. 70% as part of a Bicarbonate Ion
    • $\text{CO}_2 + \text{H}_2\text{O} \rightleftharpoons \text{H}_2\text{CO}_3 \rightleftharpoons \text{H}^+ + \text{HCO}_3^-$ (bicarbonate)
      • bicarbonate dissociates to $\text{CO}_2$ in lungs

$\text{CO}_2 + \text{H}_2\text{O} \rightleftharpoons \text{H}_2\text{CO}_3 \rightleftharpoons \text{H}^+ + \text{HCO}_3^-$ (bicarbonate)
Control of Respiration

• Homeostasis control mechanisms involve 3 components:
  – Receptors
  – Control Centers
  – Effectors

• Chemical factors primarily control respiration
  – Arterial $P_{CO_2}$ and $P_{O_2}$
  – pH
  – Monitored by chemoreceptors which send impulses to the respiratory centers in the pons and medulla of the brain
Involuntary respiration controlled by neurons in pons and medulla of the brain stem.
• [H\(^+\)] – sensed by chemoreceptors
• As CO\(_2\) increases, [H\(^+\)] increase which lowers blood pH
  – Breathing rate and depth will increase to release excess CO\(_2\)
  – Other factors that can decrease blood pH
  – Increase lactic acid from exercise
• Hyperventilation lowers CO\(_2\)