Gas Exchange Surfaces

- **Respiration** is the sequence of events that results in gas exchange between the body’s cells and the environment.
  - Ventilation
  - External Respiration
  - Internal Respiration
Gas Exchange Surfaces

• For diffusion to be effective, gas-exchange regions must be:
  - Moist
  - Thin
  - Relatively large surface area
  - Vascular

  Effectiveness of diffusion is enhanced by vascularization, and delivery to cells is promoted when the blood contains a respiratory pigment (hemoglobin).
Figure 42.19  Diversity in the structure of gills, external body surfaces functioning in gas exchange

(a) Sea star
(b) Marine worm
(c) Clam
(d) Crayfish
Figure 42.22 Tracheal systems
Water Environments

- Water fully saturated with air contains only a fraction of the oxygen present in the same volume of air.
  - Aquatic animals expend more energy to breathe than do terrestrial animals.
    - Hydras and planarians have a large surface area, making it possible for most of their cells to exchange gases directly with the environment.
Animal Shapes and Gas Exchange
Gas Exchange

- Aquatic animals often have gills, finely divided vascularized outgrowths of inner body surface.
  - Gills of bony fishes are outward extensions of pharynx.
  
  ![Ventilation]
  
  Ventilation is brought about by combined action of the mouth and gill covers (operculum).

- Countercurrent Exchange
Figure 42.21  Countercurrent exchange

Water flow over lamellae showing % O₂

Blood flow through lamellae showing % O₂
Land Environments

- Insects and other terrestrial arthropods have a respiratory system consisting of tracheae.
  - Oxygen enters tracheae at spiracles.
  - Brach until end in tracheoles that are in direct contact with body cells.
Tracheae of Insects
Lungs

- Terrestrial vertebrates have evolved lungs.
  - Vascular outgrowths from lower pharyngeal region.
    - Lungs of amphibians possess a short tracheae which divides into two bronchi that open into lungs.
      - Many also breathe to some extent through skin.
    - Inner lining of lungs is more finely divided in reptiles than in amphibians.
Respiration in Amphibians versus Reptiles
Lungs

• Lungs of birds and mammals are elaborately subdivided.
  - Terrestrial vertebrates ventilate lungs by moving air into and out of the respiratory tract.
    - Reptiles, birds, and mammals use negative pressure to move air into the lungs.
    - Muscle contractions lower the diaphragm and raise the ribs. This creates a negative pressure in the thoracic cavity and lungs, and air flows into the lungs.
Lungs

- Following inspiration, expiration occurs.
  - In mammals, when the rib and diaphragm muscles relax, the rib cage is lowered and the diaphragm rises, thoracic pressure increases, forcing air out of the lungs.

- All terrestrial vertebrates, except birds, use a tidal ventilation system.
  - Air moves in and out by the same route.
Lungs

• Birds use a one-way ventilation mechanism.
  - Results in a higher partial pressure of oxygen in the lungs.
    ✷ Oxygen uptake with each breath is greater than in other vertebrates.
Figure 42.25  The avian respiratory system

Inhalation: Air sacs fill
Exhalation: Air sacs empty; lungs fill

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Human Respiratory System

- As air moves through the nose, pharynx, trachea, and bronchi to the lungs, it is filtered so it is free of debris, warmed, and humidified.
  - By the time air reaches the lungs, it is at body temperature and is saturated with water.
Human Respiratory System

- Air passes from pharynx through glottis.
  - Vocal cords embedded in mucous membrane.
- Larynx and trachea are permanently held open to receive air.
  - When food is swallowed, the larynx rises, and the glottis is closed by the epiglottis.
    - Backward movement of soft palate covers the entrance of nasal passages into the pharynx.
Human Respiratory System

- Trachea divides into two primary bronchi, which enter the right and left lungs.
  - Branching continues until there are a great number of bronchioles.
    - Each bronchiole terminates in an elongated space enclosed by alveoli.
Ventilation

- Humans breathe using a tidal mechanism.
  - Volume of thoracic cavity and lungs is increased by muscle contractions that lower the diaphragm and raise the ribs.
    - Create negative pressure in the thoracic cavity and lungs, and then air flows into the lungs during inspiration.
      - Increased hydrogen ion and carbon dioxide concentrations in the blood are the primary stimuli that increase breathing rate.
Figure 42.23ab  The mammalian respiratory system

- Pharynx
- Larynx
- Esophagus
- Trachea
- Right lung
- Bronchus
- Bronchiole
- Diaphragm
- Heart
- Nasal cavity
- Left lung
- Branch from the pulmonary vein (oxygen-rich blood)
- Terminal bronchiole
- Branch from the pulmonary artery (oxygen-poor blood)
- Alveoli

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Figure 42.24  Negative pressure breathing

Rib cage expands as rib muscles contract

Air inhaled

Rib cage gets smaller as rib muscles relax

Air exhaled

Inhalation
Diaphragm contracts (moves down)

Exhalation
Diaphragm relaxes (moves up)
Gas Exchange and Transport

• Most oxygen entering the pulmonary capillaries from the alveoli combines with hemoglobin in red blood cells to form oxyhemoglobin.
  - Some carbon dioxide combines with hemoglobin to form carbaminohemoglobin.
  ❖ Most of carbon dioxide is transported in the form of bicarbonate ion.
Figure 42.26  Automatic control of breathing

Nerve impulses trigger contraction of muscles

Cerebrospinal fluid

Pons

Breathing control centers

Medulla oblongata

Nerve impulses relay changes in CO₂ and O₂ concentrations

Carotid arteries

Aorta

Diaphragm

Rib muscles

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Respiration and Health

- Upper Respiratory Tract Infections
  - Strep Throat
    - *Streptococcus pyogenes*
  - Sinusitis
    - Infection of sinuses.
  - Tonsillitis
    - Infection of tonsils.
  - Laryngitis
    - Infection of larynx.
Respiration and Health

• Lower Respiratory Tract Infections
  - Acute bronchitis
    ✷ Infection of primary and secondary bronchi.
  - Pneumonia
    ✷ Viral or bacterial infection of the lungs where bronchi and alveoli fill with fluid.
  - Pulmonary tuberculosis
    ✷ Caused by tubercle bacillus.
Disorders

- **Pulmonary fibrosis**
  - Fibrous connective tissue builds up in the lungs.

- **Chronic bronchitis**
  - Airways inflamed and filled with mucus.

- **Emphysema**
  - Alveoli are distended and walls are damaged reducing surface area available for gas exchange.
Disorders

- **Asthma**
  - Airways are unusually sensitive to specific irritants.
    - When exposed to the irritants, the smooth muscles in the bronchioles undergo spasms.

- **Lung Cancer**
  - Begins with thickening and callusing of the cells lining the airways.
Common Bronchial and Pulmonary Diseases

Pneumonia
Alveoli fill with thick fluid, making gas exchange difficult.

Pulmonary Fibrosis
Fibrous connective tissue builds up in lungs, reducing their elasticity.
Common Bronchial and Pulmonary Diseases

**Pulmonary Tuberculosis**
Tubercles encapsulate bacteria, and elasticity of lungs is reduced.

**Emphysema**
Alveoli burst and fuse into enlarged air spaces. Surface area for gas exchange is reduced.

**Asthma**
Airways are inflamed due to irritation, and bronchioles constrict due to muscle spasms.

**Bronchitis**
Airways are inflamed due to infection (acute) or due to an irritant (chronic). Coughing brings up mucus and pus.