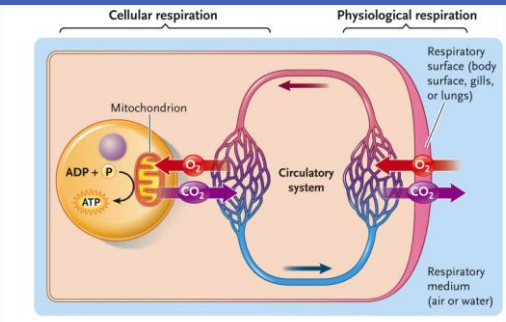
Gas Exchange: The Respiratory System

Chapter 44

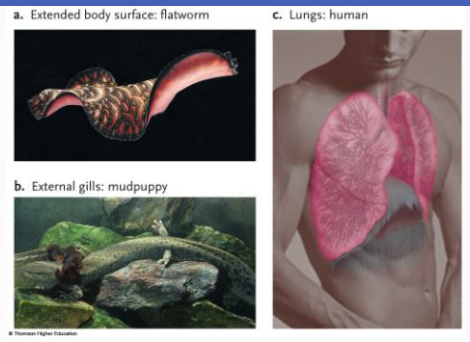
Respiration: Physiological and Cellular



Breathing (Gas Exchange)

- Two primary operating features of gas exchange
  - The respiratory medium, either air or water
  - The respiratory surface, a wetted epithelium over which gas exchange takes place
- In some invertebrates, the skin is the respiratory surface
- In other invertebrates and all vertebrates, gills or lungs are the primary respiratory surfaces

Respiratory Surface Area



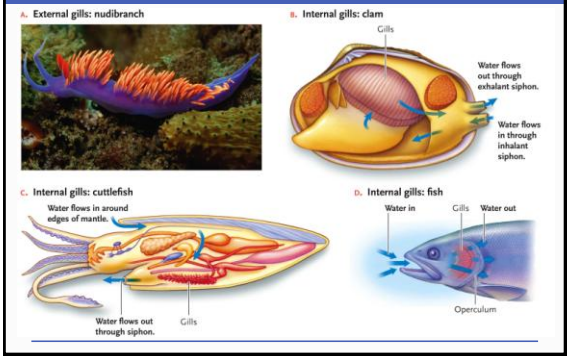
Gas Exchange

- Simple diffusion of molecules drives exchange of gases across the respiratory surface
- **Area of respiratory surface** determines total quantity of gases exchanged by diffusion
- **Respiratory surfaces must be thin, why?**
- Concentration gradients of O_2 and CO_2 across respiratory surfaces are kept at optimal levels by ventilation and perfusion

Water Breathers

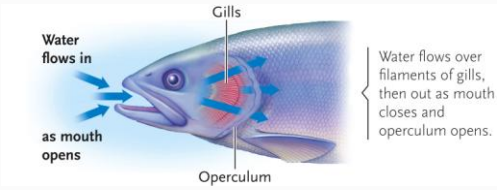
- Respiratory surfaces are wetted by direct exposure to the environment
- Require significant energy to keep respiratory surfaces ventilated
  - High density and viscosity of water
  - Relatively low O_2 content compared with air

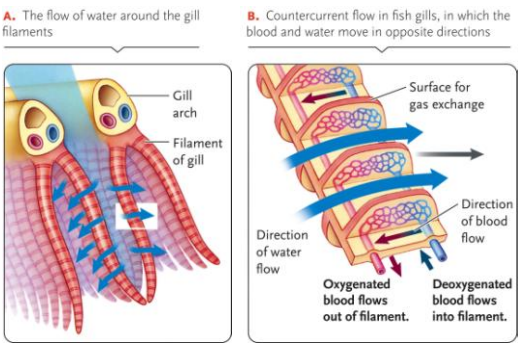
External and Internal Gills

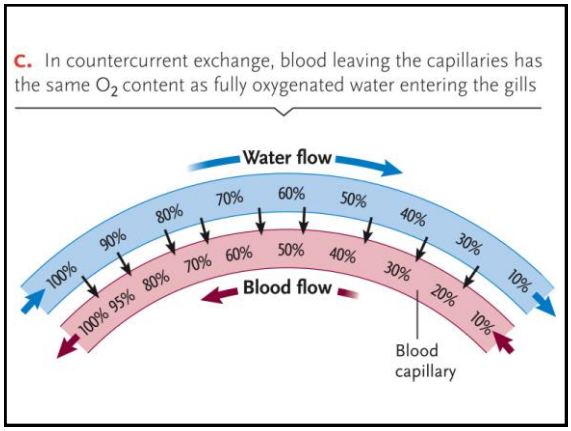


Countercurrent Exchange

- In sharks, bony fishes, and some crabs
  - Water moves in a one-way direction over the gills, against (or opposite) the flow of blood
  - Maximizes exchange of gases over the respiratory surface



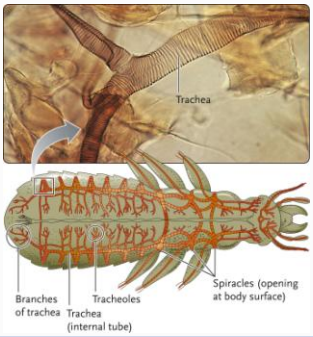




Air Breathers

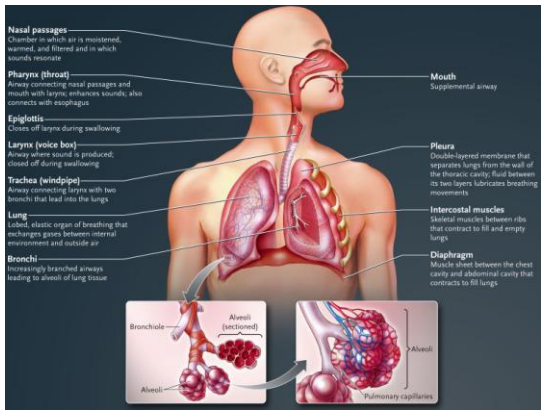
- Air is high in O_2 content
  - Allows air-breathers to maintain higher metabolic levels than water breathers
- Air has lower density and viscosity than water
  - Allows air breathers to ventilate respiratory surfaces with relatively little energy
- **What is the disadvantage of breathing air?**

Insects: Tracheal System

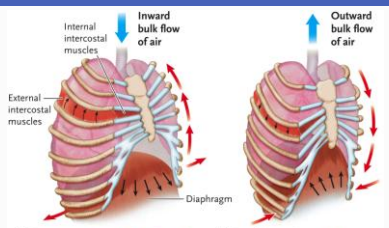


Lungs (Air Breathers)

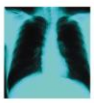
- Invaginations of the body surface
  - Allow air to become saturated with water before it reaches the respiratory surface
- Lung ventilation
  - Positive pressure breathing (frogs)
  - Negative pressure breathing (reptiles and mammals)
  - Birds have the most complex and efficient system (read about this in the text)



Respiratory Movements



Inhalation. Diaphragm contracts and moves down. The external intercostal muscles contract and lift rib cage upward and outward. The lung volume expands.



Exhalation during breathing or rest. Diaphragm and external intercostal muscles return to the resting positions. Rib cage moves down. Lungs recoil passively.

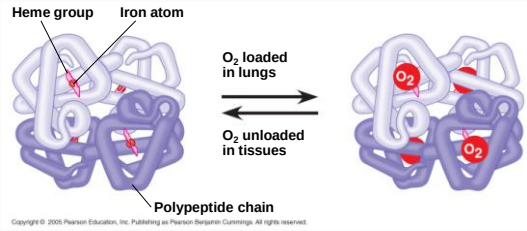
Measuring Lung Ventilation

- Tidal volume
  - Amount of air moved in and out of lungs during an inhalation and exhalation
- Vital capacity
  - Total volume of air a person can inhale and exhale by breathing as deeply as possible
- Residual volume
  - Air remaining in the lungs after as much air as possible is exhaled

O_2 Transport

- O_2 diffuses from alveolar air into blood
  - **Partial pressure** of oxygen is higher in the alveolar air than in the blood capillaries at the lungs
- Most O_2 entering the blood combines with hemoglobin inside erythrocytes
- The respiratory pigment of almost all vertebrates is the protein **hemoglobin**
- Like all respiratory pigments, hemoglobin must reversibly bind O_2, **loading O_2 in the lungs** and **unloading it in other parts of the body**

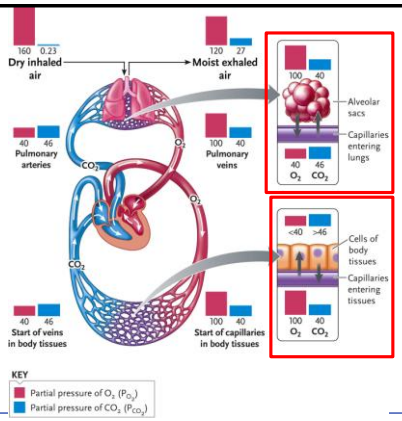
Hemoglobin



Hemoglobin consists of four subunits, each with a cofactor called a **heme group** that has an iron atom at its center

O_2 Diffuses into Body Cells

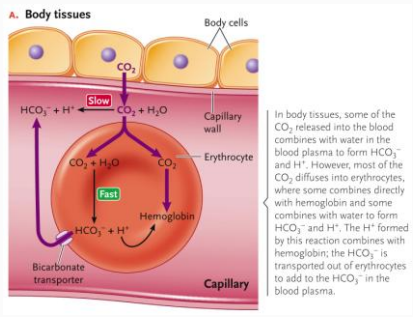
- O_2 concentration (**partial pressure of oxygen**) in interstitial fluid and body cells is lower than in blood plasma
- **O_2 diffuses from blood** into interstitial fluid, and from interstitial fluid **into body cells**
- ***Effect of pH*** on oxygen release from hemoglobin
  - ***Bohr shift (effect)***: O_2 released from hemoglobin at lower pH (higher CO_2 concentration)
  - **Carbonic acid (H_2CO_3)**



CO_2 Transfer: Body Tissues

- **Partial pressure of CO_2** is higher in tissues than in blood
  - About 10% of CO_2 dissolves in blood plasma
  - **70% is converted into H^+ and HCO_3^- (bicarbonate) ions**
  - 20% combines with hemoglobin

CO_2 Transfer: Body Tissues



CO_2 Transfer: Lungs

- In the lungs, **partial pressure of CO_2** is higher in blood than in alveolar air
  - Reactions packing CO_2 into blood are reversed
  - CO_2 is released from blood into alveolar air

CO_2 Transfer: Lungs