Chapter 41—Gas Exchange and Circulation

I. To Produce ATP, Animals Must Obtain O₂ and Eliminate CO₂
   A. Air has advantages over water as a respiratory medium.
      1. Air
         a. Concentration of oxygen 21% (measured in parts per hundred)
         b. Temperature has relatively little effect on concentration of oxygen
         c. Not particularly heavy
      2. Water
         a. Concentration of oxygen 0.08% (measured in parts per million)
         b. Warm water holds significantly less oxygen than cold water
         c. Because it’s about 1,000 times denser than air, water breathers expend much more energy for ventilation than air breathers
   B. Gas-exchange organs evolved to maximize the rate of diffusion.
      1. Definition of terms in diffusion equation Figure 41.4
         \[ K = \text{Diffusion constant, depends on solubility of gas \& temperature} \]
         \[ A = \text{Area for gas exchange} \]
         \[ D = \text{Distance or thickness of barrier to diffusion} \]
         \[ P = \text{Partial pressure on either side of a barrier to diffusion} \]
         Example: Partial pressure of O₂ at sea level:
         \[ 760 \text{ mm Hg (air pressure)} \times 0.21 \text{ (% of air that is O₂)} = 160 \text{ mm Hg} \]
      2. Oxygen and carbon dioxide gases diffuse most rapidly when a large, extremely thin surface area is available for gas exchange Figure 41.5
      3. Fish gills possess an efficient counter-current exchange system Figure 41.6
      4. Insects pump air into \& out tubes called tracheae that open onto surface at spiracles Figure 41.7
      5. Birds have an open-ended system Figures not in text
         a. More efficient than mammalian system
         b. Air flow is circular
      6. Mammals have a dead-end system Figures 41.8 \& 41.9
         a. Air enters lungs through a tube called trachea when diaphragm muscle contracts
         b. Exchange of gasses between air \& blood occurs in sacs called alveoli (alveolus singular)

II. Blood Transports O₂ and CO₂ between Site of Gas Exchange and Respiring Tissues
   A. The respiratory pigment hemoglobin transports O₂.
      1. COOPERATIVE BINDING
         a. The functional hemoglobin molecule has 4 subunits
         b. The binding of an O₂ to one subunit of hemoglobin causes a change in shape in the protein that makes the other three subunits more likely to bind O₂
      2. Cooperative binding of O₂ to hemoglobin generates a sigmoidal relationship between partial pressure of oxygen levels and degree of hemoglobin oxygen saturation. Figure 41.10a \& b
a. Because of cooperative binding, blood does not release all its oxygen at once.
b. Blood can carry oxygen to many organs that need it.

3. The BOHR SHIFT  Figure 41 10c
   a. pH As pH levels drop (become more acidic) O₂ is less likely to bind to hemoglobin
   b. Hemoglobin releases O₂ in muscles during exercise (increase in lactic acid) or when CO₂ concentration is high

B. Most of the CO₂ is transported in the blood as bicarbonate ions, while some is bound to amino groups and dissolved as a gas. Figure 41.11
   a. CO₂ is converted quickly in the blood to bicarbonate by the enzyme carbonic anhydrase
   b. The above reaction maintains a high difference in partial pressure of CO₂ between tissues and blood

III. Blood or Hemolymph Is Circulated to Tissues Using Pressure Gradients Generated by Pumps Called Hearts
   A. Open circulatory systems are low-pressure systems. Figure 41.12
      1. They have arteries and veins and NO capillaries
      2. Arthropods & mollusks
   B. Vertebrates have closed circulatory systems maintain large pressure gradients for rapid delivery and redirection of blood flow.
      1. Anatomy
         a. Have arteries & veins
         b. Capillaries with walls one cell thick Figure 41.13
      2. Maintain large pressure gradients for rapid delivery and redirection of blood flow Figure 41.14
      3. Heart chambers Figures 41.15 & 16
         c. Atria (plural) receive blood and pump it to ventricles
         d. Ventricles pump blood to body organs
         e. Fish have 1 atrium & 1 ventricle (2 chambers), one circulation loop
         f. Amphibians & reptiles (except crocodiles) have 2 atria, 1 ventricle (3 chambers) & 2 circulation loops
         g. Crocodiles, birds & mammals have 2 atria, 2 ventricles (4 chambers), & 2 circulation loops