Pressure and Atmospheric Gases

- **Partial Pressure of gases: *$PV=nRT$***
- **According to Dalton's Law:**
  $P_{TOT}V = V(P_1 + P_2 + \ldots + P_n)$, so partial pressure of gas x (P_x) is:
  $P_x = (P_{TOT} \times \%\ x)/100$
- **In dry air at sea level, P_{TOT} = 760 mm Hg, and:**

N_2	= 78.1%	P_{N_2}	= 594 mm Hg
O_2	= 20.95%	P_{O_2}	= 159 mm Hg
CO_2	= 0.03%	P_{CO_2}	= 0.23 mm Hg

- **Have to factor in water vapor pressure (P_{H_2O}):**

$P_{TOT}V = V(P_1 + P_2 + \ldots + P_n + P_{H_2O})$

***Example:* in saturated air at 20 °C, 760 mm Hg, P_{H_2O} = 17.5 mm**

Hg. P_{O_2} therefore = 0.2095(760 - 17.5) = 155 mm Hg

Standard Temperature and Pressure (STP)

- **STP is 0 °C (273 K) and 760 mm Hg**
- **Frequently used to present data in 'common' form**
  Example: dry air at (20.95% O_2) @ 20 °C and 740 mm Hg has 210 ml O_2/l @ STP. At STP:
  (273 K/293 K) × (740 mm Hg/760 mm Hg) = 190 ml O_2/l
- **Therefore, mass/vol ∝ moles/vol ∝ *vol @ STP*/vol. But, when dealing with volumes, must specify temperature and pressure**
- **At constant pressure, [gas x] ∝ P_x, increasing temperature decreases gas x**
- **The absorption coefficient (A) = volume in solution @ STP/l water. Influenced by temperature, salinity**
- **At equilibrium, P_x in water = P_x in air above it (gas tension)**

Partial Pressures and Blood

- **Partial pressures determine equilibria: *relative concentrations in air and water don't matter***

P_{O_2} in air	P_{CO_2} in air
↓↑	↓↑
P_{O_2} in solution in blood	P_{CO_2} in solution in blood
↓↑	↓↑
not HbO_2	*not* H_2CO_3
	↓↑
	not HCO_3^-

Don't participate in equilibrium (applies to *not* H_2CO_3 and *not* HCO_3^-)

Oxygen Availability in Different Media

For ml (STP) l^{-1} at P_{O_2} = 159 mm Hg:

Medium	0 °C	12 °C	24 °C
Air	208	200	192 (↓ 8%)
Distilled H_2O	10.2	7.7	6.2 (↓ 40%)
Seawater	8.0	6.1	4.9 (↓ 52%)

- Air is a (MUCH!) richer source of O_2 than water.
- Because organisms have to respire a certain amount of O_2, these differences determine how much air or water must pass over their respiratory surfaces
- Need 20× more water than air by volume
- Differences become apparent greater as temperature ↑. At P_{O_2} = 159 mm Hg and 0 °C, to obtain 1 l of O_2 requires passing 4.8 l of air, 98 l of distilled water, or 125 l of seawater over respiratory surface.
- Air breathing therefore supports the highest MRs, aquatic environments limited by low [O_2]. Ectotherms especially limited, as MR↑ with ↑T

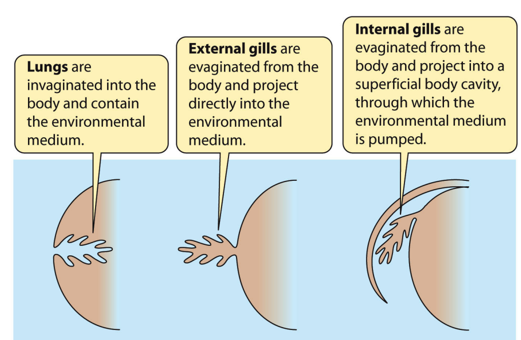
Gaseous Diffusion in Different Media

- **Rate of O_2 diffusion in air is 300,000× greater than in water**
- **Organisms compensate by:**
  - **Moving through water ('ram ventilation')**
  - **Pumping water over gills**
  - **Staying in moving water**
- **Rate of CO_2 diffusion in air is less than O_2, rate of CO_2 diffusion in water is about 25× greater than O_2**

		Air	*Water*
Density (g/ml @ 17 °C)		0.0012	about 1 (800× greater)
Viscosity		0 °C	Water about 100× greater than air
		40 °C	Water about 35× greater than air

Increased density and viscosity means that more energy must be expended to move water over respiratory surfaces
***Example*: humans use 1-2% of RMR for ventilation**
fishes use 10-20% of RMR for ventilation

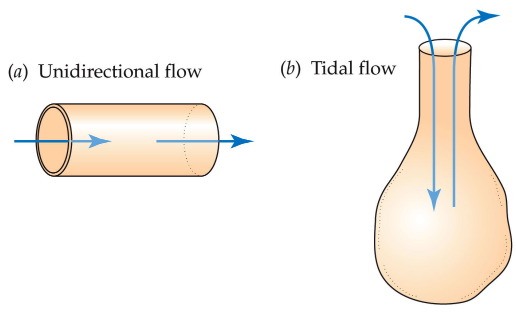
Figure 22.2 Three types of specialized breathing structures



Animal Physiology 2e, Figure 22.2

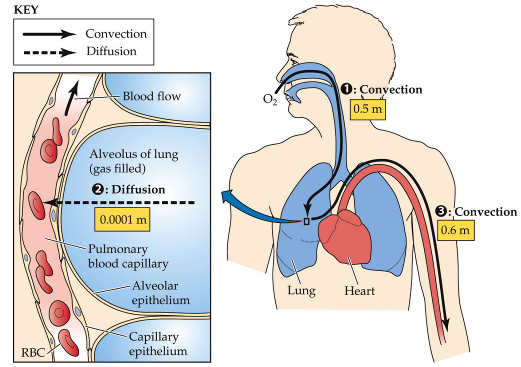
Gas Exchange and Breathing

Figure 21.5 Two types of convective transport



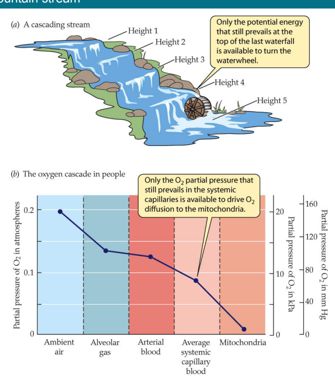
Animal Physiology 2e, Figure 21.5

Figure 21.6 Convection and diffusion alternate in transporting O_2 from the atmosphere to the mitochondria in a person (Part 1)



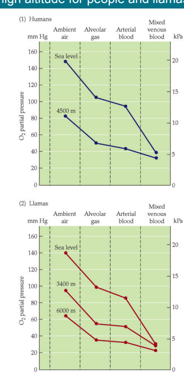
Animal Physiology 2e, Figure 21.6 (Part 1)

Figure 21.7 The concept of the physiological oxygen cascade is based on an analogy with a cascade along a mountain stream



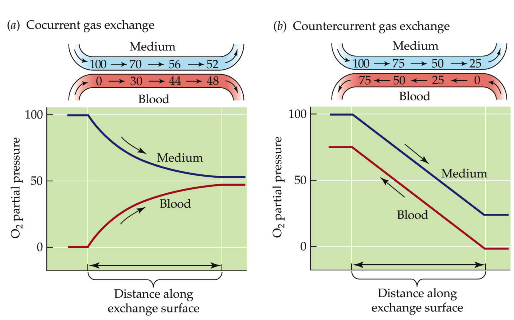
Animal Physiology 2e, Figure 21.7

Box 22.2 Oxygen cascades at high altitude for people and llamas



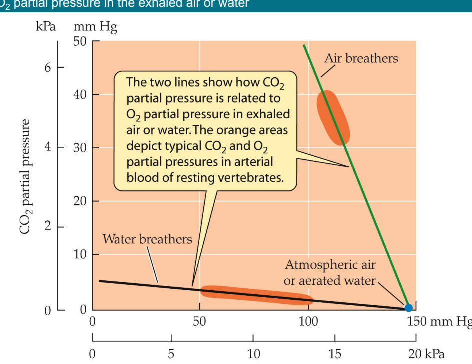
Animal Physiology 2e, Box 22.2

Figure 22.4 Cocurrent and countercurrent gas exchange: Two modes of O_2 transfer from the environmental medium to the blood when ventilation is unidirectional



Animal Physiology 2e, Figure 22.4

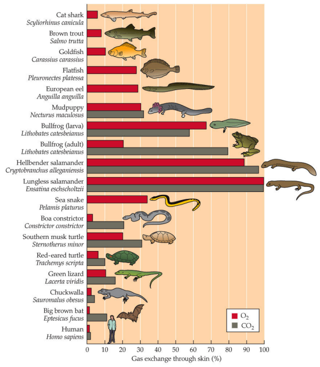
Figure 22.6 Air breathers and water breathers: Simultaneous values for the CO_2 partial pressure and O_2 partial pressure in the exhaled air or water



Animal Physiology 2e, Figure 22.6

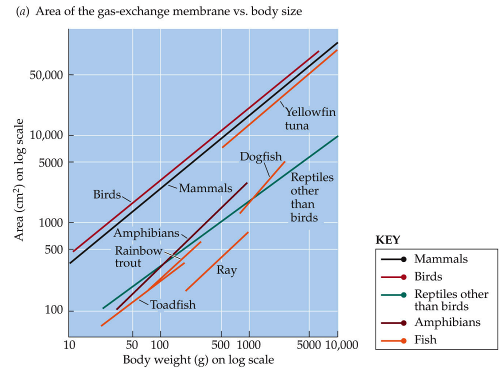
Gas Exchange and Breathing

Figure 22.8 The percentage of O_2 and CO_2 exchange that occurs across the skin in vertebrates



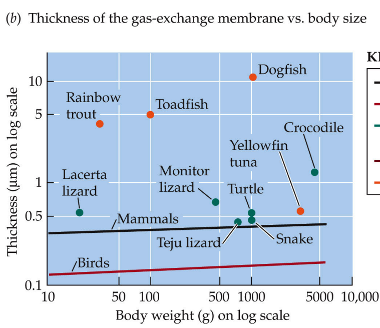
Animal Physiology 2e, Figure 22.8

Figure 22.7 Total area and thickness of the gas-exchange membrane in the gills or lungs of vertebrates as functions of body size (Part 1)



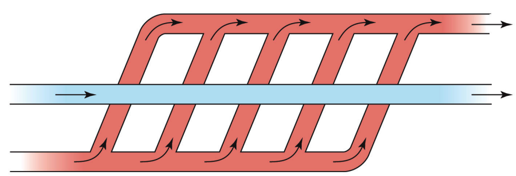
Animal Physiology 2e, Figure 22.7 (Part 1)

Figure 22.7 Total area and thickness of the gas-exchange membrane in the gills or lungs of vertebrates as functions of body size (Part 2)



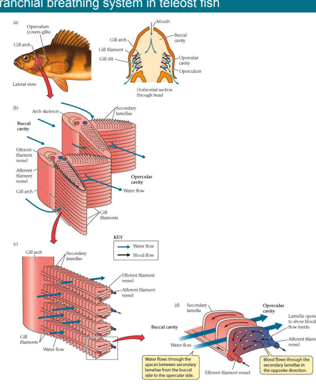
Animal Physiology 2e, Figure 22.7 (Part 2)

Figure 22.5 Cross-current gas exchange: A third mode of O_2 transfer from the environmental medium to the blood when ventilation is unidirectional



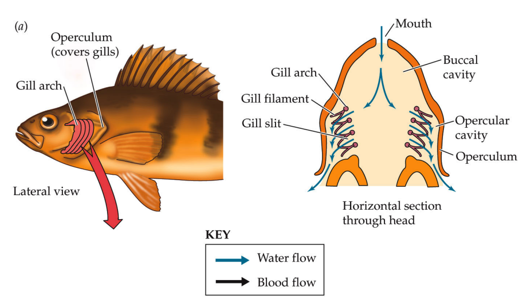
Animal Physiology 2e, Figure 22.5

Figure 22.10 The branchial breathing system in teleost fish



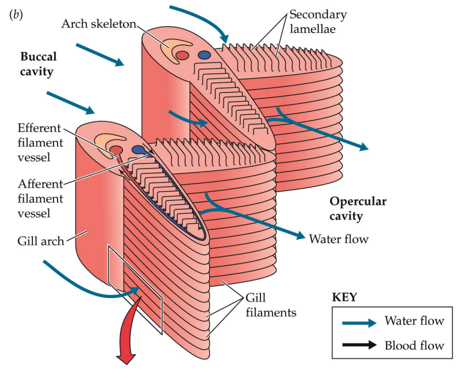
Animal Physiology 2e, Figure 22.10

Figure 22.10 The branchial breathing system in teleost fish (Part 1)



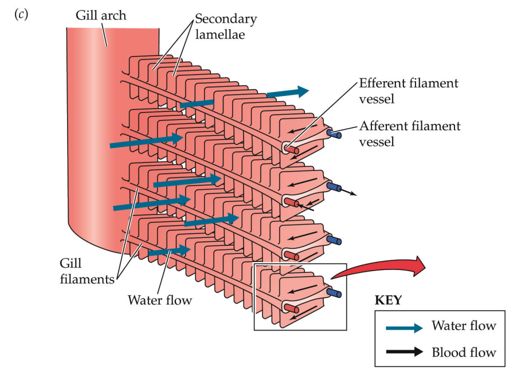
Animal Physiology 2e, Figure 22.10 (Part 1)

Figure 22.10 The branchial breathing system in teleost fish (Part 2)



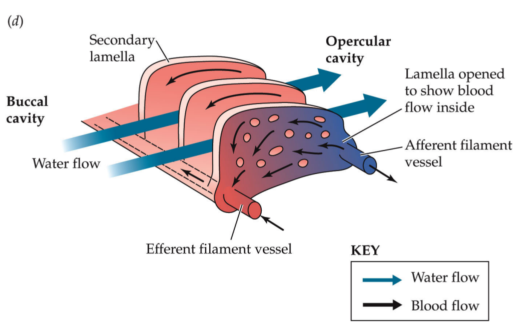
Animal Physiology 2e, Figure 22.10 (Part 2)

Figure 22.10 The branchial breathing system in teleost fish (Part 3)



Animal Physiology 2e, Figure 22.10 (Part 3)

Figure 22.10 The branchial breathing system in teleost fish (Part 4)

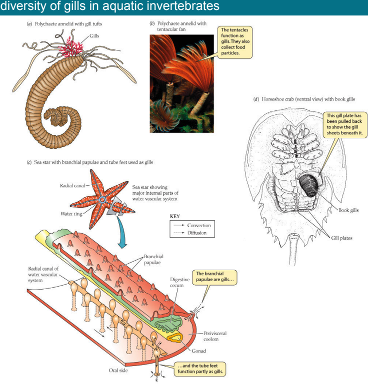


Animal Physiology 2e, Figure 22.10 (Part 4)

Chapter 22 Opener Throughout the animal kingdom, species that depend on vigorous endurance exercise for survival—such as tunas—must be able to acquire oxygen rapidly

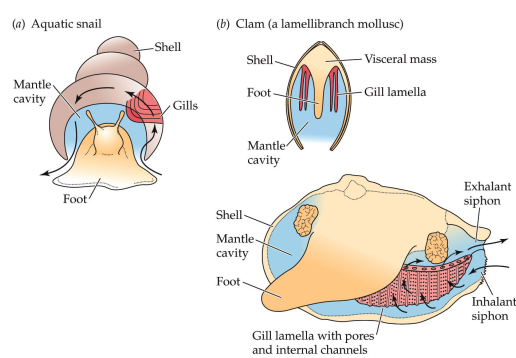
Animal Physiology 2e, Chapter 22 Opener

Figure 22.25 A diversity of gills in aquatic invertebrates



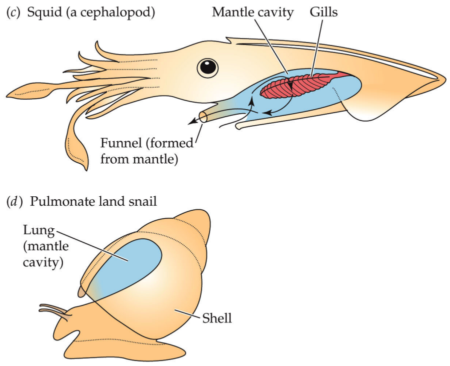
Animal Physiology 2e, Figure 22.25

Figure 22.26 The diversification of the breathing system in molluscs (Part 1)



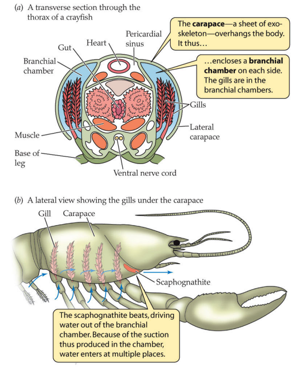
Animal Physiology 2e, Figure 22.26 (Part 1)

Figure 22.26 The diversification of the breathing system in molluscs (Part 2)



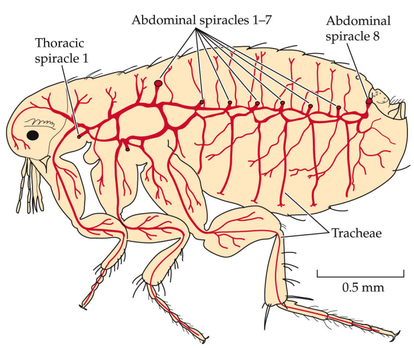
Animal Physiology 2e, **Figure 22.26 (Part 2)**

Figure 22.27 The gills and ventilation in a crayfish



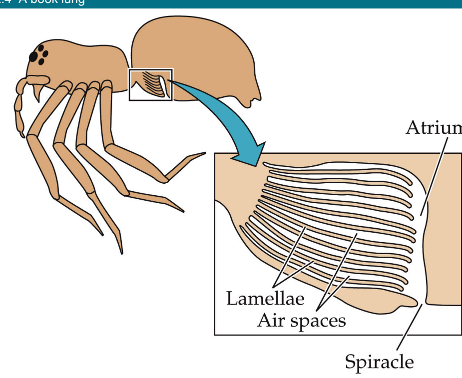
Animal Physiology 2e, **Figure 22.27**

Figure 22.29 Insects breathe using a tracheal system of gas-filled tubes that—branching and rebranching—reaches all tissues from the body surface (Part 1)



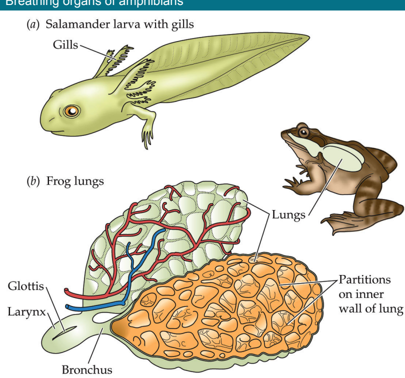
Animal Physiology 2e, **Figure 22.29 (Part 1)**

Box 22.4 A book lung



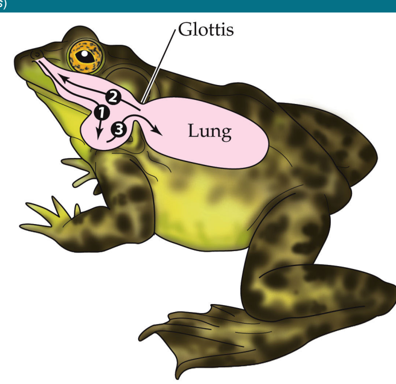
Animal Physiology 2e, **Box 22.4**

Figure 22.13 Breathing organs of amphibians



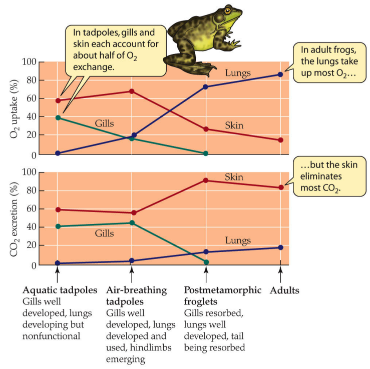
Animal Physiology 2e, **Figure 22.13**

Figure 22.14 The three major steps in the ventilatory cycle of an adult bullfrog (*Lithobates catesbeianus*)



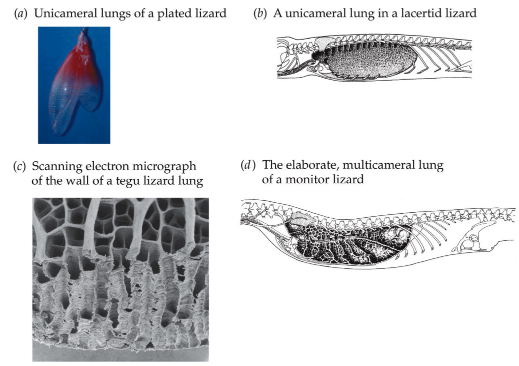
Animal Physiology 2e, **Figure 22.14**

Figure 22.15 The development of external respiration in the bullfrog (*Lithobates catesbeianus*)



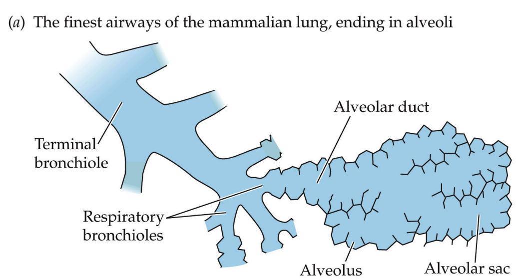
Animal Physiology 2e, Figure 22.15

Figure 22.16 Lizard lungs



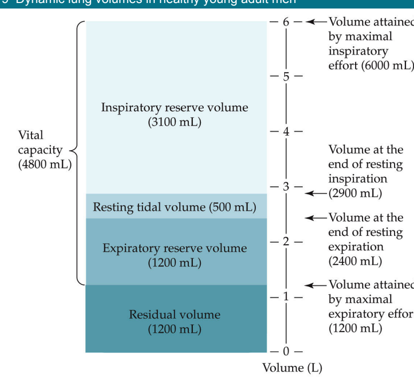
Animal Physiology 2e, Figure 22.16

Figure 22.18 Respiratory airways of the mammalian lung (Part 1)



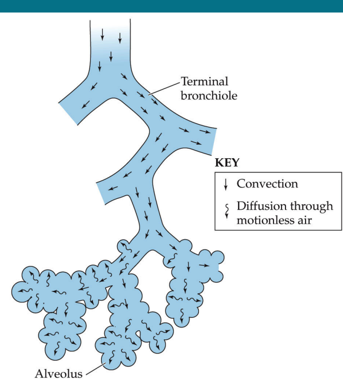
Animal Physiology 2e, Figure 22.18 (Part 1)

Figure 22.19 Dynamic lung volumes in healthy young adult men



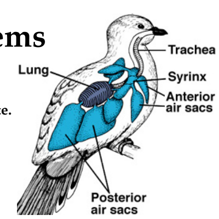
Animal Physiology 2e, Figure 22.19

Figure 22.20 Mechanisms of gas transport in the final branches of mammalian lungs during inhalation



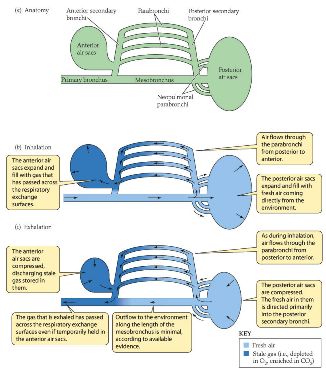
Animal Physiology 2e, Figure 22.20

Avian Respiratory Systems



- **Differs radically from the lungs of both reptiles and mammals.**
  - **Most efficient respiratory system of any vertebrate.**
- **The finest branches of the bronchi do not terminate in alveoli, but are tube-like *parabronchi*.**
  - **A large portion of the inspired air bypasses the lungs and flows directly to the air sacs.**
  - **On expiration, this oxygenated air flows through the lungs allowing continuous air flow.**
  - **It takes two respiratory cycles for a single breath of air to pass through the system.**
- **Air sacs extend into the thorax, abdomen, and even into the long bones.**
  - **This air sac system also helps cool birds during vigorous flying, when up to 27 times more heat is produced.**
  - **The air sacs in the bones, legs and wings can also provide considerable buoyancy to the bird (the usually warmer air acts like a hot air balloon).**

Figure 22.22 Airflow in the lungs and air sacs of birds



***Animal Physiology 2e*, Figure 22.22**