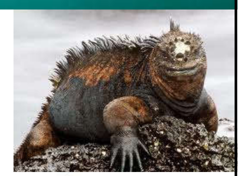
Aquatic herbivores






- Tend to be small
  - Few large macrophytes, phytoplankton more efficiently grazed by zooplankton
- Difficulties maintaining elevated body temperature to sustain active fermentation
  - Manatee – blubber, large body, reduced appendages, warm water
  - Marine iguana – leaves water to bask
- Fish
  - Ontogenetic shifts
  - Substantial detritus or microbial component taken with algae

Protection from Herbivory




- Increase cost to eat (SDA) or decrease assimilation efficiency
  - Physical defenses (thorns)
  - Digestion inhibitors (tannins)
  - Toxins (nicotine, mustard oil)
  - Contact poisons (poison ivy)
- Consumer-herbivore evolutionary arms race (red queen)
  - sulfur butterfly detoxify toxins, use it as feeding cue
  - Monarch butterfly sequester toxins in milkweek, use for protection from birds

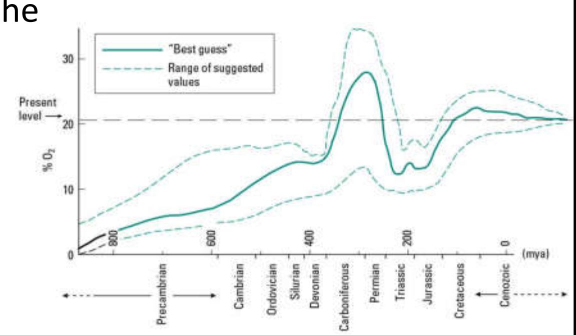
Animal Defenses

- Similar strategy…

- Physical defenses
- Toxins
- Avoidance
- Mimicry
- Size
- Chemical defenses
  - Bombadier beetle
    - Hydrogen peroxide+ hydroquinone → exothermic discharge

Gas Exchange and Circulation

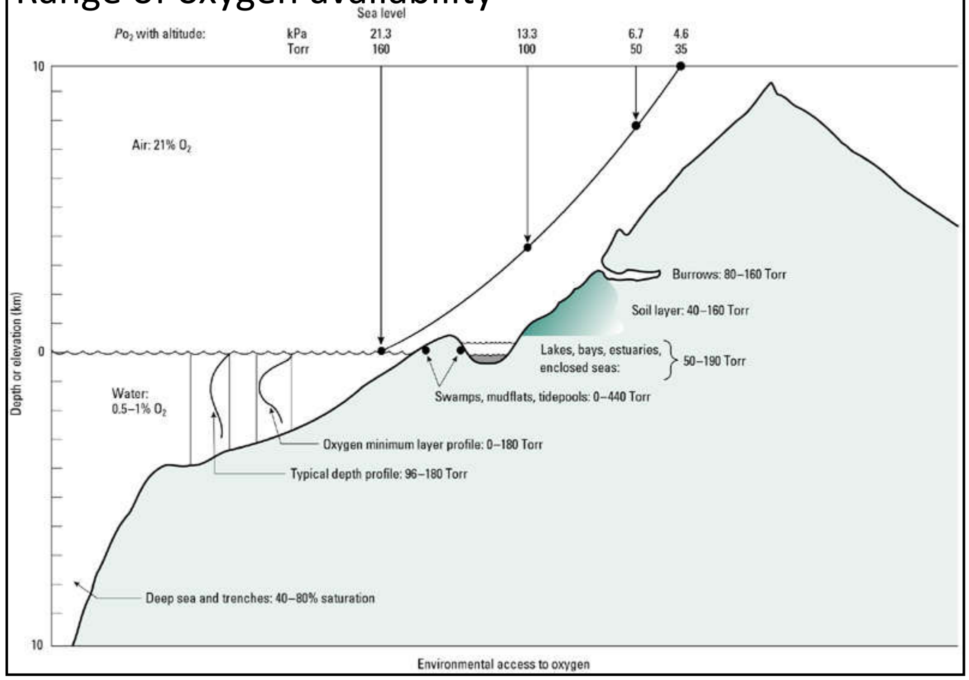
- Oxygen availability in the atmosphere



- **Dalton's Law**
  - Where p_i is the partial pressures of n individual gasses

$$P_{total} = \sum_{i=1}^{n} P_i$$

Range of oxygen availability



Oxygen availability

- Partial pressure in air (PO_2)
- Dissolved oxygen in water
  - Temperature
  - Salinity

Gas in atmosphere	**%**	**mm Hg**
Oxygen	20.95	159
CO_2	0.03	0.23
Nitrogen	79.0	600
Rare gases	~1.0	~7.6

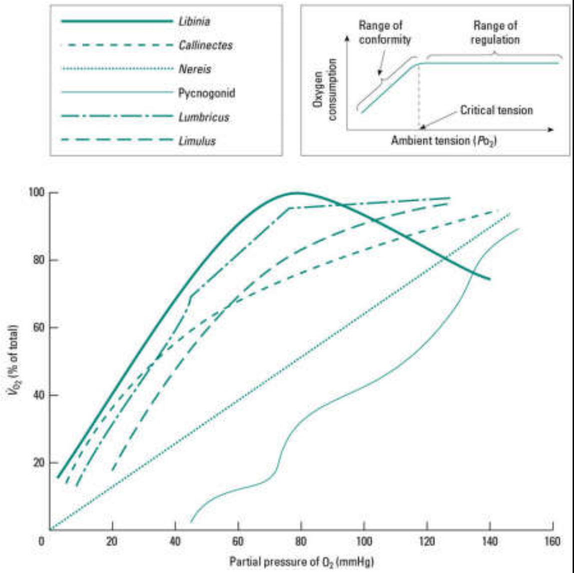
Atmospheric Pressure

Altitude (ft)	mm Hg	% sea level
0	760	100
3300	670	88
6600	593	78
13200	524	69
19800	357	47
24400	290	38

African condor files at 35,000 feet

Oxygen regulators and conformers

- Animals often not strict regulators or conformers
- **Critical partial pressure** – pressure below which animals do not regulate



Gas Exchange Basics

- All gas exchange is by diffusion influenced by
  - Permeability of surface
  - Thickness of surface
  - Surface area
  - Concentration differences across surface (environment-tissues)
- Exchange of both O_2 and CO_2

(a) (b)

Fig. 7.8 Aquatic tracheal systems with (a) no spiracles, cuticular diffusion only; (b) abdominal gills; and (c) rectal gills.

Table 7.3 The thickness of respiratory gas-exchange barriers (ambient medium to capillary or cell) in air-breathing animals.

Animal group/species	Diffusion distance (μm)
Crab	0.2–0.4
Insect	0.1–0.3
Fish (air-breathing)	
Haplochromis	
Gill	0.3–2.0
Saccobronchus	
Gill	3.6
Air sac	1.6
Anabas	
Gill	10
Branchial wall	0.2
Amphibian	
Toad	1.3–3.0
Birds	
Pigeon	0.1–1.4
Swallow	0.09
Mammals	
Rat	0.13–0.26
Human	0.36–2.5

Diffusion and solubility

- Oxygen diffuses faster than CO_2
- CO_2 is about 30x more soluble in water
- Thus, CO_2 appears to enter and move through water faster
- **Henderson Hasselbach Equation**
  - $CO_2 + H_2O \leftrightarrow H_2CO_3 \overset{K'}{\leftrightarrow} HCO_3^- + H^+ \overset{K''}{\leftrightarrow} CO_3^{-2} + 2H^+$

$$K' = \frac{[H^+][HCO_3^-]}{[H_2CO_3]}$$

  - K' typically much higher than K''
  - Most CO_2 dissolved in water winds up as $HCO_3^- + H^+$

$$\mathrm{pH} = \mathrm{pK}' + \log \frac{[\mathrm{HCO_3^-}]}{[\alpha_{\mathrm{CO_2}}][P_{\mathrm{CO_2}}]}$$

αCO_2 – solubility of CO_2
P_{CO2} – partial pressure of CO_2

Oxygen withdraw efficiency

Terrestrial animals	% withdrawal
Amphibians	1-2
Reptiles	5
Birds	31
Mammals	24

Aquatic animals	% withdrawal
Porifera	6-57
Annelida	30-70
Crustacea	40-70
Gastropoda	40-80
Cephalopoda	70-80
Echinoderms	50
Fishes	50-80