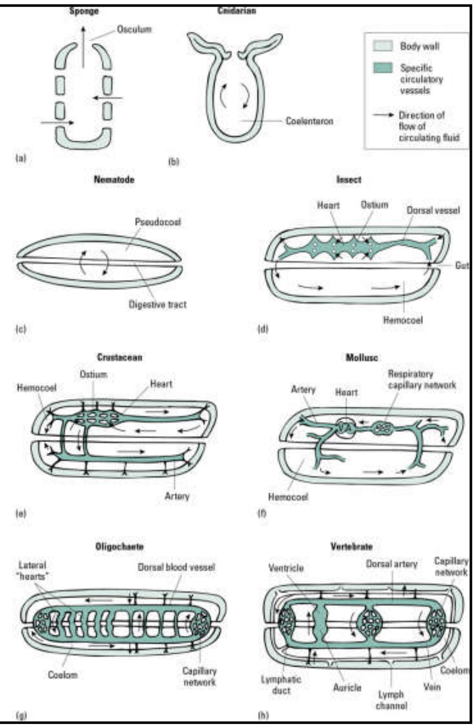
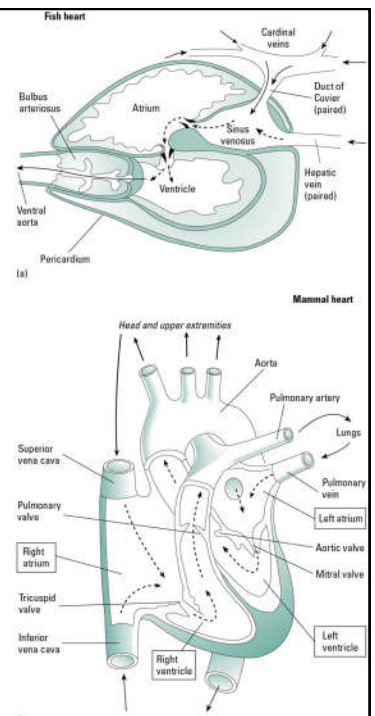
## Circulatory Systems

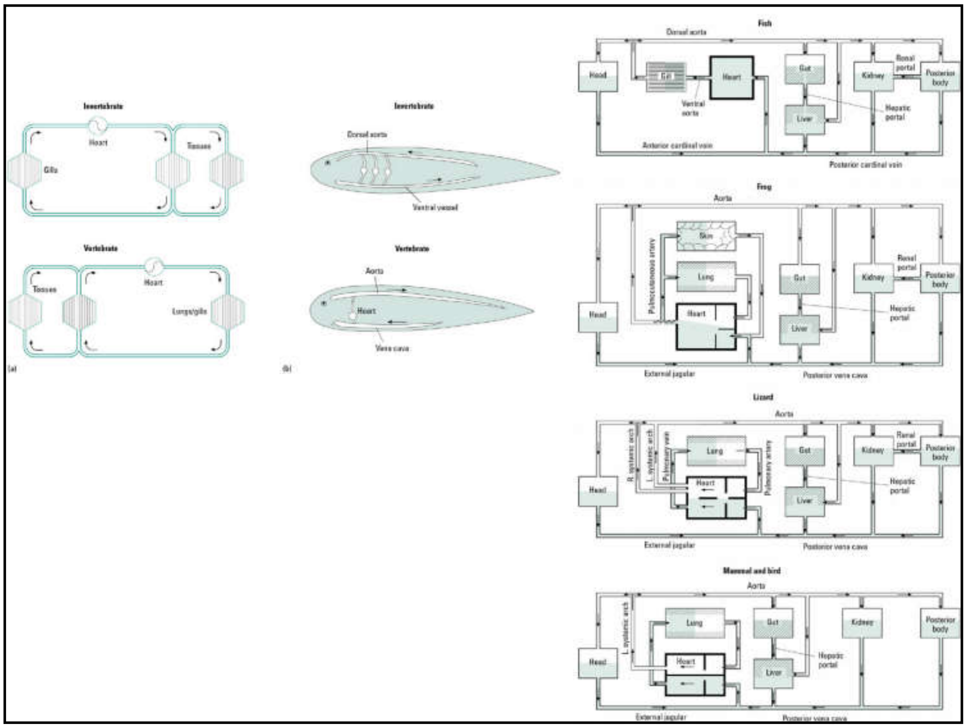
- Open vs. closed
- Components of hemolymph or blood
- Hearts
  - Simplest forms are thickened smooth muscle in arteries




## Vertebrate hearts

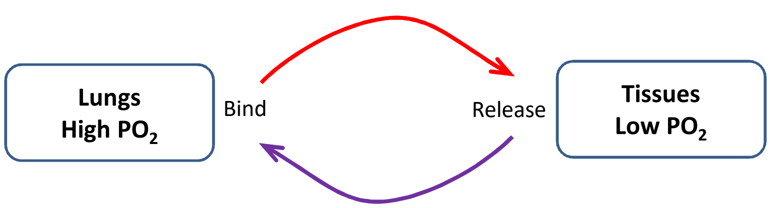
- Chambers isolate pulmonary and systemic circuits
- Blood pressure and regulation of flow rates
- Vasoconstriction and dilation
- Flow velocity minimized, area maximized in capillaries
- Flow pressure minimized in largest veins





## Respiratory Pigments

- Molecules that bind oxygen, facilitate transfer from respiratory surface to tissues that need it.

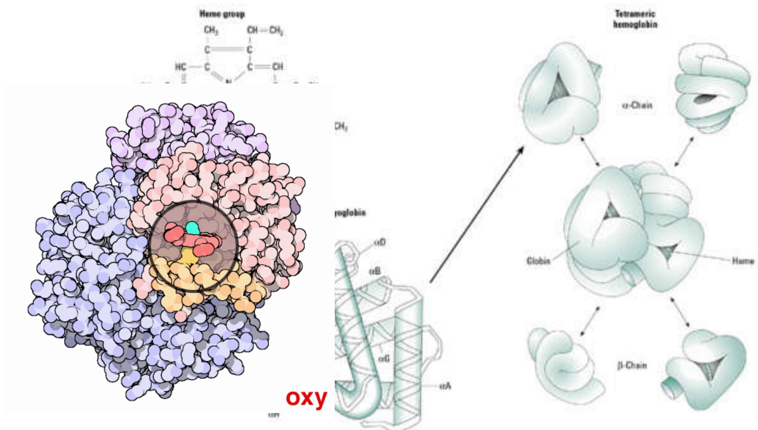



- **Oxygen affinity** –

- $\% \ saturation = \frac{[HbO_2]}{[Hb]+[HbO_2]}$ x 100

## Structure of Hemoglobin

- **Oxyhemoglobin** – bound with $O_2$, reversible
- **Deoxyhemoglobin** – not bound with oxygen, Fe reduced
- **Carbaminohemoglobin** – bound with $CO_2$, reversible
- **Carbon monoxide hemoglobin** – combined with CO, not reversible



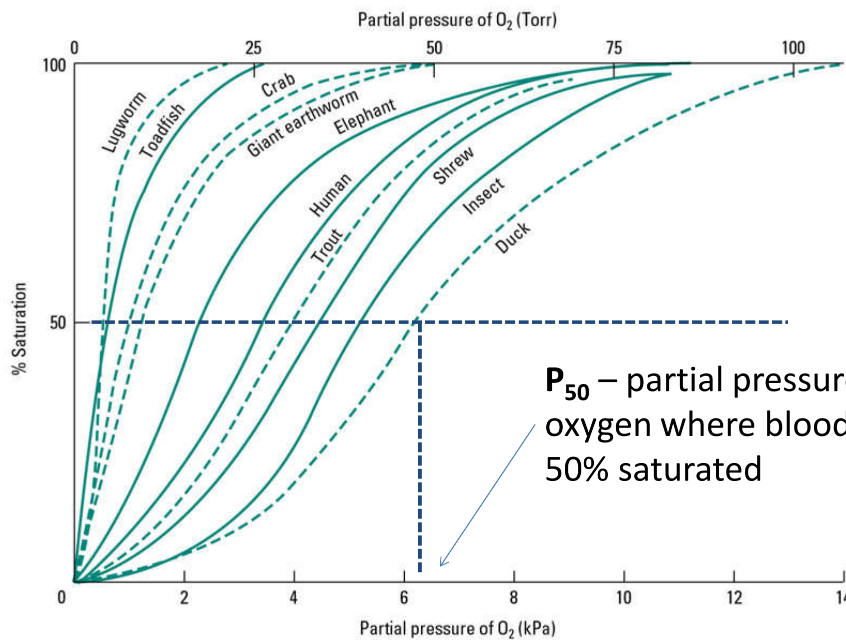

## Respiratory Pigments

| Pigment | Structure | Color (change) | Oxygen capacity (ml $g^{-1}$) | Molecular Weight (kDa) | Cells or Solution | Animal Groups |
|---|---|---|---|---|---|---|
| Hemocyanin | Protein+$Cu^{2+}$ | Blue (colorless) | 0.3-0.5 | 25-7000 | Solution | Mollusks, cephalopods, arthropods |
| Hemoglobin | Protein+heme +$Fe^{2+}$ | Red (purple/blue) | 1.2-1.4 | 16-2000 | Either | Nematodes, annelids, vertebrates |
| Chlorocruorin | Protein+heme +$Fe^{2+}$ | Green | 0.6-0.9 | 3000 | Solution | Annelids, marine polychaetes |
| Hemerythrin | Protein +$Fe^{2+}$ | Violet (colorless) | 1.6-1.8 | 16-125 | Either | Brachiopods, some marine annelids |

- Intracellular vs. solution
- Various other forms, recall gene families


Before/after methemoglobinemia

## $P_{50}$




**$P_{50}$** – partial pressure of oxygen where blood is 50% saturated

## Oxygen carrying capacity

- Total oxygen capacity of blood depends on
  - Volume of blood
  - % saturation (environmental $PO_2$, respiratory surface efficiency and respiratory pigment affinity)
  - Concentration of respiratory pigment in blood

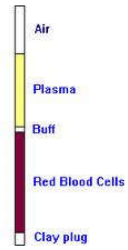
- **Hematocrit** –

**Table 7.10** Oxygen-carrying capacity of bloods with pigments from a range of animals.

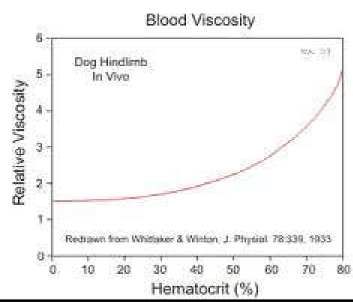
| Animal group | Pigment | ml $O_2$ 100 ml$^{-1}$ |
|---|---|---|
| Nematode | Hb | 1–3 |
| Annelid | Hb | 0.1–20 |
| | He | 3–6 |
| Echiuran | Hb | 4–5 |
| Sipunculan | He | 2–3 |
| Cephalopod mollusc | Hc | 3–4 |
| Gastropod mollusc | Hc | 1–3 |
| Crustacean | Hb | 2–3 |
| | Hc | 1–4 |
| Insect | Hb | 5–12 |
| Elasmobranch | Hb | 4–5 |
| Teleost | Hb | 4–20 |
| Amphibian | Hb | 6–10 |
| Reptile | Hb | 6–12 |
| Bird | Hb | 10–22 |
| Mammal | Hb | 14–32 |
| Water | – | 0.65 |

Hb, hemoglobin; He, hemerythrin; Hc, hemocyanin.

## Blood Properties



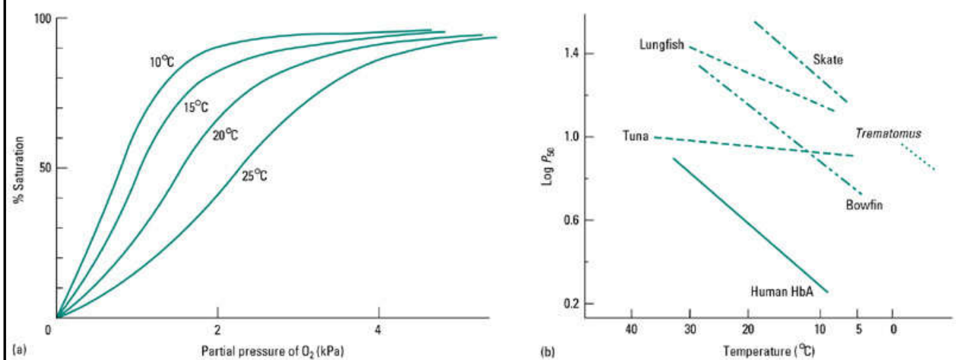

- Why not have very high hematocrit?
- Why is hemoglobin inside red blood cells?
- What are the tradeoffs?




## Icefish Adaptations

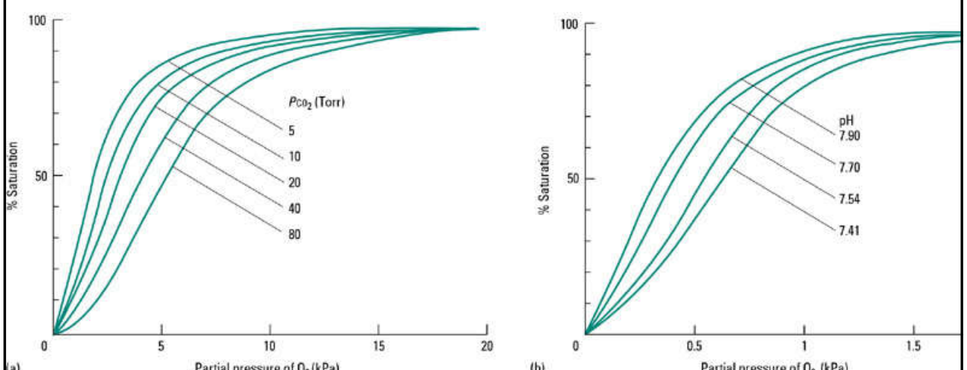
- Only vertebrate without respiratory pigments or red blood cells
- Low metabolic rate
  - 0-1.3 C temperature range
  - Low activity, large body size
- Cold increases blood viscosity
- High oxygen in environment, plasma carries all oxygen
- Myoglobin in heart muscle

## Altering Affinity for Oxygen



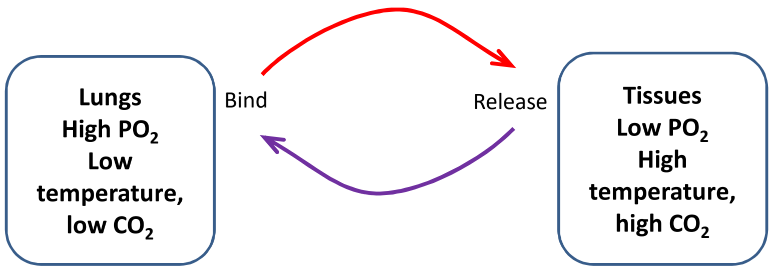

**Bohr shift** – oxygen dissociation curve shifts right with increasing temperature

## Altering Affinity for Oxygen




**Root effect** – lower pH shifts curve down

## Bohr and Root




- Conditions in metabolically active tissue will facilitate oxygen movement to tissues by shifting the curve down and to the right.
- Hemoglobin affinity for oxygen drops.